

SFG 100 Verbal Presentation Abstracts

Session – *Defining, classifying & assessing freshwaters*

The health of Scotland's fresh waters

Willie Duncan, Laurence Carvalho, Robin Guthrie, Pauline Lang, Alan MacDonald, Iain Sime & Nigel Willby

Centre for Ecology & Hydrology

The Water Framework Directive (WFD) and Habitats Directive (HD) have greatly increased monitoring of Scotland's rivers, lochs and groundwaters. A range of biological and chemical measures are now used, alongside supporting information on hydrology and morphology to assess chemical and ecological status and the condition of species and habitats of high conservation status. Using these data, we provide an overview of the current condition of Scotland's freshwater resource in relation to the targets set by the two Directives. We will highlight some of our most undisturbed and our most impacted sites, some of our most iconic species and most invasive species. Finally we will consider new ways of combining these data in a "weight of evidence" approach to enhance confidence in assessment results and discuss how best to track improvements in ecosystem health using the component measures, rather than over-arching indices of health.

The comparative value of different aquatic habitats for biodiversity: a bean counter's guide to Perthshire

Nigel Willby

University of Stirling

All things are connected, but some things are more connected than others

Alan Law, Nigel Willby, Laurence Carvalho & Philip Taylor

Stirling University

All ecosystems exhibit connectivity; however, connectivity is the quintessential property of aquatic systems being the means by which energy, materials, organisms and genetic resources move within and between the landscape. Connectivity has been studied at a wide resolution; from single lochs to catchments to continents. The traditional measures used to define connectivity such as altitude, stream order, inflow, distance to nearest waterbody have been sufficient, but as connectivity continues to be altered via land-use changes and pressures a new suite of indices must be developed to assess the resilience or redundancy of waterbodies.

New and novel connectivity measures were developed, and were tested at regional and national scales across multiple species groups. By taking each species groups' biological constraints into account, these new metrics aim to predict current distributions. Using these

new methods, we can then forecast future scenarios of biological changes given expected alterations in land-use.

Baseline groundwater chemistry in Scotland's aquifers

Alan MacDonald, Brigid Ó Dochartaigh & Pauline Smedley
British Geological Survey

Groundwater is an important natural resource for Scotland. It provides drinking water, supports agriculture, and is fundamental to the nation's mineral water and whisky industries. Groundwater also plays a vital role in sustaining the flow of rivers and supporting many of Scotland's fragile ecosystems. The naturally high quality of groundwater in Scotland is an important part of why it provides so many benefits. Here we present the results of the *Baseline Scotland* project, which mapped the natural chemistry of groundwater in Scotland's aquifers. The project ran for 10 years and the results are now available, published in 2018. The chemistry of groundwater for each of Scotland's 11 main bedrock aquifers is highly variable, reflecting a combination of lithology, mineral reactions, redox conditions, groundwater flow paths and residence times.

The power of freshwater communities

Bill Brierley
Freshwater Biological Association

The FBA has been involved in the development of our understanding, monitoring and management of freshwaters in the UK since its formation in 1929. Research carried out has contributed significantly to understanding, for example, how lakes function which led onto lake and reservoir modelling and studies of river ecology led to the development of RIVPACS and the underlying principles for the WFD. Teaching freshwater science and publishing identification keys has also been an integral part of the FBA – enthusing both amateurs and professionals. These activities underpinned the development of freshwater biomonitoring in the UK, and was originally carried out by national Agencies but now increasingly by citizen scientists. More recently new techniques and technologies such as eDNA, remote sensing and Apps are changing the way in which we monitor our freshwaters. Bringing together freshwater communities with new approaches is crucial to enable the protection and management of our freshwater systems.

The use of statistical methods to inform freshwater ecology over the last 50 years

Jennifer Dodd & Marian Scott
Veritas Ecology/University of Glasgow

The era of 'big' environmental data is here! Data collected today, in many cases, are more voluminous and complex than those of 50 years ago. The volume, variety and complexity of such data often require new and innovative statistical methods (that are practicable given some of the computational challenges). Statistical modelling and inference form the basis of management decisions and the methods available to freshwater ecologists have developed considerably over the last 50 years. This is in part due to an exponential increase in computing power but also through the availability of open source programming environments and the subsequent development of statistical languages which access complex mathematical algorithms. In this paper, we consider the changing frequency of use of different statistical methods in freshwater ecology over a 50-year period, linked to the main research questions being addressed. In this way, we also consider what some of the challenges facing the future of fresh waters are and how statistics will provide at least part of the solution.

Embracing 21st Century ecological monitoring: using emerging technologies to inform decision-making for Scotland's freshwaters

Colin Bean, Ian Winfield, Chris Conroy & Alistair Duguid
Scottish Natural Heritage

Recent technological advances have the potential to revolutionise the ways in which we monitor aquatic plants and animals and may transform the ways in which conservation biologists, environmental managers and regulators manage species and habitats. These advances extend across a range of disciplines and across a range of scales. Many previously prohibitively expensive approaches have now become affordable, are in common usage, and can generate considerable volumes of data. This talk provides a brief overview of some of these technologies and focuses on the use of eDNA as a monitoring tool. Issues relating to data, its storage and its availability are also discussed.

Exploitation of satellite remote sensing for regulation and monitoring of inland water quality

Claire Neil
University of Stirling

Session – Pressures on the freshwater resource

Environmental change in Scottish lochs revisited

Helen Bennion, Rick Battarbee, Viv Jones, Neil Rose, Handong Yang, Carl Sayer, Ewan Shilland, Isabel Bishop, Lucia Lencioni & Hannah Robson

University College London

Fifteen years ago, Bennion et al. (2002) published 'Environmental Change in Scottish Fresh Waters' which summarised findings of the latest palaeolimnological research on Scottish freshwater lochs. The paper focused on trends in surface water acidification, eutrophication, and contamination of Scottish waterbodies. In this presentation we will revisit these themes in light of new research that has been conducted in the intervening years. We will present the evidence for environmental change in both upland and lowland systems and in relation to a range of stressors including atmospheric pollution, nutrients, invasive species and climate change, often acting in combination. We will also assess the degree of recovery following restoration attempts and discuss the challenges that remain. Finally we will explore the role of palaeolimnology in the management and conservation of Scottish lochs and will look at ways in which an understanding of the past can continue to inform the future of Scottish fresh waters.

Bennion, H., Simpson, G., Battarbee, R.W., Cameron, N.G., Curtis, C., Flower, R.J., Monteith, D.T. (2002). Environmental Change in Scottish Fresh Waters. In Usher, M.B., Mackey, E.C., Curran, J.C. (Eds.), *The State of Scotland's Environment and Natural Heritage*. The Stationery Office, Edinburgh pp. 145-152.

30 Years of Aquatic Macrophyte Monitoring with the UKUWMN

Ewan Shilland & Don T Monteith
University College London

In 1988 the UK Upland Waters Monitoring Network started systematic surveys of the aquatic plants in 22 lakes and streams. In this presentation we will investigate how the aquatic macrophytes have changed in both types of site and what may be conditioning these changes. We will examine the 30 year time-series to explore macrophyte responses to the ongoing variations observed in potential chemical, physical and biological drivers.

Scotland's rivers: A review of geomorphological response to flow, sediment and ecological regimes

Rhian Thomas, Trevor Hoey & Richard Williams
University of Glasgow

Scotland's rivers are diverse, dynamic systems that respond to regional climate, geology, vegetation, soil type and topography. They exhibit episodic, spatially variable change in response to flow, sediment and ecological regimes and are influenced by natural and anthropogenic factors. We discuss recent Scottish research on these interlinked areas, reviewing progress made over recent decades and highlighting ongoing issues. Recent research on the endangered freshwater pearl mussel illustrates complex ecological

responses to flow regimes. Flow and sediment regimes control channel change over a range of scales, and responses to engineering show long-term impacts of river management. We review relationships between river restoration, ecology and hydrological and geomorphological regimes, and demonstrate changes to policy and practice, using examples such as beaver re-introductions. A consistent theme of the research is the importance of catchment-scale approaches to inform river management, encompassing hydrology, geomorphology and ecology.

Development of a national river temperature model to inform the management of Scotland's Atlantic Salmon rivers under climate change

Faye L. Jackson, Robert J. Fryer, David M. Hannah, Colin P. Millar & Iain A. Malcolm
Marine Scotland Science

Climate change is expected to increase river temperatures, potentially altering the thermal suitability of riverine habitats for brown trout and Atlantic salmon. Riparian planting is a proven mitigation strategy. However, managers require tools to determine where to focus management effort. This paper describes the development of a novel spatio-temporal model of maximum daily river temperature ($T_{w_{max}}$) for Scotland. $T_{w_{max}}$ was modelled as a linear function of maximum daily air temperature, where the slope and intercept varied as a smooth function of day of the year, further modified by GIS derived landscape characteristics. Spatial correlation was modelled at river network and regional scales. Temporal correlation was addressed through an autoregressive (AR1) error structure. Additional site level variability was modelled with random effects. The model enables temperatures to be predicted for any day or location in Scotland. The resulting maps of maximum temperature, climate sensitivity and planting potential are important management tools.

River Restoration in Scotland

Chris Spray, Jennifer Dodd & Angus Tree
University of Dundee

The restoration of river systems to alleviate flood risk and to meet water framework directive targets is happening at an exponential rate in developed nations. We discuss the current state of river restoration activities in Scotland and specifically discuss the initial results of macroinvertebrate surveys from the Eddleston Water. Theory predicts that, following the re-configuration of a river channel, the increase in the diversity of habitat types available for colonisation should result in a corresponding increase in the biological diversity of the ecological community. In practice however, this relationship is not well established and especially not so in river restoration programmes. Using data collected from a BACI field experiment, we present the early results of the response of the macroinvertebrate community to river channel re-configuration in the Eddleston Water.

Impacts of invasive riparian plants on stream ecology

Zarah Pattison Alex Seeney & Nigel Willby
University of Stirling

Riparian habitats are vulnerable to invasion by invasive alien plants (IAPs), being highly disturbed environments. The consequences of invasion by IAPs for native macrophytes is the subject of ongoing debate and significant resources are invested to control IAPs globally. Understanding environmental mechanisms for the success and failure of IAPs in riparian zones could enable better use of resources for protecting both native vegetation and riparian habitats. Data from a study across 20 Scottish rivers were used to identify whether dominant native and IAPs have contrasting responses to environmental variables; and the consequences for native vegetation. Our results show how native and IAPs respond differently to local conditions, offering insight into the use of abiotic controls for these species. We also discuss how informative the use of plant community composition v richness is in determining the impact of IAPs on native communities, as invaded habitats house a suite of different species compared to uninvaded, yet retain the same species richness.

The impact of climate change on instream hydroecological response

Annie Visser, Lindsay Beevers & Sandhya Patidar
Heriot-Watt University

The ecological role of flow is well established. Flow is essential to, not only the health of the river ecosystem, but also human survival. Climate change represents a major threat to the natural flow regime. Knowledge of the long-term implications of flow variability in the hydroecological relationship is therefore essential. This work develops a modelling framework which enables the examination of the ecological impacts of climate change and uncertainty. First, the development of a numerical hydroecological model, incorporating multi-annual hydrological indicators. A rainfall-runoff model is then derived, following a unique covariance approach which focuses on the replication of ecologically relevant hydrological indices. The models, coupled with probabilistic climate change projections, allow inferences of possible ecological outcomes. Initial results indicate the importance of both high and low flows, that is, the variability of the flow regime.

Re-examining the link between phosphorus pollution and ecological impact in Scottish streams using diatoms as bioindicators.

Miriam Glendell, Marc Stutter, Shasta Marrero, Linda May, Graeme Cameron, Brian McCredie, Mark Hammonds, Fiona Napier & Alison Bell
James Hutton Institute

Phosphorus source apportionment is an important tool for prioritising mitigation strategies under River Basin Management Planning within the EU WFD. However, not all phosphorus sources are considered 'equal' in terms of their bioavailability and ecological impact.

Furthermore, recent studies have shown a differentiated response of established benthic diatom-based indices to hydrochemical pressures in different geographical regions. In this study, we re-examine the link between phosphorus derived from different pollution sources and benthic diatoms, as indicators of ecological status, in Scottish rivers. Preliminary results using multivariate statistical modelling indicate a significant relationship between the Trophic Diatom Index, nitrate and N:P stoichiometric ratio. Further analyses will examine the relationships between diatom community composition, hydrochemistry, discharge and source apportionment to improve our understanding of the bioavailability of different phosphorus fractions, the link between 'good' physicochemical and biological status, and the potential reasons behind the observed lags in achieving overall 'good ecological status'.

Session – The use & value of freshwaters

Estimating the economic benefits from water quality improvements

Nick Hanley

University of Glasgow

In this presentation, I review the main approaches to placing economic values on water quality improvements, and what problems researchers and policy managers face in implementing these approaches. Using examples from both freshwater and coastal/marine systems, we will consider the problems caused by uncertainty, information, discounting and preference heterogeneity. We will also consider issues around the distribution of benefits: who gains and who loses out; and benefits transfer. Finally, I relate the kind of estimates of water quality benefits to recent developments in natural capital accounting.

A characterisation of Scottish drinking water catchments

Carolin Vorstius, John Rowan, Iain Brown & Zoe Frogbrook

University of Dundee

Provision of drinking water is an essential public service and its quality is strictly regulated and controlled in Scotland. In order to keep treatment costs low, drinking water catchments should be protected to yield high quality water, requiring minimal amount of water treatment to fulfil regulatory requirements. Involving collaboration with Scottish Water, this project examines the biogeochemical properties of the water that Scottish Water abstracts from catchment sources. It describes Scottish drinking water catchments with regard to their physical attributes and to pressures and anthropogenic influences on them. These attributes are used to define a typology of drinking water supply catchments, and for undertaking multivariate analysis to explore their power in explaining variations in water quality. This serves as the basis to assess the threats posed to raw water quality by climate change and land use changes, and hence inform drinking water catchment management and strategic investment.

Developing the value of Scotland's water resources through innovation, internationalisation and the Hydro Nation programme"

Jon Rathjen

Scottish Government

Investigating the use of Google Earth to capture the multiple benefits provided by river environments

Victoria Keele

Plymouth University/Scottish Natural Heritage

River environments provide multiple life-sustaining and life-enhancing functions. Ecosystem service quantification has been dominated by economic methods however valuing nature this way has limitations. Significantly economic valuation overlooks intangible cultural services which are of no less value to our wellbeing. Here the Google Earth River Ecosystem Service (GE.RES) Tool is presented as an alternative for capturing potential ecosystem service delivery. GE.RES is underpinned by a matrix that links river corridor features identifiable on Google Earth to ecosystem service provision. Provisioning and regulating linkages are based on scientific research while cultural linkages are derived from photo-elicitation. To test functionality GE.RES is used to compare ecosystem services delivered from paired Scottish SAC and non-SAC rivers. GE.RES can identify areas devoid of ecosystem services and allows the development of management plans which focus on creating rivers that provide us with the services we need to live healthy lives now and in the future.

Loch Leven: a flagship site that delivers benefits to the people of Scotland

Linda May, Laurence Carvalho, Bryan Spears, et al.

Centre for Ecology & Hydrology

Loch Leven is an internationally important long term monitoring site, with 50 years of records covering a wide range of environmental and social data. In the late 1970s and early 1980s, algal blooms plagued the loch. In the 1990s, a catchment management plan was developed to set restoration targets and reduce phosphorus inputs. As a result, phosphorus inputs to the lake fell from 20 t y⁻¹ in 1985 to about 8 t y⁻¹ by 1995. After a long period of recovery, the site has water shown significant improvements in quality, biodiversity and ecosystem service provision. The fishery has become more economically viable and visitor numbers have increased, bringing more income into the area. We will highlight how partnership monitoring of this flagship site has delivered the evidence needed to manage land-use, population and climate change impacts better, helping to realise some of the benefits that Scotland's freshwater resources can provide.

Development of a national juvenile salmon density model for Scotland to underpin fisheries management and assessment

Iain Malcolm, Karen Millidine, Ross Glover, Colin Millar, Faye Jackson & Rob Fryer
Marine Scotland Science

Models that predict spatio-temporal variability in juvenile salmonid abundance are required to assess the status of fish populations, understand the effects of environmental variability and anthropogenic impacts. Electrofishing data can provide measures of abundance and are commonly collected by fisheries managers for assessment purposes. However, their interpretation can be challenging because 1. factors that influence fish abundance also affect their capture probability and 2. it is not always clear what a reasonable expectation would be for a given location and point in time. Addressing these challenges is therefore pre-requisite to the development of reliable fish abundance models. This paper presents a two stage modelling approach for understanding and predicting juvenile salmonid densities at the national (Scotland) scale from GIS derived environmental covariates, using a diverse electrofishing dataset corrected for spatio-temporal biases in capture probability.

The resulting models have the potential to underpin assessments of fish populations at large spatial scales.

Using novel stakeholder engagement methods to identify land and water management pressures across Scottish catchments.

Kathleen Stosch, David Oliver, Richard Quilliam & Nils Bunnefeld
University of Stirling

There is a need to quantify and optimise multiple benefits from catchments to meet growing demands of food, water and energy, but also wider services such as biodiversity and the well-being of local people. However, there are uncertainties surrounding ecosystem service modelling, climate change and stakeholder opinion which is a further challenge for catchment management.

The overarching aim of this project is to explore possible trade-offs and synergies between catchment uses and to find ways to optimise landscape scale ecosystem service provision in Scottish catchments. This talk will cover novel engagement methods, such as participatory mapping, trade-off assessments and stakeholder network analysis, which were carried out across key stakeholder groups (environmental and water regulator staff, farm advisors and academics) in three study catchments across Scotland (Spey, South Esk and Ayr). The talk will discuss how the outcomes may be used to inform more holistic, integrated land and water management, help promote stakeholder collaboration and find solutions to conflict across Scottish catchments.

70 years of hydro : some lessons learnt

Alastair Stephen
Scottish & Southern Energy

A view of the main issues affecting migratory fish associated with the major hydrolisation of many Scottish rivers following WW2, by the North of Scotland Hydro-Electric Board.

Evidence provided by fish counters (some data going back >5 decades), showing in some locations the effects on salmon populations has been minimal, but in others the counter data has demonstrated significant impacts.

Recent work involving the use of PIT tagging technology and acoustic tracking has highlighted the problems are mainly associated with the downstream migration of smolts rather than the upstream passage of adult fish.

What can be done to help rectify some of the problems? Some solutions discussed

Session – *Freshwater conservation & management*

Freshwater conservation in the UK: where do we go from here?

Phil Boon

FBA

In the 70 years since nature conservation became an organised activity in the UK, many changes have taken place in freshwater conservation and management. Statutory bodies have come and gone, national and international legislation has been introduced, and new techniques for survey and monitoring have evolved. Yet despite much progress, there is little consensus on how fresh waters in the UK should be conserved and managed, or even on a set of guiding principles. This paper discusses five areas to answer the question, “Where do we go from here?”: 1. How do we decide what is important for conservation? 2. Should we focus on freshwater habitats or on individual species? 3. Can nature conservation and ecosystem services live together harmoniously? 4. How should science serve conservation? 5. As the UK prepares to leave the EU, can we envisage a new, imaginative, multi-dimensional approach to freshwater conservation from source to sea?

Freshwater invertebrates in Scotland: their importance and conservation

Craig Macadam

Buglife – The Invertebrate Conservation Trust

Over 3,800 invertebrate species spend at least part of their lifecycle in freshwater in the UK. These include well known freshwater invertebrates like dragonflies, mayflies, pond skaters and water beetles to lesser known worms and mites. Two-thirds of these species are thought to occur in Scotland’s freshwaters. They play a vital role in maintaining clean water; they help to break down and filter organic matter and provide a food source for fish, birds

and mammals. Their presence is the standard indicator of the health of the habitat they live in. However, many of our freshwater invertebrates are declining in the face of pollution, invasive species, abstraction, development and climate change. This talk will explore the importance of this fauna, highlight some of the threats to their populations, and celebrate the conservation action underway for invertebrates in Scottish freshwaters.

Saving Scotland's rare species using palaeoecology.

Isabel Bishop, Hannah Robson

University College London

Scottish freshwaters host nationally and internationally important flora and fauna, and, in recent decades, nationwide monitoring programs have vastly improved our understanding of the conservation needs and highlighted species declines. However, many threats to freshwater biota have been acting over longer timescales, and data documenting the decline of important taxa is lacking. The field of “applied palaeoecology” offers the opportunity to fill in data gaps that otherwise hinder progress in conservation, either through direct reconstruction of population changes of the species in question or through assessment of habitat decline. We present two examples of the application of palaeoecology to rare species conservation in Scotland. The history of the rare aquatic plant *Najas flexilis* was directly reconstructed from lake sediments, revealing a decline linked to complex interactions between multiple stressors. The common scoter (*Melanitta nigra*), a diving seaduck, is a rare and declining breeder in Scotland. Palaeoecology has been key to understanding recent ecological change at the remote sites where the species breeds.

Scotland's amphibians: threats and opportunities

Roger Downie, Victoria Larcombe, James Stead

University of Glasgow

Scotland is home to six species of amphibians regarded as native and currently a few small populations of one non-native species. All require good quality freshwater habitat to maintain their life-cycles. Two of the natives (great crested newt; natterjack toad) have restricted distributions and are highly protected by law; the others are widely distributed but their populations are not necessarily in good health. For example, there is worrying evidence of declines in the common toad. This talk will:

- Review what is known of the distribution and populations of Scotland's amphibians
- Review the threats to amphibians in Scotland, including climate change, disease and habitat loss
- Describe recent efforts to enhance and protect amphibian populations
- Provide a case history of Scotland's largest great crested newt population, at Gartcosh
- Discuss avenues for needed research

The patterns, processes and conservation consequences of previously unknown diversity in freshwater ecosystems.

Colin Adams, Peter Koene, Colin Bean, Calum Campbell

University of Glasgow

One of the major developments in freshwater science in the last 20 years has been the emergence of previously undescribed diversity amongst the organisms living in fresh waters and an understanding of how fresh water systems promote the evolution of such diversity. In this talk we will describe the genotypic and phenotypic patterns of such diversity using examples from both Scotland and beyond. We will outline our understanding of how freshwater systems themselves promote the emergence of these patterns and discuss how species conservation and management policy and practice is beginning to change to take account of this emerging understanding.

Application of long-term monitoring for the contemporary management and conservation of Atlantic salmon.

John Armstrong

Marine Scotland Science

The Freshwater Fisheries Laboratory has monitored national salmon rod catches, numbers of salmon leaving and returning to index sites, and associated environmental and biological data annually since the 1950s and 1960s. Coupled with advanced modelling frameworks, these data provide the foundation for well-informed management and conservation policies. Both numbers and sizes of salmon returning from sea have declined over recent decades. The impact of these changes on stock strength (egg deposition) has been mitigated to some extent by management action to regulate fisheries. Killing of fish arriving early in the season has been subject to a blanket ban. However, some limited local harvesting of later running salmon is still permitted through the Conservation Regulations process where best available evidence suggests that the stock is sufficiently robust.

The return of an ecosystem engineer, the Eurasian beaver, to Scotland: Challenges and opportunities.

Karen Taylor & Martin Gaywood

Scottish Natural Heritage

In November 2016 the Scottish Government stated they were minded to allow existing Eurasian beaver populations to remain in Scotland, and that the beaver will become a European Protected Species (EPS). This was a historic announcement, in effect the first ever formal reintroduction of a mammal species in the UK. This paper will briefly summarise the work done over the 21 years prior to the decision, and then look forward to the biological, socio-economic and legal challenges that now have to be addressed, with a particular focus on the freshwater environment. Recently this has included developing a pragmatic

licensing framework, setting up management guidance and support, evaluating management techniques, developing expertise capacity, re-assessing the current status of populations, reinforcing the Knapdale population, developing cost-effective monitoring methods and predictive modelling tools, and supporting research priorities. A new Scottish Beaver Forum, involving key stakeholders, has been established to help inform this process.

Long-term population trends of freshwater-dependent birds in Scotland and some related management issues

Bob W. Furness

University of Glasgow & Scottish Natural Heritage

After defining ‘freshwater-dependent birds’ I will review trends in the population sizes of these ca.58 species in Scotland, briefly outline perceived pressures and threats, and the extent of site-based protection aimed at these populations. I will then focus on species of particular conservation/management concern where there are strong interactions with other aspects of freshwater ecosystems, such as wintering swans and geese, cormorants, ‘sawbill ducks’ (goosander and red-breasted merganser), breeding red-throated and black-throated divers, white-tailed eagle and osprey, or where birds may be useful indicators of freshwater ecosystem health (such as kingfisher, sand martin, grey wagtail and dipper).

Back to the future: SFG’s history and success

Peter Maitland, Colin Adams, Laurence Carvalho, Pauline Lang, Jennifer Dodd.

The Scottish Freshwater Group organisers – past and present