Annex 6a: Risk assessment for Myiopsitta monachus (Monk parakeet)
Annex 6b: Evidence on measures and their implementation cost and cost-effectiveness for Myiopsitta monachus (Monk parakeet)

Risk assessment template developed under the "Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention"
Contract No 090201/2021/856738/ETU/ENV.D2[1]

Name of organism: ***Myiopsitta monachus*** **(Boddaert, 1783)**

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Risk Assessment Area: The risk assessment area is the territory of the European Union 27, 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.

Response: This risk assessment covers one species, the monk parakeet *Myiopsitta monachus* (Boddaert, 1783), sometimes also called Quaker parrot, a species of true parrot in the family Psittacidae, order Psittaciformes. It is a small, bright-green parrot with a greyish breast and greenish-yellow abdomen.

Common names regularly used within the risk assessment area include "cotorra argentina" or "cotorreta de pit gris" (Spanish/Catalan), Munkeparakit (Danish), Mönchssittich (German), Perriche veuve or conure veuve (French), monniksparkiet (Dutch), Caturrita (Portuguese), Parrocchetto monaco (Italian).

Four subspecies of the monk parakeet are currently recognized, based on geographical variation in wing length, bill size, body mass and plumage coloration (ITIS, https://itis.gov; Avibase, https://avibase.bsc-eoc.org/). According to Russello et al. (2008) and Forshaw (2010), only *M. m. luchsi* is distinct, both genetically and in terms of range (Bolivian highland). The other three (lowland) subspecies are poorly differentiated, and may need taxonomic revision (Russello et al. 2008):

- *M. m. monachus* (Boddaert, 1783): southeastern Brazil (Rio Grande do Sul), Uruguay and northeastern Argentina (Santa Fe to E Buenos Aires). Source of most introduced populations (North America: United States, Mexico, the Bahamas, Cayman Islands, and Puerto Rico; Europe and the Canary Islands; Israel).
- *M. m. calita* (Jardine and Selby, 1830): W Argentina (Salta to w Córdoba, Mendoza and La Pampa).
- *M. m. cotorra* (Vieillot, 1818): southeastern Bolivia, Paraguay, southwestern Brazil, and northwestern Argentina (Formosa, Chaco, Corrientes).
- *M. m. luchsi* (Finsch, 1868): Andean valleys of central Bolivia between 1,000 and 3,000 metres a.s.l., roughly from southeastern La Paz to the northern Chuquisaca department. Some authors (such as del Hoyo et al. 1997) consider subspecies luchsi to be sufficiently distinct, in terms of its morphology, behaviour and distribution, to elevate it to a separate species, *M. luchsi* (Birdlife International 2016).

This risk assessment deals with *M. monachus* s.l., including the four mentioned subspecies.

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

Response: The monk parakeet is a small, bright-green parrot with a greyish head and breast, and greenish-yellow abdomen, about 30 cm long, and a wingspan of around 48 cm. Males have an average weight of around 100 g and females are often 10–20% smaller than males. The general appearance is of a fairly small parakeet with a pointy tail and a large head with a pale gray face, breast and bill. There are many color mutations (e.g. yellow-headed, dark-eyed, cobalt-blue, green pallid...), but they are uncommon in the wild. Additionally, these individuals are difficult to confuse with other species.

Monk parakeet are impossible to confuse with any species native to Europe. However, to the untrained eye, it can be confused with other invasive Psittacines, such as the abundant rose-ringed parakeets *Psittacula krameri*. These are larger, have longer tails, a pale red ring around the neck and black moustache stripe, a completely different alarm call, and their green is brighter than that of monk parakeets, which also lacks coloured patches on the head.

Mori et al. (2013) reported 22 species of introduced Psittaciformes for Europe. However, the other parrots, mainly amazon species (yellow-crowned amazon *Amazona ochrocephala*, blue-fronted amazon *Amazona aestiva*, orange-winged amazon *Amazona amazonica*, Cuban amazon *Amazona leucocephala*, yellow-headed amazon *Amazona oratrix*) and Alexandrine parakeet *Psittacula eupatria*, are much larger, and difficult to confuse with monk parakeet. Other feral parakeet species in the risk assessment area include mitred parakeet *Psittacara mitratus* and red-masked parakeet *Psittacara erythrogenys*, which are medium-sized parakeets and have scattered red feathers on the head and an entirely red face respectively; blue-crowned parakeet *Thectocercus acuticaudatus*, which has a blue crown and face; and Nanday parakeet *Aratinga nenday*, which has a black hood and red thighs.

The lovebirds (Fischer lovebird *Agapornis fischeri*, masked lovebird *A. personatus* and rosey-faced lovebird *A. roseicollis*), which are all African species, are much smaller and have a more or less prominent white eye ring.

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.

Response: In Europe, (Kumschick and Nentwig 2010) and Turbé et al. (2017) (using the EICAT, GISS, Harmonia+ and NNRA protocols) have found that impact scores (summarizing environmental, economic and social impacts) for monk parakeets are variable and can be considered as a mid-level impact species (medium-high impacts on infrastructures, medium impact on agriculture, low probability of disease transmission and impacts on human life).

The risk assessment for Great Britain (GBNNSS 2005) concluded that the species posed a medium overall risk with low uncertainty, citing potential impacts including on agricultural, artificial structures, noise nuisance, potential disease transmission and competition with native birds.

An assessment of the potential economic and environmental impact was performed for the monk parakeet in Oregon (US), suggesting a moderate although very uncertain relative risk (6/10) (Stafford 2003). In Oregon, the climate of which is roughly comparable to the risk assessment area, monk parakeet was indeed considered to potentially become an agricultural pest as well as an environmental concern, given that conditions were right.

A risk assessment performed in Queensland suggest that the species should be considered as a high risk invasive species due to its potential impacts to commercial fruit orchards, grain crops and electricity infrastructure, and because the species might compete with certain species of native parrots for food in urban areas (Csurhes 2016).

The establishment of the Quaker parrot in Tasmania also has the potential for high impact on the agricultural industries (damage to grains, oilseeds, legumes, fruit and vegetables), and on native and introduced bird species, such as rosellas, cockatoos and parrots (*P. caledonicus*, *P. eximius*, *Cacatua roseicapilla*, *C. galarita*, *C. sanguinea*, *C. tenuirostris*, *Calyptorhynchus funereus*, *Neophema chrystoma*, *N. chrysogaster*) (Latitude 42 2011).

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

Response: The monk parakeet is native to temperate and subtropical South America. The native distribution area spreads east of the Andes from central Bolivia and southern Brazil to central Argentina, including the temperate and dry climatic zones (Forshaw 2010). It is reported from eastern and northern Bolivia in south-eastern La Paz, southern Cochabamba, western Santa Cruz, and northern Chuquisaca. It occurs in Paraguay and Southern Brazil in south and west Mato Grosso do Sul and the south-western two-thirds of Rio Grande do Sul, throughout Uruguay and Argentina south to Rio Negro and northern Chubut (Juniper and Parr 1998).

In its native range, monk parakeet prefers dry wooded and open country with tall, isolated trees for nesting, including, isolated chumps, woodlots and gallery forest, without a known preference for a particular tree species but depending on the availability in each area. They are also found in savannas and woodlands, and in farmlands, open *Eucalyptus* sp. forests, and palm groves, and often live near human habitation. The widespread planting of *Eucalyptus* trees as windbreaks in the pampas allowed them to expand their range onto the grasslands. The species inhabits lowland areas up to 1000m a.s.l., although subspecies *M. luchsi* inhabits areas from 1300 to 3000m a.s.l. (Juniper and Parr 1998; Forshaw 2010).

The species is not a migratory bird and cannot spread naturally to the RA area.

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

Response: The monk parakeet has been introduced to many regions of the world as a cage bird outside the risk assessment area, where feral populations have been established (Avery 2020). Preston et al. (2021), based on eBird data, the CITES trade database, GBIF data and the GAVIA database, report that monk parakeets are established or breeding outside the risk assessment area in Australia, Brazil, Cayman Islands, Chile, Dominican Republic, Israel, Kenya, Mexico, Puerto Rico, United States, United Kingdom and the US Virgin Islands.

- Brazil: the species has established in some areas outside its native range, such as Rio de Janeiro through releases and escapes of pet birds (Viana et al. 2016).
- Chile: monk parakeets have also spread to many parts of the country, aided by intentional releases (the first in 1972) and escapes (Iriarte et al. 2005; Briceño et al. 2017).
- Dominican Republic: no further information was found.
- Former records of monk parakeet in Kenya are not confirmed either (Hart and Downs 2020).
- Mexico: the species was also introduced here in the late 1990s, and it has by now spread to many parts of the country (MacGregor-Fors et al. 2011; Hobson et al. 2017).
- United States: they were first sighted in 1967 in New York and in 1969 in Florida (Neidermeyer and Hickey 1977); since then, the species has colonized many other areas through the pet trade, and the population expanded exponentially through 2003 (Avery and Shiels 2018). It was considered resident in 76 localities in 15 states by Pruett-Jones and Tarvin (1998). Breeding populations currently occur in seven states, Florida, Louisiana, Texas, Connecticut, New York, New Jersey and Illinois, but reports from other states are common (Avery 2020).
- Cayman Islands: introduced to Grand Cayman Island in 1987, where the species has been well adapted (Godbeer 2014).
- Puerto Rico: the species is widespread and increasing in the country (Falcón and Tremblay 2018).
- Israel: the first birds being detected near Tel Aviv in 1995. The population has grown exponentially, and these parakeets now occupy urban and agricultural areas (Postigo et al. 2017).
- Morocco: recorded breeding in several cities of Morocco, including Casablanca, Melilla (Spain), Tangier and Marrakech (MaghrebOrnitho 2018).
- Australia: the current status of the species is unclear. In Queensland, it is kept in considerable numbers as a pet and escape/release is inevitable (Csurhes 2016; Ehlers Smith 2020).

In Europe, outside the risk assessment area, the species is established in the United Kingdom, population size being estimated in about 100 individuals (Postigo et al. 2019). Here, it has been the subject of an eradication programme initiated by DEFRA in 2011 using cage traps and whoosh nets. In Switzerland, a population failed to establish in 1997 (Strubbe and Matthysen 2009). Outside the risk assessment area, the species became established also in the Canary Islands (Spain) in the late 1970s (Muñoz and Real 2006). A Norway record (see CABI 2022) probably represents an escaped bird.

Monk parakeets have also been observed in nine additional countries outside the risk assessment area, although breeding has not yet been confirmed. These include Taiwan, Venezuela, Bahamas, Canada, Guadeloupe, Japan, Singapore, South Africa, United Arab Emirates. More in detail:

- Taiwan: despite large numbers of monk parakeet imported, the species has not yet become established (Preston et al. 2021);
- Venezuela: there are some observations of feral individuals and some active nests (Nebot 1999; Fernandez-Badillo 2019)
- Bahamas: the species is regularly recorded in Audubon Christmas Bird Counts (Avery 2020);
- Canada: some birds have been observed from time to time in the South (Crins 2004);
- Guadeloupe: number of sightings is increasing (Avery 2020);
- Japan: there are sporadic sightings of escaped pet birds, and a few records of birds presumably nesting (Eguchi and Amano 2004);
- Singapore: occasional observations of naturalised birds, including some nest building behaviour (Avery 2020);
- South Africa: only two records of free-flying birds (Symes 2014);
- United Arab Emirates: escaped pet monk parakeets have been observed in Dubai (Avery 2020).

In their introduced range outside of the risk assessment area, monk parakeets are primarily found in urban/suburban areas, but expansion into agricultural landscapes is occurring in some areas such as Israel (Postigo et al. 2017).

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

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.

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

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 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).

Response (6a): Recorded in Mediterranean, Atlantic, and Continental biogeographic regions

The monk parakeet has been recorded in the Mediterranean, Atlantic and Continental biogeographic regions with proof of these being escaped birds.

Response (6b): Established in Mediterranean, Atlantic, and Continental biogeographic regions

The species is far more common in the Mediterranean region, where populations are growing exponentially in the last 20 years (Postigo et al. 2019).

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): The species distribution model (Annex VIII) indicates suitable areas in the Pannonian, Mediterranean, Continental, Black Sea, Atlantic, Steppic (and Macaronesian, Anatolian outside the risk assessment area) biogeographic regions, though sometimes with considerable uncertainty. In the Pannonian, the model predicts 92% (2%-100%) of the surface area as suitable for establishment. In the

Mediterranean the model predicts 90% (56%-100%) of the surface area as suitable for establishment. For the Atlantic 42% (6%-99%), for the Black Sea 47% (7%-96%) and for the Steppic 38% (2%-97%) of the biogeographic region is predicted suitable under current climate respectively. The Boreal, Arctic and Alpine biogeographic regions are not predicted to be at risk under current climate. With the exception of the Mediterranean and the Pannonian bioregion, there was however considerable uncertainty on the model predictions for all of the other bioregions.

The ensemble model suggested that environmental suitability for the monk parakeet was most strongly determined by Proxy for potential snow cover (Snow), accounting for 50.4% of variation explained, followed by Mean temperature of the warmest quarter (Bio10) (25.4%), Annual precipitation (Bio12) (17.3%) and Human influence index (HII) (7%). There was however some variation among modelling algorithms in the response plots for the different variables considered. For more details, see Annex VIII.

Response (7b): Under future climate, the modelled suitability for establishment is predicted to increase in the Mediterranean biogeographic region from 90% (56%-100%) to 97% (61%-100%) and 98% (57%-100%) under RCP 2.6 and RCP 4.5 respectively by 2070. In other words, the Mediterranean bioregion is almost entirely suitable for establishment of the monk parakeet and this will remain so under foreseeable climate change conditions. The same is predicted for the Pannonian bioregion, where the proportion suitable area increases from 92% (2%-100%) to 100% (53%-100%) and 100% (54%-100%) under both future emission scenarios. Likewise, the proportion suitable area increases in the Atlantic bioregion, from 42% (6%-99%) to 62% (20%-97%) and 66% (24%-96%) under RCP 2.6 and RCP 4.5 respectively by 2070, for the Black Sea from 47% (7%-96%) to 69% (17%-99%) and 75% (17%-100%) and for the Steppic from 38% (2%-97%) to 49% (1%-100%) and 48% (3%-100%). No such increase is to be noted in the predictions for the Boreal, Arctic and Alpine bioregions.

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): Belgium, Czech Republic, Denmark, France, Greece, Italy, the Netherlands, Portugal, Spain

In the Czech Republic there have been occasional sightings of monk parakeets, but no verified instance of nesting (Avery 2020). One preserved specimen is mentioned on GBIF for Finland, a male with inferred observation data of 1970 but this cannot be corroborated.

Response (8b): Belgium, Czech Republic, Denmark, France, Greece, Italy, the Netherlands, Portugal, Spain

The largest naturalized population appears in Spain, where population size was estimated at over 20,000 individuals in 2017 (Postigo et al. 2019). The Spanish population is distributed in different cities. Large populations appear in Catalonia (Domènech et al. 2003; Molina et al. 2016), Madrid (Roviralta and García-Bolivar 2016), Sevilla (Hernández-Brito et al. 2022) and Malaga (Postigo and Senar 2017), and population growth is exponential in all localities.

Regarding the invasion history of the species in the EU, the monk parakeet became established in Spain in 1977 (Batllori and Nos 1985), Belgium in 1980, in France in 1984, in Italy in 1986, in the Netherlands in 1992, in Portugal in 2000, and in Greece in 2010 (Kalodimos 2013, Postigo et al. 2019). Currently, the species is widespread across urban areas of Spain, Belgium and Netherlands, and appears in several locations in France and Italy (Postigo et al. 2019). Monk parakeets have previously been reported in colder, northern European countries, but these populations have likely gone extinct as we found no recent evidence of monk parakeet occurrences in Denmark, Germany, Austria and the Czech Republic. We also found some records of small monk parakeet populations that have gone extinct in France and the Netherlands, while the population in Belgium suffered two sharp declines following its establishment in Brussels in the late 1970s (Postigo et al. 2019). In Italy, the population size has been estimated in 2,474 birds (Postigo et al. 2019), and the population size continues to grow exponentially (Ciprari et al. 2022). The population size in Greece was estimated at 461 birds, in Belgium at 225 birds, in Portugal at 71, in the Netherlands at 52, and in France at 41 birds (Postigo et al. 2019). A small number of birds have also been found breeding at a locality in Denmark (Fox et al. 2015).

Its current distribution covers mostly (sub)urban areas where birds nest and feed in private gardens and public green areas, but the species is already moving into rural areas (Senar et al. 2016; Battisti 2019; Castro et al. 2021).

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): Under current climate, suitable area for establishment of the monk parakeet is estimated to be present in Mediterranean Member States including Spain (92% (62%-100%) of the grid cells in the country predicted suitable), Portugal (98%, 73%-100%), Cyprus (100%), Greece (89%, 54%-100%) and Italy (82%, 63%-100%). Suitable area is also predicted in Hungary (95%), Belgium (62%), Bulgaria (68%), Croatia (74%) and Romania (53%) with over 50% of the area in the country predicted suitable under current climate. The presence of suitable area on Malta is likely, as similar conditions are present as in other Mediterranean Member States, but Malta was excluded from the distribution model because the Human Influence Index lacks coverage for the country. Austria (11%), Czech Republic (16%) and Germany are also predicted suitable but with less than half of the country predicted suitable under current climate. Denmark (5%), Ireland (1%) and Poland (2%) are predicted only marginally suitable under current climate. The Baltic states (Estonia, Latvia, Lithuania), Finland and Sweden are not predicted suitable under current climate (Annex VIII).

Response (9b): Under foreseeable climate change conditions, by 2070, the suitable area for the establishment of the monk parakeet is increasing in all European Member States but Finland where it remains zero and the Baltic Member States where it remains only marginally suitable (below 15% under the most extreme RCP 4.5 scenario). Most of the Mediterranean Member States become about 100% suitable. All Member States with low predictions under current climate become more suitable such as Ireland (from 1% to 42% under RCP 4.5), Luxemburg (from 0 to 80% under RCP 4.5), Germany (from 12% to 87%), Netherlands (from 36% to 100%), Poland (from 2% to 85%), Slovakia (from 22 to 71%), Slovenia (from 21% to 67%), Denmark (5% to 88%), Czech Republic (16% to 77%). The suitability of France increases from 72% (14%-99%) to over 90% (36%-100%).

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?

Response: The species is known to be invasive in the USA, where Fitzwater (1988) has shown that this parakeet has a great potential for dissemination of Newcastle disease, which could have devastating effects on wild bird communities. Besides, monk parakeets have been recorded aggressively defending their nesting and feeding territories to the point of killing blue jays (*Cyanocitta cristata*), American robins (*Turdus migratorius*), and house sparrows (*Passer domesticus*) (Freeland 1973; Davis 1974; Long et al. 1981).

In Chile, Briceño et al. (2019) observed agonistic (interspecific aggressions) and mutualistic (communal breeding) interactions between monk parakeets and native bird species, suggesting a role in shaping the distribution and richness of sympatric species in urban environments.

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: The monk parakeet is present in the Atlantic, Continental and Mediterranean bioregions, but it is in the Mediterranean bioregion where the species shows the clearest signs of invasiveness: in Greece, Italy, Portugal and Spain populations are growing exponentially, causing damages to crops, vegetation and infrastructures proportional to their numbers (Conroy and Senar 2009; Senar et al. 2016; Battisti 2019; Castro et al. 2021; but see Di Santo et al. (2013)).

There is no study about impacts of monk parakeets in Belgium, Denmark, France and the Netherlands, hence there is no documented evidence of invasiveness in the Atlantic and Continental biogeographic regions.

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: Despite the lack of comprehensive studies on the impact of monk parakeets in Europe, there are signs of invasiveness in Greece, Italy, Portugal and Spain.

The largest naturalized population of monk parakeet appears in Spain, where population size was estimated at over 20,000 individuals in 2017 (Postigo et al. 2019). Large populations appear in Catalonia (Domènech et al. 2003; Molina et al. 2016), Madrid (Roviralta and García-Bolivar 2016), Sevilla (Hernández-Brito et al. 2022) and Malaga (Postigo and Senar 2017), and population growth is exponential in all localities. The Spanish populations are mainly located in cities, although some of them are colonizing rural areas (e.g., Madrid). There are published studies showing important crop damages in Catalonia (Conroy and Senar 2009; Senar et al. 2016) and Andalusia (Castro et al. 2021), and unpublished information on damage to infrastructures and vegetation in both areas.

In Italy, the population size has been estimated in 2,474 birds (Postigo et al. 2019), and the population size continues to grow exponentially (Ciprari et al. 2022). The population size in Greece was estimated at 461 birds, in Belgium at 225 birds, in Portugal at 71, in the Netherlands at 52, and in France at 41 birds (Postigo et al. 2019). Only damages to crops have been reported for Italy (Battisti 2019).

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.

Response: The monk parakeet has been widely kept as a cage bird both in private collections and in zoos, and therefore represents some economic, ornamental, sentimental, educational and aesthetic value as a pet, zoo animal and animal companion. According to the CITES database, 1.295.805 live monk parakeets were traded internationally from 1981-2017, with 61% of these birds sourced from the wild and about 10% captive bred, making them the second most frequently traded parrot globally after rose-ringed parakeet (Russello et al. 2008). At that time, monk parakeets were traded at a relatively low price compared to other parrots (e.g. amazons, macaws), which made people buy them as a common pet. However, being mostly wild animals, they were often released because they were hard to keep in a cage or escaped (M. Carrete, unpublished data). The top exporting countries are Uruguay and Argentina within the native range of the species, and South Africa, Singapore and The Netherlands outside the native range (Preston et al. 2021). The top five importing countries are Mexico, US, Taiwan, Spain and Italy. From 1975 to 2005, more than 250,000 individuals were imported into Europe (CITES database) and despite the bans issued in the US (in 1993), the EU (in 2005) and Mexico (in 2016), the number of countries importing monk parakeets continues to increase (Preston et al. 2021). On the internet, generally, monk parakeets are advertized as quaker parrots with prices varying from $250 to $550 (www.parrotwebsite.com). On the more popular online bird breeder platforms, however, prices for a monk parakeet vary from $550 to $1,350 for rare colour morphs (www.birdbreeders.com). Monk parakeet seems therefore to have been a relatively valuable bird species in trade, although the economic income was probably restricted to a few people. For example, on a popular peer to peer trading platform in Italy (subito.it) visited on 8 April 2022, there were over 150 announcements, most of which were advertising the sale of monk parakeets bred in captivity, for a cost of 50-350 euro for a single bird and 250-450 euro for a pair (up to 500 euro with the cage). In general costs were depending on colour, age, etc., but in some cases the birds were offered for free or for a very low fee. In the native range, monk parakeets are also kept as a pet. In Mexico the monk parakeet is also raised in captivity for the production of ornamental feathers (MacGregor-Fors et al. 2011).

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." In this case, no score and confidence should be given and the standardized "score" is N/A (not applicable).
- 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.
- For each described pathway, in each of the questions below, ensure that there are separate comments explicitly addressing both the "introduction" and "entry" where applicable and as appropriate. 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.

[3] https://op.europa.eu/en/publication-detail/-/publication/f8627bbc-1f15-11eb-b57e-01aa75ed71a1

[4] https://circabc.europa.eu/sd/a/0aeba7f1-c8c2-45a1-9ba3-bcb91a9f039d/TSSR-2016-010%20CBD%20pathways%20key%20full%20only.pdf

For each pathway answer questions 1.2 to 1.8 (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 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)

Of the pathways listed above, the main pathway for the monk parakeet is the "pet/aquarium/terrarium species (escape from confinement)". Another pathway considered in this RA is "botanical garden/zoo/aquaria (escape from confinement)".

As pointed out by Edelaar et al. (2015) the accidental transport of monk parakeets (e.g. as a stowaway in a plane) or the natural overseas dispersal are highly unlikely.

According to a study on *M. monachus* and *Psittacula krameri* imported to Spain (Souviron-Priego 2018) most individuals (99.9%) were imported as pets, the rest being imported for zoos or for research purposes. It is not clear whether the data refer to all species of parrots traded to Spain, or only the two target species, and since no specific introductions were documented in the EU in relation to research purposes, this pathway is not considered active the risk assessment area and is not considered in this risk assessment.

As a side note, in the period 2012-2021 a total of 23 specimen of monk parakeets labelled as "extract" (but not better defined) were imported by Spain from the US (CITES Wildlife TradeView 2022). In previous years, from 1981 to 2011. categories other than "live" were also reported in trade, e.g. "specimens" (99), "skeletons" (4), and "bodies" (2). On this regard, it may be worth mentioning that in Mexico the monk parakeet is raised in captivity not only for the pet trade but also for the production of ornamental feathers (MacGregor-Fors et al. 2011). However, as it is not clear what are the uses of the parts imported in the EU, and it is no evidence that live animals are captive bred for and the production of ornamental feathers (or any purposes other than being kept or traded as a pet), the data above were not further discussed in this document.

(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**

Response: The monk parakeet 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**

Response: The monk parakeet has been traded worldwide in very large numbers as a cagebird, including in the risk assessment area, where the species has been already successfully introduced (see also A.13). Moreover, it is very likely that large numbers of monk parakeets will continue to be introduced through this pathway because of accidental escapes or deliberate releases. Despite trade bans in some countries (and in the risk assessment area), the market for the species is growing as the focus of imports shifts to countries with no trade restrictions (Preston et al. 2021). The EU adopted a ban on the importation of wild birds in response to avian influenza in October 2005 which was 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). It should also be noted that should this ban be lifted, the situation would probably return to pre-ban levels.

Historic trade data suggest high propagule pressure, as noted by Edelaar et al. (2015) within a study demonstrating the link of invasive populations of monk parakeet in Spain (and the United States) to the international caged-bird trades. Approximately one million wild-caught monk parakeets were exported across the world to be sold as pets, resulting in numerous escapes/releases and naturalised populations in the EU and beyond, e.g. Great Britain, Israel, United States, Brazil, Bermuda, the Bahamas, Puerto Rico and Japan (Csurhes 2016, Avery 2020).

According to the data retrieved from the CITES Wildlife TradeView (2022) for the period 2012-2021, a total of 23 live monk parakeets were imported by the EU-27 (namely to Portugal, France, Poland, Germany, Spain, Ireland, Czech Republic, Italy, Greece), mostly from the US and only two from its native range, Argentina and Uruguay. However, this low figure may be just the result of the trade ban of wild-caught birds adopted (see above). In fact, since the listing of the species on CITES Appendix II in 1981, and until 2011, over 370,000 live specimens of monk parakeets were imported in the EU-27, of which nearly 240,000 from Spain and over 85,000 from Italy. Note that data were restricted to live specimens only (see below for other categories in trade) and figures were collected using only the data ascribed to 'exporter reports' because the import reports may be different in a given year for the same species. The figures collected are consistent with Souviron-Priego (2018), who reported that more than 190,000 monk parakeets were imported in just 19 years from Uruguay and Argentina, supposedly leading to self-sustaining wild populations (which peaked around 20,000 monk parakeets in 2015) even though imports of the species were banned in Spain in 2005. The same author supposed that such populations started from accidental and deliberate bird escapes, especially from birds originally captured in the wild. Moreover, according to Souviron-Priego (2018) as a result of the new regulatory restrictions in Spain, the fear of possible fines may have played a role in the releases of live specimens.

The figures and data above are also in line with those relative to the situation outside the EU, e.g. in the United Kingdom and in the United States (Spreyer and Bucher 1998, Russello et al. 2008, Campbell 2000, Stafford 2003). In these countries monk parakeet (also known as the quaker parakeet in the US pet trade (Bull 1973)) occasionally escaped from captivity (including through damaged shipping crates, i.e. in J.F.Kennedy airport, US), or were deliberately released by individuals or pet shops, for example when owners were no longer caring for their pets (CABI 2022, Spreyer and Bucher, 1998, Bull 1973, Gluzberg 2001, GBNNSS 2005).

Since monk parakeets breed readily in captivity, it is highly likely that captive breeding of this species within the risk assessment area further contributes to supply the pet trade and to act as a direct source of escapees, as noted for Great Britain (GBNNSS 2005) and the US (Stafford 2003). Some data suggested a shift in the sources of commercialized birds, from wild-caught to captive-bred birds following the EU trade ban of wild-caught birds (Cardador et al. 2019). This shift could have been possible thanks to the availability of captive-bred birds from EU countries with a longer tradition of breeding exotic birds in captivity (e.g. the Netherlands and Belgium), successively reinforced through breeding facilities in Spain and Portugal. For example, in Spain the price of captive-bred individuals was 2–3 times higher than that of their wild-caught conspecifics, reflecting their rarity in captivity (Carrete and Tella 2015). Of course, while the general availability of alien birds for sale did not change, the increased costs, along with the fact that captive bred species have lower probabilities of being successfully introduced, reduced the probability of both intentional and unintentional releases (Cardador et al. 2019). However, this pattern of lower invasiveness in captive-born individuals compared to wild-caught ones may not hold true when, as in the case of the monk parakeet, there are already established populations.

The evidence of the contribution of captive breeding on the availability of this bird can be offered by a simple online search through major peer to peer trading platforms. For example, on a popular platform in Italy (subito.it) visited in a single day (i.e. on 8 April 2022) over 150 announcements were retrieved for this species using the Italian key word "*parrocchetto monaco*". In many cases the sale was relative to one individual or a pair, but in some cases the number of birds offered for sale were not explicitly reported at all, hence it was not possible to establish the exact size of the market. This nonetheless shows that the risk of escapes is highly likely and deliberate when owners feel unable to look after their pets are also possible, as noted for other countries (GBNNSS 2005). Monk parakeets bred in captivity can be bought for a cost of 50-350 euro for a single bird and 250-450 euro for a pair. In general costs were depending on colour, age, etc., but in some cases the birds were offered for free or for a very low fee. This may suggest that both traders and private citizens are more likely to sell monk parakeets 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 monk parakeets their freedom, as has been documented for many cage birds in general.

Therefore, it is considered very likely that the monk parakeet could be introduced through this pathway as this could happen at least once a year. Given that in one day, on only one website, in one country within the risk assessment area, over 150 announcements of monk parakeets were listed for sale, there are clues that the actual volume of monk parakeet introduced into the risk assessment area is significant. Even if the birds would be eradicated after introduction into 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.

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 a population in Spain. For example, according to Edelaar et al. (2015), the Zaragoza population from Spain is thought to have been established by perhaps as little as two or three individuals in 1991, yet, this population grew to a size of over 1,000 in 15 years, which means an average population growth rate of nearly 50% per year. Interestingly, genetic data indicated a localized source area for most sampled invasive populations, suggesting that reduced genetic variation may not prevent the successful establishment of this species (Edelaar et al. 2015).

As a side note, there are no cases reported in the last 10 years on confiscation/seizure of monk parakeets within the EU-27 (CITES Wildlife TradeView 2022) and no further information was found on any illegal trade of the species in the risk assessment area.

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**

Response: Given the figures provided above on the dimension of the species trade, 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 very likely. Moreover, reproduction is very likely also while the species is kept as a cage bird by amateurs, as shown by the impressive figures reported in Qu. 1.3a.

As noted for Great Britain by GBNNSS (2005) (although this is outside the risk assessment area) large volumes of birds were imported in order to compensate for the high mortality rates during transportation, and it is considered unlikely that birds will reproduce during this phase. However, high numbers are expected to survive.

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**

Response: 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.

As a remark, the monk parakeet is listed on Appendix II to the Convention on International Trade in Endangered Species of Wild Flora and Fauna and export and import of this species in the European Union is therefore subject to provisions under the EU Wildlife Trade Regulations no.338/07 as amended, Annex B.

Morever the EU introduced a ban on the importation of wild birds to counter the spread of the avian flu. It was initially a temporal measure adopted in October 2005 and then was made permanent from July 2007 (Commission Regulation (EC) No 318/2007). Although not directly related to invasion management, this regulation had a major impact on the species trade, as preliminarily noted by the GBNNSS (2005) and successively confirmed by other authors (Carrete and Tella 2008). For example, a study by Cardador et al. (2019) suggested that the EU ban reduced invasion risks by limiting potential invaders at early stages of the invasion process (although other factors may have resulted in the observed pattern or acted synergistically with the ban). In particular, a shift in the sources of commercialized birds, from wild-caught to captive-bred birds was noted (Cardador et al. 2019).

As a side note, it is important to remark the role of regional bans in generating geographic redirections in trade flaws (Cardador et al. 2017). This may have important consequences on invasion risk at both the regional and global scale, as proved in the case of the monk parakeet in Mexico (Macgregor-fors 2011), where more than half a million monk parakeets were traded as pets between 2000 and 2015 as a consequence of the crash of the EU demand (Wilkinson 2017). Also in the United States the lack of importation regulations preventing their entry is considered as the main reason monk parakeets have become established in the country (Davis 1974).

Qu. 1.6a. How likely is the organism to be introduced into the risk assessment area or entry into the environment undetected? Please note that "detection" here is considered as any system or event that may actively contribute to record the presence of a species in a way that appropriate management measures could be potentially undertaken by relevant authorities.

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

Response: Undetected introduction into the risk assessment area along the pet pathway is very 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, because they are large, colourful and very noisy (GBNNSS 2005), and as former pet birds will likely not be afraid of humans. Their loud calls and bulky communal nests where they gather together, are very easy to spot even over long distances (Bucher and Aramburú 2014), and increase their chance of being detected. In general, they are very distinct from native birds (GBNNSS 2005), although some similarity with other alien parakeets (e.g. the ring naked parakeet, *Psittacula krameri*) may create confusion to people with no familiarity with bird identification.

Therefore, the monk parakeet 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.

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**

Response: As the monk parakeet is kept by bird keepers and breeders all over the EU, possible points of introduction and subsequent entry are widespread. This is supported by the fact that the monk parakeet has already escaped (or been deliberately released) several times from various locations (including Belgium, Czech Republic, Denmark, France, Greece, Italy, the Netherlands, Portugal, Spain…) (see Qu. A8). We have no information on absolute numbers of monk parakeets in associated and non-associated zoos, but www.zootierliste.de mentions at least 89 zoos in 19 European countries that have it, and 34 in other countries, including the United Kingdom, Liechtenstein, Switzerland, Serbia, Unkraine, Turkey.

The locations of these zoos are spread out across the entire European Union, the Middle East and Macaronesia. As noted by GBNNSS (2005) "Urban populations seem most likely to initially increase and they could then act as source populations for birds living outside of urban and semi-urban environments."

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**

Response: Even though it is difficult to determine whether introduced monk parakeets 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 or deliberate releases in the past, it is very likely that escapes and/or releases of monk parakeets will continue to occur in the risk assessment area.

(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**

Response: The monk parakeet 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

Response: There is evidence in the literature that some zoos, no longer wishing to maintain their monk parakeet exhibit, have released some animals or sold them (Spreyer and Bucher 1998, Skerton 1968, Davis 1974, Gluzberg 2001, Bull 1973). It is not clear how frequently this happened in the risk assessment area, where the only case mentioned relates to France (Paris zoo).

However, other breeding events of monk parakeet in outdoor enclosures are also available for the United Kingdom (London) and the United States (the Bronx), where they were released intentionally from zoos (Spreyer and Bucher, 1998). For example, in the United Kingdom, as reported by Fitter (1959) over 30 monk parakeets were released in 1936 at Whipsnade Zoo, where they could be seen in freedom for some years. Also at Paignton Zoo, United Kingdom, in 1967 the birds (apparently over 40 individuals) were allowed to escape and were seen up to two miles away (Skerton 1968). Similarly, in San Diego, US, in 1972, 15 individuals had been intentionally released from San Diego Zoo, and while most of them were recaptured within 6 months, two birds eventually were never detected (Davis 1974).

Within the EU 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 monk parakeets 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 monk parakeets 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 releases from zoos in the EU is therefore considered negligible.

As a result, it is considered unlikely that large numbers of individual monk parakeets 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

Response: 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**

Response: 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

Response: 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**

Response: The monk parakeet is kept in several zoos spread across the risk assessment area (see Qu. 1.7a). As not all zoos are included in this list, there are probably more monk parakeets 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

Response: Even though the monk parakeet would easily find suitable environmental conditions after escape, the total number of birds currently present in zoos in the risk assessment area seems not very high. Also, housing conditions between zoos might differ in quality, and escapes can always happen. Therefore, the risk of the species being introduced in the risk assessment area and/or entering the environment, is considered moderately likely with medium confidence.

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 likely **very likely**	**CONFIDENCE**	low medium **high**

Response: The monk parakeet 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 Belgium, Czech Republic, Denmark, France, Greece, Italy, the Netherlands, Portugal, 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 monk parakeet will continue to 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**

Response: The monk parakeet is a very popular cage bird and is probably kept as a pet throughout the EU. 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.

Therefore, we consider it very likely that the monk parakeet will continue to 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**

Response: The monk parakeet is already widely established in the risk assessment area (see Qu. A.8). Based on the species distribution model (Annex VIII) showing the suitability of the risk assessment area, it is very likely that the species continues to establish across the Mediterranean region. For the Atlantic region, the expansion and establishment of the species is likely (see Qu. A.9).

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**

Response: There is no lack of suitable habitat for monk parkaeet in the risk assessment area. Indeed, in its native range, monk parakeet prefers wooded to open country with tall, isolated trees for nesting, without a known preference for a particular tree species (e.g., woodlots, woodlands, open forests, isolated chumps in farmlands or near human habitation; Juniper and Parr 1998; Forshaw 2010). In their introduced range, monk parakeets are primarily found in (sub)urban areas, where birds nest and feed in private gardens and public green areas, with expansion into agricultural landscapes (Senar et al. 2016; Postigo et al. 2017; Battisti 2019; Castro et al. 2021).

Contrary to other parrots, which are secondary cavity nesters, monk parakeets are able to build their own nests, therefore the availability of suitable sites for nesting is not a limiting factor. Its generalist diet allows it to adapt to the different feeding sources available across the regions, both in urban and rural areas.

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**

Response: The species is already established in the risk assessment area, therefore competition with other species has not been a limiting factor. There has been no competition for breeding sites hampering successful breeding and establishment, and, due to its diet generalism, monk parakeet can exploit a wide range of resources.

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

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

Response: Establishment is likely despite predators, parasites or pathogens. Predators could however prevent the spread of monk parakeets from urban into more rural areas. Monk parakeet currently have most of their invasive populations in urban habitats which may be explained by predation release, which allows a higher breeding success in their invaded urbanised habitats than in their native ranges as was also documented in rose ringed parakeets (Schwartz et al. 2009). Senar et al. (2019) demonstrated that the breeding success of monk parakeets is twice as high in a Spanish city than in its native range. In Madrid, a protective nesting association with a native species, the white stork *Ciconia ciconia*, counteracts biotic resistance for the spread of monk parakeet from urban into rural habitats i.e. the association with the storks provided protection to the parakeets to predation by different raptor species (black kite *Milvus migrans*, booted eagle *Hieraaetus pennatus*, common buzzard *Buteo buteo*) (Hernández-Brito et al. 2020). However, in some agricultural areas of Catalonia, the low density of raptors allows parakeets to spread.

Different studies have shown that monk parakeets are resistant to several pathogens (Mori et al. 2019; Martínez-de la Puente et al. 2020; Morinha et al. 2020). Monk parakeets gain novel parasites from the recipient community in their invaded range, while also maintaining parasites from the native range. For instance, Ancillotto et al. (2018) found that 39% of monk parakeets brought into rescue centres in Rome (N = 127) were parasitized by chewing lice and hematophagous mites from the native range of the species, yet half the parasites found on them were generalist bird parasites from the introduced range. It is therefore clear that invasion success of the species in the risk assessment area is not explained by parasite release.

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**

Response: There are currently no dedicated management schemes (directed toward the species or its habitat) in place to prevent the monk parakeet from establishing. Hunting is unlikely to hamper establishment as hunting small passerines is a rather rare activity in the risk assessment area (especially also near human settlements). The practice of keeping bird feeders in urban areas is on the contrary beneficial to the species (Preston et al. 2021). There is also no shortage in natural and artificial nest structures the species can use and the species can easily switch from preferred nesting trees, such as from *Eucalyptus* (the planting of which in some areas facilitated their spread into agricultural areas) to palms (Molina et al. 2016). It is therefore unlikely that commonly applied park and garden management is going to hamper successful establishment across the risk assessment area.

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

Response: A well designed eradication campaign should be able to eradicate monk parakeets in early stages of invasion. A number of programs have eradicated, or almost completely removed, newly established monk parakeet populations, including London (United Kingdom) (Parrott 2013), Zaragoza (Esteban 2016) and the Balearic Islands (Spain) (Postigo et al. 2018). However, more widely established and distributed populations would be very hard to eradicate entirely. The species is a prolific breeder with breeding success being higher in the invasive range (Senar et al. 2019) and disperses well (Gonçalves da Silva et al. 2010) (see also A section). Considering these elements and examples of successful eradications, we scored moderately likely with medium confidence.

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**

Response: A very small number of birds is sufficient to establish a new population. For example, according to Edelaar et al. (2015) the Zaragoza population (Spain) is thought to have been established by perhaps as little as two or three individuals in 1991, yet, this population grew to a size of over 1,000 in 15 years, which means an average population growth rate of nearly 50% per year. Interestingly, genetic data indicated a localized source area for most sampled invasive populations, suggesting that reduced genetic variation may not prevent the successful establishment of this species (Edelaar et al. 2015).

A long term study of Barcelona following over 650 breeding attempts of monk parakeets over five years found that fledging success was double that in the native range, the percentage of pairs attempting second broods was three times higher and 55% of first-year birds bred compared with almost zero in Argentina where birds tend to wait at least a year before breeding (Senar et al. 2019). This indicates monk parakeet has a flexible life history that can easily adapt to (more favourable) environmental conditions in favour of establishment and population build-up. Moreover, monk parakeets are generalist and opportunistic in their diet (e.g. Preston et al. 2021).

Since the species performs well close to human populations, with requirements for food and nesting that are easily fulfilled, its characteristics fit well with the environment it is most likely to enter in first. This makes survival at the very first stage likely. Climate (see Qu. 2.1.) and mortality events through competition (see Qu. 2.3.), predation or disease (see Qu. 2.4.) or human intervention (see Qu. 2.5. and 2.6.) subsequently are critical factors for initial population build-up. As stated above, only climate stands out as a structural constraint at that stage, whereas the others may prove a constraint only by their stochastic nature. In general, the species shows behavioural flexibility, generalism (e.g. an opportunistic diet), has multiple broods throughout its lifespan and shows human commensalism (i.e. a propensity to living in close association with humans). These traits have been shown to link to invasion success in birds (Cassey et al. 2004; Callaghan et al. 2019; Sol et al. 2002).

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

Response: The monk parakeet is widely kept as a popular pet bird and it is long-lived (about 5 years on average and 13 years maximum in the wild and over 20 years in captivity; Martin 1989, Navarro et al. 1995). There is a continuous risk of escapes. In the biogeographic regions that are not climatically suited, casual records can be expected on a (close to) yearly basis (see Qu. A8a). Despite climatic constraints in some areas the birds could profit from urbanisation and use cities to establish here. We therefore scored very likely with medium confidence.

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	**CONFIDENCE**	low medium **high**

	very likely		

Response: The monk parakeet is already established in the risk assessment area, especially in the Mediterranean (see Qu. A8b). Despite some uncertainties on the model predictions in specific areas in the risk assessment area (see Qu. 9a), biogeographical regions predicted suitable for establishment under current climatic conditions are the Mediterranean, Continental, Pannonian, Black Sea, Atlantic, Steppic biogeographic regions (see Qu. A7 and Annex VIII). Competition (see Qu. 2.3.), predation or disease (see Qu. 2.4.) and current management (see Qu. 2.5. and 2.6.) are not considered constraints for establishment. In line with the guidance, as the species is already established in the risk assessment area, the likelihood of establishment is scored as very likely.

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 **very likely**	**CONFIDENCE**	low medium **high**

Response: Under foreseeable climate change conditions, the suitability for establishment of monk parakeet is expected to increase (see Qu. 7ab, Annex VIII). For example, the (already suitable) Mediterranean biogeographic region is expected to become almost entirely suitable by 2070. The same is predicted for the Pannonian bioregion. Likewise, the proportion suitable area increases in the Atlantic bioregion and the Black Sea to about 70% of the area. There is no reason to assume climate change would affect biological properties of the species that help it to establish.

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

Response: The monk parakeet is not a migratory bird, and is often considered to be a sedentary species in its native range, where natural spread would be slow (Martin and Bucher, 1993, Spreyer and Bucher 1998, Bucher et al. 1991), nevertheless it is also known to travel considerable distances in search for food, also in large flocks (Stafford 2003). In the native range short dispersal distances for this species have been reported based on mark–recapture methods (median natal dispersal distance: 1,230 m; Martin and Bucher 1993). In the invasive range, the median natal dispersal distance was 45 m (range =0-1,795 m, mean =158 m ± 310 SD, N = 76) (Dawson-Pell et al. 2021). The short median dispersal distances are usually explained by instincts that govern monk parakeets' nesting habits, e.g. the high energetic cost of building and maintaining bulky compound nests (Stafford 2003, Martin and Bucher 1993). For example, in its native range in Argentina the species expansion in relation to land use changes in the Pampas grasslands resulted between 2.1 and 7.6 km per year during the period 1860–2010, with the highest values in the 1980–2000 period (Bucher and Aramburú 2014). These data were lower than the 10 km per year estimated by Gonçalves da Silva et al. (2010) through genetic evidence in monk parakeet populations in Entre Rios, and higher than the natal dispersal distance of about 2 km per year found in Cordoba (Martin and Bucher, 1993). According to Martin and Bucher (1993) the median dispersal distance from natal nest to first breeding site recorded in Argentina was 1,230 m. In particular, according to Martin and Bucher (1993) adults moved a median distance between censuses of 503.6 +- SD of 118.2

m (n= 364), while young in their first year moved 498 +- 536.7m (n: 28). On the other hand, the maximum daily flight range from the nest is about 15 km (Bucher and Aramburú 2014).

Similarly, natal dispersal distances were short also in Barcelona, Spain, where the median distances where of 16 m for males and 144 m for females (Dawson Pell et al. 2021).

However, genetic evidence suggested that longer dispersal events may occur in invasive populations (Gonçalves da Silva et al. 2010). Long-distance dispersal of 10 km is relatively common, with some records of 50 and even 70 km (Borray-Escalante et al. 2022). According to Bucher and Aramburú (2014), there is a predominance of long-range dispersal in Europe (Muñoz and Real, 2006) and North America, where Gonçalves da Silva et al. (2010) found evidence for frequent long-distance dispersal at an invasive site (about 100 km) that sharply contrasted with previous estimates of smaller dispersal distance made in the native range (about 2 km), suggesting long-range dispersal also contributes to the species' spread within the United States. Also according to Davis (1974) the monk parakeet is known to travel up to 40 miles in search of food, and the Chicago community of birds is supposed to be serving as a source population (Pruett-Jones and Tarvin 1998) i.e. for new colonies up to 20 miles away in Illinois (Stafford 2003).

We scored moderate since it is clear that at least in the invasive range long distance dispersal in monk parakeets is not uncommon but with medium confidence since the data on dispersal reported in the literature is somehow ambiguous.

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).

Human-assisted spread could potentially occur as a consequence of translocations of birds to other areas, or release/escape pathways but these are not considered different from the same mechanisms as pathways of introductions and entry (see Qu 1.1-1.10).

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

N/A

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

N/A

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

N/A

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

N/A

Qu. 3.7a. How likely is the organism to spread in the risk assessment area undetected? Please note that "detection" here is considered as any system or event that may actively contribute to record the presence of a species in a way that appropriate management measures could be potentially undertaken by relevant authorities.

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

N/A

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

N/A

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

N/A

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

Response: Based on other invasions elsewhere in the world (see Qu. A5), the potential rate of spread is considered to be moderate. Within the risk assessment area, spread will mostly occur only through natural means (see also Qu. A8 and A11), which may be nearly impossible to contain due to the inherent caveats of the management options available for the species and the widespread range. However, given the moderate level of spread, the species may still be contained, especially in situations where newly expanding populations exists. The current situation in the risk assessment area is big populations in Spain and Italy, where the prevention of further spread would probably be difficult. In other Member States, populations are fairly or very small. In both cases, active management could prevent further spread but this needs to take into account sufficient management effort, dealing with public opposition etc.

According to the GBNNSS (2005) in the GB "At the current population level, if feral individuals are eradicated rapidly and the pet trade is limited, then containment would be relatively easy albeit controversial. Should the population be allowed to increase then containment would become significantly more difficult."

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**

Response: Figures on dispersal distance are provided under Qu. 3.1. Dispersal distances in monk parakeet are mostly short, but their distribution is highly skewed, with natal dispersal distances in the range of tens of kilometers having been described (Gonçalves da Silva et al. 2010, Borray-Escalante et al. 2022). The rate of spread at regional level is primarily determined by such long-distance dispersal events, which should become more frequent as local populations grow.

In some very arid areas the availability of (artificial) water could be a limiting factor as monk parakeets are known to be unable to maintain their body weight without supplemental water and therefore do not survive well in waterless deserts (Weathers and Caccamise 1975).

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

Response: Under foreseeable climate change conditions (see Qu. 7ab, Annex VIII), the potential for spread of monk parakeets is expected to increase. There is no reason to assume climate change would affect biological properties of the species that help it to spread. Climate change would render the bioregions that are currently less invaded more suitable. For example, the (already suitable) Mediterranean biogeographic region is expected to become almost entirely suitable by 2070. The same is predicted for the Pannonian bioregion. Likewise, the proportion suitable area increases in the Atlantic bioregion and the Black Sea to about 70% of the area. This would probably boost population build-up of monk parakeets in these bioregions and logically induce more events of (density-dependent) longer distance dispersal. It is clear that, about 30 years after their introductions, monk parakeet in Spain and Italy for instance, have gone out of their lag phase and are now exponentially increasing in numbers and also expanding their geographic range. For instance, for Italy, Mori et al. (2013) reported a tenfold increase in breeding events for monk parakeet coinciding with a tenfold increase in the number of localities since 1986. Mediterranean countries have seen faster growth in monk parakeet populations than Atlantic countries (Postigo et al. 2019, Preston et al. 2021) but, as climatic conditions become more alike, similar demographic trends can be anticipated with an increased rate of spread.

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 evidences 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". In this case, no score and confidence should be given and the standardized "score" is N/A (not applicable). Note that in principle, even if no information is available for the risk assessment area, this does not apply to Qu. 4.2 and 4.3, because the information on impact can be inferred from regions outside the risk assessment area. If no information is available from regions outside the risk assessment area either, then this should be discussed explicitly.

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

Response: Outside the risk assessment area, the monk parakeet is known to impact species and ecosystems through a number of mechanisms, which are discussed below. Although evidence of impacts on individual native species through direct aggressive competition is scarce, the species can exert ecosystem-level impacts through the facilitation of other invasive animals (i.e., birds) and plants, potentially changing species compositions in natural areas.

Although many *mechanisms* are relatively well-studied, data on the wider *magnitude* of impact are generally lacking. As there are no reported cases of extinctions of native species caused by monk parakeets, but documented cases of rather local impact, we scored moderate.

1. Facilitation of other species and interspecific associations

The monk parakeet is a provider of nest sites for different other species. Briceño et al. (2019) registered agonistic and aliative (foraging together) interactions between invasive monk parakeets and resident bird species in Chile, as well as parakeet's nest occupancy by nine bird species (two introduced, seven native). For this reason, these authors consider that the monk parakeet is an allogenic ecosystem engineer with the potential to shape the distribution and richness of sympatric species in urban environments. Of special concern is the presence of invasive species as tenants of monk parakeets, which may be favored and spreading, constituting an example of facilitative non-native species interactions (e.g., invasional meltdown hypothesis (Wagner 2012; Hernández-Brito et al. 2021b); for a list of species using monk parakeet nests, see Hernández-Brito et al. (2021a)). Wagner (2012) reported use of monk parakeet nests by American kestrel *Falco sparverius*, speckled teal *Anas flavirostris*, tree ducks *Dendrocygna* spp., spot-winged falconets *Spiziapteryx circumcincta*, guira cuckoo *Guira guira*, white monjita *Xolmis irupero*, screaming cowbird *Molothrus rufoaxillaris,* baywing *Agelaioides badius* and common pigeon *Columba livia*. In rare cases monk parakeet nests were usurped by another bird species, in most cases monk parakeets seem to tolerate other species in their nest chambers.

Monk parakeet nests can offer microclimate control (thermoregulation) that may be key in determining avian reproductive success (Caccamise and Weathers 1977; Wiebe 2001), as temperatures inside the nest can affect the survival and growth of nestlings. These microclimate conditions in monk parakeet nests, combined with the colonial life and the reuse of chambers, can also promote a high parasite load that may negatively affect the breeding success of birds (Aramburú et al. 2003). In their native range, monk parakeets have been observed to carry heavy parasite loads to which nestlings are particularly sensitive (Bucher et al. 1991; Aramburú et al. 2003). Some of these parasites have also been described for the first time in Chile associated with the introduced monk parakeet (Briceño et al. 2017).

2. Frugivory and the spread of alien plants

Monk parakeets are frugivorous and, as most parrot species, can disperse seeds of numerous plant species (Blanco et al. 2015; Blanco et al. 2018) through epizoochory (Hernández-Brito et al. 2021b), endozoochory (Blanco et al. 2016), and stomatochory (Tella et al. 2015). Thus, one important, understudied impact of monk parakeet is the spreading of exotic plant species into rural areas, where they move during their daily displacements. Hernández-Brito et al. (2021b) reported monk parakeets dispersing seeds by epizoochory in Puerto Rico, Mexico, USA, and Israel (Hernández-Brito et al. 2021b) and by stomatochory in Puerto Rico (authors unpublished data). Data on endozoochory have only been recorded in the native range and include reports of seeds of broadleaf plantain *Plantago major* (Plantaginaceae) and unidentified *Asteraceae* in faecal samples from urban Argentinian monk parakeet (Blanco et al. 2016). Due to their generalist feeding habits, monk parakeets use both native and invasive species as food resources, but no accurate estimates have been published.

3: Competition with other bird species

The monk parakeet has a very generalist vegetarian diet and, hence, overlaps and competes with native species for fruits and seeds. In the United States, monk parakeets have been recorded to aggressively defend their nests and feeding territories to the point of killing blue jays *Cyanocitta cristata,* American robins *Turdus migratorius* and house sparrows *P. domesticus* (Freeland 1973; Davis 1974; Long et al. 1981; MacGregor-Fors et al. 2011).

4: Herbivory and predation

The monk parakeet is in general a vegetarian species that mostly feed on leaves, flowers, fruits and seeds (Borray-Escalante et al. 2020; Postigo et al. 2021). Aramburú (1997), in an analysis of 166 monk parakeets from Buenos Aires province, found that 99% of the dry weight of the gut content consisted of seeds, including sedges *Cyperus* spp., thistles *Cirsium* spp., sunflower *Helianthus annuus* and maize *Zea mays*. The choice of seeds varied throughout the year, with cultivated species representing an important part of the diet in winter. Eberhard (1997) observed monk parakeets feeding on *Prosopis* spp. and *Acacia* spp., grasses, thistles, young leaves with galls, corn and bits of fat and flesh on sheep hides in Entre Rios province (Argentina). It has been estimated that a single bird has a daily intake of 10.6 g of food (Aramburú and Bucher 1999), which means that a population of 8,000 birds, as it is the case in a typical Mediterranean city, can consume more than 32 tons of food per year.

Although their diet primarily includes seeds, fruits, berries, nuts, leaf buds, blossoms etc., monk parakeets occasionally prey on small invertebrates, insect larvae and carrion. Recorded arthropoda include a few Hemiptera and Diptera (Aramburú 1997).

5: Parasite and pathogen transmission

Monk parakeets, as many other *Psittacidae*, are reservoirs of a plethora of bacterial and viral diseases. As a consequence, free-ranging monk parakeets may threaten the health of native wild species, as well as aviculture and human health (Mori et al. 2018). Moreover, the monk parakeet is a provider of nest sites for different native species in its invaded areas outside the risk assessment region, and can acquire parasites from the recipient community while introducing novel parasites and diseases (Briceño et al. 2017; Sandoval-Rodríguez et al. 2021). The microclimatic conditions in monk parakeet nests, combined with the interspecific colonial life and the reuse of chambers, can be promoting a high parasite load that may negatively affect the breeding success of birds (Aramburú et al. 2003). In their native distribution, monk parakeets have been observed to carry heavy parasite loads to which nestlings are particularly sensitive (Aramburú et al. 2003). Some of these parasites have also been described for the first time in Chile (Santiago) associated with the introduced monk parakeet (i.e., about 19% of individuals were infected by *Cryptosporidium* sp., 46% presented lice that were identified as *Paragoniocotes fulvofasciatum*, 1% had mesostigmatid acari, and 9% had free-ranging acari (Briceño et al. 2017). Furthermore, Psittacosis *Chlamydophilia psittaci* infection is one of the worst diseases monk parakeets can transmit. In Florida (US), the death of a fledgling of the bald eagle *Haliaeetus leucocephalus* due to *Chlamydophilia psittaci* infection was reported, possibly transmitted by monk parakeets nesting at the base of the eagle's nest (Avery and Shiels 2018). Newcastle Disease (NCD, caused by a Paramyxovirus), presents with acute performances and a high mortality, may affect wild bird communities, avian pet trade and poultry industries. The monk parakeet has great potential for the spread of this pathogen (Nelson et al. 1952; Fitzwater 1988; Kaleta and Baldauf 1988).

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

Response: The monk parakeet impacts species and ecosystems in the risk assessment area through a number of mechanisms, which are discussed below. Evidence of impacts on individual species through direct aggressive competition is scarce in the risk assessment area, yet the species is known to exert ecosystem-level impacts through the facilitation of other invasive animals and plants, potentially changing species compositions in natural areas (see Qu. 4.1).

We scored minor impact as there are currently no reported cases of declines in native species caused by monk parakeets in the risk assessment area. We scored the confidence low, because of the lack of studies that assess the magnitude of impacts for several of the mechanisms (e.g. the spread of alien plant seeds, or transmission of pathogens to native species).

1. Facilitation of other species and interspecific associations

The monk parakeet is a provider of nest sites for different species, which benefit from the cooperative nest defense by monk parakeets and the tenants. The presence, abundance, and richness of tenants at monk parakeet nests are higher in all introduced populations compared to the native range (Hernández-Brito et al. 2021a). Monk parakeet nests can offer microclimate control (thermoregulation) that may be key in determining avian reproductive success (Caccamise and Weathers 1977; Wiebe 2001), as temperatures inside the nest can affect the survival and growth of nestlings. These microclimate conditions in monk parakeet nests, combined with the colonial life and the reuse of chambers, can also promote a high parasite load that may negatively affect the breeding success of birds (Aramburú et al. 2003). Moreover, in the introduced range, monk parakeets can acquire parasites from the recipient community and, in turn, can potentially introduce novel parasites and diseases into the recipient community (Mori et al. 2015; Briceño et al. 2017; Ancillotto et al. 2018; Mori et al. 2019; Martínez-de la Puente, Josué et al. 2020; Morinha et al. 2020; Sandoval-Rodríguez et al. 2021). However, monk parakeets seem to be more resistant to infection by local parasites than native species (Mori et al. 2015), thus this transference of parasites could be strongly weighted towards native species. Despite the microclimatic benefits associated with communal nesting, these aggregations of species may trigger a high degree of interspecific competition that can increase breeding failure (Port and Brewer 2004).

However, aggressive encounters among monk parakeets and tenants are relatively rare and mainly initiated by monk parakeets to avoid the usurpation of active chambers. Interspecific nesting associations at monk parakeet nests may be important to reduce predation risk through cooperative defense, so considering that tenants are more frequent and abundant in rural than in urban areas where predators are more common and abundant, these interspecific associations may help monk parakeets spread from urban into more natural areas. Similar interspecific protective associations between monk parakeets and a native bird species (the White stork, *Ciconia ciconia*) have been previously described as important for the expansion of this invasive species into rural habitats (Hernández-Brito et al. 2020). Consequently, the reduction of nest predation may increase the fledging success of monk parakeets (Senar et al. 2019).

Of special concern is the presence of rose-ringed parakeets at monk parakeet nests. The rose-ringed parakeet *Psittacula krameri* is one of the most successful avian invaders which needs cavities for nesting. By providing this limiting resource, monk parakeets may be favoring the establishment and spread of rose-ringed parakeets, constituting an example of facilitative non-native species interactions (e.g., invasional meltdown hypothesis). However, monk parakeets may not only assist the establishment of invasive but also threatened (Tracey and Miller 2018) or rare native species such as the western jackdaws (*Corvus monedula*) and stock doves (*Columba oenas*) in Spain (Hernández-Brito et al. 2021a). In Spain and Italy, house sparrows *P. domesticus*, Italian sparrows *P. italiae* and feral pigeons *C. livia* nested with monk parakeets without conflict (Di Santo et a. 2016, Postigo 2013).

2. Frugivory and the spread of alien plants

Monk parakeets are frugivorous and, as most parrot species, can disperse seed of numerous plant species (Blanco et al. 2015; Blanco et al. 2018) through epizoochory (Hernández-Brito et al. 2021b), endozoochory (Blanco et al. 2016), and stomatochory (Tella et al. 2015). Due to their generalist feeding habits, monk parakeets use both native and introduced plant species as food resources. As their main populations are typically located in urban areas, their diet is dominated by exotic plants. In Sevilla, for instance, 60% of the diet of monk parakeets is composed by exotic species (Hernández-Brito, personal communication). Thus, one important, undocumented impact of monk parakeet is the spreading of exotic plant species into rural areas, where they move during their daily displacements.

3. Competition with other bird species

The monk parakeet has a very generalist vegetarian diet in the risk assessment area. Hence, it overlaps and competes with native species for fruits and seeds (Borray-Escalante et al. 2020; Postigo et al. 2021).

Most data on competition in the risk assessment area are anecdotal, but show that monk parakeets may attack individuals of native species in conflict situations, especially when at nests or feeding areas (South and Pruett-Jones 2000). For example, attacks on blackbirds *T. merula* at feeding sites (Weiserbs and Jacob 1999) and noisy and physical intimidation against corvids (e.g. jackdaw *Corvus monedula,* carrion crow *C. corone*) in the vicinity of nests have been recorded in Belgium (Dangoisse 2009). In Spain, groups of monk parakeets have also been observed repeatedly attacking blackbirds *T. merula* when they were feeding on palm fruits (Batllori and Nos 1985) and in a few cases where reported to occupy and expel the grey herons *Ardea cinerea* pairs from their nest (García & Bonfill 2007).

4: Herbivory and predation

The generalist vegetarian diet of the monk parakeet makes the species to predate on leaves, flowers, fruits and seeds (Borray-Escalante et al. 2020; Postigo et al. 2021). It has been estimated that a single bird has a daily intake of 10.6 g of food (Aramburú and Bucher 1999), which means that a population of 8,000 birds, as it is the case in a typical Mediterranean city, can consume more than 32 tons of food per year. See Qu 4.1 for more details.

5: Parasite and pathogen transmission

Monk parakeets are reservoirs of different diseases in the risk assessment area. In Madrid (Spain), monk parakeets show a high prevalence of *Escherichia coli* (75%), *Yersinia* spp. (60%) and *Klebsiella* spp. (17%) (Vázquez 2008). On a sample of 100 monk parakeets in Barcelona, 40% were seropositive to Newcastle virus (Senar et al. unpublished data). Many feral pigeons and doves were found dead by the virus, yet not a single parakeet, which suggests that monk parakeets act as reservoirs of this disease. In Sevilla, about 37% of the sampled monk parakeets were positive for the beak and feather disease virus (BFDV), while neither individual showed disease symptoms. The circovirus identified is a novel BFDV genotype common to the two parakeet species living in Sevilla (monk parakeet and rose-ringed parakeet), and similar to the BFDV genotypes detected in several parrot species kept in captivity in Saudi Arabia, South Africa and China (Morinha et al. 2020). However, a sample of 79 individuals from 15 native bird species showed negative results for the presence of the BFDV genotype previously detected in the sympatric invasive parakeets, as well as any other of the circoviruses tested. Although preliminary, this study suggests a lack of circovirus transmission from invasive parakeets to native birds at the study site. Further research is needed to determine if this apparent absence in transmission depends on the BFDV genotype present in the parakeets, which requires additional screening in other invasive and native populations living in sympatry (Blanco et al. 2022).

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. A potential increase in the distribution range due to climate change does not *per se* justify a higher impact score.

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

Response: All the effects on biodiversity recorded are proportional to monk parakeet population size and distribution. Thus, the exponential growth of its populations in the Mediterranean area (Postigo et al. 2019) will be followed by an increment in its impacts. The most relevant expected impacts include pathogen transmission to native birds, competition with native birds for food and nesting places and the spread of unwanted alien plant species from urban to natural areas (see Qu. 4.2). Considering that there are no documented cases of extinctions or serious declines in native species due to monk parakeet, we scored moderate impact. Medium confidence because there is documented evidence of impacts but often only at local scales.

Qu. 4.4. How important is 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

Response: Most populations of monk parakeets are currently located in urban areas (but see Hernández-Brito et al. (2020). Documented negative interactions with native bird species in the risk assessment area concern common, least concern species such as wood dove *C. palumbus*, blackbird *T. merula*, jackdaw *C. monedula* and hooded crow *C. cornix*. There are currently also no documented impacts on protected or conservation value habitats by monk parakeets in the risk assessment area.

Qu. 4.5. How important is 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. 4.3. and 4.4.

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

Response: Most populations of monk parakeets are currently located in urban areas (but see Hernández-Brito et al. (2020)). If the species expands into more natural areas, impacts on other species and habitats could be an issue through the above described impact mechanisms (see Qu. 4.2). However, considering documented interactions with other species mostly concern common, least concern species, and impacts can be either positive (nest site facilitation such as reported in the risk assessment area for spotless starling, Italian sparrow, house sparrow – (Di Santo et al. 2017, Postigo 2013) or negative (competition for food), those future impacts are difficult to forecast. We therefore scored minor impact with low confidence.

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

Response: Provisioning ecosystem services

Monk parakeets have negative impacts on provisioning services, such as cultivated and wild plants used for nutritional and ornamentals purposes (Provisioning, Biomass, Cultivated terrestrial plants). Parrots exhibit a number of pre-adaptations that make them more likely to be agricultural pests (Bucher 1992). The beak of monk parakeets, like that of other parrots, is an extremely versatile tool that allows them to exploit any kind of fruits and seeds (Bucher 1992). In addition, monk parakeets have a very varied diet that allows them to forage on many different food sources, both in trees or on the ground (Bucher 1992). As a consequence, the monk parakeet is considered among the most damaging pest bird species for crops in its native range, Argentina (Canavelli et al. 2012). Crop losses have been reported to range from two to 15% in Argentina, with some as high as 45% annually, attacking different crops like pears, grapes, apples, peaches, maize, sorghum, and sunflower (Davis 1974). Monk parakeets in Uruguay, also within its native range, have been found to damage mainly sunflowers and maize, but also pears, peaches and grapes (Mott 1973). Although monk parakeet damage to maize and sunflowers is not considered economically significant in particular regions of Argentina, damage may exceed 25% locally (Linz et al. 2015). As a consequence, monk parakeets, together with pigeons and doves, are responsible for agricultural losses in Uruguay and Argentina estimated at $42 million (Bruggers et al. 1998).

In its non-native range the species impacts most heavily on gardens and orchards in suburban areas (Provisioning, Biomass, Cultivated terrestrial plants), as bird density is currently higher in these areas, impacting flowers, fruits and vegetables. However, the spread of monk parakeets from urban to rural (agricultural) areas in Israel predicts that damage to agriculture may greatly increase in the coming years (Postigo et al. 2017). Introduced monk parakeets in the USA feed on corn orchards and ornamental gardens (crop losses of up to 28% for *Euphoria longana*; up to 64% on *Litchi chinensis*) (Menchetti and Mori 2014). Monk parakeets were considered responsible for damaging 30% of lychee and longan crops in Florida (Tillman et al. 2000). In California, monk parakeets preyed on many different fruits, including oranges, apricots, figs, apples, persimmons, plums, and passion fruit (Davis 1974). Damage to agricultural crops is a worldwide economic impact associated with monk parakeets, especially to a small percentage of producers who suffer most of the damage (Klosterman et al. 2013).

Damage to vegetation to obtain nesting sticks may be important (Provisioning, Biomass, Cultivated terrestrial plants and Wild plants), especially in preferred young trees (Menchetti and Mori 2014). Data from US show that monk parakeets often target a few tree species within their range to collect nest material or food, so they can damage them heavily, stripping them of most buds, flowers and fruits (Shields 1974). The risk of the entire communal nests structure falling due to continuous nest growth and the presence of strong winds and storms increases with population size (Bucher et al. 1991). The pruning operations necessary to prevent nests from falling can also cause damage to ornamental trees (Menchetti and Mori 2014).

Apart from this direct economic impact, the species has an impact by spreading weeds into natural areas and in the human environment (see Qu 4.1 - frugivory). This could in theory impacts on cultural ecosystem services. In particular, changes in vegetation structure and species composition could be caused by seed dispersal of invasive plant species (see Qu. 4.1). This may make landscapes less attractive for recreation and wildlife watching, and affect culturally important ecosystem qualities (Cultural, Direct, in-situ and outdoor interactions, Physical and experiential interactions with natural environment). However, such impact has not been reported in the literature.

We have rated this impact as major since impacts on provisioning services represent local but irreversible effects (e.g. with respect to exotic plant dispersal, or the introduction of pathogens), with medium confidence as such cases are merely anecdotal but are widely reported in the literature.

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

Response: Monk parakeets already have an impact in the risk assessment area on provisioning services such as cultivated and wild plants used for nutritional and ornamental purposes (Provisioning, Biomass, Cultivated terrestrial plants and Wild plants). Average crop losses in NE Spain were significant and varied according to crop type, from around 35% in pears or plums, to 17% in persimmons, 7% in quinces, and 0.4 in tomatoes (Senar et al. 2016). In southern Spain (Granada), the monk parakeet was identified as the most damaging animal in maize fields, being responsible for 99% of damage (Castro et al. 2021). The percentage of damaged crops ranged from 37 to 100% depending on the cultivar, while crop loss (measured as the length of the consumed cob relative to the total length of the cob) ranged from 18 to 71% (Castro et al. 2021). In Italy, monk parakeets have been recorded foraging and damaging persimmons, and damage is expected to increase over time (Battisti 2019). As in other parts of the non-native area, damage to vegetation to get nesting sticks may be important, too (Provisioning, Biomass, Wild plants).

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

Response: Damage is proportional to the number of birds. Hence, given the exponential growth of Mediterranean populations (Postigo et al. 2019), we can forecast that damage on provisioning services (crops, cultivated plants) will be major and will be occurring over a much larger area. As is the case in the native range, monk parakeet has the potential to become an important agricultural damage 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

Response: Kumschick and Nentwig (2010), in a global analysis of the impacts of alien birds (including 26 bird species), identified the monk parakeet as one of the four species with the greatest global economic impact due to severe local impacts on agriculture and human health. More recently, Strubbe et al. (2011) stated that although the economic cost was important, it was still based on local reports and should not be considered as significant. The same was stated by White et al. (2019) and Weiserbs (2010). This view, however, does not take into account the precautionary principle (Kumschick Brunel et al. 2001; Edelaar and Tella 2012), which states that damage is proportional to the number of individuals and that it is only a matter of time before feral populations reach population sizes to cause important damage. It has also been shown that monk parakeets are prone to develop foraging innovations, which can increase the risk for damage occurring (Postigo et al. 2021).

1. Damage to agriculture

Estimations on the costs of the monk parakeet are scarce, but they are probably high and will increase in coming years. Originally, monk parakeets in Argentina (native range) used to breed in spiny hackberries *Celtis ehrenbergiana*, causing very few damage (Volpe and Aramburú 2011). However, in more recent years, monk parakeets have shifted to breed in *Eucalyptus* which has facilitated spread into agricultural areas, where in some areas they are causing heavy damage, exceeding 25% of crop (Bucher and Aramburú 2014; Linz et al. 2015). Monk parakeets, together with pigeons and doves, are responsible for agricultural losses in Uruguay and Argentina estimated at $42 million (Bruggers et al. 1998). In Uruguay (native range), the government carried out a lethal control campaign in 1981-1982 over an area of >500.000 km^2. This involved 8 people for a year that killed about 250.000 birds and cost about 150.000$ (1.69$ per bird) (Linz et al. 2015). In the non-native range, it was estimated that, if well established, the monk parakeet in California (USA) could cause an estimated cost to agriculture of $2,167,709,000 (Davis 1974). In Mexico, the species has also impacts on agriculture (corn and fruit trees; (Muñoz-Jiménez and Alcántara-Carbajal 2017)).

2. Damage to infrastructure

Monk parakeets are unique among parrots in that they build communal nests with sticks. Large nests can contain 30-40 chambers, while some nests may have more than 200 chambers, and can easily weigh 200 kg (Domènech and Senar 2006; Avery and Lindsay 2016). Originally, nests were mostly built in trees. However, in some areas, the species shifted to man-made structures, damaging human facilities (Menchetti and Mori 2014). In Chicago (US), according to a 2009 survey, man-made structures (including telephone and light poles, satellite dishes, highway and railroad overpasses, and electrical utility structures) accounted for 58% of the nesting substrates (Pruett-Jones and Appelt 2012). In South Florida, 80% of nests were reported to be on man-made structures (Newman et al. 2008). In Texas, monk parakeets showed a marked preference (>75%) for building nests on man-made structures such as stadium light poles, mobile phone towers, and electric utility facilities (Avery and Shiels 2018). In Argentina, >20% of electric lines harbour monk parakeet nests (Bucher and Martin 1987). These nests damage facilities and can cause power outages. Total estimated costs associated with power outages in 2001 in Florida were $570 per outage, with a total cost of $585,000 per year (Avery et al. 2002). The cost of removing monk parakeet nests on distribution and substations was estimated at $415 per nest. Based on current nest removal rates, a conservative cost for removal of all existing nests present in 2001 was $460,650 (Avery et al. 2002). Between 2003 and 2007, the cost of nest removal in Florida was estimated to be $1.3 to $4.7 million (Avery et al. 2008).

3. Weed dispersal

Monk parakeets are frugivorous and, as most parrot species, can disperse seed of numerous plant species (Blanco et al. 2015; Blanco et al. 2018) through epizoochory (Hernández-Brito et al. 2021b), endozoochory (Blanco et al. 2016), and stomatochory (Tella et al. 2015). In Argentina, monk parakeets commonly eat and disperse seeds of invasive thistles (*Cynara cardunculus*, *Centaurea melitensis*, Carrete unpublished data) considered as important agricultural weeds. However, the cost of their management has not been estimated.

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 evidences 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". In this case, no score and confidence should be given and the standardized "score" is N/A (not applicable). 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	minimal minor **moderate** major massive	**CONFIDENCE**	**low** medium high

Response: Estimates of the costs of monk parakeet spread in the risk assessment area are scarce and there are no detailed cost evaluations available.

Damage to agriculture

Data from Barcelona and Sevilla (Spain) show that parakeets tend to concentrate in specific fields, causing locally important damage to a few producers. One of the few studies to assess the agricultural impacts of monk parakeets was performed in an agricultural area bordering the city of Barcelona (Baix Llobregat region). The average crops damage observed were significant and varied according to crop type - from around 35% in pears or plums, to 17% in persimmons, 7% in quinces, and 0.4 in tomatoes - with maximum values of crop losses reaching around 70% in some fields and for some crops, i.e. pears and corns (Senar et al. 2016) The breeding population of monk parakeets in the study area of Baix Llobregat region, which covered 1,024 Ha, was only 120 individuals, showing that even small populations can affect large areas (although it is possible that birds from the nearby parakeet population in Barcelona city also contributed to damages; (Senar et al. 2016)). Another example is from a 1,8 Ha private farm in southern Spain (Granada), where in a small-scale experimental set-up the percentage of cobs damaged by the monk parakeet – evaluated by videos recorded with camera traps -ranged from 37 to 100% depending on the cultivar, while crop loss (measured as the length of the consumed cob relative to the total length of the cob) ranged from 18 to 71% (Castro et al. 2021). The same authors warned the importance to take this result with caution given the peculiarities of the local settings, but also pointed out that the estimated population of monk parakeets utilizing the study site was below 22 individuals, hence the species may cause a serious problem should the population further spread and increase (Castro et al. 2021). In Italy, monk parakeets have been recorded foraging and damaging persimmons, and damage is expected to increase over time (Battisti 2019). Battisti and Fanelli (2022) mined scientific papers, grey literature and web-based observations of impact of monk parakeet on ornamental and commercial plants in Italy. The authors report evidence was mostly related to ornamental species in urban parks and in more in limited numbers found reports of damages from cultivated species of commercial interest located in rural sites. They found that monk parakeet foraged on 42 different taxa of which 13 taxa were of commercial interest such as sunflower *Helianthus annuus*, persimmon *Diospyros kaki*, Fig *Ficus carica*, Maize *Zea mays* and other species of Poaceae, *Malus* sp., *Prunus* sp. and *Citrus* sp. Also, they report a more significant impact on commercially important crops of monk parakeets in rural areas compared to rose-ringed parakeets.

Although overall damage could be considered as not too important, those producers that have to deal with the parakeets can lose their entire profits. Given these profound, but local, damage, we equal the response to moderate. It should also be noted that the species is managed locally (see Qu. 4.12), so the actual costs are currently below potential costs. Although we also expect the same conditions being widespread across the Mediterranean biogeographic region, the level of confidence was considered low because of the lack of more studies on this topic.

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

Response: Damage is proportional to the number of birds. Hence, given the exponential growth of Mediterranean populations and anticipated spread into rural areas (Postigo et al. 2019, former questions), we expect the future economic cost, to agricultural commodities in particular, to exceed 1 million euros per annum (major).

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 evidences 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". In this case, no score and confidence should be given and the standardized "score" is N/A (not applicable).

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

Response: Eradication costs by shooting have been estimated in about 400,000€ per 5,000 birds (Senar et al. 2021). The management of the 24.000 monk parakeets currently present in the EU area (Postigo et al. 2019) would therefore cost a minimum quantity of 2,000,000€ in case a regional eradication programme would be planned through shooting. Costs would be much higher if other methods than shooting were chosen such as trapping with nets at the nest, which are more expensive and less efficient, and could reach 500.000€ (/5.000 birds) (Senar et al. 2021).

As in other parts of the non-native area, damage to vegetation to get nesting sticks may be important, as well as the risk of the communal nest falling down. In Zaragoza (Spain) the city Council used to remove about 40 nests per year because of the danger to citizens (Esteban 2016). In Barcelona, the City Council has to remove about 120 nests each year because of risk of falling, and every year there are several nests that fall down, with the consequent risk to pedestrians. The cost of actions to remove nests that have fallen or are at risk of falling in the city of Barcelona (Spain), with a population in 2015 of 5,000 birds, was estimated in >200.000€ per year (Senar, personal data). Extrapolating the cost to the whole EU area, with an estimated population of 24.000 birds (Postigo et al. 2019), would mean an annual cost of about 1,000,000€ in case a regional eradication programme would be planned through nest removal. The cost of removing nests from human facilities has been estimated in 800-5,000€ per action. Fortunately, in Europe, less than 2% of nests are built in human facilities, which contrast with data from the Americas, where depending on the area, up to 80% of nests can be located in such structures (Newman et al. 2008). However, given the plasticity and capacity for innovation of monk parakeets (Postigo et al. 2021), we cannot discard that in the not too distant future, the species will change its nesting habits to use these human structures as substrates, which would dramatically increase management costs.

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**

Response: See also Qu. 4.12. Given the exponential growth of Mediterranean populations (Postigo et al. 2019), we can forecast that damage will be major and generalized in these areas.

We score major with high confidence because, considering all the known cases of damage in Spain, costs would easily exceed 1,000,000€ should damages become more widespread in the risk assessment area.

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

Response: 1. Noise

In residential areas, noise pollution from monk parakeets has been described as a serious nuisance (Davis 1974). E.g., tolerance to the ring-necked parakeet *Psittacula krameri* in Italian cities declined sharply with an increase in the number of loud calls (Mori et al. 2020), and there is no reason to assume this relation is different for monk parakeet. There are already many reports of nuisance experienced by citizens to local authorities in Italy and Spain.

2. Disease transmission

Parrots can host several diseases that can be transmitted to humans. Among them, the most important because of their higher zoonotic risk for humans are Chlamydophilosis *Chlamydia* spp. and Tuberculosis *Mycobacterium* (Boseret et al. 2013). There are reported cases of humans infected in the native and the invasive range of monk parakeets, although the source is not easy to identify. Other diseases also present in parrots that can be transmitted to humans include Salmonellosis *Salmonella* spp., Campylobacteriosis *Campylobacter* spp. and Cryptococcosis *Cryptococcus* spp. (all bacterias) and Newcastle disease (PMV-1, Paramyxovirus) (Boseret et al. 2013). No studies have been performed to assess the actual impact of these diseases on human health, yet in Barcelona researchers and people pruning trees were shown to have increased antibodies and anti-allergen values in the blood (Senar et al. unpublished).

Although their impact as zoonotic agents is even less known, other diseases such as Microsporidian infections (Encephalitozoon), Pneumonias, meningitis, urinary-tract, skin and tissue infections (*Klebsiella pneumoniae*), Colibacillosis (*Escherichia coli*), Staphylococcal infections (*Staphylococcus aureus*), Allergic alveolitis, Trichomonosis (*Trichomonas* sp.) can be also transmitted to humans from parakeets (Barton et al. 2003; Boseret et al. 2013; Maritz et al. 2014; Nga et al. 2019; Ahmed et al. 2021). These are not limited to monk parakeet, although the nesting behaviour of the species may be promoting high pathogen loads (see Qu. 4.1.).

3. Damages to infrastructure

Originally, monk parakeet nests were mostly built in trees. Although in the native and in other invasive areas such as the US the species use human-made structures for nesting, causing heavy damages, in the risk assessment area, less than 5% of the nests are located in man-made structures (Domènech et al. 2003), damaging human facilities (Menchetti and Mori 2014).

4. Safety risks

There is a risk of entire (big) communal nests falling down, with the consequent risk to pedestrians. Incidents and preventive actions are mentioned for Zaragoza and Madrid (Spain) under Qu. 4.12.

Considering the four above mechanisms together, representing a large number of localised, reversible effects, we equal the response to moderate.

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 evidences 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". In this case, no score and confidence should be given and the standardized "score" is N/A (not applicable).

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

Response: As in previous cases, given that population size is positively correlated with (1) noise pollution, (2) disease transmission, (3) damage to infrastructure and (4) safety risks, as defined under Qu. 4.15, an increment in population size is expected to exacerbate these impacts. Given the ability of parrots to introduce nesting innovations (Dawson-Pell 2021; Hernández-Brito et al. 2021c), new (sub)urban niches might open up, with a consequently larger number of the human population becoming exposed.

We scored moderate since under current population developments it is reasonable to assume the documented impacts would exacerbate to exceed the local level or impact larger groups, but with low confidence for knowledge gaps on disease impacts.

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

Response: Monk parakeets can build their own nests, providing nesting sites for several secondary cavity-nesters. In the risk assessment area, Hernández-Brito et al. (2021a) found that the invasive and highly aggressive ring-necked parakeet *P. krameri* can use monk parakeet chambers as nesting sites, thus increasing its likelihood of colonizing areas without availability of nesting cavities. The diet generalist behaviour of the species allows it to prey and disperse several plant species, including some invasive ones (Hernández-Brito et al. 2021b) (see also Qu. 4.1, Qu. 4.2).

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

RESPONSE	**N/A** minimal minor moderate major massive	**CONFIDENCE**	low medium high

Response: No information has been found on the issue.

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

Response: Predators, parasites nor pathogens have been able to prevent the impacts of monk parakeets outside or inside the risk assessment area. Most impacts are associated to urban and rural areas where the biotic resistance of the native communities is lower (Hernández-Brito et al. 2020). In natural areas, predators such a sparrowhawk and a range of other raptors and grey herons *Ardea cinerea* can occasionally hunt monk parakeets but this is unlikely to halt the growth of their populations in Europe (Parrotnet 2020, García and Tomás 2006) (See Qu. 2.4). Also, the monk parakeet (as also reported in the native range) exhibits protective nesting associations with a native species such as white stork *Ciconia ciconia* (Hernández-Brito et al. 2020).

Given that different studies have shown that monk parakeets are resistant to several pathogens (Mori et al. 2019; Martínez-de la Puente, Josué et al. 2020; Morinha et al. 2020), damages are not expected to decrease in the presence of diseases. However, Preston et al. (2021) noted the apparent decline in US monk parakeet numbers in the early 2000s and hypothesized that this decline coincided with the timing of the spread of West Nile Virus (WNV) in other bird populations notably corvids. However, this hypothesis could not be corroborated and in any case the decline did not impact the distribution of the parakeets in the US even if the number of birds in each area declined (Preston et al. 2021).

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

Response: Under current climatic conditions, populations are still expected to increase in number in the Mediterranean bioregion with monk parakeets jumping the urban fence and spreading more into rural and natural areas and also the Steppic, Pannonian, Atlantic and Continental bioregions (Qu. A7ab, Annex VII). Currently the evidence for impact on native biodiversity and associated ecosystem services is weak (see Qu. 4.2), but there are a number of cases of reported serious damages to agriculture in Spain and also of impacts on safety and infrastructure through nesting behaviour. Impacts on human health are very well possible but not reported so far. We score the general impact of monk parakeet under current climatic conditions as moderate but with low confidence because important aspects related to impacts of monk parakeets such as the potential for the spread of alien plants species and their role in the spread of diseases have not been studied.

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. • See also guidance to Qu. 4.3.

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

Response: Under foreseeable climate change, populations are expected to increase in number in the Mediterranean bioregion (Qu. A7ab, Annex VII), with monk parakeets jumping the urban fence and spreading more into rural and natural areas. Likewise, populations that are currently not considered as invasive, for instance in the Atlantic and Continental bioregion, could come out of their lag phase and start to increase exponentially. Although currently the evidence for impact on native biodiversity and associated ecosystems is currently rather limited (see Qu. 4.2), especially the impacts on agriculture and human health could increase. Therefore, we scored overall impact under future conditions as moderate but with low confidence because important aspects related to impacts of monk parakeets such as the potential for the spread of alien plants species and their role in the spread of diseases have not been studied.

RISK SUMMARIES			
	RESPONSE	**CONFIDENCE**	**COMMENT**
Summarise Introduction and Entry*	very unlikely unlikely moderately likely likely **very likely**	low medium **high**	The monk parakeet is the second most traded parakeet species in the world. It is and has been traded in very large numbers as a cagebird, including in the risk assessment area. Despite trade bans in some countries (and in the risk assessment area), the market for the species is growing and large numbers will continue to be introduced because of accidental escapes or deliberate releases. Despite knowledge gaps on the exact numbers kept, zoos that keep the species are distributed across the whole of the risk assessment area. Accidental escapes from such zoos remain a possibility but are considered a lot less likely. It is considered very likely that the monk parakeet will continue to be introduced into the risk assessment area and enter the environment in the future and this is not expected to change under climate change.
Summarise Establishment*	very unlikely unlikely moderately likely likely **very likely**	low medium **high**	The species is already established in the risk assessment area (Mediterranean but also in other bioregions) and in some countries (e.g. Spain, Italy) is currently exponentially increasing. Most biogeographic regions are vulnerable to invasion by monk parakeet. Predators or pathogens are unlikely to prevent successful establishment and the proportion of the area suitable for establishment is expected to increase under foreseeable climatic conditions.
Summarise Spread*	very slowly slowly **moderately** rapidly very rapidly	low **medium** high	Despite being regarded a rather sedentary species in the native range with limited dispersal beyond the natal grounds, long distance dispersal (>100km) has been documented in invasive populations within and outside the risk assessment area. This is exemplified by the spread of monk parakeet populations in Mediterranean countries. Human translocations could complement natural spread. Under foreseeable climatic conditions, an increased rate of spread can be expected.

Summarise Impact*	minimal minor **moderate** major massive	**low** medium high	Currently the evidence for significant impacts on native biodiversity and associated ecosystem services is weak. There is however good documentation of serious damages to agricultural crops and also of impacts on safety and infrastructure through the nesting behaviour in the risk assessment area. Impacts on native species through aggressive interactions or facilitation of other invasive species in the risk assessment area are either positive or negative and serious impacts on native species populations or on protected species or habitats have so far not been reported. The potential impact through the spread of seeds of unwanted plant species or pathogen spill-over represent serious knowledge gaps. Considering the potential for impacts, even if limited, to be much more widespread under future climatic conditions we scored moderate.
Conclusion of the risk assessment (overall risk)	low **moderate** high	low **medium** high	The monk parakeet was a very popular cagebird traded in very large numbers until recently, and is still kept in captivity in the risk assessment area, where large populations are well established in the wild (especially in the Mediterranean region, but not exclusively). Additionally, the area suitable for establishment is expected to increase under foreseeable climatic condition, also due to the potentialities for spread. The impact on native biodiversity and associated ecosystem services seems currently low, though is expected to increase in the future, but there is also documented impact on agricultural crops and on safety and infrastructure, therefore the monk parakeet represents a moderate risk in the risk assessment area, with medium confidence, due to the knowledge gaps highlighted in the study.

*in current climate conditions and in foreseeable future climate conditions

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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	Yes	?
Bulgaria	-	-	Yes	Yes	-
Croatia	-	-	Yes	Yes	-
Cyprus	-	-	Yes	Yes	-
Czech Republic	Yes	?	Yes	Yes	-
Denmark	Yes	Yes	Yes	Yes	-
Estonia	-	-	-	-	-
Finland	-	-	-	-	-
France	Yes	Yes	Yes	Yes	?
Germany	Yes	Yes	Yes	Yes	?
Greece	Yes	Yes	Yes	Yes	?
Hungary	-	-	Yes	Yes	-
Ireland	-	-	-	Yes	-
Italy	Yes	Yes	Yes	Yes	Yes
Latvia	-	-	-	-	-
Lithuania	-	-	-	-	-
Luxembourg	-	-	-	Yes	-
Malta	-	-	Yes	Yes	-
Netherlands	Yes	Yes	Yes	Yes	?
Poland	-	-	-	Yes	-
Portugal	Yes	Yes	Yes	Yes	Yes
Romania	-	-	Yes	Yes	-
Slovakia	-	-	Yes	Yes	-
Slovenia	-	-	Yes	Yes	-
Spain	Yes	Yes	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	Yes	?
Black Sea	-	-	Yes	Yes	-
Boreal	-	-	-	-	-
Continental	Yes	Yes	Yes	Yes	-
Mediterranean	Yes	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
Moderately likely	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 4.1-5	*Question 4.6-8*	*Question 4.9-13*	*Question 4.14-18*
Minimal	Local, short-term population decline, no significant ecosystem impact	No services affected[5]	Up to 10,000 Euro	No social disruption. Local, mild, short-term reversible effects to individuals.
Minor	Local, short-term population loss, Localized reversible ecosystem impact	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	Local to regional long-term population decline/loss, Measureable reversible long-term damage to ecosystem, 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, population loss or extinction of single species	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	Long-term irreversible ecosystem change, widespread, population loss or extinction of several species	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)

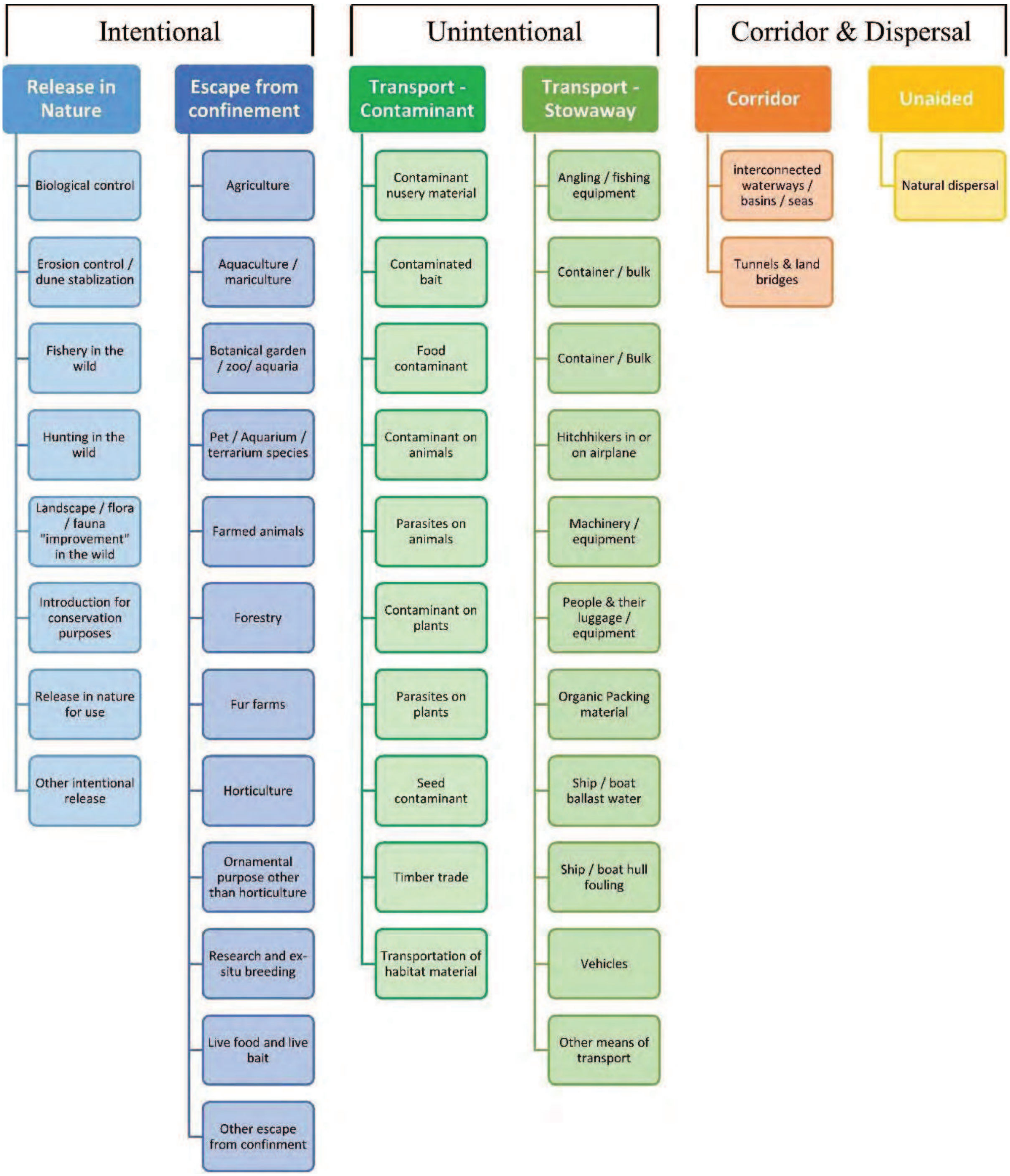
Each answer provided in the risk assessment must include an assessment of the level of confidence attached to that answer, reflecting the possibility that information needed for the answer is not available or is insufficient or available but conflicting.

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). <u>**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.**</u>



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 & 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

[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.

			Example: changes caused by non-native organisms to ecosystem functioning or structure leading to, for example, 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, wild life 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

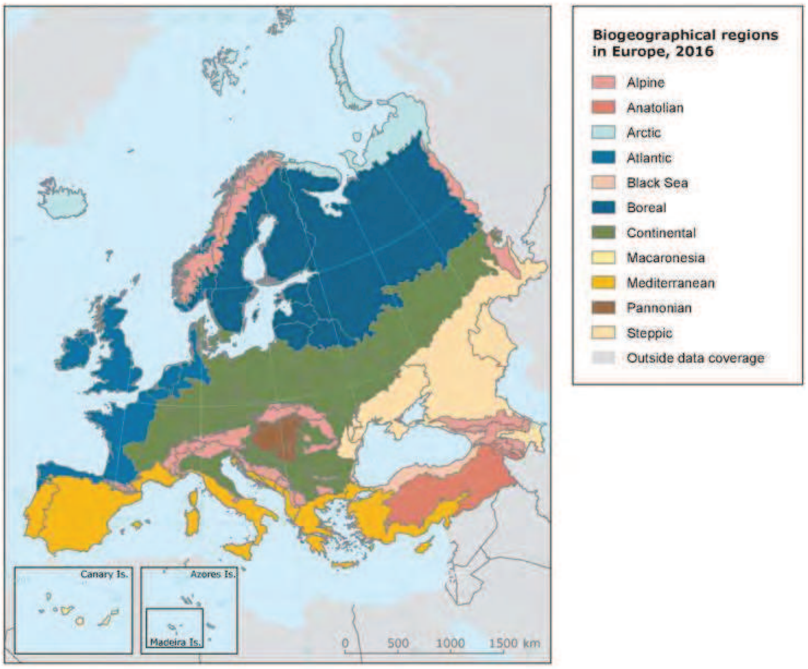
			Example: changes caused by non-native organisms to the qualities of ecosystems (structure, species composition etc.) that have cultural importance
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	**Spiritual, symbolic** and other 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.*

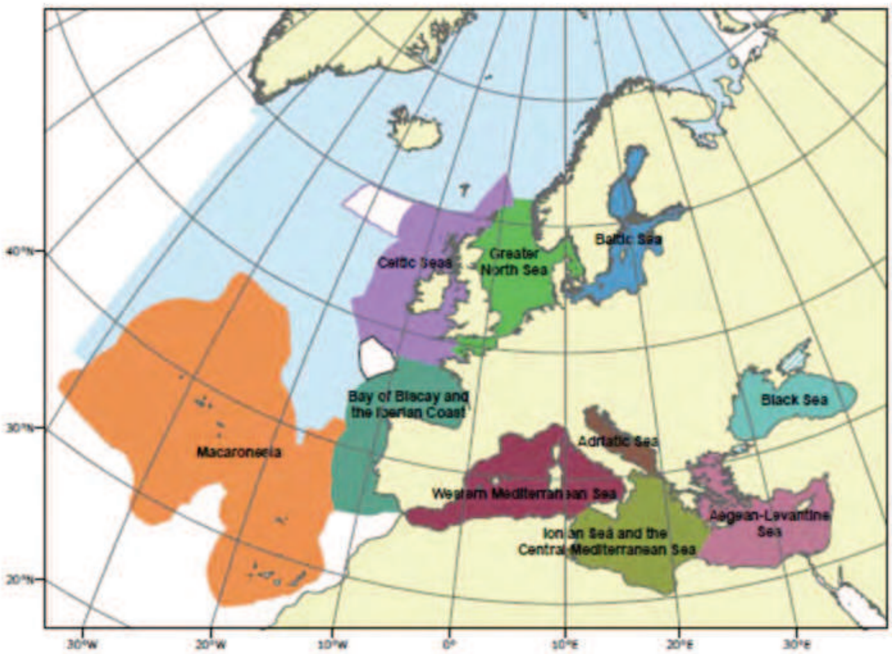
ANNEX VI EU Biogeographic Regions and MSFD Subregions

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

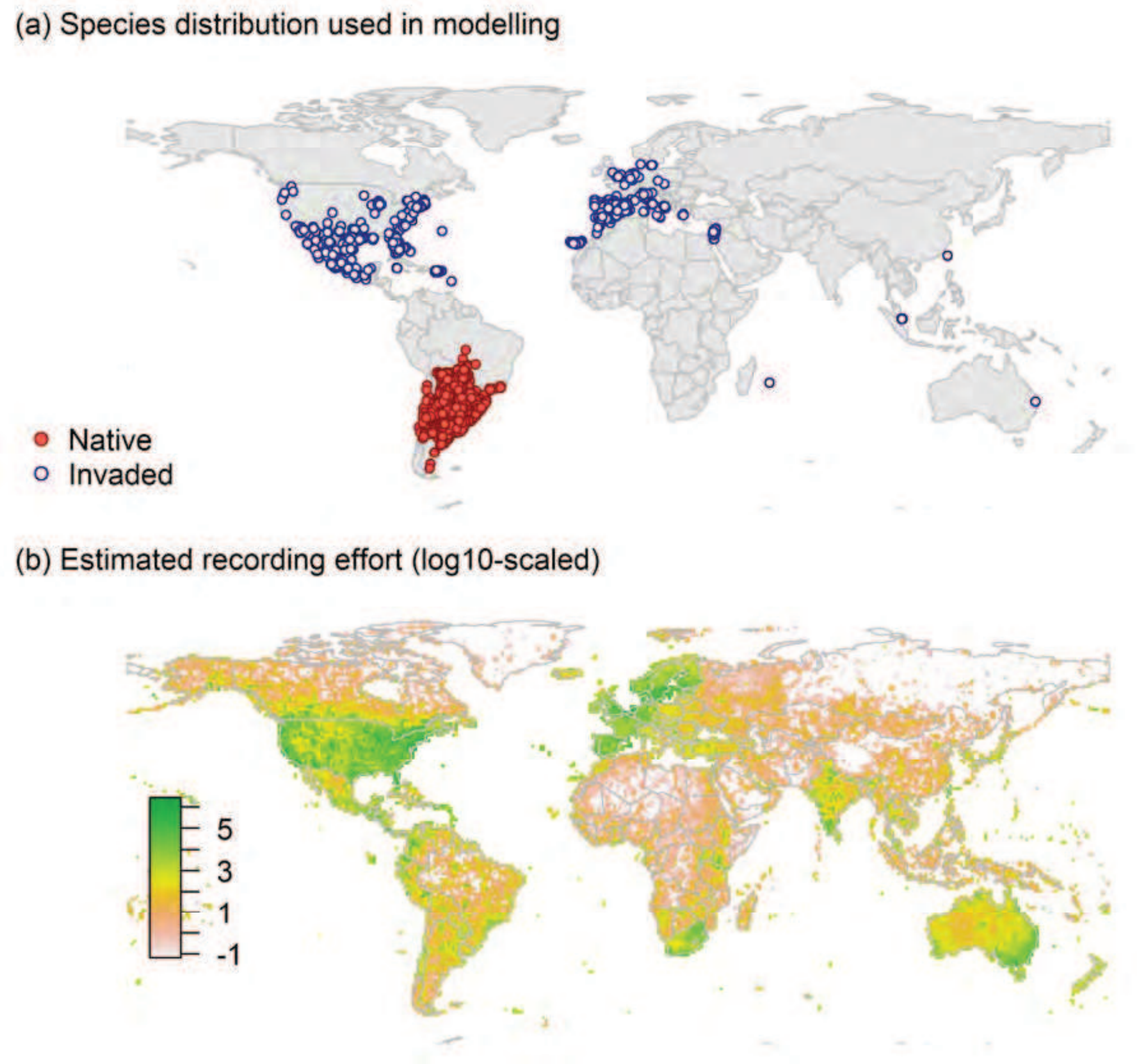
Aim

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

Data for modelling

Species occurrence data were obtained from the Global Biodiversity Information Facility (GBIF) (250293 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 3573 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 *Myiopsitta monachus* 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 *Myiopsitta monachus*, the following climate variables were used in the modelling:

- Mean temperature of the warmest quarter (Bio10)
- Annual precipitation (Bio12)
- As a proxy for potential depth and duration of snow cover (Snow), the inverse of the mean temperature of the coldest quarter (Bio11) was multiplied with mean precipitation of the coldest quarter (Bio19), to produce a number that is greatest in areas where winters are both cold and have high precipitation.

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:

- 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 and 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

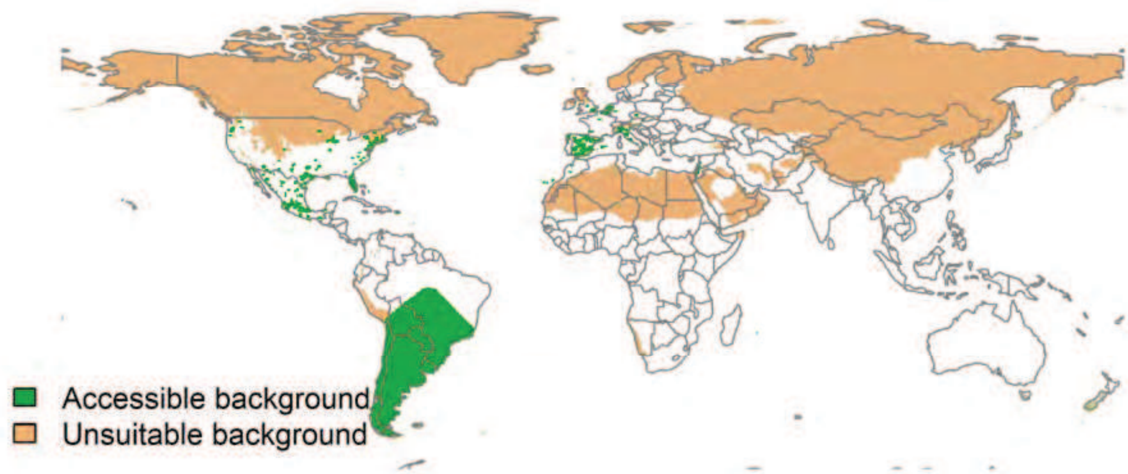
A presence-background (presence-only) ensemble modelling strategy was employed using the BIOMOD2 R package version 3.4.6 (Thuiller et al., 2020, Thuiller et al., 2009). These models contrast the environment at the species' occurrence locations against a random sample of the global background environmental 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 *Myiopsitta monachus* 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 50km 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 *Myiopsitta monachus* at the spatial scale of the model:
  - Minimum temperature of the coldest month (Bio6) < -11°C
  - Mean temperature of the warmest quarter (Bio10) < 14°C
  - Annual precipitation (Bio12) < 100mm

Altogether, 1.3% 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 (3573), weighting the sampling by a proxy for recording effort (Figure 1(b)).

Figure 2. The background from which pseudo-absence samples were taken in the modelling of *Myiopsitta monachus*. Samples were taken from a 400km buffer around the native range and a 50km 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, seven 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
- Artificial neural network (ANN)
- Multivariate adaptive regression splines (MARS)
- 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 and 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 et al. 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 et al. 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 et al. 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 and 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.

Projections were classified into suitable and unsuitable regions using a "lowest presence threshold" (Pearson et al. 2007), setting the cut-off as the lowest value at which 98% of all presence records are classified correctly under the current climate (here 0.11). In order to express the sensitivity of classifications to the choice of this threshold, thresholds at which 95% and 99% of records are classified correctly (here 0.21 and 0.07 respectively) were used in the calculation of error bars in Figures 9 and 10 below in addition to taking account of uncertainty in the projections themselves. (cf. part (b) of Figs. 5,7,8). In other words, the upper error bars in Figures 9 and 10 show proportions classified as suitable with a threshold of 0.2 (at which 99% of presence records are classified correctly), and are based on projected suitabilities plus the standard error in projections, while the lower error bars show proportions classified as suitable with a threshold of 0.42 (at which 95% of presence records are classified correctly), and are based on projected suitabilities minus the standard error in projections.

We also produced a limiting factor map 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 ones resulting in the highest increase in suitability in each grid cell.

Results

The ensemble model suggested that suitability for *Myiopsitta monachus* was most strongly determined by Proxy for potential snow cover (Snow), accounting for 50.4% of variation explained, followed by Mean temperature of the warmest quarter (Bio10) (25.4%), Annual precipitation (Bio12) (17.3%) and Human influence index (HII) (7%) (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**	**Proxy for potential snow cover (Snow)**	**Mean temperature of the warmest quarter (Bio10)**	**Annual precipitation (Bio12)**	**Human influence index (HII)**
GLM	0.883	0.593	0.639	yes	53	30	16	1
GAM	0.890	0.589	0.641	yes	46	26	15	13
GBM	0.915	0.627	0.667	yes	53	28	17	3
ANN	0.920	0.654	0.690	yes	40	31	17	13
MARS	0.895	0.590	0.643	yes	65	13	19	3
RF	0.873	0.517	0.606	no	42	28	19	12
Maxent	0.901	0.596	0.640	yes	46	24	20	9
Ensemble	**0.914**	**0.628**	**0.660**		**50**	**25**	**17**	**7**

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.

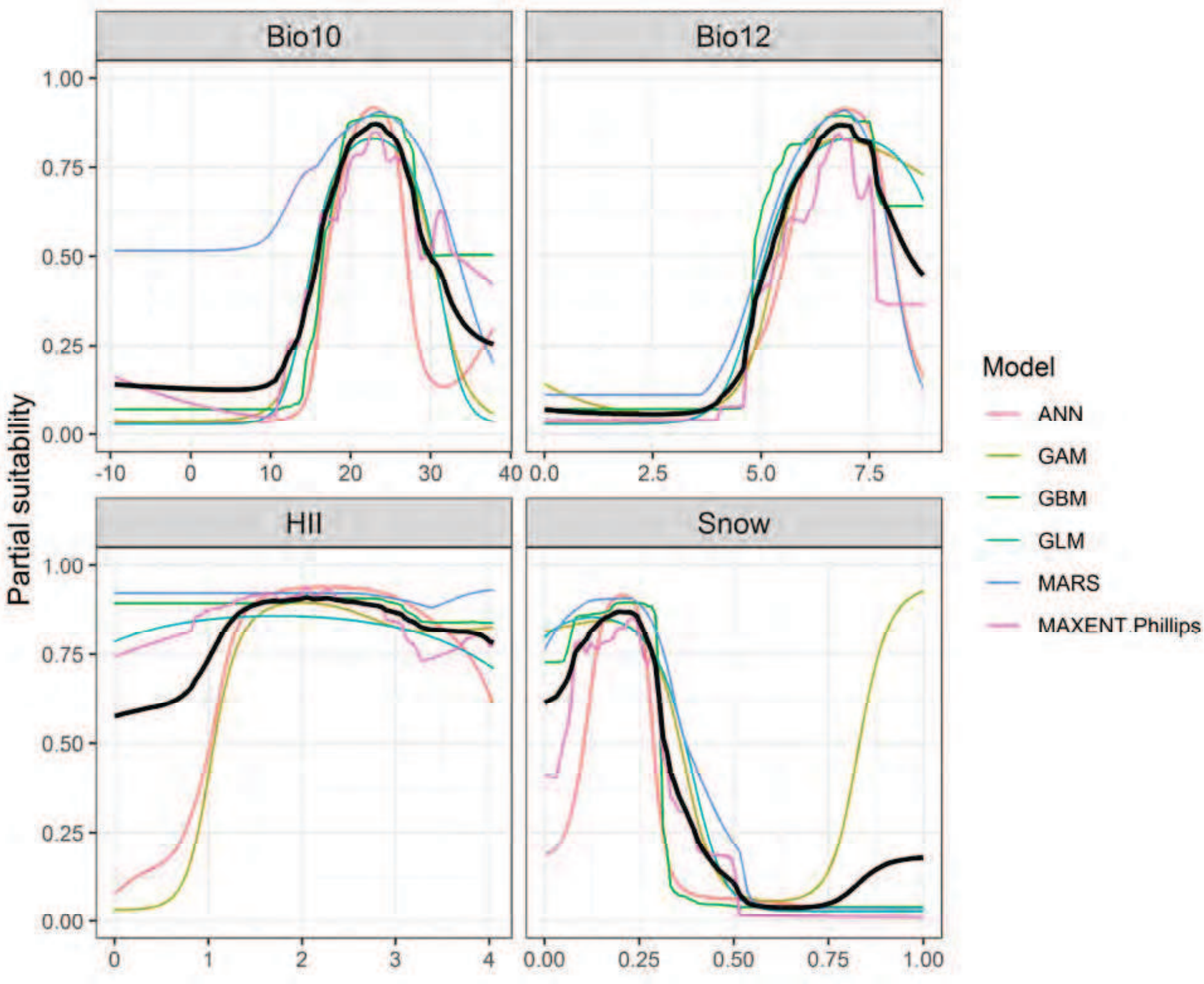


Figure 4. (a) Projected global suitability for *Myiopsitta monachus* establishment in the current climate. For visualisation, the projection has been aggregated to a 0.5 x 0.5 degree resolution, by taking the maximum suitability of constituent higher resolution grid cells. Values > 0.11 are suitable for the species, with 98% of global presence records above this threshold. Values below 0.11 indicate lower relative suitability. (b) Uncertainty in the ensemble projections, expressed as the among-algorithm standard deviation in predicted suitability, averaged across the 10 datasets.

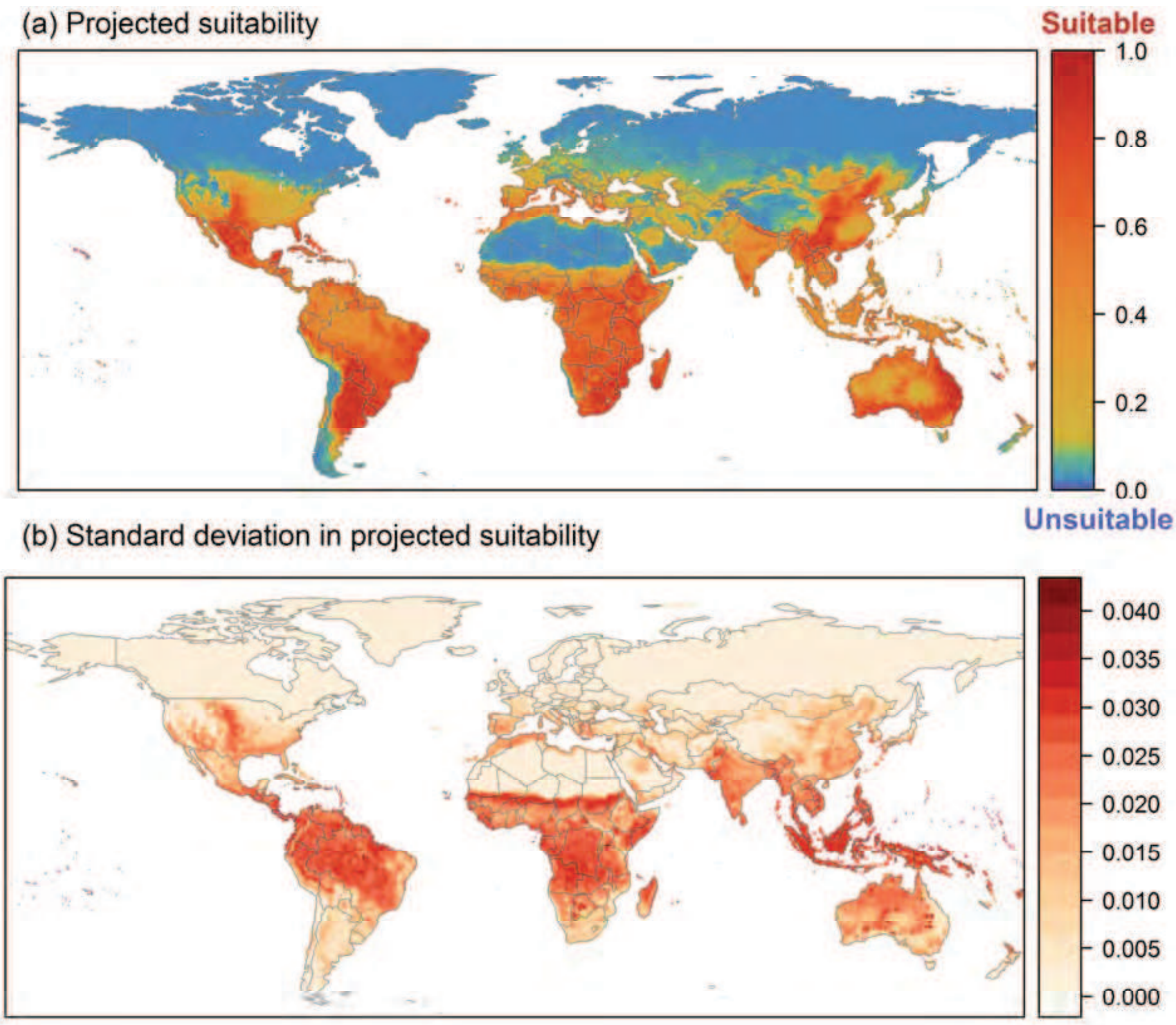


Figure 5. (a) Projected current suitability for *Myiopsitta monachus* establishment in Europe and the Mediterranean region. Values > 0.11 are suitable for the species, with 98% of global presence records above this threshold. Values below 0.11 indicate lower relative suitability. (b) Uncertainty in the ensemble projections, expressed as the among-algorithm standard deviation in predicted suitability, averaged across the 10 datasets.

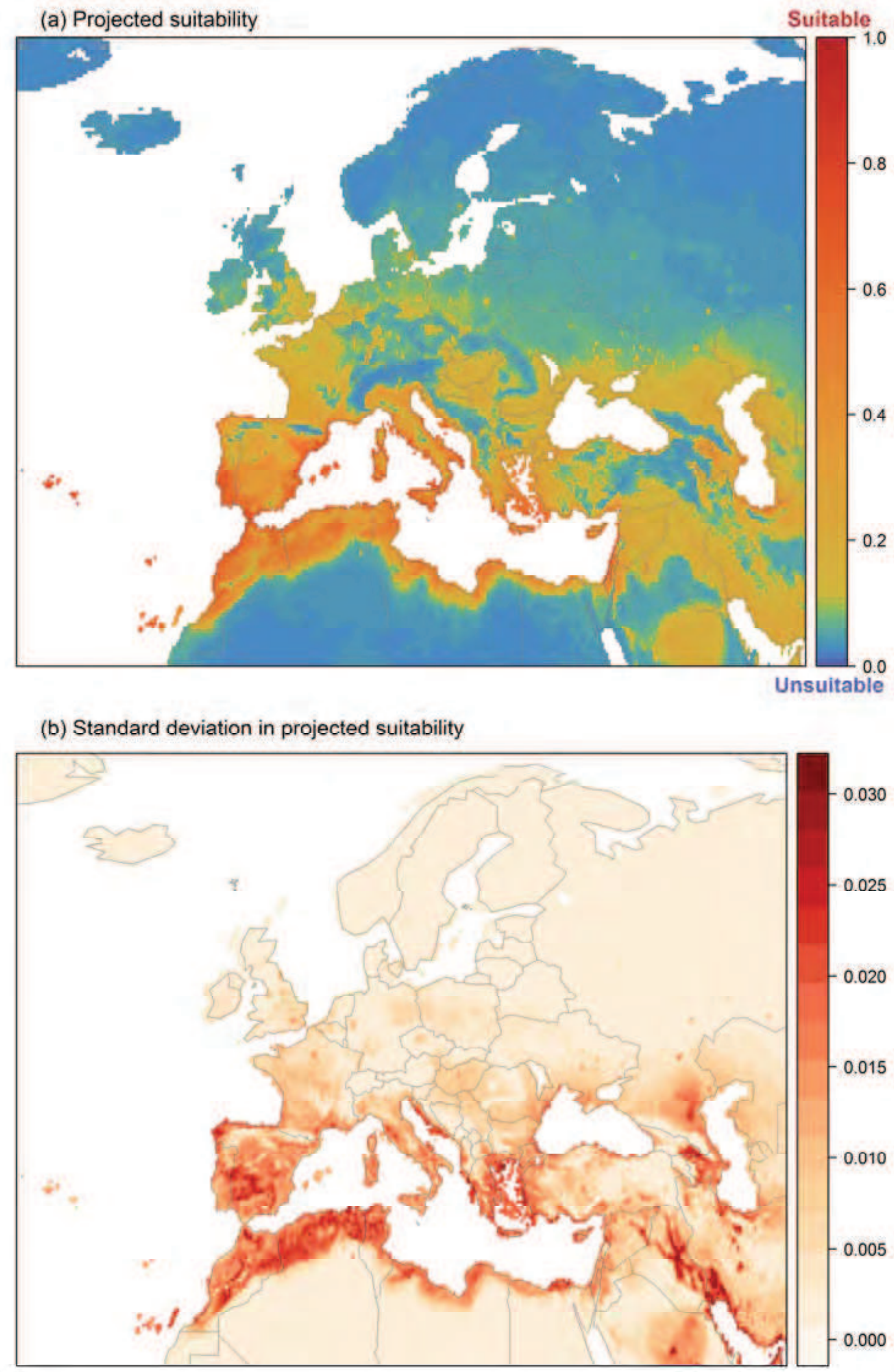


Figure 6. The most strongly limiting factors for *Myiopsitta monachus* establishment estimated by the model in Europe and the Mediterranean region in current climatic conditions.

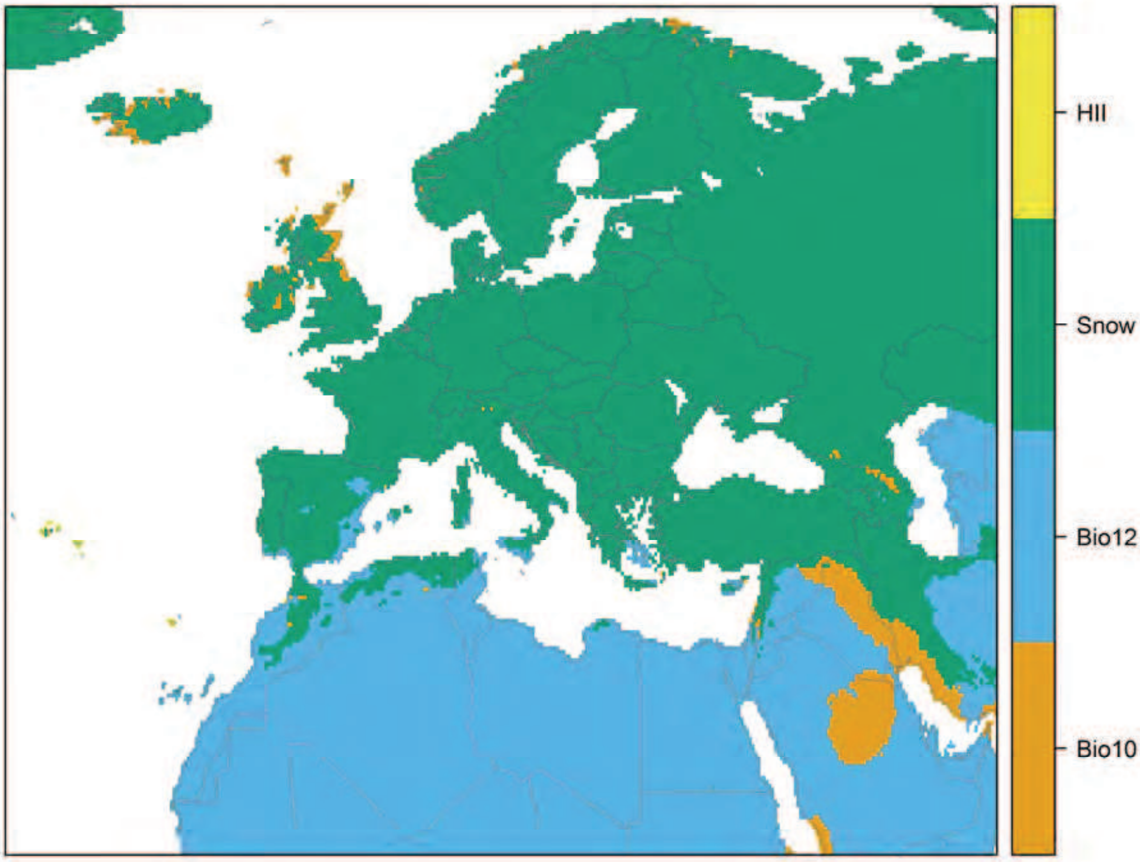


Figure 7. (a) Projected suitability for *Myiopsitta monachus* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP2.6. Values > 0.11 are suitable for the species, with 98% of global presence records above this threshold under current climate. Values below 0.11 indicate lower relative suitability. (b) Uncertainty in the ensemble projections, expressed as the among-algorithm standard deviation in predicted suitability, averaged across the 10 datasets.

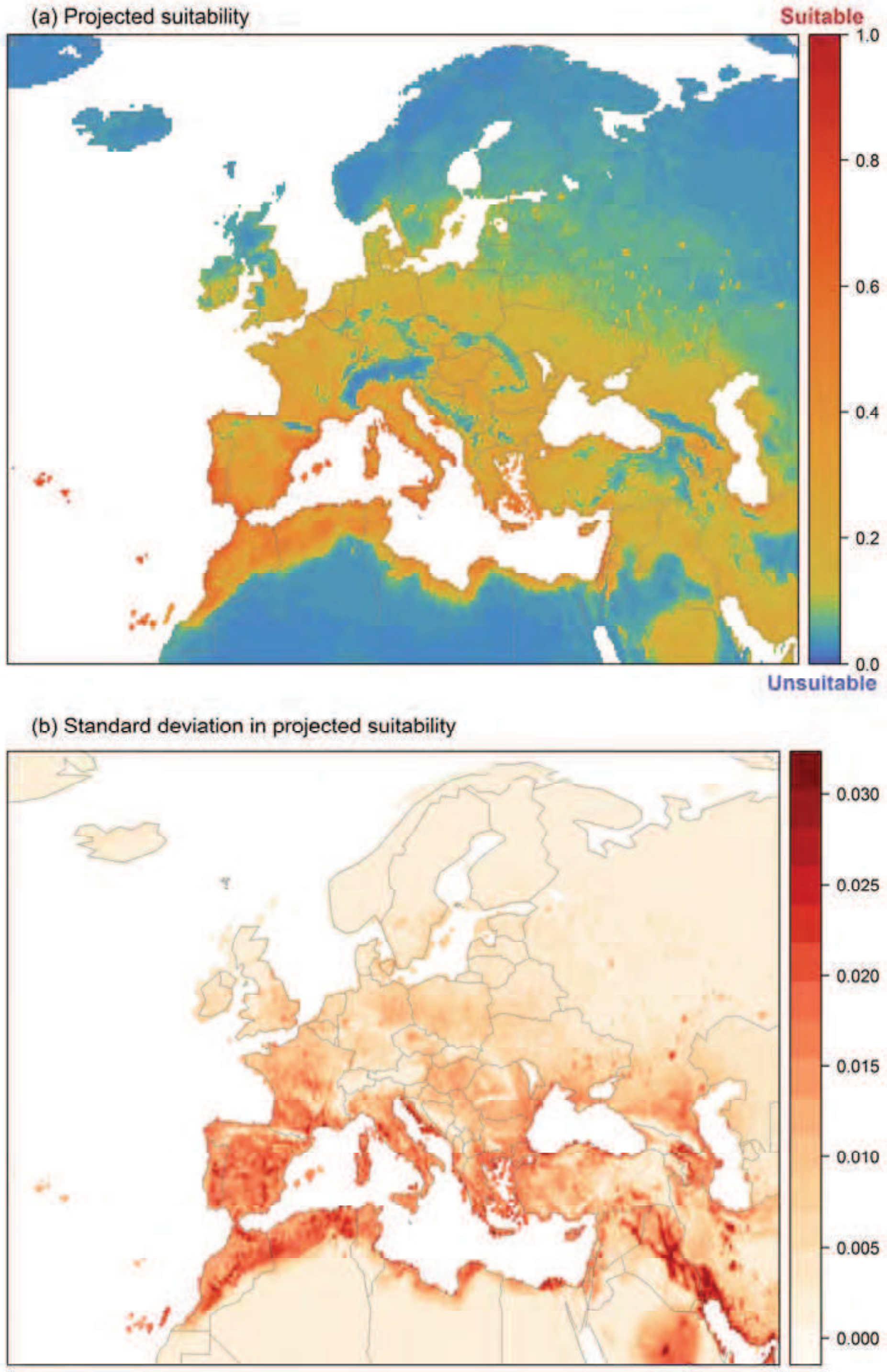


Figure 8. (a) Projected suitability for *Myiopsitta monachus* establishment in Europe and the Mediterranean region in the 2070s under climate change scenario RCP4.5. Values > 0.11 are suitable for the species, with 98% of global presence records above this threshold under current climate. Values below 0.11 indicate lower relative suitability. (b) Uncertainty in the ensemble projections, expressed as the among-algorithm standard deviation in predicted suitability, averaged across the 10 datasets.

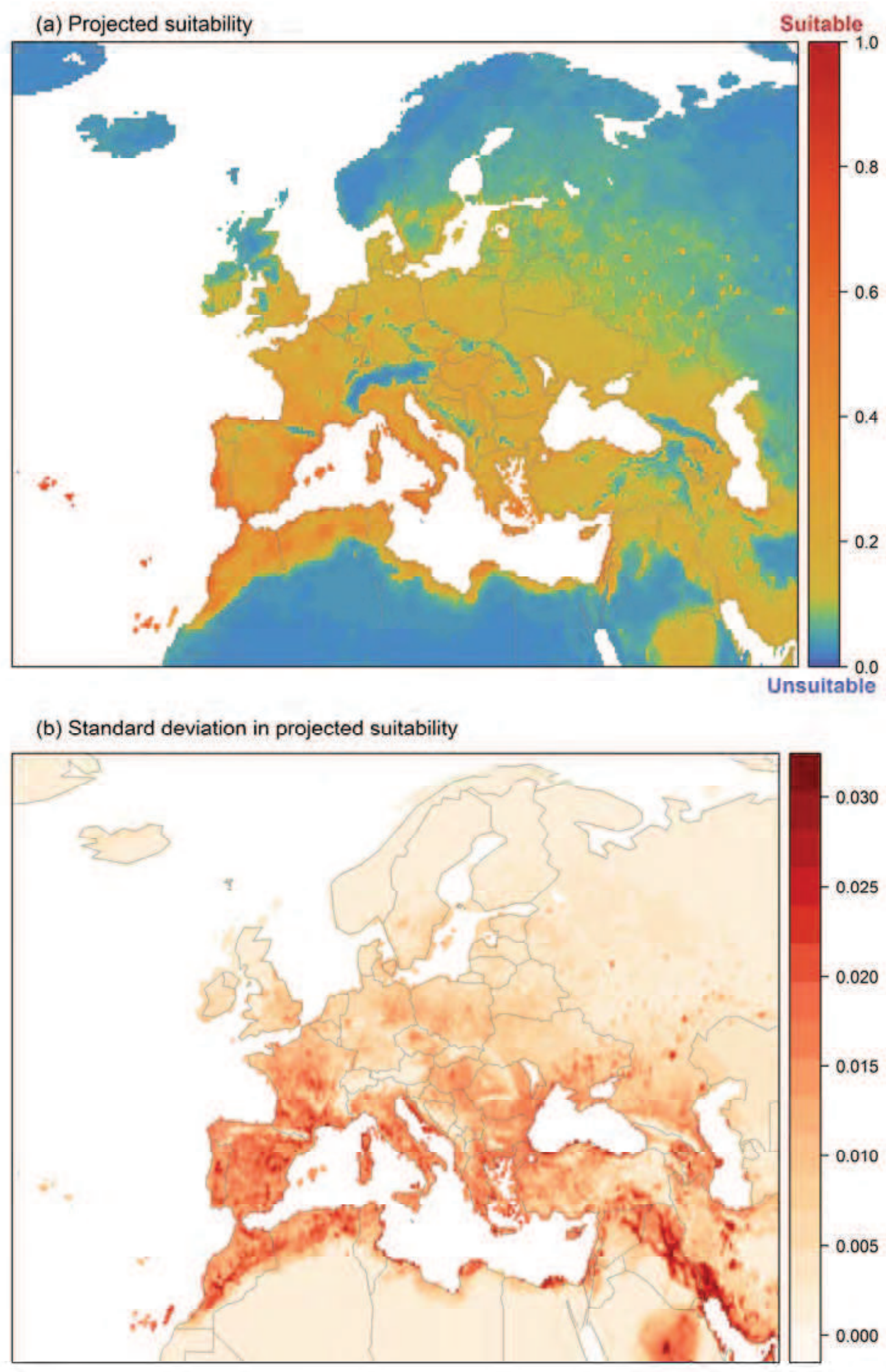
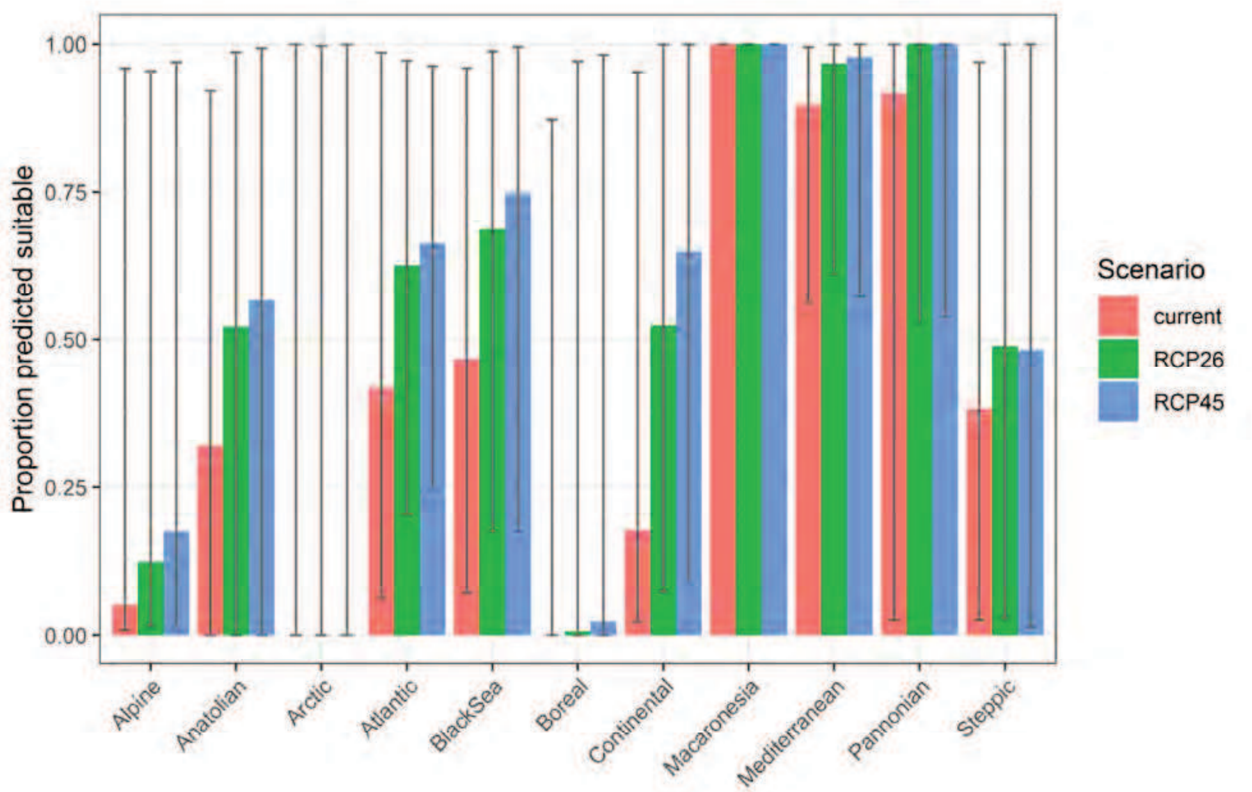


Figure 9. Variation in projected suitability for *Myiopsitta monachus* establishment among Biogeographical Regions of Europe (https://www.eea.europa.eu/data-and-maps/data/biogeographical-regions-europe-3). The bar plots show the proportion of grid cells in each region classified as suitable (with values > 0.11) in the current climate and projected climate for the 2070s under two RCP emissions scenarios. Error bars indicate uncertainty due to both the choice of classification threshold (cf. p. 104) and uncertainty in the projections themselves (cf. part (b) of Figures 5, 7 and 8). The location of each region is also shown. The Arctic and Macaronesian regions are not part of the study area, but are included for completeness.



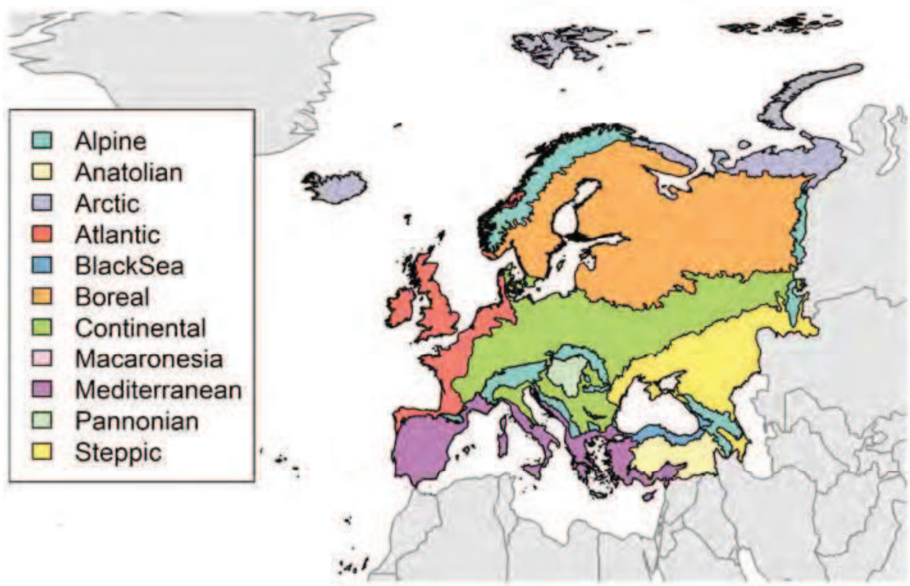


Table 2. Variation in projected suitability for *Myiopsitta monachus* establishment among Biogeographical regions of Europe (numerical values of Figure 9 above). The numbers are the proportion of grid cells in each region classified as suitable in the current climate and projected climate for the 2070s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

	current climate			**2070s RCP2.6**			**2070s RCP4.5**		
	lower	**central estimate**	upper	lower	**central estimate**	upper	lower	**central estimate**	upper
Alpine	0.01	0.05	0.96	0.02	0.12	0.95	0.01	0.17	0.97
Anatolian	0.00	0.32	0.92	0.00	0.52	0.99	0.00	0.57	0.99
Arctic	0.00	0.00	1.00	0.00	0.00	1.00	0.00	0.00	1.00
Atlantic	0.06	0.42	0.99	0.20	0.62	0.97	0.24	0.66	0.96
Black Sea	0.07	0.47	0.96	0.17	0.69	0.99	0.17	0.75	1.00
Boreal	0.00	0.00	0.87	0.00	0.01	0.97	0.00	0.02	0.98
Continental	0.02	0.18	0.95	0.07	0.52	1.00	0.09	0.65	1.00
Macaronesia	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Mediterranean	0.56	0.90	1.00	0.61	0.97	1.00	0.57	0.98	1.00
Pannonian	0.02	0.92	1.00	0.53	1.00	1.00	0.54	1.00	1.00
Steppic	0.02	0.38	0.97	0.03	0.49	1.00	0.01	0.48	1.00

Figure 10. Variation in projected suitability for *Myiopsitta monachus* establishment among European Union countries and the UK. The bar plots show the proportion of grid cells in each country classified as suitable (with values > 0.11) in the current climate and projected climate for the 2070s under two RCP emissions scenarios. Error bars indicate uncertainty due to both the choice of classification threshold (cf. p. 104) and uncertainty in the projections themselves (cf. part (b) of Figures 5, 7 and 8). Malta has been excluded because the Human Influence Index dataset lacks coverage for Malta.

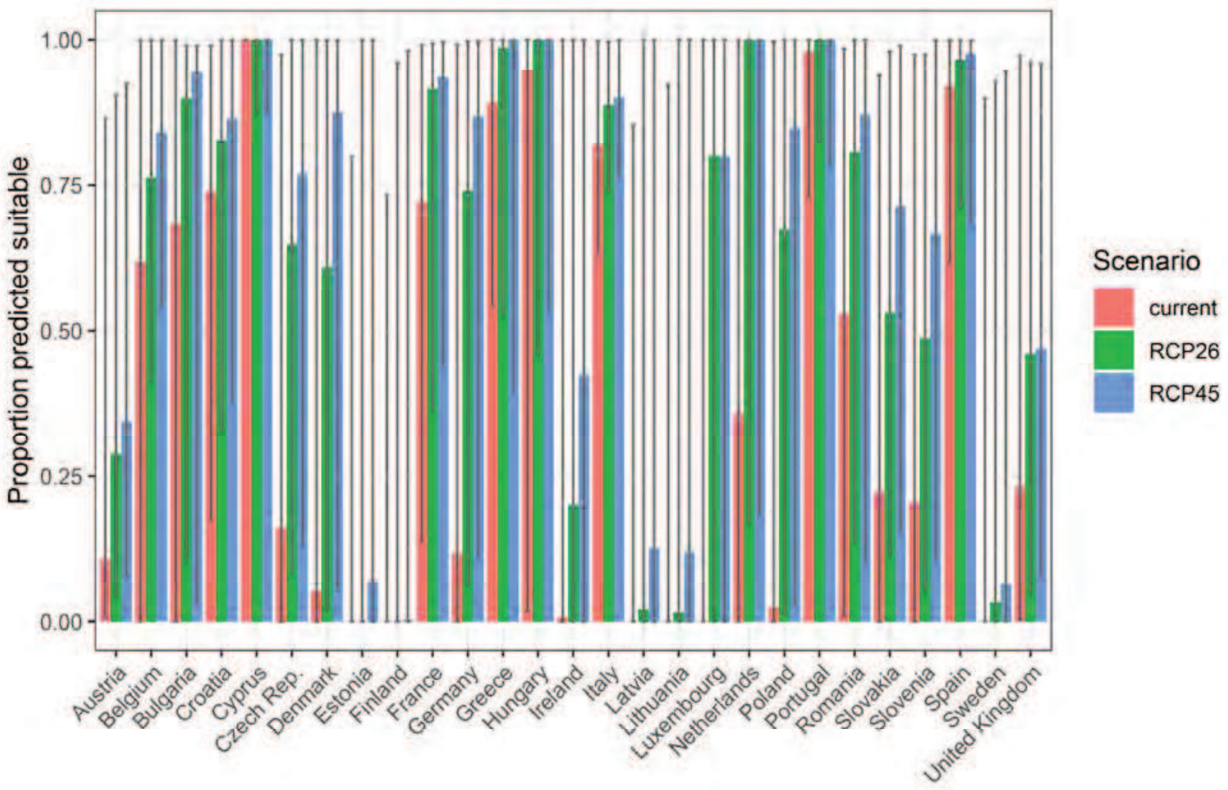


Table 3. Variation in projected suitability for *Myiopsitta monachus* establishment among European Union countries and the UK (numerical values of Figure 10 above). The numbers are the proportion of grid cells in each country classified as suitable in the current climate and projected climate for the 2070s under two RCP emissions scenarios.

	current climate			**2070s RCP2.6**			**2070s RCP4.5**		
	lower	**central estimate**	upper	lower	**central estimate**	upper	lower	**central estimate**	upper
Austria	0.01	0.11	0.87	0.04	0.29	0.90	0.08	0.34	0.92
Belgium	0.00	0.62	1.00	0.41	0.76	1.00	0.54	0.84	1.00
Bulgaria	0.00	0.68	1.00	0.10	0.90	0.99	0.03	0.94	0.99
Croatia	0.17	0.74	0.99	0.33	0.83	1.00	0.38	0.87	1.00
Cyprus	1.00	1.00	1.00	0.88	1.00	1.00	0.88	1.00	1.00
Czech Rep.	0.00	0.16	0.97	0.08	0.65	1.00	0.13	0.77	1.00
Denmark	0.00	0.05	1.00	0.02	0.61	1.00	0.05	0.88	1.00
Estonia	0.00	0.00	0.80	0.00	0.00	1.00	0.00	0.07	1.00
Finland	0.00	0.00	0.73	0.00	0.00	0.96	0.00	0.00	0.98
France	0.14	0.72	0.99	0.36	0.91	0.99	0.44	0.94	1.00
Germany	0.00	0.12	0.99	0.06	0.74	1.00	0.11	0.87	1.00
Greece	0.54	0.89	1.00	0.52	0.99	1.00	0.39	1.00	1.00
Hungary	0.02	0.95	1.00	0.46	1.00	1.00	0.53	1.00	1.00
Ireland	0.00	0.01	1.00	0.00	0.20	1.00	0.00	0.42	1.00
Italy	0.63	0.82	1.00	0.74	0.89	1.00	0.76	0.90	1.00
Latvia	0.00	0.00	0.85	0.00	0.02	1.00	0.00	0.13	1.00
Lithuania	0.00	0.00	0.92	0.00	0.01	1.00	0.00	0.12	1.00
Luxembourg	0.00	0.00	1.00	0.00	0.80	1.00	0.00	0.80	1.00
Netherlands	0.00	0.36	1.00	0.17	1.00	1.00	0.18	1.00	1.00
Poland	0.00	0.02	1.00	0.01	0.67	1.00	0.03	0.85	1.00
Portugal	0.73	0.98	1.00	0.82	1.00	1.00	0.78	1.00	1.00
Romania	0.01	0.53	0.98	0.13	0.81	1.00	0.10	0.87	1.00
Slovakia	0.00	0.22	0.94	0.11	0.53	0.98	0.15	0.71	0.99
Slovenia	0.00	0.21	0.97	0.05	0.49	0.97	0.10	0.67	1.00
Spain	0.62	0.92	1.00	0.71	0.97	1.00	0.68	0.98	1.00
Sweden	0.00	0.00	0.90	0.00	0.03	0.93	0.00	0.06	0.95
United Kingdom	0.00	0.23	0.97	0.05	0.46	0.96	0.08	0.47	0.96

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 were not included in the model.

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Annex with evidence on measures and their implementation cost and cost-effectiveness

Species (scientific name)	***Myiopsitta monachus*** **(Boddaert, 1783)**
Species (common name)	**Monk Parakeet**
Author(s)	**Pete Robertson**
Reviewer	**Tim Adriaens, Riccardo Scalera, Juan Carlos Senar**
Date Completed	**14/10/2022**

Summary[1] Highlight of measures that provide the most cost-effective options to prevent the introduction, achieve early detection, rapidly eradicate and manage the species, including significant gaps in information or knowledge to identify cost-effective measures.
The Monk Parakeet (*Myiopsitta monachus*) is an intelligent and highly social member of the parrot family of birds. It has been widely kept as a caged bird, while escapes have led to the establishment of self-sustaining populations in an increasing range of urban centres across Europe. Raising awareness of the risk posed by escapes of this species, and enforcement of existing restrictions on keeping and breeding will reduce the risks of further escapes. The species is unique among parrots in that it is not a cavity-nester, but instead it builds a bulky nest structure of sticks (e.g. in trees like cedars or palm trees, on electricity poles). A nest structure may house a single nest chamber or may be a large, communal construction that incorporates multiple independent chambers; and are used by the birds throughout the year for breeding and roosting. A number of programmes have eradicated, or almost completely removed, newly established monk parakeet populations, including London (UK), Zaragoza and the Balearic Islands (Spain). The most cost-effective control method to reduce numbers of birds appears to be shooting with a high-powered air rifle, particularly under the nesting structure which the birds continue to return to. However, the lethal control of monk parakeets can meet considerable opposition from the public while the use of firearms or air-weapons in urban centres can raise wider concerns and may be restricted in many Member States. High levels of public concern have limited the methods available in some areas, with a focus on non-lethal and more humane alternatives being used to achieve eradication. Live trapping away from the nest appears to have only limited success, as the birds are wary and soon learn if other birds are observed being captured. Nets placed over the nest entrance are labour intensive, but have proved effective if the number of nests is limited. The birds appear to be able to detect eggs that have been oiled or pricked, but are more likely to accept replacement model eggs. Egg replacement has proved a useful, if highly labour intensive method to limit reproduction and aid eradication at one site in London. Nest removal offers little benefit towards eradication as

the birds will readily renest in the same spot or local vicinity. Eradication is considered most likely using a persistent, integrated effort applying a combination of methods, and shooting followed by netting at the nest appear to be the most cost-effective approaches.

If eradication is no longer considered feasible, then a range of alternative methods have been used to limit abundance and reduce local conflicts. Nest destruction, combined with the capture and removal of adults, can reduce local conflicts, for example those caused by the build-up of nesting material on electricity infrastructure. Chemical contraceptives have been trialled on a local basis with some success in the US, but concerns remain regarding non-target species exposure and these methods are not in wide scale use at present, nor licensed for use in the EU. The use of toxins and biological control agents has been considered, but are either not licensed for use in the EU, or of only hypothetical effectiveness.

Detailed assessment			
	Description of measures[2]	**Assessment of implementation cost and cost-effectiveness (per measure)[3]**	**Level of confidence[4]**
Methods to achieve prevention of intentional and unintentional introduction[5]	**Managing pathways**. Monk Parakeets have been introduced to new areas through a variety of pathways, including the pet trade, the keeping of animals in zoos and private collections, deliberate introductions and possibly via human assisted transport. The adoption and enforcement of appropriate legislation and codes of best practice to reduce the risks posed by these pathways should reduce the probability of further introductions. However, this species is now widespread in Europe and spread within the region is also a risk (Postigo et al. 2019).	The EU Regulation (1143/2014) on invasive alien species entered into force on 1 January 2015. The Regulation places restrictions on a list of species known as IAS of Union Concern. These are species whose potential adverse impacts across the European Union are such that concerted action across Europe is required. This list is drawn up by the European Commission and managed with Member States using risk assessments and scientific evidence. This provides the framework within which their pathways are identified and prioritised, priority species controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS. If a species is included in the Union list, then this carries responsibilities to restrict the species being kept, bred, transported, sold, used or exchanged, allowed to reproduce, grown or cultivated, or released into the environment. A European Code of Conduct on Pets and Invasive Alien Species was produced and adopted by the Council of Europe. This tool aims to assist in establishing a single common standard set of behaviours that will enable the continued quiet ownership of pets while limiting to a minimum any chances of them becoming invasive and causing either economic or ecological harm (Davenport and Collins 2016). Similarly, the implementation of the European code of conduct on zoological gardens and	**High** – The EU Regulation provides the legal and policy framework to reduce the risks posed by alien species. Codes of Practice are a recognised mechanism to promote responsible activity within a sector.

		aquaria and invasive alien species (Scalera et al. 2012) may help preventing introductions from zoos and other private collections.	
	Raising awareness. Raising public awareness of the risks posed by invasive alien species in general and Monk Parakeets in particular can decrease the probability of new escapes and their rapid reporting. The production of targeted publicity and identification material is a useful element to support this.	An information sheet to aid with the identification of this species is available from the UK Non-Native Species Secretariat (www.nonnativespecies.org) and a range of other fact sheets with identification information are available such as on the website of Brussels Environment (https://document.leefmilieu.brussels/opac_css/elecfile/IF_biodiversite_conure_veuve_NL.PDF?langtype=2067&_ga=2.18666682.2094668426.1647510397-2028655672.1647510397), the Belgian citizen science reporting portal for IAS (www.waarnemingen.be/exoten).	**High** – Established methods to raise awareness.
Methods to achieve early detection[6]	**Citizen Science**. Monk Parakeets are a highly visible (and noisy) species often found in association with human activity. Encouraging rapid reporting of new incursions through Citizen Science or organised species monitoring increases the likely success of rapid response before the species can become established in an area.	Citizen Science species occurrence datasets are increasingly recognized as a valid tool for monitoring the occurrence and spread of invasive alien species across large spatial and temporal scales (Roy et al. 2015). They are dependent on citizen-scientists who collect and upload data, typically from 'opportunistic sampling' with no underlying scientific survey design (Boakes et al. 2010) which can limit the conclusions that can be drawn from these data but are still useful to inform baseline distribution and rapid response actions (Isaac et al. 2014). Most parts of north-west Europe have an extensive network of volunteer bird observers, although this is less true of southern and especially eastern Europe (Boakes et al. 2010). Unstructured citizen-science data do not reliably allow an estimate of species	**High** – Citizen science and taxa specific surveys are widely used to support alien species monitoring and surveillance.

		abundance or population trends (Kamp et al. 2016), yet in an early-warning scenario it is likely sufficient to know where a species is establishing, and these data limitations are thus of a lesser concern. Organised monitoring activities carried out by bird-watchers also provide a structured format for surveillance, although there is a risk of under-reporting if birdwatchers consider that the data will be used to support eradications. Considering the monk parakeet's conspicuous nests and their noisy habits which often cause nuisance to people, the species' profile would make it a good candidate to involve the public in reporting the presence of (sleeping) aggregations or nest sites of monk parakeets.	
Methods to achieve eradication[7]	General Background	There have been a number of documented examples of the successful eradication (or removal to very low levels) of this species. Senar et al. (2021a) compiled available information on the cost-effectiveness of different control methods based on control studies in Barcelona, Saragossa and Catalunya. This compared the cost per bird and the cost per hour of different methods, including trapping (EUR 44 per bird, EUR 70 per hour), cannon netting (EUR 282 per bird, EUR 198 per hour), shooting (EUR 16 per bird, EUR 84 per hour), nest destruction (EUR 23 per bird, EUR 204 per hour), egg pricking (EUR 19 per bird, EUR 96 per hour) and netting adults at the nest (EUR 32 per bird, EUR 96 per hour). Based on modelling to predict the effects on the population in Barcelona they rank the methods in terms of cost-effectiveness for population reduction, with	**High** – published cases describing the effective eradication or almost complete removal of this species.

		shooting the most cost-effective, followed by hand-netting adults at the nest. In 2008, three separate monk parakeet populations were known to be established in urban settings in London, UK, totalling around 100 birds (Parrott 2013). An eradication programme was initiated in 2010, and one site in an industrial area where only one nest structure (8 birds) was present was eradicated by 2013 using shooting, catching birds in nets at the nest entrance, and egg and nestling removal although it could not be confirmed whether there were additional birds in the area. A second site in a suburban neighbourhood held two nesting colonies (around 34 and 23 birds respectively) in two locations separated by approximately 800 m. Using a combination of shooting, adult trapping, nest, egg and some nestling removal, this population was eradicated by 2019. The final site (around 36 birds) was located in a suburban and parkland setting. Control at this site focused on egg replacement methods combined with live capture of adults for subsequent re-homing. Almost all nests were accessible via a cherry-picker, however, permission from homeowners to access each nest was required which was denied on occasion by individuals and prevented control of some nests in some years. By 2021, this population had been reduced to fewer than 12 birds and control was continuing. Since 2008, over the three sites, control using a variety of methods has removed – adults in cage traps (25 birds), shooting (17 adults), nest control (508 eggs), nets (5 adults) and other	

		methods such as hand-held nets at the nest entrance (11 adults) (APHA unpublished). The Spanish city of Zaragoza deployed a control plan based on removing eggs, trapping and shooting with air-rifles to remove adults. The egg removal phase failed to stop the population growth rate. The air-rifle shooting phase resulted in the removal of up to 800 individuals per year. Both methods combined reduced the population from 1400 individuals to 20 in 2 years (Esteban 2016, Postigo 2018). Management in the Balearic Archipelago (Spain), by several methods including air-rifle shooting removed three foci and achieved almost full eradication of monk parakeets in the islands (Postigo et al. 2018). The acceptability of control of this species varies widely amongst the public and this can be important in determining control strategies as most populations are found in urban centres (Crowley, Hinchcliffe and McDonald 2019). In the USA, public opinion is a major factor in influencing the implementation of any proposed management programme associated with monk parakeets (Avery et al. 2008). In the UK, public concern had limited control to only the most humane and non-lethal methods at some sites (APHA unpublished). In most places where parakeets become established they quickly gain favour with the public, who provide food to encourage the birds and facilitate their survival. Efforts to	

		control or remove the birds can be met with significant opposition. Many attempts by state agencies to implement control programmes have been thwarted by public opposition, involving citizen's action groups and lawsuits. Most of those affected by having parakeets nesting on their property are more tolerant of management measures (including lethal control) given the noise and nuisance caused. Others oppose almost all management measures, especially lethal control and perceive the parakeets to be a positive presence. In some cases, live capture followed by rehoming, or the removal of eggs from nests, has provided a more acceptable alternative, although adding considerably to the costs and time taken.	
	Shooting Free Living Birds	Shooting free living adults has been the main control method deployed in most programmes and provides a cost-effective approach to control. Control in Zaragoza and the Balearics relied on high-powered air-rifles (Esteban 2016, Postigo 2018), with custom-made shotgun cartridges with a low muzzle energy used in addition to air-rifles in the UK (APHA unpublished). Shooting from under the nesting tree has proved particularly effective, targeting birds circling the nest, settling on nearby branches of flying-in to land (APHA unpublished). Given the tendency of the birds to return to the nesting structure, shooting can be a cost-effective	**High** – figures based on direct experience of control in published materials.

		method of control. APHA (unpublished) records 15 birds removed over 14.6 hours of shooting. Senar et al. (2021) recorded 5.2 birds shot per hour in Barcelona. However, the use of firearms in built-up areas brings health and safety concerns, opposition from local residents while the use of safer, low powered weapons risks wounding animals rather than achieving a humane kill. As a consequence, the use of firearms has been limited in a number of cases, particularly in the UK, and other methods have been required. The use of weapons in public spaces may be prohibited in some Member States. However, air weapons have been widely and successfully used in Spain (Senar et al. 2021a).	
	Trapping Free Living Birds	A variety of traps have been used to capture this species. However, they are an intelligent species and can be very wary of new structures and learn to avoid them by seeing other animals being caught. This has limited the effectiveness of trapping although it remains an important capture method. Ladder traps, also known as drop-in traps, allow a bird to perch and then enter the trap through gaps in the roof. However, to exit the trap they need to fly and the gaps are too small to allow their extended wings through (https://basc.org.uk/advice/how-to-make-a-ladder-trap/). These were trialled in the UK, where traps were constructed in suburban gardens over a period of days and contained branches on which to perch and feed	**High** – figures based on direct experience of control in published materials.

		stations. Monk Parakeets proved capable of climbing out of the traps, and perspex sheets needed to be placed on the inner surfaces around the exit holes to prevent this. When birds were captured, the trap was covered with a tarpaulin and the birds removed after dark to avoid alerting other birds. A total of 25 birds were captured in this way, but captures were infrequent and birds appeared to learn the purpose of the traps and avoid them after a time. In North America, Avery et al.(2002) describe a trial with a drop-in trap in Florida, deployed with and without the presence of a decoy bird. No birds were caught. In Barcelona, Senar et al. (2021) used a modified Yunick trap to trap monk parakeets to individually mark them and study home ranges. They record a capture rate of 1.6 birds per hour using this approach. Another design is the woosh-net. This uses bungee cords to fire a net over a baited catching area (Parrott, Roy and Dendy 2009) but needs to be manually triggered by an operative, increasing the effort required. Monk parakeets at electrical substations in the US have been successfully captured using a system that incorporates a feeding tray and spring trap (spring-powered net). Bird numbers feeding on the tray are allowed to build up and then captured by manually triggering the net (Avery et al. 2002). In Spain, Senar et al. (2021a) reports a capture rate of 0.7 birds per hour using this method. As with other traps, birds observing others being captured will	

		quickly become wary, limiting the long-term effectiveness of these methods. Traps can be effective for the live-capture of monk parakeets, but extreme care is needed to avoid the birds becoming wary, and this regularly reduces the long-term effectiveness of this approach. This also increases the man-power required to deploy these methods, reducing their cost-effectiveness. If well-constructed and used, traps offer a humane method for live-capture, an important consideration given the frequent public opposition to lethal control of this species.	
	Trapping at the Nest	Birds can be captured at the nest, by placing a net over the nest holes, or by incorporating an automated 'door' across the entrance which is controlled by a wireless signal by an operator from the ground. Active trapping with hand-held nets has been evaluated in Florida using designs previously used in South America (Tillman et al. 2004). The technique can be carried out from the ground using a long-handled net, but is more easily accomplished through use of a cherry-picker to raise operators to nest height. During the day, the locations of nest entrances are determined. After dark, using the hoist, personnel quietly and quickly position hand-held nets over the entrances. Parakeets were caught in the nets when flushed from the nest. Trapping success at >400 nests in the US ranged from 0% to 100% of occupants (mean 50%) (Tillman et al. 2004). The	**High** – figures based on direct experience of control in published materials

		technique is only effective at night, as in daylight birds will flee the nest before the nets can be fully positioned (Parrott et al. 2009). On the Cayman islands, trapping at the nest with nets reduced the Monk Parakeet population by 86% within a year (Godbeer 2014). Birds were captured during the night by placing nets quietly over the nest entrances. Once close to the nest, the nets were shaken, inducing the birds to bolt and fly into the net. In Spain, Senar et al. (2021a) reports a capture rate of 3.1 birds per hour using this method. In the UK, some adults have been caught in the nest while undertaking egg removal activities, although this is a sporadic event. Some work has been undertaken to develop a remote wireless triggered 'trap door' fitted to the nest entrance. This has had moderate success depending on how wary nesting pairs are of the device with an associated risk of desertion.	
	Nest Destruction. The species is unique among parrots in that it is not a cavity-nester, but instead it builds a bulky nest structure of sticks. Nest structures are used by the birds all year and are often highly visible. A variety of methods have been used to destroy nests, including poking with long poles, manual removal from a cherry picker, or chopping down all or part of the tree.	If nest removal coincides with active breeding, then productivity is likely to be affected although there is no data on this. Beyond this, there is no evidence that nest destruction has any population level consequences for this species. Nest destruction methods are unlikely to provide a useful method to achieve eradication as the birds will readily renest and that one pair of parakeets can rebuild a nest in less than two weeks (Avery et al. 2002).	**High** – figures based on direct experience of control in published materials.

	Egg Oiling/ Pricking/ Replacement/Removal Birds eggs can be treated in a variety of ways to prevent their development or to kill the embryo they contain. These include rubbing the eggs with a light oil which limits air transfer through the shell, or by pricking the egg which kills the embryo. Eggs can also be removed and destroyed and replaced with dummy eggs. This encourages the adults to continue incubation and delay renesting. Chicks can also be removed from the nest and euthanised.	Based on experience in the UK, Monk Parakeets appear to be able detect oiled or pricked eggs, they quickly reject treated eggs and produce a new clutch which limits the effectiveness of this approach. However, if the eggs are removed and replaced with dummy eggs then the period to rejection is extended. Egg replacement is a very labour-intensive process, requiring repeated visits to each nest and access to a cherry-picker over the period April to July to ensure that no viable eggs remain. However, for sites where lethal control is not possible due to local opposition or restrictions, egg removal may be the last viable control method. Since 2015, in one site in London, around 300 eggs have been replaced with model eggs and has been a key part of the ongoing eradication campaign (APHA unpublished). Chick removal faces similar constraints to egg removal, requiring frequent visits to nest. However, the killing of chicks raises humaneness and welfare issues and enhanced local opposition beyond those encountered with egg removal. As a consequence, there are few advantages to this approach and there are no reports of its use.	**High** – figures based on direct experience of control in published materials
	Use of toxins: Spurr and Eason (1999) review the available avicides worldwide. The toxicant Starlicide (DRC-1339 or 3-chloro-p- toluidine hydrochloride)	No accounts of the control of Monk Parakeets using toxicants were found. Their use is also restricted by legislation, no suitable products are currently licensed for use as an avicide in the EU.	**High** – The legislation on the use of toxins in EU law is clear.

	(Ramey et al., 1994, ACVM, 2002) and the stupifactant Alphachloralose ((R)-1,2-0-(2,2,2- trichloroethylidene)-α-D-glucofuranose) (Thearle 1969) are the two main chemical control options used on other bird species. However, no products are currently approved for use in the EU.		
Methods to achieve management[8]	General background	The methods described for eradication can also be applied to reduce local populations and conflicts. However, some of the more labour intensive methods such as egg replacement are unlikely to be of benefit for more wide scale control.	
	Nest Destruction. Nest structures are used by the birds all year and are often highly visible. A variety of methods have been used to destroy nests, including poking with long poles, manual removal from a cherry picker, or chopping down all or part of the tree.	Nest removal can be a useful tool to move birds from a particular local site where they may be causing a public nuisance or damaging infrastructure, for example nesting material posing a fire risk on electricity infrastructure. The birds are likely to rapidly build a new nest in the same location if efforts are not made to proof the structure to prevent renesting. There is no evidence that nest destruction has any population level effects on monk parakeet numbers, but may be a useful and socially acceptable way to reduce conflicts at a local scale. In Florida, where the birds regularly nest on electricity supply structures, the cost of removing monk parakeet nests on distribution and substations was estimated at $415 per nest. The cost is likely higher on transmission lines where additional time and equipment are needed.	**High** – figures based on direct experience of control in published materials

		In 2001, about 90 nests were removed for a total cost of $37,000. A survey of monk parakeet nests throughout the Florida electrical supply system found a total of 1,110 nests, including 534 at substations, 400 on distribution structures, and 176 on transmission towers. Based on current rates for nest removal, a conservative cost for the annual removal of all existing nests would be $460,650 (Tillman et al. 2004). Because birds will readily rebuild their nest, an effective nest removal program requires that the birds be removed with the nest. The estimated cost to capture monk parakeets from a nest is $1,000. The cost to remove both a nest and the birds inhabiting it is therefore $1,500/nest. At this rate, the conservative cost to remove all 1,110 nests and the birds causing conflicts in the Florida region would be $1,665,000 with recurring costs in subsequent years. (Tillman et al. 2004).	
	Habitat Modification. Particular conflicts can arise from this species nesting on electricity infrastructure, for example certain designs of transmission towers. New constructions should incorporate these findings to adopt designs less likely to attract nests.	Descriptions of the characteristics of electricity infrastructure favoured by this species are available from Florida (APHIS 2016). However, no studies in Europe have examined the use of artificial structures in this light. The effectiveness of this approach needs to be determined, and the capital costs of replacing electricity infrastructure are likely to be high.	
Deterrence	Local concentrations of birds may be dispersed or deterred from visiting a site using a variety of methods. For Monk Parakeets, the use of these methods has	Avery et al. (2002) describe experimental studies to deter birds from nesting structures located on electricity substations in Florida, and to then deter re-nesting when the original nest had been removed. Three deterrents were used, a taxidermic monk parakeet effigy hung near	**Medium**. While studies on this species have taken place, they have been small-scale

	focused on deterring birds from nest structures.	the nest, a commercially available plastic owl device, and the use of a low-power laser. These trials were conducted initially with no nest removal and then with the nests removed from the substation. All three methods were of limited effectiveness. The effigy appeared to have little effect, the plastic owl had an initial deterrent effect but the birds soon became habituated and any benefits were short-term. Lasers proved useful in dispersing birds, but they soon returned when the treatment ceased (Avery et al. 2002). Burgio et al. (2014) showed electrical lines are critical access points to monk parakeets for initiating nest building on utility poles, as otherwise the birds would have to beak-climb and would lose their nesting materials. However, they note it is unlikely that preventing monk parakeets from nesting on utility poles will provide a means of population control as they would nest-build in trees if excluded from poles.	and short-term. No details available to assess their cost-effectiveness. These methods are not believed to be in routine use.
Biological control	Population reduction is one approach to lessening the impacts of monk parakeets to utility structures and agricultural resources. One possible approach to lethal control is the selective application of an endemic protozoan parasite. *Sarcocystis falcatula* is a protozoan parasite that cycles between Virginia opossums (*Didelphis virginiana*) and	A number of studies suggest that this parasite causes morbidity and mortality in psittacine birds. For example, in a study at a major zoo, 37 psittacine birds died (Hillyer et al. 1991). The most common signs were pulmonary edema and hemorrhage. Half of these birds died without any clinical signs. Infected birds sometimes go off feed and lose weight, but most die before any signs are evident.	**Low** – This is a hypothetical proposal and there is no available research on its use as a control method for this species.

	brown-headed cowbirds (*Molothrus ater*) and grackles (*Quiscalus* spp). (Avery et al. 2002).	Because this parasite is apparently lethal to psittacines and is apparently not harmful to native bird species, Avery et al. (2002) suggest it may be worth investigating whether selective application of the parasite can be used as a component of a monk parakeet population management plan in North America. This would need to determine an effective dose via trials with captive birds, and then develop and evaluate a selective delivery procedure so that only monk parakeets will be affected by field application of this control method (Avery et al. 2002). However, the pathogen and the other species of bird and mammal known to feature its transmission in North America are not present in Europe. The introduction of a non-native pathogen would require considerable safety assessment and approval before it could be considered as a realistic approach for Europe.	
Chemical Fertility Control	In the USA, research with the chemicosterilant Diazacon has been used on an experimental basis in an effort to use contraception for humanely controlling monk parakeet populations. Diazacon inhibits the formation of reproductive hormones and is marketed in the USA under the name DiazaCon™ and has been commercially approved for reducing feral pigeon populations.	In captive trials, *ad libitum* studies showed that monk parakeets would eat adequate amounts of DiazaCon™ coated sunflower seeds to prevent successful reproduction; in treated birds egg production was decreased by 59% and no eggs hatched (Yoder et al. 2007). In subsequent field trials, bait stations were established at electrical substations in Florida and parakeets presented with Diazacon-treated sunflower seeds for 10 days at treated sites (Avery et al. 2008). Over two years, the trials involved a total of six treated sites	**Medium** – The effects of this compound on monk parakeets are well studied and there are preliminary results from its use on an experimental basis in Florida. However, there is

		and four untreated control sites which received no treated bait. The percentage of active, complete nests that were empty was greater at treated sites (32%) compared to control sites (6%). In nests where young were produced, the average productivity at the Diazacon-treated sites was 1.31 nestlings/nest (nestlings plus viable eggs), compared to 4.15 nestlings/nest at control sites. This represented a 68% reduction in reproductive success (Avery et al. 2008). Exposure of native species to treated seed was minimal, occurring principally at one site; However, another non-native species, the Eurasian collared dove *Streptopelia decaocto*, were frequently recorded at bait stations at 50% of treated sites. It was considered that Diazacon for parakeet management warranted further development, including refinement of bait presentation procedures (Avery et al. 2008).	no available information on its cost-effectiveness, long-term effects at a population level and it is not believed to be in routine use.

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Guidelines for Completing the Annex

1 Provide a brief summary description of the most cost-effective methods drawing on the reviews in the detailed assessments

2 Provide a description of the potential method. This should be based on the available key scientific evidence which should be gathered from sources including articles and reviews in technical and scientific journals, internet searches, online databases, grey literature and relevant books and personal communications from scientists, stakeholders, conservation practitioners and governmental bodies. This information should include a full bibliographic list detailing the literature and sources considered.

3 Provide an assessment of the likely cost and effectiveness of the method. Where information is available, consider the following range of questions, accepting that not all questions will be appropriate in all circumstances.

- How effective has this approach proven to be in the past or in an analogous situation?
- How publically acceptable is the approach likely to be?
- Over what period of time would this approach need to be applied to be effective?
- What is the direct cost of implementing this approach?
- How likely are the methods used in the approach to be available?
- How likely is it that relevant licences or other approvals to undertake the approach would be difficult to obtain?
- How likely is it that health and safety issues would prevent the use of this approach?
- How significant is the environmental harm caused by this approach?
- How significant is the economic harm caused by this approach?
- How significant is the social harm caused by this approach?
- How likely is it that the approach will be criticised on welfare grounds?
- How likely is it that the approach with be acceptable to other stakeholders?

Where available, factual information on the costs of specialist equipment, or case studies of management costs from across the Union or third countries should be provided. When describing case studies, if the information is available then provide both total cost and the area over which control was undertaken so that a cost per unit area might be derived. Where such quantitative information is not available, then any qualitative information from the literature is acceptable to help guide decision making. It is accepted that in the majority of cases the information required to assess the potential total cost of management at a member state level is unlikely to be available. This would normally require information on the extent and abundance of the species which is beyond the scope of this assessment. Assessors are not expected to extrapolate the potential total costs of management at a member state level, only to report on the information provided within the literature.

4 Provide an overall assessment of the confidence that can be applied to the information provided for this method. This confidence should relate to the quality of the available information using the guidance below. It should NOT relate to the confidence in the effectiveness of the method

The confidence scores are:

- **High**: Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third country with similar environmental, economic and social conditions.
- **Medium**: Information comes from published data or expert opinion, but it is not commonly applied, or it is applied in regions that may be too different from Europe (e.g. tropical regions) to guarantee that the results will be transposable.
- **Low**: data are not published in reliable information sources and methods are not commonly practiced or are based solely on opinion; This is for example the case of a novel situation where there is little evidence on which to base an assessment.

If there are further factors beyond these that have determined the chosen level of confidence, then provide a brief written description to support the choice of the level of confidence.

5 Measures for preventing the species being introduced intentionally or unintentionally into the territory of a Member State (cf. Articles 7(1)(a), 7(2), 13, 15), i.e. preventing a species entering by blocking its pathways, including pre-border prevention and prevention of escape or release into the environment and secondary spread whenever relevant. Measures for preventing the species reproducing while in containment should be included, if appropriate. Consider all methods that might be applied, including any that have not proven useful. Provide a description of each method in turn, using separate rows to consider each method.

6 Measures to run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory.

7 Measures to achieve eradication. Preferably, but not exclusively, used at an early stage of invasion, after an early detection of a new occurrence (cf. Article 17). Consider all methods that might be applied, including any that have not proven useful. Provide a description of each method in turn, using separate rows to consider each method.

8 Measures to achieve management of the species once it has become widely spread within a Member State territory (cf. Article 19). These measures can be aimed at eradication, population control or containment of a population of the species. Consider all methods that might be applied, including any that have not proven useful. Provide a description of each method in turn, using separate rows to consider each method.

The development and completion of this template forms part of the EU project **No 090201/2021/856738/ETU/ENV.D2** Study on Invasive Alien Species – Development of risk assessments to tackle priority species and enhance prevention.

Annex with evidence on measures and their implementation cost and cost-effectiveness

Species (scientific name)	***Myiopsitta monachus* (Boddaert, 1783)**
Species (common name)	**Monk Parakeet**
Author(s)	**Pete Robertson**
Reviewer	**Tim Adriaens, Riccardo Scalera, Juan Carlos Senar**
Date Completed	**14/10/2022**

Summary[1] Highlight of measures that provide the most cost-effective options to prevent the introduction, achieve early detection, rapidly eradicate and manage the species, including significant gaps in information or knowledge to identify cost-effective measures.
The Monk Parakeet (*Myiopsitta monachus*) is an intelligent and highly social member of the parrot family of birds. It has been widely kept as a caged bird, while escapes have led to the establishment of self-sustaining populations in an increasing range of urban centres across Europe. Raising awareness of the risk posed by escapes of this species, and enforcement of existing restrictions on keeping and breeding will reduce the risks of further escapes. The species is unique among parrots in that it is not a cavity-nester, but instead it builds a bulky nest structure of sticks (e.g. in trees like cedars or palm trees, on electricity poles). A nest structure may house a single nest chamber or may be a large, communal construction that incorporates multiple independent chambers; and are used by the birds throughout the year for breeding and roosting. A number of programmes have eradicated, or almost completely removed, newly established monk parakeet populations, including London (UK), Zaragoza and the Balearic Islands (Spain). The most cost-effective control method to reduce numbers of birds appears to be shooting with a high-powered air rifle, particularly under the nesting structure which the birds continue to return to. However, the lethal control of monk parakeets can meet considerable opposition from the public while the use of firearms or air-weapons in urban centres can raise wider concerns and may be restricted in many Member States. High levels of public concern have limited the methods available in some areas, with a focus on non-lethal and more humane alternatives being used to achieve eradication. Live trapping away from the nest appears to have only limited success, as the birds are wary and soon learn if other birds are observed being captured. Nets placed over the nest entrance are labour intensive, but have proved effective if the number of nests is limited. The birds appear to be able to detect eggs that have been oiled or pricked, but are more likely to accept replacement model eggs. Egg replacement has proved a useful, if highly labour intensive method to limit reproduction and aid eradication at one site in London. Nest removal offers little benefit towards eradication as

the birds will readily renest in the same spot or local vicinity. Eradication is considered most likely using a persistent, integrated effort applying a combination of methods, and shooting followed by netting at the nest appear to be the most cost-effective approaches.

If eradication is no longer considered feasible, then a range of alternative methods have been used to limit abundance and reduce local conflicts. Nest destruction, combined with the capture and removal of adults, can reduce local conflicts, for example those caused by the build-up of nesting material on electricity infrastructure. Chemical contraceptives have been trialled on a local basis with some success in the US, but concerns remain regarding non-target species exposure and these methods are not in wide scale use at present, nor licensed for use in the EU. The use of toxins and biological control agents has been considered, but are either not licensed for use in the EU, or of only hypothetical effectiveness.

Detailed assessment			
	Description of measures[2]	**Assessment of implementation cost and cost-effectiveness (per measure)[3]**	**Level of confidence[4]**
Methods to achieve prevention of intentional and unintentional introduction[5]	**Managing pathways**. Monk Parakeets have been introduced to new areas through a variety of pathways, including the pet trade, the keeping of animals in zoos and private collections, deliberate introductions and possibly via human assisted transport. The adoption and enforcement of appropriate legislation and codes of best practice to reduce the risks posed by these pathways should reduce the probability of further introductions. However, this species is now widespread in Europe and spread within the region is also a risk (Postigo et al. 2019).	The EU Regulation (1143/2014) on invasive alien species entered into force on 1 January 2015. The Regulation places restrictions on a list of species known as IAS of Union Concern. These are species whose potential adverse impacts across the European Union are such that concerted action across Europe is required. This list is drawn up by the European Commission and managed with Member States using risk assessments and scientific evidence. This provides the framework within which their pathways are identified and prioritised, priority species controlled or eradicated, and pathways are managed to prevent the introduction and establishment of new IAS. If a species is included in the Union list, then this carries responsibilities to restrict the species being kept, bred, transported, sold, used or exchanged, allowed to reproduce, grown or cultivated, or released into the environment. A European Code of Conduct on Pets and Invasive Alien Species was produced and adopted by the Council of Europe. This tool aims to assist in establishing a single common standard set of behaviours that will enable the continued quiet ownership of pets while limiting to a minimum any chances of them becoming invasive and causing either economic or ecological harm (Davenport and Collins 2016). Similarly, the implementation of the European code of conduct on zoological gardens and	**High** – The EU Regulation provides the legal and policy framework to reduce the risks posed by alien species. Codes of Practice are a recognised mechanism to promote responsible activity within a sector.

		aquaria and invasive alien species (Scalera et al. 2012) may help preventing introductions from zoos and other private collections.	
	Raising awareness. Raising public awareness of the risks posed by invasive alien species in general and Monk Parakeets in particular can decrease the probability of new escapes and their rapid reporting. The production of targeted publicity and identification material is a useful element to support this.	An information sheet to aid with the identification of this species is available from the UK Non-Native Species Secretariat (www.nonnativespecies.org) and a range of other fact sheets with identification information are available such as on the website of Brussels Environment (https://document.leefmilieu.brussels/opac_css/elecfile/IF_biodiversite_conure_veuve_NL.PDF?langtype=2067&_ga=2.18666682.2094668426.1647510397-2028655672.1647510397), the Belgian citizen science reporting portal for IAS (www.waarnemingen.be/exoten).	**High** – Established methods to raise awareness.
Methods to achieve early detection[6]	**Citizen Science**. Monk Parakeets are a highly visible (and noisy) species often found in association with human activity. Encouraging rapid reporting of new incursions through Citizen Science or organised species monitoring increases the likely success of rapid response before the species can become established in an area.	Citizen Science species occurrence datasets are increasingly recognized as a valid tool for monitoring the occurrence and spread of invasive alien species across large spatial and temporal scales (Roy et al. 2015). They are dependent on citizen-scientists who collect and upload data, typically from 'opportunistic sampling' with no underlying scientific survey design (Boakes et al. 2010) which can limit the conclusions that can be drawn from these data but are still useful to inform baseline distribution and rapid response actions (Isaac et al. 2014). Most parts of north-west Europe have an extensive network of volunteer bird observers, although this is less true of southern and especially eastern Europe (Boakes et al. 2010). Unstructured citizen-science data do not reliably allow an estimate of species	**High** – Citizen science and taxa specific surveys are widely used to support alien species monitoring and surveillance.

		abundance or population trends (Kamp et al. 2016), yet in an early-warning scenario it is likely sufficient to know where a species is establishing, and these data limitations are thus of a lesser concern. Organised monitoring activities carried out by bird-watchers also provide a structured format for surveillance, although there is a risk of under-reporting if birdwatchers consider that the data will be used to support eradications. Considering the monk parakeet's conspicuous nests and their noisy habits which often cause nuisance to people, the species' profile would make it a good candidate to involve the public in reporting the presence of (sleeping) aggregations or nest sites of monk parakeets.	
Methods to achieve eradication[7]	General Background	There have been a number of documented examples of the successful eradication (or removal to very low levels) of this species. Senar et al. (2021a) compiled available information on the cost-effectiveness of different control methods based on control studies in Barcelona, Saragossa and Catalunya. This compared the cost per bird and the cost per hour of different methods, including trapping (EUR 44 per bird, EUR 70 per hour), cannon netting (EUR 282 per bird, EUR 198 per hour), shooting (EUR 16 per bird, EUR 84 per hour), nest destruction (EUR 23 per bird, EUR 204 per hour), egg pricking (EUR 19 per bird, EUR 96 per hour) and netting adults at the nest (EUR 32 per bird, EUR 96 per hour). Based on modelling to predict the effects on the population in Barcelona they rank the methods in terms of cost-effectiveness for population reduction, with	**High** – published cases describing the effective eradication or almost complete removal of this species.

		shooting the most cost-effective, followed by hand-netting adults at the nest. In 2008, three separate monk parakeet populations were known to be established in urban settings in London, UK, totalling around 100 birds (Parrott 2013). An eradication programme was initiated in 2010, and one site in an industrial area where only one nest structure (8 birds) was present was eradicated by 2013 using shooting, catching birds in nets at the nest entrance, and egg and nestling removal although it could not be confirmed whether there were additional birds in the area. A second site in a suburban neighbourhood held two nesting colonies (around 34 and 23 birds respectively) in two locations separated by approximately 800 m. Using a combination of shooting, adult trapping, nest, egg and some nestling removal, this population was eradicated by 2019. The final site (around 36 birds) was located in a suburban and parkland setting. Control at this site focused on egg replacement methods combined with live capture of adults for subsequent re-homing. Almost all nests were accessible via a cherry-picker, however, permission from homeowners to access each nest was required which was denied on occasion by individuals and prevented control of some nests in some years. By 2021, this population had been reduced to fewer than 12 birds and control was continuing. Since 2008, over the three sites, control using a variety of methods has removed – adults in cage traps (25 birds), shooting (17 adults), nest control (508 eggs), nets (5 adults) and other	

		methods such as hand-held nets at the nest entrance (11 adults) (APHA unpublished). The Spanish city of Zaragoza deployed a control plan based on removing eggs, trapping and shooting with air-rifles to remove adults. The egg removal phase failed to stop the population growth rate. The air-rifle shooting phase resulted in the removal of up to 800 individuals per year. Both methods combined reduced the population from 1400 individuals to 20 in 2 years (Esteban 2016, Postigo 2018). Management in the Balearic Archipelago (Spain), by several methods including air-rifle shooting removed three foci and achieved almost full eradication of monk parakeets in the islands (Postigo et al. 2018). The acceptability of control of this species varies widely amongst the public and this can be important in determining control strategies as most populations are found in urban centres (Crowley, Hinchcliffe and McDonald 2019). In the USA, public opinion is a major factor in influencing the implementation of any proposed management programme associated with monk parakeets (Avery et al. 2008). In the UK, public concern had limited control to only the most humane and non-lethal methods at some sites (APHA unpublished). In most places where parakeets become established they quickly gain favour with the public, who provide food to encourage the birds and facilitate their survival. Efforts to	

		control or remove the birds can be met with significant opposition. Many attempts by state agencies to implement control programmes have been thwarted by public opposition, involving citizen's action groups and lawsuits. Most of those affected by having parakeets nesting on their property are more tolerant of management measures (including lethal control) given the noise and nuisance caused. Others oppose almost all management measures, especially lethal control and perceive the parakeets to be a positive presence. In some cases, live capture followed by rehoming, or the removal of eggs from nests, has provided a more acceptable alternative, although adding considerably to the costs and time taken.	
	Shooting Free Living Birds	Shooting free living adults has been the main control method deployed in most programmes and provides a cost-effective approach to control. Control in Zaragoza and the Balearics relied on high-powered air-rifles (Esteban 2016, Postigo 2018), with custom-made shotgun cartridges with a low muzzle energy used in addition to air-rifles in the UK (APHA unpublished). Shooting from under the nesting tree has proved particularly effective, targeting birds circling the nest, settling on nearby branches of flying-in to land (APHA unpublished). Given the tendency of the birds to return to the nesting structure, shooting can be a cost-effective	**High** – figures based on direct experience of control in published materials.

		method of control. APHA (unpublished) records 15 birds removed over 14.6 hours of shooting. Senar et al. (2021) recorded 5.2 birds shot per hour in Barcelona. However, the use of firearms in built-up areas brings health and safety concerns, opposition from local residents while the use of safer, low powered weapons risks wounding animals rather than achieving a humane kill. As a consequence, the use of firearms has been limited in a number of cases, particularly in the UK, and other methods have been required. The use of weapons in public spaces may be prohibited in some Member States. However, air weapons have been widely and successfully used in Spain (Senar et al. 2021a).	
	Trapping Free Living Birds	A variety of traps have been used to capture this species. However, they are an intelligent species and can be very wary of new structures and learn to avoid them by seeing other animals being caught. This has limited the effectiveness of trapping although it remains an important capture method. Ladder traps, also known as drop-in traps, allow a bird to perch and then enter the trap through gaps in the roof. However, to exit the trap they need to fly and the gaps are too small to allow their extended wings through (https://basc.org.uk/advice/how-to-make-a-ladder-trap/). These were trialled in the UK, where traps were constructed in suburban gardens over a period of days and contained branches on which to perch and feed	**High** – figures based on direct experience of control in published materials.

		stations. Monk Parakeets proved capable of climbing out of the traps, and perspex sheets needed to be placed on the inner surfaces around the exit holes to prevent this. When birds were captured, the trap was covered with a tarpaulin and the birds removed after dark to avoid alerting other birds. A total of 25 birds were captured in this way, but captures were infrequent and birds appeared to learn the purpose of the traps and avoid them after a time. In North America, Avery et al.(2002) describe a trial with a drop-in trap in Florida, deployed with and without the presence of a decoy bird. No birds were caught. In Barcelona, Senar et al. (2021) used a modified Yunick trap to trap monk parakeets to individually mark them and study home ranges. They record a capture rate of 1.6 birds per hour using this approach. Another design is the woosh-net. This uses bungee cords to fire a net over a baited catching area (Parrott, Roy and Dendy 2009) but needs to be manually triggered by an operative, increasing the effort required. Monk parakeets at electrical substations in the US have been successfully captured using a system that incorporates a feeding tray and spring trap (spring-powered net). Bird numbers feeding on the tray are allowed to build up and then captured by manually triggering the net (Avery et al. 2002). In Spain, Senar et al. (2021a) reports a capture rate of 0.7 birds per hour using this method. As with other traps, birds observing others being captured will	

		quickly become wary, limiting the long-term effectiveness of these methods. Traps can be effective for the live-capture of monk parakeets, but extreme care is needed to avoid the birds becoming wary, and this regularly reduces the long-term effectiveness of this approach. This also increases the man-power required to deploy these methods, reducing their cost-effectiveness. If well-constructed and used, traps offer a humane method for live-capture, an important consideration given the frequent public opposition to lethal control of this species.	
	Trapping at the Nest	Birds can be captured at the nest, by placing a net over the nest holes, or by incorporating an automated 'door' across the entrance which is controlled by a wireless signal by an operator from the ground. Active trapping with hand-held nets has been evaluated in Florida using designs previously used in South America (Tillman et al. 2004). The technique can be carried out from the ground using a long-handled net, but is more easily accomplished through use of a cherry-picker to raise operators to nest height. During the day, the locations of nest entrances are determined. After dark, using the hoist, personnel quietly and quickly position hand-held nets over the entrances. Parakeets were caught in the nets when flushed from the nest. Trapping success at >400 nests in the US ranged from 0% to 100% of occupants (mean 50%) (Tillman et al. 2004). The	**High** – figures based on direct experience of control in published materials

		technique is only effective at night, as in daylight birds will flee the nest before the nets can be fully positioned (Parrott et al. 2009). On the Cayman islands, trapping at the nest with nets reduced the Monk Parakeet population by 86% within a year (Godbeer 2014). Birds were captured during the night by placing nets quietly over the nest entrances. Once close to the nest, the nets were shaken, inducing the birds to bolt and fly into the net. In Spain, Senar et al. (2021a) reports a capture rate of 3.1 birds per hour using this method. In the UK, some adults have been caught in the nest while undertaking egg removal activities, although this is a sporadic event. Some work has been undertaken to develop a remote wireless triggered 'trap door' fitted to the nest entrance. This has had moderate success depending on how wary nesting pairs are of the device with an associated risk of desertion.	
	Nest Destruction. The species is unique among parrots in that it is not a cavity-nester, but instead it builds a bulky nest structure of sticks. Nest structures are used by the birds all year and are often highly visible. A variety of methods have been used to destroy nests, including poking with long poles, manual removal from a cherry picker, or chopping down all or part of the tree.	If nest removal coincides with active breeding, then productivity is likely to be affected although there is no data on this. Beyond this, there is no evidence that nest destruction has any population level consequences for this species. Nest destruction methods are unlikely to provide a useful method to achieve eradication as the birds will readily renest and that one pair of parakeets can rebuild a nest in less than two weeks (Avery et al. 2002).	**High** – figures based on direct experience of control in published materials.

	Egg Oiling/ Pricking/ Replacement/Removal Birds eggs can be treated in a variety of ways to prevent their development or to kill the embryo they contain. These include rubbing the eggs with a light oil which limits air transfer through the shell, or by pricking the egg which kills the embryo. Eggs can also be removed and destroyed and replaced with dummy eggs. This encourages the adults to continue incubation and delay renesting. Chicks can also be removed from the nest and euthanised.	Based on experience in the UK, Monk Parakeets appear to be able detect oiled or pricked eggs, they quickly reject treated eggs and produce a new clutch which limits the effectiveness of this approach. However, if the eggs are removed and replaced with dummy eggs then the period to rejection is extended. Egg replacement is a very labour-intensive process, requiring repeated visits to each nest and access to a cherry-picker over the period April to July to ensure that no viable eggs remain. However, for sites where lethal control is not possible due to local opposition or restrictions, egg removal may be the last viable control method. Since 2015, in one site in London, around 300 eggs have been replaced with model eggs and has been a key part of the ongoing eradication campaign (APHA unpublished). Chick removal faces similar constraints to egg removal, requiring frequent visits to nest. However, the killing of chicks raises humaneness and welfare issues and enhanced local opposition beyond those encountered with egg removal. As a consequence, there are few advantages to this approach and there are no reports of its use.	**High** – figures based on direct experience of control in published materials
	Use of toxins: Spurr and Eason (1999) review the available avicides worldwide. The toxicant Starlicide (DRC-1339 or 3-chloro-p- toluidine hydrochloride)	No accounts of the control of Monk Parakeets using toxicants were found. Their use is also restricted by legislation, no suitable products are currently licensed for use as an avicide in the EU.	**High** – The legislation on the use of toxins in EU law is clear.

	(Ramey et al., 1994, ACVM, 2002) and the stupifactant Alphachloralose ((R)-1,2-0-(2,2,2- trichloroethylidene)-α-D-glucofuranose) (Thearle 1969) are the two main chemical control options used on other bird species. However, no products are currently approved for use in the EU.		
Methods to achieve management[8]	General background	The methods described for eradication can also be applied to reduce local populations and conflicts. However, some of the more labour intensive methods such as egg replacement are unlikely to be of benefit for more wide scale control.	
	Nest Destruction. Nest structures are used by the birds all year and are often highly visible. A variety of methods have been used to destroy nests, including poking with long poles, manual removal from a cherry picker, or chopping down all or part of the tree.	Nest removal can be a useful tool to move birds from a particular local site where they may be causing a public nuisance or damaging infrastructure, for example nesting material posing a fire risk on electricity infrastructure. The birds are likely to rapidly build a new nest in the same location if efforts are not made to proof the structure to prevent renesting. There is no evidence that nest destruction has any population level effects on monk parakeet numbers, but may be a useful and socially acceptable way to reduce conflicts at a local scale. In Florida, where the birds regularly nest on electricity supply structures, the cost of removing monk parakeet nests on distribution and substations was estimated at $415 per nest. The cost is likely higher on transmission lines where additional time and equipment are needed.	**High** – figures based on direct experience of control in published materials

		In 2001, about 90 nests were removed for a total cost of $37,000. A survey of monk parakeet nests throughout the Florida electrical supply system found a total of 1,110 nests, including 534 at substations, 400 on distribution structures, and 176 on transmission towers. Based on current rates for nest removal, a conservative cost for the annual removal of all existing nests would be $460,650 (Tillman et al. 2004). Because birds will readily rebuild their nest, an effective nest removal program requires that the birds be removed with the nest. The estimated cost to capture monk parakeets from a nest is $1,000. The cost to remove both a nest and the birds inhabiting it is therefore $1,500/nest. At this rate, the conservative cost to remove all 1,110 nests and the birds causing conflicts in the Florida region would be $1,665,000 with recurring costs in subsequent years. (Tillman et al. 2004).	
	Habitat Modification. Particular conflicts can arise from this species nesting on electricity infrastructure, for example certain designs of transmission towers. New constructions should incorporate these findings to adopt designs less likely to attract nests.	Descriptions of the characteristics of electricity infrastructure favoured by this species are available from Florida (APHIS 2016). However, no studies in Europe have examined the use of artificial structures in this light. The effectiveness of this approach needs to be determined, and the capital costs of replacing electricity infrastructure are likely to be high.	
Deterrence	Local concentrations of birds may be dispersed or deterred from visiting a site using a variety of methods. For Monk Parakeets, the use of these methods has	Avery et al. (2002) describe experimental studies to deter birds from nesting structures located on electricity substations in Florida, and to then deter re-nesting when the original nest had been removed. Three deterrents were used, a taxidermic monk parakeet effigy hung near	**Medium**. While studies on this species have taken place, they have been small-scale

	focused on deterring birds from nest structures.	the nest, a commercially available plastic owl device, and the use of a low-power laser. These trials were conducted initially with no nest removal and then with the nests removed from the substation. All three methods were of limited effectiveness. The effigy appeared to have little effect, the plastic owl had an initial deterrent effect but the birds soon became habituated and any benefits were short-term. Lasers proved useful in dispersing birds, but they soon returned when the treatment ceased (Avery et al. 2002). Burgio et al. (2014) showed electrical lines are critical access points to monk parakeets for initiating nest building on utility poles, as otherwise the birds would have to beak-climb and would lose their nesting materials. However, they note it is unlikely that preventing monk parakeets from nesting on utility poles will provide a means of population control as they would nest-build in trees if excluded from poles.	and short-term. No details available to assess their cost-effectiveness. These methods are not believed to be in routine use.
Biological control	Population reduction is one approach to lessening the impacts of monk parakeets to utility structures and agricultural resources. One possible approach to lethal control is the selective application of an endemic protozoan parasite. *Sarcocystis falcatula* is a protozoan parasite that cycles between Virginia opossums (*Didelphis virginiana*) and	A number of studies suggest that this parasite causes morbidity and mortality in psittacine birds. For example, in a study at a major zoo, 37 psittacine birds died (Hillyer et al. 1991). The most common signs were pulmonary edema and hemorrhage. Half of these birds died without any clinical signs. Infected birds sometimes go off feed and lose weight, but most die before any signs are evident.	**Low** – This is a hypothetical proposal and there is no available research on its use as a control method for this species.

	brown-headed cowbirds (*Molothrus ater*) and grackles (*Quiscalus* spp). (Avery et al. 2002).	Because this parasite is apparently lethal to psittacines and is apparently not harmful to native bird species, Avery et al. (2002) suggest it may be worth investigating whether selective application of the parasite can be used as a component of a monk parakeet population management plan in North America. This would need to determine an effective dose via trials with captive birds, and then develop and evaluate a selective delivery procedure so that only monk parakeets will be affected by field application of this control method (Avery et al. 2002). However, the pathogen and the other species of bird and mammal known to feature its transmission in North America are not present in Europe. The introduction of a non-native pathogen would require considerable safety assessment and approval before it could be considered as a realistic approach for Europe.	
Chemical Fertility Control	In the USA, research with the chemicosterilant Diazacon has been used on an experimental basis in an effort to use contraception for humanely controlling monk parakeet populations. Diazacon inhibits the formation of reproductive hormones and is marketed in the USA under the name DiazaCon™ and has been commercially approved for reducing feral pigeon populations.	In captive trials, *ad libitum* studies showed that monk parakeets would eat adequate amounts of DiazaCon™ coated sunflower seeds to prevent successful reproduction; in treated birds egg production was decreased by 59% and no eggs hatched (Yoder et al. 2007). In subsequent field trials, bait stations were established at electrical substations in Florida and parakeets presented with Diazacon-treated sunflower seeds for 10 days at treated sites (Avery et al. 2008). Over two years, the trials involved a total of six treated sites	**Medium** – The effects of this compound on monk parakeets are well studied and there are preliminary results from its use on an experimental basis in Florida. However, there is

		and four untreated control sites which received no treated bait. The percentage of active, complete nests that were empty was greater at treated sites (32%) compared to control sites (6%). In nests where young were produced, the average productivity at the Diazacon-treated sites was 1.31 nestlings/nest (nestlings plus viable eggs), compared to 4.15 nestlings/nest at control sites. This represented a 68% reduction in reproductive success (Avery et al. 2008). Exposure of native species to treated seed was minimal, occurring principally at one site; However, another non-native species, the Eurasian collared dove *Streptopelia decaocto*, were frequently recorded at bait stations at 50% of treated sites. It was considered that Diazacon for parakeet management warranted further development, including refinement of bait presentation procedures (Avery et al. 2008).	no available information on its cost-effectiveness, long-term effects at a population level and it is not believed to be in routine use.

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Guidelines for Completing the Annex

1 Provide a brief summary description of the most cost-effective methods drawing on the reviews in the detailed assessments

2 Provide a description of the potential method. This should be based on the available key scientific evidence which should be gathered from sources including articles and reviews in technical and scientific journals, internet searches, online databases, grey literature and relevant books and personal communications from scientists, stakeholders, conservation practitioners and governmental bodies. This information should include a full bibliographic list detailing the literature and sources considered.

3 Provide an assessment of the likely cost and effectiveness of the method. Where information is available, consider the following range of questions, accepting that not all questions will be appropriate in all circumstances.

- How effective has this approach proven to be in the past or in an analogous situation?
- How publically acceptable is the approach likely to be?
- Over what period of time would this approach need to be applied to be effective?
- What is the direct cost of implementing this approach?
- How likely are the methods used in the approach to be available?
- How likely is it that relevant licences or other approvals to undertake the approach would be difficult to obtain?
- How likely is it that health and safety issues would prevent the use of this approach?
- How significant is the environmental harm caused by this approach?
- How significant is the economic harm caused by this approach?
- How significant is the social harm caused by this approach?
- How likely is it that the approach will be criticised on welfare grounds?
- How likely is it that the approach with be acceptable to other stakeholders?

Where available, factual information on the costs of specialist equipment, or case studies of management costs from across the Union or third countries should be provided. When describing case studies, if the information is available then provide both total cost and the area over which control was undertaken so that a cost per unit area might be derived. Where such quantitative information is not available, then any qualitative information from the literature is acceptable to help guide decision making. It is accepted that in the majority of cases the information required to assess the potential total cost of management at a member state level is unlikely to be available. This would normally require information on the extent and abundance of the species which is beyond the scope of this assessment. Assessors are not expected to extrapolate the potential total costs of management at a member state level, only to report on the information provided within the literature.

4 Provide an overall assessment of the confidence that can be applied to the information provided for this method. This confidence should relate to the quality of the available information using the guidance below. It should NOT relate to the confidence in the effectiveness of the method

The confidence scores are:

- **High**: Information comes from published material, or current practices based on expert experience applied in one of the EU countries or third country with similar environmental, economic and social conditions.
- **Medium**: Information comes from published data or expert opinion, but it is not commonly applied, or it is applied in regions that may be too different from Europe (e.g. tropical regions) to guarantee that the results will be transposable.
- **Low**: data are not published in reliable information sources and methods are not commonly practiced or are based solely on opinion; This is for example the case of a novel situation where there is little evidence on which to base an assessment.

If there are further factors beyond these that have determined the chosen level of confidence, then provide a brief written description to support the choice of the level of confidence.

5 Measures for preventing the species being introduced intentionally or unintentionally into the territory of a Member State (cf. Articles 7(1)(a), 7(2), 13, 15), i.e. preventing a species entering by blocking its pathways, including pre-border prevention and prevention of escape or release into the environment and secondary spread whenever relevant. Measures for preventing the species reproducing while in containment should be included, if appropriate. Consider all methods that might be applied, including any that have not proven useful. Provide a description of each method in turn, using separate rows to consider each method.

6 Measures to run an effective surveillance system for achieving an early detection of a new occurrence (cf. Article 16). This section assumes that the species is not currently present in a Member State, or part of a Member State's territory.

7 Measures to achieve eradication. Preferably, but not exclusively, used at an early stage of invasion, after an early detection of a new occurrence (cf. Article 17). Consider all methods that might be applied, including any that have not proven useful. Provide a description of each method in turn, using separate rows to consider each method.

8 Measures to achieve management of the species once it has become widely spread within a Member State territory (cf. Article 19). These measures can be aimed at eradication, population control or containment of a population of the species. Consider all methods that might be applied, including any that have not proven useful. Provide a description of each method in turn, using separate rows to consider each method.

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