Target 9: Invasive alien species

By 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment.

Preface

This chapter focuses on invasive alien species pressure, state and response from current, short-term and long-term perspective. "Alien species" refers to a species, subspecies or lower taxon, introduced outside its natural past or present distribution; it includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce. "Invasive alien species" means an alien species whose introduction, establishment and spread threatens biological diversity. This chapter also highlights past, current and future drivers of biological invasions around the world, and explores actions and policies that should be implemented to achieve the Aichi Biodiversity Target 9 in 2020.

1. Are we on track to achieve the 2020 target?

1.a. Status and trends

1.a.i. Trends in introduction of Invasive alien species

Very few ecosystems are currently free of alien species and biological invasions are continuing at an unprecedented rate (Fig. 9.1). Globally, there is no improvement regarding the pressure of invasive alien species since the previous Global Biodiversity Outlook report (i.e., GBO3, 2010) and the number of invasive alien species and the damage they cause to biological diversity are expected to continue to increase. The number of alien species in Europe (i.e., Mediterranean marine, mammal and freshwater) increased by +76% between 1970-2007 (Waage et al. 2008; Hulme 2009; Butchart et al. 2010a). The numbers of alien species have also been increasing in China (Xu et al., 2012), and North America (Levine & D’Antonio 2003; Aukema et al. 2010).

Overall, considerable efforts have been made to define, characterize and identify species at different stages of the introduction-naturalization-invasion continuum (Catford et al., 2012). More specifically, work is on-going in the development of global indicators determining trends in the numbers of introduced and invasive alien species to assess progress made towards the achievement of Target 9 (Pagad et al 2014). The indicator measures the trends of invasive alien species (IAS) of 21 countries, which were selected for having at least 30 records of species with known invasion date (Figure 9.1). The indicator based on 3,914 invasive alien species shows that in 2012 countries (N=21) hosted on average 1.7 times more invasive alien species than they did in 1970 (Fig. 9.1; Pagad et al. 2014). For example, Norway has listed more than 217 invasive alien species that have a severe or high impact listed (Gederaas, et al.

1 Updated information regarding the NBSAPs report will be added for the developed countries.
2012). The average annual increase declined from 1.72 during 1970-1990 to 0.82 during 1990-2012. However, this less pronounced recent increase might reflect incomplete data coverage for the most recent years. Islands showed a threefold increase of introduced species since 1900, while continental countries showed a sevenfold increase. This trend might be the result of islands having been exposed to large numbers of alien species introductions before 1900, and thus recent increases in alien species may be less pronounced than in continental countries. However, the number of invasive alien species may be significantly underestimated, as lack of knowledge on impacts of invasive alien species is widespread (Scalera et al. 2012). For USA, UK, Australia, South-Africa, India and Brazil, there are approximately 120 000 alien species (Pimentel et al., 2005). It is inherently difficult to know how many of these alien species will become invasive in the future, and when, because there is generally a time lag of several decades between introduction and establishment of most invasive alien species (Essl et al. 2011). However, half of the established alien vertebrates successfully invaded Europe and North America (Jeschke & Strayer 2005). The rate of successful invasions for plants is usually considered lower as the "tens rule" holds that approximately 10% of introduced alien species will become established, and approximately 10% of these species will become invasive (Williamson 1996).

Since the publication of GBO3, the responses to control invasive alien species have significantly increased. The global trend in policy response has been positive for the last few decades. As reported in 2010, 55% of the countries signatory to the Convention on Biological Diversity have enacted invasive alien species relevant national legislation, and 82% of these countries have signed multinational agreements (international conventions, organization agreements and organization guidelines) relevant to preventing the spread and promoting the control/eradication of invasive alien species (McGeoch et al. 2010). Among these countries, 8% are signatory to all 10 international agreements (McGeoch et al., 2010 and Fig. 9.1). For example, the Council of Europe has been developing and adopting codes of conduct addressing key pathways of introduction (e.g., horticulture, botanic gardens, zoos, hunting, or fishing) of invasive alien species. Moreover, once the European regulation on invasive alien species is fully adopted, it will have major implications for neighbouring countries, and also at the global scale since the European institution is a major partner for global trade.

The current increase of policy tools has not yet led to a significant reduction in the number of alien species introductions (Butchart et al., 2010). This indicates inadequate implementation of adopted policies, lack of coherence between policies, or lack of adapted policies with regards to biological invasions. For example, between 1860 and 2006, nearly 70% of damaging forest insects and pathogens established in the United States were most likely introduced through imported live plants (Liebhold et al. 2012). The implementation of regulations regarding plant imports might offer an effective control of alien species introductions (NAPRA: Not Authorized Pending Pest Risk Analysis) although it has only been implemented in 2012. About 28% of infestations (pest invasions) over United States were detected under standard inspection procedures (Liebhold et al. 2012), consequently present regulations need to be more stringently implemented. Many European countries such as Portugal, Switzerland, Italy, and Greece have been invaded by a higher number of alien insect species (Bacon et al. 2012) partly because of an increasing amount of international trade in plants and transportation of goods which may bring in invasive alien insect species.
Figure 9.1. A. Trend indicator showing the number of invasive alien species across 21 selected countries with known introduction date. The indicator was based on 3,914 invasive alien species and 4,903 species-country records. While all taxonomic groups were considered, the majority of the records are plants, invertebrates, fishes, mammals, and birds. B. Trend indicator showing the geometric mean of the cumulative number of invasive alien species across 21 selected countries. Data scaled to 1 in 1970. C. Indicators trends for invasive alien species policy adoption by countries responses to address its loss. Data scaled to 1 in 1970; modelled and plotted on a logarithmic ordinate axis. Shading shows 95% confidence intervals. From Butchart et al. (2010)

1.a.ii. Consequences for biodiversity

The Millennium Ecosystem Assessment (2005) recognises invasive alien species as the second major driver of biodiversity loss after habitat loss. Invasive alien species through several mechanisms such as predation, hybridization, competition, disease transmission cause negative impacts for biodiversity at gene, species, and ecosystems levels. Of the 170 animal extinctions for which we know the causes of extinction (there are 680 known animal extinctions), 54% included the impacts of invasive alien species, and for 20% of extinctions, invasive alien species were the only cited cause (Clavero & García-Berthou 2005). These species extinctions have mainly occurred in insular ecosystems where native species are not adapted to new predators or competitors (Whittaker & Fernandez-Palacios 2007). Invasive rats and cats have been a primary cause of species extinction over the last 500 years especially in islands ecosystems (Donlan & Wilcox, 2008), and the second cause of the

\footnote{Permission from Science need for Fig 9.1C}
extinction of fish species (11 out of 23 species – Harrison & Stiassny 2004). Furthermore, of
395 European native species listed as “Critically Endangered” by the IUCN Red list of
Threatened species, 100 are in danger because of invasive alien species (IUCN, 2011; Scalera
et al. 2012). Overall, the IUCN Red List Index shows that invasive alien species pressure is
driving declines in species conservation statuses, especially for birds (33%), mammals (6%),
and amphibians (11%), and this trend increases over time (Fig. 9.2). For amphibians, invasive
alien species are by far the most important driver of extinctions (McGeoch et al. 2010a). For
example, the invasive alien Chytrid fungus (Batrachochytrium dendrobatidis) continues to
spread, and threatens amphibians globally (Olson et al. 2013). On the contrary, successful
management of invasive alien species during the last several years has benefited a small
subset of species that consequently have been down-listed to a lower category of threat of
the IUCN Red List. Although less well documented, current impacts of invasive alien species
also occur at ecosystem or gene levels (see Pejchar & Mooney 2009 for examples). One such
element is the Golden apple snail (Pomacea canaliculata) that has transformed wetlands
across Southeast Asia from a clear water purification system to a turbid, algae-dominated
state (Carlsson et al. 2004) or the hybridization of the European honeybee with the far more
aggressive Africanized honeybee in Latin America that is moving northward. Forests in North
America have also been seriously impacted by invasive alien species (i.e., chestnut blight,
dutch elm disease, gypsy moth, emerald ash borer, etc …) to an extent that major elements
of the forest biome have now disappeared or have been drastically reduced from their
historical level of ecosystem presence and function (Poland & Mccullough 2005). The impacts
of invasive alien species on biodiversity are influenced and exacerbated by biological
resource use (harvesting), human disturbance, and habitat loss (Berglund et al. 2012).

Figure 9.2. (a) Red List Index for the world’s birds (9869 species) showing trends in status driven by
the impacts of invasive alien species or their control; declines indicate that despite some notably
successful local eradication and control efforts, invasive alien species are driving birds ever closer
towards extinction. (b) Percentage of 9869 bird species that changed IUCN Red List category between
1988 and 2012 owing to impacts of invasive alien species or their control, distinguishing those for
which invasive alien species were the primary or secondary driver of the change in status. Figures
from McGeoch et al. 2010 (a) and Butchart et al. 2010 (b), both updated by S. Butchart January 2014.

1.a.iii. Current situation of actions against invasive alien species

The guiding principles on invasive alien species adopted by the Conferences of Parties to the
Convention on Biological Diversity (2002) clearly indicate that prevention is the priority
response; early detection, rapid response and possible eradication should follow when prevention fails. This is because prevention and rapid responses are generally more effective than long-term management (Simberloff et al. 2012).

There has been progress in the development of guidance relevant to invasive alien species. For instance, International Plant Protection Convention (IPPC) has included invasive aquatic plant species in the setting of international standards for phytosanitary measures, the World Organisation for Animal Health (OIE) is developing guidelines for assessing the risk of non-native animals becoming invasive, the Food and Agriculture Organisation of the United Nations (FAO) is developing guidance on the implementation of phytosanitary standards in forestry as well as applying risk analysis in aquaculture. Regional Initiatives have also been encouraging (e.g., 22 pacific countries have developed biosecurity legislation within a common biosecurity authority). The European Plant Protection Organization has also implemented standards and recommendations for risk assessment of pests and invasive alien plants in Europe that are followed by its members in Europe and the Mediterranean region (EPPO 2014). A study indicates that between 1995 and 2004, over 80% of the 302 intercepted non-native insect species did not establish in Europe (Roques et al., 2006), showing that prevention is an effective tool to fight establishment of alien species.

National programs of preventive measures have been adopted to implement a number of fundamental tools; e.g., New Zealand with a biosecurity system, Australia with risk analysis, or Brazil with national survey and funding mechanisms (see for example Australian Government, 2011). Among the different tools to prevent invasions, the Australian Weed Risk Assessment system (A-WRA) is one of the most effective risk assessment tools used. Overall, the WRA rejects an average of 80% of weeds (Weber et al., 2009), and 90% of major invaders are correctly identified. Another example in Florida showed that about 92% of test species that have been documented to be invasive were correctly rejected using the WRA system (Gordon et al., 2008). The WRA system is also successfully used in New Zealand and Japan (Nishida et al. 2008). Consequently, the number of introduced alien mammals in New Zealand has stabilized during the last few years (Box 9.2). The WRA have also been modified to be used for assessing the potential invasion of other taxa such as freshwater fish, marine fish, freshwater invertebrates, marine invertebrates, and amphibians (Copp et al., 2005), vertebrates (Bomford 2003, 2008), and aquatic invertebrates (Tricarico et al., 2010). However, important gaps remain regarding risk assessments (see Kumschick et al. 2013 for details). Fewer risk assessments have been developed for vertebrates or invertebrates (except for ants see Ward, et al., 2008) as compared plants (Kumschick & Richardson 2013), and these models were mainly developed for Australia and New Zealand (Bomford 2003, 2008; Massam et al. 2010). However, several plans are currently under development for terrestrial vertebrates in Europe (e.g., generic impact-scoring system to alien mammals, Rentwig et al. 2010) and within North America (e.g., within the U.S. Fish and Wildlife Service and USDA Wildlife Services, Canada’s Centre of Expertise for Aquatic Risk Assessment). The World Animal Health Organisation has also developed guidelines to assess the risk of non-native animals becoming invasive (OIE 2013).

There are significant improvements to document the major pathways of invasions since GBO3. Civil aviation and shipping pathways are starting to be studied at a global scale (Drake & Lodge, 2004; Tatem & Hay, 2007; Seebens et al., 2013), but a global scale pathway
management tool does not yet exist, although the International Civil Aviation Organization and the International Plant Protection Convention have attempted to develop international guidance for these pathways. Seebens et al. (2013) identify high-risk global marine invasion routes, offering an interesting perspective for the development of effective, and targeted bio-invasion management strategies. More specifically, air-travel has been used to study the connectivity that exists across the malaria-endemic world, to provide a first assessment of the infection risks resulting from movement of infections (Huang & Tatem 2013).

Identification of important pathways such as horticulture and ornamental plants for specific regions (i.e., Europe) has also been achieved (e.g. Hulme 2009, DAISIE 2009).

Beyond the identification of major pathways of invasions, there are a number of past and ongoing efforts to incorporate them in future policies (e.g., the pets trade). The European Union has also adopted a target in Biodiversity Strategy (EC 2011) and its coming legislation on invasive alien species (EC 2014) that states that its members are to identify and prioritize pathways of introduction and to adopt action plans to manage these pathways.

Eradication campaigns events, especially for vertebrates, have resulted in many important successes, particularly in island ecosystems. Over 1,600 alien vertebrate species eradication efforts have been undertaken on islands worldwide, with 1,128 confirmed as successful compared to 173 failures (an 87% success rate) (DISE 2014 and Fig. 9.3). Historically, the number of eradication campaigns has increased over time, although the last 10 years revealed a significant decrease of the eradication events (Fig. 9.3). New Zealand eradication practitioners have demonstrated significant innovation for the eradication of invasive vertebrates from islands, with only very small islands being undertaken 25 years ago. For example, growing to rat eradication from the relatively large 113 km² Campbell Island in 2002 (Broome 2009), eight species simultaneously removed from Rangitoto and Motutapu near the city of Auckland in 2011 ((Griffiths 2011 see also Glen et al. 2013), and the eradication of invasive animals has been assessed from the human inhabited 1,746 km² Stewart Island (Bevan 2008). Human inhabited islands represent a new challenge and frontier for eradicating invasive animals (Oppel et al. 2011; Glen et al. 2013). In parallel, costs of eradication have decreased over the years (Carrion et al., 2011): over 160 000 goats were removed from over 500 000 ha in less than five years for only US$18 per ha (Donlan et al. submitted; Carrion et al., 2011). However there have been very few successful eradication programmes on mainland (Baker 2010).

Overall, design of eradication programs has significantly improved, with a growing number of multispecies programs, and prevention of non-target effects such as primary or secondary poisoning of non-target species or predators (Zavaleta et al. 2001; Jolley et al. 2012).

Moreover, successful eradication programs have allowed the recovery of native biodiversity in many cases (e.g., Courchamp et al. 2011; Kessler & Service 2011; Whitworth et al. 2013).

Local communities have also undertaken efforts to control and eradicate invasive alien species though traditional stewardship and management practices (Kothari et al. 2012). For example, in India’s Biligiri Rangaswamy Temple Sanctuary and Tiger Reserve, Soliga people have reclaimed community rights to the forests and are preparing a management plan that includes traditional and new methods of controlling invasive alien species such as Lantana, which the conventional governmental management has failed to control. Thanks to all these eradication programmes, the overall risk of extinction has been substantially reduced for...
eleven bird species, five mammal species, and one amphibian due to control of invasive alien species. However, the number of species whose conservation status has improved is out-weighted by species with deteriorating status due to the pressure posed by invasive alien species (McGeoch et al., 2010). Nevertheless, progress has allowed control or eradication of species from ecosystems that were until recently deemed too large or too complex (Simberloff et al. 2012). This suggests that eradications of species or populations that are currently considered unfeasible might become feasible in the near future (Carrion et al. 2011).

Figure 9.3. Number of eradications of invasive vertebrates that are planned, successful, in progress and to be confirmed on islands since 1900. Excludes reinvasions, failures and eradications with unknown end dates Figure from DIISE 2014.

A few years ago, the vast majority of eradication projects were not initially based on a systematic prioritization; however, eradication has been starting to take a more regional and national approach, calling for prioritization schemes. Consequently, invasive alien species eradications on islands have been prioritised according to the native biodiversity threatened, eradication feasibility, economic cost, and reinvasion potential (e.g., Brooke et al. 2007; Donlan & Wilcoxon 2009; Capizzi et al. 2010; Harris et al. 2011). Prioritisation of eradication programmes is currently a dynamic field of research. Adopting a return on economic investment approach to guide mammal eradication is only beginning (e.g., Donlan et al., submitted), and integration of climate change issues into prioritisation of eradication programs have also been discussed recently (Runting et al. 2013; Courchamp et al. 2014).

In parallel to this progress on invasive species management recent literature has been critical about invasion biology as a scientific discipline and about the relevance of management of invasive alien species. For example, there are some recent claims that the native/non-native dichotomy, and human vs. non-human transport origin has only modest scientific value (Davis et al. 2011; Valéry et al. 2013 but see Richardson & Ricciardi 2013; Blondel et al. 2013; Simberloff & Vitule 2013; Shah & Uma Shaanker 2014). These arguments may become more prominent as the impact of climate change on invasive alien species increases resulting in a
redefinition of invasive alien species (Engel et al. 2011). It has also been suggest that most introductions are benign and thus do not merit management that are costly (Hasselman et al. 2012; Thomas 2013). However, in practice, as managers are limited by availability of resources, they tend to prioritise the most problematic invasive alien species (Richardson & Ricciardi 2013).

1.b. Projecting forward to 2020

In the short-term, the threat from plants and mammals invasions to mammals, birds, and amphibians, is unlikely to diminish in most parts of the world (for Europe, see Hulme et al. 2009) as well as the damage caused per species to biodiversity and society. In addition, the pressure caused by invasive alien species is likely to increase over the next decade if significant actions are not implemented rapidly (Fig. 9.4). Extrapolations of cumulative introduction events over Europe suggest that the number of invasive species will continue to increase by 2020 if there is no significant change in the key drivers of invasion (Fig. 9.4). This increasing trend is likely to be accentuated in the near future at a global scale, as trade between climatically and environmentally similar regions are predicted to increase and habitat continues to be disturbed. Although there are examples where the number of introduced non-native mammals has been stabilized or slightly decreased over the last decades thanks to the strong and innovative policies against invasive alien species (see 9.2 for further details), there is no indicator of the effectiveness of such policies to fight biological invasions.
The extrapolation of the current trend of adoption of national and international policies against invasive alien species shows a promising short-term perspective (Fig. 9.4). This extrapolation is consistent with countries commitments for which NBSAPs reports are available. For example, European Biodiversity Strategy’s Target 9 on Invasive Alien Species provides the focus for the EU countries in their work in identifying and prioritizing priority invasive alien species and managing their pathways of introduction. With the adoption of a new EU regulation on invasive alien species in 2015, the 28 member states of the European Union will commit themselves to preventing the introduction and spread of the worst invasive alien species and cooperating in managing pathways of introduction to minimize introductions of these species and prevent damage to biological diversity (EC 2011, EC2014).

A number of European countries such as Belgium, Norway, Finland, Sweden, Denmark, Austria, and Switzerland, have identified a suite of actions, such as conducting comprehensive and widely accepted risk assessment procedures, developing actions for addressing main introduction pathways, and establishing early detection and control mechanisms, in order to implement their operational objective related to invasive alien species. If these policies are adequately and promptly enforced, there is a reasonable confidence that it will significantly help to achieve the Target for these countries. Ultimately, the effect that the Target will have will mainly depend on the extent to which actions are taken to implement them (Section 6 provides additional information on countries commitments in their NBSAPs).

The successful establishment of invasive alien species as a short-term perspective will depend on many factors. Overall, characteristics that define invasive potential include both intrinsic factors (e.g., species traits) and extrinsic factors such as international trade and habitat degradation. Identifying species traits that could be related to the likelihood of invasions has been an important field of invasion biology for over two decades now, with still relatively few general results; plants and pests of agricultural concern have been studied to determine the likelihood of establishment, spread and negative effects on production and biological diversity. For example, establishment of invasive plant species is often related to a large native range size, presence of clonal organs, vigorous vegetation growth, early and extended flowering, occupation of disturbed habitats, early time of introduction and attractiveness to humans (Cadotte et al., 2006; Pyšek & Richardson, 2007). The relative importance of different traits is environment-dependant and changes over time. In addition, factors determining success concerning establishment and invasion also differ between taxa and are context-specific (Richardson & Pyšek 2012; Ricciardi et al. 2013). Some invasive plant species traits (e.g., life form, stature or pollination syndrome) could also help to predict impact (Pyšek et al. 2012a).

Overall, human-related processes (the number of alien species introduced and human population size, land use, and infrastructure) drive the diversity of introduced species (e.g.,
exotic birds in Europe, Chiron et al. 2009, or marine species, Gallardo & Aldridge, 2013). In
the Czech Republic, Chytrý et al. (2008) have also shown that the major determinants of the
level of invasion by alien plant species were related primarily to habitat properties, followed
by climate, and propagule pressure (Chytrý et al. 2008). Propagule pressure is a key element
mediating establishment success for some species such as insects, some plants, or plankton,
but less so for other large species such as mammalian predators. Consequently, increases in
the number of introductions and magnitude of spread of alien species is also strongly
associated with substantial increases in the extent and volume of trade and transport,
particularly over the last 25 years (Levine & D’Antonio 2003; Hulme 2009). European
maritime transport is predicted to rise from 3.8 billion tonnes in 2006 to 5.3 billion tonnes in
2018 (Scalera et al. 2012). The risk of biological invasions in marine environment caused by
global shipping with discharge of ballast waters and hull fouling organisms is also increasing
globally (Seebens et al. 2013). In the short-term, faster modes of transport may also increase
the opportunities for an organism to survive in transit and establish in new environments
(Ruiz & Carlton 2003; Burgiel et al. 2006). The development of new trade routes has already
led to the introduction of new alien species either deliberately or accidentally, while the
growth in the volume or trade along those routes has increased the frequency with which
introductions are repeated. An important short-term trend is also the development of
regional trade agreements that may increase the risks of biological invasions if they are not
implemented with strong policies against invasive alien species. About 420 regional trade
agreements have been signed by the end of 2008 (Perrings et al. 2010). The Treaty on Free
Trade between Colombia, Venezuela and Mexico has for example facilitated the introduction
of exotic fish into Mexico (Mendoza Alfaro et al. 2010). Consequently, if regional trade
agreements are not implemented with transparency and sharing of information and
prevention measures, they might increase the risk of biological invasions.

There is also evidence that increasing establishment rates of invasive alien species can be
attributed to an increase in degraded habitats at least for some types of habitats (Johnson et
al. 2008; Spear et al. 2013). Habitat degradation will therefore be among the most important
drivers related to invasions in the short term. For example, the highest levels of alien plant
invasions were projected for arable land, urban areas, and abandoned land in Europe (Chytrý
et al. 2012). In parallel, increases in human population density will also be an important
driver of biological invasions by adding pressure on natural areas as more land will be needed
for food production, but also by generating more intentional releases of exotic plants and
pets. At finer spatial scales, historic and contemporary land use, as well as economic benefits
of the species play also a major role in the dispersal, distribution and establishment of
invasive alien species (Mattingly & Orrock 2013).

Fast economic development (i.e., Gross Domestic Production) has also been demonstrated to
accelerate biological invasions in China (Lin et al., 2007), which might mean there are similar
trends in other economically emerging countries. For example, higher income could lead to
buy pets or ornamental plants that increase the potential risk of invasions. Between 1970
and 2004, the ratio of world trade to global Gross Domestic Production has increased from
around 13 to 29%.

Climate change has also started to affect the survival, establishment, spread, distribution and
impact of alien species throughout the world (See Walther et al. 2009 for many examples).
One such example is the pine processionary moth, *Thaumetopoea pityocampa*, a major forest pest from the Mediterranean Basin that is rapidly expanding its range towards higher latitudes and altitudes in response to climate change (Battisti, 2005, 2006). The Lessepsian migration, the dispersal of at least three hundred species from the Red Sea into the Mediterranean Sea following the opening of the Suez Canal, is one such example of invasion that has been exacerbated by climate change (Raitsos et al. 2010). This new context calls for a better integration of climate change and its interaction with the existence of major infrastructures into alien species predictive studies (see below).

**Begin Box 9.1 – Are we on track to achieve the target 9 by 2020?**

**Invasive alien species are identified** – Many alien species have been introduced globally. Among them, many are inoffensive for biological diversity or have little economic impact, and some have a large economic or social value in their areas of introduction (e.g., domesticated plants; aquaculture species). However, a significant proportion of alien species become invasive, and those need to be identified and characterised. Considerable efforts are on-going to identify invasive alien species (see GRIS initiative). There is also an urgent need to standardize terminology related to invasive alien species. Overall, invasive alien species have been better characterized with important initiatives and developments of risk assessment. Some issues about time lag between introduction of alien species and impacts require more attention. We are on track to achieve the target on this sub-objective, although important issues remain on a standardize definition and on gaps in the current coverage, which is mainly developed countries and terrestrial species.

**Invasion pathways are identified** – The control of individual invasive alien species is time and resource consuming, and cannot be successful for the control of all invasives because there is a huge number of invasive alien species that can be introduced anywhere. It is now widely accepted that it is far more effective to identify invasion pathways and implement measures to manage them (e.g., control of ballast water or hull fouling organisms, inspection of horticultural products, regulation of the nursery, aquarium, and pet trade to prohibit the trade of invasive alien plants/pets). There are good examples showing how identification of pathways could improve efficacy of prevention at a global scale (e.g., see Briski et al. 2012, Katsanevakis et al. 2013 or Seebens et al., 2013 for global shipping or Tatem & Hay 2007 for airline transportation network). Working at the invasion level can also exclude entire guilds of invasive alien species (e.g. wood boring insects or marine macro-invertebrates). However, the link between pathways and invasive alien species success and impact remain unknown.

**Invasive alien species and pathways are prioritized** – Given the sheer number of alien species, and the relatively large proportion of them that can become invasive (sometimes after a time lag of several decades), prioritizations are usually made on invasive alien species known to have a large impact elsewhere, or on invasion pathways that are known to be important sources of invasive alien species. There are significant improvements to document the major pathways of invasions and to consider them into future policies. National programs of preventive measures have been increasingly adopted (e.g. Australia, New Zealand, Norway, Belgium, Ireland, and increasingly in Caribbean and Pacific Island nations). However, the high numbers of invasive alien species and the cost of implementing stringent biosecurity
measures have hindered efficient legislation in many countries, especially in countries that are not efficiently protected by physical barriers to plant and animal dispersion. In addition, there is an absence of spatial prioritisation of the border control that could be based on sampling efforts (e.g., in Europe; Bacon et al. (2012)).

**Priority species are controlled or eradicated** - Control options including eradication to manage invasive alien species has significantly grown over time including for species and ecosystems that were still until recently deemed impossible to eradicate (see Simberloff et al 2012 for examples). Novel criteria to control or eradicate species are also considered in prioritization schemes, such as conservation value, feasibility, durability, and cost effectiveness (Brooke et al. 2007; Donlan & Wilcoxon 2009; Capizzi et al. 2010; Harris et al. 2011), but others factors such as climate change exposure need also to be included (Courchamp et al. 2014). There are now numerous examples of conservation successes resulting from control or eradication of invasive alien species (McGeoch et al. 2010). However, the increase in the number of new alien species introductions out-weighted the number of eradications, pointing towards a need for further efforts in measures to prevent introduction and establishment. In addition, the number of completed eradication programmes seems to have decreased in the last ten years, compared to an exponential increase in the previous decades. This might in part be due to a tendency to tackle logistically more challenging ecosystems and/or multi-species eradications in single projects. The recent success of the Macquarie Island Pest Eradication project is a good illustration of this. Consequently, it is likely given current trends that this sub-objective of the target will be missed, although some significant progresses have been made to control and eradicate invasive alien species.

**Measures are in place to prevent their introduction and establishment.** - The number of established invasive alien species has significantly increased in all taxonomic groups, with no signs of slowing down (mainly developed countries for which data are available). The increasing establishment rates of invasive alien species are widely attributed to increased rate of species introductions due to increasing international trade and human density. To date, there is an encouraging increase in the adoption of national and international conventions and agreements, regulations and codes of conduct to prevent introduction, establishment, and spread of invasive alien species. Yet, there still exists a gap between international agreements, regulations and measures that are implemented at the national levels. Consequently, current adopted policies and their implementation remain insufficient to achieve this sub-objective of the target.

Although notable progresses have been performed in some areas, achievement of all of the sub-objectives of the Target 9 is not likely given current trends.

**End box 9.1**
1.c. Country actions and commitments

Almost all countries have identified targets or actions related to invasive alien species, however few Parties have developed quantitative targets (high confidence). Generally the targets or actions that have been established address the main elements of Aichi Biodiversity Target 9 (high confidence). For example Suriname has set a sub-objective of limiting the spread of dangerous organisms and Finland has a set of targets to identify invasive alien species and their pathways and to prioritize these.

The targets and actions that have been set have an emphasis on controlling introduction pathways. Communication and raising awareness on invasive alien species is also another key issue that has been reflected in a number of new initiatives implemented by several countries. Among the actions, generally there appears to be less of an emphasis on controlling invasive alien species or identifying species and pathways (moderate confidence). The ultimate effect of the targets will depend on the extent to which actions are taken to implement them. In this light, several countries have identified priority actions to implement their targets, and are building on existing legislation or programs or have plans to develop new legislation (moderate confidence). For example the Dominican Republic plans to further strengthen its Program for Control of Invasive Alien Species. Similarly England has identified, as a priority action, the continued implementation of the Invasive Non-Native Species Framework Strategy for Great Britain. Belgium has also identified a suite of actions, such as conducting comprehensive and widely accepted risk assessment procedures, developing actions for addressing main introduction pathways, and establishing early detection and control mechanisms. Many countries, for example East Timor and Malta, have also identified or noted indicators in their NBSAPs, which can be used to monitor progress towards their targets or actions or have identified desired outcomes (moderate confidence). The importance of minimizing the impact of invasive alien species to make progress towards other national priorities, in particular the reduction of extinction, is noted in many NBSAPs, such as Switzerland (moderate). Several countries have also noted the link between the identification of invasive alien species and monitoring systems more generally (low).

Finally, if actions which have been identified by Parties in their NBSAPS are fully implemented they would necessarily bring the world community closer to attaining the Aichi Biodiversity Target 9. The importance of minimizing the impact of invasive alien species to make progress towards other national priorities, in particular the reduction of extinction species, is also acknowledged by many countries.

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1 This assessment is based on an examination of the national biodiversity strategies and action plans from the following countries: Australia, Belarus, Belgium, Colombia, Democratic People’s Republic of Korea, Dominican Republic, El Salvador, England, The European Union, Finland, France, Ireland, Japan, Malta, Myanmar, Serbia, Spain, Suriname, Switzerland, Timor Leste, Tuvalu and Venezuela. In addition it considers the set of national targets developed by Brazil. This assessment will be further updated and refined to account for additional NBSAPS and as such these initial findings should be considered as preliminary and were relevant a level of confidence has been associated with the main statements. This assessment focuses on the national targets, objectives, priority actions and similar elements included in the NBSAPS in relation to the international commitments made through the Aichi Biodiversity Targets.
2. What needs to be done to reach the Aichi target?

2.a. Actions

Invasive alien species are one of the main direct drivers of biodiversity loss at the global level. In some ecosystems, such as many island ecosystems, invasive alien species are frequently the leading cause of biodiversity decline. Governments are increasingly taking steps to control and eradicate invasive alien species. However while some progress has been made in identifying and controlling invasive alien species and in monitoring their introduction pathways, GBO-4 concluded that the overall rate of invasions shows no sign of slowing. Against this background, possible key actions to accelerate progress towards this target include:

(a) Raising awareness among policy makers, the general public and potential importers of alien species, of the impacts of invasive alien species, including the possible socio-economic costs and the benefits of taking action to prevent their introduction or to mitigate their impacts, including by publicizing nationally relevant case studies (Target 1);

(b) Developing lists of alien species known to be invasive (or assessing existing lists for their completeness and accuracy) and making them widely available (Target 19);

(c) Increasing efforts to identify and control the main pathways responsible for species invasions, including through the development of border control or quarantine measures to reduce the likelihood of potentially invasive alien species being introduced and making full use of risk analysis and international standards;

(d) Putting in place measures for the early detection and rapid response to species invasions; and

(e) Identifying and prioritizing those invasive alien species with the greatest negative impact on biodiversity that are established in the country, and developing and implementing plans for their eradication or control, and also prioritizing protected areas and other areas of high biodiversity value for eradication or control measures.

Decision VI/23* includes the Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species that Threaten Ecosystems, Habitats or Species as well as guidance for national invasive species strategies and action plans. Additional guidance is provided in decisions V/8, VIII/27, IX/4, X/38, XI/28. A toolkit is under development pursuant to decision XI/28. Information on invasive alien species is available through the Global Invasive Alien Species Information Partnership.

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* One representative entered a formal objection during the process leading to the adoption of this decision and underlined that he did not believe that the Conference of the Parties could legitimately adopt a motion or a text with a formal objection in place. A few representatives expressed reservations regarding the procedure leading to the adoption of this decision (see UNEP/CBD/COP/6/20, paras. 294-324).
To achieve Target 9 - by 2020, invasive alien species and pathways are identified and prioritized, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment – multiple measures should be implemented.

There is a need to develop indicators of invasions that track any progress towards achieving the targets (Rabitsch et al. 2012). These indicators can be based on a range of taxa, cover large spatial scales, assess temporal trends in invasions, or consider impacts of invasive species as well as develop large dataset about invasive alien species (but see (McGeoch et al., 2010; Nentwig et al., 2010; Pyšek et al., 2012b). For example, the levels of biological invasion across ecosystems could be calculated through relative alien species richness and relative alien species abundance (Catford et al. 2012). Indicators have already been developed such as the number of invasive alien species per country but the available data does not have global coverage, in particular in developing countries (see section: “Uncertainty and data requirements”). Data on aquatic invasive species is also currently lacking for current trends of invasions in inland waters, which limits extrapolation (but see Ricciardi 2006). Moreover, non-standardized terminology of invasive species is still a significant limit to the development of pertinent indicators. An internationally standardized procedure as for the IUCN species red list might be an option to solve this issue. Although adoption of national and international policies against invasive alien species is an important indicator of responses, this indicator fails to inform about the efficiency of such responses. Additional indicators such as the economic costs of invasive species, their impacts on ecosystem services or human health should also be developed to assess the achievement of this target (Genovesi et al. 2013).

Hence, success of management is critically dependent on adequate information and on understanding of the pathway, size and nature of biological invasion (McGeoch et al. 2010), but also on the knowledge of adequate control measures that have proven to be successful. Further facilitation of global information sharing and centralizing that assist recognition of the risk of biological invasions and analysis of these risks, is needed. In order to collate and centralise the data, a number of new initiatives have been initiated to provide scientists, environmental managers, policy-makers and others with information databases and discussion forums. For example, the Global Invasive Alien Species Information Partnership (GIASI Partnership) has come together in order to assist Parties to the Convention on Biological Diversity, and others, implement Article 8(h) and Target 9 of the Aichi Biodiversity Targets, building upon databases developed by IUCN-ISSG, CABI Invasive Species Compendium, DAISIE among others.

The multiple pathways of introduction and the huge volume of trades call for prioritization of prevention efforts that should be focused on key pathways. The data collected so far — mainly for developed countries — can already permit to identify some key activities and vectors responsible for the past introduction of invasive species; for example, the commercial trade in ornamental plants has been identified as a major and often the primary pathway for the introduction and dissemination of terrestrial invasive alien plants and invertebrate pests; shipping through the release of ballast water is also the primary pathway for introductions of aquatic organisms (mainly invertebrates); pet trade is a key pathway of introduction of alien terrestrial vertebrates (Bacon et al., 2013). The ballast water management convention has been adopted by 38 countries representing 30% of the world’s merchant fleet in 2013. Japanese legislation on invasive species enacted in 2005, introduced a ban on the import of
selected high risk invasive alien species and an authorisation process for a broader number of key invasive alien species, managed to significantly reduce the number of introductions of several taxonomic groups (Goka et al., 2010). Ballast-water treatments have also been shown to reduce freshwater zooplankton concentration in ship tanks by 99% (Gray et al., 2007). The introduction of invasive alien mammals has now been halted in New Zealand, through an effective biosecurity policy (Simberloff et al 2012). Development of promising tool to quantify the volume of agricultural trade that should be inspected has also been recently developed for insects in European countries (Bacon et al. 2012). Furthermore, detailed country level information is still needed, especially for under developed countries.

Furthermore, expansion, standardization, and interoperability of databases is required. International collaboration is essential at this scale, especially because pathways prioritization should be defined and identified at the regional/national level.

Data on trends exist for alien species in Europe, but these are not for “priority” or “invasive” species per se and impacts of invasive alien species on extinction risk are only available for mammals, birds, fish, and amphibians. However, the European Parliament will be voting on a bill to draw up a blacklist to fight invasive alien species. In addition, the European Alien Species Information Network (EASIN) aims to facilitate the exploration of existing alien species information in Europe from distributed sources, and to assist the implementation of European policies on biological invasions. The need for an integrated approach in policy development at both the regional, national, and international levels was emphasised as some countries have policy against invasive alien species that only included alien species that are unwanted for the country (e.g., Solofa 2009).

Figure 9.5. Management strategy against invasive species. The optimal strategy evolves with time-since introduction, with management efficiency decreasing and management costs increasing with time since introduction. From Simberloff et al. (2012).

The development of early detection and rapid response policies is by far the most cost-effective intervention in some cases reducing costs of intervention by over 40 times.
For example, Heikkila and Peltola (2004) determined the prevention costs of €350,000 and eradication costs of €946,000 for the Colorado potato beetle in Finland. However, when prevention measures have failed, decision support tools need to be in place for an efficient application of control measures at global, regional and national scales. The importance of the size of the infestation for eradication success suggests that eradication measures should concentrate on the early phase of the invasion when infestations are still relatively small (Pluess et al. 2012), as well as on the invasion front.

Finally, policies concerning invasive alien species have been increasingly adopted globally; however, there is a need to bridge the gap between growing scientific understanding of biological invasions, policies adaptation, and management action to ensure efficient measures against invasive alien species. For example, South Africa’s national-scale strategy has failed to effectively control the extent of invasions, demonstrating the need to prioritise both the species and the areas (van Wilgen et al. 2012). For example, setting policy frameworks such as eradication programs that fail to consider climate change and sea-level rise issue can mean missing out on vital issues that are required to succeed as a long-term perspective (Mainka & Howard 2010; Courchamp et al. 2014).

**Begin Box 9.2: Invasive species management in New Zealand.**

New Zealand is one of the most invaded countries in the world, primarily by virtue of the very high propagule pressure exerted upon it by intentional species introductions. This legacy of introductions and transformation by European colonists was intended to recreate a familiar landscape and lifestyle. Today, New Zealand is a country whose primary industry depends on alien species, but which has leveraged its isolation, as both an island nation and one very distant from major trading partners, to turn the tide on unwanted species invasions. New Zealand’s strong policy of border protectionism originated from agriculture, both from a desire to prevent deleterious invasions of disease and other organisms, to protect local markets, and also to promote export of products from New Zealand that are considered as highly valuable regarding sanitary and phyto-sanitary concerns. New Zealand is also a country rich in endemic biodiversity, and the agricultural border protection measures put in place translated readily to conservation border protection, when the biodiversity impacts of invasive species were recognised.

Despite these excellent border protections, many alien species have been and continue to be introduced, and some of these become invasive. Recognising the impacts of these invasive species on agricultural and biodiversity values, New Zealand has developed tools to respond to species invasion post-border. The successful implementation of these tools in New Zealand to combat invasive species spreading has benefitted from the small size and comparatively horizontal governance structure of New Zealand agencies tasked with pest control. Two strong legal frameworks have been implemented in New Zealand: the Hazardous Substances and New Organisms Act and the Biosecurity Act.

For protection of biodiversity from invasive species impacts, New Zealand has focused on using islands as arks where threatened species can be reintroduced. New Zealand has also pioneered the development of methods to eradicate pests as invasive alien species
particularly introduced mammals, from islands to increase the amount of pest-free land area.

New Zealand has eradicated introduced mammals from over 100 islands.

**Figure 9.6.** Number of non-native mammal species in New Zealand between 1876 and 2005 (points), Grey line represents the fit with Loess fit, and the shade represents the 95% confidence interval. Data compiled by M. Clout, P. Genovesi from Simberloff et al. (2012), updated by J. Russel.

Following its success on smaller islands, New Zealand has developed “mainland islands”, which allow the technologies developed for invasive species eradications on islands to be applied in a larger landscape context. “Mainland islands” can utilise either novel barrier technologies, specifically mammal-proof fences, to create fenced enclosures within larger landscapes, or can use sustained pest control methods to maintain pest density at close to zero for agricultural or biodiversity benefits. Through spontaneous community driven processes there are currently over 25 fenced, and 100 unfenced “mainland islands”, across New Zealand. By increasing pest control connectivity among these sites and expanding their “halo” of influence, it is predicted that pest control may scale to the entire country with appropriate governance guidance.

New Zealand has demonstrated that expediency in invasive species control (eradications) and prevention (implementation of biosecurity measures) is critical for successful invasive species management. Unnecessary delays in action due to uncertainty decrease the likelihood of successful invasive species management outcomes. As well as rolling back pest species distributions at key sites, New Zealand has developed comprehensive biosecurity protocols for surveillance and detection of incursions both pre-border and post-border at key sites. Implementation of these methods has demonstrated that the more rapid the intervention on new incursions, the greater the likelihood of success. Red imported fire ant have been detected at New Zealand ports on three occasions and successfully eradicated. The painted apple moth was detected in an inner city suburb and eradicated through an orchestrated eradication campaign. Reinvasion of islands previously cleared of invasive rats is close to zero where biosecurity surveillance occurs.

The success of invasive species prevention and management in New Zealand has depended on the buy-in of diverse groups (e.g. agricultural and tourism industries) and a strong awareness of invasive species in the wider population. This awareness and buy-in has been
crucial to overcome obstacles to successful invasive management, particularly issues relating to the controversial methods of invasive species control and eradication (e.g. toxin use). This assessment is also made through a strong legal framework for the introduction of hazardous species and new organisms.

New Zealand is still in the early stages of many species invasions, most invasive plants are only beginning their invasion, and even if no more invasive species colonised it, New Zealand will still have a legacy of invasion to combat for many decades to come.

End Box 9.2

2.b. Costs and Cost-benefit analysis

There are several benefits of investment in reducing the pressure of invasive alien species. As the cost of invasions is likely to rise as more species arrive each year and more species that are already present become invasive or more widespread, cost-benefit analyses in order to control invasive species is paramount. Meeting Target 9 would substantially reduce the total economic cost of damage caused by invasive alien species, which is roughly estimated at 2-5% of world Gross Domestic Product (GDP), or approximately US$2.6 to 6.5 trillion per annum (Pimentel et al. 2005; High Level Panel Repot). A more conservative estimate of damages is about 1.5% of GDP (High Level Panel report). Current costs of invasive alien species include direct use costs in terms of extraction of resources from the ecosystem; indirect use costs (e.g., disruption of ecosystem services) that for example encompass the effects on pollination, fertilization, seed dispersal or flood attenuation. More specifically, the estimated annual cost of alien invasive species has been estimated to be $US 336 billion per year for USA, UK, Australia, South-Africa, India and Brazil, $CA 29.2 billion for Canada and $US 17.3 billion in Europe (Pimentel et al., 2005; High Panel Level report, EC 2011b +, Table 9.1). For example, exotic pest species caused annual losses of US$12.0 billion in Brazil (Oliveira et al. 2013). It should be noted that alien species can be positive for agriculture as most food crops are deliberately introduced alien species; yet other invasive alien species can reduce crop yields by billions of dollars annually (Pejchar & Mooney 2009). Moreover, climate change could increase the cost of invasive alien species. For example, Kriticos et al. (2013) showed that the pine processionary moth could reduce New Zealand’s merchantable and total pine stem volume production by 30%, resulting in a total loss between NZ$1 550 M to NZ$2 560 M if left untreated following climate change (Kriticos et al. 2013). In Europe, invasive alien species control programme would require to create between 520 and 2 520 employments (Jurado et al. 2012). Nowadays a number of studies are modelling the cost effectiveness of different management measures (Keller et al. 2007; Lehrer et al. 2011). For instance, Keller et al. (2007) showed that risk assessment produces positive net economic benefits in the Australian plant quarantine program. The economic cost incurred by the Emerald Ash Borer could reach around $12.5 billion with no program to mitigate spread in 2020 (Kovacs et al., 2011). However, appropriate management measures could decrease the cost to $0.1 to 0.7 billion (Kovacs et al. 2011). Further, Wilson et al. (2007) applied a new model to prioritise biodiversity actions based on cost effectiveness, showing that 24% of the funds should be allocated to invasive plant control in the 17 Mediterranean ecoregions as this yielded to the greatest marginal
return on investment for biodiversity. It should be noted that there are different stakeholders paying costs and profiting benefits, therefore a cost benefit analysis is dependant of who is paying and who is benefiting. Besides, the cost benefit analyses may vary according to the part of the biodiversity targeted.

Overall, the first High Level Panel report estimated that between US$ 34 100 to 43 900 million of investment with an additionally recurrent expenditure per annum of about US$ 21 005 – 50 100 are needed to achieve the Target 9 in 2020.

Table 9.1: Annual Economic Impact of Terrestrial Invasive Species on a National Scale from Barlow and Goldson (2002); Bergman et al. (1999); Bomford and Hart (2002); Clout (2002); Colautti et al. (2006); Gren et al. (2009); Kettunen et al (2008); McLeod (2004); Oliveira et al. (2013); Pimentel et al. (2005); Reinhard et al. (2003); Sinden et al. (2004); Singh & Kaur (2005); White & Harris (2002); Williams and Timmins (2002); Williams et al. (2010); Wi et al. (2006).

<table>
<thead>
<tr>
<th>Country</th>
<th>Plant</th>
<th>Animal</th>
<th>Microbial</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia (in $AU)</td>
<td>4 billion</td>
<td>491.5 million (9 vertebrates)</td>
<td>703.9 million (10 vertebrates)</td>
</tr>
<tr>
<td>Brazil ($US)</td>
<td>1.6 billion (24 pest)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Canada (SCAN)</td>
<td>38.21 million</td>
<td>101.3 million (3 invertebrates)</td>
<td>14-16 million (emerald ash borer)</td>
</tr>
<tr>
<td>China ($US)</td>
<td></td>
<td>14,450 million</td>
<td></td>
</tr>
<tr>
<td>Europe (27 countries; $US) (EUR/year)</td>
<td>17.3 billion</td>
<td>5985 million</td>
<td></td>
</tr>
<tr>
<td>England (£)</td>
<td>1,291,461</td>
<td></td>
<td></td>
</tr>
<tr>
<td>England ($US)</td>
<td></td>
<td>239 million (vertebrates)</td>
<td></td>
</tr>
<tr>
<td>Germany (Euros)</td>
<td>103 million (8 species)</td>
<td>60.2 million (6 species)</td>
<td>5 million (dutch elm disease)</td>
</tr>
<tr>
<td>India (Rs)</td>
<td>1.688n (Fungal, bacterial, viral &amp; nematode pathogens)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New zealand ($NZ)</td>
<td>200 million (weeds)</td>
<td>270 million (vertebrates)</td>
<td>2 billion (invertebrates)</td>
</tr>
<tr>
<td>United States ($US)</td>
<td>34.5 billion</td>
<td>59.4 billion</td>
<td>39.7 billion</td>
</tr>
<tr>
<td></td>
<td></td>
<td>28 billion (birds;1990-1997)</td>
<td>14 billion (mammals; 1990-1997)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1,806,787 (black rats)</td>
<td>400 000 (reptile; 1990-1997)</td>
</tr>
<tr>
<td>Scotland (£)</td>
<td>244,736,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden (SEK)</td>
<td>1620-5080 (13 invasive)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wales (£)</td>
<td>125,118,000</td>
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<td></td>
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</tbody>
</table>
3. What are the implications for biodiversity in 2020?

The successful achievement of Target 9 is likely to guarantee a positive outcome for biodiversity conservation at the gene, species and ecosystem levels. Moreover, this will also contribute to achieve Targets 5, 10, 12, 14, and 15. For example, 49 populations of 12 invasive mammals were eradicated from 30 Mexican islands to prevent extinctions. These actions resulted in the protection of 202 endemic taxa with recolonisation of some seabirds in several islands and new recruitment of endemic tree species (Aguirre-Muñoz et al. 2008) contributing to achieve Target 12. However, recovery of native biodiversity is often uncertain, as invasions may be indicators of more fundamental environmental change.

Furthermore, in order to provide updated information about the consequences of invasive alien species on endangered species during the next years, the IUCN SSC Invasive Species Specialist Groups is working in cooperation with the IUCN Red List Unit at ensuring a full interoperability between the IUCN Red List, and the ISSG Global Invasive Species Database (GISD). The work is almost completed, and a beta version of GISD interlinked to the Red List is planned for release in the second half of 2014. To interlink the two IUCN products, for each Red list assessed species, all relevant information (scientific and common name of the alien species posing a threat, impact mechanism and outcomes, level of impact, etc.) have been analysed and integrated in the GISD. For impact mechanisms and outcomes, a revised classification that has been developed with the support of leading scientists on the topic, has been produced and integrated into GISD. Also information on the impact level has been included in the database, based on the information provided in the assessment (high, medium, low, no/negligible/unknown/future/past). The final integrated information system will allow users to i) identify invasive species affecting each Red List species and ii) identify threatened species affected by each GISD invasive species. The integration of the two products will thus provide a valuable tool of prioritization of invasive alien species for mitigating the consequences for biodiversity in 2020.

4. What do scenarios suggest for 2050 and what are the implications for biodiversity?

Increased human population, global movement of people and goods, and land-use changes will remain the major driver of biological invasions in the future. They are all expected to increase and therefore to continue accelerating the current rate of invasions. In addition, the effects of climate change are expected to increase in importance over time for some species and some regions. Thus, climate change, global land use change and increased global trade will facilitate opportunities for invasive alien species to arrive and establish in new places at a long-term horizon. On the contrary, some invasive alien species may suffer from climate change, creating new opportunities for ecosystem restoration (Bradley et al. 2009; Bellard et al. 2013).

4.i. Propagule pressure

Increases in human population density will lead to greater disruption and degradation of habitats. Increasing in global trade and movement of people will also favour propagule pressure, leading to new invasions by 2050 (Seebens et al. 2013). For example, more exotic
plant species are expected to become invasive on islands over the next century (Sax et al 2008).

Future climate change will also facilitate unintentional introductions through higher intensity and/or frequency of extreme events (Walther et al. 2009; Fig. 9.7). The Formosan subterranean termite had invaded nine southern states of the United States before Hurricane Katrina in 2006. Following Hurricane Katrina, millions of tons of wood debris, including debris infested with Formosan Termites have been under quarantine (Mainka & Howard 2010) to limit the invasion in the United States. Climate change could also provide new routes that were not available previously such as the Northwest Passage in the northwest Atlantic, as the artic ice cover is reduced and the ice-free season is extended, which offers a seasonal trading route through the northern ocean (Reid et al. 2007).

**Figure 9.7.** Potential consequences of climate change on the invasion pathway extracted from Hellman et al., 2008

4.ii. Alteration of spread

Climate, global trade and land-use changes will alter the success of invasive alien species to invade new areas by creating disturbance events, which decrease the resilience of natural communities to invasion (Roura-Pascual et al. 2011). Climate change is also expected to alter species survival and species reproduction, particularly for some plant groups (Peñuelas et al. 2013) and zooplankton (Panov et al. 2007). Climate warming can also result in an increase of dispersal performances for some invasive alien species, allowing for range expansion and invasions into new areas. For example, the mountain pine beetle can now complete a life cycle in one season, due to increased temperatures at higher latitudes and altitude (Logan & Powell 2001).

Future changes of invasive alien species distributions are uncertain, but several generalizations can be made from species distribution models analyses. Currently, species distributions models are generally performed on a species by species basis. Little attention has been devoted to address multiple invasive alien species (but see Peterson et al. 2008; Chytrý et al. 2012; Bellard et al. 2013). Peterson et al. (2008) showed highly nonlinear and
contrasting projected changes in suitable areas of the European plants distribution. Plant species with expanding potential on one continent often had contracting potential on others. These changes suggest important community reorganization. Chytrý et al. (2012) also showed that the strongest increases of invasive alien species following land-use changes were projected for areas of north western and northern Europe where current levels of invasion are low or average. In contrast, some areas such as Eastern Europe and some parts of southern Europe may experience no increase or even decrease in the level of invasion (Chytrý et al. 2012).

At a global scale, the distributions of some invasive alien species will change with poleward migrations and movement to zones of higher altitude as regions experience elevated temperature. In the long-term (i.e., 2041-2060 period), some “high risk” regions to invasive alien species (i.e., the list of the “100 among the worst invasive alien species”) are predicted to occur in Europe, United States, Southern Australia, Argentina, and Pacific and Caribbean islands due to climate and land use changes (Bellard et al. 2013). Moreover, some regions will offer higher suitable environmental conditions such as eastern part of United States, northern part of Europe, Argentina, south of China and India (Bellard et al., 2013, Fig. 9.8). Some regions could lose a significant number of invasive alien species (e.g., central America and Australia). In fact, area of suitable habitat showed contrasting results according to the region and taxa considered, some taxonomic group will suffer from a consistent shrinking of their suitable area while other group species are projected to substantially increase (see Xu et al., 2013; Bertelsmeier et al. (submitted)). Thus, species distribution and climate analogue analyses could be a useful tool to prioritize regions and target species to monitor because close climate matching is generally a fundamental requirement for invasive success (but see Broennimann et al., 2007; Gallagher et al., 2010). Overall, climate change will also lead to novel climates across the world (Williams et al. 2007), this will increase uncertainties to predict the presence of invasive alien species, in particular at low latitudes where the rates of novel climate will be important.

**Figure 9.8.** On the left, predicted number of invasive alien species of the list of the “100 among the worst invasive alien species” around the world that could find suitable environmental conditions en “2041-2060” period. On the right, difference of the number of predicted invasive alien species that will find suitable conditions between “future” and “current” period. Results from Bellard et al. (2013)

Although the effect of climate change on invasion will be important in the future, the probability that species from specific ecosystems will be introduced to climatically similar but
geographically distant ecosystems will mainly depend on global trade patterns and volumes, both of which are predictable over a reasonable period.

### 4.iii. Implications for biodiversity

In the long term, the composition of biological communities is projected to change substantially in particular because of the population responses to climate change and high number of species predicted to be at higher risk of extinction (see Target 12). Potential shifts of some invasive alien species strongly suggest that biological communities will undergo dramatic reorganization in coming decades (Peterson et al. 2008). For example, some biomes including cool coniferous forest, temperate deciduous forest, temperature mixed forest might be more suitable to invasive alien species in the future, while tropical forest and tropical woodland will be less favourable to invasive alien species in 2080 (Bellard et al. 2013). It is also projected that many more invasive alien species will become naturalized on islands in the future (Sax et al., 2008) threatening insular biodiversity. Finally, although it may be known that changes in the composition and volume of trade and land use will both affect the likelihood of species introductions, establishment, and spread, there is still insufficient data to predict with high confidence whether the direction and magnitude of changes will continue to increase at the current rate.

### 5. Uncertainties and data requirements

The literature about invasive alien species has important gaps in areas of theoretical and practical importance. In fact, most of the current research is focused on the causes of biological invasions (58% of publications), while 32% of publications is focused on the impacts of invasions (Lowry et al. 2012). Among them, most of the studies focused on the consequences of invasive alien species at the species level and do not include impacts at the gene or ecosystem levels (Pejchar & Mooney 2009). In addition, most studies are concerned with terrestrial invasions, and in particular of plant species (Lowry et al. 2012). Studies are also geographically biased positively for North America, Western Europe, eastern Australia and New Zealand, and there is a dramatic lack of studies in the tropics and on other areas of interests, such as the boreal tundra and taiga. Consequently, there are high uncertainties about the current and future pressure of invasive alien species in these regions. With regards to projections, the potential distribution of invasive alien species assumes that species will have a constant impact over the world, while the intensity and multiplicity of impacts are highly context dependent (Simberloff et al. 2012; Ricciardi et al. 2013). Moreover, there is a lack of information in the listing of invasive alien species (but see Global Register of Introduced and Invasive Species), in particular regarding impacts (Kulhanek et al. 2011). Moreover observed impacts often fail to translate to ecosystem services or evidence of environment degradation (Hulme et al. 2013). However, the recent collaboration between the IUCN SSC Invasive Species Specialist Group and the IUCN Red List Unit will facilitate integration and sharing information on the impact of invasive alien species on threatened native species. Furthermore, less than 11% of countries are considered to have adequate data on invasive alien species (Genovesi et al. 2013). Finally, while a majority of countries have identified targets or actions related to invasive alien species, few parties have developed quantitative targets. This has made difficult to evaluate and assess progress.
towards achieving Target 9. The development of new indicators to monitor the achievement
of the target is thus required. With regards to practical management, the exchange of
knowledge of successful management measures but also measures that have failed, and that
should not longer be applied should also be a future challenge.

6. Dashboard – Progress towards Target

<table>
<thead>
<tr>
<th>Element</th>
<th>Current Status</th>
<th>Comment</th>
<th>Confidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invasive alien species identified and prioritized</td>
<td><img src="image" alt="3" /></td>
<td>Measures taken in many countries to develop lists of invasive alien species</td>
<td>High</td>
</tr>
<tr>
<td>Pathways identified and prioritized</td>
<td><img src="image" alt="3" /></td>
<td>Major pathways are identified, but not efficiently controlled</td>
<td>High</td>
</tr>
<tr>
<td>Priority species controlled or eradicated</td>
<td><img src="image" alt="3" /></td>
<td>Some prioritized control and eradication, but data limited</td>
<td>Low</td>
</tr>
<tr>
<td>Introduction and establishment of IAS prevented</td>
<td><img src="image" alt="2" /></td>
<td>Some measures in place, but not sufficient to prevent continuing large increase in IAS</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Compiled by Céline Bellard and Franck Courchamp with contributions from Piero Genovesi
and Shyama Pagad and Box 9.2 text contributed by James Russell
Extrapolations: Derek Tittensoor
NBSAPs and National Reports: Robert Hoft and Kieran Mooney
Dashboard: Tim Hirsch

Version history: 3 Dec 2013 CB, 18 Dec 2013 CBK, 14 Feb 2014 CB, 23 Feb CBK

7. References


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