# Aliens: The Invasive Species Bulletin

Newsletter of the IUCN/SSC Invasive Species Specialist Group

Issue Number 30, 2010

ISSG Invasive Species Specialist Group

IUCN

SSC Species Survival Commission

ISPRA Institute for Environmental Protection and Research

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**Front Cover Photo**
Laysan albatross (*Phoebastria immutabilis*), threatened by feral cats in Guadalupe Island, México.
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# Editorial

The 10th Conference of the Parties to the Convention on Biological Diversity (CBD COP10) is now over, and I am very pleased to say that the meeting was a success. The Parties agreed – among other points - on all key elements of the strategic plan for the next decade, including new targets to reduce the current pressures on the planet's biodiversity.

Several decisions taken in Nagoya address the problems caused by invasive species. Target 9 of the strategic plan requires that "By 2020, invasive alien species are identified, prioritized and controlled or eradicated and measures are in place to control pathways for the introduction and establishment of invasive alien species."

The COP also adopted a specific decision on the creation of an Ad Hoc Technical Expert Group for providing guidance on preventing further impacts associated with the importation of invasive species as pets, aquarium and terrarium species, as well as live baits and food. It is also important to note that the terms of reference of the expert group explicitly refer to the development of international standards on these issues; this was the object of many discussions, as it touches on the delicate issue of international trade.

Furthermore, invasive species were included in several other decisions, such as that on biofuels, which called on the Parties to carefully consider the risks of invasive species being used as biofuel crops.

So, a great deal of technical work to be done over the next few years! ISSG will ensure its support for the work that the CBD is called to do, and, at the same time track the fulfilment of the formal commitments made by world leaders in Nagoya.

*Piero Genovesi*, ISSG Chair


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# News from the ISSG

## Wildlife disease risk assessment (DRA) tool development workshop

Over the next twelve months CBSG, in collaboration with Reintroduction, Wildlife Health and Invasive Species Specialist Groups, will be leading an exciting new initiative aimed at advancing the way in which disease risks to wildlife are assessed and managed.

It is intended that this new disease risk assessment (DRA) resource will be built by an international network of stakeholders, including wildlife veterinarians, epidemiologists, ecologists, modellers and biologists. The goal will be an integrated package of disease risk assessment (DRA) tools, based on the best available science and technology, serving the global conservation community. This resource will constitute a major revision of CBSG's *Animal Movements and Disease Risk: A Workbook*, last published in 2005.

Beginning in 2012, this resource will provide the centrepiece for a global training programme in best practice DRA methodology for wildlife conservation professionals. A stakeholder workshop will provide the principal engine for tool development. This is currently scheduled for April 2011 and will be hosted by CBSG's Australasian branch in partnership with Auckland Zoo's New Zealand Centre for Conservation Medicine (NZCCM). In addition to this workshop an extensive programme of remote collaboration using virtual tools is envisaged, culminating in completion of the DRA resource in December 2011.

### Vision

An integrated package of new and existing tools for risk assessment, adapted for wildlife disease analysis and management and freely available to the global conservation community.

### Context

Disease is an increasingly serious threat to the sustainability of a growing number of wildlife species. The continuing expansion of human populations and their domestic animals into wilderness areas is also fuelling an upsurge of emerging and re-emerging diseases that cross former species boundaries while global warming is enabling the dispersal of disease vectors into new territories. The 'One World One Health' paradigm, and new disciplines like conservation medicine, have emerged in response to these trends and are designed to address the complexity of disease within a broader ecological context than the current individual species-approach that dominates Western human and veterinary medicine.

In addition to its significance to conservation, wildlife disease has economic and human health importance. Consequently, an expanding range of organisations and individuals are concerned with the assessment and analysis of risks associated with wildlife disease to assist with informed decision making - often with limited data. However, despite this growing interest in developing the science of conservation medicine, we lack a proper and coherent collection of qualitative and quantitative tools that the wildlife conservation practitioner can use to systematically assemble relevant data, objectively analyze disease risk, and confidently make informed management recommendations to improve population viability.

### History

The IUCN's Conservation Breeding Specialist Group (CBSG) recognised this need some years ago and led an initiative to develop new (and adapt existing) Disease Risk Assessment (DRA) tools, resulting in the publication of a Handbook in 2002.1 A summary of its contents accompanies this notice2. Since then there have been major advances in risk assessment science and technology and a parallel increase in interest in wildlife DRA among other SSC Specialist Groups, particularly the interdisciplinary groups such as Reintroduction (RSG), Invasive Species (ISSG), and Wildlife Health (WHSG) as well national biosecurity and wildlife conservation agencies. Consequently a review and revision of this publication – that aims to benefit from the wider perspectives of these groups and incorporate scientific and technological advances – is particularly timely.

### Timeline, Venue and Workshop Participants

The workshop will run over a 3.5 day period and is scheduled for mid-April, 2011 hosted by the New Zealand Centre for Conservation Medicine (NZCCM), Auckland Zoo, Auckland, New Zealand. Our aim is to bring approximately 20 participants together representing a mix of relevant expertise and end-users of disease risk assessment tools. This group will include representatives of the key stakeholders noted above, wildlife veterinarians, epidemiologists, ecologists, modellers, and biologists who wish to pool their knowledge and work collaboratively towards achieving this important goal.

### Process

Prior to the workshop a needs assessment questionnaire will be circulated to potential participants to help guide the content, structure and development of the DRA resource. Confirmed participants will also be asked to undertake a preliminary review of the Handbook in advance. At the workshop, following an introductory scene-setting session, participants will conduct a facilitated session to identify the strengths, weaknesses and gaps in the current Handbook. A process for addressing the weaknesses and gaps will be developed with the group who will then spend the rest of the workshop implementing this process. An editorial team will be selected to ensure continuity in style and consistency in content of the final publication. Working Groups will be tasked with delivering a post-workshop report to the editorial team by August 2011. A draft publication will be circulated to these groups for review with the aim of having a completed resource, including any additional training materials, by December 2011.

We are seeking expressions of interest from potential collaborators and are keen to hear from members of your network. All correspondence and requests for further information should be directed to Richard Jakob-Hoff at Richard@cbsgaustralasia.com

## The Pacific Invasives Initiative Resource Kit for Rodent and Cat Eradication

Invasive species are the most significant threat to island ecosystems and the people who depend on them for their livelihoods. In the Pacific Island Countries and Territories (PICTs), the shortage of trained personnel and limited access to the required information, processes and tools are major constraints to effectively managing the threat (see the Guidelines for Invasive Species Management in the Pacific: a Pacific Strategy for managing pests, weeds and other invasive species, Alan Tye, SPREP, 2009. http://www.sprep.org/att/publication/000699_RISS-FinalLR.pdf ).

The shortage of capacity is also identified in the National Biodiversity Strategy and Action Plans (NBSAPs) of many Pacific island countries. This is further emphasised in the National Invasive Species Action Plans (NISAPs) that have been developed to date. To effectively protect Pacific Island ecosystems there is a widespread need to develop greater capacity in invasive species management within the region.

Invasive species management is a complex and fast evolving discipline with new knowledge and skills constantly being developed from both research and practice. This is necessary to meet the new threats that are constantly appearing as a result of the increasing global movement of people and goods. Examples of this include the recently reported spread of termites to Fiji, the introduction of the small Indian mongoose into Samoa and, very recently, in New Caledonia and the ever increasing invasion of the little fire ant across the Pacific region.

A further challenge in responding to invasive species threats is the cross-sectoral nature of the problem: some sectoral activities provide pathways for invasive species while the negative impacts may be felt across many sectors. Fostering cooperation on invasive species management between relevant sectors is essential not only to integrate sectoral inputs but also to ensure an effective approach to this issue. For example, major benefits could be gained from leveraging knowledge and skills within sectors such as agriculture and forestry, which have a long history of managing pests and diseases in PICTs, and using these to augment the capacity of the environment sector. Also, broadening the perspective of production and economic sectors beyond pests and diseases that affect not only their immediate interests but also the environment will enhance PICTs defences against invasive species threats and maintain resilient ecosystems.

**About PII**

Since its establishment in 2004, the Pacific Invasives Initiative (PII) has become a leading capacity development organisation for invasive species management in the Pacific region (for details on the origins of PII and its establishment, please see the *Aliens* Newsletter Issue No. 26, 2008).

Our vision for the next 25 years is that "*The natural heritage and peoples of Pacific Island Countries and Territories are protected from the threats of Invasive Species by Pacific people"* and we aim to achieve this through our mission "*To strengthen the capacity of Pacific Island Countries and Territories to effectively manage invasive species threats*".

PII works with Pacific agencies to enhance their capacity for managing invasive species. Building long-term institutional relationships with the agencies that empowers confidence and encourages self-reliance is an essential component of PII's capacity development work. To date we have worked with many agencies government agencies and NGOs such as the Ministry of Natural Resources and Environment in Samoa and the Ministry of Environment, Lands and Agricultural Development in Kiribati, Palau Conservation Society, Conservation Society of Pohnpei, etc. We have been supporting these and other agencies on projects such as rat and pig control in New Caledonia; rat eradication in Fiji, Samoa, Palau, Kiribati, New Caledonia and French Polynesia; rabbit eradication in Kiribati (Fig. 1); mongoose incursion response in Samoa; island biosecurity training in Samoa and Fiji, weed project management training for several Micronesian countries and American Samoa.

We work at the individual, organization and regional levels to develop Pacific capacity for invasive species management and use a number of methods to achieve this (Fig. 3).

High staff turnover is a serious constraint to institutionalising invasive species capacity within agencies. To aid in overcoming this challenge, PII has been developing best practice processes and resources that will remain with the agencies even if staff move on, helping ensure continuity of effort (see below).

Our team is dedicated to ensuring that the region benefits from the expertise and experience being generated outside and within PICTs. We leverage significant contributions from research institutions, government agencies and commercial companies in New Zealand and elsewhere as well as assistance from members of the Pacific Invasives Partnership (PIP).

Fig. 1 Photopoints showing vegetation change following the successful rabbit eradication on Rawaki Island, Phoenix Islands Group, Kiribati. Photos: Ray Pierce

## About the Resource Kit

PII is in the process of developing a Resource Kit for Rodent and Cat Eradication which will be launched in early 2011. The Resource Kit is a practical guide which will assist project managers in developing and implementing rodent and cat eradication projects on islands in the Pacific and elsewhere. It provides a best practice project process and supporting tools to apply the process.

The PII Project Process encourages a stepwise approach to deal with the complexity of invasive species management and to maximise the chances of projects succeeding (Fig. 2). It also advocates that stakeholder engagement, maintenance of biosecurity and monitoring and evaluation are essential to sustaining the outcomes of any eradication project.


Fig. 2 The PII Project Process

Although the Resource Kit is targeted at eradicating rodents or cats, the process and many of the supporting tools can easily be adapted to the eradication of other invasive species.

The Resource Kit content has undergone three major reviews by world-leading invasive species eradication experts and potential users in the Pacific and is now nearing completion. The feedback received so far has been very encouraging and supportive. Feedback from the Pacific has further confirmed the need for such a resource and its usefulness; some of the tools are already being used in the Pacific.

PII is currently working with a leading service provider in information management and process improvement on the design and build of the Resource Kit website and CD-ROM. PII is also developing a 5-day training course for the Resource Kit to help project managers get the most out of the Kit. The training course will be designed and developed between early October and the end of December 2010.

The pilot training course is scheduled for early 2011 with the location yet to be determined, but Fiji is the preferred setting. Attendees will be invited from Pacific organizations that are planning, or in the process of conducting, cat or rodent eradication projects.

PII is grateful to The David & Lucile Packard Foundation for financial support and to the many individuals and organisations such as BirdLife Fi-

ji Programme, BirdLife International, Island Conservation, Nature Fiji, New Zealand Department of Conservation, Ornithological Society of New Caledonia and the Wildlife Conservation Unit of Kiritimati, Kiribati, for in-kind support received to date.

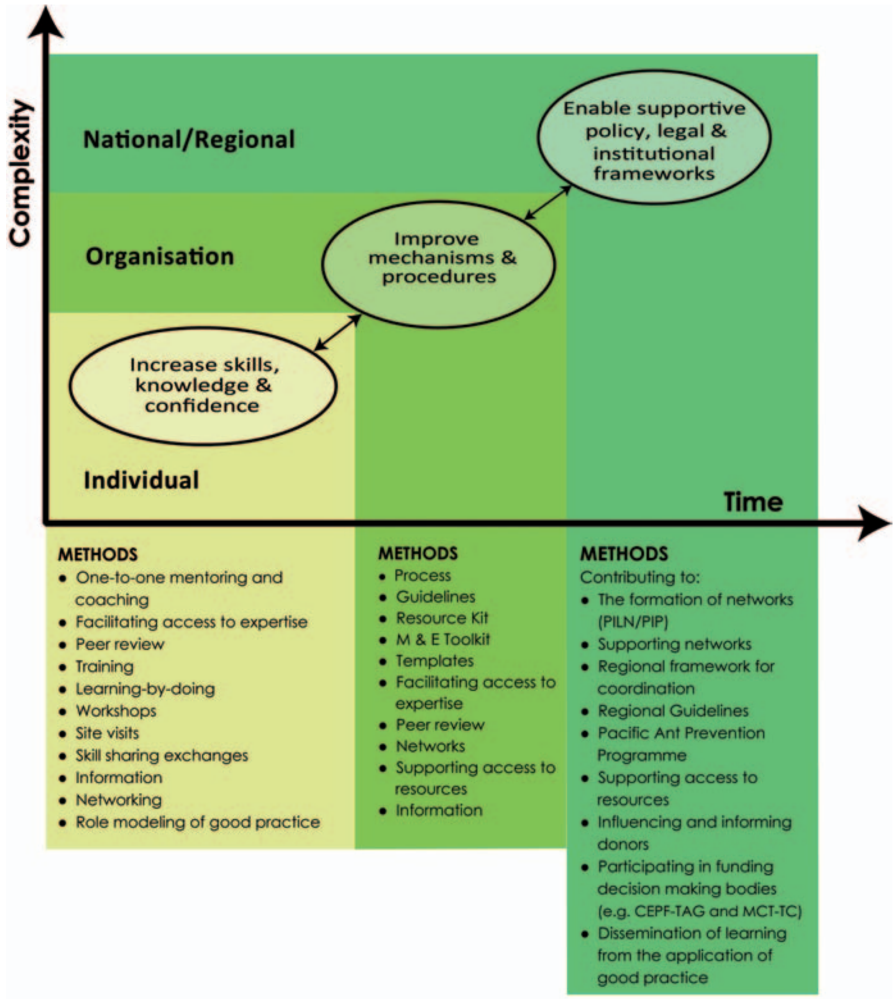


Fig. 3 PII Capacity development Framework (adapted from the Environmental Action Programme (ENACT), Jamaica

# ...And other news

## DNA fingerprinting helps map Island invaders

New research indicates there may be trouble on the horizon for Australia's unique and endangered marsupials and birds harboring in the relative safe-haven of Tasmania. The looming shadow is a breeding population of European red foxes.

Irrefutable evidence is mounting which confirms the identity of a small number of individual foxes in the island state. The challenge now facing the Invasive Animals Cooperative Research Centre is to use the research results to build population estimates to assist with control efforts.

In a scene that could have come straight from a television episode of CSI, Dr Oliver Berry, has been hard at work in a specialised wildlife forensic laboratory at the University of Western Australia, using a method commonly called 'DNA fingerprinting' to identify individual foxes in Tasmania.

Since March 2009, use of this ground-breaking Microsatellite DNA genotyping technology has demonstrated that nine male and four female foxes have recently been on the loose in Tasmania. Another two specimens are undergoing further testing to determine gender. Further analysis will establish if there is any relationship between the foxes, which may assist in developing population maps.

Dr Berry analysed the DNA from fox positive scats (fecal material) that had been identified by a team of specialists at the University of Canberra. This is no easy task when you consider the volume of scat material collected and sent to Canberra by the Tasmanian Fox Eradication Program. Over 5000 scat samples have been shipped across to date.

"The fact that we've identified at least two females indicates there's real potential for fox breeding in Tasmania. An established population of foxes will cause an ecological disaster for the Island's native wildlife, as well as cost agriculture dearly through loss of stock such as lambs," Dr Berry said.

No-one knows just how many foxes there are, but evidence of a Tasmanian fox population has been growing since the late 1990s. It is unproven how foxes arrived in the State, whether deliberately introduced or accidental introduction via such as cargo shipping – or a combination of both – but the foxes that are present pose a devastating threat to Tasmania's native wildlife.

Tasmania is the final refuge for a long list of species that have all but disappeared from the mainland, including the eastern quoll, bettong and Tasmanian native hen. Other species, such as the Eastern barred bandicoot, occur in high numbers in Tasmania, but are on the verge of extinction on the mainland largely due to fox predation. Foxes are also a significant threat to the iconic, and now endangered, Tasmanian devil and may back fill the niche left vacant as a result of the decimation of this species by the highly contagious Devil Facial Tumour Disease (DFTD). For the Tasmanian wildlife, the stakes are high.


Australia's wildlife has not evolved in the presence of foxes, and lacks adequate behavioral responses to avoid the predatory prowess of the fox. We have a chance to preserve these animals, but the clock is ticking.

Searching for physical evidence of fox activity poses a unique challenge in the Tasmanian landscape. Tasmania is an island of over 60,000 sq km and is a complex landscape that contains large areas of wilderness and other generally unpopulated areas. Given the foxes' secretive and elusive nature, combined with the current presumed low animal numbers, the likelihood of discovering evidence of fox activity is very low.

The new research findings provide important baseline data for greater understanding of the Tasmanian foxes and helps monitoring for evaluation of eradication success.

"The Fox Eradication Program faces an immense challenge in trying to achieve something that has not been done anywhere else in the world – eradication of the red fox before it is able to establish in the landscape," said Alan Johnston, Manager of the Department of Primary Industries and Water's Fox Eradication Program.

"To meet the challenge, we have been required to develop some novel methodology and employ an integrated eradication program that targets foxes in Tasmania and attempts to expose each and every one of them to risk," Mr Johnston said.

An important part of the Tasmanian fox eradication program is broadscale 1080 baiting. This is used to target areas of confirmed fox activity, locations of 'clusters' of fox sighting reports and highly suitable fox habitat within the state. Although no fox carcasses have been found following baiting programs, mainland experience shows that it is extremely rare to find a fox carcass, even after successful baiting in areas with high fox densities. It is generally believed that foxes go to ground or back to their dens to die.

The only way Tasmania will be successful in returning its environment to fox-free status will be through hard work, application of some novel technologies and, most importantly, if the Tasmanian community is able to make some tough decisions and persevere with the eradication effort.

Baiting can pose some danger to native fauna, but the Tasmanian program takes measures to dramatically reduce the risk. This includes burying baits deeper than native species usually dig and using a low dosage of 1080 poison. But 1080 poison has a shady history in Tasmania and there is much resistance to its use within the community.

Those involved in the eradication effort are constantly working to review and improve the methods. Ongoing program development means that further unpopular measures may have to be taken in the battle to eradicate foxes in Tasmania. Research is currently examining the use of alternative poisons, such as PAPP, and other methods of delivery, including M44 ejectors. Such new technologies may hold the future key to killing the last fox in Tasmania.

As the DNA analysis builds a better picture of numbers and locations, and eradication measures are refined, we can hope that the situation won't escalate to the stage where the evidence of an established Tasmanian fox population becomes irrefutable. By then, it would just be too late for some of Tasmania's native inhabitants.

For further information contact:
Andreas Glanznig
Chief Executive, Invasive Animals Cooperative Research Centre www.invasiveanimals.com

## The 2010 International Invasive Ant Management Workshop

An invasive ant management workshop was held at the CSIRO Tropical Ecosystems Research Centre in Darwin, Australia on 27-29 April 2010. The workshop aimed to facilitate networking among people from around the world involved in invasive ant management, as well as to improve the incorporation of research and ant biology into management. This event provided a perfect opportunity for researchers and managers to interact, share information and establish working relationships.

The workshop was attended by 54 people from 10 countries. It featured 36 presentations covering a wide variety of topics, from basic descriptions of ongoing ant management programs through to the latest research into invasive ant biology and ecology, as well as technology being developed for ant management. Such technology included high resolution helicopter-mounted sensors scanning for visual and thermal signatures of ant colonies from a height of 400 feet. If successful, this technology will allow the assessment of much greater areas for Red imported fire ant, *Solenopsis invicta*, than is possible using current ground-based methods.

A half day field trip gave delegates the opportunity to view numerous invasive ant species established in northern Australia, as well as to visit Howard Springs Nature Park which has been the focus of over a decade of invasive ant research, particularly focused on the African big-headed ant, *Pheidole megacephala*. Workshop participants were also shown the CSIRO Invertebrate Biodiversity laboratory which houses Australia's most comprehensive ant collection, containing 4500 Australian species and another 1500 from overseas.

The workshop didn't aim to produce conclusions or recommendations, rather stronger networking among ant management programs, and the forging of ties between researchers and managers. The high number of emails among delegates, particularly the dissemination of much "grey literature" after the event indicates that the workshop has been a great success. Many workshop presentations are available to all on the internet at *www.littlefireants.com* – go to the link displaying the workshop name.

For further information about the workshop contact:
Ben Hoffmann
CSIRO, Tropical Ecosystems Research Centre
Darwin, Australia
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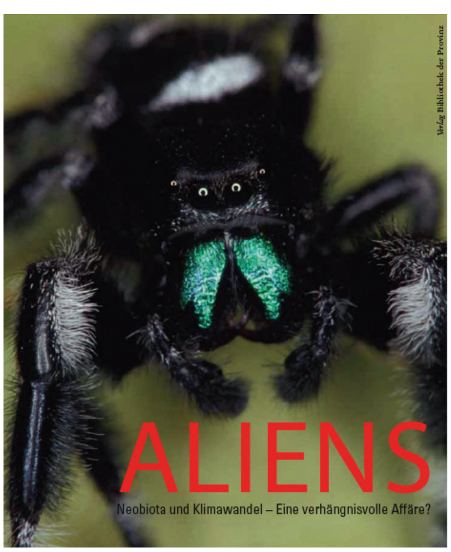
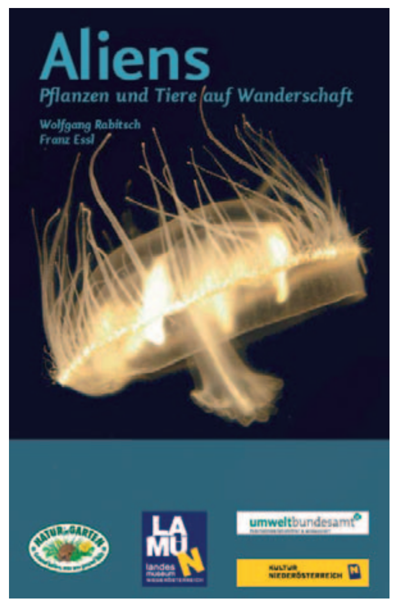
### Exhibition on Alien species in Austria

The Environment Agency Austria (Umweltbundesamt) developed and organized an exhibition on alien species for the Natural History Museum in St. Pölten, the capital of Lower Austria. On more than 500 qm exhibition space several aspects of biological invasions are shown and explained to a wider audience. The different pathways and impacts are presented with a focus to the situation in Austria, but also case studies from Europe and other continents are included as well as examples of European species being alien elsewhere.




The main part of the exhibition highlights selected examples of alien species in Austria, partitioned (in terms of content but also from an architectural perspective) into natural groups (e.g. plants, aquatic animals, invertebrates, vertebrates). Further, aspects such as climate change, health and management issues are discussed.

The exhibition is accompanied by two brochures. The "adult" version (88 pp.) includes most of the text and pictures of the exhibition; the "children" version (52 pp.) describes biological invasions for the young reader and includes games and riddles. Within the exhibition, a special room is devoted as "playground" for children with thematic games and puzzles and playthings. In addition, a scientific book was edited devoted to alien species and climate change (160 pp.). All materials are in German language.




Since the opening in March 2010 there was good media coverage and the exhibition is on display until February 2011, when it may move on to be shown at another museum (under negotiation).

Both publications can be ordered at the Landesmuseum Niederösterreich, St. Pölten, *shop@landesmuseum.net*

### Island Arks Australia

The probable extinction of the Christmas Island Pipistrelle bat as well as expensive efforts to control invasive species on many other islands provides evidence that a comprehensive and strategic island biosecurity regime is urgently needed for Australian islands. Specifically, a nationally consistent approach and standards is needed for the prevention of invasion, early detection and rapid eradication of organisms that threaten Australia's 8,300 island ecosystems.

A new proposal by a group of island conservationists suggests that for an initial modest investment Australia could establish a strategic framework for island biosecurity based on an assessment of biodiversity values and a risk assessment approach to potentially invasive non-indigenous species. Coupled to systematic planning approaches the initiative would provide a basis for maximizing island biodiversity conservation efforts and allocating resources efficiently to pest control strategies.

In simple terms the proposal requires; 1) establishing biosecurity priorities for all islands based on each island's ecological values and risk assessment, including estimates of the economic costs of eradicating likely invasive species; and 2) the development of regional biosecurity management systems for all islands; ensuring that high priority/risk islands have individual biosecurity management systems.

The initiative would lay the foundations for an effective, nationally consistent approach to island biosecurity that would assist directly in the prevention of extinction of hundreds of threatened species and ecosystems, and the protection of numerous globally significant populations of migratory species.

The detailed proposal for a National Island Biosecurity Initiative is available from the Island Arks web-site http://www.islandarks.com.au/.

For further information you can contact Ray Nias, TierraMar Consulting
*ray@tierramarconsulting.com*

## NEOBIOTA – the European Group on Biological Invasions

Europe has a long history in invasion studies. A wealth of studies on introduced species emerged in many European countries since the late 19th century. Although invasions had been recognised as a major threat to biodiversity, research on invasion topics was still highly fragmented into single disciplines at the end of the 20th century. There was virtually no exchange between plant and animal ecologists, neither between a considerable number of botanists and zoologists who systematically analysed changes in species composition and distribution patterns. Studies on terrestrial, freshwater and marine ecosystems were sharply separated as well, as were applied and fundamental research. Yet, overcoming of disciplinary borders was needed to link analyses of impacts and underlying mechanisms with assessments and subsequent actions.

### Formation and aims

NEOBIOTA was founded in 1999 in Berlin, Germany, as an informal association aiming at an enhanced integration of invasion research and policies directed at reducing the threats to biological diversity. Meanwhile, NEOBIOTA has evolved to the major pan-European group on biological invasions, representing a forum for exchange and discussion on all topics related to biological invasions as well as an interface between science, application and policies. The main tasks of NEOBIOTA are:

- Enhance communication and contact between scientists working on theoretical and applied aspects of biological invasions,
- Stimulate research on non-native species, their traits, distribution, related impacts and underlying mechanisms. Identify information deficits and coordinate efforts to fill them,
- Disseminate information on causes, mechanisms, and impacts of biological invasions and on management approaches.

### Biennial conferences

One major backbone of the NEOBIOTA activities are biennial conferences with a broad scope reaching from general theory to application. The first conference was held in Berlin in 2000, the latest in Copenhagen in 2010. The meeting in Vienna (2006) with 350 participants from 46 countries was the largest conference on biological invasions in Europe to date. Contributions by many participants from overseas strengthen the link between European research and activities from all other continents.

Some conferences resulted in resolutions aiming at the interface between science and policies. For example, the participants of the conference in Vienna adopted a resolution entitled "Biological invasions need a strong legal framework at the European level!". From discussions during the conference held in Copenhagen in 2010, recommendations emerged to the European Commission on the ongoing development of an EU Strategy on Invasive Alien Species. Proceedings of the NEOBIOTA conferences are published as NEOBIOTA volumes, with conference organizers serving as invited editors for particular volumes. This year, we came to the decision to transform the publications series NEOBIOTA into an international journal.

### Evolution of structures and outlook

One main characteristic of NEOBIOTA is its prevailing informal character. As there is no official membership, the group is open to all who work in the broad field of biological invasions. Since the first meeting, Ingo Kowarik serves as coordinator of the group, and Uwe Starfinger as secretary.

The evolution of NEOBIOTA to the major European group on biological invasions calls for a consolidation of its structures. In 2008 and 2010, during the conferences in Prague and Copenhagen, 52 representatives from 30 European countries were elected to the NEOBIOTA Council. The Council meets regularly at the NEOBIOTA conferences, i.e. at least every two years. The main aims of the Council members are to represent NEOBIOTA and to enhance the implementation of the aims of NEOBIOTA at the national scale. In Copenhagen, ten persons were elected to the NEOBIOTA Board. The members of the NEOBIOTA board, together with the chair, are the main contact group at the European level and will coordinate the future activities of NEOBIOTA.

We are confident that NEOBIOTA will continue to serve the scientific invasion community and will further on provide a European forum for advancing insights, ideas and actions on biological invasions.

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For further information:
http://www.oekosys.tu-berlin.de/menue/neobiota/

Kowarik, I. & Starfinger, U. (2009): Neobiota: a European approach. In: Py?ek P. & Pergl. J. (eds.): Biological Invasions: Towards a Synthesis. Neobiota 8: 21–28.

## From Science to Management: Biological Invasions in a Changing World - The 6th NEOBIOTA Conference in Copenhagen

There is strong scientific evidence and rising public awareness that humans have started modifying the Earth at an unprecedented scale. Global change is a complex set of interacting processes with climate, land use and transport as the most significant drivers. Biological invasions are an important component of global change, and invasive organisms have been described both as factor and symptom of local shifts in habitat conditions.

In mid September 2010, the 6th NEOBIOTA conference in Copenhagen focused on biological invasions in a changing environment (http://cis.danbif.dk/neobiota2010). This series of conferences has been hosted by various European research groups with expertise in biological invasions. The past conferences were held in Prague (2008), Vienna (2006) and Bern (2004). They have been attended by about 200–300 participants from 30–40 countries including experts from North America, Australia, South Africa and China. The conferences are supported by the European NEOBIOTA group which aims at providing a forum for researchers and environmental managers working on biological invasions.

The Copenhagen conference was again very well attended and provided a platform for discussing the latest scientific results and for networking among research groups. The meeting took a wide perspective including contributions from science and management with no bias to particular species groups, habitats or regions. It was supported by a number of outstanding keynote talks dealing with different aspects of invasions in a changing environment. Richard Hobbs (University of Western Australia) focused on interactions between invasion biology and restoration ecology, Jessica Hellmann (University of Notre Dame) discussed the consequences of climate change for biological invasions, Richard Mack (Washington State University) introduced indirect effects invasive plants have for human health by promoting human parasites and diseases, and Laura Meyerson (University of Rhode Island) presented options for management of invasive species in a changing world.

Various specialist sessions allowed for in-depth discussions on contrasting methodological approaches to biological invasions, including macroecological analyses, population modelling and molecular markers. There was also room for applied topics including impact, risk assessment, socio-economic aspects and control of invasive species in a changing world.

In conclusion, the conference showed that invasion biology is an innovative and dynamic scientific discipline with high significance for conservation and environmental management. Quick progress is made due to international collaborations, as demonstrated by results from the EU-funded DAISIE and ALARM projects.

Large data bases allow generalisations across taxa and geographical regions. Here, economy turned out as one of the main drivers for biological invasions. Increasingly sophisticated models enable an understanding of the patterns and processes during biological invasions, and they can be applied for risk assessment and management of these species.

However, talking to various participants the conference also demonstrated potential for improved communication between scientists and environmental managers. The methods and language of the former are often too complicated for local site managers and consultants, and thus they tend to conclude that the scientific results are not sufficiently relevant for them. Thus, scientists should become better in listening to the actual needs and problems of practitioners, and they should try to produce core results of their research in popular publications as done within the GIANT ALIEN project. Future conferences could try to establish a new type of interac-

tion sessions where a small panel of experts discuss current problems with environmental managers and non-specialists.
The Copenhagen conference offered also the opportunity for a discussion with invited people from the EU administration, the European Environmental Agency and applied scientists. This session cleared showed the challenge Europe faces in terms of developing a common strategy for invasive alien species.
So far the European efforts are heterogeneous and scattered, and enormous improvements will be needed to reach the standards New Zealand has achieved in the past years.
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## National invasive species strategy for Mexico

In Mexico, a National strategy oriented towards the prevention, control and eradication of invasive species has just been launched.
The aim is to contribute to the conservation of the natural capital and human wellbeing in Mexico, providing guidance for the coordinated participation and the active and responsible cooperation of all stakeholders involved in the implementation of actions to monitor, detect, control and eradicate invasive species.
In order to attend to the issue of invasive species, by the year 2020 Mexico will have efficient prevention, alert and response systems in place as well as instruments in accordance with a congruent legal framework able to prevent, mitigate, control and eradicate those species.

The National invasive species strategy for Mexico is now available online at
*http://www.conabio.gob.mx/invasoras/index.php/Portada*
An English translation of the core of the strategy is available on page 93.

# Invasive bird eradication from tropical oceanic islands

**Chris J Feare**

*The arrival of alien bird species on tropical islands can threaten components of their ecosystems and are therefore of concern. In addition, the existing presence of alien invasive birds on islands to which endemic birds are translocated to establish insurance populations can compromise the success of these introduced populations. Both eventualities can justify the eradication of the invasive birds but the methodologies for doing so are not well developed and so far only very small populations of oceanic island invasive birds have been successfully eradicated. All eradication attempts should therefore be fully documented to inform future investigations. In addition, the numbers and breeding success of threatened species should be monitored before, during and after an eradication attempt and all such attempts should involve the collection of behavioural and demographic data on the invasive species involved. Eradication methodologies on tropical islands may be constrained by risks to endemic taxa whose susceptibility, especially to avicides, is often unknown. With current poor knowledge of the practicalities of eradication of invasive birds from tropical islands it is not possible to estimate timescales needed to achieve success and thus their costs. However, it is essential that eradication attempts are fully resourced and staffed and the commitment must be regarded as open-ended and should embrace all techniques, lethal and non-lethal, that are considered to reduce the survival of the invasive species concerned.*

## Introduction

Human occupation of tropical islands, or even regular human visitation without permanent settlement, sets in train huge ecological modifications involving habitat and biodiversity change. Habitats are modified through the exploitation of existing vegetation or its removal and replacement by more "useful" forms, e.g. agricultural or forest crops, and through disturbance to sensitive water and nutrient cycles. Biodiversity change results from these habitat modifications along with introductions, both accidental and deliberate, of species that accompany man on his travels. Some of the bird species involved are commensal with humans in their natural range and thus may be pre-adapted to the degraded island habitats.

Many oceanic islands are home to endemic taxa that have evolved from continental progenitors that arrived through pre-human events, survived and bred in the new environments, and evolved in isolation from their relatives. Island bird endemics make up a significant proportion of the world's avian biodiversity, many taxa live in small populations and these have borne the brunt of known bird species extinctions (Butchart et al. 2006, BirdLife International 2010). The deliberate or accidental addition of bird species through human agency is one factor that may be involved in some extinction processes, directly through predation, competition or interference, through genetic change accompanying interbreeding, and indirectly through the introduction of pathogens to which the endemic birds have no defence. The risks of these influences for endemic birds have rarely been quantified (Pell & Tidemann 1997). Some invasive birds may have additional biodiversity impacts, e.g. spreading the seeds of plants, including invasive aliens (Kueffer et al. 2009). The presence or recent arrival of non-native birds is now generally regarded as a cause for concern, despite examples of species that have arrived on islands and appear to be benign with respect to endemic avifauna (e.g. Madagascar Fody (*Foudia madagascariensis*) in relation to the Seychelles Fody (*Foudia sechellarum*) in Seychelles – Crook 1960). Where there is any doubt over possible adverse effects of the presence or arrival of a potentially invasive species, especially one known to be invasive elsewhere, it seems appropriate to adopt the precautionary principle and to make plans to prevent any such arrival from nearby islands (Pr?s-Jones et al. 1981, Roberts 1986, 1988), or to eradicate invasive birds that have already become established (e.g. McCulloch 1991, Nagle 2006, Parkes 2006).

The translocation of endangered endemic birds to islands with appropriate habitats, and which lack mammalian predators, to establish insurance populations presents further opportunities for interaction between endemics and invasive bird species. Recently in Seychelles, such translocations have been made of endemics, especially single island populations, to other islands within the archipelago. Following the eradication of rats in 2002, Denis Island was selected to receive Seychelles Fodies (*Foudia sechellarum*) and Seychelles Warblers (*Acrocephalus sechellensis*) in 2004, and Seychelles Magpie Robins (*Copsychus sechellarum*) (Fig. 1) and Seychelles Flycatchers (*Terpsiphone corvina*) in 2008, despite the presence of Common ynas (*Acridotheres tristis*) on the island. Mynas are now believed to be retarding progress of the introduced endemic birds (Fig. 2), in response to which an eradication attempt was begun in May 2010.

The eradication of mammals, especially rodents, from oceanic islands is now almost a routine component of island restoration, often aimed at protecting indigenous birds (Nogales et al. 2004, Howald et al. 2007). The methodologies involved followed decades of study of potential poisons and their application in the agricultural and public health sectors, along with studies of the demography and ethology of the rodents themselves. Development of strategies for the eradication of invasive birds, on the other hand, lag far behind and methodologies are in the early stages of development. As a result, current eradication attempts provide important learning opportunities, providing data on invasive bird population dynamics that may contribute to the development of protocols for future more widespread use.

Fig 1. Seychelles Magpie Robin, now translocated from the only surviving population on Fregate Island to other islands within the archipelago. On Denis Island success of the translocation appears to be compromised by Common Mynas. Photo: Chris J Feare

**Objectives for control on tropical islands**

Sustained reduction of invasive bird populations requires continuing expenditure, a risk of habituation to or avoidance of the control techniques, and elevated risks to indigenous fauna that the control techniques might present. Furthermore, any long term control will be subject to vagaries in funding, interest, and political will to maintain the effort. Any let up in control effort will present the invasive species concerned with opportunities for regaining former numbers. On tropical islands, eradication of invasive birds should therefore be the goal where the survival of threatened endemic fauna and flora are compromised.

Fig. 2. Nestbox erected for Seychelles Magpie Robins on Denis Island, Seychelles. This nestbox has been taken over by Common Mynas. Photo: Chris J Feare

Few attempts at eradication have been described and among these success has been achieved only with very small populations (Millet et al 2004, Saavedra 2010, Samways et al. 2010, Suliman et al. in press). Attempts to eradicate larger populations of hundreds or thousands of birds have not so far been successful (Millet et al. 2003, Anon 2009, Rocamora & Jean-Louis 2009) or have been curtailed following investigation but before eradication was approached (Feare & Saavedra 2009, Saavedra 2009, Bednarczuk et al. 2010). Attempts to eradicate larger numbers of birds must therefore be regarded as trials and all aspects, whether successful or not, should be documented to advise future eradication attempts.

An eradication attempt offers an opportunity to assess the effectiveness of this kind of intervention in protecting endangered birds or other threatened fauna. Where invasive bird species are eradicated with the aim of protecting endemic fauna, a second objective should therefore be to monitor numbers and productivity of the vulnerable endemics before and after the eradication attempt (e.g. Donlan et al. 2007), as is being done with Seychelles Warblers on Denis Island, Seychelles, by Jildou van der Woude (pers. comm.). Ideally, similar monitoring of the endemic species concerned should be undertaken contemporaneously on an island where eradication is not undertaken (Tindall et al. 2007) but in most circumstances, and always with single island endemics, this will not be possible.

To these a third objective should be added. Knowledge of the biology of invasive birds on tropical oceanic islands is so poor that basic information on even better known species, such as the Common Myna (Feare & Craig 1998), is lacking. During an eradication attempt, especially where trapping is the predominant technique, large numbers of birds are caught over a timescale of months, possibly longer. Captured birds can reveal moult, incubation patch and gonad cycles, thereby defining the island-specific breeding and non-breeding seasons; aging and sexing the birds can provide an indication of the demographic structure of the island population and of any changes during the eradication; and body mass and morphometrics can provide data on body condition, with the possibility of identifying periods of food shortage.

**Characteristics of invasive birds on tropical islands**

On many tropical islands the invasive species are often among the more conspicuous birds. This stems from both their abundance and from their propensity to occupy man-modified habitats. Despite these traits, knowledge of the ecological attributes of tropical island invasive birds is poor and this lack of information can compromise eradication attempts.

On isolated islands, such as St Helena and Ascension in the tropical Atlantic, we assume that populations of invasive birds are closed; these islands are too far from continental or other island populations of the alien bird species that currently occur there and there is no evidence of recent ship-borne introduction to the islands. Within archipelagos, on the other hand, assumptions of isolation from sources on nearby islands may be unrealistic (Bednarczuk et al. 2010), but the relation between separation distance between islands and probability of immigration is unknown. This may vary between species and also among islands, depending on geographical relationships and meteorological and oceanographic features, along with human trade linkages. Immigration probability must be considered when deciding whether to attempt eradication on a particular island; when the probability is high, continuous management to maintain low numbers may be the only strategy unless immigration probability itself is amenable to reduction. However, the risk of immigration is rarely known prior to an eradication attempt. Following the successful eradication of small Common Myna populations on some of the smaller islands in Seychelles, the need for constant vigilance and removal of new arrivals is recognised (Millet et al. 2003, Samways et al. 2010).

In comparison with indigenous populations of invasive bird species on continental land masses, oceanic island populations of the same species are small, constrained in their capacity for migration or dispersal and thus vulnerable in response to seasonal or unpredictable food shortages. This suggests that island populations might differ in various demographic parameters from their mainland counterparts but there appear to have been few studies of this aspect of oceanic island invasive species. Indeed, recent attempts at eradication have commenced without even basic knowledge of biology, such as breeding season, clutch and brood size.

During a feasibility study for the eradication of Common Mynas on St Helena, two estimates of the number of free-flying young per pair of adult Common Mynas were obtained during the non-breeding season (Feare & Saavedra 2009). Trapping revealed different proportions of young, depending on the trapping technique used, with a higher proportion of young (45.3%) in samples caught in baited funnel traps than in traps that relied on live decoy mynas (28.3%). These values equate to 1.6 and 0.8 young/pair of adults respectively. The second estimate was obtained from records of the size of groups of mynas that arrived at communal roosts in the evening. Mynas did not arrive *en masse* but in distinct units. The vast majority of birds arrived in groups of 1-5; groups of two birds were assumed to be mated pairs without young[1], single birds independent young, and groups of 3-5 birds were thought to be a pair of adults with 1-3 young (Feare & Saavedra 2009). Of 2286 arriving groups, 67 % were of two birds (Fig. 3). Overall, these counts suggested that the arriving birds comprised 758 young and 1790 pairs of adults, or 0.4 young per pair of adults. In India, where Common Mynas are indigenous, Lamba (1963) and Sengupta (1968) reported brood sizes of 2.7 and 2.8 respectively. Comparison of these figures (recognising methodological and seasonal differences) suggests that productivity on St Helena may be lower than in India, or that post-fledging survival of young on St Helena may be low. Recorded clutch sizes in St Helena and India suggest that the former may be the case. Rowlands et al. (1998) and Ashmole & Ashmole (2000) recorded clutch size in St Helena as 2-4 eggs, which is low in comparison with clutches usually of 4-5 (range 2-6) in India (Lamba 1963, Ali & Ripley 1972). After 13 weeks of an on-going attempt to eradicate mynas on Denis Island, Seychelles, again mainly during the non-breeding season and relying almost entirely on decoy traps (other trapping techniques having largely failed), only 40 young birds were caught among 592 adults, suggesting a population comprising 0.13 young per pair of adults (C. Feare and P. Greenwell, unpublished data). Skerrett & Bullock (2001) record clutch size of 2-4 eggs in Seychelles but there are no data for mynas on Denis Island. Even allowing for possible bias towards adults from the use of decoy traps, the proportion of young recorded on Denis Island again suggests low productivity in this island population and further suggests that demographic differences may exist between oceanic island and mainland populations.

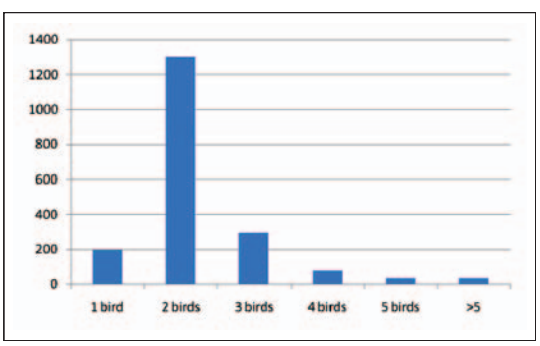


Fig 3. The number of groups of Common Mynas of different sizes arriving at roosts during ten roost counts at seven roosts, 17 July-6 August 2009, St Helena.

[1] Subsequently, Feare & Greenwell (unpublished) have found that where groups of two birds observed foraging together have been caught, they have invariably comprised one male and one female.

This clearly needs verification through more targeted studies. If confirmed, low productivity on oceanic islands could be good news for eradication teams: it could slow potential recovery during and after breeding seasons. However, if island populations are regulated by density dependent mechanisms associated with food supply or nest site availability, imposed reductions in numbers could lead to increases in productivity as density decreases. Furthermore, investigation of the limiting factors leading to low productivity on oceanic islands might reveal management practices that could contribute to population reduction. For example, if food or nest cavities are found to be limiting at certain times of year, mechanisms that further limit the availability of these resources might aid eradication programmes and limit the potential for any future recolonisation. Control in the late stages of or immediately after periods of resource limitation might be more productive, in population reduction terms, than control at other times of year; identification of these times could thus be valuable.

While culling birds will most likely remain the mainstay of eradication programmes, advantage of all possible management measures should be taken to minimise the productivity and survival of the invasive species involved. Restoration of original island habitats, which reduces the availability of man-made environments, can reduce numbers of some alien species (Samways et al. 2010). On St Helena and Ascension islands improved urban hygiene and better waste management, including transport, storage and treatment, could remove a significant amount of food that is available to mynas (Feare & Saavedra 2009). On Denis Island, proofing a small building used for animal food storage against bird entry and restricting bird access to animal feeding areas would similarly reduce feeding opportunities for mynas, and the policy of deliberate provision of food for wild birds outside the hotel restaurant, in the expectation that this helps to reduce the number of birds that visit restaurant tables, should be re-examined (pers. obs.).

### Practicalities of avian eradication

Perhaps reflecting the methodology used against island rodents, an approach that involves an initial rapid kill of large numbers, followed by a programme to remove any remaining birds, is often stated to be desirable (in discussion with island owners and managers, pers. obs.) and sometimes recommended (e.g. Millet et al. 2004, Parkes 2006). In practice, although Millet et al. (2004) claimed to have achieved a rapid reduction of Common Mynas by baiting feeding areas with the avicides “Starlicide”, subsequent observations of reduced numbers at these sites did not preclude the development of aversion to these feeding sites. Recent trials using toxicants have failed to achieve the initial knock-down but have demonstrated aversion to bait, and possibly to bait sites (Feare & Mungroo 1990, Feare & Saavedra 2009, Bednarczuk et al. 2010, Feare 2010). On North Island, Seychelles, an initial attempt to remove mynas involving toxicants and nest-box trapping was followed by intensive shooting but insufficient birds were killed to achieve eradication (Rocamora & Jean-Louis 2009).

In addition to avicides, traps of various types, shooting, mist-netting, perch adhesives, fine nooses within nests and gassing birds in nests have all been used in attempts, or in trials, to reduce invasive bird numbers on tropical islands (Feare & Mungroo 1991, Clergeau et al. 1992, Millet et al. 2004, Dhami & Nagle 2009, Feare & Saavedra 2009, Bednarczuk et al. 2010, Saavedra 2010, Tidemann et al. 2010). The utility of these techniques varies according to the species of invasive bird to be targeted and its biology (habitat use, food preferences, social behaviour). The utility of some techniques even varies among islands when used against the same species: both decoy and funnel traps were successful in catching Common Mynas on St Helena (Feare & Saavedra 2009), while on Ascension Saavedra (2009) found funnel traps to be superior and on Denis Island, Seychelles, only decoy traps have proved to catch large numbers (C. Feare & P. Greenwell, pers. obs.). Different techniques will, by their nature, perform different roles in eradication programmes. Trapping, avicides and shooting have demonstrated potential to kill large numbers, but with varying risks of aversion in the target populations, while mist nets and nest capture catch smaller numbers but may, along with shooting, be useful in targeting particular individuals during different phases of the programmes, e.g. individuals that have developed aversion to methods used earlier.

The presence of endemic fauna places constraints on the control methods used and selectivity may be essential. Live trapping carries the advantage that non-target species can be released. Non-selective techniques, such as avicides and perch adhesives, may be precluded although toxicants that need to be ingested may be given some selectivity when presented on baits that target only the invasive species. On tropical oceanic islands the presence of endemic herpetofauna presents particular problems with respect to toxicants. During registration processes avicides undergo testing against a variety of mammalian, avian and sometimes aquatic (fish and invertebrate) taxa but reptiles (Fig. 4) and amphibians are rarely included, leading to uncertainty about the safety of these chemicals.

Fig. 4. Telfair's Skinks (*Leiolopisma telfairii*), one of a suite of Mauritian endemic reptiles whose susceptibility to chemicals available as avicides is unknown. Photo: Chris J Feare

The use of techniques that allow the collection of birds has an advantage that caught birds can be used to provide data of value to the eradication attempt being undertaken, and possibly to the development of strategies for future use elsewhere (Simberloff 2002). Where recovery of birds is impossible or incomplete, as when using avicides, progress of the eradication is more difficult to assess.

**Duration and cost**

The use of toxicants, usually anticoagulants, enables rat eradications to be undertaken in a relatively short time, although post-treatment monitoring must continue for some months to confirm that eradication has been successful. The situation with invasive birds is very different. Studies so far suggest that toxicants cannot be applied in a way that satisfactorily targets all individuals and other techniques must therefore play the major part in eradication. These techniques, including trapping and shooting, involve prolonged use and are labour intensive. We are not yet in a position to estimate the time taken for complete eradication of populations of invasive birds numbering hundreds or thousands of individuals. Island owners and managers and conservation agencies that wish to eradicate invasive birds must therefore appreciate that eradication attempts must be open-ended, involving long-term commitment and resolve, and must be supported by the funding and staff necessary to complete the project.

Many conservation projects on tropical oceanic islands rely heavily on the use of volunteers (e.g. Samways et al.2010). For eradications, however, the resulting turnover of staff on short contracts can be counter-productive, e.g. an attempt to remove House Sparrows (*Passer domesticus*) from Round Island, Mauritius (Bednarczuk et al. 2009) and the current control of mynas on Denis Island, Seychelles. Invasive bird eradication differs from most conservation-oriented projects in requiring its practitioners to kill birds directly (unlike the eradication or rodents where animals die largely out of sight following ingestion of toxicants). This requires careful selection of people with appropriate aptitudes and adequate training in all aspects of the eradication processes, including humane dispatch of caught target birds. The value of this training cannot be overestimated for staff motivation and retention.

In addition, the amount of work involved in trapping, and its physical nature, must not be underestimated. Traps and live decoys need constant maintenance, the latter requiring food and water twice daily and shade during the day if traps are exposed to the sun. Traps must be moved regularly to target new birds and reduce the risk of aversion in birds not yet caught. The processing of caught birds to provide basic morphometric and demographic data has been found to take c. 10 minutes per bird: a daily catch of 30 birds thus takes 5 person-hours to process!

## Conclusions

Many of the attempted invasive bird eradications described here are essentially fire brigade actions against invasive birds, stimulated by sudden realisation of the problems they are considered to be causing (as on Denis Island) or, following earlier recognition of the problems, awaiting the availability of funding (as on St Helena). As such, they have commenced with minimal planning and minimal knowledge of the invasive populations involved. In order to increase the likelihood of success of future eradication attempts, it is important to study invasive bird populations on tropical islands in their own right, seeking information on population dynamics, limiting factors and behaviour of the species involved. Although there are constraints on the extent to which theoretical conclusions can be put into practice, demographic models have been used to predict management measures that might be most effective in increasing population growth of endangered species (Norris & McCulloch 2003). Similar analyses should be investigated for their utility in identifying life history stages that could be targeted to increase effective population reduction in invasive birds.

The eradication procedures being used are time-consuming and thus expensive. Furthermore, as we cannot predict how long they will take to achieve their objectives, they must be open-ended. This highlights the importance of utilising all avenues available for reducing population size and the capacity of islands to support invasive bird populations. Eradication attempts must therefore integrate culling with as many non-lethal approaches as are compatible with island conservation, and in some cases wider management, objectives.

Costs of eradication attempts are often minimised by using young volunteer labour. However, volunteers must have specialised interests and aptitudes to undertake this kind of work and during their work they will be trained and will gain expertise in the techniques and thought processes involved, including targeted learning demographic and behavioural parameters that may improve the chances of eradication success. Having done so, these people will have rare qualities of great value to conservation organisations and island managers who wish to undertake invasive bird eradications. These qualities should be recognised and rewarded, leading to more efficient and possibly shorter eradication attempts.

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# The conservation and restoration of Mexican islands: a programmatic approach and the systematic eradication of invasive mammals

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*Invasive mammals are the most important threat to the biodiversity on Mexican islands. 17 insular endemic birds and mammals have become extinct due to the impact of introduced mammals, such as feral cats, rats, feral goats and sheep. The nearly two thousand islands and islets with a surface area of 5,127 km, have a very high value natural capital, hosting 620,000 inhabitants. Thanks also to its distant oceanic islands off the Pacific; Mexico has the 13th largest Exclusive Economic Zone (EEZ) with rich seas and seabeds. Most of the larger islands, around 600 are located in the northwest region — Pacific Ocean off Baja California, the Gulf of California, and the Revillagigedo Archipelago — which together with the islands in the Caribbean and Gulf of Mexico significantly add to Mexico's mega diversity. In response to the threat of invasive mammals, Mexico has made important advances in regard to global eradication on islands. During the past 15 years, 49 populations of invasive mammals have been eradicated from 30 islands. These eradications have protected 147 endemic taxa of mammals, reptiles, birds and plants. Additionally, 227 colonies of seabirds have been protected. These conservation and restoration actions have followed a programmatic approach with the collaboration of local communities, federal government agencies, the congress and the senate, academic institutions, civil society (NGOs), as well as national and international donors and funds, both public and private. By keeping this pace, the eradication of invasive mammals from the remaining islands — 40 approximately — is a realistic and strategic goal achievable by 2025. This will be a significant accomplishment in terms of global biodiversity conservation.*

Fig. 1. Male Northern Cardinal (*Cardenalis cardenalis mariae*), endemic of Marías Archipelago, tropical Pacific. Photo: José Antonio Soriano/Conservación de Islas

Fig. 2. Endemic Tres Marías Amazon (*Amazona oratrix tresmariae*) in María Madre Island, tropical Pacific. Photo: José Antonio Soriano/Conservación de Islas

## Biodiversity on Mexican Islands

Mexican islands are among the richest biodiversity zones in the world (Álvarez-Castañeda y Patton 1999, Case *et al*. 2002, Grismer 2002, Samaniego Herrera *et al.* 2007, Wilkinson *et al*. 2009, Aguirre-Muñoz *et al*. 2010).

For instance, the nearly 600 islands in Northwest Mexico are habitat for 331 endemic groups of plants and vertebrates (Case *et al*. 2002). When compared with the biological richness of the Galapagos Islands, Mexican islands have 25% more endemic groups per square kilometer (Aguirre-Muñoz *et al*. In press). Mexican islands are of immense importance in the conservation of national biodiversity, since they sustain ecosystems and endemic species that are not found in the country's continental territory (Fig. 1 and 2); also because they are critical habitats for migratory species, particularly sea birds and turtles (Aguirre-Muñoz *et al*. 2010).

In many cases the conservation actions on the Mexican islands protect biodiversity well beyond the country limits, as in the case of the Baja California Pacific islands that host very important seabird populations with a wide distribution, from Alaska to Mexico, and, the Mexican islands in the Caribbean (Fig. 3) and the Gulf of Mexico.

Fortunately, the vast majority of Mexican islands are federal territories and most of them are already protected areas managed by the federal government; the exception being the Baja California Pacific Islands, now in the process of becoming a Biosphere Reserve. As federal and legally protected territories, the integrity of the islands' biodiversity and the insular ecosystems have been threatened by far less pressures and conflicts of use; their governance has been simpler than in the continental territories that face problems of multiple jurisdictions where pressures and uses overlap.

## The eradication of invasive mammals and island restoration in Mexico

While Mexican islands are largely in good condition and with a very high biodiversity value still very high, they have been threatened by the presence of invasive species, in particular introduced mammals like feral cats, rats, feral goats, feral sheep and feral pigs, among others (Aguirre-Muñoz *et al.* 1998).

Fig. 3. Panoramic view of Cayo Centro (Banco Chinchorro) in the Caribbean Sea. The internal lagoon (left) can be seen among jungle and mangrove. Photo: José Antonio Soriano /Conservación de Islas

Their negative impacts include predation and habitat loss; and they have been implicated in the extinctions of at least 17 endemic mammals and birds, plus several local extinctions or extirpations of seabirds. The vast majority of the introductions of invasive mammals occurred during the 19th century, mostly related to fur trade and guano mining periods (Aguirre-Muñoz *et al*. In press).

Table 1. Completed eradications on Mexican islands as for October 2010.

| Island | Area (ha) | Eradicated species |
|---|---|---|
| Asunción | 41 | Cats |
| Clarión | 1,958 | Sheep, pigs |
| Coronado Norte | 37 | Cats |
| Coronado Sur | 126 | Cats, goats, donkeys |
| Coronados | 715 | Cats |
| Danzante | 412 | Cats |
| Estanque | 82 | Cats |
| Farallón de San Ignacio | 17 | Black rats |
| Guadalupe | 24,171 | Rabbits, donkeys, horses, goats, dogs |
| Isabel | 80 | Cats, black rats |
| Mejía | 245 | Cats |
| Montserrat | 1,886 | Cats |
| Natividad | 736 | Goats, sheep, cats, dogs |
| Partida Sur | 1,533 | Cats |
| Rasa | 57 | Black rats, house mice |
| San Benito Este | 146 | Rabbits |
| San Benito Medio | 45 | Rabbits |
| San Benito Oeste | 364 | Rabbits, goats, donkeys |
| San Francisquito | 374 | Cats, goats |
| San Jerónimo | 48 | Cats |
| San Jorge Este | 9 | Black rats |
| San Jorge Medio | 41 | Black rats |
| San Jorge Oeste | 7 | Black rats |
| San Martín | 265 | Cats |
| San Pedro Mártir | 267 | Black rats |
| San Roque | 35 | Cats, black rats |
| Santa Catalina (Catalana) | 3,890 | Cats |
| Socorro | 13,033 | Sheep (ongoing) |
| Todos Santos Norte | 34 | Cats, rabbits, donkeys |
| Todos Santos Sur | 89 | Cats, rabbits |
| **Total** | **50,743** | |

In response to this problem, Mexico has made important advances in regard to the global eradication of invasive species. During the last 15 years, 49 populations of invasive mammals have been eradicated from 30 Mexican islands, which represent more than 50 thousand hectares in the process of restoration (Table 1). These actions have protected 147 endemic taxa of mammals, reptiles, birds and plants. In addition, 227 colonies of seabirds, highly vulnerable to rats and cats, have been protected.

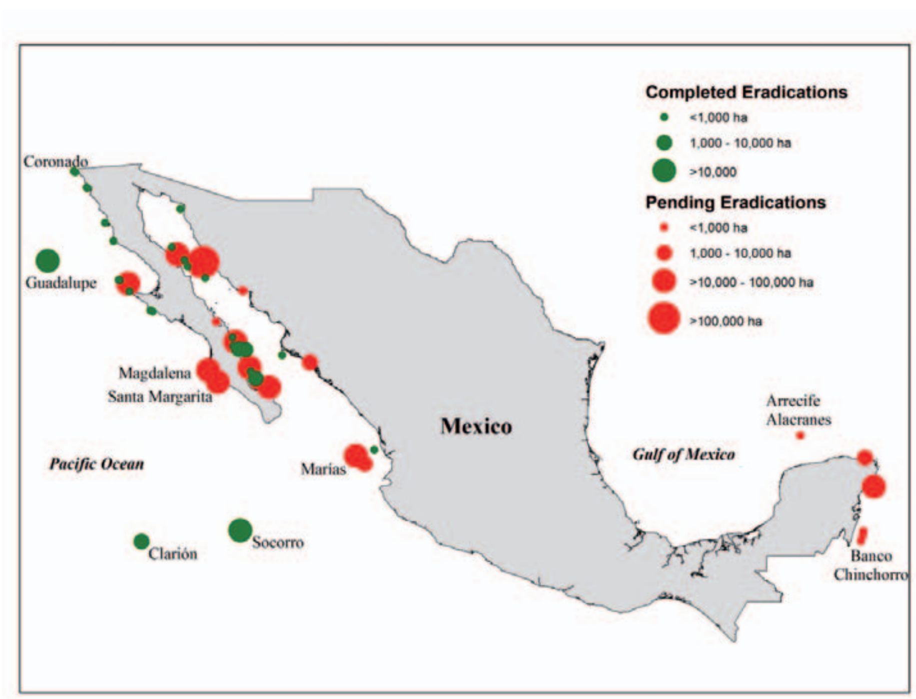


Fig. 4. Completed and pending eradications in Mexican islands as for October 2010.

Feral cats have been eradicated from 18 islands, all of them using traditional hunting and trapping techniques; rats and rabbits have been eradicated from 14 islands; ungulates from eight islands, and feral dogs from two. Island size has ranged from a few hectares to more than 20, 000 hectares (Fig. 4).

The most significant contribution have been the recent eradication of feral goats from Guadalupe Island (Fig. 6) and feral sheep from Socorro Island, where these species have heavily overgrazed native vegetation, causing erosion and habitat destruction (Fig. 5) (Aguirre-Muñoz *et al*. In press). In both cases aerial hunting from helicopters, Global Positioning System (GPS) technology, telemetry and "judas" animals were used (Aguirre-Muñoz *et al*. In press).

Fig. 5. Soil erosion and habitat destruction caused by the overgrazing of introduced sheep in Socorro Island, Revilleagigedo Archipelago. Photo: Conservación de Islas

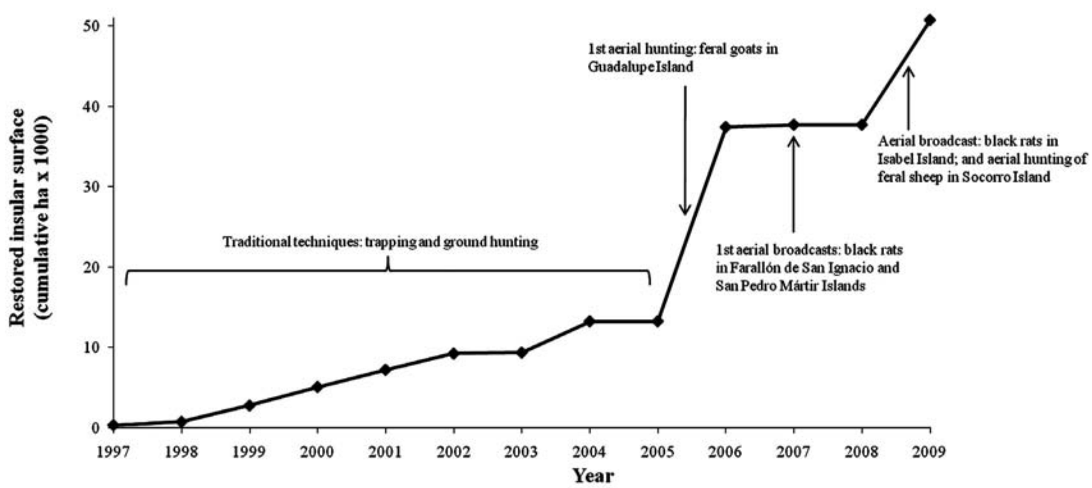


Fig. 6. Number of eradications in Mexican islands and insular surface under restoration.

Rodent eradications using advanced techniques are contributing in a crucial way to the restoration of seabirds at a eco-regional scale, especially during the past three years, when aerial broadcast methods of special baits were used, supported by Navy boats with helicopter platforms, designed helicopter buckets, on-board differential GPS, satellite imagery and telemetry (Fig. 7 and 8). The rodent eradications are moving from the desert islands of the Gulf of California to the more complex tropical ones. Two rodent eradications projects on tropical islands are now under an assessment and planning phase. One in Arrecife Alacranes, a tropical reef off the Yucatán Peninsula, in the Gulf of Mexico (Fig. 13); and the other in Banco Chinchorro, a group of tropical islands in the Caribbean, near Cancún (Fig. 14) (Samaniego-Herrera *et al.* In press).

Fig. 7. Helicopter takeoff from navy boat, during the eradication of black rats in San Pedro Mártir Island, Gulf of California. The dispersal bucket is attached. Photo: José Antonio Soriano/ Conservación de Islas

Fig. 8. Release of a black rat (*Rattus rattus*) with a radio collar for telemetry in Isabel Island. Photo: José Antonio Soriano/Conservación de Islas

Fig. 10. Decoy with two chicks of Heermann's Gull (*Larus heermanni*). Social attraction techniques are proving to be successful. Photo: Óscar Salazar/Conservación de Islas

## Seabird restoration

When invasive species, typically cats or rats have extirpated populations of seabirds, actions may be required to attract the birds to recolonize the specific island. For example, on Asunción and San Roque Islands, there was no spontaneous recolonization by seabirds even after 14 years of being predator free. Efforts are now being made to attract birds back using sound systems, decoys, and mirrors (Fig. 9) (Félix-Lizárraga *et al*. 2009) simultaneously with systematic and long term monitoring; methods that have been successfully used elsewhere (Kress 1978, Podolski 1990, Gummer 2003). The first positive results are very promising (Fig. 10). Combined with the eradications of cats (Fig. 11) and rodents (Fig. 12), these techniques should have a significant impact in the comprehensive restoration of seabird populations at the eco-regional scale, well beyond Mexican national boundaries. In this particular case, partnerships between two federal government agencies — CONABIO and CONANP —, the local fishermen co-operatives, and the NGO Grupo de Ecología y Conservación de Islas (GECI) has been key to the project's successful implementation (Towns *et al*. In press).

Fig. 11. As in many islands worldwide, feral cats have caused the extinction of six bird species in Guadalupe Island. Photo: Julio Montoya/Conservación de Islas

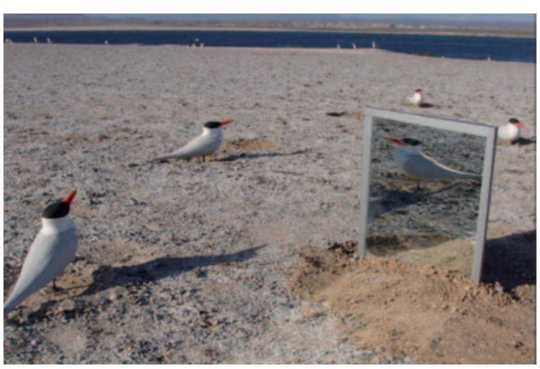

Fig. 9. Use of social attraction techniques: decoys and mirrors, to encourage the recolonization of seabirds after the eradication of invasive species. Photo: Antonio Ortiz/Conservación de Islas

Fig. 12. Invasive black rat (*Rattus rattus*) eating the fruit of the native "Roache" tree (*Crataeva tapia*) in Isabel Island. Photo: José Antonio Soriano/Conservación de Islas

## Sovereignty and natural resources

A very important context around the conservation of the Mexican islands is related to the value of these islands in regard to Mexican sovereignty and natural resources. Together, the nearly two thousand islands and islets of the country have a surface area of 5,127 $km^2$, equivalent to 0.3% of Mexico's territory, contributing significantly to the country's natural capital. Thanks to its distant oceanic islands, especially Guadalupe Island and the Revillagigedo Archipelago, Mexico has an Exclusive Economic Zone (EEZ) of 3.18 million $km^2$with rich seas and seabeds; an area that is larger than the continental territory of 1.96 million $km^2$. Thanks to this EEZ, Mexico produces sustainably, more than 100 thousand tones of tuna every year, among other important fish resources. Since 1983, with the signing of the United Nations Convention on the Law of the Sea (UN 1982) and the adoption of the EEZ, Mexico developed military and productive infrastructure establishing permanent settlements on its remote islands to exercise its sovereign rights on both the islands and the EEZ. Permanent Navy facilities, garrisons, piers and airfields were built on the remote Socorro, Clarión and Guadalupe islands (Fig. 13). Other islands, closer to the mainland, also have permanent Navy facilities. Some have permanent fishing villages and limited tourism infrastructure. Fishing resources are the main natural resources of the islands, so, fishing has been conducted since the first half of the 20$^{th}$ century by fishermen co-operatives rooted in local communities. Artisanal fisheries of valuable species such as abalone, lobster and sea-urchin, operate under limited entry schemes and are steadily improving their performance in terms of sustainability (Fig. 21). The Baja California Pacific islands lobster fishery has a sustainable certificate granted by the Marine Stewardship Council (MSC 2009).

Fig. 13. To keep Mexico's sovereignty, the Navy Ministry has facilities in remote islands, like in Socorro Island, in the Revillagigedo Archipelago. Photo: Antonio Ortiz/Conservación de Islas

## Conservation, restoration and governance

Under the Mexican Constitution all islands are an integral part of the national territory and are under federal jurisdiction, except for few islands that are in the jurisdiction of individual states, and very few which are communal or private property (CONANP 2000). Federal islands are administered by the Ministry of the Interior (SEGOB) and safeguarded by the Ministry of the Navy (SEMAR). The environmental management of the protected islands is conducted by the Natural Protected Areas Commission, part of the Environmental Ministry (SEMARNAT). Except in rare cases, the relevance of biodiversity, conservation of insular ecosystems, and sustainable use of fisheries only became consistent public policy during the second half of the last century. Social movement towards environmental conservation and concerns on the wise use of the natural resources has gained momentum in Mexico over the last three decades, associated with global views.

A programmatic approach for the conservation and sustainable use of the Mexican insular territories has been developed efficiently during the last decade for the national good. This approach, as put into action on the Mexican islands (and as the Global Environment Facility GEF-2009 proposes), effectively has been undertaken in partnership, with an enhanced scope for catalyzing actions, implied replication and innovation, is country owned and built on national priorities, is based on an open and transparent process, and increases opportunities for co-financing from a variety of sources. The programmatic approach spreads out in this case in an organic way, each actor contributing its complementary vocations, capacities and resources. This strategic program is becoming institutionalized, with the coordinated support of donors, and with collaborations between government agencies, local communities, academic institutions, and NGOs. For example, the invasive species challenge, including islands, has now a formal Invasive Species National Strategy (Comité Asesor Nacional sobre Especies Invasoras 2010). A National Strategy for the Conservation and Sustainable Use of Mexican Islands is also on its way, an initiative backed by the National Institute of Ecology (Eduardo Peters and Karina Santos, personal communication).

The active collaboration to date includes government agencies: Ministry of the Interior, Ministry of the Navy, Ministry of the Environment and Natural Resources, CONANP, National Institute of Ecology (INE), and CONABIO; the Congress and the Senate, which have promoted the creation of Natural Protected Areas and requested action to restore and conserve the islands, including invasive mammals eradications; academic and research institutes; the civil society (NGOs), implementing the restoration projects, mainly GECI; and national and international donors, both public and private.

Fig. 14. Biologist Araceli Samaniego takes measures of a captured rat. She also places an earring to the animal to follow it for several days. Photo: José Antonio Soriano/Conservación de Islas


Fig. 15. The aerial broadcast of bait, an advanced technique to eradicate invasive rodents from islands, has been successfully applied in Mexico. Photo: José Antonio Soriano/Conservación de Islas

In conclusion, the overarching activities include eradications using traditional and advanced techniques (Fig. 14 and 15) many of them with the support of the Navy equipment and infrastructure; seabirdrestoration; development of specific public policies and governance tools; environmental education (Fig. 16); divulgation; in-site infrastructure for conservation and sustainable development; promotion of good practices; long term funding; international exchange and cooperation; and scientific research. Thanks to this programmatic approach Mexican islands are being very well conserved. Contrary to the situation and dynamics of many natural places, the islands of Mexico are not only in good shape, but improving at a steady pace thanks to the systematic eradication of invasive species.

Fig. 16. Children at school playing lottery game with endemic and introduced flora and fauna of the Marías Archipelago. Photo: José Antonio Soriano/Conservación de Islas


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# Management of invasive tree species in Galápagos: pitfalls of measuring restoration success

**Heinke Jäger and Ingo Kowarik**

*With an increasing rate of habitat fragmentation, disturbance, and species invasions in ecosystems world-wide, the definitions of ecological restoration have changed over the past years.*
*Two decades ago ecological restoration was defined as the "Return of an ecosystem to a close approximation of its condition prior to disturbance" (National Research Council 1992), now, however, ecological restoration is characterised as "... the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." (Society for Ecological Restoration, SER, 2004). This evolution of the terminology of what the term "restoration" may represent reflects the problems that have been encountered in this process.*
*These problems are mainly that 1) we lack baseline information on the state of the historic ecosystem, 2) species typical for the original conditions have been lost (e.g. key species), 3) physical conditions of the area to be restored have changed (e.g. soil and climate) or 4) restoration efforts may be too expensive to be carried out (e.g. control of a dominant species) (Aronson et al. 1993; D'Antonio & Meyerson 2002; SER 2004).*
*Also, the ecosystems to be restored often have experienced multiple disturbances in the past, so that it is difficult to define a reference state for the restored ecosystem to be compared to.*

## *Cinchona* as a model system

Using the invasion of Galápagos highlands by the introduced red quinine tree *Cinchona pubescens* as an example, we illustrate some of the challenges of measuring restoration success after the control of invasive species.

*Cinchona pubescens* (red quinine tree, henceforth referred to as *Cinchona*) belongs to the Rubiaceae family and is one of the most invasive tree species in the Galápagos Islands. It was introduced to the island of Santa Cruz in the 1940s (Hamann 1974; Lundh 2006) and now covers more than 11.000 ha in the highlands (Buddenhagen et al. 2004) (Figure 1). This introduction of the new life form "tree" to formerly treeless highland vegetation zones had drastic consequences for the resident flora.

Studies showed that the presence of *Cinchona* significantly reduced indigenous plant species cover and diversity. It also reduced the photosynthetic active radiation by almost 90 % and increased the concentration of phosphorus and nitrogen in the soil (Jäger et al. 2007, 2009). Since 1974, *Cinchona* has been manually and chemically controlled intermittently in some areas of the Galápagos National Park by the Galápagos National Park Service (GNPS) (Buddenhagen et al. 2004).

We monitored the efficiency of experimental manual *Cinchona* control carried out by the GNPS in 2005 in the Fern-Sedge zone of Santa Cruz Island in an area of approximately 33 ha. We also evaluated the impacts these control actions had on the highland plant communities. Control measures consisted of uprooting large *Cinchona* trees by cutting the stems and digging up the rootstocks and the hand-pulling of seedlings (Figure 2).

## Challenges

In the case of the control of invasive species, measurements of the native community recovery and the invader's decline are considered elements of a successful campaign. But in the case of our *Cinchona* system, how do we define whether the resident vegetation has recovered and therefore has been restored? The "International Primer of Ecological Restoration" (SER 2004) lists nine attributes for determining whether restoration has been achieved. Some of these require knowledge of the previous species assemblage that could be used as a reference state to compare the restored ecosystem to.

The key question for our system remains, to which state do we want to restore the part of the highlands under investigation? The highland plant communities of Santa Cruz Island have faced several disturbance events in the past beginning with extensive fires in the middle of the 20th century.

Fig. 1. *Cinchona pubescens* invasion on Santa Cruz Island, Galápagos. Photo: Heinke Jäger

Fig. 2. Permanent plot before (a) and 2 weeks after (b) manual *Cinchona pubescens* control in 2005. Photo: Heinke Jäger

This was followed by the establishment of invasive *Cinchona* over the past 40 years, and now, as an additional disturbance, manual *Cinchona* control measures are carried out by the GNPS. As mentioned previously, characteristic species assemblages have to be identified that could serve as a reference community in order to evaluate the outcome of the control measures. However, the question arises to which vegetation state we want to compare our monitoring to, the state before the fires, before the *Cinchona* invasion or before the manual control actions?

One of the rare references for the pristine, pre-fire vegetation type is from Howell, who on his first ascent of the highest point of Santa Cruz in 1932 stated that "…from an altitude of 616 m on the vegetation consisted entirely of fern species" (Howell 1942). Although expert botanists conducted extensive studies of the Fern-Sedge zone thereafter, they mainly mention the most dominant plant species (Wiggins & Porter 1971; van der Werff 1978; Hamann 1981; Itow 1990) and it is not clear how much of the highland surveyed overlap with our study area. Therefore, the composition of the pre-invasion state of the vegetation in our study area is not well defined.

## Success of control – and open questions

To evaluate community changes after the control actions were carried out, vegetation was sampled by the line-intercept method in 20 ? 20 $m^2$ permanent plots. This monitoring was performed before and immediately after control in 2005 and then again in 2006 and 2007 (Figure 3) – and revealed variable results (Jäger & Kowarik 2010)


Fig. 3. Vegetation monitoring in permanent plots after manual *Cinchona* control. Photo: Heinke Jäger

## The good news: natives come back

1. The density of *Cinchona* could be significantly reduced.

2. Although the highland vegetation cover was significantly reduced after control actions were carried out, species re-gained their pre-control cover only two years after control. In the case of herbaceous species, they even exceeded their pre-control cover.

3. The total number of plant species increased from 49 to 62, with eight of these species being native.

4. The species diversity significantly increased.

Thus, the highland plant community demonstrated resilience.

Despite heavy disturbance from up-rooting of *Cinchona* trees, the studied highland vegetation was little affected by the manual control actions and regained its pre-control level of cover two years after control. These results parallel the findings of rapid vegetation regeneration in Galápagos following the removal of introduced herbivores (Hamann 1979; Hamann 1993). However, previous studies showed that even single *Cinchona* trees as well as a continuous *Cinchona* invasion over 7 years severely reduced the abundance and diversity of resident plant species in the Fern-Sedge zone (Jäger et al. 2007, 2009). Therefore, it is likely that the state of recovery of the resident vegetation documented in this study is not equivalent to its pre-invasion state. But in the absence of detailed baseline information on the pre-invasion state, native species richness determined in previous studies by early botanists in Galápagos can count as a proxy for the original species diversity. We hope that the fern-sedge communities will revert to a near-original state once the invader is removed, although this state might diverge from the primary, pre-fire disturbed vegetation. Not all factors investigated in this study showed clear unidirectional trends over the study period and therefore a long-term monitoring following control should reveal whether recovery is transient or long lasting.

## The bad news: aliens may also come back

1. *Cinchona* regeneration from the seed and bud bank was rapid and extensive.

2. The cover of introduced herbaceous species increased significantly.

3. Five of the new species encountered in the study area were introduced.

4. The control actions seem to have facilitated the spread of other introduced species that were already present in the study area, namely *Stachys agraria* and *Rubus niveus*.

Results showed that despite a thorough uprooting of large *Cinchona* trees, smaller individuals were overlooked, resulting in a significant increase in density and cover of the invader only one year after control actions were carried out. Continuous hand-pulling of seedlings and saplings would be necessary for control success over the long-term.

Right after control actions were carried out, seedlings of the introduced herb *Stachys agraria* were abundant in the bare ground patches created by the control actions (Figure 4). Consequently, the cover of *Stachys* more than tripled within 1 year after control. In addition, results suggested that the disturbance caused by *Cinchona* control created a "point of entry" for *Rubus niveus* (blackberry), which was not present in the study area when the plots were set up. Even though its total cover was still low at the end of the study, it is of concern, since this species is already highly invasive in other parts of the Santa Cruz highlands (Buddenhagen 2006). A post-control monitoring of those introduced species that appeared to be facilitated by manual control of *Cinchona* should be carried out to anticipate future invasions.

Fig. 4. Seedlings of *Stachys agraria* emerging 1 week after manual *Cinchona* control. Photo: Heinke Jäger

## Conclusions

The monitoring revealed that the native fern-sedge vegetation of the Galápagos highlands is resilient and can recover even after heavy physical disturbance caused by manual *Cinchona* control.

However, it remains an open question whether this vegetation matches the pre-invasion state. A complete eradication of *Cinchona* as a major woody invader is rather unrealistic because of limited management resources. Hence, alternative scenarios have to be identified for the *Cinchona* management in Galápagos. According to our experience, these would be the following:

***Scenario 1: Control in priority areas –*** In this case, *Cinchona* would be controlled in areas of high conservation value, where a nearly pre-invasion state of the vegetation is desired and financially feasible. Potential places would be the areas around the volcanic craters "Media Luna" and "Puntudo" where the endemic Galápagos petrol and Galápagos rail are nesting (and where *Cinchona* is currently controlled by the GNPS for this very reason) (Figure 5).

***Scenario 2: Control up to a certain density threshold –*** This would involve the control of *Cinchona* on a broader scale up to a pre-defined threshold density, under which resident species still manage to persist. Studies have shown that the endemic shrub *Miconia robinsoniana* can tolerate the *Cinchona* presence up to a certain density (H. Jäger, unpubl. data) which is a good example of a threshold effect. The same is probably true for the endemic tree fern *Cyathea weatherbyana* (both species shown together with *Cinchona* in Figure 6).

Fig. 5. Selective manual control in *Miconia robinsoniana* zone around Media Luna on Santa Cruz Island. Note *Cinchona*-free area around the huts. Photo: Heinke Jäger

Fig. 6 Endemic shrub *Miconia robinsonia* and endemic treefern *Cyathea weatherbyana* co-existing with *Cinchona pubescens. Photo: Heinke Jäger*

***Scenario 3: Acceptance of novel ecosystems –*** If no sufficient resources are available to carry out scenarios 1 and 2, a third possibility would be to view the presently invaded highland vegetation zone as a "novel ecosystem" (*sensu* Hobbs et al. 2006) and simply to accept the changes in the plant (and possibly animal) communities. This third option can also be applied in addition to options 1 and 2 in different parts of the Santa Cruz highlands, were conservation threats are not so imminent.

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# The status of the Indo-Pacific Red Lionfish (*Pterois volitans*) in Andros Island in 2007

**Kate Barley**

*Red Lionfish (*Pterois volitans*) sightings along the North East Andros coastline have been increasing rapidly since 2006. Over the past few years, it has become apparent that there is a risk of the lionfish becoming an established invasive species in the Bahamian ecosystem. Lionfish may prove a threat to ecosystem health and stability in the Bahamas. This research is a result of increasing reports and sightings of the Indo-Pacific Lionfish along the North East Andros coastline during 2006 and 2007. Between January and March 2007, confirmed sightings of Lionfish were collated and reviewed; this information was collected to be a 'snapshot' of what lionfish are in this specific area during this specific time period. Solitary fish were observed in deeper sites; lionfish that were sighted in a group were smaller and found at shallower depths. Juvenile lionfish have also been sighted indicating that conditions may be favourable for them to breed. Artificial man-made habitats had the highest sighting frequency. It is possible that aquarium releases may have been responsible for the sudden increase of lionfish sightings in Andros Island (personal comment). This study attempts to provide a baseline for further research on the spread and behaviour of lionfish within these waters. Since 2007, there has been a rapid increase in lionfish on Andros Island. They are regularly spotted during dives on the reef (1-2 on every dive). In creeks and docks, they have been observed accumulating in groups of 4-6 individuals; a count of 20-30 individuals for a single dock has been observed. This species may now be fully established in this area. Further research on territory ranges, feeding habits and depth ranges will be useful in determining the effect this new species may have on the local ecosystem in the future.*

## Introduction

The Red Lionfish (*Pterois volitans*) was first documented along the south east coast of the United States around 10 years ago (Whitfield et al 2007). Since that time, the lionfish has been sighted from Long Island, New York to the Florida Keys (Whitfield et al 2007). The lionfish is an Indo-Pacific predatory species with venomous spines. It has few natural enemies. Sightings in the Bahamas have been increasing; with the lionfish being a new addition to the Bahamas marine environment. The first documentation of lionfish from the Bahamas was published in 2006; this paper reported sightings of four individuals in the Abacos on Little Bahama Bank (Snyder & Burgess, 2006). The impact this may have on the environment is not yet known.

There is a large volume of literature on the effects an invasive species can have and reports have been documented for other species over time and from this, predictions can be made on the effects lionfish will have on the environment. Indirect impacts may not become apparent until sometime after becoming established

Andros Island in the Bahamas is the largest yet least densely populated island; the East coast has a range of different marine habitats from inland creeks, mangroves and patch reefs out to the barrier reef and the 'Tongue of the Ocean' a deep ocean trench. Lionfish have been sighted on Andros in different habitats from inland creeks and mangroves out to the deeper coral reef slope (personal observation). Lionfish sightings have been reported by local residents in Andros Island since 2005 with sightings in Andros increasing dramatically during 2006 and into 2007 (personal comment, Jason Kincaid January 2007).

## Successful traits

Table 1 lists some of the invasive characteristics the lionfish has (adapted from the Global Invasive Species Database, 2007). Some of the concerns locally are that lionfish have been observed hunting in groups of 3-4 individuals and preying on juvenile groupers and snappers (personal observations). They have been observed across wide depth ranges, in harbours, and have been seen to be aggressively defending territories (personal observations by Greenforce scientists and volunteers)

Lionfish could prove a threat in the Bahamas through direct predation, competition and overcrowding (Whitfield et al 2007). Studies from North

Carolina have conducted preliminary genetics data that suggests as little as three females could be responsible for an entire population (Whitfield et al 2007) This evidence is concerning as only a couple of lionfish taking up settlement in an area could be enough to establish an entire population. Groups of 2-3 individuals have been sighted on patch reefs and these may be enough to establish a population (personal observation).

Lionfish are a generalist feeder and an ambush predator. The lionfish is thought to be a nocturnal species, hiding under rocks and remaining relatively motionless during the day (NOAA, 2007); Lionfish along the Andros coastline can be active in the daytime and have been sighted actively hunting during the day (personal observation). Lionfish eggs and larvae are pelagic and are capable of dispersing large distances via ocean currents (Imamura and Yabe 1996).

Table 1: The successful traits of the introduced lionfish (information adapted from the Global Invasive Species Database, 2007).

| **Lionfish (*Pterois volitans)*** | |
|---|---|
| **Hardiness** | • Can tolerate wide temperature ranges |
| | • Wide depth range |
| | • Can adapt to al range of habitat types |
| **Reproductive success** | • Eggs and pelagic juveniles can be carried over great distances in ocean currents |
| | • A single fish can spawn millions of eggs |
| **Ability to colonise** | • Occurs in harbours, possible ballast water transport |
| | • Inhabits many varied habitats, man made and natural |
| | • Generalist feeder |
| | • Aggressive venomous species, can take over native fish territories |
| **Opportunistic** | • Opportunistic predator |
| | • Quick to adapt to new prey types |

### Possible Pathways

Lionfish are a popular fish species in public and private aquaria and are seen as an attractive species in an aquarium. One pathway of introduction for the lionfish into the West Atlantic region is thought to be from intentional/unintentional aquarium releases (NOAA, 2007). In a paper by Whitfield et al (2002), they conclude that 'Ballast-water transport and aquarium releases are the 2 most probable pathways of tropical marine fish introductions in the Caribbean'.

It is possible that aquarium releases may have been responsible for the sudden increase of lionfish sightings in Andros Island (personal comment). Aquarium trade as a pathway of marine invasions has not received much attention (Semmens B et al, 2004). On Paradise Island off New Providence, there is a luxury resort; they have large aquariums, including a large tank of Indo-Pacific Lionfish. The aquariums are filtered directly into the sea (personal observations and discussions with staff); it is not known how the systems are filtered; the possibility of lionfish eggs being released into the surrounding area is a possibility.

### From New Providence to Andros:

Along the Andros coastline, waste from Nassau can be seen daily. A lot of this waste comes directly from Nassau (polystyrene cups with cruise ships logos). A 'message in a bottle' was found with a date and the location of the owner's ship. The message had taken 9 days to travel from Nassau harbour to Andros' east coast. It may be a possibility that Lionfish could have come to the East Andros coastline directly from New Providence area (personal opinion). This is an area with high numbers of ships (ballast water possibility) and also is the home of the resort and aquarium. Could lionfish have come to Andros in the currents from New Providence?

### Danger to humans

The lionfish is venomous and if stung can cause severe pain in humans; it can be an aggressive species if threatened and great care should be taken if they are sighted. In their natural range, local people are well aware of the presence and dangers of this fish, however in areas such as Andros, there is concern that local people might not be aware of the venomous nature of the fish, especially the children who like to catch the fish (Personal comment Rivean Riley, Bahamas National Trust,2007).

Lionfish have been sighted in shallow areas along the coastline where young children play (personal observation). Greenforce Marine Research Station on Andros Island has been producing educational material to inform the local residents about the dangers of lionfish. Lionfish were also displayed in a local primary school along with an awareness presentation. Greenforce have included lionfish information on their current newsletters that are posted throughout the communities. This information includes what they look like, where they may be seen, what to do if they are stung and warns that they are venomous.

## Methods and Results

Greenforce is a non-profit UK-based company that sends volunteers for 10-week expeditions to gain experience in various projects around the world. The Greenforce marine research station has been based on Andros since 2002. In January 2007, Greenforce started monitoring and collecting data on the numbers of lionfish species seen around the area. During snorkeling and diving surveys, lionfish that are sighted are observed, measured if possible and recorded. International Field Studies is a US-based scientific educational non-profit company. Forfar field station has been based on Andros since 1968. Forfar has also been collecting information and is actively removing lionfish from sites during dives. During snorkel excursions in September 2006, college students were sighting lionfish at nearly every site. Forfar interns have been removing the fish and been gathering data and site coordinates. Fish have been spotted and removed in shallow wading areas as well as deeper reef sites. Greenforce and Forfar have sent samples of removed Lionfish to NOAA for their research on stomach content analysis

## Observations

Currently there are resident populations in the area. These are removed once they have been sighted and observed. Lionfish are regularly spotted during dives on the reef. Juvenile Lionfish (< 50mm) have also been sighted indicating that conditions may be favourable for them to breed (personal comment). The lionfish can be observed in the same locations over time indicating that they have a 'home territory' and if removed, the location has been seen to become occupied with another lionfish (personal observations); Greenforce staff has begun the removal of lionfish at some inshore locations.

Lionfish were observed and if possible were photographed. A sample of photographs is represented in Fig. 1. They do not shy away from the camera/observer and will come forward toward the camera to investigate.

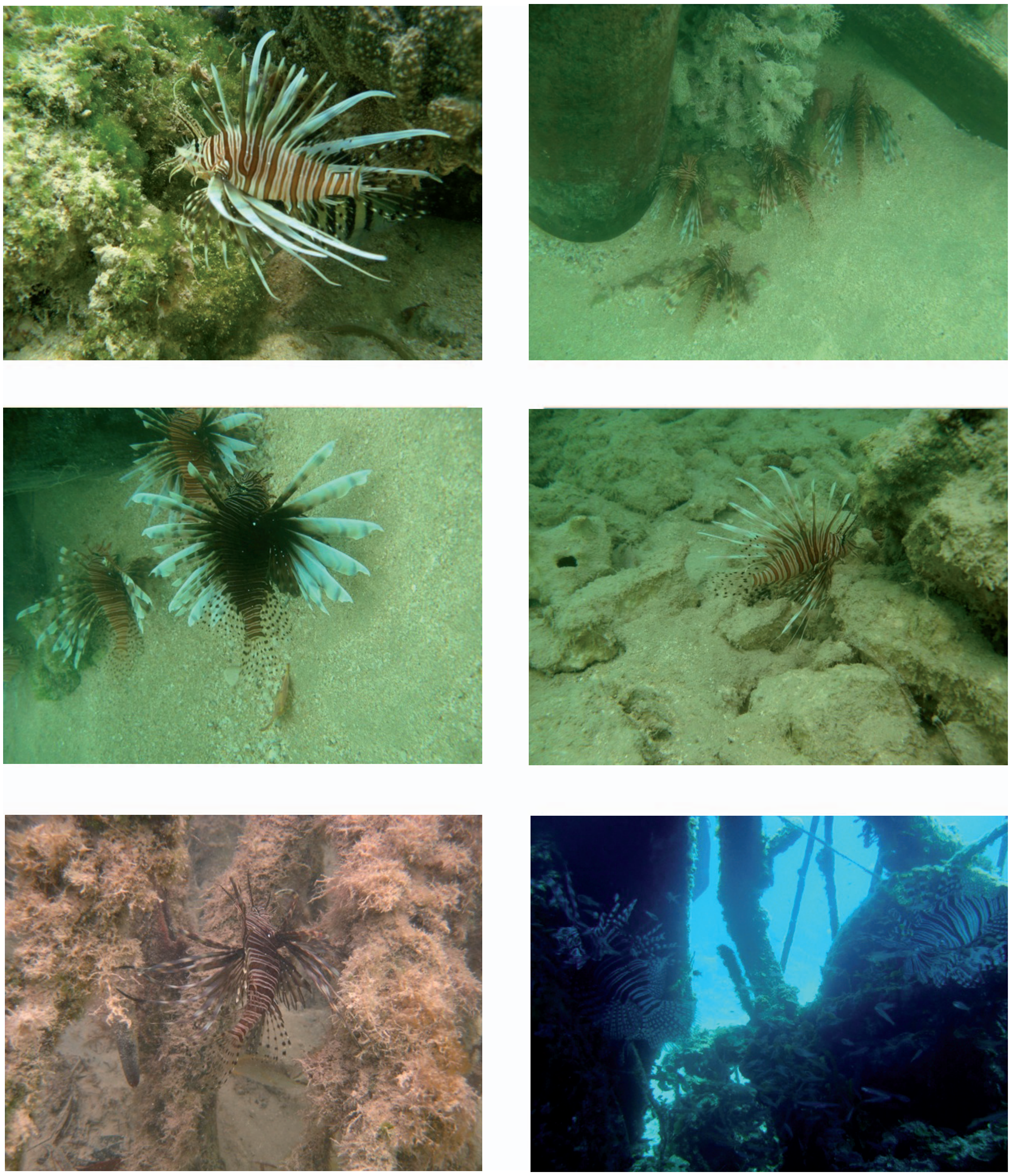

Fig. 1: *Pterois volitans* sightings along the East Andros coastline. Photo: Siobhan White, Greenforce Marine Research Station, 2008-2010

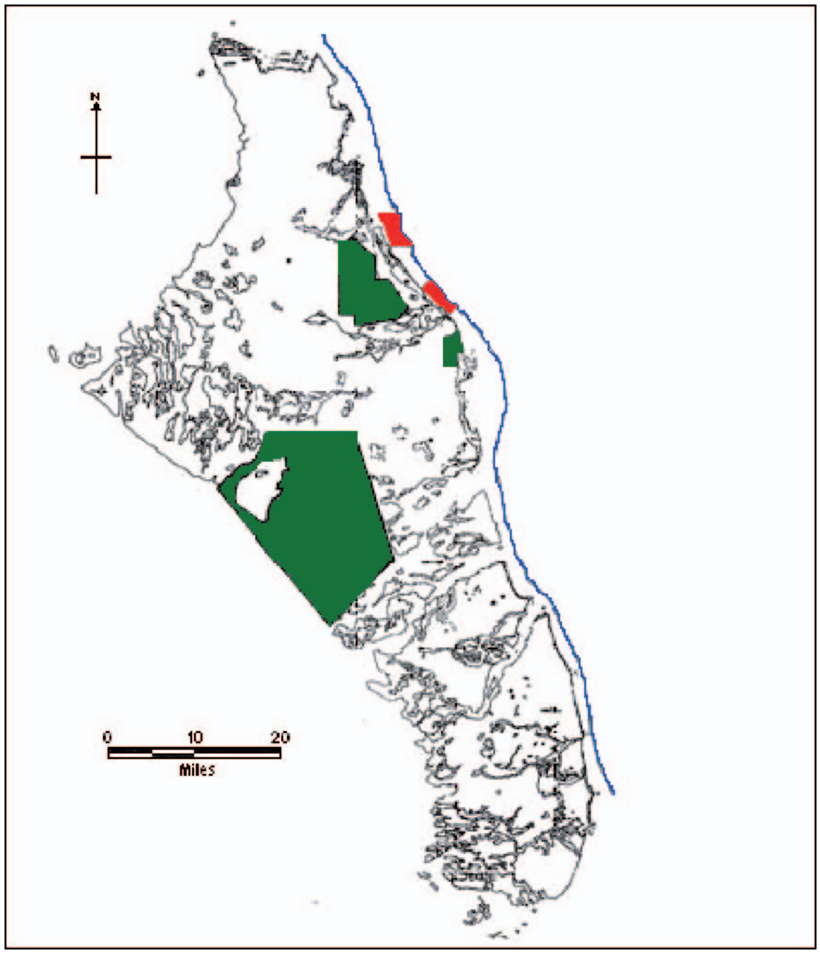


Fig. 2: Map of Andros Island, Bahamas. The red areas indicated are Marine Replenishment Zones (MRZ) and are being surveyed by Greenforce; Lionfish have been sighted in these areas by Greenforce and Forfar; sightings by local residents have occurred all along the East coastline. (Map source: Greenforce, 2006)

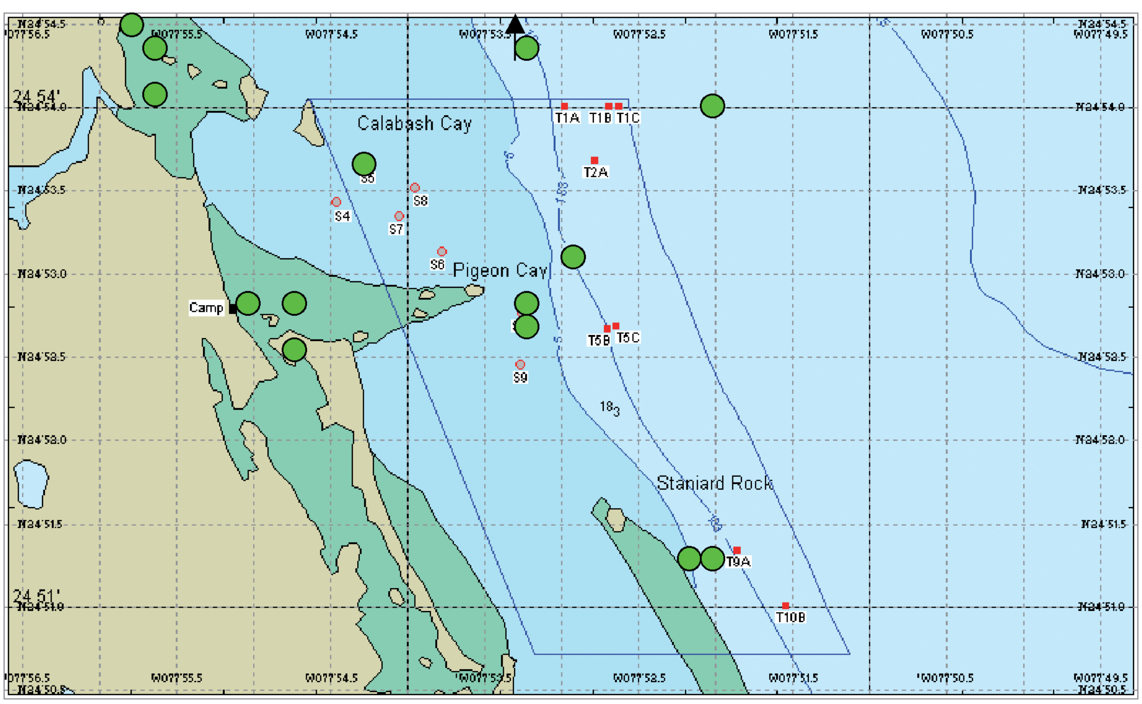


Fig. 3: Locations of Lionfish sightings within the Northern MRZ (Map adapted from Mapsource GIS, 2007)

Fig. 2 and Fig. 3 show the research locations on Andros Island. In fig 3, lionfish sighting locations are indicated with green circles. The habitat within this area is distinguished by fast moving creeks and shallow sand banks leading out to patch reef and the coral reef slope. The red markings are survey sights for Greenforce. All of the area within the blue box is within the northern MRZ.

Table 2: Individual Lionfish sighting information collected Jan-March 2007[1]

| Site Name | Date | Habitat type[1] | Depth (m) | Water ) Temp ($^0$c) | Total Length (TL) mm | Solitary /Group | Evidence |
|---|---|---|---|---|---|---|---|
| Calabash Cay | 29th Jan 07 | IC | 4 | 23 | 155 | G | Collected (Removed) |
| Calabash Cay | 30th Jan 07 | IC | 4 | 23 | 180 | G | Collected |
| Calabash Cay* | 28th Mar 07 | IC | 3 | 24 | 80 | S | Photo |
| Daves Patch Reef | 8th Feb 07 | PR | 2.3 | 23 | 75 | S | Collected |
| Jeremys Jungle | 17th Mar 07 | HPR | 20 | 23 | 250 | S | Observations |
| Log, shoreline* | 2nd Feb 07 | ART | 1 | 24 | 100 | G | Photo |
| Log, shoreline* | 2rd Feb 07 | ART | 1 | 24 | 35 | G | Photo |
| Old Forfar Dock | 6th Jan 07 | ART | 0.7 | 24 | 125 | G | Collected |
| Old Forfar Dock | 16th Dec 06 | ART | 0.7 | 23 | 134 | G | Collected |
| Pigeon Cay | 18th Mar 07 | IC | 1 | 24 | 125 | S | Collected |
| Saddleback Cay | 29th Mar07 | IC | 0.5 | 24 | unknown | S | Observations |
| Stafford Creek | 20th Mar 07 | CR | 1.3 | 24 | 150 | S | Collected |
| T5C, survey site | 12th Feb 07 | LPR | 16 | 23 | 315 | S | Observations |
| The Amphitheatre | 8th Feb 07 | HPR | 16 | 24 | 300 | S | Observations |
| The Amphitheatre | 15th Feb 07 | HPR | 14 | 24 | 320 | S | Observations |
| The old jetty, shore | 27th Jan 07 | ART | 0.5 | 23 | 140 | G | Observations |
| The old jetty, shore | 28th Jan 07 | ART | 0.5 | 23 | 110 | G | Observations |
| Three Sisters | 9th Feb 07 | IC | 2.7 | 23 | 225 | S | Collected |
| Three Sisters | 28th Mar 07 | IC | 1.7 | 24 | unknown | S | Observations |
| Tree channel marker | 2nd Feb 07 | ART | 1.4 | 24 | 150 | G | Collected |
| Tree channel marker | 3rd Feb 07 | ART | 1.4 | 24 | 75 | G | Collected |
| Tree channel marker | 4th Feb 07 | ART | 1.4 | 24 | 50 | G | Collected |

Lionfish that could be positively reported between January and March 2007, were recorded in table 2. There are many more sightings from local fishermen, visitors and divers, however only positive recordings were included in this table. This table is not designed to be an extensive count of every lionfish in the area; this information was collected to be a 'snapshot' of what lionfish are in this specific area during this time. The water temperature during Jan-March is colder ($23^0$ – $24^0$c) than the rest of the year, when temperatures stay between $26^0$-$27^0$c; this may have an effect the numbers of lionfish that are observed. Sightings ranged from 0.5m depth down to 20m, indicating they may have a tolerance to a wide depth range in this area.

The pie chart in Fig 4 illustrates the habitat types these lionfish were been observed at. The most common habitat was artificial, man-made sites such as a jetty (small dock), tree and concrete posts. Islands and small cays are the next most common location for lionfish. This indicates that man made and shallow water areas around islands may provide a favourable habitat for lionfish; these shallow sights are also nursery and juvenile grounds for juvenile grouper, snapper, conch and crawfish.

The graph shown in Fig. 4 shows the relationship between the size of lionfish and the depth it was observed at, differentiated by solitary and group sightings (Fig. 5). There may be a relationship between size and depth. Solitary fish were observed in deeper sites; these were also larger. Lionfish that are sighted in a group tended to be smaller and were found at shallower depths, indicating these could be breeding and juvenile nursery areas; this would need to be explored further and with a larger sampling size.

[1] Habitat Type: ART = Artificial/Man Made, IC = Island/ Cay, CR = Creek, PR – Patch Reef, LPR = Low Profile Reef, HPR = High Profile Reef

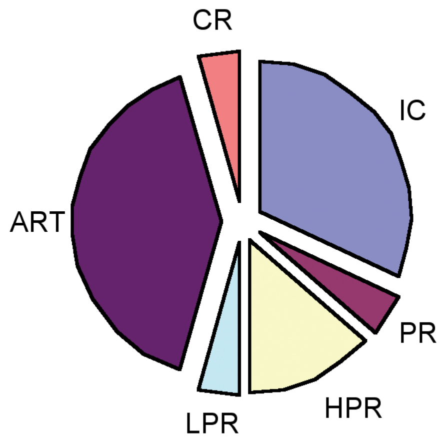


Fig 4*:* Lionfish observations by habitat type

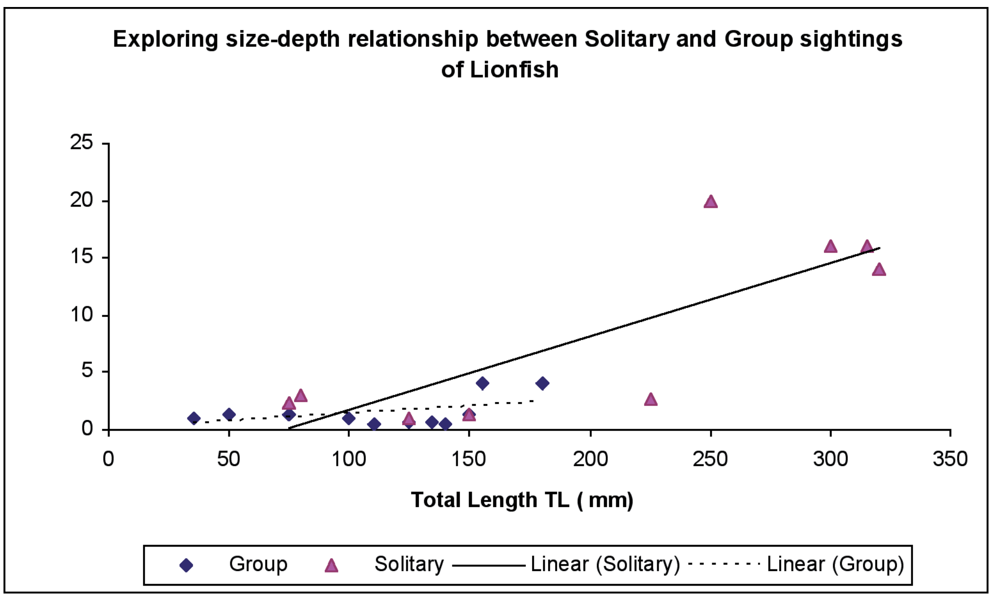


Fig. 5: The size-depth relationship between solitary and group sightings

## Discussion

Successful lionfish establishment may be due to certain traits such as (adapted from Whitfield et al 2007) aggressive tendencies (lionfish have been seen to be an aggressive hunter) and rapid establishment (sightings have increased from one sighting every month to one a week in 2007). There may be overlap of feeding niches and territorial issues as lionfish defend the areas they have inhabited (personal observations). 'Lionfish could potentially have a competitive advantage over native species such as grouper', Whitfield et al (2007).

From scientific findings of similar species, and of the lionfish establishment along the United States coastline; the Bahamas may be a favourable habitat for the lionfish and there is a danger that this species may become fully established. In the Florida Keys, an early detection and rapid response effort has kept lionfish out of the sanctuary (Semmens *et al* 2004). On Andros Island, Greenforce and Forfar have been removing lionfish, however during 2007, it has become apparent that the numbers are increasing; without a large scale eradication plan in place, Andros Island may become an area that has lionfish as an established species. Nevertheless, the rate of increase and the spread within the area should be monitored.

This research was a 'snapshot' of what lionfish there are in a certain area at a certain time period on Andros Island coupled with some key observations and notes on their behaviour. This attempts to provide a baseline for further research on the spread and behaviour of lionfish within these waters. A larger sampling size and more behavioural observation studies is needed for further analysis. Further research on their territory ranges, feeding habits and depth ranges will be useful in determining the effect this new species may have on the local ecosystem in the future.

Since early 2007, there has been a rapid increase in lionfish in the area (personal observations 2007-2008). Lionfish numbers had increased to becoming a common sighting (1-2 on every dive) on the coral reef. In the creeks and docks, lionfish have been observed accumulating in groups of 4-6 individuals and counts of 20-30 individuals for a single dock has been observed. These sightings have been passed onto the Bahamas National Trust and Greenforce are continuing to collect data on sightings. Information and awareness sessions have continued, including workshops on catching and eating lionfish, in a hope that local fishers will aid in the lionfish removal by making them part of their diet. This will take some time as there are local superstitions around eating a fish that has venomous spines. Andros Island has unfortunately become a home to lionfish in high numbers; the impacts of this on the diversity and abundance of other fish populations may not become apparent for some time.


## Acknowledgments

This work could not have been possible without the efforts of the staff and volunteers at Greenforce research station and the staff and interns at Forfar field station. Greenforce volunteers John Arthur, Andrew La Niece and Danny Gray helped with collecting the lionfish information during their stay. I would like to thank the staff at Forfar Field Station for additional lionfish data and their assistance with the removal of these invasive species. Thanks also to Ryan Stolee, Education Director of FORFAR field station for his assistance and suggestions throughout this study.


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# Booming Research on Biological Invasions in China

**Fang-Hao Wan, Jian-Ying Guo and Feng Zhang**

*China is one of the countries that have been most affected by biological invasions, with about 520 invasive alien species (IAS) recorded in agriculture, forestry and aquatic ecosystems across the country. New introductions of IAS are frequently occurring with the country's fast economic development and increasing international trade and tourism. To meet this challenge, China has invested many millions of* Renminbi (*RMB) to support basic and applied research on biological invasions since 2003. With increased funding support, good research progress has been made with guidance from a structured research framework. Fundamental research projects have been focusing on a) population establishment and expansion of IAS, b) ecological adaptation and rapid evolution of IAS and c) invasion impacts on structures and functions of ecosystem. Very importantly, a national research network on IAS has been established with 50 leading scientists from ten institutions. Applied research projects have been focusing on technology development towards sustainable management of IAS, including early warning and risk assessment technology, rapid detection and network monitoring technology, effective containment and rapid eradication technology, area-wide control and sustainable management technology*.

## Introduction

With the fast development of economy, international trade and tourism, China faces a growing threat from biological invasions. China's huge investments in infrastructure such as dams, bridges, highways, railroads, airports and ports disturb a variety of habitats and provide favorable conditions or pathways for IAS to spread and expand. For example, China's total length of railways has increased from 883,300 km in 1979 to 3,457,000 km in 2006. Higher abundance of IAS (>200) is recorded in the more economically developed coastal regions in southern and southeastern China, in comparison with less than 70 IAS distributed in western China. In 2008, Chinese Customs intercepted 2,856 harmful pest organisms from 228,626 batch of checks, an increase of 245 species (from 53,838 batch of checks) compared with the records in 2007. The number of international tourists in China has increased over 10-fold from 1979 to 2007 and reached 131,873,000 people in 2007. In 2008, there are 3,823 batches of quarantine pests intercepted from Chinese tourism port tests. Recent surveys indicate that there are about 520 IAS, causing damage in agriculture, forestry and aquatic ecosystems in China, including 268 invasive alien plants, 193 invasive alien animals (insects, crustaceans, mollusks, mammals, birds, amphibians, reptiles and fishes etc) and 61 invasive alien microorganisms (bacteria, fungi and virus etc) (Wan *et al.* 2009).

In China, IAS have already posed serious threats on the economy, ecological security, social well-being and national interest. Wan *et al* (2005) estimated that just 13 invasive alien insect pests and weeds would cause RMB 57.43 billion economic losses per year. It was estimated that the indirect economic losses in 2000 caused by IAS to wetland and forest ecosystems was RMB 69.34 billion and 15.44 billion, respectively (Li & Xu 2004, 2005). IAS also threaten China's genetic resources, biodiversity, and ecosystem structures, resulting in severe losses of ecosystem services. For example, the extensive spread of smooth cordgrass, *Spartina alterniflora* has not only destroyed the habitat of neritic organisms, but also competed with native plants for growing space, which finally led to the disappearance of mangrove trees and impossible restoration of habitat conditions in areas that had been invaded (Chen *et al.* 2004). Furthermore, some of the invasive alien species affect human health, damage public facilities, thus endangering the social securities. Pollen from invasive common ragweed, *Ambrosia artemisiifolia*, and giant ragweed, *Ambrosia trifida* is the main cause of human pollen hypersensitivity. There are about 6 million people diagnosed with hay fever in ragweed growing areas.

The current challenge posed by biological invasions is real and pressing with increasing new introductions of IAS to China. Prevention and control of IAS and mitigation of biological invasion risks at the lowest level are protecting agricultural production safety, national ecological security, national interests and social stability. In order to realize sound IAS management, China has invested in basic and applied research extensively to establish scientific research systems in the field of biological invasions. This paper provides a short overview of current research on biological invasions in China, including fundamental and applied research. More detailed information is available from the recently published book, *Research on Biological Invasions in China* (Wan *et al*. 2009).

## Research Questions for Biological Invasions in China

From an ecological point of view, biological invasions could be considered as a sequential ecological process with five phases, namely introduction, establishment, lag phase, dispersal and outbreak. Although different IAS may take different phases or duration in various ecosystems, the nature of the invasion events are similar. Bearing this in mind, research on biological invasions in China are targeting different key questions during the invasion process.

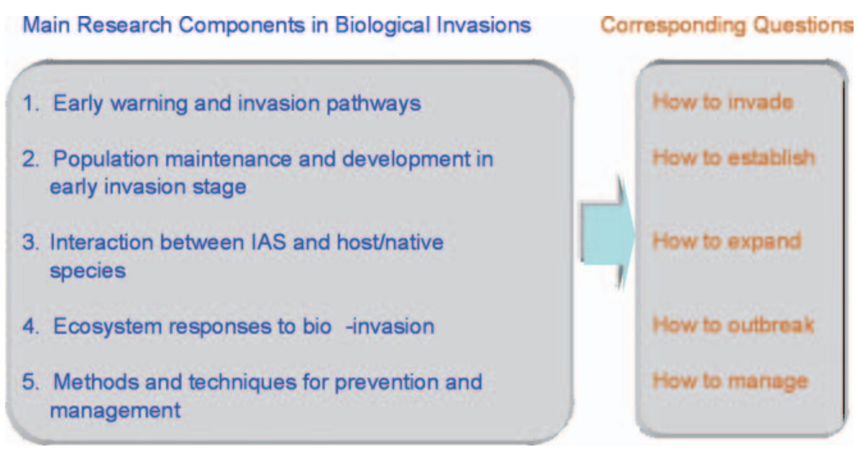


Figure 1. Main research contents and corresponding questions for biological invasions in China (Wan *et al*. 2009)

To answer how IAS invade, establish, disperse and outbreak in the introduced ecosystem and finally how to manage IAS sustainably, we suggest five research components to be emphasized in accordance with different invasions phases: early-warning and invasion pathways, population formation and development, interaction and competition between invasive species and host or native species, response of ecosystem and technologies and methods for prevention and control of IAS (Fig. 1). For potential IAS, research would focus on risk evaluation and development of rapid inspection and detection techniques. For those IAS already occurring in the country, research should be carried out on their genetic variation, ecological adaptation, population expansion activity and mechanisms, relations with native species and resources utilization. At an ecosystem level, research emphasis should be put on effects made by IAS, changes of ecosystems structure and function, and resistance or resilience to invasions.

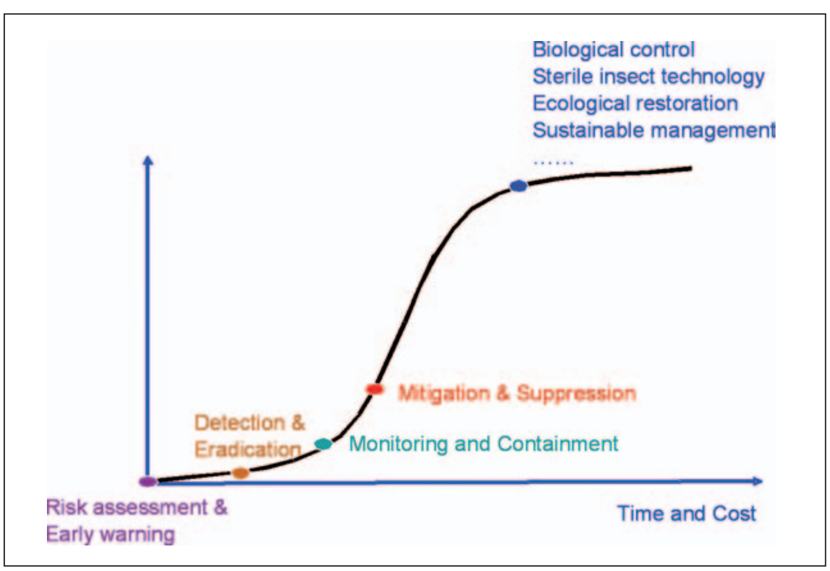


Figure 2. Management strategies of invasive alien species (Wan et al. 2009)

Based on those research works, effective prevention and control strategies would be formulated and applied at different invasion phases (Fig. 2). As for general management strategy, emphasis should be put on developing prevention and early-warning technology. In establishment and lag phases, emphasis should be put on detection, monitoring and eradication. In dispersal and outbreak phases, emphasis should be put on control and management technology (e.g. bio-control, sustainable management, etc.). Management strategies should also be varied in accordance with the targets. For example, ecosystem restoration technology would be more suitable for invasive weed management.

## Development Trend of Invasion Biology Research in China

The National Natural Science Foundation of China (NSFC) is an important governmental funding source for sponsoring China natural science research. Up to 2008, there were over 150 invasion biology research projects sponsored by the NSFC. The accumulative funding exceeds RMB 50 million. We analysed NSFC's public data from1999 to 2008 to demonstrate the development route of invasion biology research in China.

The NSFC sponsored research projects usually include general projects (funding size RMB 300,000 – 400,000) and key projects (funding size more than RMB 2 million). The majority of the NSFC sponsored projects are general projects covering a wide range of subjects in different research fields. In the recent decade, the number of general projects had a dramatic increase in the basic research of biological invasions (Fig. 3). There were only two general projects in 1999 and less than 20 projects before 2003. Thereafter, NSFC-funded general projects were increasing year by year. In 2008, the sponsored general projects reached 33 with about 15-fold increase in comparison with 1999.

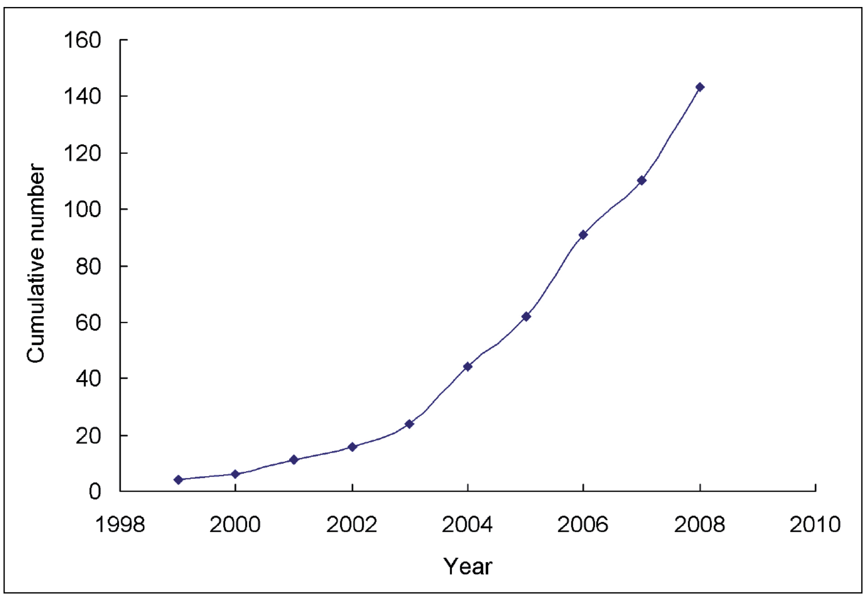


Figure 3. The number of cumulative sponsored general projects on biological invasions from National Natural Science Foundation of China from 1999 to 2008 (Wan et al. 2009)

Until the present time, there are already seven NSFC-funded key projects in the field of biological invasions. These sponsored key projects focus on the research of invasion mechanisms of IAS in agriculture and forestry, for example, pathogenic molecule mechanism and control technology for pine wood nematode, symbiotic pathogenic mechanism of pine wood nematode and its carrying bacterium, the chemical communication mechanism among natural dispersal of pine wood nematode, the vector pine sawyer beetle (*Monochamus alternatus*) and the host (pine), control technology and their mechanism of the harmful IAS, the process and physiological mechanism of the interaction among vector insect-virus-plant aggravating biological invasions, the invasion mechanism of exotic plant and the evolution of invasive alien plant, common floss flower *Eupatorium odoratum*, etc.

So far, research on biological invasions in China can be categorized into ten topics: risk assessment and early warning, detection and surveillance, genetic diversification and evolution, ecological adaptation mechanism, interaction between invasive species and native species, the process of species formation/expansion and outbreak, resistance of ecosystem to biological invasion, ecological and economic impacts of biological invasions, and the impact of human activities on biological invasions (Table 1).

From 1999 to 2003, the NSFC-funded projects focused on risk assessment, dispersal mechanism, ecological impacts and integrated management of IAS. Since 2004, the research topics have been broadened gradually and covered most aspects of biological invasions.

Table 1. Sponsoring range of general projects in Invasion Biology from National Natural Science Foundation of China from 1999 to 2008 (Wan et al. 2009)

| Year | Research Topics | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | RA | D/S | GV | EA | IBS | PE | RE | EEI | HAI | CM |
| 1999 | • | | | | | • | | • | | • |
| 2000 | | | | | | | | • | | • |
| 2001 | • | | | • | • | | | • | | |
| 2002 | • | | | | | • | | | | • |
| 2003 | | | • | | • | | | • | | |
| 2004 | | • | • | • | | • | | | | |
| 2005 | | • | • | | • | • | • | • | • | • |
| 2006 | | • | • | • | • | • | • | • | • | • |
| 2007 | • | • | • | • | • | • | • | • | • | • |
| 2008 | • | • | • | • | • | • | • | • | • | • |

RA: Risk assessment; D/S: Detection/ surveillance; GD: Genetic variation; EA: Ecological adaptation; IBS: Interactions between species; PE: Population expansion; RE: Resistance of ecosystem; EEI: ecological and economic impacts; HAI: Human activity impacts; CM: Control & Management

## National Fundamental Research on Biological Invasions in China

Since 2003, the Ministry of Science and Technology (MOST) of China has supported several national projects in the fields of basic research on invasion mechanisms of IAS, and applied research on prevention and management techniques of IAS, with a total budget of over RMB 100 million. Among those, the most significant project is a two-phase research project in ten years: First Phase - "**Invasive Biology and Control Strategy of Alien Species in Agriculture and Forestry** (2002CB111400)" and Second Phase - **"Invasion Mechanisms and Management of Major Alien Species** (2009CB119200)", which belong to National Fundamental Research Program of China ("973" Plan). The target IAS include tobacco whitefly (*Bemisia tabaci* biotype B/Q), rice water weevil (*Lissorhoptrus oryzophilus*), oriental fruit fly *(Bactrocera dorsalis)*, coconut leaf beetle (*Brontispa longissima*), red turpentine beetle (*Dendroctonus valens*), American white moth (*Hyphantria cunea*), codling moth (*Cydia pomonella*), pine wood nematode (*Bursaphelenchus xylophilus*), crofton weed (*Ageratina adenophora*), common ragweed (*Ambrosia artemisiifolia*), alligator weed (*Alternanthera philoxeroides*), water hyacinth (*Eichhornia crassipes*), smooth cordgrass (*Spartina alterniflora*) and mile-a-minute weed (*Mikania micrantha*), etc. The core scientific issues being chosen to study in this MOST-funded project are as follows.

### 1. Population establishment and expansion of IAS

To answer how invasive species break "bottleneck effect" to establish population, disperse and finally led to an outbreak, requires comprehensive understanding of population eco-genetics and clarifies living features and biotic/abiotic limitations for IAS' population establishment and maintenance. Meanwhile, an hypothesis on interaction and competition between IAS and native species (or allied species in niche), allelopathic effect of invasive plants, co-invasion of IAS and native species, as well as competitive evolution are of equal importance. In addition, elucidation on key points of "mechanisms of establishment, dispersion and expansion of invasive population" would provide scientific basis for early-warning of population establishment and geographic expansion and development of IAS remote monitoring and control techniques.

### 2. Ecological adaptation and rapid evolution of IAS

Invasive alien species comprise highly differentiated natural groups *in situ* with plenty of genetic diversity. When an invasive species enters into a new environment, its "pre-adaptation" is determined by phenotypic plasticity and "post-adaptation" determined by genetic diversification were two ecological evaluation strategies for IAS to adapt to the new environment. Under which condition would these two strategies work and how are these two strategies coordinated with each other for a successful invasion? How did IAS adjust its "post-adaptation" strategy to adapt to a new environment for a successful invasion? To construct IAS risk early-warning and develop RNA interference technology, these research questions need to be addressed and studied. In addition, "post-adaptation" mechanisms like drift, mutation and hybridization with closely related species is essential to explain "IAS eco-adaptation and evaluation mechanism".

## 3. Invasion impacts on structures and function of ecosystem

After population establishment, IAS would multi-directionally interact with other neighboring species and environmental factors directly or indirectly during its range expansion. How do IAS affect species diversity and genetic diversity, disrupt food chain among different trophic levels, damage material energy recycling and finally cause collapse of ecosystem structure and function? To answer this question, we have to study at community and ecosystem levels on IAS impacts on native species loss, genetic resource erosion, structure and food chain change and malfunction, laterality effect on circulation of materials and flow of energy material, and service malfunction of ecosystem. We need to understand impacts on invasibility and resistance of the ecosystem caused by ecological factor in heterogeneous habitats and habitats interference. We also need to analyze disorder of colony structure and function and ecological service degradation caused by IAS. Theoretical principle and scientific basis for eco-restoration of invaded ecosystem service functions are provided through illustration of "mechanism for structure collapse and functional decline".

In the completed first-phase project, breakthroughs have been achieved in invasion theory and hypothesis, such as "Asymmetric mating interactions hypothesis" on tobacco whitefly B-biotype (Liu *et al.* 2007), "Positive feedback mechanism" on crofton weed (Niu *et al.* 2007), "Mutualism facilitation hypothesis" on red turpentine beetle (Lu *et al.* 2007), "Pre-adaptation" and "Post-adaptation" of IAS (Wan & Guo 2008), etc. This project also provided theoretical and practical guidance for early warning, detection, monitoring, containment and sustainable control of IAS in China, as well as valuable information on decision-making of IAS management for the government. Very importantly, a national research network on IAS was established and strengthened through the first-phase project, with 50 scientists from ten institutions such as Institute of Plant Protection of Chinese Academy of Agricultural Sciences (CAAS), Nanjing Agricultural University, Zhejiang University, Institute of Vegetables and Flowers of CAAS, Institute of Plant and Environmental Protection of Beijing Academy of Agriculture and Forestry Sciences, Beijing Forestry University, Research Institute of Forest Ecology, Environment and Protection of Chinese Academy of Forestry, Nanjing Institute of Environmental Science of Ministry of Environmental Protection, Beijing Entry-Exit Inspection and Quarantine Bureau and China Agricultural University. This research network is further expanded through implementation of second-phase project.

## National Applied Research on Biological Invasions in China

In recent years, the Ministry of Agriculture, Ministry of Environmental Protection, State Forestry Administration of China, MOST and other governmental departments funded a series of technology innovation programs focusing on prevention and control of IAS. For example, in 2006, MOST started National Key Technologies R & D Program under Eleventh Five-Year Plan to support research on new technology of prevention and early warning, detection and monitoring, emergency control, ecological regulation and sustainable management of important IAS in agriculture. These programs push the technological innovation and development for prevention and control of IAS entering into a new development phase. According to the current situation and national needs, the following applied research has been carried out to develop more effective prevention and control technologies for sustainable management of IAS in China.

## 1. Early warning and risk assessment technology

This research is targeting invasive species, not yet introduced but higher potential, already introduced but only occurring sporadically, and those alien species with higher invasibility and outbreak potential. The aim is to establish various early earning systems and emergency control plans in accordance with different kinds of IAS and risk assessment results on its invasion, dispersal and adaptation. Based on CLIMEX, DYMEX, GARP, MAXENT and BIOCLIM, the analysis of adaptability risks for 64 invasive species have been studied, as well as their potential distribution and control plan (Wan *et al*. 2010). For example, Figure 4 shows potential distribution areas for Canada goldenrod *Solidago canadensis* in China.

China has also established seven databases related to IAS (Wan *et al*. 2009). For example, the Chinese Invasive Alien Species Database (*http://www.invasivespecies.org.cn/wzjs/ index.asp*) is operated by the Institute of Plant Protection of CAAS and the Center for Management of Invasive Alien Species, Ministry of Agriculture. It includes more than 400 IAS with information such as taxonomic status, morphology, biology, habitat types, photos, origins, introduced time and place, pathways, distribution, potential spread regions, prevention and control methods, etc.

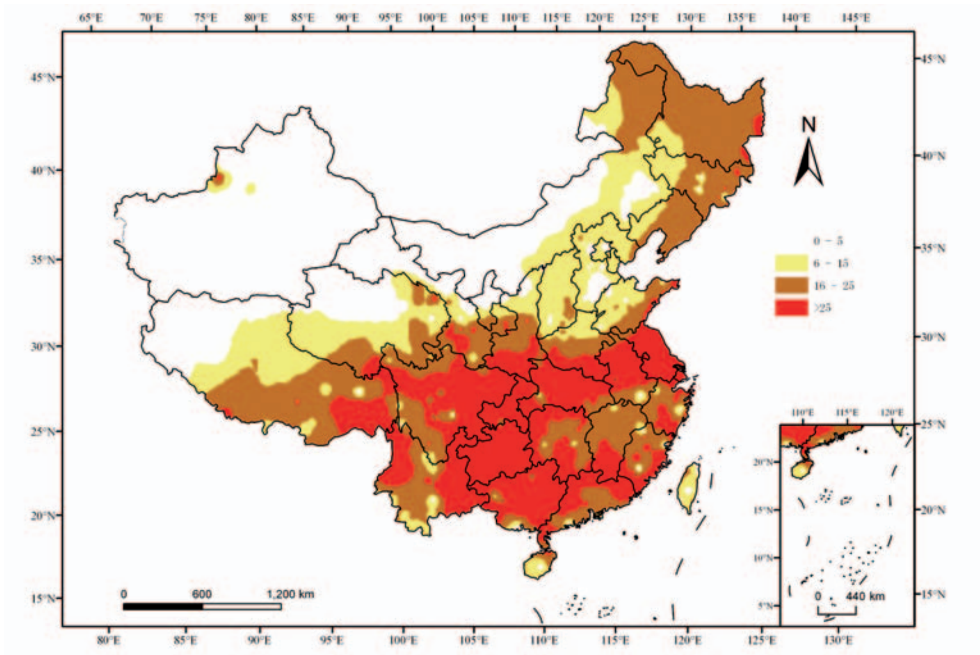


Figure 4. Suitable areas for Canada goldenrod *Solidago canadensis* survival in China


Figure 5. Field traps for adults (left) and larvae (right) of codling moth *Cydia pomonella* in China. Photo: Gui-Fen ZHANG

## 2. Rapid detection and network monitoring technology

This research is targeting the invasive species that are difficult to identify from morphological characteristics or require f labor and costs for monitoring, such as *Ralstonia solanacearum* race 2, codling moth (*Cydia pomonella*), whiteflies, thrips, scales and fruit flies, etc. It is essential to develop rapid molecular detection technology, DNA barcoding technology, un-manned field monitoring technology and remote diagnosis and identification network platforms. Rapid detection and monitoring technology has been developed for 39 important IAS in agriculture and forestry sectors (Wan *et al.* 2010).

For example, plant volatile odor and sex pheromone trapping techniques have been applied to monitor the occurrence and spread of *C. pomonella* in Xinjiang and Gansu provinces (Fig. 5). According to the risk levels, field monitoring sites have been established in the neighboring fruit production areas and potential distribution areas of codling moth to effectively monitor its further spread. In infected areas, 15-20 traps per ha are set up for monitoring purposes. In the surrounding areas where there has not yet been an introduction, two straps per ha are set up 100 km from the infected areas. Meanwhile, key monitoring spots (five traps per spot) are set up in the fruit warehouses along the potential spread path from Gansu, major highways and the neighboring apple production areas. In pest-free areas of the main fruit production provinces such as Shaanxi, Shandong, Hebei, Shanxi and Henan, a monitoring spot (five traps) per km was set up in high-risk areas (e.g. fruit warehouses), every two km in moderate-risk areas and every five km in low-risk areas. Thus, a national network monitoring system for *C. pomonella* has been successfully established (Wan *et al*. 2009).

## 3. Effective containment and rapid eradication technology

This research is targeting invasive species that are newly introduced and require emergency treatment, e.g. red imported fire ant (*Solenopsis invicta*), *B. tabaci* biotype Q and *Phenacoccus solenopsis*. It is important to establish an efficient isolation area, pest-free area, emergency control and rapid eradication techniques and measures.

Figure 6. Field survey of red imported fire ant *Solenopsis invicta* in Guangdong Province. Photo: Yong-Yue LU, Ling ZENG

For example, red imported fire ant (*Solenopsis invicta*) was first found at Wuchuan, Guangdong in mainland China in September, 2004. The monitoring results revealed that 28 county-level regions had been infested by the ant at late 2005, and the area infested was about 28,000 ha (Fig. 6, Lu *et al*. 2008). Followed by its introduction, the Ministry of Agriculture of China immediately initiated a field survey program on the red imported fire ant. A series of technical guidance documents have been published and widely distributed, such as Red Imported Fire Ant Eradication Program of China, Red Imported Fire Ant Management - Disseminating and Training Program of China, Handbook of Red Imported Fire Ant Quarantine of China, Rules for Chemical Control of Red Imported Fire Ants, Rules for Eradication of Red Imported Fire Ants, Emergency Pre-plan for Red Imported Fire Ants Prevention and Control, etc (Huang *et al*. 2007). Field demonstration plots for eradication of red imported fire ant have been set up for technology transfer.

## 4. Area-wide control and sustainable management technology

This research is targeting the invasive species that are already widely distributed and causing serious damage to the environment, agriculture or forests production, e.g. *A. adenophora*, *A. artemisiifolia*, *A. philoxeroides*, *E. crassipes*, *S. alterniflora*, *M. micrantha*, *L. oryzophilus*, *Eriosoma lanigerum*, *Viteus vitifoliae*, fruit flies, etc. The aim is to establish area-wide integrated management system based on mechanical control, biological control and chemical control (Wan *et al.* 2008 a, b). As an important measure of integrated management, classical biological control has been carried out on more than 20 invasive species in China. More than 40 natural enemies have been introduced into China, within which 20 are of great value of application and over ten perform well after field releases (Wan *et al*. 2009).


Figure 7. Combined control effect of *Epiblema strenuana* and *Ophraella communa* on *Ambrosia artemisiifolia* in the field (2008, Miluo City, Hunan Province). Photo: Zhong-Shi ZHOU.

*Ambrosia artemisiifolia* was introduced into the southeastern coastal region of China in the 1930s. It is now widely distributed in 23 provinces in China, and has caused serious economic losses in agriculture and threatened biodiversity and human health (Ma *et al.* 2008a). Five natural enemies, including *Zygogramma suturalis*, *Tarachidia candefacta*, *Epiblema strenuana*, *Euaresta* sp. and *Liothips* sp. were introduced into China from Canada, Former USSR and Australia in the mid

1980s. *Epiblema strenuana* has established and spread into Hunan, Hubei and Jiangxi provinces since its first field release in 1993. Although released in north China, *Z. suturalis* failed to establish its population in the fields. *Ophraella communa* is an alien natural enemy insect, and was accidentally discovered in Nanjing, Jiangsu Province in 2001. Both *E. strenuana* and *O. communa* are now well adapted to climatic conditions of the weed's distribution areas in China, and play an important role in common ragweed control (Ma *et al.* 2008b). Mass rearing of the two natural enemies and combined release technique have been successfully developed and implemented in Hunan Province (Fig. 7). A sustainable management program of common ragweed based on biological control, mechanical control, chemical control and ecological restoration is now widely implemented across the country.


## Acknowledgements

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# Snapshot on introduced invasives in a desertic country, the United Arab Emirates

**Christophe Tourenq and Maral Khaled Shuriqi**

Despite being regarded as a vast desertic and unfertile area, the Arabian Peninsula, and the United Arab Emirates (UAE) in particular, hosts a unique and remarkably adapted fauna and flora (Tourenq and Launay 2008). Because of climatic and environmental harshness, the invasion by alien species on land has been contained until recently to man-made habitats in this region. However, an increasing human population and economical wealth, and an encroachment of natural habitats through farmland, forestry and residential areas expansion, are changing the pattern.

Introduced for greenery in the 1970s, mesquites (*Prosopis juliflora* and *P. glandulosa*) form nowadays in some areas impenetrable and dense habitats (Fig. 1), competing strongly with native species for soil and water resources, suppressing grass growth, reducing understory species diversity and triggering allergies in the local population (Rasanen 2000; El-Keblawy and Al-Rawai 2007; Alsowaidi et al. 2010).

Fig. 1 Introduced mesquites (*Prosopis juliflora*) invading coastal plains of the Emirate of Fujairah, UAE. The tree in the centre of the picture is a native Ghaf tree (*Prosopis cineraria*). Photo: EWS-WWF.

Probably imported with soil, fertiliser and plants, 15 species of non-native ants have been identified in the UAE, including the Singapore Ant (*Monomorium destructor*), the Samsum Ant (*Pachycondyla sennaarensis*), and the Ginger or Tropical Fire Ant (*Solenopsis geminata*), which are serious public health problems and nuisance pests (Collingwood et al 1997; Reunala et al 2005). Probably through the same way, six species of terrestrial gastropods molluscs have been iintroduced (Feulner et al. 2005) of which the African slug (*Laevicaultis alte*) and the Florida snail (*Polygyra cereolus*) are listed as pests for plantations requiring intensive use of pesticides with a risk of polluting groundwater.

Contained in some cities of the Gulf coast until the 1980s, introduced Red-vented Bulbul (*Pycnonotus cafer*), Ring-necked Parakeet (*Psittacula krameri*), Common Mynah (*Acridotheres tristis*), House Crow (*Corvus splendens*), and Grey Francolin (*Francolinus pondicerianus*) are nowadays amongst the commonest birds in the UAE (Aspinall 1996; Richardson 2003; Kahn et al. 2009). In the region, Ring-necked Parakeet, Common Mynah and House Crow are known to expel the native avifauna through predation or competition for nesting sites, occasion nuisances for people (including carrying a wide range of human pathogens) and damage to cultures (Holzapfel et al. 2006; Ryall and Meier 2008; Eason et al. 2009).

During the building of oil exploitation facilities, Brown and Black Rats (*Rattus norvegicus* and *R. rattus*), House Mouse (*Mus musculus*) and subsequently, domestic cats as a way to control the rodents, were introduced on islands of the Arabian/Persian Gulf occasioning noticeable predation on reptiles and bird species, some of which being of international importance, (Drew *et al.* 2003; Soorae *et al.* 2005; EAD-AGEDI 2008). Inland, feral donkeys (*Equus africanus*) have escaped or being released in the wild after the introduction of motorised vehicles in the 70s, causing havocs on the roads and grazing/trampling of the sparse vegetation in some places (pers. obs.).

For a decade now, Red-eared Sliders (*Trachemys scripta* spp.) have been recorded in the UAE: in a pond in Abu Dhabi town (D. Gardner, unpubl.), in a quarry hole in Ras al Khaimah Emirate, and more worryingly: in natural mountains wadis of Sharjah Emirate (Wadi Shi), Dubai (Hatta area; G. Faulner, unpubl.) and more recently (2007) Fujairah Emirate (Fig. 2). In the region, feral populations of Red-eared Slider are established in freshwater marshes of Palestine and Bahrain (Gasparetti et al. 1993).

Fig. 2 Red-eared slider (*Trachemys scripta spp.*) found in Wadi Wurayah, Emirate of Fujairah, UAE. Photo: Eman Ali Mousa, HCT Sharjah

Molly fish (*Poecilia spp*.) has been mentioned in Dubai emirate so far (Feulner 1998), but non native Tilapia (*Oreochromis spp.*), used in fish farming locally, have been observed in several wadis of the country (Feulner 1998). Recently (2008), the presence of Mozambique Tilapia (*O. mossambicus*), as well as ornamental domesticated variety of the Common Carp (*Cyprinus carpio*) have been identified in Wadi Wurayah, Fujairah Emirate, the first mountain protected area of the UAE: prompting their eradication (Tourenq et al. unpubl.).
The UAE are a major hub for importation and re-exportation of fauna and flora items between Asia, Africa and Europe. If pet trading is one of the most frequent ways of alien species introduction, most of invasives are however not concerned by the Convention on International Trade of Endangered Species (CITES) which for the UAE are signatory. Having one of the most complete legal arsenal of the region for the protection of their native species, but already several invasives amongst the "100 worst in the world" (http://www.issg.org/database), the UAE need urgently to establish rigorous ways to control of importation of exotic species, including plants for ornamental purpose, to avoid further introduction of invasive aliens with dramatic ecological and economical consequences.

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# Workshop on Invasive Alien Plants in Mediterranean-type Regions

**Eladio Fernández-Galiano and Sarah Brunel**

Mediterranean regions are listed among the most important biodiversity hotspots in temperate climates. The Mediterranean basin, parts of California, Chile, South Africa and Southwest Australia contain some of the world's major centres of plant diversity. The Mediterranean basin alone houses some 25.000 to 30.000 species, up to 50% of which are endemic to the region. Unfortunately they are suffering, like many other parts of the World, from invasive alien species which proliferate in natural habitats and modified ecosystems alike and pose an important threat to the unique and interesting native species that characterise Mediterranean biotas. To examine the extend of the invasions, know more about the ecology of invasions, analyse preventive conservation action and suggest ways forward to tackle the problem of invasive alien plants, the European and Mediterranean Plant Protection Organization (EPPO) together with the European Environment Agency, the Council of Europe, the Igdir University and the Turkish Ministry of Agriculture organised a Second Workshop on Invasive Alien Plants in the Mediterranean-type Regions of the World that met in Trabzon, Turkey, from 2 to 6th of August 2010. Over 70 scientific papers and communications were presented and discussed in small workshops. The main conclusion were summarised in the enclosed "Trabzon message"

## Trabzon message

The Participants:

1. **Warmly thank** Turkish authorities and the Technical University of Black Sea for their warm welcome and excellent hosting of the meeting and the European Environment Agency, the European and Mediterranean Plant Protection Organization, and the Council of Europe for their support, as well as the sponsors.

2. **Recall** the Mèze Declaration and note that Invasive Alien Plants are a major threat both to natural and semi-natural habitats and agriculture and that our societies would highly benefit from addressing the issue and taking further steps to control their spread and mitigate their impacts.

3. **Encourage** governments, the scientific community, conservation practitioners, the agriculture profession, the horticulture industry, National Plant Protection Organizations, and other appropriate stakeholders to publicize and implement the recommendations below which are the result of discussions in the different workshops from this meeting:

- **Promote awareness** on IAP, targeting diverse public, by creating a well-planned and effective communication strategy, and **organize a wide Mediterranean "cleanup day"** including hands on activities to control IAP (2011 or 2012) which should be widely publicized;
- Encourage the elaboration **of lists of priority alien plants** as a tool to raise awareness on emergent invasive alien species by biogeographical zones, particularly in Mediterranean countries where global databases are lacking, as it is planned to be done by a number southern Mediterranean countries with the EPPO prioritization process;
- Promote the **eradication** of invasive alien plants as a tool to be used as part of the integrated management of IAS, giving due consideration to its costs, feasibility and the health, economy and conservation gains; prioritize species and target habitats, monitor results and publicize and exchange information;
- Take necessary steps to make **Codes of conduct** on invasive alien plants better known and used and to encourage their use, establishing a dialogue with the horticulture industry and its customers (including managers involved in landscaping operation); use meetings of the horticulture industry like the one to held in Turkey in 2016 to draw their attention to the need of cooperation; publicize the Council of Europe/EPPO Code of conduct on horticulture and invasive alien plants, and translate it to different languages and adapt it nationally;
- **Discourage the planting of** Acacia species known to be invasive; establish a network to transfer knowledge so that management can be improved and risk assessment communicated;
- Encourage and support the inclusion and integrations of **North African countries** in the European early warning system being developed by organizing a workshop targeting representatives of national authorities and academics so as to raise awareness and promote the increase in knowledge;
- Encourage **cooperation** on, training of specialists and early warning in the **Black Sea region** which is subject to high trade and fast spread of IAP and relatively difficult exchange of information;
- Promote **early warning and rapid response** systems, including at the local and/or regional level; create awareness among governments and international bodies on the need to deal soon and effectively with new invasive alien plants; promote flexible mechanisms of early response, based on local expertise and resources; work towards and integrated European system like the one proposed by the EEA.
- Use **risk assessment** for the selection **of biofuel crops**, and monitor closely the plants that are used in order to assess their invasiveness in new cropping systems;
- Launch a questionnaire on the important invasive alien plants in **arable areas** in Mediterranean countries to be spread to the participants and any relevant contacts, analyze and update these data on the Internet;
- Focus research on new invasive alien plants under **global change** (e.g. aquacrop model of FAO);
- Support the preparation of **national inventories and herbaria** of IAP as useful tools for IAS national strategies and promote local and regional exchange of information.

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# Time for chytridiomycosis mitigation in Spain

**Jaime Bosch, Saioa Fernández-Beaskoetxea and Bárbara Martín-Beyer**

*It is well known that the introduction of alien invasive species greatly alters the natural dynamics of ecosystems. The spread of pathogens between species that do necessarily have the evolutionary adaptations to resist them have had serious consequences leading to population declines. The spread of chytridiomycosis an infectious disease of amphibians, caused by the chytrid fungus* Batrachochytrium dendrobatidis *has been linked to severe population declines or even extinctions of amphibian species. The fungus is spread through infected amphibians and potential vectors, some of whom have been introduced worldwide for biomedical research, through the pet trade or for biocontrol purposes. Chytridiomycosis is a major cause for concern for conservationists and biologists.*

## Introduction

The infectious disease Chytridiomycosis has been defined as "the worst infectious disease ever recorded among vertebrates in terms of the number of species impacted, and its propensity to drive them to extinction" (Gascon et al. 2007). Its etiological agent, the fungus *Batrachochytrium dendrobatidis* (*Bd*) could be one of the most dangerous alien species of our times.

Following its discovery from dead amphibians in Panama and Australia (Berger et al. 1999), it was believed that the disease was particularly active in tropical areas. However, before the formal description of *Bd* as a new genus and species, common midwife toads were dying by the hundreds in protected areas of central Spain (Bosch et al. 2001). Although amphibian extinctions are of most concern in the tropics, temperate areas, and particularly southern Europe, are highly suitable regions for *Bd* (e.g. Rödder et al. 2009).

While it is clear that mass amphibian mortalities have occurred, as a result of Bd infection, it is also true that the occurrence of Bd does not always result in mass amphibian mortalities, and that Bd is able to endure in naïve amphibian populations without having noticeable effects. Despite the shocking image of hundreds of dead frogs on pond shores, the most deleterious effect of the disease is often underestimated and that is its indirect effects. Chytridiomycosis causes weight loss and fitness reduction on larvae and animals in post-metamorphic stages (e.g. Parris and Beaudoin 2004, Garner et al. 2009), and is able to modify the structure of amphibian assemblages by favoring less sensitive species (Bosch and Rincón 2008).

Further, *Bd* infected animals exhibiting controlled infection are, in fact, not experiencing the disease, and that could be the most common condition in most places in the short term. Severely ill and dead animals are only seen in situations where the threshold burden of *Bd* infection is exceeded.

Unfortunately, we still are far from being able to eliminate *Bd* from the environment. Additionally, we are unable to stop its dispersal. Therefore it is imperative that other approaches are tried. Fortunately, mathematical models predict that mass mortalities can be reduced if we are able to reduce infection loads in affected populations, (Mitchell et al. 2007, Briggs et al. 2010).

## The case of midwife toads in Spain

In Spain, though *Bd* is broadly distributed, episodes of mass mortality are only known to have occurred in montane areas where temperatures are not very high (Walker et al. 2010). Midwife toads (genus *Alytes*) are probably the most susceptible species in Europe (Bosch et al. 2001, Walker et al. 2010). Although they are terrestrial and only males approach the water to release egg clutches, tadpoles (that characteristically have a long lifespan) are in permanent contact with the aquatic fungal zoospores. Since midwife toad populations exhibit great ecological variability (occurring in habitats from the sea level up to 2500 m), the threshold burden of *Bd* infection is usually reached above 1500-1800 m (Walker et al. 2010). Infected populations located at lower altitudes are still abundant.

The Peñalara Natural Park in Madrid is an alpine area located just 70 km away from Madrid, a city with a population of four million people. However, most parts of the Park remain pristine, and up to ten species of amphibians are found to occur in this area (fig. 1). This protected area is exceptional for its recent conservational efforts. In 1999, the old ski station present in the area was removed to restore natural conditions. Helicopters and mules were used to avoid any additional damage.

Fig. 1. The Laguna de Pájaros at the Peñalara Natural Park in Madrid held a large population of *Alytes obstetricans* before chytridiomycosis crash. Photo: Jaime Bosch

In 1997, the first case of Chytridiomicosys in Europe was reported in this area (Bosch et al. 2001). The dynamics of the disease has been followed every year since then. Each of the 250 or more ponds in the Park is sampled up to six times every year for counts of egg clutches and tadpoles. In addition, automatic call recorders (frogloggers), visual encounter surveys at night and mark-recapture programs with some species are conducted to follow population trends of every amphibian species.

The outbreak of the disease rendered the population of the common midwife toad, *Alytes obstetricans*, close to extinction. Tadpole abundance dropped remarkably in successive years (e.g. from more than 5000 to 20 in a pond holding the largest population) and in just three years the species disappeared from 96% of ponds. Dead or ill adults were never found in the area, while thousands of dead or moribund metamorphs could be easily collected (fig. 2).

## What can we do?

In the years following the first mass mortalities, we tried to help the affected species by creating additional pools and refuges. However, mass mortalities did not stop and common midwife toads were close to local extinction.

Precise surveys in the area indicated that every *Alytes* tadpole consistently died after metamorphosis. Pilot experiments verified that infected tadpoles did not die after metamorphosis when kept in captivity at more than 21ºC (Bosch et al., unpublished data), as has been found in the case of other species and life stages (e.g. Woodhams et al. 2003). Hence, every single tadpole found in the area was collected and kept in the laboratory under that temperature. After the completion of metamorphosis, the treated animals were released, even though some of them tested positive for *Bd* using molecular techniques.

In 2008, the thermal treatment was replaced by itraconazole baths (following Garner et al. 2009); and detailed studies of infection status and survival of released animals are now in progress. Although we expect re-infection of treated animals in both cases, it is hoped that released animals will at least reach adulthood and breed, since no dead adults have been ever found in the field.

To avoid the extirpation of *A. obstetricans* in the Park, a captive-breeding program was established by the local government of Madrid (Consejería de Medio Ambiente, Vivienda y Ordenación del Territorio), the Spanish Museum of Natural History (CSIC) and Durrell Wildlife Conservation Trust (fig.

3). A few individuals (mostly tadpoles) were collected from every remaining population and kept in captivity in new facilities specifically designed for that purpose.

Fig. 2. Dead *Alytes obstetricans* metamorphs at the Peñalara Natural Park. Photo: Jaime Bosch

The main objective of the program was to keep a captive stock to prevent total extinction, but the colony is also a source of individuals to be reintroduced into the wild. After a couple of years, some animals have started to reproduce, and the first young animals have been reintroduced in the Park.

More than 350 *Alytes* froglets have been released in three different locations. In one location, the aim is to reinforce the existing population, while in the other two locations the aim is to found a new population after the original one went extinct. One of the three selected locations is the only temporal pond which supported an *Alytes* population in the past. Since this pond usually dries out for a couple of weeks every year, it was thought to be the least suitable pond for *Bd*, among those able to support *Alytes* populations. Last spring three animals were seen and males were heard calling, so some individuals remain alive after the winter, although they did not breed yet.

Fig. 3. Three climate-controlled room of the breeding center of *Alytes obstetricans* at the Peñalara Natural Park. Photo: Jaime Bosch

## How Bd reaches and survives in naïve populations?

After the crash of the *Alytes* population in Peñalara, *Salamandra salamandra* and *Bufo bufo* also experienced mass mortalities due to *Bd* (Bosch and Martínez-Solano 2006). Interestingly, since then *B. bufo* has expanded its range in the Park, occupying those permanent and large ponds where *Alytes* had disappeared (Bosch and Rincón 2008). Thousands of *B. bufo* froglets died every year after metamorphosis; but now without the competition of *Alytes* tadpoles, *B. bufo* adults can lay their egg masses in these recently empty ponds. Since *B. bufo* clutches can reach 10.000 eggs, and not every individual died after metamorphosis, this species has been favoured by the disease. For *S. salamandra* the situation is more complex because the species breeds also in temporal streams and ponds where the fungus is less abundant. Therefore, even if the species experienced a significant population reduction a few years ago, its situation now is not as worrying as that of *Alytes*.

*B. bufo* tadpoles are now one of the best reservoirs of the infectious fungus in the large ponds where *Alytes* has disappeared, making the recovery process more difficult. Other species, like *Pelophylax perezi* and *Hyla arborea*, are also good *Bd* reservoires. They have expanded their distribution range in the Park, and are now found at higher altitudes probably due to a warming climate. A similar condition occurs with the alpine newt, *Mesotriton alpestris*. The newt was introduced to Peñalara in the 80's and has expanded its range in the past few years (Martínez-

Solano et al. 2003). However, the species is endangered in its natural range of distribution in Northern Spain, so its extirpation from Peñalara is worrying.

Fig. 4. Reintroduction of *Alytes obstetricans* at the Peñalara Natural Park. Photo: Paco Cantó

It is possible that *Bd* may have been introduced to the Park through introduced alpine newts.. The source population of the newts were close to Bd infected populations. Changes in the infection levels of endemic species are being evaluated based on the addition or removal of *M. alpestris* larvae from particular ponds.. If the results of these experiments are conclusive, there will be a strong case to initiate the extirpation of the alpine newt from Peñalara.

While, the thinking a few years ago was that the arrival of *Bd* to naïve populations could occur through zoospores attached to people's boots; we are now confident that introduced infected animals are the main cause of *Bd* spread through long distances. The first known case of *Bd* was found in a sample of the African clawed frog (*Xenopus laevis*) collected in the late 30's. At that time, this frog was being exported to USA, Australia, Asia and Europe for pregnancy tests. In addition to their export for biomedical reasons; trade of amphibians for food (*Lithobates catesbeiana*), biocontrol (*Rhinella marina*), or as pets (dendrobatids in general), has propitiated the spread of these species globally including their introduction into the natural environment (Fisher and Garner 2007). The low vulnerability to infection and rapid spread of these species has led to the expansion of *Bd* and other pathogens, such as some specific amphibian iridovirus. For these reasons, *Bd* and ranavirus are now included in the Aquatic Animal Health Code of the World Organization for Animal Health (OIE) with recommendations for certifying the disease status of countries and amphibian products. Controversially, samples of *Bd* have been found in formalin-fixed and ethanol- stored specimens of the Japanese giant salamander (*Andrias japonicus*) collected in 1902 (Goka et al. 2009). However, their relationship to *Bd* isolates found infecting continental communities is thus far unknown.

Only a few cases of amphibian introduction are known in Spain. Bullfrogs or clawed frogs have not yet been introduced, even if there have been a few failed attempts to establish factories. The only recently introduced amphibian species in Spain is *Discoglossus pictus*, which was introduced to northeastern Spain in the 60's from southern France (Montori et al. 2007). However, *D. pictus* inhabits lowland areas and it still confined to northeastern Spain, so it is unlikely to have been the source of *Bd* introduction in Spain.

It is possible that Bd introduction to Mallorcan midwife toad (*Alytes muletensis*) populations on the Spanish island of Mallorca, in 1991, was through the *A. muletensis* recovery programme.(Walker et al. 2008). The critically endangered Mallorcan midwife toad may have been doomed to extinction were it not for the recovery programme established in the 90's. Unfortunately, infected *Xenopus* from South Africa were kept in the same room as the Mallorcan midwife toads in Jersey Zoo, prior to reintroduction in Mallorca. Now, 4 out of thirty existing populations are infected, and there is concern about possible cross-contamination among them. Luckily, infected populations are located in a very dry environment which constraints animal movement along torrents, and makes impossible dispersal among different basins.

## New mitigation approaches

The infected populations of *A. muletensis* are appropriate targets to explore mitigation approaches. No other amphibian species are present in the area and pools holding tadpoles are small and relatively free of organic. In 2009 we tried to eliminate *Bd* from an infected population, with assistance from the local government of Mallorca (Conselleria de Medi Ambient I Mobilitat), MC Fisher (Imperial College) and TWJ Garner and J Bielby (Zoological Society of London) (Lubick 2010). Tadpoles were collected during several visits over a 6 month period from an infected pool. The tadpoles were taken to the laboratory, where they were cleaned with itraconazole. Field work commenced before the breeding season with the collection of over-wintering tadpoles, and ended when no new egg clutches were found. When all tadpoles were collected, the pool was completely desiccated, and cleaned tadpoles were placed back in the pool after the first autumn rains. Regrettably, after a few months in the pool all the released tadpoles were found infected again, although the infection levels in winter dropped to regular levels during summer time (when the infection levels are lower due to warm temperature). In 2010 a similar approach was tried on an infected population of the Betic midwife toad, *A. dickhilleni*, with help from the Fuengirola Zoo. The Betic midwife toad is another endemic *Alytes* species of Spain, and its long larval development period and montane habits make the species highly susceptible to Bd. The selected population used a cattle trough for reproduction. Instead of taking the tadpoles to the laboratory, they were kept in situ in a small plastic swimming pool during the seven days of treatment. At the same time, the cattle trough was dried out and rebuilt with concrete for maintenance reasons.

## Lessons learnt until now

We are now confident that *Bd* eradication is a difficult goal to achieve and, mitigation is the only affordable approach at the moment. The only current option is to keep infection levels controlled to avoid mass mortalities of susceptible populations. If we make this effort for a while, maybe natural selection against the disease will develop or new mitigation approaches will be developed. Among these, biotherapy or immunization may be the most encouraging methods, although they require significant resources and work. Recently, a consortium called RACE (Risk Assessment of Chytridiomycosis to European amphibian biodiversity), headed by MC Fisher from Imperial College London has been funded by the European Union's Biodiversa research initiative. RACE will develop a standardized European Union-wide monitoring scheme by disseminating information to national and international stakeholders, and by building collaborations in under-surveyed countries to gain understanding on which conservation efforts are most necessary to mitigate the effects of Chytridiomycosis and preserve amphibian biodiversity.

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# The management of raccoon dogs (*Nyctereutes procyonoides*) in Scandinavia

**Fredrik Dahl, P-A Åhlén, and Åke Granström**

*The raccoon dog (*Nyctereutes procyonoides*) is an invasive species native to eastern Asia which was introduced as a fur game species to the western parts of the Soviet Union in the 1930s-1950s. Apart from causing ecological damage to the native fauna in colonized areas in Europe, the raccoon dog is also one of the main vectors of rabies in Europe and an important vector of several parasites dangerous to humans. The LIFE programme is the EU's funding instrument for the environment. The programme recently approved funding for a three-year project (Management of the invasive Raccoon Dog* Nyctereutes procyonoides *in the north-European countries), aiming to prevent the invasive raccoon dog from establishing in those Nordic countries it has not already invaded. Eradication and reduction will, to a large extent be achieved, by using innovative methods for culling and management developed in earlier national projects. This paper describes the methods that will be used in the LIFE project along with experiences from earlier projects. Even though the practical results so far are very promising, the early work also suggests that the cooperation between countries is as important as the methods used to eradicate and control the species.*

## Introduction

Invasion by non-native species has been recognized as one of the main threats to global biodiversity, second only to habitat loss and fragmentation (Walker and Steffen 1997; Weidema 2000). Ebenhart (1988) further showed that the largest effect by introduced species on native fauna globally comes from introduced predators. Today, the impact of non-native species is a major concern throughout the world and their management and control is likely to become a main challenge for conservation biologists and managers during the coming decades (Allendorf and Lundquist 2003).
The raccoon dog is an opportunistic generalist carnivore native to eastern-Asia. Between 1929 and 1955 a total of 9 100 individuals were introduced to the wild as fur game in the European parts of the former Soviet Union and it soon became widespread in central and northern Europe (Helle and Kauhala 1991). In the period from 1935 to 1984 the raccoon dog colonised 1.4 million km$^2$ of Europe by secondary expansion (Nowak 1984). The raccoon dog is already established in Finland and is at the moment invading Sweden and Norway via Finland and possibly Russia, as well as Denmark via Germany. The raccoon dog has many features which make it a successful canid (Kauhala 1994). It is omnivorous and their food niche is much wider than those of most other carnivores. It has a very high reproductive capacity and sleeps through the winter where they are harsh and is generally very adaptable to new environments (Kauhala 1994). For further details on the biology, ecology and behaviour of the raccoon dog see e.g. Kauhala and Saeki 2004 (and references therein). One specific feature for the importance of this project is, however, the social behaviour of the raccoon dog. They are strictly monogamous and a pair rarely leaves the side of the partner except during the rearing of their young, however, if either of the pair dies, the other will try to find a new mate (Kauhala and Saeki 2004). The raccoon dog causes severe damage to native waterfowl in Europe (Kowalczyk 2006, refs in Kauhala 1996; Kull *et al* 2001; Väänänen 2003) and may be a threat to amphibian populations (Kauhala 1996). The raccoon dog is also one of the main vectors of rabies in Europe and an important vector of several parasites dangerous to humans such as the fox tapeworm (*Echinococcuss multilocularis*) (Oivanen *et al*. 2002; Westerling 1991). All Nordic countries have ratified the RIO-convention on biological diversity as well as the Bern and Ramsar conventions.
These conventions state that we must prevent alien invasive species from establishing in countries and, if they have already done so, we are committed to try to eradicate or reduce the populations as far as possible and to limit their further expansion into other countries. The raccoon dog is listed in Recommendation no. 77 of the Bern Convention (Convention on the Conservation of European Wildlife and Natural Habitats) among the invasive species that have proven to be a threat to biological diversity and should be eradicated. In Recommendation No. 139 (2009) the Bern Convention Standing Committee recommends contracting parties to the Convention to monitor, control and eradicate the raccoon dog as effectively as possible.

In Sweden in 2008 we initiated several national projects, funded by the Swedish Environmental Protection Agency, the Directorate for Nature Management in Norway, and the Swedish University of Agricultural Sciences (Environmental Monitoring and Assessment of Game Species) to develop and evaluate methods that could be used for finding and eradicating raccoon dogs and to prevent the raccoon dog from establishing in Sweden and thereby also Norway. The work was done in an adaptive approach, where management and research efforts ran simultaneously to support and continuously improve each other. Even though the results were encouraging, we soon realised that without including our neighbouring countries, our efforts will most likely be insufficient to stop the raccoon dog from establishing also in Sweden and Norway (Dahl *et al.* 2009). In 2009 we were approved a LIFE project for the period 2010-2013 to include Finland and Denmark in our efforts (Management of the invasive Raccoon Dog (*Nyctereutes procyonoides*) in the north-European countries, LIFE09 NAT/SE/ 000344). The LIFE project started in September 2010 and has a budget of 5.3 million Euro. The LIFE project essentially aims to prevent the raccoon dog from establishing in the Nordic countries, and where it has already invaded (parts of Finland) we aim to keep the population reasonably confined and try to stop its further expansion into other countries. The project is headed by The Swedish Association for Hunting and Wildlife Management (SAHWM) and is a cooperative effort between SAHWM, the Swedish University of Agricultural Sciences, the County Boards in the counties of Västerbotten, Norrbotten and Skåne, The National Veterinary Institute and The Swedish Institute for Infectious Disease Control in Sweden, the Danish Forest and Nature Agency in Denmark and the Hunters´ Central Organization in Finland. The LIFE project is co-financed by the Swedish Environmental Protection Agency and the Norwegian Directorate for Nature Management. The projects mentioned above have permission from the Animal Ethics Committee, in the Umeå court of appeal, to conduct experiments in alignment with their project plans. This paper presents the methods developed and practically evaluated in the previous Swedish project that will be used in the current LIFE project. We also present experiences from the previous Swedish project.

## Management methods

Raccoon dog observations, including tips from the public, are followed up with IR/motion triggered cameras directed at scent lures (animal movements are monitored by a highly sensitive Passive Infra-Red motion sensor), and by tracking in the winter. When observations have been confirmed, animals are captured using traps or dogs. All captured individuals (both males and females) are sterilized to prevent reproduction (Arnemo *In prep*.), fitted with ear tags (to minimise the risk of shooting valuable project animals that are already ecologically dead due to sterilisation), GPS/SMS transmitters and then released (Fig. 1).

Figure 1. Raccoon dog fitted with ear tags and GPS/SMS transmitter. Photo: Swedish Raccoon dog Project 2008-2010.

Due to the social nature of the raccoon dog the animal will, at least in theory, search for and lead us to other raccoon dogs of the opposite sex in the area. This method, called Judas animals, has proved to be very effective for other social animals such as goats (e.g. Campbell and Donlan 2005), but has never been used for raccoon dogs prior to the Swedish projects in 2008. When a critical number of Judas animals has been found all new unmarked individuals will be killed. The GPS/SMS-equipped animals will be moved around within the raccoon dog's distribution range, especially to areas where we have confirmation of presence or where research indicates a high probability of raccoon dog occurrence. When a raccoon dog stops dispersing, or at a preset time-interval, we recapture the Judas animal and capture any new partner. The raccoon dogs may also reveal other established couples and individuals of the same sex by pausing in occupied areas while investigating the status of the present animals (Fig. 2).

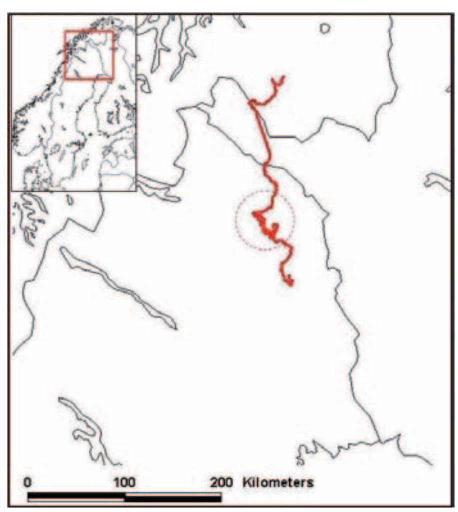


Figure 2. An adult male raccoon dog dispersing from northern Sweden, passing through Finland and into Norway, crossing a total distance of 220 km (measured as a strait line) within 45 days. About one third of the way the raccoon dog made a stop for 16 days, investigating the area within the red circle before deciding to move on.

In addition to the flexible actions (i.e. flexible IR/motion triggered cameras, Judas animals, tips, tracks and traps), permanent grid systems of cameras (approximately 100-150 cameras per country) directed at scent lures are being set up adjacent to the borders between Sweden-Finland, Sweden-Denmark, and in Denmark against the border with Germany. Together with the Judas animals, these systems will reveal new immigration and monitor the development of the population as well as the effect of our actions. This monitoring allows us to adapt to present situations, for example to increase our efforts in certain areas if the population is growing.

Local education efforts, especially of hunters, ornithologists and nature conservationists, on species recognition, tracking, hunting and trapping takes place continuously. An information booklet with contact information, an educational package and a tracking guide in pocket format is being produced in each country. The education is, apart from the purpose of eradication, intended to involve the local community in the project and thereby obtain more observations of higher quality. Both the methods and the training material can be easily translated and used by other countries. The general public is also reached via local and national media, encouraging the public to report sightings of raccoon dogs.

When the LIFE project is fully up and running there will be approximately 20 field staff employed full time to carry out the work.

## Experiences from previous projects

*Public observations*

From the Swedish projects we have learnt that observations by the public are an important means of finding new areas of raccoon dog occurrence. These observations must however be treated with care since it has proven to be very difficult for a layman to differentiate between observations or tracks of the raccoon dog and other medium-sized mammalian predators. Even though most observations come from experienced hunters in the core area that have previous experience with the species, only about 20-40% of the public sightings of raccoon dog occurrence have actually proven to be raccoon dogs. This figure decreases the further away from the core area we get. To avoid a skewed picture of the occurrence of the raccoon dog it is therefore of utmost importance that professionals confirm any observation. From the Swedish project we have public observations of raccoon dogs all over Sweden; most of these have, however, proven to be other species. Species commonly mistaken for raccoon dogs are badgers (*Meles meles*), foxes (*Vulpes vulpes, Alopex Spp.*, including escapees from fur fox farms), martens (*Martes martes*), otters (*Lutra lutra*), cats (*Felis catus*) and dogs (*Canis lupus familiaris*). Confirmed raccoon dog occurrences 2008-2010 are shown in Figure 3.


Figure 3. Raccoon dog occurrences in Sweden confirmed by the project 2008-2010.

Figure 4. This GPS/SMS collared raccoon dog was photographed by an IR-camera directed towards a scent lure during dispersal, 35 km from its location of release. Photo: Swedish Raccoon dog Project 2008-2010.

*Scent lures*

In previous projects we have evaluated several different scent lures (Dahl *et al*. 2009), with one commercial North American scent lure (Hawbaker´s Grey Fox 100) which has proven to attract raccoon dogs both in Finland and Sweden (Kauhala 2004; Dahl *et al*. 2009) (Fig. 4).

According to our experience predators passing by are very eager to investigate the lure (made from anal glands) and to cover it with their own odour (Figure 5 a, b, c). Since this lure attracts all mammalian predators we are constantly evaluating other lures that may be more species specific.

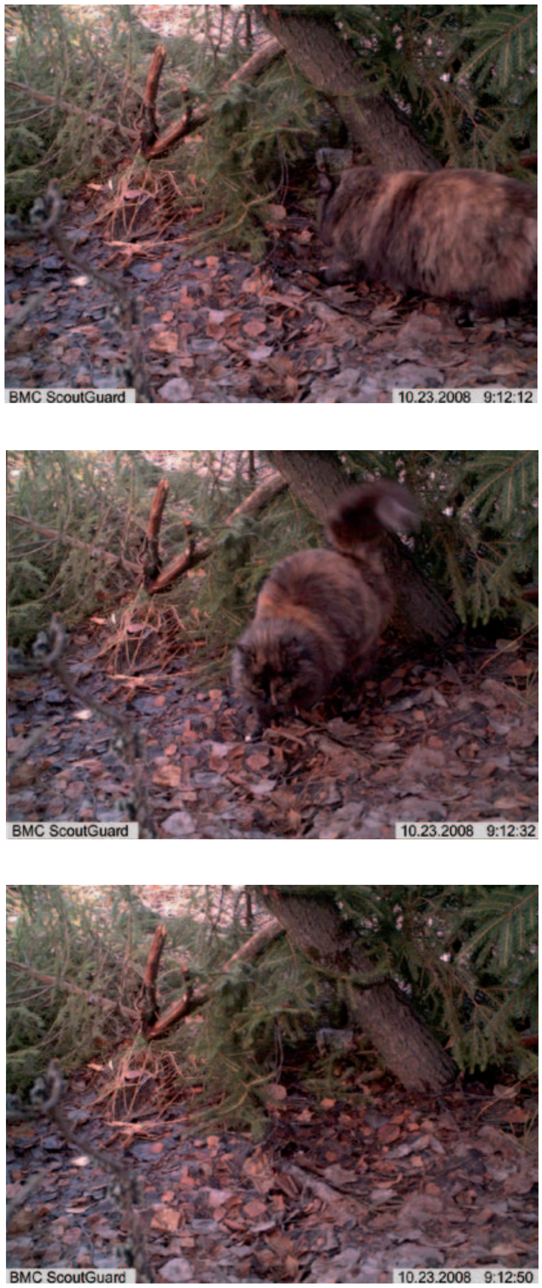


Figure 5 a, b, c. A domestic cat approaching the scent lure on the tree trunk (left) and leaving its marking on the scent lure (middle). The cats marking can be seen on the tree trunk in the right picture. Photo: Swedish Raccoon dog Project 2008-2010.

*Hunting and trapping*

Hunting with dogs has so far been the most effective way to capture animals in Sweden (Fig. 6). Once cornered the raccoon dog is fairly easy to handle since it often displays the behaviour of appearing dead when physically confronted.

Traps have been used with some success in Sweden. In Finland, however, they have a larger experience of trapping raccoon dogs which will be used to further develop trapping in the other countries.

Figure 6. Recapture of a Judas animal using a baying dog. Photo: Swedish Raccoon dog Project 2008-2010.

*Judas animals*

The Judas animals have performed as expected from theory. Released animals start dispersing soon after release and it seems they do not stop until they find a mate. In all, 26 animals have been captured between 2008 and 2010, although not all have been released. Approximately 65% of the released animals have so far found at least one other raccoon dog. Both males and females show the same behaviour. Two individuals have moved very long distances. One female with a VHF collar disappeared soon after release and was found six months later with a mate 200 km from the release site. One male has, so far, moved 220 km from northern Sweden, crossing Finland and continuing into northern Norway without pairing up with a female (Fig. 2). This indicates that the raccoon dog has not crossed paths with a suitable partner, probably due to a very low population density in this area.

## Discussion

The results so far are indeed very encouraging. However, without including our neighbouring countries it is unlikely that we will be able to stop the raccoon dog from establishing in Sweden and Norway. Cooperation within and between countries is an absolute necessity to succeed in a project involving mobile invasive species such as the raccoon dog. Even with a very successful cooperation within our current project, certain challenges still exist that need to be solved at an international level. The law relating to hunting and management of alien species differ, usually by tradition, between most countries. International agreements on how to handle alien species and minimising the bureaucracy would greatly enhance the possibilities to succeed in a mission such as ours. We have solved most of our challenges as we have come to them, but we would have saved a lot of time had there been a straight-forward route to follow. As stated in e.g. the RIO-convention on biological diversity, it is of utmost importance to meet the threat of an invasive species as early as possible. Doing nothing, or waiting for decisions to be taken on national levels will only mean that the cost could be multiplied once the species has established, and then there is the need to reduce the effect of the species instead of stopping it from invading. A Finnish study showed that the cost of the material needed for reducing the negative biological effects of the raccoon dog in wetlands, where they can reach densities of 300 animals per 1000 ha, was 3.3 Euro per hectare (Lintulahdet Life, 2003-2007). In Sweden there are nine million hectares of wetlands. If the population is allowed to establish before we try to live up to our international commitments, the costs will be around 29.7 million Euros annually to keep the population within reasonable bounds, not including salaries for field personnel (the work in Finland was done by volunteer hunters). Relating to this it is important to appreciate that a project like this can hardly succeed by using volunteer staff alone. A lot of the work is done at night and at weekends since we have to follow likely sightings while the tracks are still fresh. Similarly, however, it would also be very difficult to succeed if we did not have help from local hunters and the public to hunt animals, find new occurrences and support us with local knowledge.

When our LIFE project has ended we hope that the structure and organisation of the cooperation within and between the countries in our project will work as a successful showcase for other countries in their work with invasive species in general. Similarly we anticipate that the innovative methods for culling and management of the raccoon dog developed and demonstrated in the project can be used in other countries and possibly also in the efforts to prevent invasions from other invasive species. Our ultimate goal though, is obviously to succeed in our efforts to keep Scandinavia free from the invasive raccoon dog. We would like our children and coming generations to be able to experience our nature the way we do, without the risk of being restricted in their sustainable use of our natural resources.

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# Opportunities for financing projects on invasive alien species in Europe

### Interview to Angelo Salsi by Riccardo Scalera

*LIFE is the European Union's financial instrument supporting environmental and nature conservation projects throughout the EU, as well as in some candidate, acceding and neighbouring countries. Since 1992, LIFE has co-financed some 3115 projects, contributing approximately 2 billion euro to the protection of the environment. Although the LIFE programme did not specifically address the problem of IAS, many LIFE projects included actions dealing with their management (Scalera and Zaghi, 2004). An assessment of the contribution of the LIFE programme in facing the problems caused by the spread of IAS has highlighted that during the years 1992-2006, the EC supported almost 200 projects dedicated to reducing or eliminating their threats, for over 44 million euro (Scalera 2010). An impressive quantity of data and knowledge supported by hands-on experience has been acquired through 100's of projects since 1992. Last, but not least, LIFE projects have been a key tool to inform and raise awareness on IAS and their impact on biodiversity and also on human activities. The large amount of financing LIFE has devoted to this subject makes LIFE one of the most relevant tools in our fight against IAS. For this reason Mr. Riccardo Scalera, programme officer of the ISSG and co-editor of Aliens, asked Mr. Angelo Salsi, Head of "LIFE Nature" Unit of DG ENV.E.3 at the European Commission (Brussels, Belgium) to reply to a few questions on the relation between the LIFE+ financial programme and invasive alien species.*

**Mr Salsi, various projects dealing with alien species were financed by the LIFE programme of the European Commission. In the past some of them have been also described in the Aliens newsletter, like we have done on this issue with the Raccoon dog management project (see pag. 59). What is exactly the LIFE programme and which opportunities can offer to deal with IAS?**

I am very grateful for this opportunity as LIFE has been and still is a very important vehicle to deliver effective mitigation, control and eradication of many IAS.

The LIFE programme started in 1992 and it's currently in its 4th generation called LIFE+ running from 2007 till 2013. LIFE has always financed nature conservation projects aimed at the set-up of the network of protected areas Natura 2000 (LIFE Nature) and projects dealing with all other EU environmental policies (LIFE Environment). Today, under LIFE+ we also finance projects aimed at wider biodiversity issues (LIFE+ Biodiversity) and communication and information (LIFE+ Information). As far as IAS are concerned, LIFE financed single actions part of a larger project or whole projects aimed at IAS. In most cases these action and projects consist of concrete actions, but investigations or preparatory works needed to execute control or even eradication actions are not excluded. All sectors of LIFE can be useful for IAS. Under LIFE+ Nature we can deal with IAS impacting on Natura 2000 sites and species listed in the Habitats Directive. Under LIFE+ Biodiversity it is possible to cover other aspects related to the impact of IAS on biodiversity beyond Natura 2000. Under LIFE+ Environment IAS projects addressing their impact on other environmental policies could be fit, while under LIFE+ Information campaigns, information activities and training can be financed.

**A recent study supported by the EEA has shown an increased trend on both the number of LIFE**

**project dealing with alien species and the relative amount of budget spent. In your opinion, how can such data be interpreted?**

The nature conservation sector is increasingly aware of the pressure IAS have on biodiversity. IAS control and eradication needs solid planning, a flexible approach to adapt to the context and significant medium/long term investments. All these elements are generally well fit to the LIFE approach. The good results of many LIFE projects also show that it is possible to obtain important successes. Furthermore, LIFE+ with its new strand on wider Biodiversity allows financing projects that are somewhat different than the usual best-practice activities. All these elements may explain the increased number of LIFE projects dealing with IAS.

**What are the new possibilities open up for projects dealing on alien species by the new LIFE+ programme for the years 2007-2013? What are the expected future trends?**

So far LIFE Nature only financed IAS control and eradication when necessary to ensure the favourable conservation status of species and habitats covered by the Birds and Habitats directives. With LIFE+ it is now possible to finance also innovative or demonstrative projects of a broader nature. It should also be noticed that LIFE+ information may support projects aimed at information, communication and training. This is clearly an area worth exploring when dealing with IAS.

**What would you suggest to new potential project beneficiaries? Are there any specific tips that are worth considering before submitting proposals for dealing with alien species?**

So far LIFE financed rather classic control and eradication activities. Many of these projects have been very successful with a very effective control or even complete eradication of IAS in well-identified areas. This type of project, especially when targeting Natura 2000 sites will certainly continue being the most popular.

Yet, it would be good if we could widen the scope and think a bit outside the box. There are many activities that are crucial for IAS control and do not require only on-site activities. Such activities may and should also involve stakeholders other than the classical nature conservation world. Examples could range from the control at the port of entries, to training and awareness raising, involvement of private business, etc.

Those who wish to consider these new avenues should carefully prepare their proposals taking care of the key features of each LIFE+ strand. For example under LIFE+ Biodiversity it is crucial that a proposal well explains the demonstrative or innovative nature of the project. Under LIFE+ Information it will not be enough to describe a generic awareness raising campaign to get LIFE support. A clear link with an environmental problem should, if possible, be established. The ex-ante situation should be described and quantified and the project should contain specific actions to monitor the effect of each action and to measure its specific and global impact on the problem addressed.

A good LIFE+ proposal requires a lot of work and a careful preparation. Partnership should be well prepared and a solid financial plan established. Good proposals have a high probability of receiving LIFE funding.

To conclude I can only underline once more how LIFE has been instrumental to address the impact of IAS on biodiversity. I invite every interested party to further consider this programme as a possible vehicle to initiate their "ideas" also considering the wider spectrum of activities LIFE+ can finance.

*For information about the LIFE programme and future calls for proposal, you can visit the LIFE website at:*

http://ec.europa.eu/environment/life/index.htm

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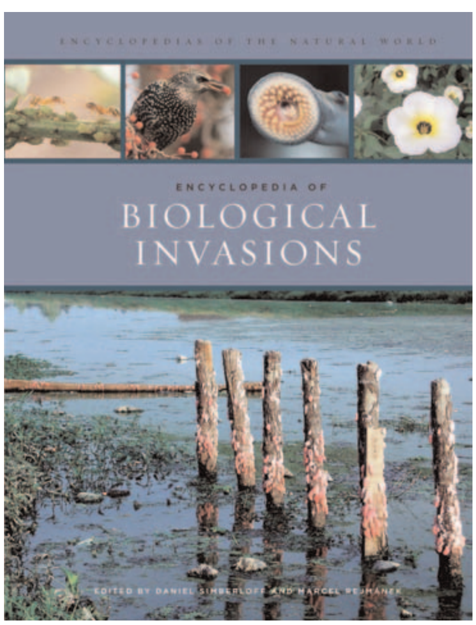
# New publications

## Encyclopedia of biological invasions

The Encyclopedia of Biological Invasions is a comprehensive, complete, and authoritative reference dealing with all the physical and biological aspects of invasive species and invasion biology and theory. The articles are written by researchers and scientific experts and provide a broad overview of the current state of knowledge with respect to the patterns and processes of invasion, the theories associated with invasion, and particular accounts of organisms that have become invasive. Biologists, ecologists, environmental scientists, geographers, botanists, and zoologists have contributed reviews intended for students as well as for the interested general public.




The Encyclopedia of Biological Invasions, edited by Daniel Simberloff and Marcel Rejmánek, includes 153 topics that review the various ways scholars have studied invasive species. The Encyclopedia comprises the following subject areas:

- Invader Attributes
- Ecosystem Features
- Processes
- Impacts
- Notable Taxa
- Pathways to Invasion
- Management and Regulation
- History
- Notable Invasions

To aid the reader in using this reference, a summary describes this *Encyclopedia*'s features, reviews its organization and the format of the articles, and is a guide to the many ways to maximize the utility of this *Encyclopedia*.

Because the articles in the *Encyclopedia* are intended for the interested general public, each article begins with an introduction that gives the reader a short definition of the topic and its significance.

To access the *Encyclopedia of Biological Invasions* website, please visit

http://www.ucpress.edu/books/encyclopedias/invasions

This site provides several sample articles as well as a list of the articles, the contributors, published reviews,

and links to a secure website for ordering copies of this *Encyclopedia*. The content of this site will evolve with the addition of new information.

## Invasive Species and the World Organisation for Animal Health

In 2010, the World Organisation for Animal Health (OIE) has published the following two volumes of the Scientific and Technical Review series on Invasive species:

- Invasive species – Part 1: general aspects and biodiversity. *Scientific and Technical Review 29 (1)*

Author(s): P.-P. Pastoret & F. Moutou; Ed.: 2010

- Invasive species – Part 2: concrete examples. *Scientific and Technical Review 29 (2)*

Author(s): P.-P. Pastoret & F. Moutou; Ed.: 2010


PDF copies can be downloaded from this website: http://www.oie.int/eng/publicat/en_numerosrt.htm

## Management of biological invasions

The science of biological invasions has matured in the last decade, increasing our ability to understand the main factors operating behind the introduction, spread and impact of invaders. Nevertheless, the problem continues growing. One of the main challenges to face the threat of invasive alien species is to rapidly and effectively transfer scientific knowledge to the arena of practical prevention, control and eradication actions.


Many day to day decisions have to be made under high levels of uncertainty in order to prevent the problem to grow to a scale at which effective management is extremely costly or even not affordable. Management of Biological Invasions is a new journal devoted to help reduce these uncertainties by focusing on real experiences in the field of biological invasion management.

The journal is free to authors, institutions and readers, and papers are accepted in English and Spanish. These characteristics, combined with the fact that it is an indexed journal (Digital Open Access Journals, Latindex, Dialnet, WorldCat of University of Washington), makes this publication an interesting alternative for researchers and practical managers both as contributors and as readers.

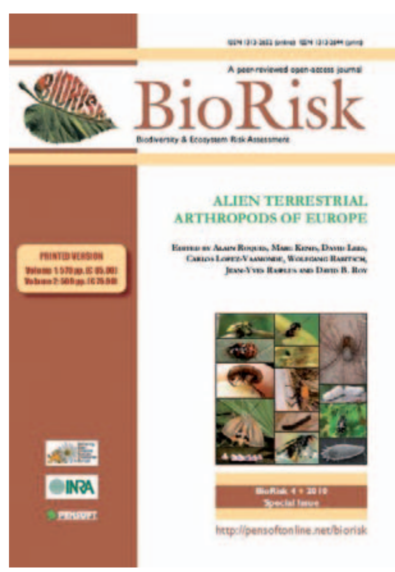
All researchers actively involved in reducing the impact of biological invasions on biodiversity and human livelihoods are encouraged to send their contributions to this new journal and to help provide solid foundations for solving real problems.

The website of the journal is the following: www.managementofbiologicalinvasions.net/index.htm

For further information, please contact:
Sergio M. Zalba Universidad Nacional del Sur, Bahía Blanca, Argentina www.inbiar.org.ar
E-mail: szalba@criba.edu.ar

## Alien terrestrial arthropods of Europe

This book provides the first comprehensive review of the fauna of alien terrestrial arthropods that have colonized the European continent and its associated islands. Directly ensuing from the DAISIE project, this is the result of the joint work of 89 authors from 27 different European countries. The book summarizes present knowledge of the arthropod invasion process, from temporal trends and biogeographic patterns, to pathways and vectors, invaded habitats, and ecological and economical impacts.

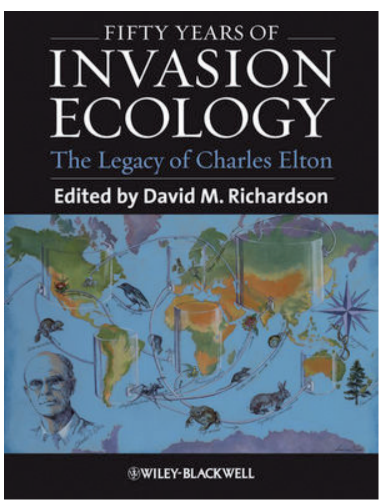


A total of 1590 species alien to Europe, including crustaceans, myriapods, mites, spiders, and insects, are listed in two volumes and 21 separate chapters that detail the different taxonomic groups. For each species, all key information – feeding regime, date and country of first record in Europe, invaded countries, invaded habitats, plant or animal host – is supplied. More detailed factsheets are provided for the 80 species considered to be most representative of the different pathways of introduction and of the diversity of impacts on ecosystems, economic activities and human and animal health.

This book is published by Pensoft Publ., in the open access online journal BIORISK.
BioRisk 4 (2010) Special Issue, *edited by* Alain Roques, Marc Kenis, David Lees, Carlos Lopez-Vaamonde, Wolfgang Rabitsch, Jean-Yves Rasplus and David B. Roy

BIORISK Biodiversity and Ecosystem Risk Assessment is a peer-reviewed, open-access, rapid online journal on biodiversity and ecosystem risks and opportunities caused by global change and local factors. All articles are published without barriers to access, immediately upon acceptance. Free download: http://pensoftonline.net/biorisk/index.php/journal

### Fifty Years of Invasion Ecology. The Legacy of Charles Elton



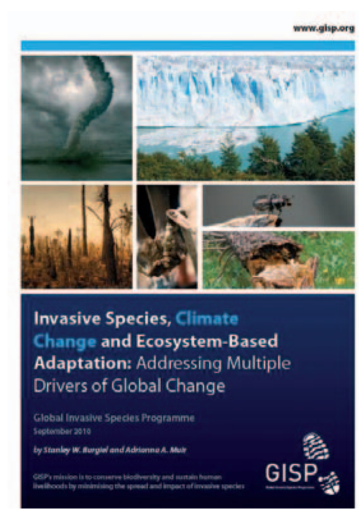

Invasion ecology is the study of the causes and consequences of the introduction of organisms to areas outside their native range. Interest in this field has exploded in the past few decades. Explaining why and how organisms are moved around the world, how and why some become established and invade, and how best to manage invasive species in the face of global change are all crucial issues that interest biogeographers, ecologists and environmental managers in all parts of the world. This book, edited *by* David M. Richardson (Stellenbosch University, South Africa), brings together the insights of more than 50 authors to examine the origins, foundations, current dimensions and potential trajectories of invasion ecology. It revisits key tenets of the foundations of invasion ecology, including contributions of pioneering naturalists of the 19th century, including Charles Darwin and British ecologist Charles Elton, whose 1958 monograph on invasive species is widely acknowledged as having focussed scientific attention on biological invasions.

By quoting the promotion code LIFE it is possible to receive a 20% discount when ordering online at www.wiley.com

### Climate Change & Ecosystem-Based Adaptation

Separately, climate change and invasive species are two of the greatest threats to biodiversity and the ecosystem services upon which humanity relies. Combined their impacts will be compounded, potentially resulting in negative feedback loops with increasingly dire consequences. The latest publication from GISP "Invasive Species, Climate Change & Ecosystem-Based Adaptation: Addressing Multiple Drivers of Global Change" by Stas Burgiel & Adrianna Muir highlights recent efforts to identify the underlying dynamics linking these two global change drivers and the optimal responses for the policy-making and research communities.

Download your free copy as a pdf here:
http://www.gisp.org/whatsnew/docs/Climate_Change_ReportA4.pdf




### Pets, Aquarium, and Terrarium Species: Best Practices for Addressing Risks to Biodiversity

Invasive alien species are a direct driver of biodiversity loss, and considered a cross-cutting issue of the CBD, a key matter of relevance to all major biomes. In addition, invasive alien species have been estimated to cost our

economies hundreds of billions of dollars each year, due to both the economic implications of present invasions to agriculture and ecosystem services, as well as the high cost of eradication efforts. At the same time, the pet trade has the potential to generate significant socio-economic benefits, including benefits for developing states.

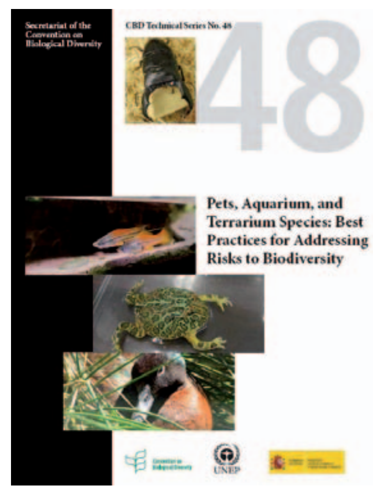
The movement of live animals and plants around the world, facilitated by increased global trade and the accessibility of online marketing tools, poses a risk of spreading invasive species and their associated problems around the globe more widely and more rapidly. The existing international regulatory framework does not cover the introduction of species such as pets, aquarium, and terrarium species, live bait and live food, which constitute a significant risk to ecosystems. Measures which would not impede the trade of species with the lowest risk of harm to native biodiversity are needed.

One third of the world's most damaging aquatic invasive species are a result of aquarium or ornamental releases.

The information collected through the expert workshop on best practices for pre-import screening of live animals held in Indiana, United States of America, from 9 to 11 April 2008 demonstrate that effective prevention strategies can be targeted where needed though risk-assessment practices. This edition of the CBD Technical Series provides a resource to those Parties or Governments who wish to establish their own import/export control mechanisms to determine how they may effectively and efficiently evaluate the risks posed by the potential import/export of live animals and plants as pets, aquarium and terrariums species as well as mechanisms to control these imports or exports if the risk level warrants such control.

This publication also provides a list of information resources which may be utilized by those who wish to conduct a risk assessment on a particular species. As the best predictor of invasiveness is previous invasiveness elsewhere, these resources are essential tools in the effort to avoid the damage caused by invasive alien species, and to protect native biodiversity and local economies.

This colorful and useful report is largely based on an expert workshop held in 2008 at the University of Notre Dame (summarized in this GISP report *http://www.gisp.org/publications/policy/workshop-riskscreening-pettrade.pdf*), but the CBD report includes much additional information beyond what was covered in that workshop.




Secretariat of the Convention on Biological Diversity (2010). Pets, Aquarium, and Terrarium Species: Best Practices for Addressing Risks to Biodiversity. Montreal, SCBD, Technical Series No. 48, 45 pages

*http://wwwcbd.int/doc/publications/cbd-ts-48-en.pdf*

# Events

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

### 21-24 November 2011 in Mar del Plata, Argentina.

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 more information about this meeting, visit the website www.grieta.org.ar/biolief/

Instructions for registration and abstract submission will soon be provided. To be included on the BIOLIEF mailing list please email biolief@grieta.org.ar including your name and organization.

## USDA Interagency Forum on Invasive Species

### 11-14 January 2011 in Annapolis, Maryland, USA.

The USDA Forum on Invasive Species is an annual meeting that began in 1990 as the "USDA Interagency Gypsy Moth Research Forum". The purpose was to coordinate research on the European and Asian gypsy moth, Lymantria dispar L., among USDA agency scientists and their university cooperators by facilitating the exchange of information and data and encouraging their collaboration. This assured a degree of accountability and minimized the duplication of effort among the many scientists who conduct research on this serious forest pest. This meeting gained added stature when scientists from Europe, Asia, and elsewhere in North America learned of this meeting and began to attend and participate. The involvement of foreign scientists from countries where gypsy moth and related species have been native pests for centuries has added a different perspective to the meeting and has enhanced international cooperation, particularly in the use of biologically based technologies.

Consequently, beginning with the 1996 meeting, the scope of the Interagency Research Forum was broadened and the Program Committee has devoted a significant portion of the agenda to highlight the threat of select nonnative invasive species. In recent years, a complex of nonnative species (NIS) including the Asian Longhorned beetle, large-pine shoot moth, hemlock woolly adelgid, cedar emerald ash bores and Asian gypsy moth have been introduced into North American and collectively threaten our North American forest and urban ecosystems. Additionally, pathogens (e.g. Beech Bark Disease, sudden oak death, and butternut canker) and exotic weeds(e.g. mile-a-minute weed and kudzu) contribute to our management problems.

Web site for the annual conference is http://www.nrs.fs.fed.us/disturbance/invasive_species/interagency_forum . The meeting is held every year and focuses on exotic insect, pathogens and plants in forest ecosystems. Proceedings of previous meetings are available at the web site.

## 15th Australasian Vertebrate Pests Conference

### 20-23 June 2011 in 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.

A symposium is being organised on 'Island Pest Eradications', and people interested in contributing can contact Elaine Murphy (email *emurphy@doc.govt.nz*) or John Parkes (email *ParkesJ@landcareresearch.co.nz*).

The conference will be hosted by the Invasive Animals Cooperative Research Centre and the New South Wales Department of Industry and Investment.

To read more about the proposed Scientific Program you can visit the following website *http://www.avpc.net.au/*

## 9th Workshop of the EWRS Working Group

### 28-30 March 2011 in Samsun, Turkey.

We are pleased to give you some general information on the 9th workshop of the European Weed Research Society working group. Please forward this circular to any interested colleagues in your institution/country. Information on the workshop will also appear on the working group's web site: *http://www.ewrs.org/pwc/*

The aim of the workshop is to create a forum where people involved in research in physical and cultural weed control can come together and exchange results, experiences, information, and establish new contacts and networks.

The workshop aims to be informal and to stimulate as much discussion as possible among participants. 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. We would also like to organise a keynote theme followed by an extensive discussion. You are most welcome to suggest relevant speakers and themes.

## 23rd Asian-Pacific Weed Science Society Conference (APWSS 2011)

### 25-30 September 2011 in North Queensland, Australia.

The Asian-Pacific Weed Science Society Conference returns to Australia for the third time in 2011 and will focus on the theme "Weed Management in a Changing World". The Conference is the only international weed management conference to be held in Australia since the early 1990s and the only major national Conference in three years.

There will be presentations on climate change, lack of water, Biosecurity, population growth and the utilisation of weeds in the future.

Field trips will be organised to demonstrate weed issues affecting Northern Queensland, Australia and activities undertaken to reduce their impact. These will be selected based on their applicability throughout the Asia Pacific region.

There will be ample time available for networking and discussions during breaks in the program and through a social program incorporating a Welcome reception, Conference dinner and Field Trips.

The aim of the Conference is to bring people involved in weed management together from throughout the Asia Pacific and Australia to network with industry colleagues. These include:

- Government Weeds Officers and Councillors
- Landowners and Managers throughout the Asia Pacific Region
- Agribusiness and Utility Providers, including Power, Rail, Roads and Water
- Government agencies such as forestry, environmental protection, resource management, Biosecurity and primary industries.
- Government agencies staff
- Landcare & Agforce Members from Asia Pacific countries
- Researchers and students involved in weed management
- Contractors and Community Project Officers
- Weed Managers
- Policy Makers
- Quarantine Officers
- Researchers, educators and students involved in weed management
- International Weed Management Product Manufacturers
- Those in the agricultural industry with an interest in weeds and their management

For more information about this meeting, visit our website http://www.apwss2011.com/

Please direct any queries to Sally Ford sford@eventcorp.com.au

## 22ndt USDA Interagency Research Forum on Invasive Species

### 11-14 January 2011 in Annapolis, Maryland, USA.

The Program Committee is pleased to announce the following draft agenda for the 2011 meeting.

Keynote Speakers:

- Tom Tidwell, Chief, USDA-FS, "Forest Service challenges in protecting natural resources from invasive species"

- Dr. Julie Lockwood, Rutgers University, "How important is propagule pressure in invasion ecology?"

General Session Topics

Applying population ecology to strategies for eradicating invasive forest insects

Chemical and behavioral cues used by Buprestid and Cerambycid wood borers

Bio-economic analysis of forest insect and disease invasions to support more sound trade policies

Emerald ash borer program highlights

In addition to the General Sessions, this year's program will include several invited and offered presentations on topics that are relevant to the issue of non-native invasive species:

- What we have learned from our experiences with *Phytophthora ramorum*

- Thousand canker disease of walnut: developments and spread

- Use of arboreta surveys and sentinel tree plantings in Eastern Asia to identify potential forest pests in Europe

- Chemical attractants for *Sirex noctilio*

- Winter moth: biological control and dynamics of outbreak populations in New England

- Update of EPPO activities in Forest Quarantine in 2010

Poster displays on invasive species and related topics are always welcome. Please contact Vince D'Amico (vdamico@fs.fed.us or vincentdamico@yahoo.com) regarding guidelines and space availability. A limited number of openings are available on the Program for research presentations. Please contact Michael L. McManus at mlmcmanus@fs.fed.us as soon as possible if you are interested in giving a presentation.

Mark your calendar to set these dates aside. Please share this announcement with others who may not be on the mailing list. Information on registration, hotel, abstract and poster guidelines, and the program will be available in November at the new meeting website:

*http://www.nrs.fs.fed.us/disturbance/invasive_species/interagency_forum/*

## 2nd International Invasive Bird Conference

### 7- 9 March 2011 in Cape Town, South Africa.

The conference will be hosted by the Percy FitzPatrick Institute of African Ornithology, based at the University of Cape Town together with the Centre for Invasion Biology at Stellenbosch University. The 2011 IIBC follows the successful 1st International Invasive Bird Conference held in Fremantle, Australia, in December 2008.

Appropriate management responses to avian invasives depend on improved understanding and quantification of patterns and consequences of establishment and invasion. The conference is organised in partnership with BirdLife South Africa, the South African Working for Water Programme, Dept of Agriculture and Food Western Australia, the Animal Demography Unit (University of Cape Town), WildWings (UK), Ingrip Consulting (Germany) and the City of Cape Town. The aim will be to explore developments in invasive bird biology, to assess the level of understanding of the different facets of bird invasions and our ability to manage them, and to discuss priorities for the future.

The programme will be structured to address key themes presented through keynote talks, oral and poster presentations. We have confirmation from keynote speakers, Tim M. Blackburn, Zoological Society of London, UK, Chris J Feare, WildWings Bird Management, UK and Phil A.R. Hockey, Percy FitzPatrick Institute, South Africa, and trust that we will be able to introduce the other speakers soon.

Further information can be obtained at: http://www.iibc2011.co.za/

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