Aliens: The Invasive Species Bulletin

Newsletter of the IUCN/SSC Invasive Species Specialist Group

Issue Number 31, 2011

ISSG Invasive Species Specialist Group

IUCN

SSC Species Survival Commission

ISPRA Institute for Environmental Protection and Research

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The yellow-legged hornet *Vespa velutina*
© Photo by Quentin Rome

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www.issg.org/newsletter.html#Aliens

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Editorial

In the past few months there has been an active discussion on the key principles of the global efforts to manage biological invasions. Several articles and letters have been published in the world's leading scientific journals, stimulating a flourish of responses and rebuttals.

ISSG has actively contributed to this discussion. Letters have been published in Science, and Nature magazines. A statement– calling to strengthen, not weaken the struggle against invasive species, written with the support of many subscribers of ISSG's Aliens-L list (with over 1045 subscribers) was posted on our website at http://www.issg.org/pdf/rebuttal.pdf.

An important result of the debate is a letter, published in the July 22 (Vol. 333 no. 6041, pp. 404-405) issue of Science, signed by senior leaders of global conservation organizations - including Birdlife International, International Union for Conservation of Nature (IUCN), Conservation International (CI), the World Wildlife Fund (WWF), Island Conservation (IC), Wildlife Conservation Society (WCS), Flora and Fauna International (FFI), and the ISSG - reaffirming the urgency of addressing the threats posed by biological invasions, and confirming the commitment of the conservation community to continue work on this issue. The letter was widely circulated and was warmly welcomed by the CBD (Convention on Biological Diversity) with a dedicated press release aimed at expressing support for continued action against the spread of invasive species -a key target of the Strategic Plan for Biodiversity 2011-2020 adopted at the Conference of Parties to the CBD in 2010 in Nagoya, Japan.

It is indeed important that scientific discussions on conservation priorities continue, and I believe that our community of invasion biologists and practitioners must remain open to new perspectives and approaches to conservation of biological diversity. At the same time I think that it is essential that we do our best to avoid discussion that may discourage scientific institutions, public administration and even countries to strengthen their efforts to prevent and mitigate the impacts of biological invasions.

Piero Genovesi, ISSG Chair

News from the ISSG

Strategies to stop invasives

In the last months the IUCN SSC Invasive Species Specialist Group (ISSG) has carried out several activities to support the development of strategies to deal with invasive alien species (IAS) at both local and international levels.

Piero Genovesi, chair of ISSG, attended the meeting of the *Ad Hoc* Technical Expert Group (AHTEG) established at the 10th meeting of the Conference of the Parties to the Convention on Biological Diversity. The AHTEG, held in Geneva, February 2011, specifically addressed the risks associated with the introduction of invasive alien species as pets, aquarium and terrarium species, live bait and live food. The report of the meeting is being edited by the Secretariat of the CBD, and will be presented for consideration at a meeting of the Subsidiary Body on Scientific, Technical and Technological Advice prior to the 11th meeting of the Conference of the Parties.

Piero also took part in the meeting of the Inter-Agency Liaison Group on Invasive Alien Species, a consultative group with representatives of the CBD, the World Trade Organization, the World Animal Organisation for Animal Health, the International Plant Protection Convention, CITES, IUCN and the Global Invasive Species Program.

ISSG has also actively participated to the working group established by the European Commission (EC) to contribute to the development of the EC strategy on invasive alien species, due by end 2012. Additionally, in collaboration with the European Environment Agency, the ISSG has organised a workshop on invasive alien species in the West Balkan countries. The workshop, held in Zagreb, Croatia, in October 2010, was aimed at encouraging and supporting the establishment of an Early Detection Rapid Response framework in the region. It will be coordinated and/or integrated to the European strategy on IAS which is under development (see additional details in article at page 54).

Within the frame of the activities to support the implementation of early warning system in Europe and worldwide, the ISSG is collaborating with the Council of Europe on the realisation of voluntary regulatory mechanisms needed to guarantee compliance with a defined standard of reasonable conduct to tackle specific pathway risks. Examples of such voluntary tools aimed at providing guidance to help Bern Convention Parties in their efforts to increase awareness and information on IAS, and to strengthen national and regional capacity and co-operation to deal with the issue, are the following two codes of conduct:

- European Code of conduct on IAS and Hunting (coordinated by Andrea Monaco).
- European Code of conduct on IAS and Zoological Gardens and Aquaria (coordinated by Riccardo Scalera).
- European Code of Conduct on Protected Areas and IAS (coordinated by Andrea Monaco).

The two codes have been discussed during the 9th meeting of the Bern Convention group of experts on IAS held in Malta on 18-20 May 2011, and collaboration is being sought with relevant stakeholders in order to guarantee that the last version to be endorsed by the Council of Europe and circulated among Parties, e.g. under the form of a recommendation of the Standing Committee, will be formally agreed to from all key concerned actors.

Updates from ISSG - Information Services

The Global Invasive Species Database (GISD) (http://www.issg.org/database/welcome/) as of now features profiles of 845 invasive alien species. 2011 is the International Year of Forests; in recognition of this the ISSG, during 2011 will focus on creating profiles of invasive species that are a threat to forests ecosystems. Species we are working on include two species of invasive earthworms, invasive insects and plants that are a threat to the integrity of forest ecosystems.

We are working through the last few glitches and will soon feature Chinese language content on the GISD; limited French language content is already available.

The Aliens-L list service *(http://www.issg.org/about.htm#networking)* has been very active in the past few months recording as many as 200 exchanges in the month of April. New member requests include many young researchers and practitioners. The list membership stands at 988.

Planned updates for the ISSG website *(http://www.issg.org/index.html)* include a dedicated information portal that will recognise the cross-cutting nature of the invasive species issue and have pages dedicated to individual themes like biofuels, wetlands, threatened species, climate change etc.

We also plan to create an RSS feed of information updates for global invasive species stakeholders.

ISSG's 'Invasive Species of the Week' button *(http://www.issg.org/index.html)* will feature invasive species that are a threat to forest ecosystems through 2011. Check the feature on the FAO Forestry *(http://www.fao.org/forestry/aliens/en/)* and CBD Invasive Aliens Species pages *(http://www.cbd.int/invasive/)*.

ISSG is already on Facebook, please join in and keep up-to-date with emerging issues and news items from around the world.

Toward a strategy for IAS in Croatia

The ISSG is contributing to the development of the this "Draft proposal for the development of a National strategy on IAS in Croatia", built as part of the WWF MedPo project "Protected Areas for a Living Planet – Dinaric Arc Ecoregion Project: Study on invasive species". The objective of the proposal is to ensure a prompt and coordinated response to prevent the introduction of IAS into nature in Croatia and to continue resolving the issues of existing IAS – as foreseen within the 2008 "Strategy and action plan for the protection of biological and landscape diversity of the Republic of Croatia". In fact, to fulfil the obligations arising from international treaties in the field of nature protection, such as the Convention on Biological Diversity, and in the light of the future European Union accession, Croatia needs to develop mechanisms compatible with instruments developed in Europe so far, as well as replicable in the region to be able to effectively deliver on the issue of IAS. The proposal sets out the Croatian regulatory framework relevant to the issue, and details the key actions required to address the problems caused by IAS, e.g. by supporting the development and/or improvement of regulatory/legislative framework to prevent invasions and by proposing the structure of early detection and rapid response system and related decision support tools to implement measures to remove established IAS, or managed them when removal is not appropriate. The overall aim is the future development of a comprehensive national policy framework on IAS, to be harmonised/integrated with other frameworks implemented in the South East Europe region and in Europe (see article at page 54. In drawing up this document substantial input from national nature protection authorities was sought, particularly during a dedicated workshop where a preliminary document has been presented and discussed with key representatives of the Ministry of Culture – Nature Protection Department, and Directorate for Nature Protection Inspection, the State Institute for Nature Protection, and the Croatian Environmental Agency. The meeting - organized on 4 April 2011 in Zagreb the Croatian section of WWF MedPo in collaboration with the ISSG – was aimed at transferring the knowledge and experience on IAS management in EU and gaining further feedback on the draft proposal for the development of a strategy in line with the country needs and EU requirements.

...And other news

Micronesia to Develop Strategic Plan on Invasive Species

Micronesian leaders that form the Micronesia Regional Invasive Species Council (RISC) have agreed to develop a five-year strategic plan on addressing invasive species. RISC is the advisory body on invasive species to the Micronesia Chief Executives, which is the highest political body in Micronesia. RISC includes members from Palau, Guam, Commonwealth of Northern Mariana Islands, the Marshall Islands and the Federated States of Micronesia (including Yap, Kosrae, Pohnpei and Chuuk).

This follows the successes from the 2007-2011 Plan, of which the appointment of Invasive Species Coordinators for each of the member jurisdictions was seen as a highlight. RISC agreed to five goals for the 2012-2016 Plan, including: public awareness; communication and cooperation; working closely with the Micronesia Chief Executives; human and financial resources; and harmonisation of regional biosecurity measures.

According to SPREP The Secretariat of the Pacific Regional Environment Programme) the cost for eradicating invasive species (the leading cause of biodiversity loss in island countries) often exceeds the national budget of many island countries.

Shyama Pagad (Invasive Species Specialist Group Regional Pacific Office)

New GEF invasive species project for the Pacific

A new project financed by the Global Environment Facility for invasive species management in 10 Pacific island nations was approved by GEF in March, after several years in development. The project, which will be managed by the Secretariat of the Pacific Regional Environment Programme (SPREP) provides US$3 million in GEF funding to support more than 80 separate projects in the 10 countries over the next four years.

Project activities include strengthening capacity for invasives management by establishing national invasives coordinator positions and by staff training. Coordination and mutual support between the small nations of the Pacific will be fostered by support for participation in regional invasives networks. Political and public support for invasives management will be improved by awareness and social marketing projects. International and inter-island biosecurity will be strengthened by new legislation, protocols and risk assessment, and improvement of inspection, early detection and rapid response systems. Invasive species information systems will be developed, including databases and GIS, and surveys carried out to improve knowledge of invasives in the participating countries. Several of the projects focus on the complete eradication of populations of a target species from an island. Others incorporate the evaluation of management goals and the writing and implementation of management plans for populations of invasives where feasible management goals have not yet been determined. Several projects envisage the testing of biological control agents, or the introduction of agents that have already been tested. A number of the projects include invasive species management as part of whole ecosystem restoration programmes. The project is expected to start up officially sometime later this year.

Alan Tye (Invasive Species Advisor and Pacific Invasives Partnership Coordinator: Secretariat of the Pacific Regional Environment Programme).

"New and Emerging Agricultural Pests, Diseases and Weeds" was discussed in The 3rd ENDURE Summer School

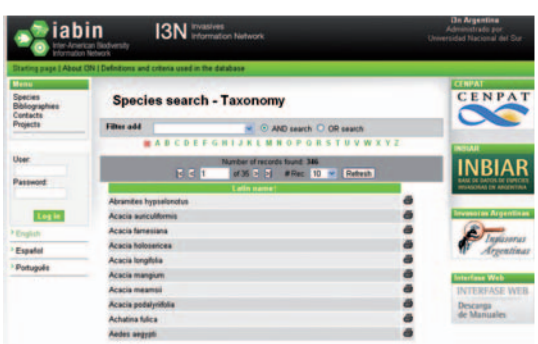
The 3rd summer school of ENDURE was organized by Scuola Superiore Sant'Anna of Pisa in Volterra in Italy on 4-8 October 2010. ENDURE (European Network for the Durable Exploitation of Crop Protection Strategies) is a Network of Excellence funded by the European Commission under FP6 programme. ENDURE is an initiative to reshape European research and development on pesticide use in crops for the implementation of sustainable pest control strategies. Its third summer school focused on new and emerging agricultural pests, diseases and weeds. Attendees who were 15 PhD students from all over the world were chosen among 86 applicants from 44 countries. The programme included lectures and team work to facilitate active participation of the students and their interaction with the lecturers. Paolo Bàrberi who is from Scuola Superiore Sant'Anna, ENDURE Summer School Coordinator, Italy explained the summer school activities and scoped. Pierre Ricci, director of INRA's Institut Sophia Agrobiotech, France presented ENDURE project. Ahmet Uludag, European Environment Agency, Denmark gave lectures on Role of Invasive Organisms in AgroEcosystems and EU strategies for invasive organisms. Christian Bohren from Station de recherche Agroscope Changins-Wädenswil ACW, Switzerland. Gabor Lövei from Faculty of Agricultural Sciences, Dept. of Integrated Pest Management, Denmark, and Sylvia Bluemel, Austrian Agency for Health and Food Safety (AGES), Institute for Plant Health (PGH), Aus-

tria, lectured on invasive weeds, pests and diseases, respectively. Gionata Bocci facilitated team works.
For further information see
http://193.205.80.76/aesito/endure and
http://www.endure-network.eu/

Ahmet Uludag, European Environment Agency, Denmark

A new version of the I3N – IABIN invasive species database

The I3N thematic network for invasive species is part of the broader IABIN – InterAmerican Biodiversity Information Network. An invasive species database in Access format was developed in 2004-2005 by the Horus Institute of Brazil and the Universidad Nacional del Sur in Argentina with support from the network, then implemented in Argentina, Brazil, Uruguay, Chile, Paraguay, Bolivia, Colombia, Ecuador, Costa Rica, Jamaica, and Guatemala. Links for these databases can be found at *http://www.institutohorus.org.br/index.php?modulo=sitesEng&tipoLingua=ingles*.
The database is in development in Venezuela, Suriname, the Dominican Republic, Honduras, and El Salvador, with Nicaragua to receive I3N training in April this year. A new open-source version of the I3N database is nearly completed and will replace the former version. More fields were added from suggestions gathered over five years of training in countries, especially to improve data on coordinates and on herbaria and museum records. The new version also has better search options and users can print factsheets of the species. These new databases will be available from the same web links. Contents are at the national level, but all databases are available in English, Spanish or Portuguese for screens and controlled vocabulary, while descriptive text is in the country's official language only.



Silvia R. Ziller, I3N Lead, Brazil / The Horus Institute, for Environmental Conservation and Development, Brazil, *sziller@institutohorus.org.br, www.institutohorus.org.br*

Michele de Sa Dechoum, The Horus Institute, Brazil

Breaking ground for legal herbicide use in Brazil

In Brazil there is little awareness on the impacts of invasive species, and much resistance on the use of chemical control. There is also a general belief that national laws prohibit the use of herbicides in natural and protected areas. As available herbicides are labeled for use in agriculture, grazing lands or forestry, natural areas are left aside. The Horus Institute and Dow Agrosciences are working for the registration of five active ingredients with the Federal Environmental Agency (IBAMA) to solve this problem and have invasive alien species specifically listed in the labels.
A workshop held in October, 2010 brought together different types of public who are concerned with this issue and are often frustrated by not receiving permits to control invasive species in non-cultivation areas.
These include governmental agencies with control programs at the state level, forest companies, NGOs and private property owners. Many species prevent restoration from occurring when control is not done efficiently, and many companies are restoring riparian areas with native species where non-native trees had been planted in past decades. This is a legal obligation in Brazil, and needs to be backed by the use of appropriate tools to lower costs and increase conservation results. In another year or two herbicides for non-agricultural areas should be widely available and greatly improve the chances of successful invasive species control in the country.

Chemical control (with triclopyr) of Casuarina equisetifolia in coastal dunes, Guarda do Embau, Santa Catarina, Brazil. Photo: Silvia R. Ziller

Silvia R. Ziller, I3N Lead, Brazil / The Horus Institute, for Environmental Conservation and Development, Brazil *sziller@institutohorus.org.br, www.institutohorus.org.br*

Volunteers and chainsaws for pine control on the southern coast of Brazil

A volunteering program put together by the Federal University of Santa Catarina and the Horus Institute has been taking Biology students to on the

ground work taking down pine trees (*Pinus elliottii* and *Pinus taeda*) from coastal sand dunes in Florianopolis, Santa Catarina state, in the South of Brazil. The area is a municipal park protecting fragile sand dunes and vegetation. Pines planted in backyards on the park borders spread seed into the area and grow in high densities. Volunteers have been pulling seedlings and cutting smaller trees with machetes and manual saws.
A small donation from Deutsche Post to the Global Invasive Species Programme (GISP) is funding complementary chainsaw operators to take large trees down.

Pine tree being felled in the dunes. Photo: Silvia R. Ziller

Some pines are nearly 30 years old and grew into large trees with 40cm in diameter or even more. By February, 317 trees had been cut down, clearing large areas of pine interference. At least 3,000 trees will be taken down in total, and we hope that the funds will be enough to cover the full area. Volunteers will do follow up work pulling seedlings that come up. This work needs to be continued for years, but as there is more community awareness we hope the community will also join this effort.

Cut stump: 24 years old, 37cm in diameter. Photo: Silvia R. Ziller

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Michele de Sa Dechoum, The Horus Institute, Brazil

Monitoring and control modalities of a honeybee predator, the yellow-legged hornet *Vespa velutina nigrithorax* (Hymenoptera: Vespidae)

Quentin Rome, Adrien Perrard, Franck Muller and Claire Villemant

The yellow-legged hornet, Vespa velutina nigrithorax*, was accidentally introduced from south-east Asia into France before 2004. Being a stinging insect as well as a predator to bees, this species was rapidly noticed by French people and considered a dangerous insect and major threat to beekeeping. However, the number of people that were stung did not increase in the invaded area. Monitoring the invasion through public warnings showed that the alien hornet spread very rapidly over a large part of the country and has now reached northern Spain. Climatic suitability models suggest that this species could spread over a large part of Europe, as well as in other areas of the world, since the scenario of introduction through international trade could well be repeated. The study of the prey spectrum of the hornet, as well as the huge size of its colonies, have led to the fear of potential threats to the native insect biodiversity, notably pollinators. Honeybees are one of the hornets main preys, so it is expected to have an economic impact on beekeeping activities that are already threatened by a wide panel of adversary factors. Nonetheless, the uncontrolled mass trappings and colony destruction performed every year in France, inside and outside the invaded area, might be more deleterious to entomofauna than the pest problem itself. Until research to develop an effective control method succeeds, recommendations are given to perform control methods limiting the local impact of the hornet on bees and other insects.*

Introduction

There are 22 hornet species in the world, most of them restricted to Asia. Only two species, *Vespa crabro* and *Vespa orientalis,* naturally reached the European and Middle East areas (Carpenter and Kojima 1997) (Fig. 1).

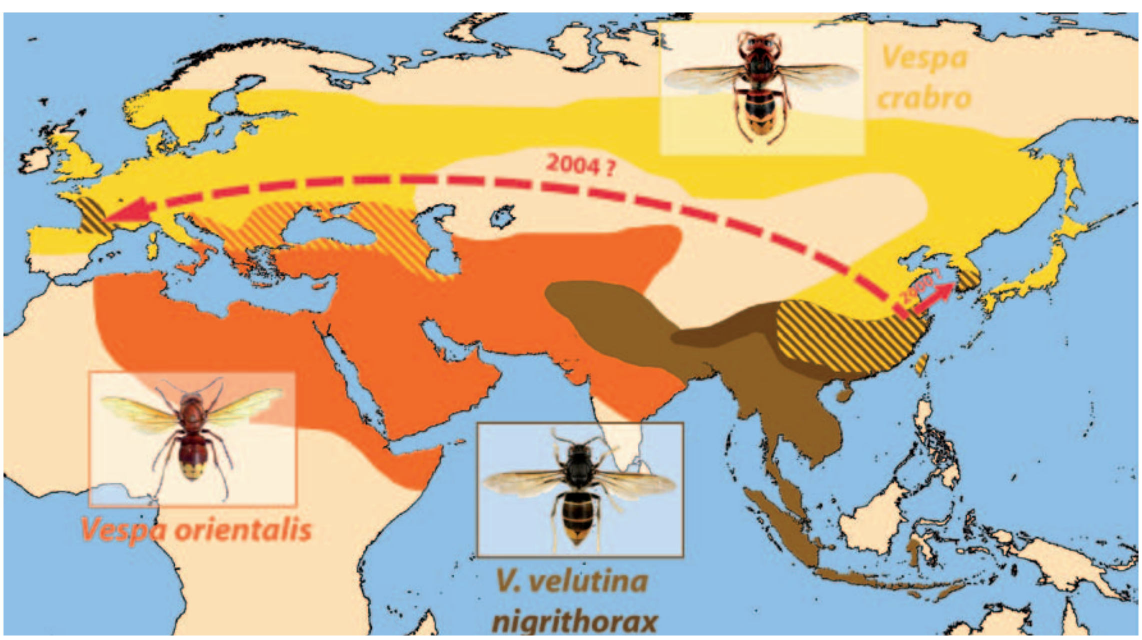

Fig. 1. World distribution of the only three species of *Vespa* that ever reached Europe. Stria corresponds to areas where two species are present and dark brown colour to the variety *nigrithorax* inside the distribution area of *Vespa velutina nigrithorax*

The yellow-legged hornet, *Vespa velutina nigrithorax,* originally distributed in south-east Asia, was accidentally introduced into Korea in the 2000s (Jung *et al.* 2008; Kim *et al.* 2006). Its presence was first recorded in France in 2005 (Haxaire *et al*. 2006) and the species rapidly spread across southwestern France (Rome *et al*. 2009; Villemant *et al.* 2006; Villemant *et al.* 2011a, b), becoming the first successful invasive hornet in Europe (Rasplus *et al.* 2010). The origin of introduction of *V. v. nigrithorax* remains uncertain. However, locally collected data suggests that hibernating queens could have been accidentally imported from China through the horticultural trade before 2004 (Villemant *et al.* 2006).

Like many social wasps, *Vespa velutina nigrithorax* produces annual colonies, initiated by a single queen, after overwintering. Only the founders (future queens) survive the overwintering period; after hibernation, each fertilized founder builds a primary nest. Thus, the colony, initiated by a single individual, develops through the warm season by producing, up to, several thousands of workers, finally decreasing and dying in the fall after the sexual generation has emerged. By then, the colony will have raised hundreds of males and new founders able to mate and subsequently produce new colonies. This efficient life cycle initiated by only one individual makes social insects, such as hornets, redoubtable invaders.

Monitoring the invasion

Cartography

Since 2006 the monitoring of *V. v. nigrithorax* presence in France is made by individual public warning through an online biodiversity database held by the MNHN *(http://inpn.mnhn.fr*; INPN 2010). The web page dedicated to *Vespa velutina nigrithorax* provides general information on the invasive hornet and other species with which it can be confused. Articles, fact sheets and a slideshow are also downloadable (INPN 2010). People can report online their observations of nests or individuals occurrences of this species. A spreadsheet to gather nest records at a regional or local scale is also spread throughout naturalists and beekeepers networks, state and regional services, firemen and municipal services and private wasp controllers (Rome *et al*. 2009). To avoid duplicate reports, only mature nests are recorded and localities are checked. In 2004, only 3 nests were recorded in only one French *département* (Lot-et-Garonne), while 1,637 nests were reported across 32 *départements* (160,000 km^2) in 2009 (Villemant *et al*. 2011a). The precise numbers of nests recorded in 2010 is still unknown due to an ongoing verification process. However, 7 new *départements* have already been colonised during this year in France and the hornet was also reported for the first time from the north of Spain (Basque Country and Navarre) (Castro and Pagola 2010) (Fig. 2). The invasion spreads at around 100km per year. A few nests have also been recorded more than 200km away from the invasion front, suggesting accidental human transport or migration of founders (Rome *et al.* 2009; Mulhauser and Vernier 1994).

Avoiding wrong records

Most of the data allowing this monitoring is supplied by the participative work of the public, which can lead to a major bias: despite the distinctive coloration of *V. v. nigrithorax* (Fig. 2) among European insect fauna and its numerous illustrations in descriptive spreadsheets and online contents, almost 30% of public identifications are wrong (Fig. 3). Misidentifications mainly concern Vespids (*Vespa crabro, Dolichovespula media*), other Hymenoptera (*Megascolia maculata, Urocerus gigas, Xylocopa violacea*) and insects that look likes hornets (*Milesia crabroniformis, Volucella zonaria*). Confusions are also made between mature nests of *V. crabro*, *Vespula* spp. or *Dolichovespula* spp. and those of *V. v. nigrithorax* (Fig. 3). The latter are round or pear shaped, from 50 to 80 cm in diameter, and with a small circular entrance on the lateral side (Fig. 2). They are generally located at more than 10m above the ground, hidden in tree crowns, but they can also be found in hedges or eaves in more sheltered places such as bramble bushes or ground holes. Due to such confusion risks, a photo of the nest or its inhabitants must be added to each report of the invasive species (a dead hornet can also be sent by mail) in order to control the identification and avoid overestimation of the species population densities and invasion range (Fig. 3).

Invasion risk modelling

Eight climatic suitability models have been used to predict the potential invasion risk of *V. v. nigrithorax* (Villemant *et al*. 2011a) based on eight climatic data from WorldClim at 5 arc-minutes grid (Hijmans *et al*. 2005). We used occurrence data in the models from the invaded range as well as from the native range of this particular variety, gathering information from museum collections, published records and recent field sampling in its native range. The consensus map obtained from the models shows that *V. v. nigrithorax* could successfully invade many other parts of the world (Fig. 4) since the scenario of introductions through international trade - as it occurred in France - could well be repeated (Villemant *et al*. 2011a). The potential worldwide distribution of the hornet significantly matches the current distribution of another invasive social wasp, the German yellow jacket, *Vespula germanica* (Villemant *et al*. 2011a).

In Europe, the potential extent of *V. v. nigrithorax* concerns almost all European countries, with reduced risks in the dryer southern regions (Fig. 5a). Without excluding incorrect records, the potential extent map would have been strongly overvalued, expending more in eastern continental and Mediterranean regions (Fig. 5b).

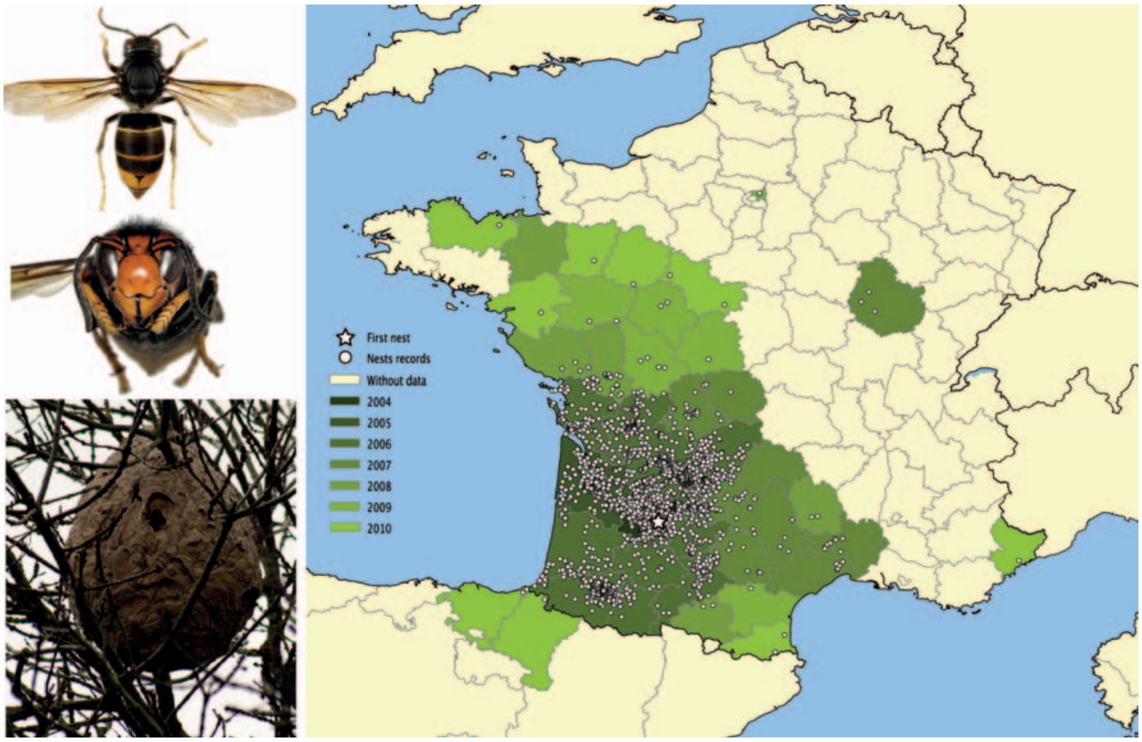

Fig. 2. Adult and nest of *Vespa velutina nigrithorax* and its distribution in its invaded range. Photos of *Vespa velutina nigrithorax* Quentin Rome, photo of nest Michel Duret

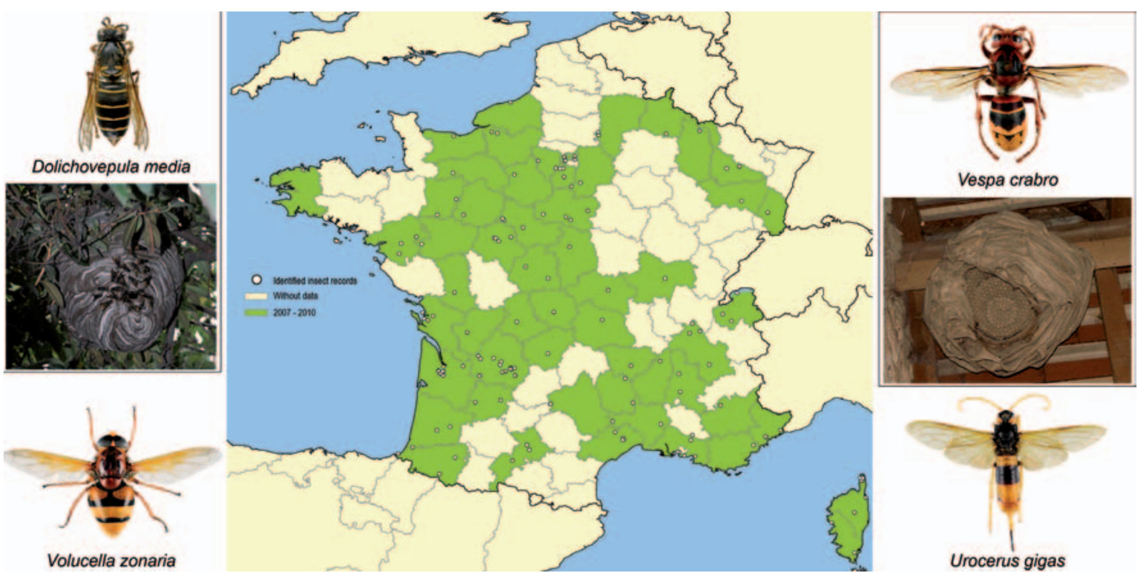

Fig. 3. Distribution of the wrong records of *Vespa velutina nigrithorax* nests/individuals sent by the public and examples of nests/individuals of other species commonly confused with this hornet. Photos Quentin Rome.

Potential impacts of the invasive hornet in Europe

A new threat to honeybees

The main threat due to *V. v. nigrithorax* on human activities concerns beekeeping activities. The hornet is a well known predator of *honeybee*s in Asia (Van der Vecht 1957; Shah and Shah 1991). Workers fly in front of the hives, facing bees that fly back to the nest. They catch their prey while flying, land nearby to transform them into pellets, and bring them back to the nest to feed to the larvae. This predation can be intense during late summer, when the worker population reaches its maximum and while the sexual brood has to be fed. During this period, several hornets can be seen flying together in front of a hive repeatedly capturing *honeybee*s.

Asian bees are able to resist these attacks by making heat-balling (Abrol 2006; Tan *et al*. 2007; Villemant 2008). A similar behaviour has been very occasionally observed in some French *honeybee*s, but this is still very rare.

While beekeeping is already suffering a noteworthy decline under the pressure of multiple factors (VanEngelsdorp and Meixner 2010; Ellis *et al*. 2010), reports of devastated apiaries by the invasive hornet causes great concern among beekeepers (Fig. 6) and *V. v. nigrithorax* appears to be a new factor of honeybee decline in France (Jourdain 2010).

Potential threat to native insect preys

V. v. nigrithorax diet is not restricted to honeybees. During the high season, the hornet preys intensively on various insects and spiders, indicating that vulnerable prey species may become threatened by this new predator. To analyse the prey spectrum, we collected prey pellets since 2007 by catching the hornets that brought their prey back to the nest (Perrard *et al*. 2009) (Fig. 7).

The identification of about 2 500 pellets collected between 2007 and 2009 allowed us to compare the hornets' prey spectrum in relation to the environment (urbanised, agricultural or forestry) of their nests (Villemant *et al*. 2011b) (Fig. 8).

While its prey spectrum is much diversified, *V. v. nigrithorax* shows a real preference for social Hymenoptera: honeybees (37%), common wasps (18%) as well as other pollinators such as hoverflies (Syrphidae) and necrophagous Diptera, such as carrion and house flies (Calliphoridae, Muscidae) (34%). The hornet has a clear impact on bees but, even if hardly visible, its threatening impact on wild insect species may be even more deleterious knowing that large colonies can produce up to 10 000 individuals in a season (Villemant *et al*. 2011b).

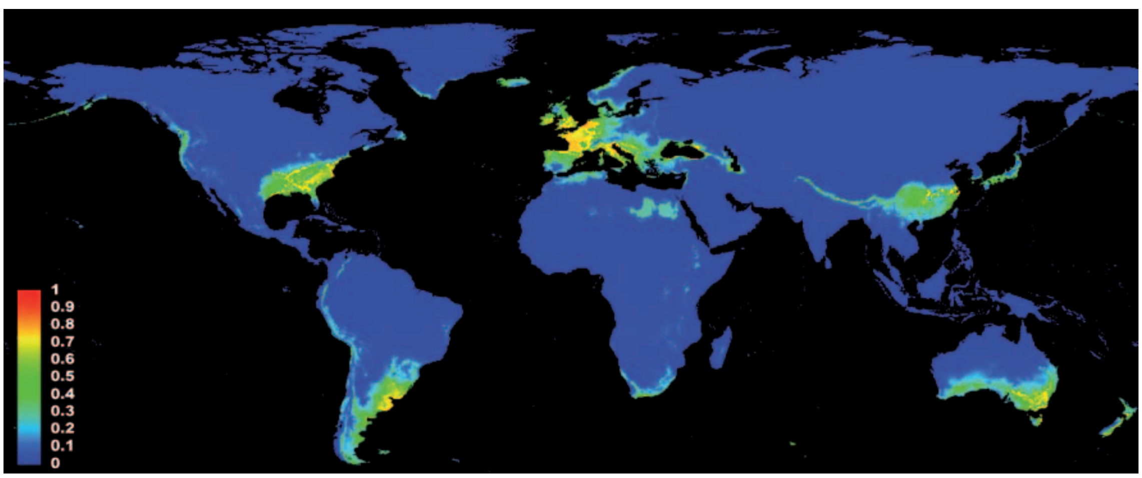

Fig. 4. Predicted potential invasion risk of *V. v. nigrithorax* based on ensemble forecast models using eight climatic data from WorldClim

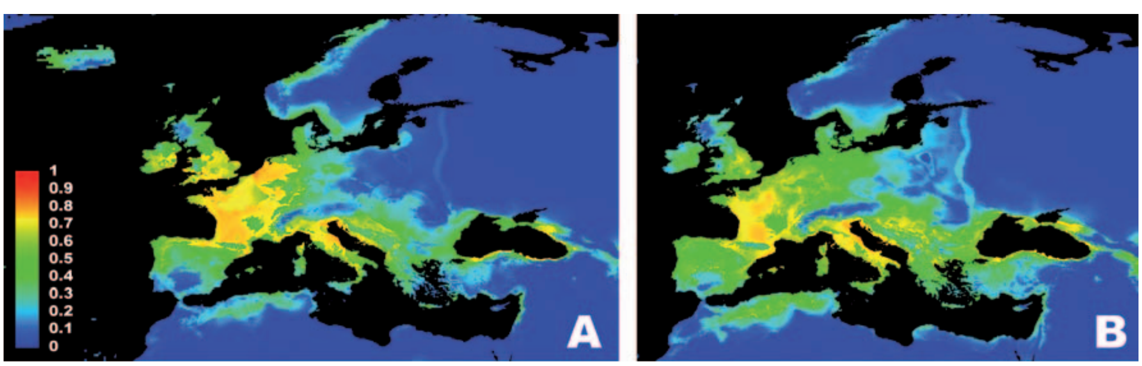

Fig. 5. Potential distribution of *Vespa velutina nigrithorax* with A) verified data only and B) all data including wrong records

Fig. 6. *Vespa velutina nigrithorax* worker attacking a beehive. Photo Jean Haxaire

Fig. 7. Net catching of *Vespa velutina nigrithorax* workers to collect prey pellets in front of studied nests. Photos Quentin Rome

Sting risk for humans

Its large size, painful sting and noisy flight make these hornets one of the most frightening stinging insects. Moreover, the discovery after leaf fall of an enormous nest in the crown of a tree often leads people to be concerned, even if, at that time of the year, the colony has most often already died. Stings can occasionally cause a life threatening allergic reaction (Golden *et al*. 2006), but as long as the colonies remain undisturbed, hornets will not attack. Nonetheless, the increase and spread of *V. v. nigrithorax* in France, notably in urbanized areas, raises the question of an increasing number of sting accidents. However, probably because its nests generally hang very high in the trees (Perrard *et al*. 2009; Rome *et al*. 2009; Rortais *et al.* 2010), the presence of *V. v. nigrithorax* did not induce an increasing rate of Hymenoptera (bees, wasps and hornets) stings in the colonized regions (De Haro *et al.* 2010).

Control and its by-side effects

Trapping

The use of baited traps is generally regarded as the best means to control wasps, although it is not always the case. Despite scientific advice, this control method remains the most commonly used while uncontrolled mass trapping induces side effects on non target species.

As observed by Thomas (1960) for invasive yellowjackets, mass destruction of founder queens in spring seems to have virtually no effect on nest density for the following summer months (Villemant *et al*. 2011b; Beggs *et al.* in press). Indeed, a successful *Vespa velutina nigrithorax* colony may produce more than 400 founder queens, but only a few survive (Villemant *et al.* 2011b). Competition for nesting sites and the hard living conditions each queen undergoes before emergence of its first workers cause most of the young colonies to be abandoned. However, the survival of only few colonies is sufficient for the population to sustain and multiply (Haxaire and Villemant 2010).

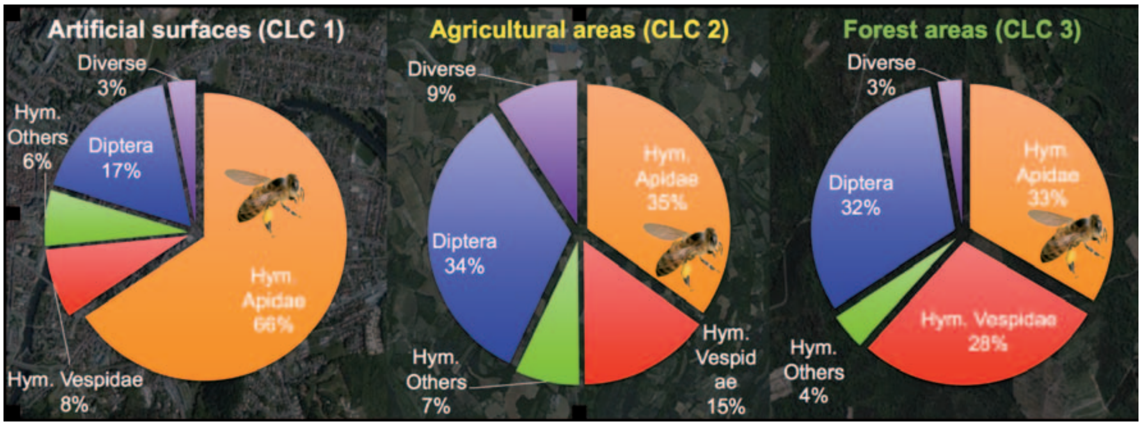

Fig. 8. *Vespa velutina nigrithorax* prey spectrum: preliminary results in three different environments (Villemant *et al*. 2011b)

Fig. 9. Impact of Asian hornet mass trapping. *Vespa velutina nigrithorax* specimens are circled in red, the other trapped insects are non-target victims of this non specific control method. Photos of traps André Lavignotte, photo of insects Quentin Rome

In the very same way, trapping of workers is not a good method to control Vespidae populations. Indeed, removing 50 to 75% of adults in a *Polistes* nest induces only a reduction by 29% to 34% of the colony size (Toft and Harris 2004). Trapping should only be used to limit the impact of *Vespa velutina nigrithorax* predation on apiaries (Rome *et al*. 2011). Furthermore, none of the traps currently being used show selectivity for *Vespa velutina nigrithorax*. The most used traps baited with sweet beer kill a huge number of non-target insects, versus only few *V. v. nigrithorax* (about 1% of the captures in average) (Dauphin and Thomas 2009; Rome *et al.* 2011) (Fig. 9). To maximise captures of *V. v. nigrithorax* and minimise the number of non-target insects, trapping must be done with traps combining mechanical selection (with holes allowing small insects to escape) with bait made of fermented honeycomb juice. These traps, placed from July to November close to beehives in apiaries attacked by *V. v. nigrithorax,* captured about 40% of *V. v. nigrithorax* (Rome *et al*. 2011). Research to develop an effective control method for *V. v. nigrithorax* by using specific bait is still under investigation (Maher *et al*. unpubl. data).

Colony destruction

V. v. nigrithorax nests are difficult to find and one colony could potentially produce a sufficient number of new founders to colonise an entire French *département* (about 10 000 km?). Therefore, manual destruction of nests cannot be intensive enough to control vespid populations in wide areas (Beggs *et al*. in press). However, destruction of nests could locally and temporarily reduce predation. *V. v. nigrithorax* is a diurnal hornet, so destruction must be done at nightfall or sunrise and always with adapted protection.

Fig. 10. *Vespa velutina nigrithorax*. Photo: Quentin Rome

Destroying nests with a shotgun (as used by many people in France) does not kill all the individuals, increases the risk of accident and does not prevent a new nest to be reconstructed. If the queen is killed, brood development and predation could be continued by workers that begin to lay eggs instead of the queen (but they produce only males). The most effective method for colony destruction is the injection into the nest of a poison (cypermethrin or SO_2) with a telescopic perch. Destroyed nests (with dead hornets inside) must be removed to avoid other animals, such as birds, to be intoxicated by eating poisoned brood and hornets. The use of toxic-bait which is taken back to the nest by workers to feed larvae and other adults could result in the destruction of the whole colony but such bait is attractive for all vespid species and the problem remains for the removal of the poisoned nest (Beggs *et al*. in press).

Recommendations

In the present state of scientific knowledge, we recommend limiting trapping to the proximity of attacked beehives by using traps as selectively as possible. Preventive trapping must be avoided, or performed only punctually to survey *V. v. nigrithorax* arrival in a given region and warn beekeepers as soon as possible that they should increase their vigilance. Although they are difficult to find before leaf fall, destruction of colonies remains the best way to limit locally the impact of this hornet on bees and other insects.

Conclusion

Probably introduced through international trade from China, *Vespa velutina nigrithorax* appears to be an effective invader in France that could potentially spread across a large part of Europe.

Even if this species is not a direct threat to people, its predation on honeybees add a new component to the decline of *honeybee* populations in Europe and its big colonies and large prey spectrum suggest that it could have a noticeable impact on local insects biodiversity, including many wild pollinators.

Moreover, inconsiderate trials of control of this invasive species such as massive trapping by the general public also have a negative impact. While they have already proven to be poorly efficient against social insect invasions, they're also considered to have a great impact on the local insect biodiversity Thus, until more selective and efficient traps and baits are made available, the only solution that could reduce the impact of this species on beekeeping activity is to only trap *V. v. nigrithorax* in apiaries during the high predation period.

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Improving ant eradications: details of more successes, a global synthesis and recommendations

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Invasive ant management has a poor track record, partly exacerbated by the lack of publication of project outcomes detailing both what did and didn't work. Here we detail 11 eradications of five species, which are all the remaining eradications that we are aware of that have not been published. Data from these eradications are combined with all other published successes to provide a brief summary of the 76 records of ant eradications achieved without the use of organochlorines, and compared with successes achieved within the organochlorines era. The majority of eradications (42) are very small (< 1 ha), in some cases being just one or a few nests. Two species, Pheidole megacephala *and* Anoplolepis gracilipes, *were the targets of most eradications (30 and 24 respectively). It is only in the last decade that the size of eradications has greatly increased, but the largest eradication covered only 41 ha. In contrast, approximately 3000 infestations covering approximately 15,800 ha were eradicated over the equivalent time using organochlorines, the largest eradication covering approximately 300 ha. We then discuss the current global status of ant eradication management options, and identify what we see as the actions that will provide the greatest immediate enhancement of invasive ant management, which are proactive management and greater incorporation of ant biology into eradication protocols.*

Fig. 1. Yellow crazy ant *Anoplolepis gracilipes* worker (left) and queen (right). Photo: Phil Lester

Introduction

Ants are disproportionally represented as invasive taxa and equally disproportionate is our appalling record of dealing with their invasions, with only 12 publications confirming eradications despite nearly a century of efforts (Hoffmann et al. 2010).
However, our poor track record of effectively dealing with invasive ants may not only be due to the real difficulty of the task, but be partially because of a lack of publication of project outcomes (Wittenberg and Cock 2009).
In contrast to scientific research on exotic species that must be formally published to be recognised, eradication programs are not required to communicate their results, good or bad, to a global audience, and consequently a vast amount of valuable information about ant eradications, including successful completions, remains either as grey literature or unrecorded. This lack of dissemination of information, especially of lessons of failure that indirectly results in others making similar mistakes, is no doubt hindering the advancement of ant eradications.
Here we detail 11 eradications of five species, which are all the remaining eradications that we are aware of that have not been published. We define an eradication as the complete extirpation of a spatially and reproductively isolated population in a landscape with or without the persistence of other spatially and reproductively discrete populations. Eradication was deemed to have been achieved two years after the final treatment, irrespective of the date of any formal declaration of eradication. Additionally, we present a brief summary of the cumulative record of ant eradications, and the global status of ant eradication management options. Finally, we identify what we see as the actions that will provide the greatest immediate enhancement of invasive ant management.

Eradications

Argentine ant, Victoria Park, Western Australia
A 1 ha infestation of Argentine ant *Linepithema humile* around a shopping centre in the Perth suburb of Victoria Park in Western Australia was baited with 5 g/kg hydramethylnon contained within the Department of Agriculture and Food Western Australian (DAFWA) bait matrix. Two treatments were conducted in July and August 1994. No *L. humile* have been found in multiple visual surveys since the second treatment.

Argentine ant, Perth, Western Australia
A 6 ha *L. humile* infestation encompassing the Sir Charles Gairdner Hospital in Perth, Western Australia was delimited and treated in August 1996 using 10 g/kg sulfluramid within the DAFWA bait matrix. A small area required retreatment 43 and 88 weeks later. No Argentine ants have been detected by visual surveys in this area since.

Argentine ant, Brisbane, Queensland
A 41 ha *L. humile* infestation in the Brisbane suburb of Geebung, Queensland was treated in December 2002 using the DAFWA bait matrix containing 10ppm fipronil.
A second treatment covering 7ha of surviving ants was conducted in March 2003. Post-treatment assessments of this work are potentially insufficient, but no *L. humile* have since been found in visual assessments, the last assessment occurring on July 15 2008.

Red imported fire ant, Yarwun, Queensland
An infestation cluster of Red imported fire ant *Solenopsis invicta* covering approximately 0.5 ha, as well as an additional two isolated nests approximately 1.5 km from the cluster (considered as a single infestation) were discovered at Yarwun, Queensland in March 2006. All visible mounds were treated with direct injection using fipronil, and a granular bait containing hydramethylnon was dispersed in heavily infested areas. Additionally, six prophylactic treatments extending to 1 km from the main infested area were conducted between May 2006 and November 2007 using granules containing s-methoprene or pyriproxyfen. The last *S. invicta* was detected in September 2006, prior to the cessation of the delimiting surveillance in November 2006. Visual post-treatment assessments confirming eradication were conducted in May and June 2009.

Tropical fire ant, Perth, Western Australia
An infestation comprising a single Tropical fire ant *Solenopsis geminata* nest was detected at a commercial nursery in the Perth suburb of Wanneroo, Western Australia, during surveillance for Red imported fire ant *S. invicta* in May 2005. The nest and the surrounding 50 x 50 m area were treated the following day using the DAFWA bait matrix containing 10 ppm fipronil. Two days later, the surrounding 3,000 potted plants were rod-injected with chlorpyrifos at a rate of 40 mL (of 500 g/L chlorpyrifos) per 100 L of water. The bay, once cleared of these plants, was then sprayed with fipronil, followed by a broadcast of Amdro®. No *S. geminata* have since been found.

Tropical fire ant, Port Hedland, Western Australia
A 1,500m^2 *S. geminata* infestation was detected in a nursery in Port Hedland, Western Australia during surveillance for Red imported fire ant *S. invicta* in August 2005. The nursery was sprayed with 5 g/L chlorpyrifos and 500 potted plants were rod injected. Due to continued *S. geminata* activity, a sec-

ond application was applied in early September and a third using pyriproxyfen baits followed by a fipronil spray several days later. No *S. geminata* have been seen since the third treatment, with the last formal inspection occurring in August 2007.

Tropical fire ant, Waianae Mountains, Oahu, Hawaii
A small (approximately 0.05 ha) *S. geminata* population was found on a bare, sunny knoll surrounded by mesic forest at roughly 600 m elevation in March 2006. Because this location is very distant from typical open, lowland habitat where *S. geminata* predominantly occurs in Hawaii, a joint effort was initiated by the Department of Land and Natural Resources and the Oahu Army Natural Resources Program in which the population was treated twice with Amdro®. Monitoring for two years post-treatment, and an additional thorough survey almost four years later has failed to detect *S. geminata*.

Yellow crazy ant, Goodwood Island, New South Wales
A <1 ha Yellow crazy ant *Anoplolepis gracilipes* (Fig. 1) infestation was detected by quarantine monitoring at Goodwood Island Wharf in July 2004. Broadscale treatments using unregistered baits containing fipronil and s-methoprene were conducted between September 2004 and December 2005. A single treatment using a contact insecticide spray was conducted by a pest controller on the last nest found in January 2006. Five post-treatment surveys over the next two years failed to detect *A. gracilipes* and it was declared eradicated.

Yellow crazy ant, Portsmith, Cairns, Queensland
An infestation of *A. gracilipes* covering approximately 6 ha was detected at Portsmith Cairns Queensland in April 2001. This was the first detection of this ant in Queensland. The infested area received several rounds of treatment using granulated bait containing fipronil or s-methoprene and direct nest treatment using liquid fipronil. No *A. gracilipes* have been observed at this site since 2005.

Yellow crazy ant, Woree, Cairns, Queensland
An infestation of *A. gracilipes* covering approximately 6.5 ha was detected at Woree, Cairns, Queensland in March 2006. The infested area received several rounds of treatment using granulated bait containing fipronil or s-methoprene bait and direct nest treatment using liquid fipronil. No *A. gracilipes* have been observed since the end of 2006, including within formal post-treatment assessments using a grid of lures (with tuna, cat food or jam as an attractant) in 2007 and 2008.

Lepisiota frauenfeldi, Guam
Lepisiota frauenfeldi was found established in a cargo container holding area at Guam International Airport in October 2005. The area was treated twice in March and April 2007 with two baits containing boric acid and hydramethylnon respectively. Post-treatment surveys conducted tri-monthly revealed no *L. frauenfeldi* until April 2008. The area was retreated with another two baits containing thiamexotham and orthoburic acid respectively. Tri-monthly post-treatment surveys have not detected the ant since.

Global status of ant eradications

Prior to the development of modern treatment products, ant eradications were attempted primarily using organochlorines, with mixed success. Efficacy of individual treatments could indeed be quite high, but failure to prevent the production and dispersal of new sexuals resulted in unabated spread, and reinfestation of effectively treated areas (Williams et al. 2001). As far as we are aware, only *L. humile* populations were eradicated using organochlorine sprays, presumably because this species does not disperse via a nuptial flight. Of all such programs, the only one with a published record is the one conducted in Western Australia from 1954 to 1988 (van Shagen et al. 1994).

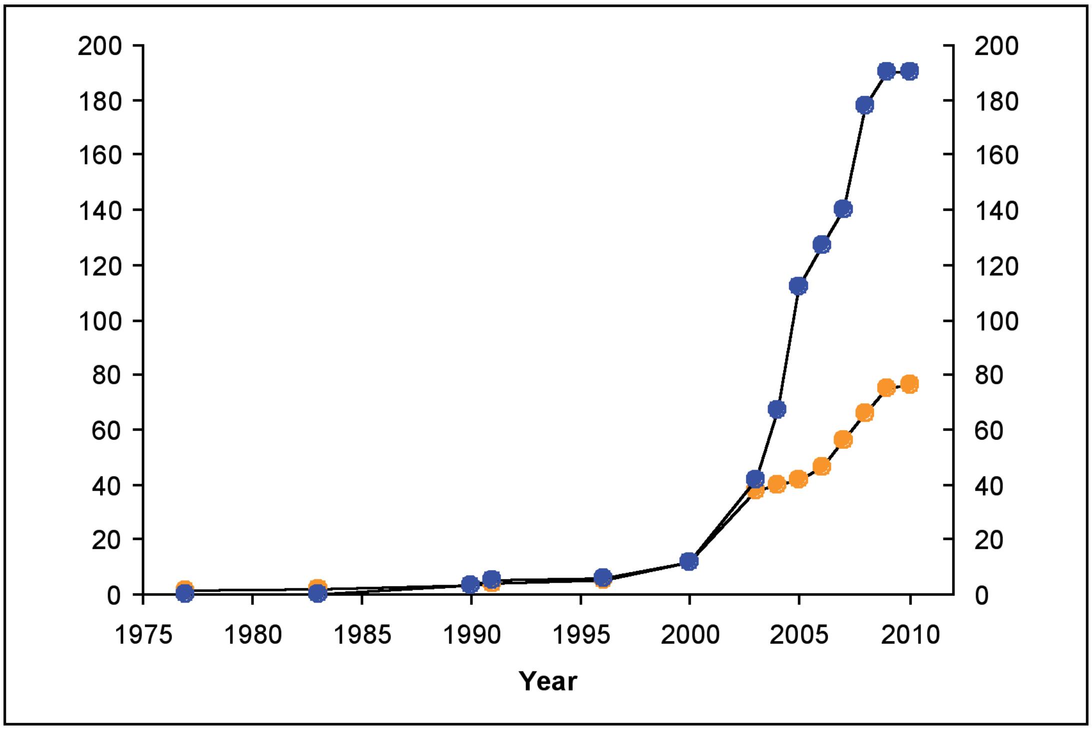

Fig. 2. Cumulative number (orange points) and area (blue points) of published eradications of established ant populations globally. Eradication was deemed to have been achieved two years after the final treatment. If treatment dates were not provided then the year of paper submission was used. An area of 0 ha was used where the size of an infestation was not detailed. Data used are from those projects detailed here, the publications listed in Hoffmann et al. 2010, as well as Plentovich et al. (2009); Hoffmann (2010) and Hoffmann (in press).

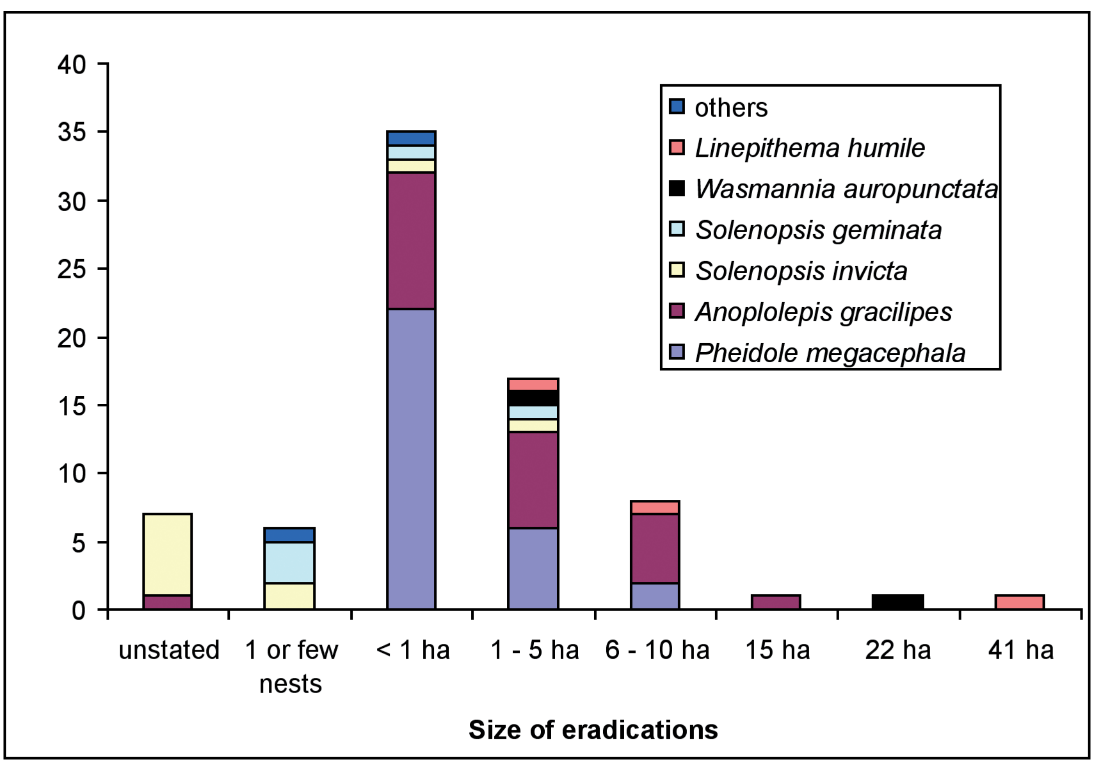

Fig. 3. Number of ant eradications in multiple size classes for multiple key species

This program reduced a combined infested area of approximately 17,300 ha to 1,458ha, of which approximately 75% couldn't be treated for environmental or residue reasons. Data for individual infestations remains unavailable, but the number of discrete eradications was approximately 3000, having an average area of about 10 ha, the largest being approximately 300 ha. Despite overall eradication not being achieved due to this program being cancelled, largely due to the lack of treatment products following the deregistration of organochlorines, we acknowledge the successful completion of the many individual eradications.

The eradication achievements within the 34-year Western Australian program that used organochlorine sprays far outweigh that of the combined global efforts using other products and methods over the past 34 years (Figure 2). Only 76 localised eradications covering 189 ha have been formally published, the great majority (72) being achieved within the last decade. It is also only in the last decade that the size of these eradications has greatly increased. The majority of eradications (42) are very small (<1 ha), in some cases being just one or a few nests (Figure 3). Two species were the targets of most eradications, *Pheidole megacephala* (30 eradications) and *A. gracilipes* (22). Interestingly the two largest eradications (41 and 22 ha) are of two species which have been eradicated the least (only two completed eradications of both species), *L. humile* and *W. auropunctata* respectively.

Eradication sizes will undoubtedly increase in the future, but then as now, there is a great difficulty in providing adequate demonstration that complete extirpation of an animal the size of an ant has occurred over large areas. Indeed, it is likely that larger eradications have already occurred against *A. gracilipes* in Arnhem Land, but are too large to adequately assess with the limited resources available. Unless new technologies or techniques are developed to alleviate this issue, it is likely that longer and longer timeframes will be required for ever larger eradications to be adequately demonstrated.

Chemical treatments directly targeting ants

Prior to the deregistration of organochlorines, broad-scale ant management programs attained the unenviable reputation of having among the greatest non-target impacts of all management efforts globally (Carson 1962; Markin et al. 1974; Summerlin et al. 1977). Since the deregistration of organochlorines, broad-scale ant treatments have changed from spraying liquid products, predominantly contact insecticides, to the broadcast spreading of granular baits. Solid baits are more targeted at ants (Williams et al. 2001), resulting in far fewer non-target issues (Marr et al. 2003; Stork et al. 2003; Forgie et al. 2006; Plentovich et al. 2010).

The increased targeting towards ants is achieved either from the bait matrix used (e.g. corn grit targeting seed-harvesting species and fishmeal for species seeking protein) which will not necessarily be consumed by other biota, or from the active constituent being predominantly non-toxic to other land-based biota (e.g. juvenile insect hormone analogues).

Ideally, treatment products would attract the target ant species and repel non-target organisms, but no such options are yet available for ant management, nor are we aware of any such products for use against any other invasive taxa.

Since the change to granular baits, one of the greatest remaining hindrances to treatment efficacy has been the lack of universally attractive and effective treatment products. Species have different preferences for carbohydrates and protein, and there can be marked seasonal differences of dietary preferences within a species (Stein et al.1990). Efficacy is additionally affected by a colony's food management strategies (e.g. stored vs utilised immediately) and nutrition pathways to the queen(s). Most baits have been developed to target fire ants (*Solenopsis* spp.), and unfortunately these baits usually have lower efficacy against other species (Rey and Espadaler 2004), particularly species that prefer aqueous sugar matrices, or are not greatly attracted to corn grit or to the oil in other dehydrated solids (e.g. *Tapinoma melanocephalum* and *A. gracilipes*). Multiple products developed most recently appear to have wider target acceptability and efficacy, which is hoped will lead to greater eradication success. Interestingly, all eradications to date of fire ants (*Solenopsis* spp.) have been achieved only by drenching all nests with liquid toxicant.

Companion methods

All ant eradications to date have been achieved using chemicals, and unfortunately non-chemical management options, especially bio-control, alone are considered unlikely to achieve eradication. The following techniques are those that we believe will provide the greatest support for eradications based on chemical treatments.

The most promising techniques target the carbohydrate supply to ants, which is a key driver of ant population densities.

Carbohydrate supply to ants can be interrupted in two ways. The first way is by reducing or eliminating populations of mutualistic phytophagous insects. Chemical control of phytophagous insects is currently possible using sprays or systemic insecticides within urban and agricultural areas (Cooper et al. 2008), but this is an unacceptable option within intact ecosystems. Thus, this technique will likely only become fully viable following the identification of biocontrol options for phytophagous insects that are effective in the presence of ants.

The second way of interrupting carbohydrate supply is by preventing ants sourcing honeydew directly from plants by the use of fire, where appropriate.

Fire, as well as other techniques such as drainage restriction (Holway and Suarez 2006), also alter habitat conditions, and can reduce the abiotic suitability of the environment to the invader and reduce nest site availability. Simultaneously, these environmental changes may increase biotic resistance from aggressive native ant species (Menke et al. 2007).

Actions needed to enhance invasive ant management

Improvements in ant eradication will inevitably occur as treatment products, methods and technologies develop (Figure 4). However, we highlight here four proven strategies that can immediately improve ant management, three of which involve a shift from reactive to proactive management. Notably, these actions are just as applicable for all other biological invasions as they are for ants.

The first is port-of-exit biosecurity. The continual occurrence of new invasions within countries like Australia with stringent biosecurity at ports-of-entry (Stanaway *et al*. 2001), demonstrate that border biosecurity as an independent strategy is far from adequate. But why should we only wait for exotic species to come to us when their arrival can also be actively avoided at the port-of-exit? New Zealand biosecurity measures recently extended into four ports in three surrounding nations, resulting in a 98.5% reduction in contamination rates of inbound goods within just 12 months (Nendick 2008).

Clearly, significant reductions of contamination rates could potentially be achieved globally if ports-of-exit ensured they were free of organisms declared as pests in trading destinations.

Second is proactive surveillance. Early detection of incursions is often a critical factor for eradication success (Simberloff 2003; Lodge et al. 2006), but proactive surveillance for new incursions has been historically rare. Instead, most governments rely predominantly or even solely on passive surveillance, being the discovery and reporting of incursions by the public. Yet simultaneously, governments often apply a disincentive to report strange biota through charges for identification services.

Fig. 4. Aerial treatments against yellow crazy ant *Anoplolepis gracilipes* in Arnhem Land, Australia, using a motorised bait dispenser slung under a helicopter. The helicopter flies along pre-determined flight paths guided by a differential GPS

Proactivity of governments to monitor high risk areas, both at and beyond the port-of-entry, would greatly enhance prospects of early detection, and hence eradication. Clear examples include the recent *S. invicta* detections and eradications in New Zealand (Pascoe 2003; Biosecurity New Zealand 2009), and the *A. gracilipes* detection, and probable eradication, in Darwin, Australia (Walters 2008).

Third is preparedness. A high level of preparedness enhances a jurisdiction's ability to rapidly initiate on-ground measures should an incursion occur, thereby enhancing the possibility of eradication. Such preparedness largely results from a proactively prepared Pest Risk Analysis (PRA: Leung et al. 2002). A PRAs basic role is to consolidate global knowledge of the biology, ecology and impacts (beneficial and negative) of target species, and use this to assess the overall potential benefit or impact within a landscape, should it establish there. If the risk of a species establishing within a region is considered unacceptable, a PRA also details on-ground procedures that actively prevent incursions, detect incursions, allow rapid response to a detection, and effectively manage established populations. In other words, a PRA developed prior to an incursion results in a jurisdiction being fully aware of the potential issues, implementing measures that prevent incursions, and being fully prepared for action should an incursion occur. While there is an almost inexhaustible list of species that can potentially invade or be analysed, PRAs should at the very least be conducted for the few species that are well known, or considered potentially to be, invasive.

Arguably the greatest benefit for ant eradications is that a PRA identifies a potential lack of treatment options available in a location, such as a proven treatment product being unregistered in the jurisdiction, or simply not being registered for use against the target species. This knowledge can subsequently be used to proactively obtain permits or registrations for product use, and even supply of treatment products prior to an incursion, thereby eliminating unnecessary delays in the commencement of treatments following a detection. Such preemptive registrations have been implemented by the New Zealand government for many invasive ants following their first experience of dealing with an *S. invicta* incursion in 2001 (S. O'Connor, personal communication).

Another proactive action that increases preparedness is public education of key species. Public support is highly advantageous because it induces greater adherence to quarantine and biosecurity measures, and it facilitates access to, and treatment of, property without the need for legal enforcement. Public vigilance is also a useful tool to detect new incursions, satellite populations, or populations persisting post-treatment. The overwhelming usefulness of public education makes it an important requirement throughout all phases of ant management.

Fourth is a greater incorporation of ant biology into eradication protocols. Very few protocols for ant eradications are truly based on ant biology, and this has been highlighted as a contributing factor to eradication failure (Davidson and Stone 1989; Tschinkel 2006). Not only is knowledge of ant biology important to ensure that eradication protocols are appropriate, it also underpins the integrity of eradication declarations. Examples of biological information that should be incorporated into protocols and why include: phenology, to determine the appropriate timing for the use of some treatment products as well as the entire treatment program, and to aid the criteria for declaring eradication; annual abundance cycles, to identify key treatment times, as well as to determine whether declines in populations post-treatment are due to treatments or merely natural population fluctuations; and nest densities and foraging distance, to ensure post-treatment assessments are sufficient to detect persistent and potentially cryptic populations. Biological information can often be obtained from scientific literature, however, there will always be some uncertainty associated with applying information from elsewhere, especially when an invasion is within a new environment. As such, there is no substitute to an active adaptive approach (Hoffmann and Abbott 2010), whereby site-specific research is embedded within a management program. Indeed, understanding key aspects of *S. invicta* biology within Australia is now considered to be fundamental to the success or failure of the Australian *S. invicta* eradication program (Davidson et al. 2010).

Conclusions

Our ability to conduct ant eradications is rapidly improving, with the number and size of eradications increasing greatly in the past decade. However, it is clear that most successes remain relatively small, with the greatest to date in the post-organochlorine era being only 41 ha. The lesson here for new eradication attempts is that unless there are significantly different and improved methodologies and/or products than those used in the past, any large-scale program currently has a very low chance of success.

Part of the issue preventing eradication success is that ant eradications remain reactive in that they are only initiated after an incursion is detected, usually accidentally, and often in the absence of a pre-prepared PRA which results in unnecessary delays in management action. Invasive ant management would immediately improve globally through a shift from reactive to proactive management, thereby eliminating much of the threat before it arrives, and having a high level of preparedness should an incursion occur.

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Introduced reindeer on South Georgia – their impact and management

Darren Christie

South Georgia is a subantarctic island with a native flora that has evolved in the absence of grazing animals, and as a consequence copes poorly with grazing pressure. Reindeer are a northern hemisphere species that were introduced by Norwegian whalers for subsistence to two discreet areas of South Georgia on three occasions between 1909-1925. Combined, the areas occupied by reindeer equate to the largest snow free, and consequently most biologically productive, part of the island. Subsequent to their introduction, the reindeer herds were managed through regular hunts. Since the closure of the whaling stations in the 1960's no management of the herds has occurred, and as a consequence the herds have expanded substantially, to the point where nearly all available grazing habitat has been utilised. The boundaries of these areas are limited by glaciers, which prevent the animals spread to the island as a whole.

Fig. 1. Reindeer resting in areas with the introduced *Poa annua* (spread by reindeer) and patches of erosion caused by their grazing. Photo: Martin Collins

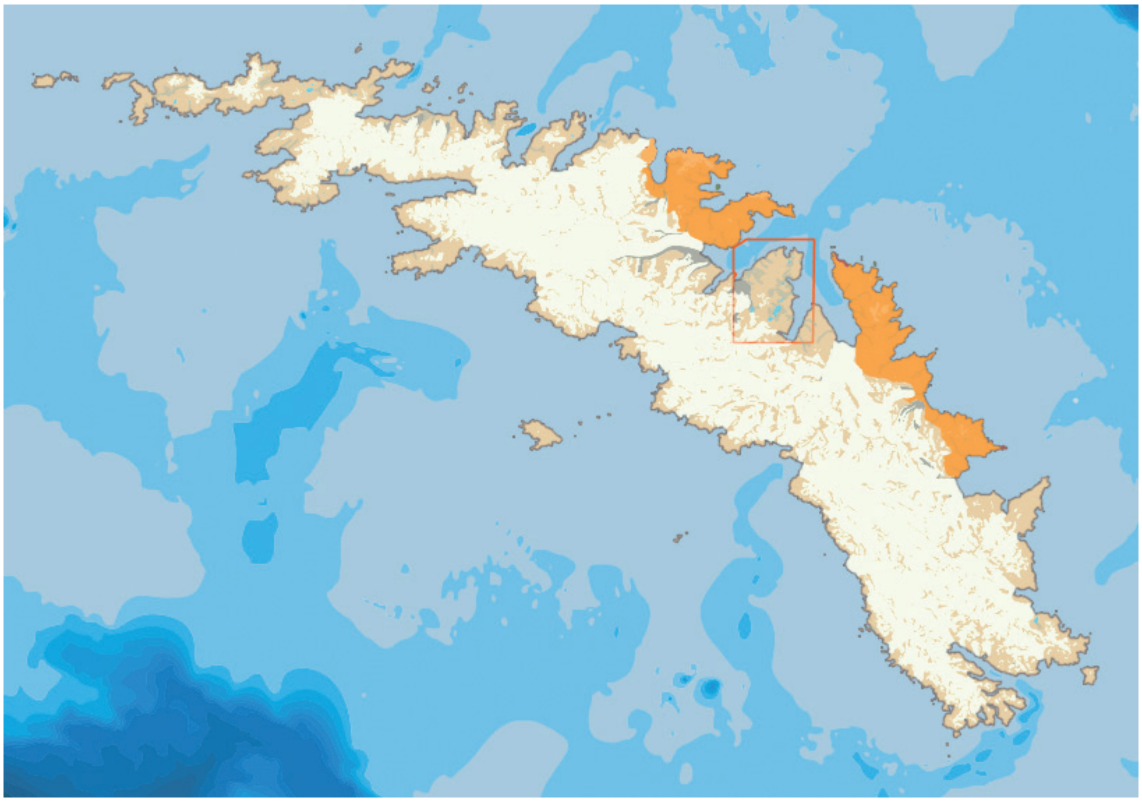

Fig. 2. Location of the two reindeer herds, shown in orange (red box shows peninsula where the administrative base is located) Adapted from the South Georgia GIS, 2009

Climate change and the consequent recession of glaciers, combined with the detrimental impact of reindeer on native vegetation, through overgrazing, trampling, soil erosion, loss of native biodiversity and increased distribution of introduced plants, has required that the management of the herds as a whole be discussed and decided upon as a matter of urgency. In line with a broader policy of habitat restoration, which has seen the Government of South Georgia and the South Sandwich Islands (GSGSSI) begin a programme of invasive plant eradication and support an island wide rodent eradication programme, GSGSSI has announced that it will eradicate the reindeer from South Georgia in line with responsible environmental management practices.

Introduction

The island of South Georgia is a British Overseas Territory, which is administrated by the Government of South Georgia and the South Sandwich Islands (GSGSSI) based in Stanley, Falkland Islands. GSGSSI are committed to the responsible management of the island through environmental best practise. In 2010 GSGSSI undertook a review of the impact of reindeer on the island (Fig. 1), which was followed by a stakeholder consultation on management options. In early 2011, GSGSSI announced their intention to undertake an eradication of the reindeer on South Georgia.

History of reindeer on South Georgia

After the establishment of the commercial sealing and whaling industries on South Georgia, efforts were made to introduce numerous species in order to provide food or sport for the resident working population. None of these introduced species had a high enough winter survivorship to establish viable long-term populations (Leader-Williams, 1978). The exception to this was reindeer, which were originally transported to South Georgia in order to provide fresh meat for the whaling communities (Kightley and Lewis Smith, 1976), and exist to this day.
There were three separate introductions of reindeer, the first by Captain Larsen who introduced 8 does and 3 stags from Numedal in central Norway (Leader-Williams, 1978) to Ocean Harbour (Barff) in 1909 (Bonner, 1958). In 1911, 5 individuals were released at Leith on the Busen Peninsula, but these were later all killed in an avalanche (Olstad, 1930). There was a replacement introduction of 3 males and 4 females made to Husvik in 1925, and this herd survives to the present day (Bell and Dieterich, 2010).

There are currently two discrete land areas affected by reindeer, the Barff and Busen Peninsulas (see Fig. 2). The Barff Peninsula covers $189km^2$ and the Busen Peninsula covers $124km^2$ (Leader-Williams 1980), giving a total affected area on the island of $313km^2$, of which approximately $100km^2$ is vegetated. This is one third of the entire vegetated area of South Georgia, ($306km^2$). These areas are coincidentally the most floristically rich and vegetated areas on the island, with unaffected areas elsewhere on the island only supporting a limited diversity of flora (Leader-Williams et al. 1989).

The Barff and Busen populations have remained genetically isolated since their introduction (Leader-Williams and Payne, 1980), due to the presence of glaciers that terminate in the ocean and act as an effective barrier to dispersal.

Population and population densities of reindeer on South Georgia

In contrast to their northern hemisphere relatives, the South Georgia reindeer herds are constrained in range by glaciers, have no predators, and are currently not managed in any way by man. The South Georgia animals are unusual when compared to their Northern hemisphere relatives in that they are non-migratory, occur at high densities, and as an adaptation to their new environment, do not depend on lichens for their winter forage (Leader-Williams et al, 1987). Within two years of introduction to South Georgia, the reindeer had altered their breeding season by 6 months in order to fit the austral seasons (Leader-Williams, 1978).

Population counts have varied in accuracy over the years (Bell, 2001). Population models estimate maximum populations to be 5000 animals on the Barff, and 1500 on the Busen (Lovatt, 2007). In reality, the Busen herd is currently thought to be 1000 (Bell, 2001, Lovatt, 2007) animals, and the most recent count on the Barff estimated a population of 2100 animals (Leader-Williams, 1988). Bell and Deitrich (2010) estimate the total South Georgia population to be 2600 animals.

Effects of reindeer on vegetation

South Georgia does not have any native herbivorous animals, and as such the native vegetation is sensitive to any grazing pressure (Moen and MacAlister, 1994). The introduced reindeer have had a serious detrimental impact on vegetation across the range of the herds on the island. Trampling and grazing in combination have caused localised erosion, leading to a high proportion of bare earth in affected areas.

To date, no species of vegetation is thought to have become extinct due to grazing pressure on South Georgia. Exclusion experiments have shown that key species can recover quickly with the removal of grazing pressure, though lichens may take decades to recover. In contrast to native species, the alien grass *Poa annua* tolerates severe grazing and trampling and has increased dramatically (Lewis-Smith 1982). It readily invades degenerate communities where native species have been removed, and can attain a cover of up to 90% in those grazed areas. In areas where *Poa flabellata* and *Acaena magellanica* have been eradicated by grazing the grass establishes rapidly, and it can also be spread within deer excrement, which also serves to enrich the soil and subsequently aids the colonisation of the species (Kightley and Lewis-Smith 1976). However, the grass only poorly tolerates competitive pressure by native species if they are allowed to recover in the absence of grazing (Vogel et al, 1984).

Payne (1972) suggests that species and community composition on the Barff appeared to be changing due to impoverishment of the habitat by grazing. Studies at Royal Bay showed that after only ten years of the arrival of reindeer, lichens were virtually eliminated and closed swards of the grass *Deschampsia antarctica* were severely overgrazed.

Kightley and Lewis-Smith (1976) note severe degradation of tussac stools caused by intensive grazing pressure, with formerly dense stands of tussac reduced to scattered live plants interspersed amongst dead plants and eroding stools, in marked contrast to Bonner's (1958) observations less than 20 years previously. Therefore it appears that tussac grassland is only seriously affected by high densities of reindeer (Leader-Williams et al, 1981). However, the relationship between the area of ungrazed vegetation in general and the population density of reindeer is such that a relatively low number of animals can graze a significant proportion of the vegetation available (Moen and MacAlister, 1994). Tussac plays many important roles in the ecosystem; stabilising soil and providing a habitat for key invertebrate species and birds. As a result, overgrazing of tussac has far reaching negative consequences on the ecosystem as a whole (Leader-Williams 1985).

The limiting effect of snow cover on South Georgia means some of the summer forage species are unavailable for up to six months (Leader-Williams et al, 1981). Indeed, the success of reindeer on South Georgia can be attributed solely to the existence of the winter-green tussac grass (*Poa flabellata)* (Lewis-Smith, 1982). Overgrazing on other sub-Antarctic islands with introduced reindeer reliant on lichens as forage has resulted in catastrophic population collapses (Leader-Williams, 1980). The abundance and regenerative ability of tussac on South Georgia has resulted in a higher sustained population than was possible on Arctic islands (Leader-Williams et al, 1987).

Results of an exclusion experiment

In the 1970's, Kightley and Lewis-Smith (1976) established a long-term exclusion experiment to monitor and survey the vegetation changes caused by reindeer grazing. A mixture of large 10mx10m exclosures and smaller 2.5mx2.5m cages were erected across key habitats, in stands of the island's principal plant communities in order to monitor changes in the composition, abundance and productivity of plant species in permanent quadrats inside and outside the fences (Lewis-Smith 1982). Within 16 weeks of construction *Acaena magellanica* was observed to have grown to heights of 15-20cm, where no comparable growth was observed in control sites.

Fig. 3. Photograph showing the recovery of tussac grassland in the absence of grazing pressure, either side of a wire fence. Sorling Valley exclosure, Barff Peninsula. Photo: Darren Christie

Surviving tussac stands in exclosures grew long entire leaves (see Fig. 3), whereas stands in control sites had frayed and short leaves due to grazing and antler rubbing (Kightley and Lewis-Smith, 1976).
Over seven years of observations, the greatest changes were observed in communities dominated by *P. flabellata, P. annua* and *A. magellanica*, with little change observed in bog communities dominated by rushes (*Rostkovia magellanica* and *Juncus scheuchzerioides*) and bryophytes. Considerable regeneration by *P. flabellata* and *A. magellanica* occurred where vegetation was protected, and the introduced *P. annua* decreased as other native species overgrew it, indicating an intolerance of competition, although it remained dominant where grazing kept it closely cropped. There was little sign of lichen recovery (Lewis-Smith, 1982).
Provided damage to the vegetation had not resulted in soil erosion and root destruction, regeneration appeared to occur quite rapidly and the plant communities recovered to their original state (Lewis-Smith, 1982). In areas where grazing had progressed too far (resulting in erosion with loss of topsoil) recovery of tussac grass was not possible, even in exclosures (Vogel et al, 1984). In areas with a long history of grazing, grazing eventually caused the tussac to die and the pedestals to become overgrown with mosses – wind exposure of these degraded slopes then causes erosion (Moen and MacAlister, 1994). If overgrazing continues unchecked, lack of management in reindeer areas may preclude recovery of climax vegetation in the long term (Leader-Williams et al, 1987). The exclusion experiment demonstrated that several of the important components of the vegetation impacted by reindeer rapidly regain their former abundance when grazing pressure is removed, with the exception of macrolichens which may take several decades to recover (Leader-Williams et al, 1987). As lichens only recover their former abundance several decades after damage due to grazing or trampling, they provide a good example as to the delicate balance between reindeer and the habitat they inhabit (Leader-Williams, 1988).
The exclusion experiment demonstrated that the species that showed the greatest recovery on cessation of grazing were tussac grass and *Acaena magellanica*, both species conversely showed the greatest decline in control plots. In contrast, the introduced *Poa annua* showed the greatest decrease in exclusion plots and the greatest increase in control plots. After 12 years of protection from grazing, exclosure plots showed no sign of recovery of macrolichens, though comparison with northern hemisphere sites shows recovery can take decades (Leader-Williams et al, 1987). A further study of remaining exclosures in 2002 did not analyse data statistically, but showed that trends in vegetation recovery had continued in the 20 years between studies, with many exclosures being "overwhelmingly dominated by *Acaena magellanica*" in stark contrast to control sites (Poncet and Scott, 2002).
In 1973 the Sorling Valley exclosure was recorded as dry meadow, dominated by *Rostkovia magellanica,* and in the first 12 years of the experiment there was no *Poa flabellata* present (Leader- Williams et al, 1987). In contrast, this exclosure site is now vegetated with a regenerating tussac-mossbank community with significantly higher lichen cover than outside. This clearly shows the significant detrimental effect that reindeer have had on total tussac cover in reindeer populated areas of South Georgia (Upson, 2009).
Both the exclosure and control site at Husvik were co-dominated by *Festuca contracta* and *Acaena magellanica* when the experiment was started in 1973 (Leader-Williams, Smith, and Rothery, 1987). Now, 35 years on, there is almost total ground cover by *Acaena magellanica* within the exclosure and less than 5 % outside (see Fig. 4) (Osborne et al,

2009; Upson, 2009). Outside the fenced area the vegetation has been completely modified to *Rostkovia*-dominated bog (Osborne et al, 2009).

Retreat of glaciers on South Georgia

Reindeer on South Georgia are restricted in range due to the presence of glaciers, the majority of which act as barriers to further expansion (Leader-Williams, 1988). The coastal glaciers on South Georgia have shown a trend of accelerating retreat over the past fifty years, with the most rapid increase occurring in the past decade. This has occurred simultaneously with the recent period of climate warming that began in the 1930s. Analysis of the rates of advance or retreat of over 100 coastal glaciers on South Georgia from the 1950s to the present show that 97% of these glaciers have retreated over the period (Cook et al, 2010).

The average amounts of retreat show that the majority (64%) of glaciers retreated by between 0 and 500 m since the first observations were made. Two glaciers stand out as having retreated the most: the Neumayer Glacier has retreated by 4.4 km since 1957, and the ice front fed by the Ross and Hindle Glaciers has retreated by 2.14 km since 1960 (Cook et al, 2010).

Fig. 4. Image showing the stark contrast at the remaining Husvik exclosure, with near 100% cover of the native *Acaena magellanica* within compared to no *Acaena magellanica* outside. Photo: Joanna Osborne

The rate of retreat for all 103 glaciers has increased from an average 8 ma^{-1} (meters per annum) in the late 1950s, to 35 ma^{-1} at present revealing an accelerating rate of retreat since the 1990's. Glaciers in the northeast of the island are currently showing an average retreat of 60 ma^{-1}. Of these, some individual glaciers have shown particularly great changes, for example the rate of decrease of the Neumayer Glacier has increased from 3 ma^{-1} retreat in the late 1950's to 384 ma^{-1} retreat at present (Cook et al, 2010).

There is a corresponding trend of increasing average annual temperature over time on the island which drives the melting of the glaciers (Cook et al, 2010). The accelerating rate of decline of the glaciers means that their role as barriers containing the reindeer herds is unlikely to continue.

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Invasive plant species in Asian elephant habitats

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Although it has been recognized that invasive plants pose a major threat to native flora and fauna, invasive plants are very poorly documented in Tropical Asia compared to other regions. Results from a preliminary survey which covered respondents working in nine countries with Asian elephants indicate that invasive plants are ubiquitous and, one or more invasive plant species are frequently encountered in most Asian elephant habitats. Findings from this preliminary survey suggests that quantitative assessment of invasive plants in Asian elephant habitat should be taken up without further delay to assess impacts of invasive plants on Asian elephants and also to help forest managers deal with invasive plants in a scientific manner.

Introduction

Invasive alien plant species (IAPs) are non-native plants which have been introduced to a region through human activities.

Across the globe, IAPs have established and begun to dominate native vegetation. IAPs have attracted increasing attention both because of significant economic and biodiversity losses (Pimentel et al. 2000). IAPs can significantly alter native plant, invertebrate and vertebrate populations and communities. For example, *Lantana camara* L., which has invaded large areas of Tropical Asia and Australia, has probably lead to the extinction of native plants on the Galapagos Islands (Mauchamp et al. 1997) and contributed to declines of several endangered species in Australia (Coutts-Smith and Downey 2006).

However, few studies have addressed the impact of IAPs on large native herbivores such as elephants, rhinoceros or large ruminants, many of which are endangered in their native ranges.

Fig. 1. Asian elephant in tropical dry forests of Mudumalai, invaded by *Lantana camara* and *Chromolaena odorata*

There have been very few studies that have focused on IAPs in Tropical Asia, even for widespread invasive plants such as *L. camara*. There is no systematic assessment of the extent of invasive cover within protected areas, the susceptibility of different habitats to invasion, or the threats posed by IAPs to native flora and fauna. Reviews by Py?ek *et al*. (2008) and Nuñez and Pauchard (2009) have also identified a strong bias in the regional representation of research on IAPs, with notably lower representation of developing countries. Given the paucity of information on IAPs and their scientific management in Tropical Asia, managers have generally resorted to controlling IAPs using techniques which are often counter-productive in the long term. Observations by some Asian elephant biologists about the potential threats posed by IAPs to Asian elephants prompted us to carry out this preliminary survey to document the extent of IAPs across Asian elephant habitat. A major concern in heavily invaded habitats, is that IAPs could potentially reduce the quantity and quality of forage available to Asian elephants. Common IAPs in Asia such as *Chromoleana odorata* (L.) R.M. King & H. Rob., *Mikania micrantha* H.B.K., *L. camara*, *Parthenium hysterophorus* L., *Prosopis juliflora* (Sw.) DC., and others are known to displace native plant species and dominate landscapes (Goodall and Erasmus 1996). For example, *P. hysterophorus* can reduce pasture carrying capacities by up to 90% (Jayachandra 1971), while *L. camara* reduces forest biodiversity (Fensham et al. 1994). *C. ordorata* thickets shade out and displace palatable species and obstruct movement of livestock and wildlife (Goodall and Erasmus 1996). In addition, many of these species can be highly toxic and unpalatable to domestic livestock (McFadyen 2004), and may have similar effects on wildlife.

The displacement of fodder plants and the toxicity of some IAPs may reduce the carrying capacity of habitats for Asian elephants, which in turn could lead to increased levels of human-elephant conflict. For example, *M. micrantha,* which is unpalatable to the greater one-horned Rhinoceros, has invaded 50% of preferred rhino habitat in Chitwan National Park, Nepal (DNPWC 2009). Regular monitoring in a buffer zone, which is rapidly being invaded by *M. micrantha*, has seen a 50% decline in rhinos over the past decade. This could lead to rhinos and other wildlife seeking additional grazing areas elsewhere, in adjacent buffer zones and farmland, where the probability of being poached is significantly higher (Martin and Martin 2006).

The threats posed by IAPs to Asian elephant habitat needs to be assessed systematically and the first step towards this is to ascertain the extent of the problem across the present-day Asian elephant range. Given the paucity of information on IAPs in Asian elephant habitat, we conducted an online survey to understand the extent of the problem.

Methods

Using a free online survey (www.surveymonkey.com), respondents were asked to provide information on common IAPs found in Tropical Asian landscapes. Since there is little quantitative information on the density or extent of these IAPs in this region, relative qualitative descriptors such as extensive, common, etc. were used for this preliminary survey. For each site that they were familiar with, respondent was asked to address:

a. Common Invasive plants in Asian elephant habitat: From discussions with ecologists working on both Asian elephants and IAPs in the region, seven IAPs (*L. camara, C. odorata, M. micrantha, P. juliflora, P. hysterophorus, Ageratum conyzoides and Eichhornia crassipes*) were shortlisted for the preliminary online survey. Respondents were then asked to note the extent/cover of these IAPs within their study sites on an ordinal scale as not present, rare, common, very common, and extensive.
b. Respondents were also asked to list any other invasive plants that they were aware of within Asian elephant habitats.
c. Respondents were also asked to provide details of any research on invasive plants at their sites and email published or unpublished reports.

Results

There were a total of 39 responses, with some respondents reporting for more than one location. Locations were grouped into 18 regions based on a visual examination of connectivity and proximity in forest cover maps for these areas. Some regions such as the Nilgiris-Eastern Ghats complex (India), Terai Arc landscape (India-Nepal) and southern Sri Lanka had more than 3 respondents, and locations within these regions were fairly well-represented in the survey (Table 1). Others such as north-east India (only one location), Myanmar (a single respondent), Malaysia (a single respondent from Peninsular Malaysia), Thailand (only 2 sites represented) were inadequately represented (Table 1). There were no respondents from some countries with Asian elephants such as Vietnam, Cambodia and also from Sabah (Malaysia).

Every site and region covered by this survey (Table 1) reported at least one of the IAPs listed in the survey. Over 60% of the Asian elephant habitat covered by the survey (11 of 18 regions) documented one or more of the seven IAPs as abundant or widespread. Most sites which were not severely invaded by the seven surveyed IAPs, reported that other IAPs such as *Mimosa pigra* L., *Clidemia hirta* (L.) D. Don., *Merremia peltata* L., *Acacia* or bamboo species were widespread (5 of 18 regions). Just two of the 18 surveyed regions did not report any IAPs as dominating Asian elephant habitat. These preliminary results indicate that IAPs are widespread and that one or more IAPs has begun to dominate the vegetation in most Asian elephant habitats.

Table 1. Asian elephant habitats covered by respondents to the online survey

	Region	# of respondents
1	Assam, North-east India	2
2	Chittagong Hills, South-east Bangladesh	1
3	Maymenshing, Central Bangladesh	1
4	Perak, Peninsular Malaysia	1
5	Kachin, Northern Myanmar	1
6	North Bengal, North India	2
7	Nilgiris - Eastern Ghats, Southern India	10
8	North-Central Sri Lanka	1
9	Orissa, Eastern India	1
10	Southern Sri Lanka	3
11	Southern Western Ghats, India	2
12	Southern China	1
13	Aceh, Northern Sumatra	1
14	Lampung, Southern Sumatra	2
15	Riau, Central Sumatra	1
16	Terai-Arc Landscape, India-Nepal	4
17	Kui Buri, Southern Thailand	2
18	Salakpra, West Thailand	2

L. camara appears to be the most common IAPs (Fig. 2) and was reported from almost all the sites, and for 17 of the 18 regions (the only exception was Tessa Nilo, Riau, Indonesia). *C. odorata, P. hysterophorus* and *A. conyzoides* were also reported from c.75% of the surveyed regions. Among the surveyed IAPs, *L. camara*, *C. odorata* , *M. micrantha* and *E. crassipes* appear to be the most dominant IAPs in Asian elephant habitats, being ranked as "extensive" or "very common" in 38%, 33%, 28% and 22% of the 18 surveyed regions, respectively. While most respondents stated that IAPs were a threat to Asian elephants, some respondents reported that some IAPs found at their sites such as *P. juliflora* (in southern coastal Sri Lanka), bamboo species (in Minneriya and Kaudulla NP, North Central Sri Lanka) and grasses such as *Pennisetum purpureum* Schumach. (Kui Buri NP, Thailand) were part of the diet of Asian elephants. Eight of the 18 regions represented in the survey reported that there had been research on IAPs at their sites. However, none of these research projects had resulted in peer-reviewed publications, and the project reports were not easily accessible (except in two cases where the reports were available on the web: *www.wildlifetrustofindia.org; www.kfri.org*).

Suggestions for future research and management actions: During this survey, and also from interactions with forest managers and ecologists, we identified the questions that need to be addressed immediately in order to scientifically manage IAPs in Asian elephant habitat:

1. How extensive are invasive plants in Asian elephant habitat?

The qualitative survey indicates that IAPs dominate Asian elephant habitats at most sites. As indicated by several respondents, we need to adopt a more quantitative approach to mapping IAPs within key elephant habitats without further delay. Firstly, we need an inventory of IAPs within selected Asian elephant habitats. Using a grid-based approach combined with remote-sensing data, the distribution of IAPs needs to be mapped at these sites in collaboration with forestry departments and local botanists. Areas outside of protected and managed forests should also be considered since elephants frequently move outside protected areas and also because emerging IAPs which pose a threat to elephant habitats often establish in surrounding areas first.

2. Do Asian elephants exhibit thresholds for tolerance to invasive plants in their habitat?

We need to examine the relationships between habitat use and IAP cover in different landscapes to understand the exact nature of the relationship between IAPs and Asian elephant habitat use. While low IAP abundances might have little impact, a threshold level may exist, above which the suitability of the habitat for elephants declines rapidly. Identification of such thresholds can help set targets for management of widespread IAP (Gooden et al. 2009).

2. *Does the presence of invasive plants lead to increased levels of human-elephant conflict?*

IAPs might differ in the extent to which they modify elephant habitat use. Identifying IAPs that can significantly alter habitat use can help prioritize IAPs for management. To address these questions we need to develop research projects adopting comparative approaches – to examine differences between invaded and uninvaded areas w.r.t. to forage availability and levels of human elephant conflict; and also, examining regions with different degrees of human-elephant conflict to understand the extent to which IAPs can explain the variation in human-elephant conflict.

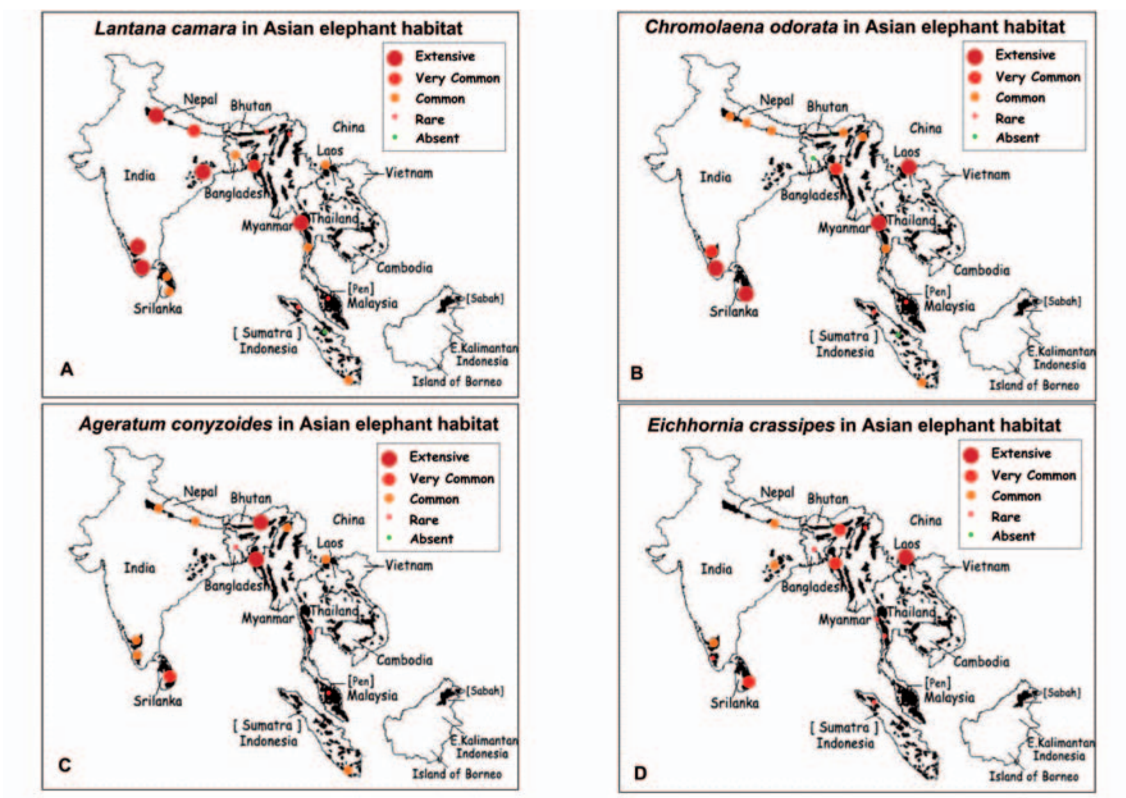

Fig. 2 Extent of common invasive plants (A. *Lantana camara*, B. *Chromolaena odorata, C. Ageratum conyzoides, D. Eichhornia crassipes)* in Asian elephant habitat indicated by preliminary online survey

3. How do we manage invasive plants in Asian elephant habitat?

IAPs have become the focus of scientific management in the developed world, where effective management action has been backed by extensive research. Research and management protocols from these regions have shown that:

a. Examining stages of invasion: *identifying management practices for effective control programs*

Plant invasions (i.e. becoming widespread and locally dominant) typically go through a series of invasion stages. Potential invaders are generally introduced intentionally or unintentionally, mainly through human activities, with further spread mediated by animal or abiotic dispersal vectors. A non-native species may be localized and numerically rare, widespread but rare, localized but dominant or widespread and dominant (Colautti and MacIsaac 2004). It is generally only possible to eradicate IAPs that are localized (either rare or dominant) and occasionally some species that are widespread but rare (Veitch and Clout 2002). Since successful eradication within landscapes is dependent on the early detection of non-indigenous species which have just started expanding their range it is critical to develop an inventory of introduced species with the potential to invade Asian elephant habitat at an early stage.

For IAPs that are widespread and dominant within protected areas and the surrounding matrix, managers need to implement integrated management strategies for critical wildlife habitats using a combination of chemical, mechanical and biocontrol agents targeting the removal of low density infections along with steps to contain the spread of well-established patches (van Klinken et al. 2007).

b. *Where do we look for invasive plants within our landscapes:* incorporating seed dispersal patterns into developing models to predict invasive spread

Native frugivores, including Asian elephants and human beings, effectively disperse several non-native plants. Incorporating disperser movement and behaviour gives us better abilities to predict where invasive seeds are like to arrive within landscapes. Strategic approaches such as incorporating patterns of seed dispersal into models that predict IAP spread allows managers to narrow down their searches and use available resources more effectively in combating IAPs (Westcott et al. 2008).

c. Monitoring invasive plants in time: *Evaluating management actions*

If resources permit, critical parameters and trends of select IAPs should be monitored over time and space in order to examine effectiveness of management actions and design better locally-adapted strategies.
It is critical to back our management action with strong data for effective management of IAPs in Asian elephant habitat. We need to develop landscape level management plans for IAPs, incorporating species-specific information on distribution, invasion stage and dispersal properties of different IAPs that can potentially reduce the quality of Asian elephant habitat.

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AlterIAS: a LIFE+ project to curb the introduction of invasive ornamental plants in Belgium

Mathieu Halford, Etienne Branquart, Sonia Vanderhoeven, Leen Heemers, Catherine Mathys, Claire Collin, Sabine Wallens and Grégory Mahy

Ornamental horticulture is recognized to be the main pathway for plant invasions worldwide. To decrease the influence of the horticulture sector on the issue, a LIFE+ information and communication project entitled "AlterIAS" (ALTERnative to Invasive Alien Species) was launched in 2010 in Belgium. It aims at raising awareness about the environmental risks of invasive ornamental plants amongst the whole horticulture supply chain. This is done through collaboration between scientists, environmental agencies and professionals in the horticultural sector, considering the socio-economic importance of species to elaborate a code of conduct and conduct awareness campaigns.

Introduction

The horticultural industry in Europe and elsewhere in the world has brought great social and economic benefit and has made a vast array of plant diversity available to the public. In Europe more than 70,000 plant species and cultivars are grown in green areas and new introductions are constantly being sought (Harrington *et al*. 2003; Dehnen-Schmutz *et al*. 2008; Heywood and Brunel 2009; Drew *et al*. 2010). Ornamental horticulture is widely acknowledged as the main pathway of plant invasions worldwide (Reichard *et al*. 2001; Bell *et al*. 2003; Burt *et al*. 2007; Dehnen-Schmutz *et al*. 2007). They are facilitated through repeated local introductions and cultivation of non-native plant species that increase the likelihood of escape and establishment in natural habitats (Mack 2000, Kowarik 2003, Dehnen-Schmutz *et al*. 2008). Like in many countries worldwide, Belgian land managers face an increasing occurrence of invasive ornamental plants (IOP) showing detrimental effects on the environment. Despite the growing number of studies that highlight the environmental, economic and public health hazards of plant invasions, they are less well known outside the scientific audience. Recent surveys of horticulture professionals in Belgium showed that most have a limited understanding of the range of threats posed by IOP, do not know which plant species are invasive in Belgium and consider themselves poorly informed (Halford *et al*. 2011; Vanderhoeven *et al*. 2011). Due to the lack of information, ornamental plant users or producers still produce, distribute and plant IOP. It is therefore necessary to inform and communicate with them to change attitudes, reduce the frequency of secondary releases and slow down plant invasions.

Fig. 1. *Cotoneaster* species are often sold in nurseries and used for ornamental purposes in Western Europe. They produce seeds that are bird-dispersed and are increasingly observed in rocky habitats and dry grasslands, where they may outcompete rare and threatened plant species (Piqueray *et al*. 2008; Dickoré & Kasperek 2010). Photos: Etienne Branquart (left) and Mathieu Halford (right)

A European LIFE+ information and communication project entitled “AlterIAS” (ALTERnative to Invasive Alien Species) was launched in 2010 in order to deal with this problem. The project is co-funded by federal and regional environment administrations. It aims at raising awareness about the environmental risks of IOP amongst the whole ornamental horticulture supply chain in Belgium, including plant growers and retailers, garden contractors, public green managers, landscape architects, horticulture teachers and home gardeners. It also aims at promoting best practices for preventing release and spread of IOP in the environment, e.g. through a sectorial engagement in a Belgian voluntary code of conduct on IOP, based on the general framework recently proposed by the European Plant Protection Organisation and the Bern Convention (Heywood & Brunel 2009). The goal is to reduce voluntary introductions (propagule pressure) of IOP via gardening and landscaping activities which act as catalysts for invasions in natural environments. The AlterIAS team involves scientists from different institutions in Belgium, i.e. Gembloux Agro-Bio Tech (Liège University), the Research Centre for Ornamental Plants (Destelbergen) and the Horticultural Technical Centre of Gembloux.

Invasive ornamental plants in Belgium

A list system of non-native organisms established in Belgium has been developed at the initiative of scientists gathered within the Belgian Forum on Invasive Species (Branquart *et al.* 2010). It aims to help land managers and policy makers in the identification of species of most concern for preventive or mitigation actions, namely action plans, legislative tools and voluntary codes of conduct. Lists are built using a standardised assessment protocol, ISEIA (Invasive Species Environmental Impact Assessment), which allows assessing and categorising exotic species from any taxonomic group according to their invasion stage in Belgium and to their impact on native species and ecosystem functions. The ISEIA protocol is one of the first national standardised risk assessment tools developed for non-native species (Verbrugge *et al.* 2010) and it has been used as a model for the development of other comparable initiatives in Europe (e.g. Parrott *et al.* 2009).

The Belgian list system (the *Harmonia* list system) is based on three different categories as recommended in the European strategy on Invasive Alien Species (Genovesi & Shine 2004). They are defined according to the severity of impacts on the environment: no negative impact (white list), negative impact moderate or suspected (watch or grey list) and negative impact confirmed (black list). The assignment of a non-native species to one of those categories is assessed by four main criteria matching the last steps of the invasion process: 1) the potential for spread, 2) the colonisation of natural habitats and adverse ecological impacts on 3) native species and 4) ecosystems.

Dated the 1st January 2011, 57 established vascular plant species were assigned to the *Harmonia* lists, with a large majority of terrestrial species (79%); 30 species were known for significantly impacting the environment and therefore belonged to the black list, while 27 species were ascribed to the watch list with moderate impact. Concerning pathways, a large majority (95%) of plant species were introduced through horticulture or aquaculture and only three species, *Senecio inaequidens*, *Bidens frondosa* and *Impatiens parviflora* were accidentally introduced in Belgium. They originated from North America (48%), Asia (24%), South America (7%), Africa (3%) and Australia (1%).

Socio-economic importance of invasive ornamental plants

A socio-economic analysis has recently been conducted by the AlterIAS team for quantifying the relative importance of IOP within the horticulture market in Belgium. The analysis was based on an inventory of the horticultural catalogues and a survey addressed to nurserymen (Halford *et al.* 2011). Results showed that 93% of terrestrial and aquatic IOP are still available in nurseries and that 67% of terrestrial IOP are mentioned in catalogues. Invasive trees and shrubs such as: *Acer negundo, Amelanchier lamarckii, Buddleja davidii, Cotoneaster horizontalis, Mahonia aquifolium, Prunus laurocerasus, Rhododendron ponticum, Robinia pseudoacacia* and *Quercus rubra* were the most frequent IOP found in catalogues, which suggest that they are widely used for gardening and landscaping. Even widespread and well known invaders like the Asian knotweeds (*Fallopia* spp.) and the giant hogweed (*Heracleum mantegazzianum*) are still present in catalogues and available in nurseries.

IOP were assigned to three classes of economic importance based on the answers collected from the survey: high economic value (for IOP considered as important by more than 5% of nurserymen), moderate economic value (for IOP considered as important by 1-5% of nurserymen) and low economic value (for IOP that were not considered as important by the surveyed nurserymen). It should be noted that most species with a high economic value only have a moderate environmental impact in Belgium. Only 5 of them (*Cotoneaster*

horizontalis, *Rhododendron ponticum, Rosa rugosa, Spiraea alba* and *Spiraea douglasii*) are included in the Belgian black list, being invasive in very specific site conditions such as dune ecosystems, heathlands or dry grasslands.
The socio-economic survey also included some questions to perceive how a code of conduct would be welcomed by the horticultural sector. Interestingly, a large proportion of surveyed horticulture professionals had a strong willingness to change their attitude and take concrete action to reduce the dissemination of IOP in the environment. 54% of nurserymen would agree to stop selling IOP and more than 65% of private and public green managers agreed not to plant them in the future. 86% of gardeners claimed they would prefer to buy their plants in nurseries which do not sell invasive plants (e.g. in nurseries engaged in codes of conduct).

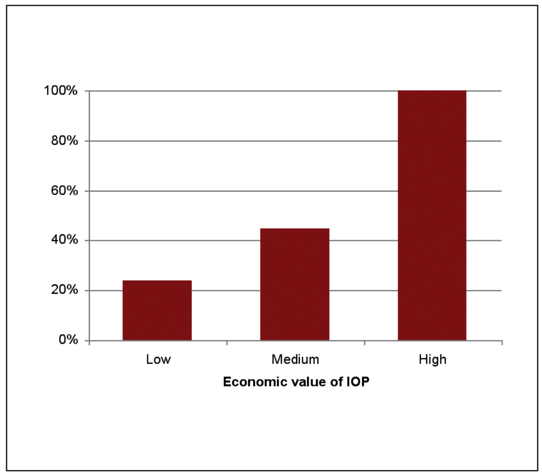

Fig. 2 Relationship between the willingness of code representatives to include IOP species in the consensus list and their economic value

Towards a Belgian code of conduct

Round table discussions were conducted at the initiative of the AlterIAS team to identify workable measures to reduce trade and use of IOP in Belgium and develop a sectorial code of conduct taking into account both the environmental impact and the economic value of IOP. A code working group was established in October 2010 gathering representatives of the Belgian Forum on Invasive Species and of the main horticulture federations active in the country.
Two target groups were consulted, i.e. ornamental plant producers and sellers (nurseries and garden centers) and ornamental plant users (public green managers, landscape architects, garden contractors and representatives of botanical gardens). Five main preventive measures were identified by the working group: to know the list of IOP, to disseminate information on IOP and alternatives to customers, to stop selling or planting IOP, to promote the use of non invasive (alternative) ornamental plants and to participate in early detection of new invaders.
The key measure of the code is the limitation of IOP use.
As a ban on the production and the planting of all the black and watch list species would not be immediately accepted by some of the working group participants (i.e. plant producers), it was decided to develop a code with two main engagements depending on the plant species.
The first corresponds to a commitment to stop selling or planting species (including cultivars and varieties) from a consensus list including 28 terrestrial and aquatic IOP, which represents 67% of the black list species and 30% of the watch list species (figure 2).
The second refers to a commitment to inform gardeners and citizens about potential threats linked to the used of other black and watch list species. The willingness of sector representatives to include IOP species in the consensus list was directly linked to their economic value: no agreement was found to include plant species with a high economic importance in this list (figure 3).
On top of that, species that only invade very specific habitats were hardly perceived as detrimental by horticulturists because of their limited distribution.
It should be noted that another preventive measure that is often cited in codes of conduct on IOP is the adoption of labelling practices mentioning invasiveness peculiarities (e.g. ability to escape, ecosystems at risk, etc.).
This measure was however considered as poorly applicable by the working group participants as it is costly, time consuming and detrimental to the green image of the sector.
They preferred to choose a system where detrimental species are not distributed anymore when a strong environmental impact has been demonstrated.
This code is nearly finalised and its implementation is expected to start in June 2011. As with other codes of conduct, it will be a voluntary tool based on the principle of self-regulation. This instrument allows more flexibility than legally binding measures and is well adapted to the specificity of horticultural trade.
Similar or equally appealing non-invasive plants can often be used as alternatives and moreover, the high public visibility of the horticulture trade increases the potential for self-regulation within this industry wishing to project an environmentally friendly image (Baskin 2002, Harrington et al. 2003, Heywood & Brunel 2008).

Fig. 3 – All black listed IOP that are widely distributed in Belgium species were included in the consensus list of the code of conduct: *Fallopia japonica* (up) and *Impatiens glandulifera* (down). Photo: Emmanuel Delbart (up) and Sonia Vanderhoeven (down)

Communication campaigns

The results of the AlterIAS survey shows that both nurserymen and gardeners often have limited understanding of the range of threats posed by invasive species, do not know which plants are invasive and consider themselves as poorly informed. It means that very efficient awareness raising campaigns should accompany voluntary approaches to advertise the potential risks of exotic plants and promote good practices. Also, the US experience (Saint-Louis voluntary codes of conduct) demonstrated that a shortage in communication may lead to a low participation of nursery professionals in preventive measures and a limited success in code endorsement (Baskin 2002, Harrington et al. 2003, Burt et al. 2007, Gagliardy & Brand 2007).

To avoid those pitfalls, the AlterIAS project is deeply grounded in information and communication activities. A lot of energy has, and will be, invested in several communication campaigns dealing with general information on IOP and the promotion of the code of conduct in order to encourage its support and subscription from horticulture professionals. A variety of communication tools are produced to this purpose: website, DVD, TV and radio reportages, brochures, folders, posters, and articles in horticultural magazines.

Discussion

The main purpose of voluntary codes of conduct in horticulture is not to avoid the introduction of a new potential harmful exotic plant into Belgium (initial introduction), but rather to decrease the propagule pressure of IOP that are already present and used in gardening practices. Although cultivated plants may naturally establish locally, human assistance through gardening highly increases the probability of invading natural ecosystems. Today, many populations of detrimental IOP found in semi-natural habitats directly descend from direct plantations or from human assisted accidental releases rather than from natural dispersion. Regulating the various pathways of plant secondary releases within an already existing range may therefore strongly reduce the speed, the impacts and the costs of biological invasions (Kowarik 2003).

The specificity of the Belgian code of conduct compared to other initiatives abroad is that it is built upon a consensus list that has been negotiated with the horticultural sector. It may be considered that this tool is not ambitious enough as some plant species included in the Belgian watch and black lists do not appear in the consensus list due to the current high economic importance they represent or because they are not perceived as invasive by horticulturists. Our goal is however not to have strict measures that very few professionals will adopt but rather to involve as many people as possible to change attitudes and take the biological invasion issue into account in their activities from day to day. However, it has to be noted that this code is a first step in an ongoing process in the course of which scientists, administrations and horticulturists learn to talk to each other. Project ambitions will increase in the future as the code is designed as a dynamic instrument that will be revised on a 3-year basis by a dedicated working group, e.g. to allow the inclusion of additional IOP in the consensus list. We think that raising awareness amongst plant users will gradually encourage plant producers and retailers to increase their level of engagement.

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Additional information

The LIFE+ AlterIAS project
http://www.alterias.be

The Harmonia list system of invasive organisms
http://ias.biodiversity.be

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Investigation of invasive plant species in the Caucasus: current situation

George Fayvush and Kamilla Tamanyan

The Caucasus region is one of the biologically richest hotspots in the world. There are different threats to its biodiversity and ecosystems, but until now the distribution of invasive species has been underestimated by scientific communities. The description of the level of invasive plant species in different regions of the Caucasus is given in this article.

Introduction

The Caucasus region is among the top 34 biologically richest and most endangered biodiversity hotspots in the world. The Caucasus hotspot, historically interpreted as the isthmus between the Black and Caspian seas, covers a total area of 580,000 km^2 (CEPF 2003). The flora of this hotspot is extremely rich - the number of vascular plant species of the Caucasus is ca. 6,500 and the approximate number of species endemic to the region ca. 1,600 or 25% (Schatz *et al* 2009). The major ecosystems in the Caucasus hotspot consist of forests, high mountain habitats, dry mountain shrublands, steppes, semi-deserts and wetlands. Broadleaf forests, consisting of oriental beech, oak, hornbeam and chestnut, make up most of the forested landscape of the Caucasus. Dark coniferous forests, made up mainly of oriental spruce and Caucasian fir, are found in the western part of the Lesser Caucasus Range and on both sides of the western and central Greater Caucasus Range. Arid open woodlands form on dry, rocky slopes, made up of juniper, pomegranate, oak, pistachio and sometimes pyre species. High mountain meadows are dominated by herbaceous species. Alpine mats, formed by dense low-lying perennial plants, cover the terrain on the upper belts of the Caucasus. Unique communities of cliff and rock vegetation are distributed throughout the high mountains of the Caucasus. Mediterranean and Anatolian-Iranian shrublands occur in the arid mountains of the Caucasus where a continental climate prevails, particularly in the foothills of the Araks River watershed. Steppe vegetation used to be widespread on the Caucasus Isthmus, but today only fragments of primary steppe communities have survived on slopes that are unsuitable for agriculture. The few semi-deserts and deserts that have been preserved are made up of either predominately wormwood or salt habitat species. Wetland ecosystems are found throughout the Caucasus and include estuaries and river deltas, marshes, swamps, lakes and streams.

Biodiversity of the Caucasus is being lost at an alarming rate. On average, nearly half of the lands here have been transformed by human activities. For the Caucasus as a whole, about a quarter of the region remains in reasonable condition, while less than 10 percent of the original vegetation can be considered pristine.

The major threats to biodiversity in the region are illegal logging, fuel wood harvesting and the timber trade; overgrazing; infrastructure development; and pollution of rivers and wetlands (CEPF 2003).

It is a bit strange that distribution of invasive alien species is not considered among these threats. In our opinion, this threat was underestimated by the scientific community of the Caucasus as well as by decision makers.

Investigation of invasive plant species in the Caucasus

Caucasian adventive plant species have attracted botanists for a long time. Some of themes were described in botanical works in XVIII-XIX centuries. Special attention was paid to these species in the beginning of XX century because of intensification of land use in the Caucasus. In 1916 Yu. N. Voronov published an article on “alien species of Caucasian flora”. Then an interesting work was published on “ the distribution of some alien subtropical monocot weeds in the Caucasus” (Grossheim 1939). During the last century invasive plant species were not the subject of special investigation in the Caucasus. Attention was paid only to those species which could threaten agriculture.

Fig. 1. Topographic-map of Caucasus ecoregion

Now this situation is slowly changing. We connected with our colleagues in different regions of the Caucasus and tried to find out what investigations are carried out, and what are planned.

Armenia. The invasive plant species problem in Armenia used to be underestimated. It was considered that due to the mountainous and indented landscape and absence of big plain territories, invasive species could not harm natural ecosystems. By our efforts the attitude towards the problem of invasive species has changed. Our research has shown that in Armenia one invasive species cannot occupy large territories. Actually, large numbers of invasive and expansive species spread in suitable habitats, and occupy relatively small areas, but as a whole the picture is rather concerning.

Preliminary estimation results of the threat of invasive plant species to the natural ecosystems and biodiversity in Armenia allowed us to prepare a list of more than 120 species requiring immediate attention.

Invasive alien species have expanded their areas and indicate a real threat to natural ecosystems and biodiversity. Investigation of the distribution of invasives in Armenia has started; trends in their distribution over the last 40-50 years are being evaluated and forecasts for their future distribution are being processed.

Estimation of threats from invasive alien species to some ecosystems has started. These investigations are being carried out by the Institute of Botany of Armenian National Academy of Sciences (G. Fayvush, K.Tamanyan).

Azerbajdzhan. No Data.

Georgia. The investigation of invasive alien species has started. A list of 386 introduced plant species has been prepared, 16 species from this list are estimated as invasive. “The Alien flora of Georgia” (Kikodze *et al*. 2009, 2010) has been published. Investigations have been carried out in the National Botanical Garden of Georgia (D. Kikodze) and in Batumi Botanical garden (N.

Memiadze, D. Kharazishvili, Z. Manvelidze).. Current knowledge clearly indicates that invasive plants may threaten some of the unique natural ecosystems of the country and pose threats to the indigenous species diversity, agriculture and human health.
Additional intensive research activities are necessary to better understand the role of alien species and elaborate both preventative (legislation, regulations such as limited trade, border controls, etc.) and curative control measures (chemical, mechanical, biological as well as their integrated combination) in order to mitigate further spread of alien plant species, and thus reduce the predicted high ecological and economic losses imposed by alien and invasive plant species.
This knowledge is urgently required to fulfil the commitments made by Georgia as a signatory of the Biodiversity Convention.
Abkhazia. Investigations of invasive alien species has not been carried out. The Conspectus of adventive flora of Abkhazia is compiled (S. Chitanava).

Fig. 2. *Ailanthus altissima*. Photo: Kamilla Tamanyan

Russian Federation. The Komarov Botanical Institute of the Russian Academy of Sciences in St. Petersburg plays an important role in the study of the flora of the Caucasus and its Russian region. The institute publishes the "Conspectus of the Caucasian Flora" (Vols. 1, 2, 3(1) have been published, vols. 3(2), 3(3) expected in near future) which includes all naturalized invasive species. The Herbarium of the institute is an extremely important source of information on alien and invasive species.
During 2002-2004 the Komarov Institute took part in the research on invasive plants and animals of Russia supported by the Ministry of Science of the Russian Federation.
The Russian region of the West Transcaucasia (Black Sea coast) was selected as a model area in such work. As a result, a preliminary list of invasive species was compiled and analyzed especially in terms of their origin (N. Portenier).
As a part of this project a review on the existing terminology on invasive species was published in Russian (D. Geltman). However after this project there were no special activities on invasive species of the area.
The Caucasus is also a source of plants which become invasive in other areas. Staff at the Komarov Botanical Institute took part in a study of giant *Heracleum* species which are native to the Caucasus but are a noxious invasive species in Europe and North America.

Krasnodar territory. In the territory of Russian Caucasus the most intensive investigations of invasive species are being carried out in the North-West region, and especially in the Caucasus State biosphere reserve. The "flora" of the region has been published (Zernov 2006)and includes 252 adventive species (A. Zernov). Inventory of invasive species has been carried out including their distribution, system for their monitoring, , measures for prevention of distribution, and eradication of invasive species (V. Akatov, T. Akatova, B. Tuniev, I. Timukhin, G. Soltani). In the territory of "Sochi" National Park and in the area for the Olympic Games buildings, special investigations are being carried out by B. Tuniev and I. Timukhin. New adventive species have been found (A. Seregin, A. Zernov, O. Kalashnikova). Theoretical and practical problems of plant diversity and vegetation conservation in the Krasnodar territory as a whole, including the problem of invasive alien species, are in the hands of Prof. S. Litvinskaja.

Stavropol territory. Investigation of the flora of Stavropol territory are being carried out, in which some attention is being given to new species, but rare species are considered as most important. This report will go to the Stavropol State University (A. Ivanov) and in Ecology-botanical station "Pjatigorsk" of the Komarov's Botanical institute of Russian Academy of Sciences (A. Mikheev and specialists from Botanical institute).

Fig. 3. *Astragalus galegiformis*. Photo: Kamilla Tamanyan

N. Osetia-Alania. Investigations of invasive plant species are not being carried out. During the investigations of the flora of N.Osetia-Alania some data on invasive species were collected (ecological characteristics, distribution, etc.). The coordinator of these investigations is A. Komzha, participants – K. Popov and R. Tavasiev.

Karachaevo-Cherkessia. Special investigations of invasive plant species are not being carried out. Adventive species are being notified during the work on a compilation of flora. These investigations are being carried out by V. Onipchenko, D. Shilnikov, A. Zernov.
The Conspectus of the flora of the Republic is prepared. It includes 1905 species; more than 100 of them are adventive species. The penetration of some steppe species into mountain part of the Republic on disturbed ecosystems is notified. Conspectus of the flora of “Teberda” reserve (F. Vorobieva, V. Onipchenko) and conspectus of the flora of Cherkessk city (A. Zernov, O. Khubieva) are published.

Kabardino-Balkaria. Special investigations of invasive plant species have not been carried out. Investigations of the flora of the Republic will be recorded at the Kabardino-Balkarian State University. The publishing of this “flora” is planned (S. Shhagapsoev). “The flora of Nalchik city and its vicinity” (S. Shhagapsoev, E. Karachaeva) was published in 2009. This flora includes analysis of an adventive element.

Chechnya. The Conspectus of the flora is in preparation now. Adventive species will be notified in this edition. Investigations are carrying out by M. Umarov and M. Taysumov.

Ingushetia. Attention is being paid to adventive and invasive plant species during reporting of the flora: special investigation on estimation of their impact on natural ecosystems is planned (M. Dakieva).

Dagestan. Intensive investigations of the flora and vegetation of Dagestan are being carried out. During these investigations special attention is being paid to the distribution into different ecosystems of invasive species. This report will be based at the Mountain Botanical garden of the Dagestan Scientific center of the Russian Academy of Sciences (R. Murtazaliev) and in Dagestan State University.

Conclusion

Humans have inhabited the Caucasus for many millennia. Legions of rulers and government regimes have vied for control of the region and its rich natural and cultural resources. Nearly half the lands in the Caucasus have been transformed by human activities. Any strategy for conservation of the rich biodiversity of the region will have to take the human factor into account by seeking alternative ways to boost local economies through integrating sustainable practices of natural resource use and include local communities in conservation programs.

Special investigations of invasive plant species in the Caucasus are only carried out in a few scientific centers. All these investigations are implemented by different methodologies and are in different stages.

The most important result of this review is the conclusion, that scientific cooperation is absolutely necessary. It has to include all scientific centers in all regions of the Caucasus.

The special project on the inventory of invasive plant species in the whole Caucasus is important and necessary. Spanning the borders of six countries, the Caucasus hotspot is a globally significant center of cultural diversity, where a multitude of ethnic groups, languages and religions intermingle over a relatively small area. Close cooperation across borders will be required for conservation of unique and threatened ecosystems,.

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The annual cost of invasive species to the British economy quantified

René Eschen and Frances Williams

Invasive alien species (IAS) can cause large economic costs, but in most countries this has not been quantified. An economic assessment of the damage of IAS can be useful to inform policy and management decisions, but where such assessments have been made the estimated costs vary widely and detail is often lacking. We assessed the current annual costs of individual IAS to England, Scotland and Wales and eleven sectors of their economies. In addition, the eradication cost of five case study species at early and later stages of invasions was estimated. The assessment revealed that the current annual cost of IAS is ca. £1.7 Bn. Most costs are incurred in England, mainly as a result of the larger area of agricultural land, the warmer climate, and the larger number of harbours and airports than in Scotland and Wales.

The case studies indicated that the cost increases exponentially as IAS spread. It is suggested that the arrival and spread of non-native species with restricted distribution be limited. The detail in this work may assist targeting sectors and IAS with the greatest impact.

Introduction

Invasive alien species (IAS) can do great damage to the economy of a country. It has been estimated that IAS cause a loss of 5% of the global production (Pimentel *et al*., 2001). Management and policy are influenced by the size of the problem and therefore it is important to have an accurate estimate of the cost of IAS to a country. Estimates of the economic cost of IAS exist for various countries. While these estimates vary widely, it is clear that the cost can be very high.

Some of the variation in the estimates is due to methodology (Born et al., 2004), but in general, inclusion of more species and sectors of the economy should result in a more accurate and detailed estimate.

Such detail is essential for the development of policy and targeted management.

The costs caused by IAS can be due to their direct impact on ecosystem functioning and goods and services used by man. Many of these impacts, such as additional management costs, structural damage or crop losses have a monetary value that can be assessed. IAS often also have indirect impacts, for example the loss of employment or price increases.

These indirect impacts can be hard to put a value on, although there are various common techniques to assign a monetary value. The aim of our work was to assess the current annual cost of IAS based on available data. We did not employ valuation techniques to generate new data.

Several estimates of the economic impact of IAS on Great Britain or the UK exist (Williamson, 2002; White and Harris, 2002; Pimentel et al., 2005; Oreska and Aldridge, 2010), but these mostly lack detail for sectors of the economy. We investigated the current annual cost of IAS to eleven sectors of the economies of England, Scotland and Wales. The estimated costs included damage and control costs, as well as research and quarantine and surveillance measures.

In addition, the evolution of the eradication costs as an invasion progresses through the country was assessed in five case studies. We acknowledge that many non-native species have a positive impact, but only negative impacts were included here. The full calculations and results were presented in a report for the Scottish government, the UK Department for Environment, Food and Rural Affairs and Welsh Assembly Government (Williams et al., 2010).

The methodology we used to estimate costs of individual IAS and to the various sectors depended on the available information. Information was obtained through internet and literature searches, an online questionnaire that was sent to over 250 people and organisations and follow-up interviews.

Over 300 species were identified as potential IAS with costs to the economy at the start of the project, but cost information about relatively few species was found.

Using this information, estimates for individual species and sectors were calculated. The calculations and cost estimates were reviewed by over 40 (mostly anonymous) experts in either the species or the sectors prior to publishing the report. This led to corrections, valuable improvements and additional information.

The estimated cost of IAS

The total cost of IAS to Great Britain was estimated at 1.7 Bn annually (Table 1). By far the largest impact was on the agricultural and horticulture sector, as a combination of crop losses and control costs, which amounted to about just under two thirds of the total cost estimate. An over-proportionally large part of these costs was incurred in England. This can be explained by the larger agriculture sector, larger population density, warmer climate and a greater number of harbours and airports, which are often the start of invasions, than in the other two countries. This was also reflected in the higher costs of quarantine and surveillance in England than in Scotland or Wales.

The information about the impacts of IAS we found was very diverse, which was reflected in the way we calculated the cost of individual species, species groups or sectors. For example, the control and management cost of rabbits in agriculture and forestry, as well as crop losses in those sectors, could be estimated in great detail based on published data on yield losses due to rabbits, areas under various crops, management costs for the whole country and estimates of rabbit population size.

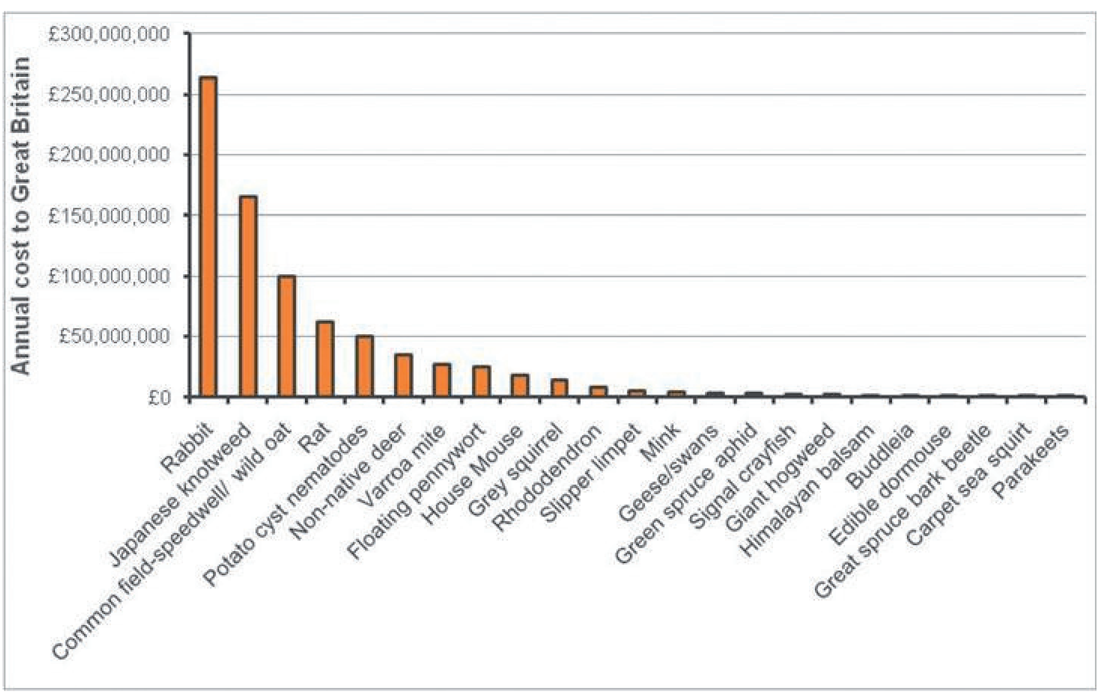

Fig. 1. The estimated annual cost of individual IAS to the British economy, arranged by magnitude of impact.

Table 1. Estimated total costs of IAS to Great Britain by sector and country (figures expressed in pounds)

	England	Scotland	Wales	Great Britain
Agriculture	838,189,000	156,120,000	71,110,000	1,066,419,000
Forestry	45,780,000	48,666,000	14,950,000	109,396,000
Quarantine and Surveillance	14,523,000	1,287,000	1,956,000	17,766,000
Aquaculture	4,370,000	722,000	2,053,000	7,145,000
Tourism and Recreation	78,920,000	13,059,000	5,759,000	97,738,000
Construction, Development, Infrastructure	194,420,000	6,870,000	11,078,000	212,368,000
Transport	62,894,000	9,621,000	8,768,000	81,283,000
Utilities	8,515,000	1,119,000	483,000	10,117,000
Research				17,387,000
Biodiversity and Conservation	11,176,000	5,802,000	6,218,000	40,583,000[a]
Human Health	37,844,000	4,470,000	5,816,000	48,130,000
Subtotal	1,297,631,000	247,736,000	128,191,000	1,708,332,000[a]
Double count	6,170,000	3,268,000	3,073,000	27,638,000[b]
Total costs (excluding double counting)	1,291,461,000	244,468,000	125,118,000	1,678,434,000

[a] *The total cost for biodiversity does not equal the country totals, due to the inclusion of research costs, which are not divided by country. Similarly, the GB total does not equal the country totals.*

[b] *The double counting, removed to obtain the overall total cost estimate, relates to the £1,855,000 cost of quarantine and surveillance for forestry species that is included in both the quarantine and forestry sectors. In addition, the entire cost of research is included in the biodiversity and conservation sector, as all research carried out on IAS will be of benefit to biodiversity and conservation either directly or indirectly.*

By contrast, other costs could only be estimated at a species group or sector level, mostly because of the way that IAS are dealt with. The treatment of weeds in arable land, for example, happens irrespective of the origin of the weed species. Consequently, the cost of management was calculated based on the cost of herbicide treatment per area, the average percentage of controlled weeds that are non-native and published data about the area planted with each crop. The yield loss as a result of IAS was estimated as the percent yield loss after control, assuming that the yield would increase by the same percentage if the IAS were not present, while adjusting for consequential price changes per tonne of crop produced. In some sectors, apparently no or limited costs specific to IAS were incurred. For example, several people in the boating sector confirmed each others' statement that IAS cause no costs at present because of the recommended practice of cleaning the hull of boats every year, irrespective of the presence of IAS.

The annual cost estimates for rabbits (*Oryctolagus cuniculus*, £263 M) and Japanese knotweed (*Fallopia japonica*, £166 M) were the highest in terms of individual species estimates (Fig. 1), but the estimates for plants, mammals and fungal plant pathogens were of a similar order of magnitude (£483 M, £403 M and £403 M, respectively). The top ten species quoted in the questionnaire responses as having a cost and those species for which cost estimates were provided in the responses were very similar, suggesting that the inclusion of these IAS in our cost estimate covered many of the species that are perceived as damaging.

The total cost estimate is low. This is partly as a result of deliberately conservative estimates when no accurate information was available. It was impossible to obtain seemingly obvious figures about control efforts by local governments, volunteer groups or commercial companies, because in some cases no information that recorded expenditure on IAS was kept or the information was commercially sensitive. Other reasons for the low estimate are that information about the economic cost of a relatively small number of species was found and most of the available costs are direct costs. Only 1% of the total estimate is indirect or non-use costs. An analysis of 16 previous studies of the economic impact of IAS revealed that the estimate was on average 57 times higher if indirect or non-use values were included in the estimate. This suggests that the annual cost of IAS to the British economy could be as high as £97 Bn. No attempt was made to verify this, as such verification would involve a lot of additional work that was beyond the scope of our study.

As with previous studies (e.g. Oreska and Aldridge, 2010), this study has shown the lack of knowledge of conservationists of the monetary value of ecosystems and the cost of biodiversity loss. Most of the respondents to our questionnaire were active in the biodiversity and conservation sector, but the costs they stated were low compared to those quoted by respondents from other sectors. It is difficult to value the presence of a native species or an ecosystem. As the ecosystem function of many species is unknown, this often leads to an underestimate of the value of ecosystems (European Commission, 2008). However, an estimate of monetary value of a species or an ecosystem service is useful for the assessment of the need for, and extent of measures against IAS. Hence, better recording of control/management efforts targeting IAS would improve the quantification of the impact of IAS.

Evolution of costs as invasions progress

The cost of eradicating five case study species was calculated to indicate how such costs could develop over the course of an invasion. The cost of early intervention, i.e. eradication of first outbreaks in the country, was calculated for of Asian long-horned beetle (*Anoplophora glabripennis*) and early-stage eradication costs were calculated for three species that are established and are likely to become widespread (carpet sea squirt, *Didemnum vexillum*, and water primrose, *Ludwigia* spp.), or that are widespread and cause costs (grey squirrel, *Sciurus carolinensis*). In addition, the cost of eradicating coypu (*Myocastor coypus*) from East Anglia in the 1980s was summarised. The costs of late-stage eradication costs were estimated for all five species, based on the assumption that the species would be established in all suitable habitats in Great Britain. The analysis shows that eradication costs increase exponentially as the extent of the invasion progresses (Fig. 2). Hence, the results indicate that early intervention is essential to reduce the costs in the long term. This is in general agreement with the consensus about how to deal with biological invasions (Wittenberg and Cock, 2001). In addition, most attempts to eradicate well-established IAS have failed (Pimentel et al., 2001), which emphasises the cost-effectiveness of early eradication.

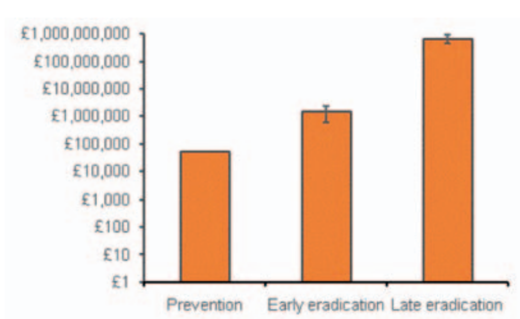

Fig. 2. The average eradication cost of the five case study species in different stages of the invasion. Annual prevention costs for one species are included.

Early detection of species impacts, in Great Britain or abroad, could help to bring about a quick response if new IAS arrive from other countries or if non-native species become invasive. Many ecosystem functions are not well understood and the disruption of such services by IAS and many IAS problems are not unique to Great Britain. Hence, investment in research is needed as this may allow the early identification of problems and impacts. However, a search of the CAB Direct database (www.cabdirect.org) revealed that in recent years, the proportion of European scientific papers about IAS that comes from research institutes in Great Britain has fallen steadily, from ca. 0.7 in 2000 to 0.3 in 2008. Research such as this is important, because it allows better analysis of the costs and benefits of control, mitigation or eradication strategies, and it provides policy makers with the knowledge required for informed decisions. For example, as a result of the level of detail in the collected information and our calculations, we were able to separate management costs from damage for a number of species, which revealed that in some species the cost of damage is far larger than the management expenditure (e.g. slipper limpet, *Crepidula fornicata*) while in other species the reverse was found (e.g. non-native deer in the agriculture sector). The separation of the costs of control efforts and damages or losses as illustrated, is useful to enable decisions to be made that balance these costs, so as to optimise the economic return on IAS management.

Conclusion

This research has revealed some of the costs of IAS to England, Scotland and Wales in a great level of detail. Despite our arguably low estimate, it is clear that the costs are considerable, and the case studies indicate that the costs are likely to increase. With the continuous arrival and establishment of new non-native species (Hulme et al., 2009) some of these species will become invasive, as illustrated by the recently arrival and spread of the carpet sea squirt, *Didemnum vexillum*, which already causes considerable costs in other parts of the world (Pannell and Coutts, 2007; USGS, 2009). Continuing investment is therefore needed to identify potential IAS before they become established and widespread. It is important to eradicate newly established, potential future invasive species as soon as possible, to limit the further spread of locally or regionally established IAS, whilst not ignoring the need to mitigate the impact of widespread IAS which have the highest costs. Although the cost of these control measures may appear high, it is money well spent, as without them the future costs of IAS to the British economy will be much higher.

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Eradication of the non-native sea squirt *Didemnum vexillum* from Holyhead Harbour, Wales, UK

Rohan Holt

The invasive non-native sea squirt *Didemnum vexillum* was discovered in the marina in Holyhead Harbour, Anglesey, North Wales, by MSc student Kate Griffith from the School of Ocean Sciences in the summer of 2008. Subsequent surveys in the British Isles located this species in Largs (west Scotland), Plymouth and Dartmouth (south-west England), Solent (south England) and Malahaide and Carlingford Lough in the republic of Ireland. Virtually all instances of this species were found in marinas implicating leisure craft as the prime vectors.

The Countryside Council for Wales surveyed its distribution and extent in the harbour. It appeared to be confined to living on the floating pontoon structures and chains anchoring the marina in place. Later in the year a feasibility study for its eradication drew evidence from other eradication programmes around the World – particularly from New Zealand – and on the basis of a potential success an eradication programme was initiated. The eradication pilot started in October 2009, using plastic wrappings and bags to isolate, smother and kill the sea squirt by inducing a stagnation reaction around the pontoons and chains. Later in the year, once appropriate FEPA permissions had been obtained, the eradication process was accelerated by adding calcium hypochlorite to the bags and wraps.

Although very labour-intensive this process apparently worked well; the pontoons were treated in batches of up to 60 floats at a time and cleared of virtually all marine life. The entire marina (over 530 pontoons and associated mooring chains) and around 100 surrounding swinging moorings were treated through the winter and finally cleared by the end of May 2010.

As part of the quality assurance measures during the eradication programme, inspection of the marina and other structures in Holyhead Harbour during late winter and early spring, revealed no trace of *D. vexillum* on any of the structures within the marina. However, in May 2010, diving surveys revealed a colonial didemnid sea squirt, with many of the characteristics of *D. vexillum*, growing on the ferry terminals and 'Tinto aluminium' jetty in the outer harbour.

Once the summer had progressed sufficiently to find larvae-producing specimens this was confirmed to be a native species – this misidentification issue highlighted the difficulty in identifying *D. vexillum*.

Fig. 1. *Didemnum vexillum* colony on pontoon side. Photo: R. Holt

Fig. 2. Heavily fouled yacht with *Didemnum vexillum* colonies on its hull. Photo:R. Holt

Fig. 3. Diver wrapping chains with sheet plastic. Photo: R. Holt

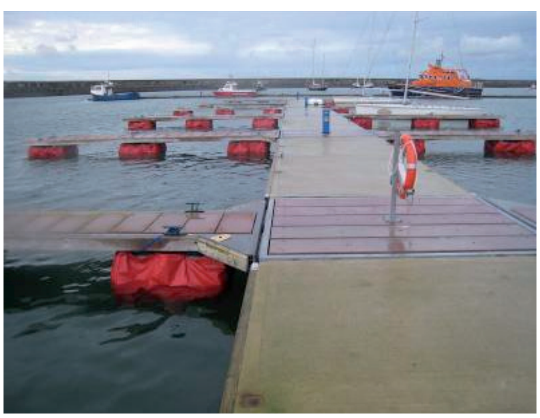

Fig. 4. Marina pontoon floats with custom-made eradication bags. Photo: R. Holt

In early October 2010, immediately before the eradication work recommenced, further survey work revealed large numbers of very small
colonies and rapidly growing larger colonies over a much larger proportion of the marina. In early October 2010, immediately before the eradication work recommenced, further survey work revealed large numbers of very small colonies and rapidly growing larger colonies over a much larger proportion of the marina. In late August and early September 2010 a few small colonies confirmed to be *D. vexillum* were found in the marina during a routine survey and plans were initiated to re-treat these few small areas.

In early October 2010, immediately before the eradication work recommenced, further survey work revealed large numbers of very small colonies and rapidly growing larger colonies over a much larger proportion of the marina than had been detected earlier. By early January 2011 it was evident that CCW had neither the funds nor time remaining while sea temperatures were sufficiently low to suppress larval production to re-run an improved eradication programme.

It was therefore decided to re-direct funds and effort towards improving biosecurity and monitoring, including the building of a prototype quarantine berth and self-antifouling pontoons. In the meantime CCW will be raising funds for a full-scale and much improved eradication attempt for the winter of 2011-2012.

Fig. 5. Holyhead marina – general view. Photo: R. Holt

More information on the Holyhead eradication project can be found in the CCW report (Holt and Cordingley 2011)

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Challenges, needs and future steps for managing invasive alien species in the Western Balkan Region

Ahmet Uludag and Riccardo Scalera

Introduction

Invasive alien species (IAS) are becoming one of the most important environmental issues due to increasing global changes, such as those driven by trade, travel and climate change. The growing perception of the impact of this major driver of biodiversity loss is stressed by the number of policy strategies being developed. For example, according to the recent CBD strategic plan for the period 2011-2020 (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".

Also at the European Union (EU) level, steps are being undertaken on IAS issues, as indicated by the Commission's Communication (COM(2006) 216 final) - which stressed the need to substantially reduce the impact of invasive alien species and alien genotypes on EU biodiversity, and highlighted the need to develop specific actions including an early warning system - and the Commission's Communication 'Towards an EU Strategy on Invasive Species' (COM(2008) 789 final). An essential part of this strategy is the development of an Early Warning and Information System (EWIS) for alien species in Europe, which has been the subject of a 2010 EEA technical report (Genovesi *et al*. 2010). Of course a European EWIS would not be complete without Western Balkan countries. For this reason a workshop has been organised with a selection of concerned people from West Balkan countries with the objective to exchange ideas, share information about current legal and technical situations in Western Balkan (WB) countries and Europe, and discuss future steps on the issue.

The workshop was organized by the European Environment Agency (EEA) in cooperation with IUCN/SSC Invasive Species Specialist Group (ISSG). The organizers invited three experts from each WB country with different backgrounds, and particularly from the administrative sector (i.e. a representative from both the Ministry of the Environment or related institution, and the Ministry of Agriculture) and the research sector. Some leading experts from WWF MedPO who have already been involved in, or informed on, recent policy activities at EU or Western Balkan level had been also invited.

Objective

The workshop - held in Zagreb, Croatia on 28-29 October 2010 - pursued the following key objectives:

- to share information on invasive alien species within EU and neighboring countries,
- to review the information available on invasive alien species in Western Balkan countries,
- to discuss possible approaches for future activities and collaborations in view of the establishment of a European EWIS.

The Zagreb workshop was thus a preliminary step aimed at encouraging and supporting the establishment of a EWIS in Western Balkan countries, to be coordinated and/or integrated to the European system which is being developed. The workshop represents a follow up of other related initiatives carried out by the EEA and ISSG in the last months, such as the mentioned publication of a dedicated report and the organization of similar international workshops in Ireland (see *http://www.nobanis.org/events_EW.asp*) and Turkey (Fernández-Galiano and Brunel 2010). In particular the first workshop was aimed at the implementation of an EWIS in the context of the NOBANIS network in Northern and Central European countries, while the workshop in Turkey – among the other things – has started the discussion for the establishment of EWIS in Mediterranean and North African countries.

Challenges, needs and future steps

The workshop, characterized by a number of presentations, an excursion in the field and a round table, was aimed at discussing - and possibly at finding an answer – to three key questions:

1. What are the challenges for managing invasive species in the Western Balkan Region?
2. What are the necessary elements for a strategy to facilitate regional cooperation?
3. What are the steps to establish regional collaboration and promoting action?

Although there were differences among countries and sectors in terms of challenges, needs and future steps, the participants reached some common conclusions. A brief summary of the main conclusions is reported below.

The Zagreb workshop participants:

1. Recognize the existence of invasive alien species (IAS) as a major driver of biodiversity loss and socio-economic impacts, and as a main cause of diseases in humans, animals and plants;
2. Stress the importance of regional cooperation for sharing information and other scientific and technical resources as a necessary means for effective implementation of measures to prevent, eradicate, and control IAS;
3. Are aware of the need to tackle biological invasions by implementing the existing guiding principles and guidelines, and particularly the CBD guiding principles, the European Strategy on alien species published by the Council of Europe (under the Bern Convention), and all relevant policy documents developed by key organizations and institutions such as EEA, ISSG, WWF and EPPO;
4. Encourage – with the active support of the EEA and the ISSG – all concerned actors (such as governments, the scientific community, conservation practitioners, local NGO's, national plant protection organizations, environment agencies and other appropriate stakeholders) to publicize and implement the recommendations below which are the key results of discussions from the Zagreb workshop:
   a) Recognize and promote regional coordination of action toward IAS in Western Balkan countries;
   b) Encourage and support the inclusion and integration of Western Balkan countries in the EWIS being developed in Europe;
   c) Promote the development and implementation of EWIS, at both the local and regional level, on the basis of the technical document realized by the EEA in cooperation with ISSG (Genovesi *et al*. 2010);
   d) Raise awareness among governments and international bodies on the urgent need to tackle the problem of IAS by implementing effective strategies based on sound legislation and by providing the required resources;
   e) Promote the existence of flexible mechanisms of early response, by guaranteeing the availability of sufficient human and financial resources;
   f) Establish, with the technical support of ISSG, a network of concerned people, such as experts, representatives of national authorities, NGO's and international organizations as well as identifying national focal points;
   g) Support and promote the realization of harmonized national and local inventories on IAS, integrated with other European information systems, by raising awareness on the benefits of open access information systems on biodiversity related issues;
5. As an immediate follow up, promote voluntary mechanisms and undertake concrete steps to start up networking activities within Western Balkan countries by:
   a) Creating a list of contact people and institutions with their roles and activities under the coordination of the ISSG;
   b) Urging the EEA as a leading coordination body to initiate, in cooperation with ISSG and WWF MedPO, a Western Balkan regional network to at the least identify the possibilities of establishing such a network;
   c) Support initiatives in the Western Balkan region aimed at the development of reviews on (invasive) alien species at either the regional or country level[1].
   d) Seek the support from existing *fora* on initiatives such as RENA, Mediterranean initiatives, including relevant EU institutions and funding mechanisms (e.g. IPA, GEF) to establish a regional network and identify implementation bodies in Western Balkan countries;
   e) Explore ways (e.g. through further regional workshops) to set up a regional secretariat and promote capacity building of all stakeholders, from government and expert institutions to the relevant NGOs;
   f) Take the opportunity of the network being developed to increase the level of sharing information – both at the Balkan scale and to the larger European context - on IAS related initiatives carried out, such as national or local monitoring schemes, risk assessments, control and eradication projects, management plans and national strategies;
   g) Maintain contacts with other existing networks such as ISSG, NOBANIS, NEOBIOTA, DAISIE etc. or proposed networks such as Mediterranean, and Black sea, etc.

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[1] Four experts from the WB countries have proposed the initiative to run up the review and/or checklist of IAS in the Western Balkan region: Predrag Simonovic (Serbia, Belgrade, Faculty of biology) for the alien (invasive) fish species, Vladimir Dzabiriski (FYR Macedonia, Skopje, Faculty of agriculture and forestry) for IAS in agriculture and forestry, Vesna Macic (Montenegro, Kotor, Institute for marine biology) for IAS in marine area and Milica Rat (Serbia, Novi Sad, Faculty of sciences) for IAS of plant

Regional call for action to control biological invasions in the Lake Tanganyika basin

Geoffrey Howard and Saskia Marijnissen

From 29-31 March, a meeting was organised in Bujumbura, Republic of Burundi by the UN Development Programme (UNDP) / Global Environment Facility (GEF) Project on Lake Tanganyika, in collaboration with the Lake Tanganyika Authority (LTA) and the International Union for Conservation of Nature (IUCN).

The meeting was part of the continuing collaborative efforts by the riparian countries Burundi, Democratic Republic of Congo, Tanzania and Zambia to address the threats posed by invasive species in the Lake Tanganyika basin. Key stakeholders from the four countries were brought together to discuss ways to monitor, manage, and control biological invasions.

Lake Tanganyika is one of the African Great Lakes. It is a hotspot of aquatic biodiversity, harbouring hundreds of species of fish that are found nowhere else in the world, as well as endemic species of snails, crabs, shrimps, sponges, and many other taxa. The catchment basin of Lake Tanganyika encompasses several forest reserves and national parks, including Gombe Stream and Mahale Mountains in Tanzania, which serve as refuges for some of the few remaining populations of chimpanzees in the region. The basin furthermore contains extensive wetland areas, including the deltas of the Rusizi and Malagarasi Rivers, which are recognised according to the Ramsar Convention on Wetlands of International Importance and which provide key habitats for a wide diversity of waterbirds and other native species.

Fig. 1. Participants of the Regional Workshop on Monitoring, Management and Control of Invasive Species in the Lake Tanganyika Basin, Bujumbura, Burundi, 29-31 March 2011. Photo: A. Gashaka/LTA

Fig. 2. Water hyacinth invading the delta of the Ntahangwa River as it enters Lake Tanganyika in Burundi. Photo: G.Howard/IUCN

Biodiversity in Lake Tanganyika and its catchment basin is increasingly at risk from biological invasions. A biological invasion occurs when a new species is introduced to a new area where it spreads causing significant damage to biodiversity and productivity of natural and agricultural ecosystems. Multiple species of invasive plants and animals are already present in Lake Tanganyika and its basin, and there is great concern for dispersal as well as for introduction of other (potentially) invasive species.

One of the invasive species of concern is the water hyacinth (*Eichornia crassipes*), which came to Africa in the 1880's and has since then caused tremendous damage to freshwater ecosystems in the East African region, including Lake Victoria. Water hyacinth was known as a decorative water garden plant in urban areas near the lake for many decades but then observed in the northern parts of Lake Tanganyika in 2003, and has been rapidly spreading since. Other aquatic plants that are currently invading the lake as well, including Water cabbage (*Pistia stratiotes*) and Red water fern (*Azolla* spp). All these introduced, floating and invasive weeds can reduce oxygen and sunlight, exclude other aquatic species, and provide a harbour for vectors for human diseases such as malaria and the snail vectors for human bilharzia.

Other threats are occurring on land, where plants such as *Mimosa* spp., *Lantana camara* and the Mexican sunflower (*Tithonia diversifolia*) are increasingly gaining terrain, overtaking other plants and reducing available habitats for wildlife as well as reducing agricultural productivity.

Great concern also exists for future invasions, particularly of freshwater crayfish that have been introduced for aquaculture purposes in the region. Crayfish are notorious for their ability to escape, disperse, rapidly reproduce, adapt to new environments, and feed on a wide range of other animals and plants. The Louisiana crayfish (*Procambarus clarkii*) has been observed near Lake Kivu in Rwanda, while the Red claw crayfish (*Cherax quadricarinatus*) has invaded several water bodies in Zambia in the Zambezi catchment. There is great risk that the crayfish will reach the Lake Tanganyika basin, which would pose a significant threat to endemic species diversity.

Fig. 3. *Mimosa diplotricha* invading a riparian are of Lake Tanganyika in Burundi and encroaching on a maize plantation. Photo: G. Howard/IUCN

Figure 4. Water hyacinth invading shallow waters of Lake Tanganyika in a riparian area of Bujumbura, Burundi. Photo: G. Howard/IUCN

It is not too late to manage invasive species in the Lake Tanganyika basin. Action can be taken to prevent them from spreading and causing further damage to ecosystems and local people. Stakeholders from the riparian countries have recognized the threats of biological invasions, and are keen to address them. By ratifying the Convention on Sustainable Management of Lake Tanganyika, the governments of Burundi, DR Congo, Tanzania and Zambia agreed to prevent, control and eradicate invasive species. As a result of the commitment of the riparian countries, as well as the capacity that already exists in several of these countries to manage invasive species, Lake Tanganyika provides a perfect opportunity to focus on the protection of an entire ecosystem.

During the meeting, discussions took place on the extent of existing biological invasions, and the need to monitor the presence and future spread of invasive species in the Lake Tanganyika basin. The riparian countries will need to develop a clear structure for the monitoring process, as well as ways to enhance regional cooperation. It was emphasized that prevention is less costly than management or control of biological invasions. Therefore, regional bio-security mechanisms are needed at the external entry points between countries, including across the lake.

The participants of the meeting discussed strategic use of combinations of mechanical, chemical and biological control to manage existing invasions such as those of water hyacinth, *Lantana camara* and *Mimosa* spp. The participants also discussed the need to raise awareness about existing and potential future biological invasions at all relevant levels - ranging from local communities to politicians and members of the Lake Tanganyika Authority.

With support of the UNDP/GEF Project, the IUCN project will implement several pilot activities in the Lake Tanganyika basin to demonstrate measures to manage and control invasive species. The initial pilots will take place in the northernmost part of the lake basin, near the capital of Burundi where multiple invasions of aquatic and terrestrial plants are present. The IUCN will work in close collaboration with the Lake Tanganyika Authority, the Burundi National Institute for the Environment and Nature Conservation (INECN) and local NGO's. Concurrently, further support will be provided for awareness raising, monitoring, management and control of invasive species at the regional level.

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Removal of an introduced tilapia species from a wadi in the United Arab Emirates

Christophe Tourenq, Maral Khaled Shuriqi, Moaz Sawaf and Emma Smart

*In February 2008, the non native invasive Mozambique tilapia (*Oreochromis mossambicus*) was introduced to the waterfall pool of Wadi Wurayah, a unique freshwater ecosystem in the Emirate of Fujairah, United Arab Emirates (UAE). Because of the potential impact of the species on the freshwater ecosystem, eradication operations were attempted in June and October 2008, including non-chemical methods and the piscicide Rotenone. From the initial 15 individuals counted in April 2008, the tilapia population increased by 8,106% to reach 1,231 individuals. In total, juveniles and fry represented 67%, small adults less than 10cm: 31.5%, and large adults more than 10cm: 1.5% of the total removed population. Along with Mozambique tilapia, four other alien species were recorded from the waterfall pool: "shark fish" (*Pangasianodon *sp.), catfish (*Plecostramus *sp.), koi carp/goldfish and an aquarium Poecillid, the black molly (*Poecilia sphenops*). Following treatment, the pool was checked regularly and after 56 weeks aquatic invertebrate and amphibian populations were beginning to re-establish and there was no signs of all life stages of the non-native species. The native* G. barreimiae *population recovered as well but unfortunately, adult tilapias were again observed one year later. Recommendations include the implementation of protection of Wadi Wurayah with warden control combined with an awareness campaign to highlight the significance of the introduction of non native species to natural environments in the UAE.*

Introduction

Ecosystems of the Arabian Peninsula and the United Arab Emirates (UAE) in particular, are often regarded as simple vast desertic and unfertile, with basic food chains, low primary production and little or no value at all from a biodiversity point of view. However, a wide variety of habitats typifies the region, from coral reefs to high mountains, including coastal mangroves and wetlands, permanent or temporary freshwater rivers (*"wadi"* in Arabic), extensive sand dunes, salt plains (*"sabkha"* in Arabic), acacia savannah plains, inland gravel outwash plains. These habitats host a unique and remarkably adapted fauna and flora (Hellyer and Aspinall 2005, Tourenq and Launay 2008). Because of harsh climatic and environmental conditions, the invasion by alien species on land has been contained until recently to man-made habitats in this region. However, since the 80s, the increase in human population and economic wealth, plus the encroachment of natural habitats through agricultural and residential development, are effecting the containment.

For ten years now, species highly invasive and classified as amongst the "100 of the world's worst alien invasive species" by the Invasive Species Specialist Group of the World Conservation Union (ISSG-IUCN; http://www.issg.org/database), such as the red-eared rlider (*Trachemys scripta spp*.) and tilapia (*Oreochromis spp*.), have been found in wadis in the UAE (Feulner 1995; Tourenq and Shuriqi submitted). "Tilapia" is the generic name of a group of cichlids endemic to Africa. The group consists of three aquaculturally important genera: *Oreochromis, Sarotherodon* and tilapia that have been farmed throughout the tropical and semi-tropical world since the last half century. Today, all commercially important farmed tilapia belong to the genus *Oreochromis* including Nile tilapia (*Oreochromis nilotica nilotica*) that represents more than 90 percent of all commercially farmed tilapia outside their native range (Gupta and Acosta 2004). Less commonly farmed species are blue tilapia (*O. aureus*), Mozambique tilapia (*O. Mossambicus*) and the Zanzibar tilapia (*O. urolepis hornorum*). Tilapias were first observed in permanent freshwater pools of Wadi Wurayah, Fujairah emirate, UAE, in February 2008 (G. Feulner, pers. com.). In March 2008, 6 adult tilapias (*Oreochromis spp*.) were spotted and two weeks later, 15 tilapia individuals were observed by snorkelling.

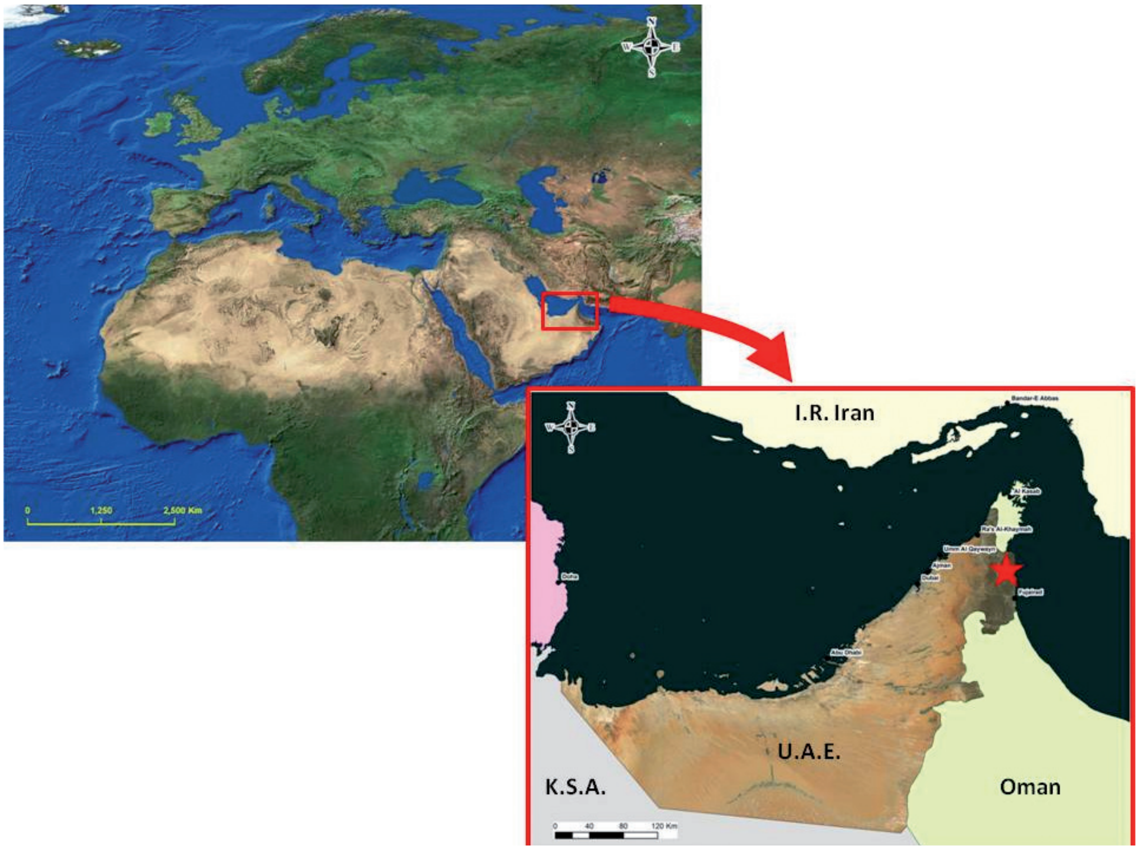

Fig. 1. Location of the study area (indicated with a red star).

At the end of April 2008, fry were recorded for the first time, indicating that tilapia reproduction was ongoing. In common agreement with the local authorities, a removal operation was attempted to remove this highly invasive alien species to preserve the integrity of the unique freshwater ecosystem of Wadi Wurayah catchment basin that had since been declared officially protected in March 2009 by the government of the Fujairah emirate. This paper gives an account of the removal operation.

Methods

Characteristics of the area

Most of the information below is extracted from EWS-WWF (2006) and Tourenq *et al*. (2009).

The Wadi Wurayah catchment basin expands from UTM 2815831.815 (North) to 2800263.544 (North) and 420127.757 (East) to 430850.218 (East) between the towns of Kohr Fakkan (Sharjah Emirate) and Bidiyah (Fujairah Emirate) on the Oman Gulf Coastline (Fig. 1). The whole catchment is about 129 km? in area and has a maximum elevation of 956 m.a.m.s.l. The catchment contains 371 separate streams of 301km total length and the dendritic drainage branches from six main wadis. Wadi Wurayah lies within the priority WWF Global 200 Ecoregion (Ecoregion 137, Arabian Highlands and Shrublands), sheltering a rich diversity of rare and endangered mountainous and freshwater habitats and species (http://www.worldwildlife.org/wildworld; Olson and Dinerstein, 1998).

The climate of Wadi Wurayah is characteristic of a hot, hyper-arid mountain desert environment. Temperatures are highest during the period of April to October, and are coolest from November to March. In summer, typical daytime temperatures can reach almost 50ºC. The atmospheric relative humidity (RH) varies between less than 1% in summer between April and August and 100% during autumn-winter (September-January) corresponding to night dew formation. As with the rest of the country, annual precipitation is highly variable; the majority of rainfall events occur during winter months (October-April). The area receives an average annual rainfall that provides a total of 18.7 Mm?/yr available water with an average of 2.24 Mm?/yr occurring as run-off. Because of the particular geology of the area, this creates a unique hydrogeological system in the UAE of perennial streams, falls and pools slightly alkaline with a mean pH value of 8.3 (range 8.1-9.1) and mean temperatures ranging from 22 to 28ºC owing to their diverse physical nature and location. With such characteristics, Wadi Wurayah freshwater ecosystems host a unique native fauna in UAE and the region, including the regional endemic threatened wadi fish: *Garra barreimiae* (Feulner 1995; Tourenq *et al*. 2009).

Fig. 2. Pools where tilapias were introduced. Photo EWS-WWF

The location of the waterfall pool where non-native fish species were introduced is the water body most frequently visited by tourists within Wadi Wurayah National Park. It can be reached by four-wheel drive vehicles along the wadi bed or by foot from the car park on the adjacent plateau. The waterfall pool is located at the downstream point, where surface water is found in the wadi and is rather physically isolated from the rest of the freshwater system by an 8 metre high waterfall that prevents the fish from moving naturally upstream (Fig. 2). The waterfall pool is a combination of two joined pools: a "bottom pool" of 9 m in length by 7.5 m width with an average depth of 2.83 m (range: 2.54-3.25 m) and a "upper pool" of 14 m in length by 12.5 m width with an average depth of 1.22 m (range: 0.89-1.60 m). Temperatures of the pools ranged between 20°C and 27°C, dissolved oxygen between 9.34 mg/l and 9.41 mg/l, conductivity between 515μS/cm and 535 μS/cm and pH between 7.3 and 8.4.

Removal of tilapia using non-chemical methods

Several methods exist for the removal of introduced non-native species of fish from natural water bodies. Fish can be physically removed by nets, traps or electrofishing, however this last method may not remove small, juvenile individuals and the fish may re-establish.

Water can also be removed from the water body through pumping, damming or diversion, although this is not easily feasible with large or flowing habitats as in this particular case. Before using chemical methods that would risk eradicating all the aquatic life in the pool infested with tilapia, an effort to rescue the maximum of the native *G. barreimiae* population was attempted using conventional trapping methods. Bottle trapping, net sweep, lifted net, fish line and hooks methods were used first on 18th June 2008 and on 27th October 2008 before application of chemical methods. The most successful method was bottle trapping: recycling normal plastic bottles where the top of the bottle is cut and placed back in the bottle but inverted with the lid removed to form a trap (Fig. 3). Originally two litre bottles were used, however these were only efficient at trapping individuals below a certain size as a result five gallon bottles were used in addition. The traps were baited with bread.

The second method used was a net sweep. Eight people were involved in the sweep; two sweeping the net, one making sure the net didn't get caught on the bottom and the remaining five trying to catch them using a net. However due to the small size and speed of the fish, and their ability to escape in small crevices, the sweep method was not efficient. The deeper part of the pool was also too small for a boat sweep and too deep for a hand sweep. A lifted net approach was used. The net was out-stretched horizontally and bait placed above the net. The idea was that the fish would swim into the middle and the net could be lifted to enclose the fish into a small section of the net where they could then be caught using a hand net. Three juveniles were caught with this method. The fish swam too fast and/or were too small. In addition, the mesh size 5mm was too big for some of the smaller fish.

An attempt was also made to 'chase' the fish into traps and into the large net for a more successful sweep. However this method was very ineffective as the fish just swam under or over the hand nets. The conventional fish line and hooks method was successful in catching the large breeding adults. However it was very slow and time consuming. Three people caught five fish in a two hour period. In conclusion, physical removal of tilapia by non-chemical methods was time-consuming and ineffective and limited to the middle size ranges of individuals.

Fig. 3. Non chemical methods used to remove tilapias. Clockwise: fish net, hook and line and bottle trap (containing two juvenile tilapia and a native *Garra barreimiae* in the forehand). Photos EWS-WWF / Laura Bates

Removal of tilapia using the piscicide Rotenone

Chemical piscicides can be used to kill fish species, this is also lethal to native fish species and impacts on invertebrate communities but it removes all life history stages (including eggs) so is the preferred method for absolute, complete removal of an alien fish species (see numerous examples in *http://www.issg.org/database*, and Clearwater *et al*. 2008).

Rotenone is a naturally occurring chemical obtained from the roots of several tropical and subtropical plant species belonging to genus *Lonchocarpus* or *Derris* used in solution as a pesticide and insecticide. It is classified by the World Health Organization as moderately hazardous (WHO 1992). It is mildly toxic to humans and other mammals, but extremely toxic to insects and aquatic life including fish due to the fact that the lipophilic Rotenone is easily taken up through the gills or trachea, but not as easily through the skin or through the gastrointestinal tract. When properly applied, it is lethal to all fish stages from eggs, larvae to adults (Marking *et al*. 1983). The compound breaks down when exposed to sunlight. In soil and water, its half-life in both is between one and three days. Nearly all its toxicity is lost in five to six days of spring sunlight, or two to three days of summer sunlight. It does not readily leach from soil and it is not expected to be a groundwater pollutant.

Rotenone was purchased in derris powder formula; the amount to be administered was determined by calculating the volume of the pool which was estimated to be approximately 400m^3. The amount to be used was slightly increased to ensure complete removal of the non-native fish species. Points of applications were chosen according to the flow of water and to enhance a better mixing and distribution of the piscicide in the system. As the area is frequented by tourists, the area was cordoned off using fluorescent tape and warning notices were erected indicating that a hazardous chemical was being used. The Rotenone powder was diluted in water and detergent added to facilitate dissolution and mixing. Facemasks, gloves and protective eyewear were used during mixing to minimize the risk of inhalation or exposure to the skin. About 60% of the total Rotenone was applied in the first dose: 40% was poured from above the waterfall and 20% from the margins of the lower pool. The waterfall flow was used to assist mixing to ensure the chemical penetrated into the deeper waters of the top pool and fish could not escape by swimming into untreated waters. The remaining 40% of the total Rotenone was applied 90 minutes after the first dose; approximately 50% was poured into the flow above the waterfall and 50% to the lower pool. Diluted Rotenone solution was poured into the outflow from the lower pool where the water continues in a shallow stream covered with dense reeds. This area was treated separately to ensure no small fish were able to shelter amongst the vegetation and then potentially re-populate the main pool later. Observations were made to monitor the action of the Rotenone including the time the first mortalities occurred and clarification that all life stages were removed. The pool was monitored for 72 hours following treatment to remove dead fish and prevent access to the water by the general public. Fish collected were counted, sorted into three size classes and weighed.

Results

Introduced species

Tilapias were first observed in February 2008 (G. Feulner, pers. com.). On the 24 March 2008, 6 adult tilapias (*Oreochromis spp*.) were spotted and two weeks later (April), 15 tilapia individuals were observed by snorkelling. At the end of April 2008, fry was recorded for the first time, indicating that tilapia reproduction was ongoing (Table 1).

Table 1. Chronology of tilapia's population in the Wadi Wurayah waterfall pools in 2008.

Date	Notes	Observer
February	Adult tilapias observed in bottom pool	G. Feulner (pers. com.)
28th March	6 adults swimming in bottom pool	EWS-WWF
11th April	15 adults; territorial behaviour by males observed by snorkelling. Fry observed in bottom pool	EWS-WWF
Early June	5 adults, including one dead	G. Feulner (pers. com.)
18th June	146 adults caught using trapping methods in both bottom and upper pools	EWS-WWF
6th July	Territorial males spread all over both bottom and upper pools; aggressive interactions with *Garra barreimiae* observed.	EWS-WWF
27-28th October	1,084 individuals killed using chemical and non-chemical methods	EWS-WWF, Fujairah Municipality

After examination of the characteristics of individuasl caught during the removal operation in June and October, we attributed the species discovered in Wadi Wurayah to Mozambique tilapia (*Oreochromis mossambicus*). Some breeding males clearly showed a dark coloration, with white lower parts on the head, including throat, lower lips, lower parts of cheeks and opercles, and red margins to dorsal and caudal fins (Fig. 4). However, since tilapias are known to hybridize, we cannot exclude that more than one species was present in the Wadi Wurayah pools. Along with tilapia, four other alien species were recorded from the waterfall pool (Fig. 4): "shark fish" (*Pangasianodon sp.*), catfish (*Plecostramus sp.*), koi carp, an ornamental domesticated variety of the common carp (*Cyprinus carpio*), and an aquarium Poecillid, the black molly (*Poecilia sphenops*).

Removal of tilapia

After eight hours of attempting to remove tilapias using non-chemical methods on 18th June 2008, 146 tilapia were captured. The majority of the catch comprised juveniles and small adults less than 10cm (93% of the catch; Table 2).

The bottle trap method was initially successful, however after an hour the adult tilapias stopped swimming into the trap. Conversely, the *G. barreimiae* were consistently swimming into the traps the whole day, making them a relatively easy fish to catch. On 27th October 2008, 784 tilapias were removed prior to the treatment using non lethal trapping methods (Table 2). Fry and juveniles were 82% of the catch.

After application of the Rotenone on the 28th October, 300 more tilapias were recovered of which 51% were fry and juveniles. A total of 1,084 Tilapia were removed using both non-chemical methods and Rotenone from the contaminated pools, representing a biomass of almost 5kg. Juvenile tilapias (less than 5cm) represented 73% of the total population in numbers and 33% in weight. Large adult tilapia (> 10cm), presumably the original colonisers, represented just 1% of the total individuals, but 12% of the total biomass.

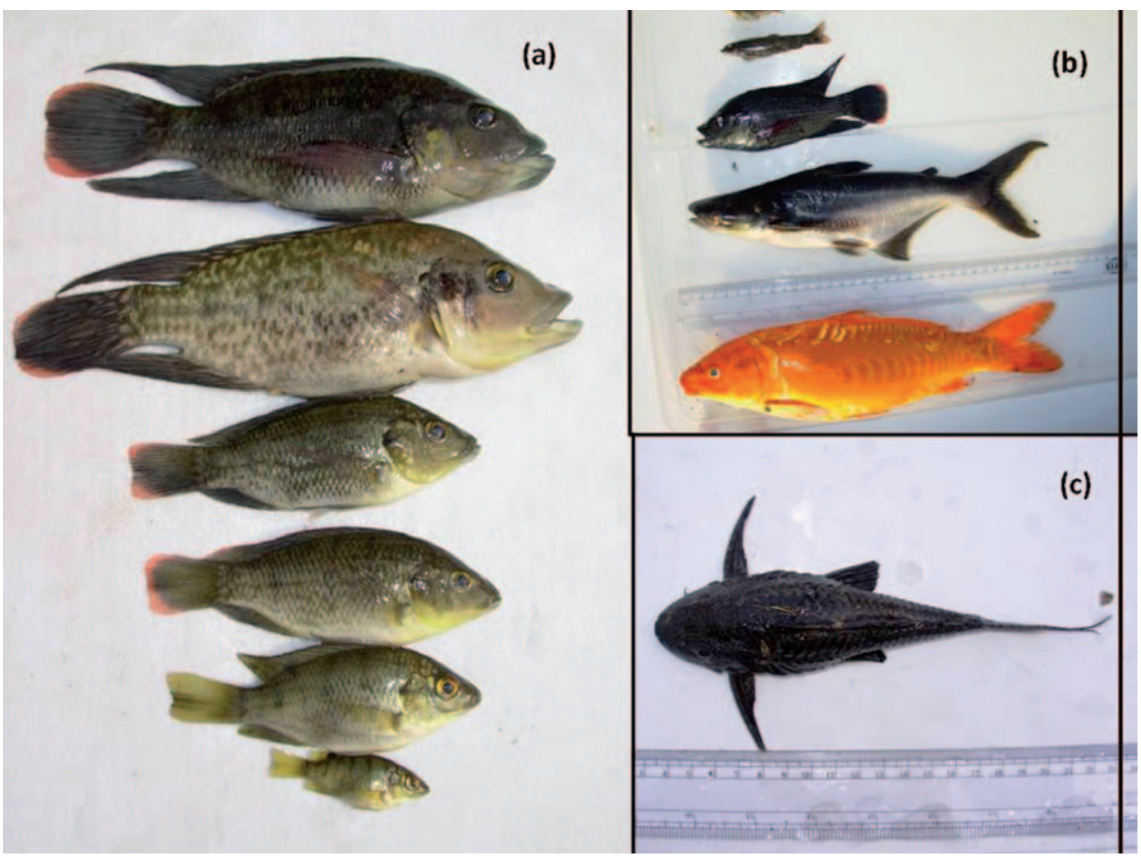

Fig. 4. Tilapia and introduced fish species: (a) different stages of Mozambique tilapia (*Oreochromis mossambicus*) captured in 2008; (b) from top to bottom: *O. mossambicus, Pangasianodon hypophthalmus, Cyprinus carpio,* and two native *Garra barreimiae* at the top for comparison; (c) *Plecostomus sp.* Photos EWS-WWF

Table 2. Total numbers and weight of individuals collected during the tilapias removal

	Class size (Weight in grams)			
	< 5 cm	**5 – 10 cm**	**> 10 cm**	**Total all sizes**
18.06.08 (non-chemical methods)	29 (n.a.)	106 (n.a.)	11 (n.a.)	146 (n.a.)
27 - 28.10.08				
Non-chemical methods (pre-treatment)	644 (1,340)	135 (1,600)	5 (420)	784 (3,360)
Rotenone (post-treatment)	152 (310)	146 (1,240)	2 (160)	300 (1,566)
Total pre- and post-treatment	*796 (1,650)*	*281 (1,840)*	*7 (580)*	*1,084 (4,926)*
Total removed	**825**	**387**	**18**	**1,230**

In total, between the 3 days of removal operation, juveniles and fry represented 67% of the total population removed, small adults less than 10cm: 31.5% and large adults more than 10cm: 1.5%.

On the basis that 15 tilapias were observed in the waterfall pool in April 2008, and with the hypothesis that the monitored pools were a "closed system" (*i.e*. no more tilapia were introduced and removed since the early colonisation) and supposing that the use of Rotenone achieved the total eradication of the population of the contaminated pool on 28th October 2008, the total population would have been:

1,084 + **146** (removed the 18th June) **+ 1** (found dead early June 2008; Table 1) = **1,231 individuals**

Considering that the 15 individuals observed on the 11th April constituted the pioneer population, the growth rate (PGR) of the tilapia population in Wadi Wurayah pools can be calculated as:

PGR = (Population at the end of the period –Population at the beginning of the period)

Population at the beginning of the period =

(1,231 – 15) / 15 = 81.06

The population increase was then 8,106 % in 214 days, with an average of 38% per day.

The total cost (including staff) of two days non-chemical treatment and of one day Rotenone treatment was estimated at 6,900 USD and 5,000 USD respectively. The purchase and shipping of the Rotenone represented 27% of total cost of the chemical treatment.

Follow-up observations during and post-treatment

The pool was checked regularly during the eradication operation and over a four week period following the Rotenone application. During the operation, mortality of aquatic Coleoptera larvae and Gastropods was observed, as well as tadpoles of the Arabian toad (*Bufo arabicus*). We did not record any Odonata larvae as well as adult toad casualties. No fish, aquatic invertebrates or tadpoles were observed during the four week period following the treatment and the adult amphibian population appeared to be unaffected. Algal growth was rapid in the absence of grazing fish, approximately 25% algal cover was observed after 14 days. After 8 weeks, there were still no signs of any introduced fish. Aquatic invertebrates were observed, including Ephemoroptera (mayflies), an indicator of good water quality, as well as Coleoptera and Gasteropoda. Tadpoles were observed as well. The *Garra barreimiae* population recovered subsequently. However, in October 2009, adult tilapias were observed again in the treated pools.

Discussion

Freshwater ecosystems are rare in the Arabian Peninsula. They host a remarkably unique and adapted fauna surviving in one of the harshest regions of the planet. As an example, in addition to the endangered *Garra barreimiae*, Wadi Wurayah Protected Area alone hosts ca 44% of the terrestrial plants (ca 300 on 688), 42% of the terrestrial mammals (20 on 48), 24 % of the terrestrial reptiles (13 on 53), 17 % of the birds (74 on 435) and the only two amphibian species recorded for the country: the regionally endemic Arabian (*Bufo arabicus*) and Dhofar (*B. dhufarensis*) toads (Tourenq *et al*. 2009). With a rich dragonfly community, including the only record for the country of the bloody darter dragonfly (*Crocothemis sanguinolenta*) (Feulner *et al* 2007), the area is also a stronghold for invertebrates: to date, 30 species of Arthropod new to science have been found in the Wadi Wurayah Protected Area alone, including three species of aquatic beetles (Coleoptera), and five species of mayflies (Ephemeroptera), whose larvae are water-dependent (van Harten 2008, 2009, 2010).

Also taking Jordan and Palestine into account, up to 46 species of freshwater fish can be found in the Arabian Peninsula, of which 18 are primary and two secondary endemic freshwater fish. At least, four of these native species must be considered critically endangered; some of these species' distribution being restricted to a single wadi or sinkhole (Krupp 1983; BCEAW-EPAA. 2003, Krupp and Budd 2009, Krupp 2010). In addition to *G. barreimiae*, the UAE hosts two other native species: *Cyprinion microphthalmum* and *Aphanius dispar* (Feulner 1995).

For decades now, non-native freshwater fish species have been introduced in aquatic ecosystems of the Arabian Peninsula and the UAE in particular. Alien fish species were introduced for a variety of reasons: to improve the 'aesthetics' of a water body, for sport fishing, as a food source, biological control (e.g. against mosquito larvaes), aquaculture, and even socio-cultural and ideological motives (Goren and Ortal 1999, Tamir 2010). If molly (*Poecilia spp*) and tilapias were already recorded in the UAE (Feulner 1995), to our knowledge, it is the first time that "shark fish" (*Pangasianodon sp*.), catfish (*Plecostramus sp*.), and koi carp, (*Cyprinus carpio*) have been recorded in wadis of the country. The constant temperature and oxygenation of the waterfall pools create suitable conditions for the survival of these species during the summer when water body temperatures can exceed 30^{o}C in the sun.

The Mozambique tilapia (*O. mossambicus*) is particularly invasive, ranking first in globally introduced fish that cause the most detrimental consequences to the ecosystem's biodiversity (Casal, 2006) due to its reproductive mechanisms and ubiquitous feeding habits. The high proportion (67%) of small, juvenile tilapia removed indicated the high reproductive activity of the introduced species in the pool with an estimated 8,106 % of population increase in 8 months. Similar to tilapias, the common carp. and its various forms, are considered among the top 100 of the "World's Worst" invaders by ISSG-IUCN (http://www.issg.org/database) because of its high reproductive rate and its tendency to either directly predate on all forms of native aquatic organisms, or indirectly by modifiying habitats and disrupting the ecosystem functioning (i.e. increase of turbidity and reduction of photosynthese process, destruction and uprooting of the aquatic vegetation). Both species introduction directly lead invariabily to the reduction of species diversity and extinction of native species (Zambano *et al*. 2006).

In addition to the physical, trophic and functioning alterations on the wadi ecosystems of Arabia, introduced species can also carry parasites, pathogens and diseases susceptible to infect native fish and amphibian species (Kiesecker *et al*. 2001).

The advantages of non-chemical eradication methods were that they were easily selective, with no direct effects on the ecology of the whole habitat as plant, invertebrate and amphibian populations are not disturbed and no threat to human health. Non-chemical methods were significantly cheaper than the chemical method. The main disadvantage with non-chemical methods was the incapability to completely remove all individuals at every life stage. The removal of tilapia using some non-chemical methods was time-consuming, inefficient and inconsistent as fish became wary after several hours and the catch rate fell significantly. Larger individuals in particular were difficult to remove and as these represent the breeding adult population, the pool would be quickly re-colonised. The methods tested were biased towards juveniles and small adults; fry were too small to be removed efficiently so these would just grow and supplement the population. By using non-chemical methods, populations can be temporarily reduced, consequently slowing reproductive potential. Overall, they are not successful as a long-term solution.

The application of the piscicide Rotenone was found to be a highly efficient method for the complete removal of fish species. Whilst potentially not suitable for all freshwater environments, it was an effective and appropriate technique for the monitored pools in Wadi Wurayah due to their isolation with the up-stream wadi system. The main advantages of using Rotenone was the complete removal of every fish at all life stages, the rapid break down of the chemical in sunlight and due to the constant flushing from the waterfall flow, the chemical was not be retained in the system for more than a few days. The disadvantages of using Rotenone included the high cost for the derris powder and shipping (27% of total costs), mortality of the aquatic invertebrate and tadpole populations and the potential threat to human health during handling and mixing of the concentrated powder. The location and size of the waterfall pool attributed to the success of the Rotenone treatment. A relatively small water body combined with the absence of vegetation and a waterfall to facilitate mixing and complete distribution of the solution.

The growth of filamentous and epilithic algae following the removal of fish was attributed to the sudden absence of grazers. The *Garra barreimiae* population recovered to levels before tilapia introduction. However, the observation of adult tilapias in the treated pools one year later suggested a human assisted introduction of the alien species. Introductions are generally not a malicious act and, from interviews of visitors carried out during the treatment, it is simply a lack of understanding and a desire to 'beautify' the area by putting large, colourful fish into the pools. During the eradication operation, we met people who admitted to having introduced the fish for beautification reasons. Nevertheless, it is not clear if all the fish originated from this source: local residents mention tilapias farmed and released in wadis by the "Ministry of Agriculture" (currently Ministry of Environment and Water) staff. An eradication campaign is currently planned but it must be accompanied with an environmental awareness campaign for the public and staff form the different authorities to highlight the severe negative consequences of putting exotic species into natural environments. As the area is officially protected since March 2009, it would benefit highly from the implementation of the relevant legislation (including fines for introducing non-native species). The deterrent effect of such legislation, plus the presence of wardens to enforce the laws during peak recreational times (i.e. weekends) should decrease the likelihood of future problems.

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New publications

Invasion biology journal NeoBiota launched!

The journal NeoBiota is a continuation of the former NEOBIOTA publication series founded in 2002 by the working group with the same name. This group meanwhile evolved into 'NEOBIOTA, the European Group on Biological Invasions' and decided in 2010 to transfer the publication series into the open-access, peer-reviewed journal NeoBiota. Previous volumes of NEOBIOTA (1-8) can be viewed at:
http://www.oekosys.tu-berlin.de/menue/neobiota/

NeoBiota builds upon the tremendous success of its sister journals ZooKeys (www.zookeys.org), PhytoKeys (www.phytokeys.com) and BioRisk (www.biorisk-journal.com) and offers numerous innovative ways to publish and disseminate information on processes of biological invasions and consequences of alien species. NeoBiota has an editorial team of highly renowned specialists in the field and the support of a scientific community which have hosted the biennial NEOBIOTA conferences. Current members of the editorial board are Sven Bacher, Tim Blackburn, Laura Celesti-Grapow, Milan Chytr?, Franz Essl, Emili Garcia-Berthou, Stephan Gollasch, Vojta Jaro?ik, Jonathan M. Jeschke, Johannes Kollmann, Moritz von der Lippe, Michael L. McKinney, Laura Meyerson, Jane Molofsky, Wolfgang Nentwig, Bruce Osborne, Petr Py?ek, Wolfgang Rabitsch, Alain Roques, Richard Shaw, Daniel Sol, Mark van Kleunen, Mark Williamson. All papers are open access and free to read, download, print, and distribute. NeoBiota is more than a journal. It is a linked environment built upon its own content management software. Linking is provided at the internal level (within an article, within the journal, or within the publishing platform of Pensoft) and to external resources (Global Biodiversity Information Facility, Encycloppedia of Life, Biodiversity heritage Library, PubMed and PubMedCentral, Morphbank, International Plant Names Index, Tropicos, The Gymnosperm Database, ZooBank, Wikipedia, Wikispecies, etc.) through a dynamic web profile of each taxon mentioned within a paper (www.ptp.pensoft.eu). Geo-referenced localities can be mapped within taxon treatments or for the entire paper. The journal can be followed on Twitter, Facebook, Mendeley, and other social networks. NeoBiota is published in four different formats: (1) high-resolution, full-color print version (2) PDF identical to the printed version; (3) HTML to provide links to external resources and semantic enhancements to published texts for interactive reading; (4) XML version compatible to PubMedCentral archiving, thus providing a machine-readable copy to facilitate future data mining. Neither restriction nor charges are imposed on the use of colour illustrations.

The open access fees will be waived for all submissions published in the first four issues of NeoBiota. The standard fee of 200€/paper up to 10 pages and 20€/additional page will be reduced by 25 % until the journal will be covered by the ISI Web of Science. All papers published in the first issues will be later ISI covered and will have an Impact factor when the journal receives it. In this way, we would like to offer everyone interested in invasion biology the chance to test the efficiency and innovative approach to publication and distribution of information on biological invasions and alien species in NEOBIOTA! We welcome yours and yours colleagues' manuscript submissions.

Ingolf Kühn (Editor in Chief) and Lyubomir Penev (Managing Editor)
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Strategy against invasive alien species Reunion Island

Awareness of the impact of invasive alien species in Reunion Island, has emerged in the early 1980s, with a real political determination to tackle this serious ecological threat. But if many actions were taken in the last twenty years, both in scientific research and in field operations by various organizations, until now all these actors could not refer to a shared global strategy for Reunion Island. As the Grenelle of Environment organized by the

French government, pointed the importance of the topic of invasive alien species in the overseas regions, the MEEDDM (Ministry of Ecology, Energy, Sustainable Development and Sea) has sent to the DIRENs (Directions Régionales de l'Environnement) in 2008, elements of framing to implement local strategies against invasive alien species in the Overseas Regions, as Reunion Island. In addition, the new National Park of Reunion Island aims to safeguard the natural heritage and, therefore, identify the main threats to biodiversity of its territory. Developing a local strategy against invasive alien species is a major step to achieve this goal. Through mobilization of all local actors, working on the problem of biological invasions, the first shared strategy against invasive alien species has been drafted and has been validated by the "Conseil Scientifique Régional du Patrimoine Naturel" (CSRPN) in June 2010. It includes four approaches: (1) prevention of new introductions of invasive species, (2) early detection / eradication and control / containment measures, (3) awareness, communication, education and training, (4) governance and animation. Based on this strategy, a "Programme Opérationnel de Lutte contre les Invasives" (POLI), with 15 action sheets was established with the aim to stop the erosion of biodiversity in Reunion Island.

The number of exotic plant species in Reunion Island is currently estimated in more than 2000 species of which nearly 130 are reported invasive, against only 892 native species. For fauna, 65 exotic species are already present, including more than 20 invasive alien species.

Internet link:
http://www.reunion.ecologie.gouv.fr/rubrique.php3?id_rubrique=360
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National strategy for invasive alien species for Finland

The objective of the national strategy on invasive alien species (IAS) is to reduce the damages and risks caused by invasive species to the Finnish nature and socio-economic wellbeing (e.g. human health and sustainable utilisation of natural resources). The aim of the strategy is to take action at the earliest stage possible with a view to prevent the entry of new invasive alien species into Finland and also stop the further spread of already established IAS within the country. Such a preventative approach aims to ensure that negative impacts of IAS can be addressed in the most efficient and cost-effective manner. According to the group of national experts responsible for developing the national strategy, in the beginning of 2011 there were a total of 157 IAS permanently established in Finland which cause clearly identifiable, direct or indirect damage. A significant share of these species (108 species) are agricultural and forestry species. Of the remaining species 5 occur in the territorial waters of Finland in the Baltic Sea, 6 are land vertebrates, 24 are plant species and 9 are indoor pests. In addition, about 128 potential IAS for Finland were identified. These include 1) established alien species that may be locally harmful or 2) IAS not yet established within the national borders but considered harmful at European or global level, with a high probability to arrive to Finland. Finally, a number of the established and potential invasive alien species were considered as particularly harmful IAS requiring immediate action at the national level. These species include quarantine pests (37 species), Japanese rose (*Rosa rugosa*), crayfish plague (*Aphanomyces astaci*), giant hogweed (*Heracleum mantegazzianum*), Spanish slug (*Arion lusitanicus*) and mink (*Mustela vison*).

The proposal for a national strategy on invasive alien species puts forward 16 measures to reduce the harmful impacts of IAS in Finland. These include improving and harmonising the legislation on IAS; establishing a national IAS board to oversee the implementation of the strategy; initiating communication and training actions on IAS; establishing a national IAS information portal and setting up a system for early warning and monitoring of IAS; establishing a national risk assessment system for IAS;

increasing research on IAS (especially related to risk assessments); taking necessary actions that enable prevention of the entry of IAS to Finland and rapidly eradicate IAS entering the country; encouraging voluntary action on IAS by citizens; securing adequate financing to implement the agreed IAS measures (e.g. developing new, innovative sources); preventing the spread of IAS through Finland to neighbouring countries; and taking actions to prevent the spread of IAS also at the global level. In addition, a set of targeted measures are suggested to prevent damage caused by IAS in the Baltic Sea and inland waters, and to address the negative impacts of invasive alien land vertebrates and plants. One of these specific measures concerns the eradication of giant hogweed in Finland within the next 10 to 20 years.

The proposal for a national strategy on invasive alien species was submitted to Minister of Agriculture and Forestry Sirkka-Liisa Anttila on 30 March 2011.

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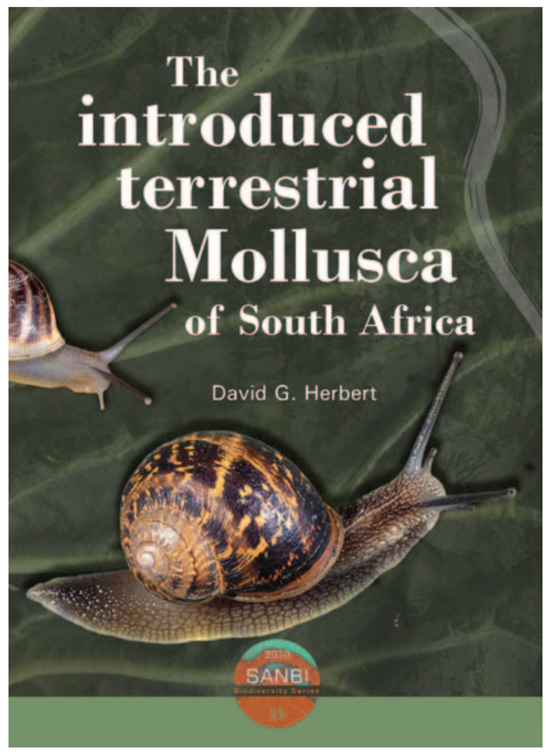
The introduced Terrestrial Molluscs of South Africa

In this book written by David Herbert the alien terrestrial mollusc fauna of South Africa is comprehensively reviewed. 34 species are considered to have been introduced to the country, of which 28 are considered established and 13 of these invasive. The history of introduction and recording is summarised and patterns of introduction are analysed. Introductions continue at a rate of approximately two species per ten years, with no evidence of levelling off. The agriculture and horticulture industries are considered to be major contributors to the introduction and spread of alien species. The composition of this alien fauna shows considerable similarity with that known from southern Australia, reflecting the similar colonial history of the regions and climatic matching with regions of origin in western-Europe and the Mediterranean. Each species is discussed in terms of its distinguishing features, habitat preferences, date of introduction and first record, native range and global distribution, distribution in South Africa, pest status, and similarity with indigenous species. Further taxonomic notes and biological observations relating to behaviour, reproduction and parasite transmission are included where relevant, and references to sources of additional information are provided. In addition, some consideration is given to potentially pestiferous species which are not yet known to occur in South Africa, but which represent a significant future introduction risk. New records: *Discus rotundatus*, *Hawaiia minuscula*, *Vitrea contracta*, *Aegopinella nitidula*.



The book is published by SANBI, the South African National Biodiversity Institute and its cost is US25.00. It is available either by e-mail at book-shop@sanbi.org.za or from the online bookshop http://www.sanbi.org/index.php?option=com_virtuemart&page=shop.advanced_search&Itemid=203

Events

BIOLIEF 2011 – 2nd World Conference on Biological Invasions and Ecosystem Functioning

21-24 November 2011 - Mar del Plata, Argentina

The first BIOLIEF meeting, held at Porto, Portugal on October 2009 gathered an attendance of nearly 300 people from more than 20 countries. With BIOLIEF 2011, we expect to further strengthen the communication among the large international community of scientists devoted to the study of biological invasions. BIOLIEF 2011 will be a forum for the presentation, discussion, and synthesis of research on biological invasions in its broadest sense. The conference will place a particular emphasis on studies concerning the impact of invasive species on ecosystem functioning and/or services, irrespective of taxonomic groups or ecosystem types. However, studies on any other ecological aspect of biological invasions will also be welcome. Topics such as the spread of invasive species into ecosystems, the biogeography and history of species introductions, and the community- or species-level impact of biological invasions will also have an important coverage in the final conference program. For updates on this meeting follow us in Facebook (*www.facebook.com/BIOLIEF*) or join our mailing list by sending a message to *biolief@grieta.org.ar*

8th European Vertebrate Pest Management Conference

26-30 September 2011 - Berlin, Germany

The European Vertebrate Pest Management Conference is a biennial meeting of people interested in various aspects of vertebrate pest management. The conference is a forum for all involved in basic research in vertebrate biology and ecology, methodology and legislation and their application in wildlife management. Its focus is on Europe but participants and contributions from other regions of the world are welcome.

Symposia

- Evolutionary ecology & management of vertebrate pests
- Fertility control
- Invasive vertebrates
- Management of birds
- New tools & methods-anticoagulants and alternatives
- Population dynamics
- Rodenticide resistance
- Zoonoses

Details of the conference and abstract submission process are at *www.evpmc.org*

Weed management in arid and semi-arid climate and Weed management systems in vegetables

4-8 September 2011 – Huesca, Spain

The aim of the workshop is to create a forum where people involved in research in weed management in vegetables and in arid and semi-arid agro-ecosystems weed control can come together and exchange results, experiences, and information and establish new contacts and networks. The workshop aims to be informal and to stimulate as much discussion as possible among participants. As in past workshops, we will combine plenary scientific sessions with oral and poster presentations, concurrent round-table discussions, and a final plenary session (reports on round-table discussions, directions for the future, etc.). Session chairs will briefly introduce each poster associated with the theme of their oral session presentations. One of the topics is: Invasive weeds: control and quarantine regulations. For additional information: *http://huesca.ewrs.org/*

2nd Workshop of the EWRS working group: weed mapping

21-23 September 2011 - Jokioinen, Finland

The aim of the workshop is to learn about the latest weed mapping activities in Europe. This includes both micro- (plots, small areas) and macro-mapping projects (regions, countries). Methodology will be emphasized as we would like to find tools to allow us to combine data for an European overview of weed distribution and to derive conclusions and trends from our existing data. Information on the workshop are available on the working group's web site: http://www.ewrs.org/weedmapping/default.asp

The Second Conference of the Near East Weed Science Society

16-19 November 2011 - Amman, Jordan

The Near East Weed Science Society (NEWSS) tends to hold its second conference with cooperation of the local and international supporting parties during the period 16-19 November 2011 (Sunday-Wednesday) at the University of Jordan, Amman, Jordan. The conference will include sessions for presenting research papers, posters . Keynote speakers will be invited to address recent issues in weed science. Conference themes include:

• Weed management in Agricultural systems

• Parasitic weed management

• Aquatic weed management

• Resistance to herbicides

• Allelopathy

• Private sector activities in weed management

A tour to agricultural and historic sites will be included. For additional information: http://www.ju.edu.jo/sites/NEWSS/Pages/conferencesandworkshops.aspx

11th World Congress on Parasitic Plants

7-12 June 2011 - Martina Franca, Italy

The Congress continues a long tradition of regularly assembling the world's experts on parasitic plants for professional and scientific meetings, which started in 1973 with the first international meeting in Malta. The Congress will bring together scientists representing a wide spectrum of disciplines, research approaches, and geographical representation of parasitic plant research. Assembling specialists with different perspectives, all focused around the common theme of plant parasitism, provides a stimulating environment for learning, exchanging ideas, and connecting with old and new colleagues. Parasitic plants - both the weedy species that severely constrain agriculture and the many other nonweedy species - present unanswered questions with regard to their origin and evolution from non parasitic plants, population structures and dynamics, evolutionary pathways towards crop parasitism, ecology, physiology, molecular biology, and the structure, function and development of their history. The Congress will include presentations at the cutting edge of parasitic plant research and management of parasitic weeds. A major emphasis in the Congress will be the fostering of interaction among participants. For additional information: http://ipps2011.ba.cnr.it/

The VI International Weed Science Congress

17-22 June 2012 - Hangzhou, China

The scientific programme will consist of invited keynote presentations, discussion sessions on topical issues, educational sessions led by distinguished scientists, and oral and poster sessions based on offered contributions. One of the five congress days will be used for field excursions. The SPC is dedicated to developing a scientific programme with a truly global scope that will be attractive to scientists as well as graduate students in Weed Science and related disciplines. You are invited to send ideas and suggestions for specific sessions (for example, within innovative and emerging research areas). to Per Kudsk, Chairman Scientific Programme Committee (*per.kudsk@agrsci.dk*). The suggestions received will be regularly uploaded we to the IWSS webpage (*www.iwss.info*). The second circular that will be released in June 2011 will contain the full list of sessions and a call for abstracts. For additional information: http://www.iwss.info/Vith_congress.asp

International Congress for Conservation Biology (ICCB 2011)

5-9 December 2011 - Auckland, New Zealand

The Society for Conservation Biology International Congress for Conservation Biology (ICCB) is recognized as the most important international meeting for conservation professionals and students. ICCBs are a forum for addressing conservation challenges. They are the global venue for presenting and discussing new research and developments in conservation science and practice. Most importantly, they connect our global community of conservation professionals and serve as the major networking outlet for anyone interested in conservation. Attendance has increased 60% in the past six years, reaching 1600 at our 2007 meeting in South Africa. Each year the congress features numerous symposia, concurrent sessions, workshops, short courses and field trips. Past symposia have included such diverse topics as: the population biology of invasive species; global amphibian decline; how to integrate conservation research into policy; indigenous communities and conservation; comparing marine and terrestrial ecosystems–implications for conservation theory and practice; the application of top predator distribution to the design and efficacy of reserves; and real-world social and economic solutions to preserve biodiversity. Our attendees are concerned with the science and practice of conserving biological diversity. The ICCB is always global in scope, bringing together conservation professionals and students from every sector of the field including the biological and social sciences, management, policy and planning. Attendees work for universities, government agencies, non-governmental organizations, private foundations and organizations and publications. They are scientists, students, managers, decision-makers, writers and other conservation professionals from throughout the world. Please visit the website for the most current information on the meeting: www.conbio.org/2011

11th International Conference on the Ecology and Management of Alien Plant Invasions

30 August - 3 September 2011 – Szombathely, Hungary

The series of EMAPi meetings began with the International Workshop on the Ecology and Management of Invasive Riparian and Aquatic Plants held at Loughborough University in the U.K. in 1992. The initial focus of EMAPi on Europe and North America quickly extended to other parts of the World which later led to EMAPi becoming truly global in its reach. Speciality of EMAPi is that it covers all aspects of plant invasion from pure science to management of plant invasions. Following this tradition, the title of this conference is 'Bridging the gap between scientific knowledge and management practice'. Oral and poster sessions, as well as the social events and excursions make good possibilities for personal contacts and information exchange between nature conservationists, land use managers and researchers. Scientific topics cover almost every aspects of plant invasion, thus everyone will be able to find something relevant during the scientific part.

The aims of the conference are: 1) to make possible show new results and exchange information related to any aspects of plant invasions. 2) To facilitate the communication between scientists, stakeholders and practioners working on nature conservation, land management or any other area influenced by plant invasion

Topics of EMAPi 2011:

1. Introduction pathways and spread of invasive specie
2. Biology and ecology of invasive plants
3. Interaction with other trophic levels: enemies and mutualists
4. Genetics and evolution of invasive plants
5. Invasion patterns and invasibility of habitats
6. Impact of plant invasions (on plant communities, on other trophic levels, and on ecosystem functions and services)
7. Mapping, inventories, databases and internet resources
8. Risk assessment, prioritisation, policy and programs for early detection and rapid response
9. Managing alien plant invasions through policy and vegetation management practices (including practical management experiences)
10. Restoration and rehabilitation after successful control
11. Plant invasion in a changing world: relationship between plant invasion and other global change components (climate change, pollution, eutrophication and land use change)
12. Communication and outreach
13. Networking and international cooperation

You are kindly recommended to visit the website of the conference frequently for up-to-date http://www.emapi2011.org/

3rd International Symposium on Weeds and Invasive Plants

2–7 October 2011 – Ascona, Switzerland

The primary objectives of the symposium are: 1) To provide a forum for the presentation and discussion of recent and ongoing research in field of invasive plants. 2) To foster communication among young and old researcher and practitioners involved in disciplines as biology, mapping, early detection, control, public relations and legal bases encompassed by invasive plants.

The focus of this symposium is to stimulate and advance discussion among researchers in weed biology and plant invasions. Both weeds in agro-ecosystems and natural environments are of increasing concern in our society. For additional information: http://invasive.weeds.ascona.ewrs.org/

XIII International Symposium on Biological Control of Weeds (ISBCW 2011)

11-16 September 2011 - Hawaii, USA

The ISBCW is a quadrennial international gathering of scientists and managers working in biological control of weeds. International cooperation is central to the practice of biocontrol, and this forum provides a critical opportunity for colleagues to reconnect, share experiences, and plan future collaborations. The meeting in Hawai'i will provide a unique opportunity to take stock of a century of biocontrol in the Pacific and examine emerging issues, including climate change, that affect invasive plant management across the globe. For additional information: http://isbcw2011.uhhconferencecenter.com/

The Fisheries Society of the British Isles 2011 Annual International Conference

18-22 July 2011 – Bournemouth Dorset, UK

The conference aims to establish a pan-continental base of knowledge and to provide scientific evidence towards the development of sustainable conservation for fish communities. Biological, behavioural and genetic responses of fish will be amongst the many indicators presented as evidence of ecological impacts on freshwater ecosystems. Rehabilitation/ restoration programmes and policy frameworks will be presented as examples of fish conservation in action.

The Fisheries Society of the British Isles invites you to its annual, international conference on "Fish Diversity and Conservation: Current state of knowledge" to take part in the debate. One of the main themes is "The role of introduced species in the decline of fish diversity". For additional information: *http://www.fsbi.org.uk/2011/index.html*

The 15th Australasian Vertebrate Pest Conference

20–23 June 2011 - Sydney, Australia

The Australasian Vertebrate Pest Conference is a not-for-profit event held every three years to bring together researchers, managers, students and policy makers dealing with pest animals. In 2011 the 15th meeting will be held at the spectacular Dockside Convention Centre, Cockle Bay Wharf, Sydney, Australia. The meeting is convened by the multigovernment Vertebrate Pests Committee and will be hosted by the Invasive Animals Cooperative Research Centre and the New South Wales Department of Industry and Investment. Anyone working in the area or interested in animal control should plan on attending. New tools and methodologies will be discussed as well as the vital community aspects of pest animal control. Animal welfare and community attitudes to human-wildlife conflicts will be explored. As part of the conference a symposium on "Assessing and Managing Risks of Exotic Animals" particularly regarding issues of import and keeping and a symposium on "The management of vertebrate pests on islands" will be held. For additional information: *http://www.avpc.net.au/*

Seventh International Conference on Marine Bioinvasions

23-25 August 2011 - Barcelona, Spain

Entitled 'Advances and Gaps in Understanding Marine Bioinvasions', the conference will encompass the following themes:

- Development and tests of invasion theory
- Drivers of invasibility
- Patterns of invasion and spread at local, regional, and global scales
- Impact of bioinvasions on ecosystem structure and function, including the biology and ecology of invasive species
- New tools for identification, monitoring, risk assessment, and management

Learn more about the conference at the website: *http://www.icmb.info/*

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