

BESTNet/ecoSERVICES workshop on the economics and ecology of biological invasions: developing a synthesis of ecological and economic research on the biological risks of growth in world trade

Program

(We should attach copies of the presentations to each item in the program).

Monday 29 October 2007

SESSION 1: GLOBAL DRIVERS OF INVASIVE SPECIES (Chair: Hal Mooney)

Note: Presenting authors in bold type

- 09.00 – 09.45 **Charles Perrings** (ASU), William Brock (Wisconsin-Madison), Ann Kinzig (ASU) and Margherita Gioria (ASU), **Globalization and invasive species**
The widening and deepening of international trade has had a number of environmental consequences, of which the most significant may well be the redistribution of species. There are two processes involved. The opening of new markets or trade routes has resulted in the introduction of new species either as the object of trade or as the unintended consequence of trade, while the growth in the volume of trade along existing routes has increased the frequency with which introductions are repeated. At the same time, the probability that an introduced species will establish and spread depends both on the characteristics of the species and on the vulnerability of the host system. More disturbed, less diverse systems are more vulnerable. We focus on the first process. The risk of introductions is increasing in the volume of trade, each unit of trade being regarded as a sample from the potentially invasive species in a source country. We model the problem and show that the existence of invasion risks of trade reduces both the socially optimal level of imports and the socially optimal level of harvesting effort. Evidence for the impact of trade-related invasion risks is presented and evaluated.
- 09.45 – 10.30 **Peter Daszak**, Marm Kilpatrick (Consortium for Conservation Medicine), and K.E. Jones (Inst Zoology), **Globalization and invasive pathogens**
International travel and trade are major driving forces in the spread of pathogens, which can be considered an important and often neglected group of invasive species. Globalized trade and travel underpin the emergence of human diseases such as West Nile virus in the USA, SARS, and have led to widespread dissemination of important disease vectors. They also drive the emergence of pathogens affecting wildlife (e.g. amphibian chytridiomycosis), wild plants (e.g. chestnut blight) and crops (e.g. Karnal bunt), with wide-ranging impacts on biodiversity, ecosystem services, and the global economy. Our preliminary analyses show that and that this process ('pathogen pollution') is both measurable and predictable. Using data on global trade and travel volume, we have been able to produce simple, predictive analyses for the future spread of West Nile virus and H5N1 avian influenza. These analyses are cost-effective to conduct, and have direct relevance to policy measures to combat the global spread of invasive diseases.
- 11.00 – 11.45 **Mark New**, Ana Lopez and Carol McSweeney (Oxford), **Climate and invasive species: the limits to climate information**

Climate change can affect invasive species either directly, through shifts in climate niche, and less directly through factors that are climate dependent, such as fire or drought regime. Predicting the effects of climate change on invasive species is complex because of the compounding influences of other factors and interactions. Typical modelling approaches involve bioclimatic envelope or niche models, which most usually predict the shift in climatic envelope identified through empirical analysis of collocated species and climate or climate-dependent variables. Any projections are therefore, at best, estimates of 'climatic potential' for invasion, ignoring other factors. Starting from the assumption that invasive species models that accept climate data as input have some utility, this paper addresses issues related to the climate data itself. We first deal with the uncertainties in gridded (interpolated) climate data, illustrating the typical resolution skill/error in such data, and the dependence of the errors on station network density and underlying climate heterogeneity. Then we discuss the space and time scales at which climate model simulations can provide information (rather than data) on the climate variables needed for invasive species modelling.

11.45 – 12.30 **Chris Thomas (York), Ralf Ohlemueller (Durham) Climate change: an alien future?**

The paper aims: 1. To review extremely briefly the impact of recent and Quaternary climate change on species distributions (i.e., recapping recent reviews and IPCC 2007); to describe in more detail the few examples of apparently climate-driven changes to ecosystems involving invasive species (i.e., biome shifts delivered by invasives); and to discuss the role of disturbance in speeding-up biome shifts (and invasion). 2. To review briefly the value and constraints of using climate-related approaches (distribution models etc.) to model areas of species invasion; and the difference between predicting establishment and pest status. 3. To produce a new analysis, showing parts of the world that have rare climates locally, but where that type of climate is common across the world as a whole (likely to reflect the pool size of local to global species adapted to that type of climatic environment, and therefore probable climatic invisibility). 4. To extrapolate this approach to one or more future possible climates, to show regions for which invasions might become more (or less) of a problem in future. 5. To discuss the global distribution of garden plants, and the implications for the future of global ecosystems. The paper will conclude by discussing the philosophical difficulties in distinguishing between native and alien in the context of climate change, and the need to project both simultaneously when considering impacts of climate change.

12.30 – 13.30 Lunch

SESSION 2: LOCAL CAUSES AND CONSEQUENCES OF BIOLOGICAL INVASIONS (Chair: Ann Kinzig)

13.30 – 14.15 **Mark Williamson, University of York, Variation in the spread of introduced species and its implications**

Although spread is the easiest of the stages of invasion to study, there is still a lot to learn about its drivers, rates and patterns and about the relative importance of biological, environmental, social and economic factors. It is well established that there is appreciable variation in the rate of spread of particular species in different times and places. This part of variation is usually ascribed to environmental factors but seldom tested rigorously. It can also be affected by evolution and management. Less studied are the

variations between species in both pattern and rate. Studies on alien plants in Europe have shown that there are several distinguishable patterns of spread of which the standard linear wave of advance is but one though the commonest, that the rate varies markedly between species, and that biological variables seem of little importance for explaining patterns or rates. The time since the establishment of an alien population, residence time, has an important effect on the observed range and indicates that even in relatively small European countries it takes centuries for the spread of typical species to be complete. The median rate of spread is quite small. Economic and social factors which affect the movement and establishment of species may be important, which has implications both for the understanding and management of alien species.

14.15 – 15.00

Petr Pyšek, Milan Chytrý & Vojtěch Jarošík, Habitats and land-use as determinants of plant invasions in the temperate zone of Europe

Studies exploring large-scale patterns in plant invasion are mostly based on numbers of alien species recorded for regions and countries. Although the importance of habitat and land-use is widely recognized, data to test their role are largely missing. Large databases of vegetation plots sampled for phytosociological purposes have potential to provide insights into the issue of habitat invasibility. One such database, comprising over 20,000 of vegetation records in fine-scale plots in the Czech Republic, Central Europe, is used to (i) assess the invasion in habitats classified according to the standard European EUNIS system, (ii) evaluate the relative importance of habitat identity, propagule pressure and climate, and (iii) separate the actual level of habitat invasion (i.e., the number of alien species that are found in a habitat) from its invasibility. To distinguish the level of invasion from habitat invasibility requires to factor out the effect of propagule pressure and climate, and compare the habitats under the assumption of these two variables being equal. At a regional scale, propagule pressure can be quantified using proxies related to human activities, such as the proportion of surrounding urban/industrial or agricultural land and human density in the area of sampled plot. The results demonstrate that it is necessary to analyze separately archaeophytes (historic invaders introduced since the beginning of Neolithic agriculture until the end) and neophytes (modern invaders introduced after that date), since both groups differ in their ecology. Invasions by archaeophytes are more deterministic, with overwhelming role of habitat; in neophytes propagule pressure and climate are also important determinants of invasion. In general, habitat identity is the most important predictor of invasions by alien plants, while propagule pressure and climate explain much less variation in data. Between-habitat comparisons of habitat properties suggest that the most important determinants of the level of invasions are disturbance regime and the fluctuations in resource availability. Finally, the importance of habitat history is demonstrated by comparing archaeophytic and neophytic weeds of agricultural fields: old crops introduced with the beginning of agriculture harbour more archaeophytes, while recently introduced crops provide more suitable habitat to neophytes. These patterns can be explained by the history of plant invasions in Central Europe.

15.30 – 16.15

B.W. van Wilgen & D.M. Richardson, Current and future consequences of invasions: A case study from South Africa

This paper will review what is known about the direct consequences of growing populations of invasive alien species in terms of ecological and economic impacts, using South Africa as a case study. We intend to review the rate at which alien species arrived in the

country over the past three centuries, and the rate at which these became invasive. We will also review trends in the recognition of problems associated with invasions. A tradition of ecological research in the country has resulted in a high degree of awareness of these problems, both in terms of the biophysical impacts of invasions, and the economic consequences of these impacts. While these impacts are clearly large, and increasing, relatively little research has been conducted to accurately quantify these impacts in a way that facilitates objective prioritization. We will also review several studies that have sought to predict the future consequences of invasions on ecosystem services. Our conclusion will probably be that the problem is reasonably well understood in a broad sense, but that a lack of specific and defensible quantification of impacts and prognoses could impede the acceptance, adoption and implementation of appropriate responses. We will therefore end with a statement of research priorities and some ideas on how to improve strategic planning for dealing with biological invasions.

16.15 – 17.00

Liba Pejchar and Gretchen C. Daily (Stanford University),
The impact of invasive species on ecosystem services and human well-being

Native ecosystems are not only crucial habitat for biodiversity but also provision many services that sustain human well-being. These ecosystem services include clean drinking water, flood control, climate regulation, and cultural values. Native ecosystems, however, are increasingly threatened by the invasion of non-native species. Although the effects of these invaders on native flora and fauna are in many cases well-documented and often devastating, it is less clear to what extent and through what mechanisms invasive species are impacting ecosystem services and the communities that depend on them. In this review we assess what is known about the effect of invasive species on ecosystem services, and we illustrate the status and severity of this problem using four diverse case studies where the intersection of invasive species and ecosystem services is particularly acute: Hawaii, South Africa, Brazil and the Great Lakes region (U.S.). Next we identify knowledge gaps, defined as those aspects of the relationship between invasive species and services that remain poorly understood and under-addressed. Finally, we lay out a research agenda for resolving these gaps and we specify the questions and actions that are of the highest priority. We conclude that new research is needed to motivate funding and aggressive policies for control, but we must also rapidly deploy existing knowledge to control areas with ecosystem services sensitive to invasion, thereby preserving those life-support services that nature provides and human and natural communities depend upon.

17.00 – 17.30 Day 1 wrap up

TUESDAY, 30 OCTOBER (Venue: DCDC, Brickyard Orchid House, Suite 126B, 21 East 6th Street, Tempe)

SESSION 3: ECONOMICS OF INVASIVE SPECIES (Chair: Charles Perrings)

09.00 – 09.45

Stephen Polasky (Minnesota), **A model of inspection, detection and control for invasive species**

Management actions to prevent the establishment and spread of invasive species can occur at various distinct stages of the invasion process. First, inspections of incoming goods, trade restrictions, ballast water exchange and other actions can reduce the number of

individuals of an invasive species that are introduced into the environment. Second, detection efforts can be used to find populations of invasive species in the environment while the population is still small and potentially controllable. Third, actions can be taken to control or eradicate invasive species from the environment. This paper presents a simple unified approach to inspection, detection and control of invasive species. Optimal policy is found given underlying parameter values for costs of management actions, the likelihood of introduction, population dynamics of the invader, and expected damages from establishment and spread.

09.45 – 10.30

David Finnoff (Wyoming), Stationary Policies in the Control of Invasive Species

We consider the problem of optimal management of an aquatic invader spreading in a lake system. Given the complexity of deriving a full characterization of the optimal path of control, we consider two infinite-horizon optimal control problems: (A) minimizing discounted cost of bringing the controlled system to a steady state, and (B) minimizing discounted cost of keeping the controlled system at a steady state. We show that the solutions of both problems are close for small discount rates across a range of initial conditions. However the analysis of problem B is usually much simpler, since it does not require an optimization of the initial transients of the dynamical system. In policy settings this formulation may be of most use as it allows a clear and concise view of the long-run equilibrium, uncluttered by the complexity of an optimal characterization of the initial transients (which may not even be possible). Furthermore, this may also provide a socially advantageous solution, because it concentrates on the properties of the terminal state. The optimal control problem gives more weight to initial transients, and therefore provides a terminal steady state with higher average costs.

11.00 – 11.45

Christopher Costello and Michael Springborn (UCSB), Bayesian Profiling with Learning for Pests

Learning and taking action are generally treated as separate choices in adaptive management and decision-making under uncertainty. When management actions produce information, this dichotomous choice is no longer optimal – the value of information and immediate returns must be considered simultaneously. One family of such endogenous learning problems, which highlights the central tradeoff between exploitation and exploration, is profiling of trade partners for invasive species risk. Selective examination of imports for invasive species provides both for immediate interceptions of infested shipments and data to reduce uncertainty over risks, improving future targeting decisions. We develop a Bayesian learning model of infestation risk and use advances in multi-armed bandit theory to balance the objectives of exploitation and exploration. Our integrated approach endogenizes learning to the targeting decision – exploration is constantly considered but only pursued when explicitly worth the opportunity cost of forgoing greater immediate payoffs. A demonstration of the multi-armed bandit model provides insight into when the riskiest shipment should not be the highest inspection priority. Expected economic gains from the approach will be estimated using U.S. customs data on inspections and interceptions of invasive pests.

11.45 – 12.30

David Simpson (Johns Hopkins), What Would Chou En-lai Have Said About the Columbian Exchange?

When is an ounce of prevention worth a pound of cure? Some have argued for placing restrictions on international trade and travel to prevent further biological invasions rather than trying to control

exotic plants and animals after they have gained a foothold. If those who accidentally or intentionally introduce exotic species into new environments do not internalize the costs of their actions, they will import too many species. Like other polluters, they should be made to pay for the damage they cause.

I find this view problematic for several reasons:

1. It is not clear that the consequences of transplantsations are generally negative.
2. Even if one stipulates that consequences are asymmetrically negative, there is little hope of estimating costs well enough to inform policy.
3. The trade policy cure may be worse than the invasive disease.
4. The biological consequences of trade restrictions might prove surprising.
5. Biological invasions may turn conventional wisdom on its head; the ostensibly more "conservative" strategy may favor short-, as opposed to long-term interests.
6. Dealing with invasive species, like dealing with climate change and other complex issues, involves reconciling widely divergent world views. I have serious doubts that our economic tools can get much traction on these issues.

Public policy toward invasives - like public policy toward climate - should probably be driven by worst-case scenarios. What's the worst that could happen to us? There's an interesting historical precedent: the European colonization of the New World was the greatest biological catastrophe in history. This begs a couple of questions. First, has the world changed enough between then and now to make the Columbian Exchange irrelevant? I'll argue that it may not have, and suggest we may face analogous choices. Consider, then, what one might have done if appointed Court Economist to Ferdinand and Isabella. The implications of that thought experiment may be surprising. Would a prescient Court Economist have 1) screeched "Don't let him sail!"; 2) determined that after five hundred years, as Chou En-lai famously remarked of the significance of the French Revolution, it would still be too early to tell; or 3) reluctantly said "Unless you want to follow the path of your Chinese contemporaries, let him go"?

SESSION 4: MANAGEMENT OPTIONS (Chair: Ann Kinzig)

13.30 – 14.15 **Julia Touza, Martin Drechsler, Karin Johst, Katharina Dehnen-Schmutz, The role of space in invasive species management**

The spatial dimension of establishment and spread of invasive species is crucial for assessing policies and institutions to deal with biological invasions. It allows to evaluate different management activities over entire landscapes (Smith et al. 2007, Mehta et al. in press). This chapter surveys recent ecological economic research that incorporates the spatial dimension, summarising the conclusions and implications for invasive species management. We argue that space matters in two main aspects: contiguity and heterogeneity. Contiguity means that the proximity of a site to the current area of occurrence of an invasive species determines the site's probability of being invaded. Since the dispersal rate (distance crossed per time) of most species is limited, this effect is relatively obvious and considered in various large scale invasion management studies (e.g. Sharov and Liebhold 1998, Knowler and Barbier 2000). The dispersal rate itself, however is not a "natural" (species-specific) constant, but it emerges from the behaviour of the species in the heterogeneous landscape and the interaction of species and landscape characteristics (e.g., Thulke et al. 1999, Revilla et al. 2004). Landscape characteristics here comprises

susceptibility of individual areas to establishment of local invasive species population (which is determined e.g. by vegetation and climate) as well as the spatial arrangement of these areas and their size distribution. The role of spatial heterogeneity of landscapes has been so far underemphasised in the study of invasive species policies. Lessons can be learnt here from general ecological and epidemiology analysis (e.g. Thulke et al. 1999, Revilla et al. 2004). We illustrate the importance of spatial detail for invasive species management in a fragmented (metapopulation type) landscape using a numerical example.

14.15 – 15.00 **R. Uma Shaanker** (UAS, Bangalore), Gladwin Joseph (ATREE), N. A. Aravind (ATREE), Ramesh Kannan (ATREE) and K. N. Ganeshiah (UAS, Bangalore), **Invasive plants in tropical human dominated landscapes: need for a paradigm shift in their management**

The negative effects of invasive species on biodiversity and well being of human societies are well known. In tropical biodiversity hotspots, invasive species can exacerbate biodiversity crisis by reducing the population densities of indigenous species, many of which fulfill subsistence needs of rural poor. Against this backdrop there have been intense efforts in preventing the invasion and spread of invasive plants as also in managing them. However in most cases, these efforts have not been successful. A classical example of this is *Lantana camara*, a native of South America, but which has now successfully invaded more than three quarters of earth's land mass. Numerous studies have documented the negative effects of *Lantana* on native biological diversity as well as on livelihoods of people dependent on forest resources. Efforts to manage the plant, through manual, chemical and physical means have not been successful. Clearly classical approaches to managing such invasives are not tenable and a new paradigm is required to address them. In India, we have initiated an ingenious approach that has actually promoted the use of *Lantana* as a substitute for scarce bamboo and cane resources, to enhance people's livelihood. Our studies have shown that encouraging the use of *Lantana*, may not only enhance local livelihoods but could also help in restoring native biological diversity. Based on our studies, we propose a need for a shift in our paradigm of viewing invasives, from one of exclusion to one of inclusion. The apparently simple model of using invasives for resource substitution is easily replicable elsewhere in the world and could have important implications for managing invasives in human-dominated forested landscapes in the world.

15.30 – 16.15 **Reuben P. Keller** and **David M. Lodge** (Notre Dame), **Management and policy for invasive species at the national level**

Invasive species present policy and management challenges to all countries, and there is widespread desire to reduce overall numbers and impacts of these species. To achieve this goal, the risks from three groups of species need to be addressed, 1) species not yet in a country; 2) species established in a small area; and 3) widespread species. The first group should be managed according to vector. Many vectors introduce species accidentally (e.g. ships' ballast water), and efforts should be made to remove all species. In contrast, many vectors introduce species for commerce. We advocate a policy of scientific risk assessment to pre-screen these species for invasiveness. Species likely to cause more harm than benefits can then be excluded. Monitoring programs should be designed to maximize the chance of locating established species before they

become widespread, and will be most effective when concentrated where species are most likely to be introduced (e.g. near ports). If resources are made available, rapid response measures will often be able to eradicate these incursions before the species becomes widespread. Species that do become widespread and invasive should be managed to prevent further spread, to mitigate impacts, and, where possible and practical, to reduce population size. Options to slow spread include vector management, while herbicides, biological control and manual removal can be used to reduce population size. If adopted, these recommendations for policy and management could meet the goals of reducing future economic and environmental impacts from invasive species.

16.15 – 17.00 **Stas Burgiel (TNC), Hal Mooney (Stanford), Mark Lonsdale (CSIRO). Prevention - Management Options for Invasive Alien Species at the International Regional and National Levels**

Much effort has gone into managing invasions at the level of infestations in catchments, national parks, habitats, farms, and individual water bodies. The subject of this paper, however, is how we can better manage the flux of invasive species at the international, regional, and national scales. At these scales, the armoury of weapons used against invasive species locally is not so relevant: pesticides, biological control agents, cultural control methods, and other tactical approaches, are less important than getting the strategy right. Instead, the key weapons are changes and developments in policy. Here, we focus on changes to international policy to manage invasive pathways, to build regional collaboration, and to manage movements of invasive species within and between countries. We also consider tools and policies to manage risks associated with the explosive growth in the volume of trade, sharing knowledge and early warning systems via the Internet, and quarantine inspection services. We also review biosecurity policy developments from a range of countries internationally.

17.00 – 17.30 Day 2 wrap up

WEDNESDAY, 31 OCTOBER (Venue: Room 158, GIOS, Tempe Centre, Mill Ave, Tempe)

SESSION 5: DRAWING CONCLUSIONS (Chair: Hal Mooney)

09.00 – 10.30 Review of key findings
 11.00 – 12.30 Next steps, workshop wrap up

SESSION 6: BESTNET FELLOWS SESSION (Chair: Charles Perrings)

14.00 – 17.00 BESTNet Training Workshop/Field Trip

Participants

Aaron Strong*	Arizona State University	USA
Stas Burgeil	The Nature Conservancy, GISP	USA
David Cook	CSIRO	Australia
Chris Costello	University of California, Santa Barbara	USA
Peter Daszak	Consortium for Conservation Medicine	USA

David Finnoff	University of Wyoming	USA
Gustavo Garduno*	Arizona State University	USA
Margherita Gioria ⁺	Arizona State University	USA
Steven Hovick*	University of Georgia	USA
Ann Kinzig	Arizona State University	USA
Maya Kapoor*	Arizona State University	USA
Reuben Keller*	Notre Dame University	USA
Elisabeth Larson*	Arizona State University	USA
David Lodge	Notre Dame University	USA
Mark Lonsdale	CSIRO	Australia
Hal Mooney	Stanford University	USA
Mark New	Oxford University	UK
Liba Pejchar	Stanford University	USA
Charles Perrings	Arizona State University	USA
Steve Polasky	University of Minnesota	USA
Anne-Hélène Prieur- Richard	DIVERSITAS	France
Petr Pysek	Inst of Botany, Acad of Sciences	Czech Rep.
Uma Shaanker	University of Bangalore	India
Hoski Schaafsma*	Arizona State University	USA
David Simpson	Johns Hopkins University	USA
Mike Springborn*	University of California, Santa Barbara	USA
Chris Thomas	University of York	UK
Julia Touza	UFZ	Germany
Brian van Wilgen	CSIR, South Africa	South Africa
Mark Williamson	University of York	UK

* BESTNet Fellows

+ ecoSERVICES Project Officer