BRITISH COUNCIL

CSIC
Consejo Superior de Investigaciones Científicas

"The ecology of inland waters"

ESTACIÓN BIOLÓGICA DE DOÑANA (HUELVA), 13-17 OCTOBER 2013

COORDINATORS:

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SCIENCE

THE ECOLOGY OF INLAND WATERS

Opening Doors

Scientific workshops for young researchers

Doñana, (Huelva) Spain, 13 - 17 October 2013

INTRODUCTION

The British Council in Spain, in collaboration with the Spanish National Research Council (CSIC) is organising a series of scientific workshops to provide opportunities for young researchers from the UK and Spain to meet face-to-face for the exchange of ideas, knowledge and information on priority topics and to explore future areas of research and collaboration.

This workshop on "The Ecology of Inland Waters" was the eleventh in the series.

PRESENTATION

The workshop programme included 10 key lectures of 30 minutes in length and 20 presentations of 15 minutes by a total of 30 researchers in the field preceded by a short welcome introduction by British Council and CSIC representatives.

Opportunities for dialogue were provided at the end of each session. The workshop finished with general impressions on the state of the subject area and funding opportunities and questions about where is freshwater ecology going, what collaborations might be interesting, what makes a good proposal and where might you get it funded.

The workshop was coordinated by Emeritus Professor Brian Moss and Professor Andy J. Green.

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PROGRAMME

SUNDAY 13TH OCTOBER	
20:00:	**Welcome drinks and informal welcome dinner at the Palacio de Doñana**
MONDAY 14TH OCTOBER	
9.30	**Welcome by British Council and CSIC representatives**
Session 1: (Chair, Nùria Bonada)	
9:50	Introduction, **Brian Moss**, Freshwater research: key and global or going nowhere?
10:20	**Andy Green**, Freshwater birds as major players on the aquatic stage
10.50	**Kevin Wood**, Quantifying the effects of grazing on aquatic ecosystems
11:05	**Alan Law**, A long-term study of the effects of herbivory by European beaver on aquatic vegetation
11:20	**General discussion**
11:35	***Coffee***
Session 2: (Chair, Stephen Maberly)	
11.50	**Jordi Catalan**, Predictability requires understanding: some paradoxes on persistent organic pollutants and aquatic organisms
12.20	**Gareth Jenkins**, Species interactions may inhibit biological recovery in acidified freshwaters
12.35	**Núria Bonada**, Biological traits, evolutionary history, and community assembly of freshwater biodiversity
13.05	**Ana Filipe**, Using time to first detection to improve species distributions models
13:20	**Margarita Florencio**, Biotic interactions and environmental variability determine biodiversity patterns in macroinvertebrate assemblages of temporary ponds
13:35	**General discussion**
13:50	***Lunch***
Session 3: (Chair, Isabel Reche)	
15.30	**Jonathan Grey**, Connectivity: cornucopia or curse for inland waters?
16.00	**Mireia Bartrons**, Aquatic-Terrestrial Linkages Create a Trophic Bypass that Reduces Methylmercury in Terrestrial Food Webs
16.15	**Hugh Feeley**, Small headwater streams and their importance in freshwater research: Case-studies from Ireland
16.30	**Eduardo García-Roger**, Bet-hedging strategies in the hatching of rotifer diapausing eggs from temporary populations
16:45	**General discussion**
17:00	***Coffee***

Session 4: (Chair, Jonathan Grey)	
17:30	**Isabel Reche**, Inland waters as a model system to study microbial metacommunities
18:00	**Erika Hogan**, Nutrient limitation of phytoplankton growth in Arctic lakes
18:15	**Eleanor Mackay**, From small lakes to global biogeochemical cycles: the influence of mixing processes on phosphorus accumulation and cycling
18:30	**General discussion**
20:00	***Dinner at the Palacio de Doñana***
TUESDAY 15TH OCTOBER	
Session 5: (Chair, Isabelle Durance)	
9:30	**Nigel Willby**, What can landscape-scale approaches teach us about the conservation and restoration of freshwaters?
10:00	**Carles Alcaraz**, Long-term changes in the lower Ebro River: top-down versus bottom-up effects
10.15	**Susana Bernal**, Opening the black-box: the use of experimental catchments to understand ecosystem function and its response to environmental change
10.30	**General discussion**
10.45	***Coffee***
Session 6: (Chair, Jodi Catalan)	
11.00	**Emili García-Berthou**, Invasion biology and inland waters: from conservation to communication
11.30	**Belinda Gallardo**, Is Great Britain on the brink of invasional meltdown of Ponto Caspian species?
11.45	**Christopher Lejeusne**, Invasive brine and decapod shrimps: what can they tell us about invasion mechanisms in aquatic environments?
12:00	**Kit Magellan**, The role of behaviour in biological invasions: interactions between invasive fish and native Iberian species
12:15	**Marta Sánchez**, Studying feeding rate in Artemia provide insights on the competitive superiority of the exotic A. franciscana and its potential impact in hypersaline ecosystems
12.30	**General Discussion**
13:00	***Lunch***
15:00	Guided tour of Doñana National Park
20:30	***Dinner at local restaurant***

TUESDAY 16TH OCTOBER	
Session 7: (Chair, Nigel Willby)	
9:30	**Stephen Maberly**, Climate change effects on the functioning of inland waters: pervasive influence or minor factor?
10:00	**Aitor Larrañaga**, Global change: perspectives from the not so dry Spain
10:15	**Cayetano Gutiérrez**, The effect of natural and anthropogenic stressors on the structure and function of aquatic ecosystems
10:30	**General discussion**
11:00	***Coffee***
Session 8: (Chair, Emili Garcia-Berthou)	
11:30	**Isabelle Durance**, Freshwater ecosystem services: a new way of communicating the importance of freshwaters and freshwater biodiversity
12:00	**Christopher Hassall**, Urban ponds and aquatic biodiversity
12:15	**Daniel Perkins**, Land-use effects on stream food webs and services
12:30	**General discussion**
13:00	***Lunch***
Session 9: (Chair, Andy Green)	
15:00	**César Alcácer Santos** (Coordinador Gestión Ecosistémica del Agua, Fundación Centro de las Nuevas Tecnologías del Agua), Funding opportunities in the area of aquatic ecology
15:45	Sessions for Sub group discussions. 4 mixed groups of 5 younger scientists and 2 groups of 5 older scientists discussed their general impressions on the state of the subject area. In particular, they were asked to discuss "Where is freshwater ecology going?" and "What collaborations might be interesting?", with the aim of 2-4 main points from each group for each question.
17:30	*Coffee*
Session 10: (Chair, Brian Moss)	
18:00	Reports from discussion groups and general discussion
20:00	***Dinner at the Palacio de Doñana***

SUMMARY OF DISCUSSIONS

Our workshop was held in a relaxed and informal atmosphere on the edge of Doñana's huge marismas (temporary marsh system) in a World Heritage Site. The relatively small size of the meeting, and the fact that everyone made a presentation, and no one was there only as a member of the audience, helped to foster an atmosphere of interaction and less sense of hierarchy between very experienced and early career scientists. Scientific meetings are usually organised in such a way that they are largely one-way exercises. Most of the time, someone talks whilst the rest listen. There will usually be questions after a talk, or in a later discussion section, but these too are essentially interactions between only two people (the speaker and the questioner) and only rarely does a real discussion ensue. In this workshop, where a major theme was the direction in which the subject of freshwater ecology is going and is likely to go, and how to take advantage of such predictions in future collaborations, we felt it useful to devote time to small-group discussions. So that discussions were not dominated by the older and (perhaps) more confident, we randomised membership in groups of five but created separate groups from the older and the younger participants. The topics for discussion were 'Where is freshwater ecology going?' and 'What collaborations might be interesting?' Discussions ranged more widely than these, however, as well they should, with the independent minds that good scientists inevitably have.

One of us had pointed out that there were considered to be some problems within the organisation and promulgation of freshwater ecology in Europe. It was perceived (by terrestrial and marine ecologists) to be less important than terrestrial and marine ecology, because of an emphasis on practical problem-solving, and an orientation towards the medium of water rather than towards abstract ecological problems, which are perceived to be intellectually more challenging (at least by those that are orientated towards that sort of approach). An approach to summarising the discussions, which were reported group by group to a plenary session, is thus to construct a SWOT (strengths, weaknesses, opportunities, threats) analysis for freshwater ecology and ecologists, with the potentially interesting collaborations being presented as opportunities.

Strengths

The strengths of freshwater ecologists were perceived as a long tradition of making links, both intellectual and personal, with other disciplines. The talks given had illustrated this with examples, on the one hand, from animal behaviour, concerning mating and aggression in small fish, to the biogeochemical transfers of mercury from lakes by chironomids and of nitrogen from catchments to lakes, on the other. Secondly, freshwater ecologists have contributed to the formulation of major principles in ecology as a whole (the trophic-dynamic concept (Lindeman), the niche concept (Hutchinson), the winkling out of pseudoreplication in experiments (Hurlbert)) in the past, and have been particularly important (with marine ecologists) in exploring the use of stable isotopes, particularly of carbon and nitrogen, in the elaboration of food webs, and the movements of carbon across the landscape and into the waters. Freshwater ecology was also seen to have had a wide scope, both geographical (in fish biogeography and speciation), and in time (through the development of palaeolimnology to a far greater sophistication than terrestrial palaeoecology).

Weaknesses

Weaknesses were seen in a developing degree of isolationism compared with the breadth of approach of the past, (which was seen as a strength), a tendency to concentrate only on the freshwater system with sometimes little attention to the catchment, and a tendency to publish the best work in non-specific journals with high impact factors, which is understandable, but which camouflages the freshwater origin of the work. There might also be a more gentle pacing of the work, linked with emphasis on organisms with long life-histories or patterns in population change that emerge only after study of many annual cycles. It had been pointed out that Winfried Lampert had accused freshwater ecology of continual reinvention of the wheel, through creating more and more examples of the same phenomena (studies on eutrophicated lakes, engineered

rivers, drained and drying wetlands, population cycles described but not analysed, for example). It was also felt that we might not be forward enough in advertising ourselves and our work. If a scientific meeting of ecologists contains 95% terrestrial papers and 5% freshwater, the freshwater marketing needs to have 19 times the impact to maintain parity.

Threats

Threats were not perceived to be greatly different from a continuation of our current weaknesses. But despite the fact that many problems in the oceans can be tackled much more conveniently in freshwaters (and sometimes have already been exhaustively studied there), the prestige of large grants for expensive ships and cruises may sometimes work to our disadvantage.

Opportunities

Most interesting were the possibilities of collaborations, which reflect opportunities in this analysis. General perceptions were that we could adopt the confident attitudes of terrestrial ecologists and simply push our interests more, that we could improve our communication abilities to sell our research, and that we have not in general been deficient in developing new techniques and fields. There was certainly a case for *'emerging from the water and thinking outside the cup'*, but perhaps that is something we have often done, and perhaps reinventing the wheel is not such a bad thing if it leads to new perceptions of the wheel: the equivalents of pneumatic tyres to replace iron-shod rims, lightweight alloys to replace heavy steel and improved gearing systems, for example.

It was felt that future research would inevitably (because of political influences reflected in funding) be in the applied area, but that need not exclude a clever incorporation of fundamental studies. The future will also depend more on collaboration because specialist techniques demand deeper skills (in chemistry and bioinformatics and statistics for example). There was also an opportunity to improve communication techniques, especially as users of our results, who provide funds, and stipulate requirements, expect clear communication of results and their implications. One major point made by a speaker cognizant with the intricacies of submitting EU grant proposals was in thinking about the reviewers (often non-specialists), so that plain English was a priority. There was evidence, that as with other scientists, much could be learned through wider collaboration as required to obtain the large EU grants, though it would need a maintenance of the divergent thinking of past tradition. Techniques might increasingly involve the use of social media. Indeed, several of the workshop participants experimented with the use of Twitter to broadcast the workshop itself before and during the event, and presented the results during our discussions. Twitter was more widely established among the British participants than the Spanish, and several of the Spanish participants decided to adopt Twitter as a professional tool directly as a consequence of the workshop.

Making time for collaborative thinking as well as practical working could also pay dividends. There were ways to help the process. Being creative in other activities outside science could help increase creativity within it. It was worth allocating some time to risky research whilst also carrying out the bread-and-butter research that is enforced by the pressures of modern funding and institutional management. In the future, deep expertise will continue to be required, but too great a specialisation can be hazardous in a world of changing fashions in funding. Flexibility is needed. Learning new techniques is always a good thing. Familiar techniques applied repeatedly in different situations can become prisons. There are opportunities to apply new tools (e.g. stable isotopes, genomics) especially to investigate processes, but it should be remembered that the best research is always driven by questions, not technology, and fashion can be a false seducer. In general, freshwater ecologists have probably not thought enough about the links with evolution, notwithstanding the excellence of studies on speciation in fish and on adaptive radiation through traits. Finally models, now widely used, are generally restricted and do not include nearly enough attention to microbially driven processes on the one hand, and larger organisms such as birds and mammals (and often even fish) on the other. It is necessary to think big. Peter Medawar, a Nobel Prize-winning physiologist once said that important answers come only from important questions.

EU funding was identified as essential to enable future collaborative research on inland waters in

the UK and Spain, especially given the current challenging financial situation for Spanish research. There are many commonalities for collaboration, especially between countries like the UK and Spain with markedly contrasted terrain, climate and recent geological history. The valuation of ecosystem goods and services is currently of high and growing profile. It provides opportunities for working with other areas in the social sciences and engineering. It would be valuable to use this as a platform for creating a desired increase into more fundamental research, and funding for long-term studies, and it contributes to communication of the benefits of conservation, and the changing of attitudes among the public and politicians. It also increasingly uses remote sensing and geographical information systems, techniques that have not been so widely used by freshwater ecologists but approaches that allow research on remote areas that might not otherwise be possible, as well as going back in time e.g. to retrace flooding patterns in Doñana back in the 1980s before these were monitored. Beyond that the commonalities of invasive and migrating species, climate and other global change, not least floods and drought, and the implications of fragmentation of the landscape, offer contrast and comparisons for future work linking Spain and the UK. Doñana was an ideal place to be reminded of such themes, as Europe's most important wintering area for ducks and other migratory waterbirds that breed in northern Europe, and as a highly protected natural area surrounded by transformed landscapes such as a seaside resort, strawberry fields, and other agriculture.

ABSTRACTS

Long-term shifts in the lower Ebro River

Carles Alcaraz, *IRTA, Sant Carles de la Ràpita, Spain*

The Ebro River is ca. 930 km long and drains an area of 85534 km2 crossing the North-eastern part of the Iberian Peninsula. It is one of the most important rivers flowing into the Mediterranean Sea, with a mean annual flow of about 426 m3/s, but there are significant differences between dry (118 m3/s) and wet (569 m3/s) years. In the lower Ebro River (100 km upstream the mouth) there are two large reservoirs (Mequinença and Riba-roja) built in the 1960s for hydropower purposes, thus impacting river hydrology, geomorphology and ecology. The lower Ebro River has also recently undergone a regime shift to a macrophyte-dominated from a phytoplankton-dominated system. Two initial hypotheses have been proposed to explain the collapse of the phytoplankton: bottom-up (oligotrophication by the diminution of phosphorus); top-down (zebra mussel introduction and colonization). The zebra mussel *(Dreissena polymorpha)* is among the most invasive organisms worldwide with well documented ecological impacts on ecosystems functioning and native fauna besides imposing huge economic costs. In order to check these hypotheses we gathered data (from 1990 to 2005) on water quality, hydrology and biological communities (phytoplankton, macrophytes and zebra mussel) from existing data sets. A Principal Components Analysis (PCA) was carried out in order to explore patterns of association among limnological variables, Generalized Additive Models (GAMs) were applied to model the response of chlorophyll concentration to temporal, and the relationship of chlorophyll to limnological variables was analyzed by Generalized Linear Models (GLMs) using an information–theoretic approach. Since mussel density has been proposed as a key factor determining its impacts we also constructed a demographic model, using a monthly time step, mortality and fecundity was controlled by temperature and population growth was limited by a carrying capacity calculated from local data. Results clearly show that the decrease in phosphorus is the main cause of chlorophyll reduction, and thus triggering the ecosystem shift through an increase in water transparency and the subsequent colonization of macrophytes. The decrease in dissolved phosphorus (GLMs models) had a relative importance 14 times higher than the increase in zebra mussel density to explain the variation of total chlorophyll, and river hydrology did not present a significant influence on the decreasing trend of total

chlorophyll along the study period. This novel ecosystem shift is causing remarkable changes in the biological communities beyond the decrease of phytoplankton and the proliferation of macrophytes, such as massive colonization of Simulidae (black fly) and other changes in the benthic invertebrate communities that are currently investigated. Mussel model predictions at a local scale may additionally be helpful in developing adequate control plans by forecasting management effects.

Taking the Trophic Bypass: Aquatic-Terrestrial Linkage Reduces Methylmercury in Terrestrial Food Webs

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Ecosystems can be linked by the movement of matter and nutrients across habitat boundaries through a variety of processes, including aquatic insect emergence. Aquatic organisms tend to have higher concentrations of certain toxic contaminants such as methylmercury (MeHg) compared to their terrestrial counterparts. If aquatic organisms come to land, terrestrial organisms that consume them are expected to have elevated MeHg levels. But emergent aquatic insects could have other impacts as well, such as altering consumer trophic position, or increasing ecosystem productivity as a result of nutrient inputs from insect carcasses. Here, we measure MeHg concentrations in terrestrial arthropods at two lakes in northeastern Iceland, and use carbon and nitrogen stable isotopes to quantify aquatic reliance and trophic position. Contrary to our expectations, terrestrial consumers that consumed aquatic prey had lower MeHg concentrations. MeHg concentrations were positively correlated with consumer trophic position. Path analysis was used to examine the direct and indirect effects of aquatic reliance and trophic position on MeHg. Across all terrestrial arthropod focal taxa (Lycosidae, Linyphiidae, Acari, Opiliones), aquatic reliance had significant direct and indirect (via changes in trophic position) negative effects on terrestrial consumer MeHg. Overall, our results highlight the potential for cross-habitat linkages to affect MeHg dynamics via several mechanisms, including effects on consumer trophic position. Terrestrial arthropods that fed on aquatic insects had lower MeHg, which runs counter to the conventional wisdom that aquatic systems are a universal source of MeHg contamination to surrounding terrestrial ecosystems.

Keywords: Ecosystem Linkages, Food Web, Aquatic Insects, Methylmercury, Stable Isotopes

The use of experimental catchments to understand ecosystem function and its response to environmental change

Susana Bernal, *Centro de Estudios Avanzados de Blanes (CEAB-CSIC), Girona, Spain*

Freshwater ecosystems are excellent integrators of ecosystem processes occurring at the catchment-scale because they are recipients of waters draining throughout the catchment. This intimate relationship between freshwater and terrestrial ecosystems allows approaching challenging questions in our today's world such as the effect of climate change on ecosystem nutrient flux and cycling. While rare, long-term records such as those collected at the Hubbard Brook Experimental Forest (NH, USA), offer a unique opportunity to disentangle effects of climate from other anthropogenic influences. Our study indicates that climate alone cannot explain the occurrence of a dramatic >90% drop in catchment nitrate export over the past 46 years, despite longer growing seasons and higher soil temperatures. The strongest climate influence was a warming-induced shift in soil-water flow paths within the catchment, but this effect explained at best only ~40% of the nitrate decline. In contrast, at least 50-60% of the observed change in the N export could be explained by the long-lasting effect of forest cutting in the early 1900's on the N cycle of the soil and vegetation pools. Our analysis shows that past events can obscure the influence of modern-day stresses on the N cycle, even when analyses have the advantage of being informed by half-century long data sets. These findings raise fundamental questions about how effects of climate change can be resolved on terrestrial ecosystems still under the influence of past perturbations.

Biological traits, evolutionary history, and community assemblage of freshwater biodiversity

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Freshwater ecosystems hold an enormous number of species despite occupying a very small fraction of the Earth's surface. However, under the current freshwater crisis, many of these species are highly threaten, some have been recently extinct, and others are declining much faster than those in terrestrial or marine ecosystems. Understanding global patterns of freshwater biodiversity is thus a key issue for its conservation but still remains a challenge in macroecology and macroevolution. In particular, despite biodiversity is a very broad concept and include many different dimensions (from genetic to ecosystem diversity), most macroecological and macroevolutionary studies deal with simple measures of biodiversity, such as species richness. These simple measures do not account for species identity and consider all species and their relationships as equal. Species differ in their functional (what they do) and evolutionary (from where they come from) characteristics and therefore these features should be considered when analysing biodiversity patterns. Thus, sites with functionally complementary species would be more diverse that sites with functionally redundant species because they hold broader functional information. Likewise, sites with phylogenetic distant species would be more diverse than sites with closely related species because they integrate more evolutionary information. Based on this idea, we showed that macroecological and macroevolutionary patterns might differ depending on how we consider diversity. Stream macroinvertebrates showed that the most accepted macroecological pattern of species richness in latitude was followed by species richness and functional diversity but not by phylogenetic diversity. When looking at the macroevolutionary pattern, species diversification along the evolutionary time followed what is known for all the eukaryotes but changes in functional diversity of taxa showed that most recent clades have lower diversity than older clades. Only by analysing the different dimensions of biodiversity in space and time we will be able to understand global patterns of species and address appropriated conservation measures.

Predictability requires understanding: some paradoxes on persistent organic pollutants and aquatic organisms

Jordi Catalan1,2

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The current global change provides countless opportunities for research in ecology. Research on these issues has a societal demand for prediction. In this talk, the aim was to highlight the need for understanding the mechanisms behind observed patterns in order to extrapolate results beyond the detailed case studies. Excessive confidence on the statistical associations between observed patterns can lead to serious inconsistencies and errors in projections of future scenarios. To illustrate these contingencies, we looked at some paradoxes arising from patterns in the distribution of persistent organic pollutants (POPs) in freshwater organisms.

The consequences of the progressive accumulation of POPs in nature are largely unknown. However, this was not the subject of the talk. Examples of the distribution of these compounds in freshwater organisms were used to illustrate how necessary is an adequate knowledge of physicochemical principles and biological idiosyncrasies of organisms to extrapolate or accept explainations for observed patterns.

Polychlorobyphenyls (PCBs) were used as demonstrative compounds. The production and use of PCBs was banned long ago in the 1970s, but their slow fate in the environment determines that they are spreading throughout the planet and bioaccumulating in the biota. They are interesting as model compounds because include a number of congeners with a different amount of chlorination, which ultimately determine individual volatility properties and partition characteristics between air, water and lipids (i.e., living beings).

PCBs reach remote areas, far from they were produced and used, by atmospheric transport and then dissolve partially in water and eventually accumulate in the aquatic organism. The interesting issue is that the proportion of the different PCB congeners may vary across the different compartments in this pathway due to their specific physicochemical features. In the atmosphere of remote sites, the less chlorinated congeners, which are lighter and more volatile, usually predominate. When they dissolve into the water, the ratio among congeners tends to be similar because the more-volatile dissolve less. Then, when the compounds bioaccumulate, the less volatile become more abundant within the organisms because they are more hydrophobic. Thus, the short story is that the most abundant in the air should become the less abundant in the organisms according to theory and considering organisms essentially as a simple lipid (fat) ball.

In fact, it has been found that the less volatile PCBs are relatively more abundant in the macroinvertebrates of mountain lakes, reversing the tendency in the air of these locations, which show a higher proportion of the most volatile. Fine, they were following the expected pattern, and several species were showing the same. But then, started to appear species with the completely opposed pattern: more relative concentration of the most volatile, as in the air. What was wrong with the expectations? What did these "outlier" species have in common? All of them were species that respire air rather than water despite being aquatic. They either get a part of the body outside and keep air in a bubble or even are permanently under water but with a system (plastron) that allows them to keep an air layer attached to the ventral part of the body so that gases in this "air chamber" exchange with water. Thus, fine again. The ones respiring water have a PCB signature closer to water concentrations and the ones respiring air a signature closer to air concentrations. We understand the process again; let's make some calculations check it. Ops! It turns out that at thermodynamic equilibrium respiring in the air or water does not make any difference in the final concentrations. Both types of organisms should show the same PCBs profiles. In fact, the difference between air-lipid partitioning and water-lipid partitioning is exactly compensated by the partitioning between air and water. Where does the difference in observed patterns come from then? Perhaps the simple thermodynamic "fat ball" model is not enough. That is, we are observing patterns resulting from kinetic processes: food uptake, excretion with faeces and exchange through the respiratory system. The key points are that ventilation rates in the respiratory system for organisms respiring water are higher than for those respiring air as oxygen concentration is 30 times higher in air than in water and that coefficients of PCB partition between air-lipid and water-lipid differ in orders of magnitude.

Beyond the details of the case, the take home message is that, by simple association of patterns, we do not explain the process. Even when there is some theory behind, the simplest model may result too simple. This is particularly true for living systems that are far from thermodynamic equilibrium. Consideration of physicochemical principles, biological traits and some calculations may help questioning about the mechanisms behind observed patterns. Another example, about PCB altitudinal patterns in sediments and fish was also presented to illustrate how easy is to accept inappropriate ad hoc explanations when two patterns match.

Freshwater Ecosystem services, challenges and opportunities for freshwaters and freshwater biodiversity

Isabelle Durance *and the Duress team, Cardiff University, United Kingdom*

There is growing consensus that inappropriate valuation of the world's ecosystem services have led to widespread errors in environmental management with associated social disbenefits. Freshwater ecosystems are a prime example: when managed appropriately, they provide major services such as fish production, water supply, nutrient transport, health benefits and recreation. However, these services have been compromised extensively because they are seldom recognised in catchment activities. Pressures on river ecosystem services will grow in future as land use intensifies, water demands increase and climate changes further.

Sustainable management of river ecosystem services depends on understanding the processes that underpin them. In particular, there is a need to quantify how services depend

on river organisms, and to assess whether are there biodiversity thresholds under which a service cannot be delivered or is compromised. While our understanding is that the level and stability of ecosystem functions tend to improve with increasing biodiversity, the nature of the relationship that links biodiversity to ecosystem services still needs to be defined. The DURESS project, a £3 million trans-disciplinary research programme funded by NERC, is seeking to assess quantitatively i) how biodiversity and service delivery are linked; ii) how river biodiversity affects the resilience of ecosystem service delivery through time; and to iii) define how changes in catchments and climate affect services delivered by river biota in order to inform improved management.

First lessons from this project are that i) the ecosystem service approach requires a holistic, real life, large scale approach; but also that ii) the ecosystem service approach - by shifting focus from biodiversity or habitat to service – bridges the gap between natural and social sciences, and brings scientists out of their zone of comfort. Clearly, addressing the major societal challenges of our times will require a major shift in the way our environment is managed and an out of the ordinary approach. The ecosystem service approach is not without difficulties, but freshwater ecologists, with their integrated and interdisciplinary catchment tradition, are also clearly the best suited to lead the path.

Small headwater streams and rivers and their importance in freshwater research: Case studies from Ireland.

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Headwater streams and rivers constitute a high percentage of the riverine network in many countries worldwide (e.g. Ireland ~77%, U.S. ~85% and U.K. ~90%). Their extensive spatial distribution, range of physiochemical characteristics and variable land-use cover provide an unlimited array of ecological templates ideal for research opportunities. Using headwaters categorised into conifer forest cover classes throughout Ireland my research has indicated the significant reduction of inorganic drivers (e.g. SO42- and NO3-) of acidity during episodic storm events and the significant increases in organic acidity arising from increases in dissolved organic carbon (DOC). The concentration of DOC during episodic events increases with increasing forest cover and interestingly, concentrations have increased by up to 35% over the last 30 years in these small peaty catchments. Ecological recovery in the same forested headwaters seems to have improved, although storm event frequency and associated low pH reduces acid-sensitive taxa periodically. Nevertheless, ecological resistance and resilience has increased. The extensive number of headwaters with varying land-use types in close proximity (<2km) has also allowed us to examine the longitudinal extent of acid impact on macroinvertebrate populations and exclude the effects of catchment physiochemical characteristics such as aspect, soil, geology, elevation etc, and allowed us to highlight the limited (~1.5km) ecological impact. Other research has also highlighted the importance of headwaters in regional macroinvertebrate biodiversity (12-30%), and emphasises their importance in freshwater conservation. Nevertheless, extreme climatic events may reduce this biodiversity significantly which may have knock on effects on the sustainability of ecosystem services into the future. While headwaters are vital in future freshwater research, a holistic, multidisciplinary approach across the ecological, environmental, social, cultural and economic disciplines are essential for the successful communication and implementation of our research.

Using time to first detection to improve species distribution models

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Since early times researchers worried about the possibility that an organism is present but might not be detected during a survey. In fact, species detectability is a primary cause of biodiversity data uncertainty, particularly when modelling the distributions of species inhabiting fresh waters. Here we predict fish distributions while accounting different detection probabilities for

the Sabor catchment (Douro basin, Iberian Peninsula). First, we estimate the species probability of detection using a new Bayesian approach based on a time-to-first-detection. Second, we incorporate such detection in logistic regression models.

Time to detection varied with sample site depth and species analysed. Substantial differences were found when contrasting results of the logistic regression models that do not correct for detectability with the ones that incorporate detection estimates. For the majority of species no more than five minutes was needed to achieve high probability of detection.

Results of our study highlight the importance of incorporating detectability estimates while predicting species occurrences. Not accounting such source of uncertainty can certainly influence the results obtained, with strong implications on the accuracy and reliability of biodiversity databases as well as in regional or global conservation and management plans.

Biotic interactions and environmental variability determine biodiversity patterns in macroinvertebrate assemblages of temporary ponds.

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Temporary ponds are water bodies that present recurrent desiccation phase of variable duration. The Doñana National Park (SW Spain) can present more than 3000 water bodies usually being formed after the first rains of autumn or winter. The macroinvertebrate organisms inhabiting temporary ponds (mainly coleopterans, heteropterans and odonates) are adapted to the typical fluctuations of these ponds, developing strategies to disperse and survive pond desiccation. We explored macroinvertebrate biodiversity patterns in Doñana temporary ponds across time and space. A highly nested pattern was detected, which consists in species-poor sites harbouring subsets of the species contained in the species-rich sites. Detecting properly nested biodiversity patterns and the background mechanisms has important consequences for conservation. We detected that weak dispersal limitations in the pond network together with the environmental variability were the main drivers of the observed nested pattern. Therefore, the best strategy for conservation is to guarantee the high connectivity and heterogeneity in the pond network to support the high diversity of the system. We also identified different phases during the annual cycles of pond inundation and desiccation. During the filling phase, the pond inundation occurs in the whole network after the first heavy rainfalls. During the intermediate phase, the establishment of the assemblages and the organisms' life cycles occurs. The drying phase starts when the first ponds are close to desiccation and organisms thus develop their strategies facing desiccation. During the filling and the drying phase, we detected Urodele's predation on the macroinvertebrate assemblage structures. We also identified competitive exclusion and habitat segregation operating together to determine spatial assemblage segregations. We also detected that the degree of nestedness increased after the first pond inundation until the drying phase. In the drying phase, the simultaneous occurrence of drying ponds under stressing conditions and more stable non-drying ponds determine a non-nested macroinvertebrate pattern. Temporal variability in temporary ponds must be taken into account to determine properly priorities for conservation.

Key words: macroinvertebrate assemblages, temporary ponds, biodiversity patterns, conservation, spatio-temporal variations

Is Great Britain on the brink of invasional meltdown of Ponto Caspian species?

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This study seeks to assess the full scope of the threat posed by a high-risk group of freshwater invaders originating from the Ponto-Caspian region (SE Europe) across Britain. Approximately 40% of invasive freshwater invasive species currently known in Britain are reported for the first time from coastal catchments of the Thames river basin district, followed in importance by the Anglian and Humber districts. At least 15 out of the 23 alert Ponto-Caspian organisms investigated are well established in the Rhine estuary and Dutch ports. Four of these species *(Hemimysis anomala, Dikerogammarus villosus, D. haemobaphes and H. invalida)* have recently

crossed the channel and established in Great Britain. Linear regression models suggest the rest are under a critical risk of being transported, with four species predicted to have arrived already to Great Britain *(Echinogammarus ischnus, Jaera istri, Limnomysis benedeni and D. bispinosus)*. According to species distribution models performed with data on the current spatial distribution of Ponto-Caspian invaders, the cumulative risk of invasion of multiple Ponto-Caspian species, thus invasional meltdown, is highest in the SE of England and decreases north and westwards. Generalized Linear Models used to address the response of Ponto Caspian invaders to water chemistry were able to explain between 30 and 70% of the species presence-absence. Alkalinity was the most important factor in all models with Ponto Caspian invaders showing high probabilities of successful establishment at alkalinity levels higher than 120 mg/L, which correspond to most of England and the eastern part of Wales. Overall, the predictive models and maps developed in this study provide a means for a scientifically informed prioritization of species and river basins for the management of existing and future invasions of Ponto Caspian species. To conclude, we have compiled enough information to make the case that Great Britain might be on the brink of invasional meltdown and, as a consequence, confronting the problem of alert Ponto-Caspian invasive species is a vital element for national biosecurity.

Invasion biology and inland waters: from conservation to communication

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Freshwater ecosystems are very important for biodiversity conservation and among the most threatened worldwide. This is well exemplified in the Iberian Peninsula with most freshwater native fish being endemics that are declining due to severe multiple environmental pressures. One of these pressures are invasive alien species. I provide an overview of invasion biology using our research on freshwater fishes in the Iberian Peninsula. Five classical questions of invasion biology are: What are the distinctive features of invasive species? What determines invasibility of ecosystems? Why do these invaders do so well and where do they come from? What are the effects of these invasions? And how can we manage this issue? Although we have advanced much on the answer to these questions, many uncertainties remain that call for a precautionary approach. Probably the most unsolved of these questions is how to reduce the frequency and mitigate the impacts of invasive alien species. Improvement of several communication aspects is one of the key tools to reduce the exponential increase of this environmental issue.

Bet-hedging strategies in the hatching of rotifer diapausing eggs from temporary populations

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Habitat unpredictability is a local adaptation factor shaping life-history traits in aquatic organisms. In the case of rotifers, which were used here as model organisms, such an uncertainty may select for the evolution of bet-hedging through risk-spreading strategies in diapausing egg hatching. This means that a fraction of diapausing eggs in wild populations do not hatch even when the conditions are favourable for population growth. Thus, there is a remaining fraction of viable diapausing eggs waiting on stand by in the sediments for longer periods. According to theory, it is expected that the incidence of bet-hedging strategies for diapausing egg hatching will be higher in more variable habitats. However, there is still little empirical evidence to support this prediction. This is most likely due to the difficulties in accomplishing the requirements needed to identify and analyze bet-hedging strategies, avoiding confusion with genetic variation and phenotypic plasticity. Essentially, these requirements are: (1) maternal control over offspring phenotype, and (2) population differentiation associated to habitat predictability. Preliminary analyses have showed a gradient of predictability in habitats occupied by the rotifer *Brachionus plicatilis*, and the existence of a significant positive correlation between hatching fraction of diapausing eggs and an index of habitat predictability. This suggests that environmental variance in this model system tends to decrease as it increases the frequency of good years for population growth. Our recent research has also showed

evidence of maternal control over offspring phenotype respect to their hatching pattern. Typically, the first diapausing eggs produced exhibited longer diapauses than diapausing eggs produced later. Although genetic variability cannot be completely discarded, our results suggest that variation in diapause duration is likely to have evolved by the spread of a bet-hedging strategy.

Keywords: Bet-hedging, Diapause, Evolutionary ecology, Habitat unpredictability, Rotifers.

Freshwater birds as major players on the aquatic stage

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Since Hurlbert & Chang published a seminal paper on "ornitholimnology" in 1983 (PNAS 809: 4766-4769), surprisingly little attention has been paid to the role of birds in aquatic systems. Ornithologists tend to focus on the population ecology of their study species, without considering their influence on the ecosystems they inhabit. Aquatic ecologists tend to ignore birds, as illustrated by their near or complete absence in textbooks such as Lampert & Sommer's Limnoecology and Wetzel's Limnology. However, birds are often more important than fish in many freshwater systems, especially shallow or temporary ones. Using examples from Spain and elsewhere, we present a review of the limnological role of birds in the hope of stimulating further research. As predators, grazers and ecosystem engineers they have a profound effect on the abundance of other organisms and on ecosystem functioning. As such, waterbirds provide many ecosystem services (reviewed by Green & Elmberg 2013 Biol. Rev.) They influence sediment stability and suspension, and the switch between clear water and turbid water states. Owing to their mobility, they play an important role in nutrient cycling and can cause guanotrophication. They can have a major influence in methane production and other aspects of biogeochemical cycling in wetlands. As ideal vectors for the dispersal of plankton, macrophytes and macroinvertebrates they have a central role in maintenance of biodiversity and in metapopulation dynamics, and are especially important in the redistribution of these organisms in response to climate change. Waterbirds also disperse parasites, pathogens and invasive species between aquatic systems, and can also be vectors of heavy metals and other contaminants. Much more collaborative research between limnologists and ornithologists can improve our understanding of aquatic systems. To quote Comin & Hurlbert (2012 Hydrobiologia) a "full integration of the ecology of aquatic birds with the ecology of lakes and rivers is far away".

Keywords: waterbirds, ecosystem services, ornitholimnology, seed dispersal, guanotrophication

Connectivity: cornucopia or curse for inland waters?

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Inland waters are not isolated ecosystems and must be considered in the perspective of a larger landscape unit to include the entire drainage basin if we are to maintain the integrity of their ecosystem structure and processes. Connectivity is thus crucial and approaches such as stable isotope analyses have been key to illustrate the importance of movements of organic matter into them from the land, and the regulatory roles of fish that move among the waters and birds and mammals that migrate between the waters and the land. Inland waters also play a regulatory role in the transfer of carbon through the hydrological cycle, and release of that carbon back to the atmosphere as various important greenhouse gases, rather than just conduits between the land and the oceans. The incorporation of methane-derived carbon into food-chains identified by distinct stable isotope values from biogenic methane, has not only caused us to re-evaluate the relative importance of chemosynthetic versus photosynthetic production in inland waters but also highlights the importance of biology in mitigating greenhouse gas mediation from terrestrial sources through aquatic ecosystems to atmospheric sinks.

However, the likelihood of human induced stressors being introduced to inland waters is also enhanced through connectivity. Excess nutrients applied to agricultural land, as well as mobile fine sediments from regularly tilled fields, contaminants from urban landscapes,

and the introduction of invasive non-native species are all promoted through connectivity and are clearly beginning to act in concert with climate change. While palaeolimnology has been influential in identifying the start of the industrial revolution as a turning point in the 'quality' of standing waters, and hence the labelling of pre-industrial revolution structural and functional conditions as a pristine state ideal to aim for in terms of rehabilitation, humans have been modifying the wider landscape throughout the drainage basin for thousands rather than hundreds of years. To what extent then should we be viewing, for example, changing trends in water colour influenced by dissolved organic carbon against these much longer term pervasive human influences in the catchment? I raise and explore such questions using a variety of stable isotope studies from the past 25 years.

The effect of natural and anthropogenic stressors on the structure and function of aquatic ecosystems

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Chronic stress modifies the structure and function of ecosystems through different processes. Despite that some convergent responses have been found, as changes in community composition and a reduction in diversity, there is unclear how this may affect to the processes explaining changes in beta diversity and ecosystem features. In my research, I used stream macroinvertebrates to explore these questions, as they offer interesting properties to test ecological hypotheses. As these organisms respond to marked environmental habitats, we use natural and anthropogenic stress gradients to see if the degree in which the regional pool of species is adapted to a type of stress, may cause patterns that help to predict responses to ongoing global change. In a first work, I found that natural and anthropogenic stressors reduced species richness and generate contrasting patterns in beta diversity that arise through different mechanisms. While species turnover along natural stress gradients, nested subset of species developed over anthropogenic stress gradients. In a second work, we estimate some ecosystem features from a multidimensional space composed of axes that represented the variation in biological traits of the aquatic community. We used this reduced space as proxy of the functional niche to estimate mean taxon niche (functional richness at taxon level), niche similarity (the percentage of niche overlap between taxon pairs), community niche (functional richness at community level), functional dispersion (functional diversity, as mean departure from community centroid) and functional redundancy (sum of overlapping areas between species pairs). We found similar functional responses to natural and anthropogenic stress, where mean taxon niche and niche similarity augmented with increased stress, and community niche, functional dispersion and functional redundancy decreased when stress intensity augmented. The reduction in functional richness arose from the development of nested subsets of community traits along stress gradient. The results of these studies may have strong conservation implications and may help to predict the ecosystem responses to global change and to elucidate how organisms colonized and evolved in stressful habitats.

Urban ponds and aquatic biodiversity

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Working on wetlands in urban areas involves a unique set of problems and opportunities. Urban areas are generally considered to be "unnatural" regions that contain little or no biodiversity. Furthermore, ponds themselves are thought to be insignificant due to their small size and variable quality. However, in the aggregate ponds can provide a substantial landscape-level biodiversity as well as generating greatly-enhanced connectivity across otherwise impermeable built-up areas. Increasing concern over the capacity of species to shift their ranges in response to climate change has led to a focus on ensuring that habitat connectivity is maximised (for example, through the Natura2000 Network). From a purely academic perspective, urban ponds represent a fascinating array of different water body types, including bomb craters, swimming pools and fountains in addition to garden ponds, park lakes and sustainable drainage systems. Using data from a set of 30 ponds sampled across the City of Ottawa in Ontario, Canada, I demonstrate the problems with definitions of "urban" and "natural": all ponds were impacted by human

activity, but to varying degrees and in different ways. The principle cause of variation in water chemistry between the ponds in the present study was likely road salt, which varied strongly between the most urban (a highway drainage pond) to the most natural (a small lake in a Provincial Park). However, biodiversity surveys showed that even highly-managed storm water retention ponds can have equivalent biodiversity to peri-urban unmanaged ponds. Finally, I show that there exists the possibility for considerable outreach within urban environments and highlight a new project, the West Yorkshire Ponds Project (www.wypp.org), which seeks to partner with schools to further knowledge of freshwaters. This would create a series of ponds across the City of Leeds which could be used by researchers as an outdoor laboratory and by schools as an educational resource, strengthening partnerships between primary, secondary and tertiary education and providing school children with much-needed exposure to nature and ecological systems.

Nutrient limitation of phytoplankton growth in arctic lakes

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There is growing evidence of ecological change in arctic lakes. The majority of this evidence comes from lake sediment records which suggest the composition of algal communities has changed, and productivity has increased over the past 150 years. This change is most commonly attributed to climate, in particular, an increase in temperature. However, such interpretation often ignores other drivers of change, for example, long-range atmospheric nitrogen (N) deposition, which has been shown to occur over a similar time frame at many sites across the arctic. The region of south west Greenland is typical of much of the arctic in terms of lake density, precipitation patterns and vegetation. It also provides a unique opportunity to investigate atmospheric N deposition as a driver of ecological change, as it has only very recently experienced rapid, significant 20th century warming which has been observed elsewhere in the Arctic. Evidence from Greenland ice core records also indicate that N-NO3- concentration as a result of atmospheric deposits has increased over the past c. 150 years. There is a climate and precipitation gradient which exists across south west Greenland from the inland ice sheet margin (continental climate, colder and drier) to the coast (maritime climate, warmer and wetter). We hypothesised that the precipitation gradient might also represent a gradient in wet atmospheric N deposition, and might result in a shift from N-to phosphorus (P)- limitation between lakes at the ice sheet margin and coast. Study lakes (n = 21) were situated in 3 distinct locations across the region: the ice sheet margin, inland at the head of Søndre Strømfjord, and at the coast. Nutrient limitation was investigated 3 times between August 2010 and July 2011, allowing both seasonal and regional differences to be explored. Phytoplankton growth was assessed over 14 days following in vivo fluorescence of samples treated with 1 of 6 nutrient additions: control (no addition), P (6 µM NaH_2PO_4), NH_4^+ (90 µM NH_4Cl), NO_3^- (90 µM $NaNO_3$), P + NH_4^+ and P + NO_3^- (final concentrations as before). A clear response to nutrient addition was found in 95 % of all bioassays, and of these, co-nutrient limitation was most commonly recorded (70 % of cases). There was no evidence of regional variation in nutrient limitation. However, strong seasonal variation, with a shift from P-limitation under ice to co-limitation during spring and summer was recorded.

Keywords: arctic, nitrogen, nutrient limitation, phytoplankton, phosphorus

Species interactions may inhibit biological recovery in acidified freshwaters

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The extensive acidification of fresh waters across Europe and North America during the 20th century led to systematic and widespread loss of species, which in turn fundamentally changed the structure of resident aquatic communities. While attempts to limit or halt the causative acidifying emissions have been

successful in a widespread reversal of the chemical consequences of acidification, such as lowered pH and toxic compounds, there has not been a corresponding biological recovery, with evidence for species recolonisation patchy or lagged at best. Here I present work aimed at investigating potential ecological constraints on this biological recovery, using manipulation of both antagonistic direct (such as predator functional response) and more subtle indirect (such as apparent competition) species interactions. By experimentally varying the densities of both acid-tolerant and acid-sensitive species in the presence of large invertebrate predators, I provide evidence that the lag in recovery of acidified aquatic communities is, at least in part, due to intrinsic resistance to re-colonisation by acid-sensitive species. This resistance is conferred by a combination of both direct and indirect interactions between predators and prey, and is manifest at various levels of organisation. These findings increase our understanding of the drivers which govern the structure and function of ecological networks in response to an important climatic stressor. This is especially relevant given the rapid industrialisation of developing countries with large populations, such as India and China, which could well soon lead to further anthropogenic acidification on a significant scale. Understanding of how communities respond to this stress will be vital if large-scale loss of taxa is to be avoided or mitigated.

Key words: Acidification, recovery, predator-prey interactions, functional response, climatic stressor

Global change: perspectives from the not so dry Spain

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Humanity has increased the rate at which natural systems are modified and natural processes are being significantly altered globally. Although scientists are building up knowledge on how to manage those affections, local authorities have a limited capacity to palliate the effects of some of the issues that the term 'global change' encompasses. Among those we find global warming that irremediably will affect most ecosystems. A recent study carried out in the north of Spain suggests that global warming will enhance microbial growth, together with the immobilization of nitrogen to and decomposition of detritus. Moreover, the same study suggests that fungal taxa richness in the coldest streams will be most affected by the temperature increments. Contrastingly, some other affections included within global change can be locally managed. In this sense, while a great effort has been dedicated to prevent the effects of big dams (>1 hm3) on inland waters (e.g., maintaining ecological flows downstream or reducing water flow discontinuity with fish ladders) small dams have been classically understudied. The typical lack of management leads to droughts in the reaches below the dam that are repeated every summer, creating a very significant effect on stream communities and functions. On the other hand, the replacement of native vegetation by plantations in the catchments (e.g. eucalypt or pine) is proven to alter stream communities, although preserving a native riparian corridor seems to reduce the magnitude of the impact. In light of these and similar recent studies, future projects should consider three aspects that are essential to understand global change effects on inland waters. Firstly, they will need to marry the potential for transferring knowledge to society with the possibility for developing ecological theories. Secondly, they should enable to rank locally unmanageable and manageable affections to have an idea of the ability of local actions to cope with global change. Thirdly, they will need focus on interactions among factors to identify the most sensitive areas or situations.

Keywords: Global warming, water regulation, land use changes, manageability of the affection, future projects

Engineering diversity: the impacts of beavers on aquatic vegetation

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Human influenced global and local pressures on freshwater systems are increasing and show no sign abating. Therefore it is vital that any impacts, pressures or conservation projects are assessed scientifically and independently in order to understand potential related impacts. As an example, the beaver (Castor spp.) is a keystone species where populations are increasing globally through reintroduction

projects. They have the potential to create, modify and alter freshwater and riparian habitats through ecosystem engineering (i.e. dam building) and selective herbivory. Our studies in a moderately productive pond over a ten year period documented highly selective foraging on macrophyte species resulting in reduced density dependant competition with foraged habitats having a 3 times greater species richness, increased species diversity and increased species turnover. As no beaver created dams physically altered the pond hydrology, selective beaver grazing alone accounts for significant changes in habitat structure. Studies were also conducted in Sweden whereby changes in macrophyte and aquatic coloeptera richness and diversity between beaver created and control wetlands were observed at the landscape scale. Sites where beaver created dams altered the hydrological regime had a significantly higher macrophyte and coloeptera richness and diversity with species composition differing between wetland types. Underlying abiotic environmental variables could not consistently explain observed differences, yet 30% more species were added to the landscape species pool with the addition of these beaver created habitats. Therefore reintroductions and increasing populations of beavers in these studies appear to positively influence the freshwater landscape; though our observations are not necessarily universal.

Keywords; beaver, diversity, richness, macrophytes, coleoptera

Invasive brine and decapod shrimps: what can they tell us about invasion mechanisms in aquatic environments?

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Biological invasions are, with climate change, the two major threats to biodiversity and likely one of the biggest scientific challenge for the 21st century. Each disturbance has ecological and economical effects but they can also interact, inducing potentially stronger ecological consequences on biodiversity. It is now quite well admitted that climate change favours invasive species, at least the spread of the thermophilic ones. Aquatic environments such as estuaries are particularly sensitive to biological invasions because of the strong anthropogenic pressures acting on them and favouring multiple vectors of introduction. However, the mechanisms allowing a species to become invasive are still incompletely understood. Various hypotheses have been proposed (e.g. propagule pressure, enemy release hypothesis) but remain insufficient to explain the mechanisms. Recently, the stress tolerance hypothesis emerged in the context of climate change and supposes that if an invasive has a broader range of temperature tolerance than a native then an increase in temperature is likely to have a disproportionately negative impact on the native. Using an ecophysiological approach, we tested this hypothesis. We determined the critical thermal maximum of both native and invasive congeneric estuarine crustaceans, and measured their oxygen consumption and their survival under different acute thermal stress. In all experiments, the invasive species performed better than the native. We also characterize the transcriptomes of both species to study their differential gene expression facing an acute thermal stress. Molecular functions involved in the stress response were very similar between species, but the number of differentially expressed unigenes was ten times higher for the native compared to the invasive. All in all, this work tends to confirm the importance of the stress tolerance hypothesis as an important (but likely not unique) mechanism of biological invasions.

Keywords: *biological invasions, estuaries, mechanisms of invasions, stress tolerance hypothesis*

Climate change effects on the functioning of inland waters: pervasive influence or minor factor?

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Inland waters respond to multiple external stressors operating at a hierarchy of scales from global (e.g. climate change) to regional (e.g. atmospheric deposition) to local (e.g. nutrient enrichment). These affect different components of a lake ecosystem and trigger a complex series of bottom-up and top-down internal interactions that control the structure and function of inland waters. The recent (2013) IPCC report clearly demonstrates the global trend of changing climate and the link between this and greenhouse gas emissions. Forecasts of

future change depend on future anthropogenic emissions, but there will be substantial warming, with geographic variation, and altered patterns of precipitation in the coming century. Lakes are very sensitive to weather and climate and detailed analysis of long-term data sets from lakes in the English Lake District such as Windermere, have shown strong effects of large scale processes linked to the position of the Gulf Stream, the North Atlantic Oscillation and Rossby Wave breaking that alter lake ecology. Some will cause coherent interannual responses in lakes across large geographic regions, others will be translated differentially depending on lake sensitivity to a particular factor such as flushing. Since around 1990 there has been a signal of warming water and longer stratification in the English Lake District. There is some evidence that this has caused phenological changes in the growth of phytoplankton, zooplankton and fish spawning, with possibilities of trophic mismatch. For some species though, part of this change is caused by resource availability rather than by a direct temperature effect. Climate change will open niches for non-native species from warmer climates and close them for species adapted to cooler conditions with consequences for food web structure and diet shifts at higher trophic levels. So long as nutrients are available, cyanobacterial blooms are likely to be favoured by climate change and longer and stronger stratification has been shown to exacerbate oxygen-depletion in deep water. Local management of a particular site cannot control global climate change, but some effects can be mitigated by reducing nutrient loads.

Keywords: climate change, long-term data, multiple stressors, phenology, trophic mismatch

From small lakes to global biogeochemical cycles: the influence of mixing processes on phosphorus accumulation and cycling

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Small lakes (<1km2) are numerically the most dominant lakes globally and represent a large proportion of the total area. They are also considered to be hotspots of biogeochemical cycling, processing nutrients at higher rates than larger waterbodies. As a consequence, they are an important component of freshwater systems globally. However, our understanding of physical mixing processes that interact with biogeochemical activity has largely been based on observations from large lakes or atypical events and the assumption that the same processes apply in small lakes have not been tested. Physical mixing processes contributing to biogeochemical cycling were studied in a small, eutrophic lake in the northwest of England. Typical weak forcing consistent with average summertime weather conditions resulted in the upwind advection of buoyant phytoplankton. This is consistent with patterns found on large lakes where wind forcing is stronger. Shallow water transition zones between the river and lake were shown to be dominated by hydrological dilution, although a significant effect of algal up take was found in relation to phosphorus concentrations, suggesting that the zone could be a hotspot for biological production. Models of sediment distribution developed for large lakes were a poor descriptor of sediment phosphorus and organic carbon distribution. Calculation of resuspension by theoretical wind-induced current speeds better reflected the distribution patterns of these variables. Using only the deepest site for estimates of lake burial of organic carbon and phosphorus could lead to an overestimate of burial rates by 60 to 100%. Internal phosphorus loading from hypolimnetic sediments was found to be strongly influenced by seasonal weather patterns, resulting in large inter-annual variability. This source of phosphorus is often poorly quantified in lake phosphorus budgets, yet the variability in internal loading found in this study has implications for lake management plans in the context of changing weather patterns due to climate change.

Keywords: Phosphorus, Physical mixing, Sediment, Transition zones, Esthwaite Water

The role of behaviour in biological invasions: interactions between invasive fish and native Iberian species

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The role of behaviour in biological invasions is becoming increasing evident. One focus is factors

that contribute to invasive success, dispersal ability and aggressiveness having both been implicated. I investigated interactions between the highly invasive mosquitofish, *Gambusia holbrooki* and the native Iberian toothcarp, *Aphanius iberus*, specifically examining male *Gambusia's ability* to differentiate between species and sexes. I found that male *Gambusia* consistently differentiated between male and female heterospecifics but initially failed to distinguish heterospecific females from those of their own species. However, they began to learn to recognise species differences within 24 hours. Given that most male mating attempts towards female *Gambusia* are unsuccessful, males may be selected for persistence despite rejection. This, together with the lack of costly mating displays and nuptial gifts in the mosquitofish mating system suggests sex recognition and misdirected mating attempts may be less costly than species recognition. The detrimental effects of *Gambusia* on *Aphanius* are therefore not limited to aggression and competition, but include sexual harassment by male *Gambusia* towards female *Aphanius*. Selection for persistence and a rapid learning ability may be factors explaining the invasive success of G. holbrooki.

Keywords: Behavioural ecology, Ethology, Invasive species, *Gambusia holbrooki, Aphanius iberus*

Freshwater research: key and global or going nowhere?

Brian Moss, *University of Liverpool, United Kingdom*

In 2005, a report, sponsored by the Freshwater Biological Association and Centre for Ecology and Hydrology, lamented a decline in the numbers and consequent productivity of freshwater researchers in the UK. The quality of the work was not questioned. But in 2007, an article by Winfried Lampert, on his retirement from the Max Plank Institute for Limnological Research in Plön, Germany, and its conversion to an institute for molecular ecology, lamented the quality of European freshwater research. It had become, he alleged, largely practically orientated, and driven by the needs of European Union legislation; it was now largely descriptive, though served by more sophisticated statistics, but lacking in attention to fundamental science. Was he right?

Freshwater sciences have contributed much to fundamental ecology, not least Raymond Lindeman's trophic-dynamic concept, and G.E. Hutchinson's essay on Santa Rosalia and the niche concept, based on his observations of corixids in a Sicilian pond. We understand freshwater systems well at the fundamental level, with a strong grounding in the relationships among catchments and their drainage systems. Nonetheless, in Europe we may have contributed less recently to these fundamental concepts because our heavily populated, grossly altered, and disconnected landscapes imbue a boundaried attitude. We think in terms of isolated lakes and river reaches, and have not the opportunity to investigate the greater systems, such as the linkages uncovered in western North America among the ocean, the rivers, and the forests, catalysed by the movements of salmon and the predation of bears. Likewise we perhaps avoid opportunities to think in terms of the great global cycles of water, carbon and oxygen that regulate the composition of our oceans and atmosphere, and regulate our climate.

The compartmentalization of Europe, reflected in our thinking, has many consequences that support Winfried Lampert's analysis. We attempt to conserve aquatic habitats on too small a scale, with too limiting a legislation, so that many of our attempts at restoration are disappointing. We try to reinstate species lists in defined places rather than to restore the key features of nutrient parsimony, characteristic structure (both physical and biological) and size and connectivity. In turn this influences our approach to the rising problem of coping with climate change. Of course we need to reduce carbon emissions and find ways of generating energy by renewable means, but we also need to attend to carbon storage. Temperatures will not fall until storages are greater per annum than emissions. Instead of minor activities and even of widespread geoengineering, with techniques either yet to be invented or with likely serious side effects, we need to restore large areas of biome, with interconnected terrestrial and freshwater systems that serve to store carbon efficiently. These must come from areas that we currently use for agriculture (anthromes) that currently occupy three-quarters of the land surface. We need grand strategies to release this land through more efficient farming, much reduced food waste and changed diets.

Such grand strategies are alien to the disconnected thinking and inadequate training of our political leaders, who are unlikely to find solutions to the nexus of problems of climate change, over-consumption, developing world poverty and exploitation, and biome destruction, with its losses of goods and services that we face. Change will have to come from the bottom-up, and scientists, especially ecological and environmental scientists, will have to have a major role in educating and leading the public into this grander scale thinking. But education and leadership mean good communication, and beyond widening our compartmentalist thinking, we need to improve our skills vastly in this respect. Scientific writing has become more obscure, more inwardly directed, and increasingly ineffective in getting important information to where it might be best used, as it has proliferated into a plethora of new journals. We need urgently to put our own house in order.

Land-use effects on stream food webs and ecosystem services

Daniel Perkins, *Imperial College London, Ascot, United Kingdom*

Organism size often plays a key role in determining the structure of ecological communities because it influences ecological processes across multiple levels of organization, from individuals and their interactions to food webs and ecosystems. For example, Charles Elton in 1927 described a 'pyramid of numbers' where the numerical abun¬dance of organisms are organised by their size, because 'the enemy is larger than the animal upon which it preys'. Understanding how this 'size structure' might be altered by human impacts is an important contemporary challenge for ecology. Freshwater systems (e.g. streams and rivers) might particularly susceptible in this respect, because these systems tend to be strongly size structured and have the potential to be greatly influenced by changes in adjacent land-use (e.g. changes in type and amount of terrestrial subsides entering systems). I compiled a data set comprising approximately 60, 000 individual size measurements of benthic diatoms, macro-invertebrates and fish sampled from 36 streams across the UK and their trophic interactions (i.e. who eats whom). This data set was used to test for the influence of riparian land-use (deciduous woodland, coniferous woodland and moorland) on food web and community structure. I find that stream communities from deciduous woodland sites are less size structured than we would predict (from metabolic theory) and support greater biomass at higher trophic levels than streams in coniferous or moorland riparian zones. This is driven by a greater amount of terrestrial subsidies (in the form of leaf litter) and greater proportion of detritivore links in these sites, which increases the flow of energy to higher trophic levels. These results have important implications for predicting changes in ecosystem services such as those related to fisheries (fish standing stocks and production) and regulation of detrital processes (e.g. leaf litter decomposition) under different land-use change scenarios.

Keywords: Body size, food webs, metabolic scaling, terrestrial subsidies, ecosystem services.

Inland waters as model systems to study metacommunities

Isabel Reche, *Departamento de Ecología, Facultad de Ciencias, Universidad de Granada, Spain*

Since the Forbes seminal article "The lake as a microcosm" (1887), most limnology was focused on within-lake processes to understand plankton dynamics. More recently, lakes are been considered in a landscape context interacting with the terrestrial and human processes, recognizing finally its influence at temporal and spatial scale. This new approach allows considering lakes as islands, eventually connected by organisms' dispersal, establishing a metacommunity. Therefore, besides competition and predation as within-lakes processes, species immigration can be affecting plankton communities among lakes. Nestedness analysis emerges as a useful tool to determine the balance between within- and among-lakes processes structuring plankton assemblages.

In this seminar, nestedness analysis was proposed to explore the influence of diverse landscapes on microbial metacommunities. Nestedness measures the degree to which species assemblages are representative subsets of larger assemblages. Microbial ecologists, since the advent of DNA-based

molecular technologies, have started to test general ecological patterns and use the diverse and well-developed metrics provided by the macroecology. We determined the nestedness of bacterial assemblages in twelve metacommunities from well-contrasted (boreal, alpine, temperate) landscapes and connectivity level (presence/absence of inlets and geographical distances). We obtained nestedness metrics using the sofwares provided by Ulrich (2006) and Almeida-Neto and Ulrich (2011). The matrix temperature ranged from 24.6 to 34.5 ºC (0º represents an entirely nested assemblage and 100ºC a completely disordered assemblage) and the NODF index ranged from 30.8 to 76.2. The comparison with null models indicated that most of the bacterial metacommunities analyzed were significantly nested, irrespectively of the presence of inlets connections, as it was expected for the high dispersal availability of microorganisms. Highly connected lakes showed a higher proportion of species from the general pool (% fill was higher) with low idiosyncratic species and the mass effect (immigration) appears to be the dominant process. By contrast, scattered lakes showed higher idiosyncratic species likely driven by species sorting within lakes. Therefore, the landscape structure can significantly influence microbial assemblages in lakes and lakes a very useful model to test metacommunity hypothesis.

Studying feeding rate in Artemia provide insights on the competitive superiority of the exotic A. franciscana and its potential impact in hypersaline ecosystems

Marta Sánchez, *Estación Biológica de Doñana-CSIC, Sevilla, Spain*

One of the most dramatic cases of biodiversity loss in hypersaline ecosystems in the Mediterranean Region and worldwide is the invasion of the North American brine shrimp *Artemia franciscana*, which is leading to the extinction to most native *A. salina* and *A. parthenogenetica* populations. The success of *A. franciscana* has been attributed to its higher fitness combined with a low regulation by parasites which highly impact native taxa (decreased fertility and increased predation). *Artemia* is a keystone species in hypersaline ecosystems; it is the dominant macrozooplankton, serving as the main prey of birds and affecting phytoplankton density and community structure through its filter feeding activity. In this study we compare feeding rates between native *A. parthenogenetica* and the invasive *A. franciscana*, as well as the effect on feeding rate of the two most prevalent avian cestode species in *A. parthenogenetica*. Grazing experiments showed a strong difference in the grazing rates of native and invasive *Artemia*, with *A. franciscana* exhibiting significantly higher values. Feeding rate was higher in females compared to males. The grazing rates also clearly differed between infected and uninfected *A. parthenogenetica*, with important differences between particular cestode species. *F. liguloides* (adults infecting flamingos) significantly reduced feeding rate in its host, while *Confluaria podicipina* (adults infecting Grebes) induced a slight but marginally insignificant increase in filtration rates. We conclude that higher filtration rates in *A. franciscana* compared with native species may add an additional competitive advantage to the invader, which would be enhanced by the effect of cestode parasites on the feeding rate of infected native *Artemia*. At the ecosystem level, the introduction of a more efficient grazer may destabilize the phytoplankton community and affect hypersaline ecosystem functioning through a range of direct and indirect ecological effects.

Quantifying the effects of grazing on aquatic ecosystems

Kevin A. Wood, *School of Applied Sciences, Bournemouth University, United Kingdom*

Foraging by primary consumers on primary producers is a fundamental biotic process in nature. The outcomes of such plant-herbivore interactions control primary producer abundance and regulate the flow of energy and nutrients between primary producers and higher trophic levels. Thus understanding how plant-herbivore interactions are regulated is critical to our understanding of, and ability to manage ecosystem structure, functioning and service provision. Despite the recent proliferation of small-scale studies on the effects of herbivores on aquatic plant abundance, ecologists lack an understanding of the factors which control consumer regulation of vascular plants across aquatic ecosystems. I conducted a global meta-analysis of the factors influencing the

outcome of plant-herbivore interactions using a dataset comprised of 292 values from 152 studies. I examined eight factors, identified from previous small-scale studies: herbivore biomass density, herbivore taxonomic identity, whether herbivores were native or non-native, habitat type, latitude, phase of the plant growth cycle, size of experimental area, and study length. I showed that changes in plant abundance were a plastic function of two aspects of the herbivore assemblage: density and taxonomic identity. Plant abundance declined with increased herbivore density, with plants eliminated at high densities. I report substantial between-taxa differences in herbivore effects on plant abundance, with birds and insects having least effect and molluscs and echinoderms having the greatest effect for a given herbivore density. I suggest that such between-taxa differences are linked to differences in herbivore foraging ecology and individual dispersal ability. In contrast, no effects of whether herbivores were native or non-native, habitat type, latitude, phase of the plant growth cycle, size of experimental area, or study length were detected. My talk highlights the key roles that two aspects of the herbivore assemblage, herbivore density and taxonomic identity, play in regulating the outcomes of plant-herbivore interactions across aquatic ecosystems.

Keywords: *Grazing; Herbivores; Macroecology; Macrophytes; Plants*

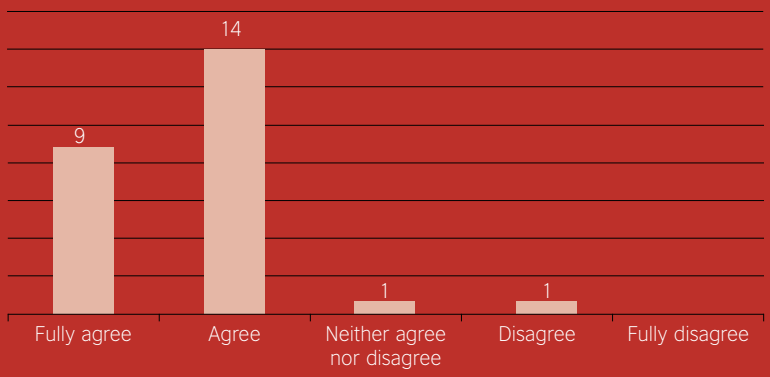
Landscape-scale conservation of aquatic biodiversity and the contribution of different habitats

Nigel Willby, *University of Stirling, United Kingdom*

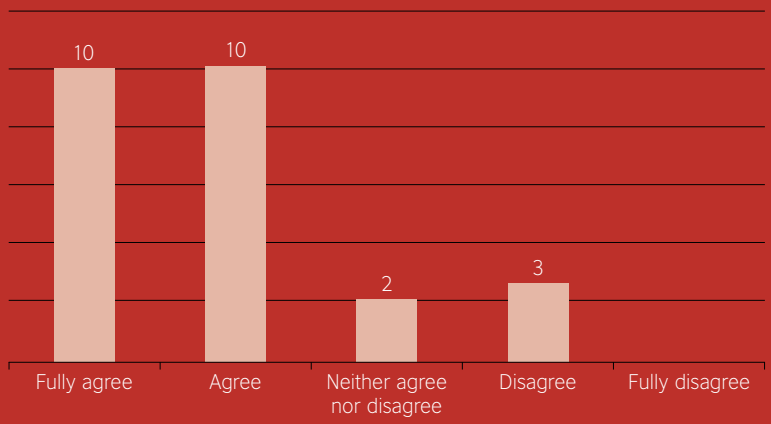
Landscape-scale thinking, including the creation of interconnected and more resilient networks of habitats, is the new mantra of nature conservation bodies, and is heralded as the means to promote collaboration, improve adaptation to climate-change and halt biodiversity decline. However, freshwater ecologists traditionally pigeon-hole habitats and use habitat-specific sampling protocols meaning that the relative value of different habitats to regional biodiversity is poorly understood and potential interactions between habitats are largely ignored. Hence the knowledge available to underpin landscape scale conservation is likely to fall short of requirements. Connectivity is a quintessential feature of freshwater systems but the various dimensions of connectivity, vertical, lateral and longitudinal, and the linkages between populations have been highly disrupted by human activities. An improved understanding of the comparative biodiversity of different aquatic habitats and the linkages within and between these habitats is therefore important to underpin conservation strategies and catchment scale planning. This theme is developed by considering different aspects of plant diversity - local richness, rarity, invisibility, turnover and the total species pool - across a range of aquatic habitats that coexist in lowland landscapes, to assess how large scale diversity and resilience depends on mosaics of interconnected habitats. Hydrologically connected backwaters (a habitat ignored by most conventional monitoring schemes) had the highest local richness but their species pool was similar to ponds and lakes due to lower turnover between sites. All habitats – including medium and large rivers - contributed to the regional species pool, but the relationship between biological similarity and spatial proximity of sites varied between habitats. Arresting biodiversity loss and improving the success of costly site-specific restoration projects requires thinking at far larger scales, including connecting or enlarging low priority sites, and looking beyond the traditional confines of discrete habitats; a century of experience shows that instinctively ring fencing the cathedrals of nature from their surroundings is not enough.

EVALUATION QUESTIONNAIRE

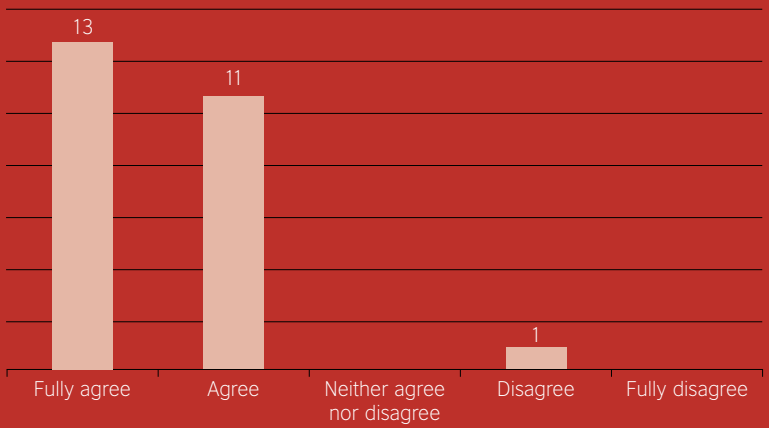
1. It was a well balanced programme



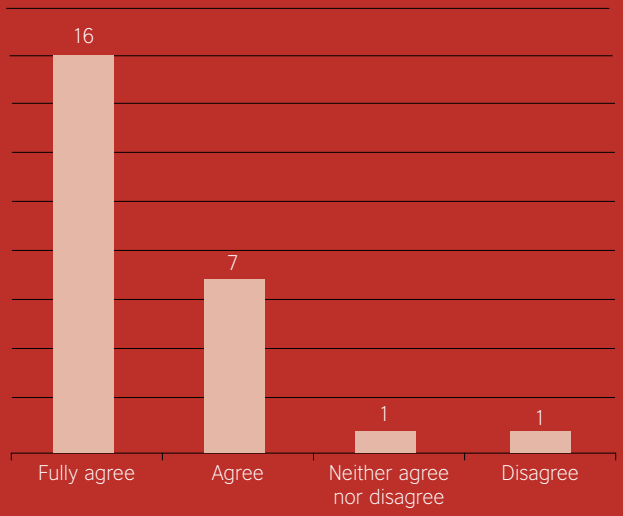
2. The discussion timing was right



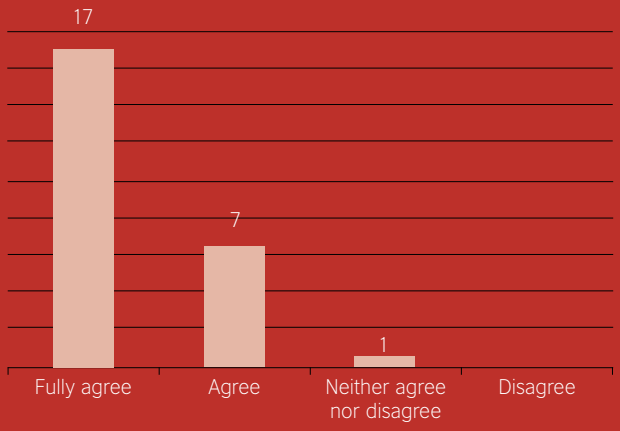
3. The length of the seminar was correct



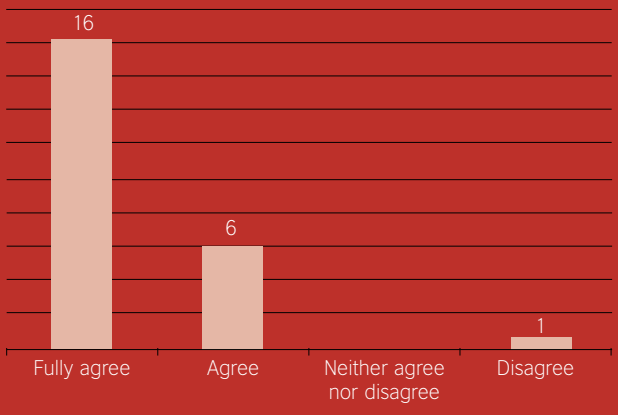
4. The mix of participants was right



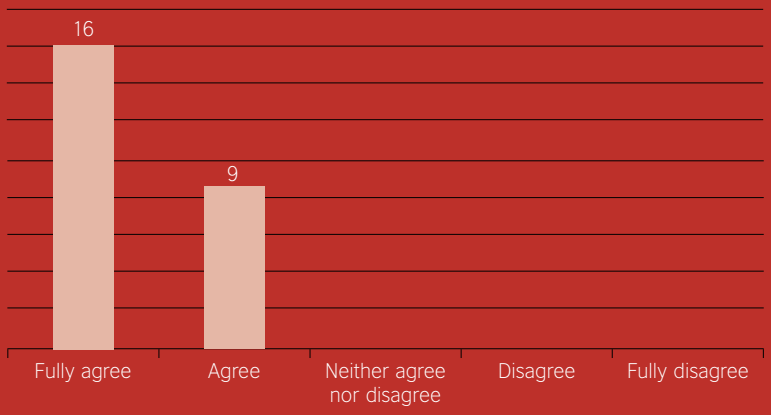
5. The conference facilities were good



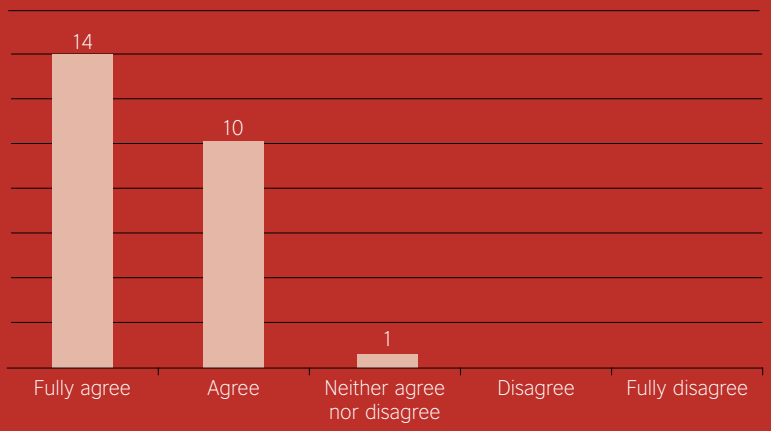
6. The standard of accommodation was good



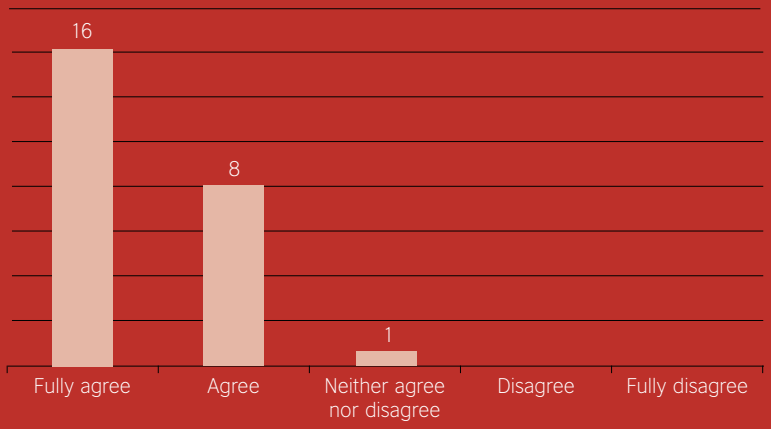
7. The food was good



8. The seminar meet my expectations?



9. Overall, this was a high quality seminar



10. Overall, how would you rate the quality of our services?

Results of Event Evaluation Questionnaires

General data

Number of participants	30
Number of questionnaires received	25
Percentage	83%

GENERAL COMMENTS

Thank you very much for organising the workshop. I felt I got a great deal out of attending. (Erika Hogan)

I had an excellent time, and the workshop was extremely productive *(Alan Law)*

Very enjoyable and well organised meeting – helped by an excellent location. *(Stephen Maberly)*

Overall it was a great forum to discover more about the research of other people in the field and make new contacts and connections that may be of use in the future.
(Eleanor Mackay)

Thank you for organising an excellent workshop. We all found the workshop very useful. *(Kevin Wood)*

We spent a lot of time sitting through presentations but there was less time for formal discussions of collaborations some "special interest groups" could have been useful to help this. On the whole, an excellent and highly worthwhile meeting. *(Christopher Hassall)*

There is nothing I can think of that can improve the experience. *(Aitor Larrañaga)*

Thank you again for organising such a great workshop. I had a brilliant time! *(Gareth Jenkins)*

ACKNOWLEDGEMENTS

We would like to thank the Consejo Superior de Investigaciones Científicas and the British Council for organizing this excellent and thoroughly enjoyable scientific meeting. The event has provided many excellent opportunities for dialogue and discussion, whilst demonstrating the strength and vitality of our young scientists. We would like to emphasize in particular the hard work and kindness of Belen Fortea of the British Council. Her careful continued support and efficiency made the success of the workshop in Doñana possible. The EBD director Juan José Negro Balmaseda also provided essential support before and during the workshop. At the Palacio de Doñana, Fernando Ibáñez and Pilar Bayón provided continuous and essential logistical support. Rafael Martín Guitart also helped with preparations. With their help, the workshop was a very pleasant experience for the participants, as well as being very stimulating from the scientific point of view.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inland waters
ESTACIÓN BIOLÓGICA DE DOÑANA (ISLA CRISTINA)
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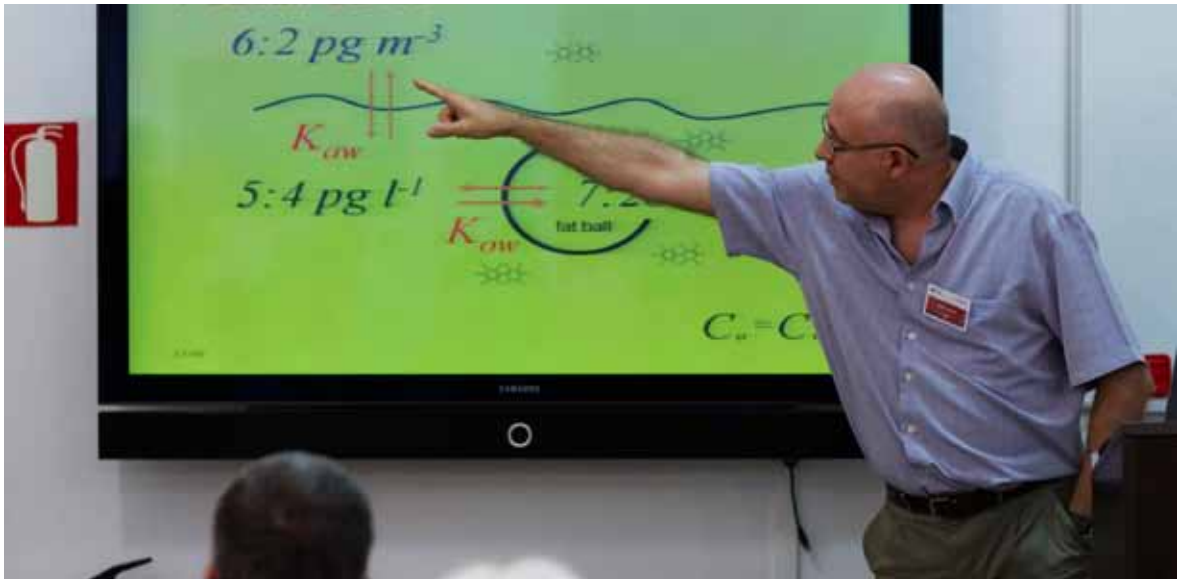
SCIENTIFIC WORKSHOPS FOR YOUNG RESEARCHERS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Bulletin
Dear Sir, I have just attempted to read a paper
Society's Journals about the transfer of
to land by the excretion and death of
should have read:
'Moose feed on
on land, thus
from the
random
kill them

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