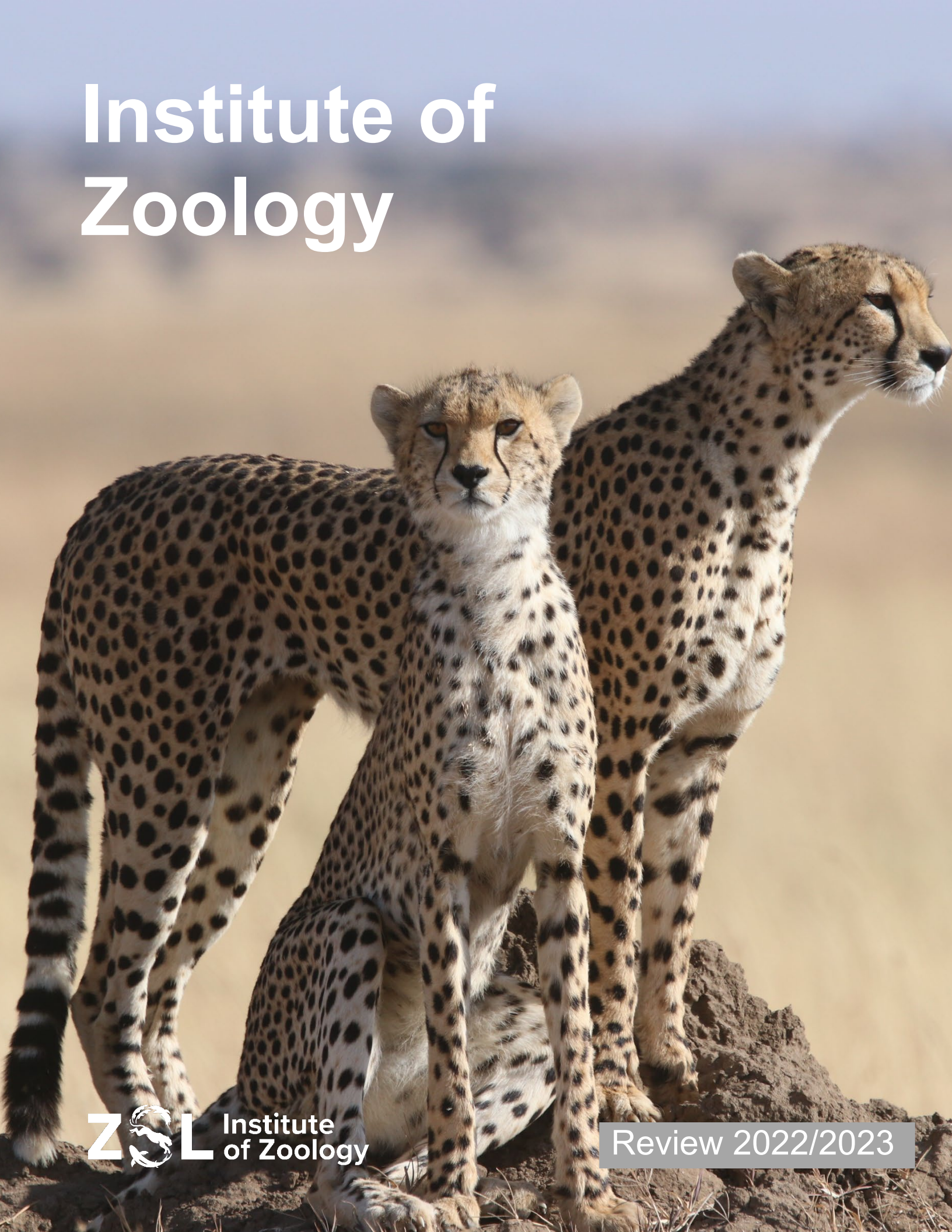
Institute of Zoology



Institute of Zoology

Review 2022/2023

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Cover image. A cheetah mother and her cub in the Serengeti National Park, Tanzania. The Serengeti Cheetah Project has collected nearly 50 years of data on individually recognised cheetah living in the Serengeti National Park. The knowledge generated by the project has been vital for informing the range-wide conservation planning process that aims to reverse declines in this threatened species. Photo: Sarah Durant

Executive summary

The Institute of Zoology (IOZ) is the research division of ZSL, an international conservation NGO whose vision is *A world where wildlife thrives*. In 2022/23, the IOZ continued to serve its purpose to understand wildlife ecology in a changing world, identify threats to biodiversity, and develop solutions to global conservation challenges. To achieve this, we advanced our work in **research, impact, teaching,** and **public engagement**.

Our **research** and **impact** efforts addressed our five **Conservation Challenges**. Research on the **Biology and Recovery of Small Populations** produced two papers in *Science*. Our impact included research-based conservation programmes for evolutionarily distinct and globally endangered species in the wild, and for species that are already extinct in the wild. Outcomes of our work on the **Co-existence Between People and Wildlife** included the adoption of three regional conservation strategies for cheetah and African wild dogs, and research on badger vaccination and the social barriers to a wider vaccination rollout across the UK. Our research on illegal fisheries informed the establishment of bilateral agreements with India to ensure more effective management of the Chagos Archipelago LMPA. Our work on **Global Biodiversity Monitoring** resulted in two major publications - a new typology for Earth's ecosystems, published in *Nature*, and the *Living Planet Report 2022*, published in collaboration with WWF, which reported a 69% global decrease in wildlife abundance in monitored populations between 1970 and 2018. Our research into **Mitigating and Adapting to Climate Change** included a modelling study predicting that higher temperatures will cause population collapse in African wild dogs, with wider lessons for other social species, published in *Global Change Biology*. A report on *Climate Change Vulnerability and Potential Conservation Actions: Seabirds in the North-East Atlantic* assessed the impacts of climate change and possible conservation actions for all 48 breeding seabird species in the region, drawing on expert input from over 80 conservationists and policymakers across 15 European countries. In the field of **Wildlife Health**, major outputs included papers in *Nature Communications*, *Journal of Applied Ecology* and *Science of the Total Environment*. Conservation impacts included a census of the Critically Endangered mountain chicken frog in Dominica and the integration of biodiversity conservation into global one health policy.

Teaching and training activities in 2022/23 were directed at a postgraduate community of 79 PhD students (including 13 new students) across ten university partners, and 81 Masters students across six courses run with RVC or UCL, including the new MSc in Ecology and Data Science. In parallel we ran our veterinary residency in Wildlife Population Health. In total, we trained 446 conservation practitioners in 22/23.

Public engagement in 2022/23 included six free public lecture evenings, each of which was subsequently posted on YouTube where they were viewed in >50 countries. We developed a NERC-funded engagement programme for asylum seekers and refugees which won the BIAZA EDI Silver Award, and we ran our international Soapbox Science programme, which involved 32 events in 14 countries with 384 speakers and an audience of >32,000 people. Our work also contributed to educational programmes for >75,000 school visitors to ZSL's Zoos, including 34 'Scientist in your Classroom' sessions to 25 schools with 1,621 attendees.

IOZ researchers continued to work alongside ZSL's wildlife conservation professionals, including

- ZSL's Conservation and Policy directorate, which informed IOZ's science to ensure it is relevant to policy frameworks and management realities, providing pathways to conservation impact
- ZSL's living collections, London Zoo and Whipsnade Zoo, which contributed to IOZ's research programmes, providing ZSL's unique research and teaching environment
- ZSL's communications and Community and Learning teams, who continued to provide access to a wide diversity of audiences for IOZ's public engagement with science activities

In 2022/23 the IOZ adopted its updated 3-year **Business Plan** and developed a **Theory of Change** through a series of workshops involving staff, students, and our Independent Science Advisory Board. **Total income** for the year was £8.27 million of which £2.16 million was from Research England and the rest from research grants (£4.97 million) and income from overheads, student fees, publications, meetings and endowments (£1.14 million combined). The Research England grant was thus 26% of our total income and, after adjusting for year grant movements and including support costs, a year-end deficit of £717,000 was underwritten by ZSL.

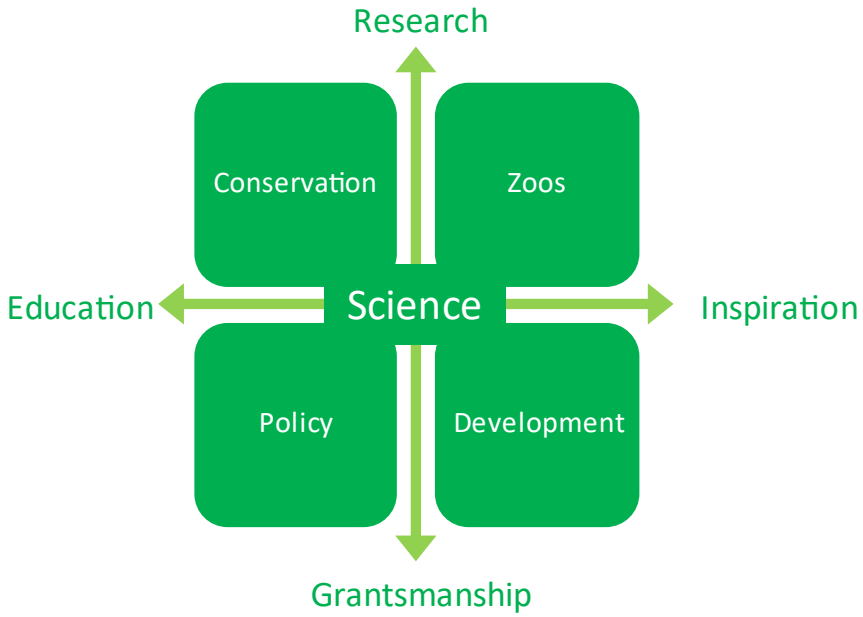
At the end of the year, our Acting Director of Science, Guy Cowlishaw, stepped down with the arrival of our new permanent Director of Science, Johan du Toit.

Introduction

The Institute of Zoology is a world-leading research organisation, directly addressing global challenges in the field of conservation science. Our purpose is to understand wildlife ecology in a changing world, identify threats to biodiversity, and develop solutions to global conservation challenges, thus enabling sustainable, healthy societies and ecosystems.

In the 2022/23 academic year we have continued to advance our purpose. An important milestone has been the adoption of our updated 3-year Business Plan (22/23–24/25), which has provided us a valuable opportunity to review progress since our first Business Plan (19/20–21/22) as well as set out our priorities for the next three years. Coinciding with the start of our new Business Plan, the IOZ also participated in an Interim Funding Review. This gave us further opportunity to assess our recent achievements and our unique contribution to the UK academic landscape and wider society. In recognition of this contribution, Research England supported the recommendation of the Review that our Special Funding arrangements should continue. Another major piece of work this year has been the development of an IOZ Theory of Change. This involved a series of three workshops involving staff, PhD students, and our Independent Science Advisory Board (ISAB). The Theory of Change produced from these workshops presents a clear articulation of the pathways we expect to see connecting our activities and outputs with their shorter and longer term outcomes and ultimately their impacts. Throughout this year, the ISAB provided expert feedback on our Business Plan, Interim Funding Review, and Theory of Change. We are very grateful to members of the ISAB for this input and for their guidance on our strategic development more generally. Finally, at the end of this year, our Acting Director of Science, Guy Cowlishaw, stepped down from the role and our new permanent Director of Science, Johan du Toit, joined the team. A big thank you to Guy for all his work, and a very warm welcome to Johan.

The unique position of IOZ as a Higher Education Institute (HEI) within ZSL brings a variety of benefits to our research and amplifies our conservation impact. It also creates a unique research and education environment that allows staff and students to work alongside wildlife conservation professionals, as well as to access ZSL's living collections, providing experiences and opportunities that that go beyond their immediate academic disciplines. Examples of how IOZ science is both integrated and supported by ZSL are given on pages 36 and 37.



The integration of IOZ within ZSL means that science conducted by IOZ is both the driver of ZSL initiatives and an emergent property of the communities of conservation practice across ZSL

This Annual Review is structured around four Routes to Delivery through which the IOZ achieves its purpose:

- Research
- Impact
- Training
- Engagement

Within this framework, we report our research and impact in the context of the five global Conservation Challenges around which our work focusses:

- Biology and Recovery of Small Populations
- Co-existence Between People and Wildlife
- Global Biodiversity Monitoring
- Mitigating and Adapting to Climate Change
- Wildlife Health

This review also includes a summary of key grants awarded during the year, an update on our Equality, Diversity and Inclusion activities and IOZ Environment, and a summary of our Theory of Change. A complete list of our 2022/23 publications is included in Appendix A.

The IOZ Business Plan (22/23–24/25), outlines our priorities for the next three years.

Generating world-leading research

ZSL's Institute of Zoology creates knowledge through research to directly address global challenges in conservation science and practice. A selection of our research activities during the 2022/23 academic year are described below for each of our five Conservation Challenges.

Between 1 September 2022 and 31 August 2023, IOZ staff and students published 147 peer-reviewed research papers. Eight datasets were published during the year, and ten software packages were produced. An additional 38 publications, including books, book chapters and major reports were published (see Appendix A).

Biology and Recovery of Small Populations

IOZ staff and students continued to research the genetic, demographic and socio-ecological processes that underpin the conservation of small populations, and to advise on structured decision-making in line with new developments in recovery science.

Extinct in the Wild initiative

IOZ provides the science support to recover wild populations of species that have become restricted to captive care in our zoos, aquaria and botanic gardens globally. The precarious state of these species was highlighted in a major publication in the journal *Science* (Smith et al., 2023) where we provide a history, current status, and a call to action for all species that have been lost from the wild and exist only in captive care. One exciting example is the sihek or Guam kingfisher (*Todiramphus cinnamominus*), a species that is Extinct in the Wild due to the accidental introduction of brown tree snakes to Guam in the 1940s. Before their extirpation, some wild individuals were rescued to captivity and this population has been maintained on the US mainland and captive facilities in Guam. IOZ researchers have led evaluation of captive management, developed release protocols and planned post-release monitoring. Recent work has focused on sex- and age-specific causes of mortality and contributions to population growth rate in sihek (Trask et al., 2023). In a substantial boost to this recovery programme IOZ raised £1,296,860 this year to oversee the first five years of releases outside their indigenous range on Palmyra Atoll.

Aotearoa New Zealand Hihi Recovery Programme

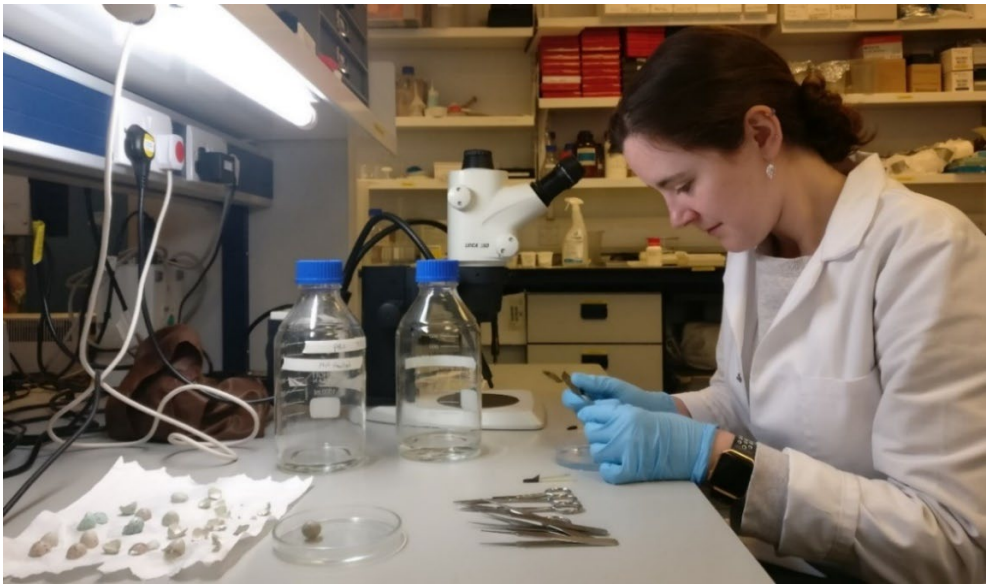
The IOZ's long-term programme of research on hihi or stitchbird (*Notiomystis cincta*) continues in collaboration with the Department of Conservation, New Zealand, a range of university departments and site-based community conservation projects. IOZ assists in the management and monitoring of all reintroduced populations including the curation of the long-term demographic and genetic data generated. This year the hihi dataset contributed to publications ranging from genomic signatures of inbreeding (Duntsch et al., 2023) to early-life telomere length and life-history (Morland et al., 2023).

Decision Science for species recovery

Numerous species recovery programmes benefit from the specialist skills that IOZ brings in Decision Science. Decision-making in conservation in complicated, and particularly so for threatened species where we often lack information, despite there being diverse and strongly passionate voices for action. We excel in this space and develop or use a range of decision support tools to help groups make the best possible choices in species recovery. During the year we published aspects of our Decision Science and supported species including Aotearoa New Zealand's Tara iti (*Sternula nereis davisae*) or fairy tern, and kuaka *(Pelecanoides whenuahouensis)* or Whenua Hou Diving Petrel. We also worked with a range of stakeholders on planning for red squirrel (*Sciurus vulgaris*) recovery in England, and contributed these skills to ongoing work with sihek and hihi. Recent outputs include a data-driven counterfactual evaluation of management outcomes to improve emergency conservation decisions (McMurdo Hamilton et al., 2022) and decision analysis for seabird recovery (Fischer et al., 2023).

Why eggs fail

Birds are among the most well-studied taxa; however, large gaps remain in our understanding of why eggs fail to hatch. This issue becomes increasingly urgent for species at risk of extinction when every egg counts to ensure long-term survival. To address this gap we compiled the largest, most comprehensive dataset on rates of hatching failure in birds globally. A phylogenetically controlled meta-analyses of these data showed that hatching failure across birds is higher than expected with an average 17% of eggs failing to hatch. Rates of hatching failure increased significantly with increasing threat status, with Critically Endangered birds experiencing on average twice as much hatching failure as birds of Least Concern. This research is also the first formal assessment of the impact of management interventions on hatching failure rates, showing that captive populations experience significantly higher rates of hatching failure compared to wild populations. Populations subject to artificial incubation, supplementary feeding and those provided with artificial nests also experience higher hatching failure compared to those without these interventions. The drivers of this correlation between hatching failure and management remains unclear, but could be an indirect result of threatened species being more likely subject to management. Our results suggest that conservation efforts are being focused toward species most at risk from extinction, but also that hatching failure needs to be better understood within the suite of conservation interventions. Our review of avian hatching failure (Marshall et al., 2023) also provides conservation practitioners with direct evidence of the impact that each intervention has on hatching failure, informing future conservation management decisions.



PhD student Ashleigh Marshall dissecting unhatched and undeveloped eggs from bird breeding programmes at ZSL (her PhD CASE partner). Photo credit: Fay Morland

European eel migration

A key focus for our research is the recovery of the European eel (*Anguilla anguilla*), a species now recognised as Critically Endangered globally. One important aspect of European eel biology is their migratory behaviour, which involves the longest spawning migration of all anguillid eels, some 5,000 to 10,000 km across the Atlantic Ocean to the Sargasso Sea. Despite almost 100 years since Johannes Schmidt proposed the Sargasso Sea as their breeding location on the basis of larval surveys, no eggs or spawning adults have ever been sampled there. Answering the fundamental questions of where eels spawn and the characteristics of their oceanic migration is urgently needed to aid conservation efforts and support stock recovery. A multi-partner project including IOZ and ZSL staff recently provided the first direct evidence of adult eel migrating to their breeding place in the Sargasso Sea. Migration data were received from 23 of 26 adult eels that were satellite tagged and released in the Azores archipelago. Five eels were tracked to within the Sargasso Sea boundary and one eel reached the presumed breeding area, covering straight line distances of up to 2274 km. Building on these ground-breaking first outputs published in *Scientific Reports* (Wright et al., 2022), this ongoing project seeks to reconstruct the trajectories of a larger sample size of tracked eels and analyse these with concurrent environmental data to better understand the drivers and threats to their oceanic migration.

Tracking European eel on their spawning migration.
Photo: OurWildMedia

Using interdisciplinary approaches to establish conservation baselines

IOZ researchers have established new science-led baselines for guiding conservation planning through the use of environmental archives and other alternative and interdisciplinary data sources. Rigorous investigation of historical archives, including museum records, archaeological collections and the recent fossil record, has provided a crucial new understanding of the former status, ecology and extinction of the Dalmatian pelican (*Pelecanus crispus*) in Britain (Crees et al., 2023). Similar historical research is now underway to understand the past population status and vulnerability of the UK's now-lost populations of European sturgeon (*Acipenser sturio*) and Atlantic sturgeon (*Acipenser oxyrinchus*). These baselines are being used to directly inform possible reintroduction planning for these species. At a wider scale, historical archives have also been used to identify human-caused threats that have shaped Europe's mammal fauna over the past 10,000 years (Ament et al., 2023), and to reconstruct patterns of extinction risk that have led to the loss of many of the world's evolutionarily remarkable island mammals (Rozzi et al., 2023). Related research using social-science methods has been employed to assess the social feasibility of reintroducing Dalmatian pelicans to UK landscapes where they formerly occurred (Alif et al., 2023). These investigative methods have also been employed further from home, where they have been used to demonstrate the remarkable continued survival of the Seram orange melomys (*Melomys fulgens*), an Indonesian rodent species that has not been seen by researchers for over a century (Turvey et al., 2023), and to evaluate the implications of regional extinction of dugongs (*Dugong dugon)* from Chinese marine waters (Lin et al., 2022).

Developing open-source software for population analysis

In collaboration with other institutions, IOZ researchers have advanced new methodologies to calculate the probability of excluding aunts from being assigned the maternity of a haploid male in haplodiploid species, and proposed more rigorous and robust methods to estimate relatedness and inbreeding coefficients from genetic marker data. Further, we have evaluated the ability of methods to estimate the current effective size of very large populations from a single sample of marker genotype data. New software packages implementing the novel methods for calculating exclusion probability (AuntExcPrb) and estimating relatedness/inbreeding (EMIBD9) have been published on the ZSL website for free download.

Co-existence between People and Wildlife

IOZ staff and students continue to develop transdisciplinary research that focuses on the human dimensions of wildlife conservation.

Range-wide conservation of cheetah

The Africa Range-Wide Cheetah Conservation Initiative (CCI), led by IOZ, works across the cheetah range states of Africa, identifying and addressing the challenges to cheetah conservation. Only 7,000 individuals of this highly threatened and wide-ranging species survive today, distributed over 3 million km^2 covering 20 countries. Cheetahs face multiple threats, particularly on unprotected lands where the majority still live. The CCI continues to develop and implement a holistic strategy for the conservation of cheetah that it coordinates across the enormous scales needed. Current priorities are to increase conservation impact in four cheetah landscapes, add three new landscapes to the programme and work to restore cheetah to at least one landscape where they have become extirpated. We are also working to establish lasting capacity and leadership for cheetah conservation across the range states where we work in order to build local institutional sustainability for conservation action. This involves securing commitment from range state governments through our National Carnivore Coordinator Programme and investment in a new generation of African cheetah scientists and conservationists through a series of studentships and practitioner training. Our work continues to put communities at the centre of conservation progress, by building tolerance towards large carnivores through reducing human wildlife conflict while developing sustainable wildlife-based economies.

Rewilding our Cities

Rewilding is a flexible, low cost, hands-off management approach to biodiversity conservation that can be deployed across a range of urban settings. Rather than restoring ecological states, rewilding seeks to reinstate natural processes and promote reorganisation and redevelopment of ecological systems under changing environmental conditions, which increases ecological resilience. As such, it may provide a successful approach to managing urban sites to enhance wildlife within cities, particularly sites that are experiencing rapid climatic changes. In the Rewilding our Cities ZSL report, our researchers and ZSL colleagues explored the science behind how rewilding could work for urban ecosystems, and show how rewilding cities could provide opportunities for climate change mitigation and adaptation, reduce air pollution, slow biodiversity loss, reduce environmental management costs and improve human health and wellbeing. Integrating rewilding with other nature conservation initiatives at the landscape scale could also bolster ecosystem services from open spaces and make cities more resilient to global environmental change, including the most extreme effects of climate change. Crucially, rewilding of our cities also offers an opportunity to engage an often-disconnected public with nature.

Urban fox (Vulpes vulpes). *Photo: Matthew Maran*

Sustainable fisheries

In partnership with the Greenland Institute of Natural Resources, IOZ researchers continue to provide evidence of potentially vulnerable marine ecosystems to annual audits of Greenlandic fisheries by the Marine Stewardship Council (MSC). Our research cruise of October 2022 uncovered a diverse coral and sponge community north of the West Greenland Offshore Greenland Halibut Fishery. We demonstrated that sea pen coral fields within the footprint of the fishery are the same species as those within the protected area, and that the protected community has greater diversity and complexity with many more, larger, older colonies, thus acting as a valuable habitat refuge as well as nursery ground for the fishery.

Illegal fishing dynamics in a large-scale MPA during Covid-19

IOZ research this year has revealed a significant spike in illegal fishing activity in the Chagos Archipelago Large Marine Protected Area in the Indian Ocean (Collins et al., 2023), likely due to Covid-19 restrictions during the pandemic, which prevented boarding and therefore prosecution of apprehended vessels. The drop in deterrence was followed by a spike in fishing vessels of Indian origin, marking a shift in fishing dynamics from before the pandemic, which was largely dominated by Sri Lankan vessels.

Badgers and bovine tuberculosis

Since 2013, the UK Government's bovine tuberculosis (bTB) control policy has entailed widespread killing of badgers (*Meles meles*), with licences issued to reduce badger numbers by ≥70% across >30,000 km^2 of England. More recently, the government decided to scale back widespread badger culling in favour of badger vaccination. The IOZ Cornwall Badger Project aims to provide the evidence base to support this transition, and the eventual control and eradication of bTB. In 2022/23 we expanded our badger vaccination research across a growing area, monitoring vaccination coverage and bTB prevalence in vaccinated populations to assess the technical effectiveness of the approach. We also initiated a social science project to identify the social barriers to the wider rollout of badger vaccination. We share our ongoing findings with participating farmers to build a common understanding of evidence in this controversial area.

Wildlife trade in badgers in South Korea

A recent IOZ assessment of trade in badgers (*Meles leucurus* and *Arctonyx* spp.) and badger-derived products in South Korea (Elves-Powell et al., 2023) has revealed a lack of protection for both legally farmed animals and wild badger populations. The research, carried out with Seoul National University, showed that badger farms continue to supply the trade, supplemented by imported badger-derived products and some apparent illegal harvesting of wild *Meles leucurus* in South Korea. Recommendations for improved monitoring and regulation of the trade were made, given that legal farming and the potentially illegal wild harvest present risks to wild *Meles leucurus* populations in South Korea and *Arctonyx* spp. populations in Asia. In addition, the research led to a call for improved welfare of traded badgers and highlighted the risks of badger farms as potential sources of novel zoonotic diseases.

Illegally harvested Asian badgers kept on a farm in South Korea. Photo: Anonymous

Global Biodiversity Monitoring

Over the past year IOZ researchers have continued to advance and improve our international biodiversity monitoring datasets. These data feed into our efforts to communicate biodiversity trends through global indicators, such as the Living Planet Index, and also inform our scientific outputs.

Living Planet Report

The 2022 Living Planet Report, a collaboration between ZSL and WWF, was published in October. This globally recognised report communicates trends in global biodiversity and highlights the Living Planet Index (LPI), one of our flagship biodiversity indicators. Our Indicators and Assessments Unit continues to grow this globally important database of wildlife population trends, which now includes over 32,000 populations trends for over 5200 vertebrate species.

Living Planet Index

The Living Planet Index project continues to be a core component of IOZ's global biodiversity monitoring. A major output this year reviewed the value of the LPI to the field of biodiversity monitoring, and how it's components have portrayed a compelling account of the changing status of global biodiversity through its application at policy, research and practice levels over the last 20 years (Ledger et al., 2023).

Penguindex: a Living Planet Index for *Pygoscelis* penguins

The Living Planet Index database was used to examine historical trends in penguin populations through the development of a 'Penguindex' (Talis et al., 2023). *Pygoscelis* penguins, which comprise Adélie, chinstrap, and gentoo penguins, serve as an important window into the larger marine ecosystem, but the patchiness and heterogeneity of the census data available have made it difficult to assess trends in a policy-accessible way. The *Pygoscelis* biodiversity index, the 'Penguindex,' used the framework of the Living Planet Index (LPI) to distil 40-year population trends of pygoscelid penguins for the first time into a single pan-Antarctic indicator for use by policymakers. Species- and region-specific indices, from which discrete eras of population dynamics can be identified, were developed. These indices reflect comparable population trends and the relative magnitude of these changes. Penguindex also identifies several marked eras of regional pygoscelid population change that may help identify key mechanistic drivers. We expect that the Penguindex will act as a useful reference tool for policymakers and hope that by following this example, other taxonomic groups in the Antarctic might be tracked using the Living Planet Index framework. Importantly, our development of the Penguindex should facilitate the much-needed integration of Antarctic data into global biodiversity monitoring.

Over-exploitation and delayed responses to environmental change

New research was published showing how ecological lags are critical to our understanding of how populations of terrestrial birds and mammals respond to anthropogenic land-use and climate change (Cornford et al., 2023). Ecological lag duration was shown to vary between drivers, vertebrate classes and body size groupings. For example, lags linked to climate-change impacts were found to be 13 years for small birds, rising to 40 years for larger species. Past warming and land conversion generally combine to predict population declines; however, such conditions are associated with population increases for small mammals. The results indicate the positive effects of management (>+4% annually for large mammals) and protected areas (>+6% annually for large birds) on population trends, in contrast with the negative impact of exploitation (<−7% annually for birds), highlighting the need to promote sustainable use. Model projections suggest a future with winners (e.g., large birds) and losers (e.g., medium-sized birds), with current/recent environmental change substantially influencing abundance trends to 2050. The research suggests that without urgent action, including effective conservation interventions and promoting sustainable use, ambitious targets to stop declines by 2030 may already be slipping out of reach.

A function-based typology for Earth's ecosystems

Ecosystems vary in their biota, service provision and relative exposure to risks, yet there is no globally consistent classification of ecosystems that reflects functional responses to change and management, hampering the development of conservation targets and sustainability goals. To address this, IOZ collaborated with researchers worldwide to present the International Union for Conservation of Nature (IUCN) with a new Global Ecosystem

Typology, which was adopted by the IUCN in 2020 and published in *Nature* in October 2022 (Keith et al., 2022). The typology is based on a conceptually robust, scalable, spatially explicit approach for generalizations and predictions about ecosystems' functions, biota, risks and management remedies across the entire biosphere. This novel framework places all of Earth's ecosystems into a unifying theoretical context to guide the transformation of ecosystem policy and management from global to local scales. This information infrastructure will support knowledge transfer for ecosystem-specific management and restoration, globally standardized ecosystem risk assessments, natural capital accounting and progress on the Global Biodiversity Framework.

Mitigating and Adapting to Climate Change

Over the past year IOZ researchers have continued to explore species and ecosystem vulnerability to climate change and to investigate nature-based solutions for mitigation that will benefit wildlife and people.

Climate, cropland distribution and fire size

Climate and land use changes often interact, yet our ability to predict their combined effects on biodiversity is currently limited. In particular, the combined effects of climate and land use on key ecosystem dynamics, such as disturbance regimes, that shape biodiversity across large spatial scales, are poorly understood. In a recent study (Schulte to Buhne et al., 2022), IOZ researchers assessed how indirect climate–land use interactions influence disturbance regimes by examining the mechanistic pathways by which climate and proximity to cropland interact to shape fire size in a West African grassland ecosystem, the W-Arly-Pendjari transboundary protected area complex. Using satellite imagery, we demonstrated that in areas where wet season grass production is higher, fires are larger, but that this relationship depends on the distance to cropland. Close to cropland, environmental drivers of fire size (wet season grass production, and progressive loss of fire fuel during the fire season) have little effect on fire size, as fuel breaks induced by cropland limit fire size. The results suggest that the extent to which climate factors control fire dynamics in this African grassland depends on the spatial distribution of land use. More broadly, considering the relative spatial distributions of interacting stressors may be key to improving predictions of their combined impacts on ecosystem functioning.

Climate change vulnerability and conservation of seabirds

Many seabird populations across Europe are severely threatened by present and future climate change, largely due to changes in prey availability, the effects of changes in extreme weather patterns and direct heat stress. While many conservation groups are aware of the threats there has been a lack of information available to guide decision-making, frequently causing a disconnect between ecological research and conservation practice. The IOZ-led project Climate Change Vulnerability and Potential Conservation Actions: Seabirds in the North-East Atlantic has published a major report (Häkkinen et al., 2022), which includes input from over 80 conservationists and policymakers across 15 European countries. The project assessed the threats of climate change on all 48 breeding seabird species across the Atlantic and Baltic coasts of Europe, ranging from Svalbard and Iceland to Portugal and Spain. In a series of eight workshops, we brought together over 80 key stakeholders to discuss the threat of climate change to seabirds, assess possible actions, and guide design of the report to make it as useful as possible to conservation organisations.

Northern Gannets (Morus bassanus) *nesting at Bempton Cliffs, UK. Gannets were one of 48 species assessed in a report on climate change and seabird conservation in the north-east Atlantic. Photo: Seppo Häkkinen.*

Climate change-caused population collapse in wild dogs

Some species may have evolved cooperative breeding strategies in response to extreme climatic conditions; however, climate change may push such species beyond their ability to cope with extreme climates and reduce the group sizes in cooperatively breeding species to a point where populations are no longer viable. Predicting the impact of future climates on these species is challenging as modelling the impact of climate change on their population dynamics requires information on both group- and individual-level responses to climatic conditions. Using a single-sex individual-based model incorporating demographic responses to ambient temperature in an endangered species, the African wild dog (*Lycaon pictus*), IOZ researchers showed that there is a threshold temperature above which populations of the species are predicted to collapse (Rabaiotti et al., 2023). The threshold was found to be higher for larger simulated populations (30 packs), but 84% of real-world populations number <30 packs. This work highlights the importance of social dynamics in determining impacts of climatic variables on social species, and the critical role that recruitment can play in driving population-level impacts of climate change.

Climate-driven species-on-the-move

Over recent decades, our understanding of climate change has accelerated greatly, but unfortunately, observable impacts have increased in tandem. Both mitigation and adaptation have not progressed at the level or scale warranted by our collective knowledge on climate change, and effective approaches to engage people on current and future anthropogenic climate change effects are urgently needed. In response to this challenge, IOZ staff recently collaborated on a study (Pecl et al. 2023) showing how species whose distributions are shifting in response to climate change, that is, 'species-on-the-move', present an opportunity to engage people with climate change by linking to human values, and our deep connections with the places in which we live, in a locally relevant yet globally coherent narrative. Species-on-the-move can impact ecosystem structure and function, food security, human health, livelihoods, culture and even the climate itself through feedback to the climate system, presenting a wide variety of potential pathways for people to understand that climate change affects them personally as individuals. Citizen science focused on documenting changes in biodiversity is one approach to foster a deeper engagement on climate change. However, other possible avenues include arts, games or collaborations with rural agriculture (e.g., new occurrences of pest species) or fisheries organisations (e.g., shifting stocks) or healthcare providers (e.g., changing distributions of disease vectors). Through the importance we place on the aspects of life impacted by the redistribution of species around us, species-on-the-move offer emotional pathways to connect with people on the complex issue of climate change in ways that have the potential to engender interest and action on climate change.

Wildlife Health

IOZ research continues to explore infectious and non-infectious disease as a conservation threat and investigate the determinants of cross-species pathogen transmission, including zoonotic disease spillover from wildlife, in order to better understand the implications for the health of wildlife, people and domestic animals. This work is grouped here under three headings: *Investigating the determinants of zoonotic disease spillover from wildlife, Investigating disease threats to amphibian conservation*, and *Disease surveillance to support recovery of British wildlife.*

Investigating the determinants of zoonotic disease spillover from wildlife

Zoonotic disease emergence from bats

IOZ researchers continue to improve understanding of the drivers of zoonotic disease emergence and how these can be mitigated. We previously showed that fruit bats in West Africa host a plethora of viruses, including henipaviruses, that could have zoonotic potential. Elsewhere, we know that the intensive farming of pigs in the absence of adequate biosecurity to separate fruit bats from farmed animals can lead to an increased risk of zoonotic emergence of novel viruses; for example, the emergence of Nipah virus in Malaysia in the late 1990s. Once viral spillover from bats to pigs occurred, high pig population densities on intensive farms enabled pig-to-pig transmission with virus amplification and adaptation to a new mammalian host. This in turn led to people becoming infected and being killed by the highly virulent Nipah virus. In West Africa, there has been a recent government-sponsored drive to increase pig production through the transition from traditional, extensive farming methods to the intensification of pig farming. Along with colleagues in the Universities of Ghana and Cambridge, we have started a new project investigating if this move to intensive pig farming alters the risk of zoonotic emergence of bat viruses. This work is funded by the European Commission and UKRI for the next five years.

Investigating disease threats to amphibian conservation

Amphibian infectious disease

IOZ has been at the forefront of amphibian infectious disease research for more than 30 years, and we continue to illustrate the severity of this conservation threat. This year we have focused on the distribution of different variants of *Batrachochytrium dendrobatidis* (Bd) in Africa, how they may be responsible for host species extinction, how climate can affect their distributions, and the likelihood the variants will recombine. In addition, research on the effects of chytrid fungi and ranaviruses on various host species in Iberia has shown that ranavirus infections are affecting native fish as well as amphibians (Coutinho et al., 2023). In partnership with the Leverhulme Centre for the Holobiont, we are exploring options to develop new approaches to examine microbiome dynamics and how they may be managed for disease. We are establishing new research on microbial metabolomes, in silico studies of microbiome community dynamics, and exploring opportunities to develop organ-on-a-chip replacement models for amphibian research with various partner groups based at Imperial College. Our related welfare work also progresses on several fronts: application of pathogen eDNA systems to wild and captive amphibian populations as a means of characterizing risk of disease, and the development of machine learning-based analyses of video systems to identify behavioural welfare indicators in larval anurans and adult caudates. We also published evidence that invasive alpine newts in the UK have been introduced numerous times, and that the invasion process at all geographic scales is largely achieved by the movement of newts by humans (Ball et al., 2023).

Darwin's frog conservation project

The temperate forests of Chile and Argentina hold several endangered and evolutionarily distinct species. These include northern and southern Darwin's frogs (*Rhinoderma rufum* and *Rhinoderma darwinii*), the only known amphibians where males brood developing tadpoles in their vocal sacs. Repeated efforts have failed to find the Chilean endemic northern Darwin's frogs, last seen in 1981, now categorized as Critically Endangered, Possibly Extinct. Southern Darwin's frogs are Endangered. Key threats include native forest loss and the infectious disease

amphibian chytridiomycosis. Since 2009, IOZ researchers have led an amphibian conservation project integrating ecological and social research, education, outreach, and management in collaboration with private landowners and other stakeholders in Chile, which holds over 90% of the distribution range of the southern Darwin's frog. In the past year we continued the epidemiological and demographic monitoring of six free-living southern Darwin's frog populations that have been surveyed by our team since 2014; tested the effectiveness of a mitigation action against chytridiomycosis in southern Darwin's frog populations, and monitored 30 land conservation agreements with private landowners which are protecting c. 16,000 ha of native forest. In addition, we trained over 30 conservation managers, landowners, and students in amphibian monitoring, biosecurity, and habitat management, as well as evaluating the effectiveness of an amphibian-focused education programme for raising conservation awareness and engagement.

Accounting for bias in prevalence estimation in a globally emerging pathogen

Accurate quantification of infection parameters is necessary to ensure effective surveillance, investigation and mitigation of infectious diseases. However, hosts and pathogens are often imperfectly observed and key epidemiological parameters, such as infection prevalence, can be biased if this observational uncertainty is not properly accounted for. We evaluated the combined effects of imperfect pathogen detection and host pseudoreplication on the estimation of infection prevalence of the pathogen *Batrachochytrium dendrobatidis* (Bd) in the southern Darwin's frog (*Rhinoderma darwinii*) in two areas of southern Chile (Sentenac et al., 2023). Our results showed that Bd prevalence could be underestimated by 55% if false negatives and host pseudoreplication were not accounted for. Host pseudoreplication had a greater impact on prevalence underestimation than pathogen imperfect detection in our study. This underestimation in prevalence changed our interpretation of the impacts of Bd infections on our model species, from a nearly stable population using the naïve period prevalence to a declining one using our robust estimate. The methods developed for the study can be applied to a wide range of host–pathogen systems, and will be of interest to both researchers and practitioners aiming to investigate and mitigate the impacts of infectious diseases on free-ranging populations.

Female Darwin's frog in southern Chile. Photo: Andrés Valenzuela Sánchez

Mountain Chicken Recovery Programme

Once found on at least seven Caribbean islands, free-living populations of the mountain chicken (*Leptodactylus fallax*) remain only on the island of Dominica. Field data show the species was abundant in Dominica and Montserrat until the 2000s, when the emergence of amphibian chytridiomycosis caused rapid population crashes in both islands. In response, ZSL and other partners launched the Mountain Chicken Recovery Programme, an international partnership that led the implementation of a recovery strategy for this Critically Endangered species. In December, IOZ staff participated in a workshop in Montserrat that brought together local and international stakeholders to review and update the conservation strategy. Priority actions included a field survey to determine the number of mountain chickens remaining in Dominica. An unprecedented collaborative effort comprising 28 local and international collaborators from 13 organisations carried out the survey during 46 fieldwork days in July and August 2023. We were only able to detect 23 mountain chickens across more than 40 plots thoroughly surveyed using capture-recapture methods. Ongoing threats to mountain chickens in these two populations were also identified, including chytrid infection, invasive species, and habitat loss. We are using the results from this survey to inform the next actions that will be required to bring this species back from the brink of extinction.

Disease surveillance to support recovery of British wildlife

Garden Wildlife Health

IOZ staff have continued to coordinate the Garden Wildlife Health (GWH) project, a long-running citizen science programme that monitors the health of, and identifies disease threats to, amphibians, garden birds, hedgehogs and reptiles in Great Britain. The project is run in partnership with the British Trust for Ornithology, Froglife and the Royal Society for the Protection of Birds, and the data obtained feed into Defra's GB Wildlife Health Partnership.

Escherichia albertii infection in garden birds

Escherichia albertii was first identified as a gastrointestinal bacterium in 2003 and is known to infect animals as well as humans. Our recent collaborative study (Bengtsson et al., 2022) analysed phylogenetic and epidemiological data to better understand the risk factors of *E. albertii* infection in people (such as recent international travel), and to infer the likely significance of *E. albertii* infection to wild bird health. The UK Health Security Agency conducted whole genome sequence analysis of *E. albertii* isolates from humans, wild and captive birds; the University of Liverpool led on the phylogenetic analyses, and IOZ provided cultured bacteria and post mortem data for wild birds. The study found that finches were more frequently associated with 'significant' inferred disease associated with *E. albertii* infection than all non-finch species combined. The majority of isolates of the bacterium from humans and birds in GB were genetically distinct from each other, indicating that substantial transmission of the bacterium from people to wild birds, or vice versa, is unlikely. However, since a small number of isolates from people were genetically similar to those from wild finches, it is possible that some people are infected from direct or indirect contact with wild birds. It is therefore important to provide guidance on hygiene precautions to members of the public who feed garden birds, provided in our recently updated *Escherichia albertii* factsheet. This research utilized a 20-year archive of bacterial isolates that have been obtained through disease surveillance of wild birds conducted at IOZ, demonstrating the value of our long-term programmes that investigate the health of native species.

Usutu virus infection in wild birds in the UK

Following the first detection of Usutu virus (USUV) in wild birds in the UK in summer 2020, IOZ staff have continued to collaborate with veterinarians and curatorial staff at ZSL, scientists from the Animal & Plant Health Agency, the UK Health Security Agency and the British Trust for Ornithology on USUV surveillance in bird hosts and mosquito vectors. USUV was subsequently detected in wild birds in Greater London in the summers of 2021–2023, and in rural Cambridgeshire in 2023 (Folly et al., 2022; Schilling et al, 2023). While a reduction in blackbird reporting rates combined with a cluster of disease incident reports of blackbirds in southern England pointed to regional occurrence of USUV infection in 2020 (Lawson et al., 2022), the Cambridgeshire case is the first confirmed detection of the virus in the UK outside the Greater London area. Sequence analyses found that the recent detections share a most recent common ancestor with the 2020 USUV UK lineage, which supports local persistence and spread rather than multiple independent introduction events as the likely explanation for repeat occurrence. Whether the UK climate is permissive for long-term persistence of USUV is currently unknown.

Disease Risk Analysis and Health Surveillance

The Disease Risk Analysis and Health Surveillance (DRAHS) project is led by IOZ and largely funded by Natural England. The DRAHS team studies methods of disease risk analysis and health surveillance for assessing and minimising the impact of conservation translocations, such as reintroductions, on the health of native species, and the effect of diseases on the translocated species. We gather data on these questions through health monitoring of animals involved in over 40 species translocation programmes. In 2022, we published a book chapter which explains the method of disease risk analysis for conservation translocations developed at IOZ (Sainsbury and Carrano, 2022). The method has been used on 27 species-specific conservation translocations and a publication is available in each case to facilitate information transfer to other groups translocating the same, or closely related, species. In the last year we have produced disease risk analyses for translocations of hen harrier (*Circus cyaneus*) and pine marten (*Martes martes*) for translocations in the British Isles.

Cetacean Strandings Investigation Programme

The Cetacean Strandings Investigation Programme (CSIP), led by IOZ and funded by Defra and the Welsh Government, investigates the causes of strandings of cetaceans (whales, dolphins and porpoises), seals, marine turtles and some large bodied shark species around the coast of England and Wales. In 2022, the CSIP received further funding from Defra to extend the coordination of seal mortality investigation across England and Wales for an additional eight-year period from 2023–2031. During necropsies that CSIP staff conduct on UK stranded marine wildlife a wide range of samples are routinely collected to support collaborative research. Our outputs continue to link strandings to climate change; for example, documenting the northerly range expansion of the smalltooth sand tiger shark (*Odontaspis ferox*) via the first confirmed records of strandings in the United Kingdom and Ireland (Curnick et al., 2023).

Grey seal entangled in netting. Photo: CMPT James Barnett

Developing a marine mammal contaminants indicator for European waters

Due to their long lifespan and high trophic level, marine mammals can accumulate high concentrations of persistent organic pollutants, including polychlorinated biphenyls (PCBs). European countries are developing indicators for monitoring pollutants in the marine environment and assessing the state of biodiversity, as required under both Regional Seas Conventions and European legislation. As sentinel species, marine mammals can be used to assess contaminants otherwise below current analytical detection limits in water and lower trophic level marine biota. To support the development of marine mammal contaminants indicators, data collected by CSIP (1990 to 2017) was used to assess the trends and status of PCBs in harbour porpoises. Mean PCB blubber concentrations were observed to decline in all harbour porpoise Assessment Units and OSPAR Assessment Areas. However, a high proportion of animals were exposed to concentrations deemed to be a toxicological threat. A recommendation to fully implement a marine mammal contaminants indicator in European waters was made, including recommendations for agreement on species, assessment areas and the contaminants to be monitored, as well as agreement on targets to indicate the level at which conservation objectives will be met. The research also led to recommendations for the development of standardised sample and data collection protocols, standardised reporting methodology, and a database of individual pollutant levels. The results highlight the need for further research to assess the effects from exposure to multiple pollutants, including emerging pollutants (Williams et al., 2023).

Long-term programmes providing insights into wildlife ecology and conservation in a changing world

Changes in wildlife populations and ecological communities take place over a long period and interventions aimed at reducing detrimental human impacts also take time to be effective. Access to long-term data is therefore key to conservation science. IOZ manages a significant number of long-term datasets and these have been used for research and teaching throughout the year. For example, IOZ provides technical support for the monitoring and management of six reintroduced populations of hihi spread across northern New Zealand in addition to the remnant population on Te Hauturu-o-Toi.

IOZ's long-term programme on hihi, established in 1991, involves the development and application of database software to manage the data resources generated across our different sites. These database systems provide secure data storage and are accessible to conservation practitioners and researchers at IOZ and elsewhere. Under intensive management the hihi has been steadily increasing in numbers but is still at risk of extinction. Introduced predators, disease, the loss of genetic diversity, and environmental disturbances continue to pose a risk to the long-term viability of the species. Long-term ecological data derived from our research programmes provides the scientific evidence to inform conservation interventions and develop global best practice in endangered species management.

Photo: Mhari McCready

ZSL Biobank

ZSL owns internationally important collections of biological samples that are derived from our long-term programmes, including the West Africa bat project and British wildlife health projects (Garden Wildlife Health, DRAHS and the CSIP). In addition to the frozen collections, tissues from these projects are stored at IOZ as wet (formalin-fixed) tissues, paraffin-embedded tissues and histology sections. Our audit and curation of the biobank is continuing, and processes for the transfer of biological samples have been developed with the Natural History Museum (NHM) and the European Association of Zoos and Aquaria (EAZA) to enable wider research on the collections.

Accelerating the translation and use of research to maximise conservation impact

Institute of Zoology research underpins conservation practice and policy, and we work with our network of partners to reduce the impacts of human activities on wildlife at national, regional and global scales. Our activities are supported by ZSL's Conservation and Policy colleagues, as well as press office and public engagement teams, who provide pathways through which IOZ's science is shared with the wider conservation community. A selection of IOZ's impact-related activities during the 2022/23 academic year are described below for each of our five Conservation Challenges.

In 2022/23, IOZ conducted conservation-relevant work in 69 countries and collaborated with 333 institutions in the UK and overseas. Over 300 species were the focus of IOZ conservation science. IOZ scientists also contributed to a wide range of policy development and implementation activities, some examples of which are included below.

Biology and Recovery of Small Populations

Conservation planning for Russian desman
IOZ staff established new conservation initiatives for several top-ranking Evolutionarily Distinct and Globally Endangered (EDGE) species. These include the first conservation research programme for the Critically Endangered Russian desman (*Desmana moschata*) in Kazakhstan, working closely with the Association for the Conservation of Biodiversity in Kazakhstan (ACBK) to set up integrated field activities involving ecological and community-based surveys of desmans and their threats. Project findings will guide conservation policy and protected area planning in the Ural River basin.

Emergency recovery planning for tooth-billed pigeon
IOZ staff are working with BirdLife and the IUCN SSC Pigeon and Dove Specialist Group to coordinate a range-wide survey for the Critically Endangered tooth-billed pigeon or manumea (*Didunculus strigirostris*), one of the rarest birds in the world, to try to determine whether any populations or individuals of the species still survive across its former range in Samoa. The findings of this survey will directly inform 'emergency' recovery planning for this global-priority species.

London HogWatch
Camera trapping methods and protocols developed by the IOZ's London Hogwatch project were used as the basis for the new National Hedgehog Monitoring Programme funded by Natural England (led by the People's Trust for Endangered Species, PTES). IOZ staff participated in the 'Hedgehogs in Britain threat analysis workshop' in January 2023 and 'Hedgehogs in Britain Strategic workshop' in March 2023, organised by PTES. In addition, our hedgehog monitoring project in North Camden assessed conservation interventions for the threatened Regent's Park population. This led to Heath Hands funding a hedgehog officer to promote hedgehog highway schemes and other activities to improve connectivity of hedgehog habitats in areas identified by the London HogWatch around Hampstead Heath. Ealing Wildlife Group has also set up a Hedgehog Highways campaign across the borough, following a London HogWatch survey carried out in 2022. The results from our Kingston surveys have fed into Kingston's Biodiversity Action Plan and Hedgehog Species Action Plan.

Camera trap photo of a hedgehog during the hedgehog survey in Kingston, Surrey. Photo: London HogWatch

Informing Important Shark and Ray Areas (ISRAs)

In 2022, the IUCN Shark Specialist Group initiated an ambitious project to enhance the conservation of all shark, ray, and chimaera species through the implementation of a systematic place-based approach, supported by the identification of Important Shark and Ray Areas (ISRAs). IOZ staff advised on important areas for sharks and rays around the Chagos Archipelago in the Indian Ocean and contributed insight and data from IOZ's long-term monitoring of megafauna in the area. This resulted in three proposed ISRAs being put forward: the Sandes-Swart Seamount complex for silvertip sharks (*Carcharhinus albimarginatus*) and silky sharks (*Carcharhinus falciformis*); Benares Shoal, Peros Banhos and Salomon Atoll for grey reef sharks (*Carcharhinus amblyrhynchos*), silvertip sharks, and reef manta rays (*Mobula alfredi*); and Egmont Atoll for reef manta rays. These proposals will be refined during a workshop in September 2023 before being formally submitted to the independent review panel for peer-review.

Silvertip shark in Chagos. Photo: David Curnick

Providing science-based decision support for species recovery programmes

IOZ staff are approached by governments and conservation practitioners to provide consultancy on a range of issues for species recovery programmes. Some examples for 2022/23 are given below.

Sihek (USA)	IOZ staff chair the Sihek Recovery Team for the US Fish and Wildlife Service (USFWS). This year we completed our first trial for producing sihek for release to Palmyra Atoll within an IOZ-designed quarantine facility. Working with USFWS, Guam Department of Agriculture and The Nature Conservancy, IOZ has secured all required permits and funding needed to run this project. We have successfully raised an additional £1,296,860 to lead this release programme on Palmyra Atoll for the coming five years.
Hihi (New Zealand)	IOZ staff chair the Hihi Recovery Group for the New Zealand Department of Conservation. An adaptive management framework developed to manage hihi over the next 20 years is now in place. Translocation was again not possible this year, but we have a location ready assuming permissions will be provided for 2024. We have extended our contract to manage the reintroduced population on Tiritiri Matangi island for an additional four years, continuing a management lead we took over in 2007. The reintroduced population on Tiritiri Matangi Island produced 194 fledglings this year, an increase of 26 fledglings on the previous year.
Kuaka (New Zealand)	IOZ staff completed a structured decision analysis on the kuaka (Whenua Hou Diving Petrel) for the New Zealand Department of Conservation and partners, identifying the best management strategy for kuaka recovery. The focus was to support the New Zealand Government to determine which protection mechanisms should be lobbied for to protect kuaka on the high seas. This included an assessment of the newly internationally ratified Biodiversity Beyond National Jurisdiction Treaty.
Wild camel (Mongolia)	IOZ staff advised the Wild Camel Protection Foundation on all aspects of management of the only captive herd of wild camel.
Red squirrel (UK)	IOZ staff are applying Decision Science skills to red squirrel recovery in England, working closely with Natural England and the UK Squirrel Accord. The first workshop was held this year.

Co-existence between People and Wildlife

Range-wide cheetah conservation in the Horn of Africa

The Horn of Africa landscape (Ethiopia, South Sudan, Uganda, Kenya and Somalia), encompassing 750,000km^2 across north-east Africa, represents an area for which we know little about the status of cheetah. Cheetahs in this landscape comprise the rare *Acinonyx jubatus soemmeringii* subspecies, which faces a growing threat due to illegal wildlife trade. Security issues make work in the landscape challenging; however, the IOZ's Cheetah Conservation Initiative (CCI) is working with in-country partners to help overcome some of the difficulties. In 2023, training was provided to 22 participants from Horn of Africa countries in the first Cheetah Survey and Monitoring Training Workshop, Bishoftu, Ethiopia. Training was designed to ensure that in-country partners were provided with the information and tools they need to contribute to the survey program, initiating a sustained process to strengthen local capacity, including governments, to conduct surveys and monitoring for cheetah populations in each country.

African Carnivores Initiative (CITES-CMS ACI)

The CCI supported the Benin and South Sudanese National Cheetah Coordinators (NCCs) to attend the Second Meeting of the Range States of the Joint CITES-CMS ACI (May 2023): the African Carnivores Initiative (ACI) developed jointly by the Convention on International Trade in Endangered Species (CITES) and the Convention on the Conservation of Migratory Species (CMS). NCCs from Niger, Angola, Namibia and Zimbabwe also attended this meeting. The meeting adopted the three Regional Conservation Strategies for Cheetah and African Wild Dogs. The outcomes included the enhancement of transboundary cooperation on big cats, identification of agreed regional priorities and adoption of the 14 recommendations to conserve cheetahs in the Horn of Africa. The CCI submitted a report on the situation of cheetah in the Horn of Africa to the Joint CITES-CMS African Carnivore Initiative, outlining the precarious situation of the North East African cheetah, and the impact of trade on the remaining populations. The report also provides 14 recommendations to address the situation.

CMS Connectivity Working Group

The Cheetah Conservation Initiative provided a series of recommendations through the CMS Connectivity Working Group to the Terms of Reference for a forthcoming International Panel on Biodiversity and Ecosystem Services (IPBES) report on connectivity. The majority of the changes were accepted, helping to ensure that the report better addresses the importance of connectivity in the conservation of wide-ranging species and the role of connectivity in strengthening ecosystem resilience in the face of climate change.

Convention on International Trade in Endangered Species (CITES)

The CCI supported Ethiopia and Somalia in the submission, presentation and debate of a document, 'Illegal Trade in Cheetah (*Acinonyx jubatus*)', at the 19th Conference of the Parties (COP19) to CITES in Panama. The CCI organised a side event at COP19, presenting an introduction to the conservation status of cheetah. The CCI gave an intervention on illegal trade on cheetah in support of the Decisions proposed and amendments suggested by the US. This intervention noted that evidence indicates that trade continues to pose a threat to cheetah, particularly populations of the rare subspecies *Acinonyx jubatus soemmeringii* in the Horn of Africa, and rejected proposals to address illegal trade in cheetah under the newly initiated Big Cats Task Force. The Decisions and amendments had strong support from Cheetah range states, and represent an important step forward in combatting this trade.

The CITES Cheetah Trade Resource Kit

Over the reporting period, the CITES Secretariat commissioned CCI to develop a series of eight factsheets and a poster to provide an accessible summary of the kit. These products are now available online and provide a much-needed resource for enforcement officials to identify and confiscate cheetahs and their products.

Regional Conservation Strategies and National Conservation Action Plans (NCAPs)

At Mpala Research Centre in Laikipia, Kenya, the CCI team led the process to revise the eastern African regional conservation strategy for cheetah and African wild dogs (September 2022). The workshop included representation from Djibouti, Somaliland and Puntland for the first time in the conservation planning process for eastern Africa, as well as representatives from Tanzania, Kenya, Ethiopia and South Sudan.

Advising UK government on transmission of bovine TB and efficacy of badger vaccination trials

IOZ's Cornwall Badger Project has continued to provide a valuable resource for the development of bovine tuberculosis (bTB) policy in 2022/23. Nationally, we work with policymakers through Defra's 'bTB Partnership', to help facilitate the Government's bTB eradication strategy, especially its planned transition from culling to vaccination. The bTB partnership has provided a network through which we can share our findings (from both natural and social science) with leaders in the farming and veterinary communities, contributing to the consensus on policy development. Locally, we are working with Cornish farmers, farm vets, and other stakeholders through the Cornwall bTB Eradication Group to better integrate the Cornwall Badger Project with bTB eradication efforts.

Informing fisheries management
IOZ research on illegal fisheries around the Chagos Archipelago Large Marine Protected Area (LMPA) in the Indian Ocean is informing the establishment of bilateral agreements with India. These agreements will ensure more effective management of the protected area and illegal fisheries prosecution and deterrence.

Global Biodiversity Monitoring

Living Planet Report 2022
The Living Planet Report, published in collaboration with WWF was profiled in over 400 national and international news outlets with 92 million views.

Providing evidence to measure progress towards international convention targets
In November 2022, nations from across the world gathered in Montreal, Canada for CBD COP15 to agree the Kunming-Montreal Global Biodiversity Monitoring Framework. IOZ staff actively engaged at the conference to inform and encourage attendees about the adoption of species focused goals and targets. In collaboration with NGO partners, we helped ensure the adoption of key parts of the framework to prevent extinctions, minimize extinction risk and increase the abundance of wild, native species to healthy and resilient levels. The indicators we have developed have been included within the monitoring framework to measure progress towards set goals and targets.

Wildlife Comeback in Europe
With ZSL, IOZ researchers compiled assessments of recovering European species for the Wildlife Comeback in Europe report 2022. In partnership with Rewilding Europe, Birdlife and RSPB, the report features assessments of 50 recovering European bird, mammal and reptile species, and provides a synthesis of the spatial and temporal pattern of their recoveries and how threats and conservation measures impact those recoveries. The report suggests that many wildlife species are thriving in Europe owing to protection and re-introduction, with grey wolves, Eurasian beavers and European bison seeing some of the strongest recoveries in numbers and geographical range. Launched in September 2022 at Cambridge University, the report attracted wide press coverage and was featured in over 180 news outlets.

Extinction risk assessments of swallowtail butterflies

Working with the IUCN Specialist Group, regional experts from the Lepidopterists' Society of Africa (LepSoc Africa) and the African Butterfly Research Institute (ABRI), IOZ researchers have made strong progress in conducting extinction risk assessments for Afrotropical swallowtail butterflies. A total of 12 species have been submitted to the IUCN Red List. Maps and drafts for all 65 remaining species in the region have been drafted and are awaiting external review.

A function-based typology for Earth's ecosystems

The new IUCN Global Ecosystem Typology, developed in collaboration with IOZ, facilitates integrated assessment of Earth's ecosystems, enabling a more powerful and complete evaluation of progress towards biodiversity targets and sustainable development goals than previously possible. This fills a significant gap, exemplified by the limited range of ecosystems assessed in the Convention on Biological Diversity (CBD) Global Biodiversity Outlook and the IPBES Global Assessment. It also provides the theoretical basis needed to expand the number of ecosystems to be assessed under the Red List of Ecosystems approach, itself a key indicator of the Global Biodiversity Framework agreed in Kunming in December 2022. The United Nations Statistical Commission recently adopted the IUCN typology as a reference classification for extending the System of Environmental Economic Accounting (SEEA) framework to Ecosystem Accounts, meeting a long-recognized need for a spatially explicit, functionally based ecosystem typology to underpin natural capital accounting.

Sussex kelp recovery

IOZ's work on kelp and other seaweeds extends across the country, and culminated this year with the publication of the first official national Red List of British Seaweeds, which showed 7% of our 617 species are threatened, but also that more than half of these remain data deficient. IOZ is also a partner of the Sussex Kelp Recovery Project, which this year saw the publication of its Sussex Kelp Recovery Project: Progress and Impact report 2021-2022, documenting the wide range of research and monitoring activities being conducted by the partnership.

Mitigating and Adapting to Climate Change

Rewilding our Cities at the COP27 Climate Conference

There is an increasing recognition that although the climate change and biodiversity crises are fundamentally connected, they have been primarily addressed independently and a more integrated global approach is essential to tackle these two global challenges. Nature-based Solutions (NbS), such as restoration and rewilding, are hailed as a pathway for promoting synergies between the climate change and biodiversity agendas. In 2022, IOZ presented its work on rewilding our cities during a side event at the 2022 United Nations Climate Change Conference (UNFCCC COP27) in Egypt. The event, entitled 'Bringing nature-based climate action into cities in challenging times', focused on how urban nature-based action such as rewilding brings health, climate and nature benefits. It was brought together by ZSL in partnership with the German Development Institute, the Boticário Group Foundation for Nature Protection, Sociedade de Pesquisa em Vida Selvagem e Educação Ambiental (SPVS), and York University in Canada.

Providing a framework for predicting the effects of climate change on ancient woodlands in the UK

Predicting the impact of climate change on forests at management-relevant spatial and temporal scales is a key challenge for forestry science. Making such predictions accurately is challenging because the ecological responses of forests to climate change are often altered by the presence of other anthropogenic pressures, such as land use and land cover (LULC) change. While predictive quantitative models of forest responses to climate change are constantly improving, they are time- and data-intensive, making them often impractical to implement as a decision-guiding tool. Forest decision-makers need actionable information to choose forest management strategies and prioritise areas for intervention, meaning there is a need to synthesise the best available knowledge and data in a transparent, effective way. To address this, IOZ researchers showed how open-source data can be combined with a conceptual model of climate change-LULC interactions to derive maps of LULC-modified climate

change risks to different forest types. They illustrated their approach using ancient woodlands in the UK as a case study, mapping risks from changes in average climatic conditions and extreme climatic events, and where these may interact with edge effects from surrounding non-woodland LULC. The framework provides actionable information for forest decision-makers on where climate change and land use are likely to create hotspots of ecological change for different forest types.

Wildlife Health

Informing international One Health policy

IOZ researchers have played a leading role in the public discourse about wildlife health and disease spillover from wildlife to humans. IOZ's Professor Andrew Cunningham is a member of the intergovernmental Quadripartite (WHO/WOAH/FAO/UNEP) One Health High Level Expert Panel (OHHLEP), which was convened in 2021 to provide advice and guidance at the international level on the One Health approach. Over the past year, the OHHLEP has published two white papers to influence and guide policy: a paper on a One Health Theory of Change (Dar et al., 2022) and a policy paper on the Prevention of Zoonotic Spillover (Markotter, 2023). The latter was written in response to an apparent lack of prevention being included in the Pandemic Instrument negotiations by the intergovernmental negotiating body, which was established to draft and negotiate a convention, agreement or other international instrument to strengthen pandemic prevention, preparedness and response. Both of the OHHLEP white papers have been published in the open-access scientific literature (Adisasmito et al., 2023; Markotter et al., 2023) in order to increase their scientific credibility and to make them more accessible to researchers, policymakers and to the public. In addition, the OHHLEP published a scientific paper on developing disease surveillance systems using a One Health approach (Hayman et al., 2023). This paper includes guidance on One Health governance and the inclusion of surveillance of changes in the human-animal interface, since this is often what triggers the emergence of novel human diseases.

Eklipse Biodiversity and Pandemics Expert Working Group

Eklipse was created in 2016 to help governments, institutions, businesses, and NGOs make better-informed decisions when it comes to biodiversity and ecosystem services in Europe. In 2022 a Biodiversity and Pandemics Expert Working Group was established to provide policy advice to the EU on research funding for biodiversity and pandemic prevention. Andrew Cunningham is a member of the Expert Working Group, which has conducted literature reviews, canvassed scientific and practitioner opinion and run a focus group over the past year. An interim report in June was used by the EU to inform the next round of Horizon funding and a final report has been produced to inform EU research funding policy going forwards.

WHO Europe One Health Implementation Technical Advisory Group

World Health Organization/Europe – In 2022, the World Health Organisation (WHO) Europe regional office set up a One Health Implementation Technical Advisory Group, to which Andrew Cunningham was appointed. This group met in person twice in 2023, with additional on-line meetings, and is in the late stage of developing One Health implementation guidance that will hopefully be adopted by all 53 member states of the WHO Europe region.

Informing UK government policy on biodiversity and health

IOZ's disease surveillance work is carried out under contract to Defra, the Animal and Plant Health Agency, and Natural England. IOZ researchers meet policy makers on a 6-monthly basis to present findings as part of the GB Wildlife Health Partnership. Assessments are submitted as required to the Veterinary Risk Group and to the Human Animal Infections and Risk Surveillance group (HAIRS) to inform UK government policy.

Professor Andrew Cunningham gave oral evidence on One Health to the Parliamentary Science, Technology and Innovation Select Committee as part of their enquiry into "Emerging diseases and learnings from Covid-19".

Rob Deaville, Project Manager of the UK Cetacean Strandings Investigation Programme gave oral and written evidence on threats to UK cetaceans to the Parliamentary Environment, Food and Rural Affairs Select Committee enquiry into "Marine Mammals" in October 2022.

Dissemination of best feeding practice to reduce finch trichomonosis

In 2021, the greenfinch (*Chloris chloris*) was moved directly from the Green List to the Red List in the fifth review of Birds of Conservation Concern, due to the 62% reduction in its UK breeding population since 1993. This decline in greenfinch is result of finch trichomonosis and marks the first time that revision of threat status has occurred due to an infectious disease. Research by IOZ and BTO published in 2022 (Hanmer et al., 2022) showed how both greenfinch and chaffinch population declines are explained by a reduction in adult survival, which is most marked in peri-domestic habitats where supplementary feeding is common. Supplementary feeding has been implicated in the spread of trichomonosis through the congregation of birds at shared food and water resources. In an effort to safeguard wild bird welfare, IOZ is providing the public with best practice advice on feeding garden birds, which includes information on steps for disease prevention and control.

Disease risks from conservation translocations

IOZ staff gave evidence to the Environment, Food and Rural Affairs Select Committee on Species Reintroductions, in particular explaining the risks from disease of allowing unlicensed translocations of wild animals for conservation purposes and the threat these translocations represented to species conservation as illustrated by the plight of the red squirrel and the white-clawed crayfish in the UK.

Cetacean Strandings Investigation Programme

As part of its remit with the UK Government, IOZ's Cetacean Strandings Investigation Programme (CSIP) provided significant contributions to the 2022 (Agreement on the Conservation of Small Cetaceans of the Baltic, Northeast Atlantic, Irish and North Seas) and the International Whaling Commission. The CSIP also provided additional information to the UK's national report to Convention on Migratory Species (CMS). During 2022, CSIP staff gave testimony at a Defra select committee inquiry on the status of marine mammals in UK and international waters held at Parliament. The report arising from this inquiry is helping to shape future UK Government policy on marine mammals.

Developing a marine mammal contaminants indicator for European waters

IOZ research on the development of a marine mammal contaminants indictors for European waters informed the OPSAR Commission Quality Status Report 2023: Pilot Assessment of Status and Trends of Persistent Chemicals in Marine Mammals.

In 2022 the Cetacean Strandings Investigation Programme informed the Agreement on the Conservation of Small Cetaceans of the Baltic, Northeast Atlantic, Irish and North Seas and the International Whaling Commission. Killer whale (Orcinus orca). *Photo: CSIP-ZSL.*

Building capacity through teaching and training

The Institute of Zoology's integration with ZSL creates a unique research and education environment that allows staff and students to work alongside wildlife conservation professionals, as well as providing access to ZSL's living collections, enabling experiences and opportunities that go beyond their immediate academic disciplines.

PhD supervision

This year, IOZ hosted 79 PhD students, including 13 new students working on projects across the Conservation Challenges. These projects included 'Humpback whales of the Pitcairn Islands' (Biology and Recovery of Small Populations), 'The influence of habitat and anthropogenic pressures on cheetah hunting success and habitat use in the Serengeti ecosystem' (Coexistence Between People and Wildlife), 'Developing a next-generation biodiversity indicator to provide improved estimates of trends in wildlife abundance' (Global Biodiversity Monitoring), 'Building a modelling framework to aid the identification and management of key conservation areas for UK seabirds' (Mitigating and Adapting to Climate Change), and 'Can vaccination protect African wild dogs from canine distemper? Addressing a conservation emergency' (Wildlife Health).

IOZ is not a degree-awarding institution so all our PhD students are co-registered with university partners. The 13 new students in 2022/23 were co-registered at ten universities, including University College London (UCL), University of Oxford, University of Lisbon (Portugal), University of Agronomic Sciences and Veterinary Medicine (Bucharest), University of Pretoria (South Africa), Kings College London, University of Reading, University of Exeter, University of Sussex and University of Leeds.

Most of our PhD students are associated with one of five Doctoral Training Partnerships (DTPs). Four of this year's 14 new students came through the London NERC DTP (led by UCL), but we also welcomed students through the NERC SCENARIO DTP (led by University of Reading) and the NERC SuMMeR CDT (led by University of Plymouth). IOZ is also a member of three further DTPs (the SSCP DTP, led by Imperial College London; ARIES DTP, led by the University of East Anglia; and Oxford DTP, led by the University of Oxford) and another Centre for Doctoral Training, or CDT (the QMEE CDT, led by Imperial College London). The SuMMeR CDT (Sustainable Management of UK Marine Resources) welcomed its first PhD students in September 2022. Two studentships in the first cohort are affiliated with IOZ and a further three IOZ-affiliated projects were selected for the cohort starting in 2023.

Overall, 20 IOZ PhD students submitted theses during the academic year, with 100% completing within four years of starting their PhD.

Cost recovery for our PhD students is based on fee-sharing arrangements with our university partners. In 2022/23, full partnership arrangements accounted for 67% (53/79) of PhD students, which compares with 79% (61/77), 73% (62/83) and 60% (40/67) in 21/22, 20/21, and 19/20, respectively. We typically recover 50% of the student fees, which contributes towards the cost of supporting these students.

MSc courses

In an important milestone, we marked the first post-pandemic year with delivery of Masters teaching fully back to normal, although some online teaching tools learned during the pandemic have been retained to enhance the teaching experience. There have also been a number of further developments in course delivery, as well as an expansion of student numbers.

Masters courses with University College London (UCL)

The new MSc in Ecology and Data Science ran for the first time, recruiting strongly and attracting students with computing, engineering, mathematical, or statistical training who want to apply these skills in the field of ecology and conservation. The MSc in Biodiversity and Global Change ran successfully for the second year, with good growth in student numbers, while the MRes in Biodiversity, Evolution and Conservation continued to attract good numbers of students for a more research-intensive training in this field.

Masters courses with the Royal Veterinary College (RVC)

A review and restructure of the MSc Wild Animal Health and Wild Animal Biology courses was implemented with validation completed ready for implementation in the 2023/24 academic year. This had the twofold aim of reviewing course goals and content to ensure that they remain attractive by meeting the needs and aspirations of students, while streamlining the management of the courses to ensure smooth delivery. This has been a substantial piece of work for which all involved deserve a great deal of credit, but which we hope will bear fruit in the coming years as we continue to develop the courses to maintain their excellence and reputation. The revised course has enabled students on a separate One Health course (run by the RVC and London School of Hygiene and Tropical Medicine) to take our Ecosystem Health module.

Current student numbers

Course	Partner University	2019/20	2020/21	2021/22	2022/23
PhD students	Various	78	87	81	79
MSc Wild Animal Health	RVC	9	10	9	4
MSc Wild Animal Biology	RVC	16	18	17	15
MSci Wild Animal Biology	RVC	3	12	9	10
MRes Biodiversity Evolution and Conservation	UCL	18	16	18	17
MSc Biodiversity and Global Change	UCL		Started 2021/22	12	17
MSc Ecology and Data Science	UCL			Started 2022/23	18
Interventions in Wild Animal Health Field Course	RVC, Edinburgh, Melbourne, WII	26	18	37	21
TOTAL		150	161	183	181

Interventions in Wild Animal Health Field Course

The 2023 Interventions in Wild Animal Health Field Course marked the welcome return of international participants and lecturers to our field site in Sariska Tiger Reserve, India, after two years away. Twenty-one veterinarians attended the course bringing the total number of wildlife health professionals trained through this programme to 202. This year we hosted veterinarians from a range of countries including Hong Kong, Canada, Philippines and our first student from Iran. The course has now taught veterinarians from 31 countries, with 69% of students from low-to-middle-income countries, demonstrating the Wildlife Health Bridge's dedication to capacity building for wildlife professionals on a global scale. The 2023 course saw a particularly strong bond built between the students, who stay in regular contact through WhatsApp, sharing experiences and skills with each other. We are fortunate that continued sharing of knowledge is a consistent theme for our IWAH courses and we are proud to have been part of building such a network.

Veterinarians at the Interventions in Wild Animal Health Field Course in Sariska in 2023. Photo: ZSL

Residencies

The ZSL/RVC partnership is the only place in Europe that hosts European College of Zoological Medicine residency programmes in both Wildlife Population Health (WPH) and Zoo Health Management (ZHM). These programmes are validated by the European Board of Veterinary Specialisation and build on ZSL's international reputation as a world-leader in veterinary zoological practice and education, augmenting global capacity in this field to promote wild animal welfare and conservation. Our current WPH Resident, Marco Vecchiato, successfully completed his MVetMed second year and is working on a research project co-supervised by UK Health Security Agency scientists to investigate the occurrence of *Borrelia* spp. infection in wildlife hosts and vectors.

Undergraduate training

IOZ staff delivered invited lectures to undergraduate students at universities in the UK, including presentations by the Cetacean Strandings Investigation Programme team to a total of 290 undergraduate students across Bangor University, University of Surrey, University of Exeter, Keele University, University of Liverpool and Newcastle University.

Practitioner training

IOZ's training provides opportunities for conservation practitioners to benefit from our expertise. Over 2022/23 this included running two 2-day in-person IUCN SSC Conservation Translocation Specialist Group training courses, delivered to 64 participants, including 34 from Natural England. The training focused on enabling participants to apply the 'IUCN Guidelines for Reintroductions and Other Conservation Translocations' and 'Defra's Reintroductions and Other Conservation Translocations: Code and Guidance for England'. The training supports practitioners to achieve pre-determined objectives, identify and manage risks, and draw on a suite of stakeholder engagement tools to improve conservation translocation success.

IOZ's research programmes also provide opportunities for staff to deliver a wide range of practitioner training throughout the year, including training on seabird survey, capture, handling and sampling techniques in Rodrigues and Mauritius; acoustic telemetry methods and fish tagging processes; training on standardized interview techniques for collecting local ecological knowledge in Kazakhstan, and training Chilean Park Rangers on amphibian monitoring.

Overall, during 2022/23, 446 conservation practitioners participated in IOZ training courses, including 219 overseas participants, and 66 trainees from low- and middle-income countries.

Andrés Valenzuela Sánchez, IOZ Research Fellow in Wildlife Health, training Park Rangers from the Parque Nacional Alerce Costero and the private protected area Reserva Costera Valdiviana, southern Chile. Our team supported the design and establishment of long-term amphibian monitoring in the Nature Conservancy's Reserva Costera Valdiviana. This represents the first large-scale, amphibian-focused monitoring programme in Chile and is being used as a model by other protected areas interested in setting up conservation monitoring efforts. Photo: Andrés Valenzuela Sánchez

Placement schemes

In August we hosted five 16-year-old Nuffield Research Placement programme students, giving science skills workshops to students from low-income backgrounds and those who are first in their immediate family to attend university. We also hosted three students in the In2Science placement programme, which aims to promote social mobility and diversity in STEM.

Five Nuffield Research Placement students spent a week at IOZ in August. Photo: Lucy Brown ZSL

Inspiring new, diverse, and existing audiences to care about and better understand wildlife and its conservation

A key part of ZSL's work involves communicating science to a range of audiences, and we are in a unique position to engage with over 1.9 million people visiting ZSL's Zoos annually. Our public engagement programming creates opportunities for staff and students to discuss research with public audiences and provides pathways to impact through policy and practitioner engagement. The full cost of ZSL's communications and Learned Society activities, including ZSL's public lecture series, symposia, public engagement and outreach, is met by income from ZSL's portfolio of scientific journals.

Science and Conservation Events

Our free public lecture series continues to highlight new research and draw on our wider collaborations and conservation work across ZSL. This series included two online and four in-person events, all of which are posted on the ZSL Science and Conservation YouTube channel so that lectures are accessible to audiences worldwide. To date, 25 Science and Conservation Events have been uploaded to the YouTube channel, accruing 35,400 views in 51 countries and territories. Over 2,790 people now subscribe to the channel.

International Symposia

International Symposia enable science and conservation professionals to share the latest research and create networking opportunities. Workshops associated with Symposia focus on priority setting and outputs, including scientific papers and position statements. Our two-day, in-person symposium *Ecological connectivity across temperate coastal habitats – moving towards seascape scale restoration* brought together scientists, policy makers and conservation practitioners working on seascape restoration. This symposium contributed to the aims of the ReMeMaRe Connectivity in Estuarine, Coastal and Transitional Ecosystem Restoration (ConnECTER) Special Interest Group.

Public Engagement with Science

Our public engagement and outreach focuses on (1) engaging traditionally underserved audiences by prioritising the needs of these groups through co-production and (2) engaging wider audiences through our Zoos, outreach and Community and Learning activities.

Refugia

A highlight this year was Refugia, a 6-month NERC-funded engagement programme, developed by IOZ and the New Art Studio, a therapeutic arts group for asylum seekers and refugees. The co-created programme focused on topics relevant to both the lived experiences and cultures of asylum seekers and refugees and wildlife conservation. With access to art materials, translators and ZSL London Zoo, participants shared insights on topics including urban wildlife, wildlife and people, life in water, forests and animal migration. The programme enabled a safe and inclusive environment for mutual learning, expression, discussion and understanding. By making art together, participants connected in profound ways, immersed in the therapeutic benefits of nature and art. A co-produced exhibition of 200 artworks produced by the 42 participants involved in the project allowed the wider public to engage with the role of ZSL in conservation and the lived experiences of migrant artists. Refugia received a BIAZA Silver Award for Equality, Diversity and Inclusion. One participant from New Art Studio has since joined ZSL's team of Biobank volunteers.

Members of the New Art Studio sharing art practice and a panel in the Refugia Exhibition. Photo: Lucy Brown

Science festivals

IOZ staff and students provided science input for the Southbank Centre's programme *Planet Summer,* including two participatory art projects Bird Rave and Red Rope, reaching over 700 people, a sound installation focusing on threatened species on the Southbank, and advised on art in the Dear Earth exhibition at the Hayward Gallery. Fifteen researchers travelled to the Green Man Festival in Wales, participating as Human Books to the Living Library in Einstein's Garden. IOZ staff and students spoke to over 1,000 people during the 4-day festival, as well as led workshops on hedgehog conservation.

Kate Scott-Gatty, Isabel Hesse and Chloe Hartland at the Green Man Festival. Photo: Lucy Brown

Soapbox Science

Our international public outreach platform *Soapbox Science* showcases the work of women and non-binary scientists by placing them on soapboxes in public spaces in a fun, informal setting. Each event offers scientists a chance to break free of conventional communication methods, such as lectures, and aims to inspire young scientists of the future, while challenging stereotypes on who or what a scientist really is. During the year, 32 Soapbox Science events were held in 14 countries including 384 speakers and reaching an audience of over 32,000 people. The London event in 2023 was again generously sponsored by the L'Oreal UNESCO For Women In Science Scheme.

Engagement at ZSL

IOZ staff and students benefit from working with ZSL's wider teams, including the Community and Learning teams at London and Whipsnade Zoos and ZSL's central events team. IOZ science provides content to ZSL's standard educational offer, reaching 75,675 schools visitors over the 2022/23 academic year. In addition, ZSL's Education Access Scheme allows pupils at 51 schools in Camden and Westminster to visit the Zoo as often as they wish, with 43% of these visits involving a workshop that includes IOZ science. Our online engagement provides virtual opportunities for learners to engage with our work without visiting the Zoo, such as Scientist in Your Classroom. Over the past year we have organised 34 Scientist in your Classroom sessions to 25 schools with 1,621 attendees. IOZ staff and students also participated in ZSL's Zoo Nights, a series of late opening evenings, engaging with 1,450 visitors at science stalls and Scientist on the Sofa sessions.

Public engagement training

Training during the year was attached to programming, so that staff and students involved in public engagement activities felt confident to participate. In addition, 17 researchers received training on public engagement and trauma-informed practices and creative facilitation in advance of their involvement with asylum seekers and refugees in the Refugia project, developing the necessary skills to create and deliver similar projects in the future.

Local organisers for Soapbox Science were trained through a series of video and skype sessions. Training for 35 teams (150 people) covered all aspects of organizing a public outreach event, including funding, press and media, and how to run a training workshop for speakers. For the London event, a training session was held for 12 researchers from a variety of disciplines. Training covered preparing a talk for a non-specialist audience, use of language, use of props, and issues affecting women and non-binary people in science. We also train volunteers for all events on how to collect evaluation data and how to support speakers and the audience. An estimated 350 volunteers took part in this training during the year.

Student Award for Excellence in Societal Engagement

Two IOZ PhD students in the Urban Wildlife Challenge Team, formed under the Science and Solutions for a Changing Planet Doctoral Training Programme at the Grantham Institute (Imperial College), were presented with the Student Award for Societal Engagement. The team developed and delivered a series of 11 workshops for 300 local primary school children, allowing them to explore the wildlife that urban London has to offer.

Careers events

We continue to contribute to ZSL's wider careers events, as well as offer sessions specifically for young people who are under-represented in wildlife conservation. We welcomed 250 Year 9 students from Mulberry School Academy in Whitechapel, where 90% of the students have Bangladeshi heritage, and we plan to work with the Mulberry Schools Trust to develop a science enrichment programme in the coming year. We also contributed to a RVC careers and curriculum talk reaching 500 16-year-olds from under-represented backgrounds in science.

Press reach and media

IOZ researchers were supported by ZSL's press team throughout the year. Since 1 September 2022, IOZ research has appeared in 2,982 news articles, with a total reach of 1,060,995,745 (with an equivalent advertising value of £32,733,862).

Recruiting citizen scientists

IOZ has a strong track record of enlisting help from citizen scientists to enable projects to run in the long-term that would otherwise be logistically and financially unfeasible. Since 1 September 2022, the Garden Wildlife Health project received 6000 disease incident reports from c. 2300 members of the public.

Over the year 116 citizen scientists participated in the London HogWatch project, including park surveys, which involve deploying and setting up camera traps. Forty-five volunteers have hosted cameras in their garden in Kingston, Hammersmith and Fulham. London HogWatch expanded the Historical Knowledge Survey to a London-wide Hedgehog and Wildlife Survey in order to gain a better understanding of hedgehog, badger, and fox distributions in Greater London and changes in populations over time, with 600 responses to the survey during the year. In partnership with Network Rail, 19,900 camera trap photos of wildlife from railway line sides have been analysed by citizen scientists.

The Cetacean Strandings Investigation Programme received reports of strandings from c. 1000 citizen scientists during the reporting period.

Scientists participating in Soapbox Science in Arusha, Tanzania. Photo: Soapbox Science Arusha

How ZSL supports and amplifies the work of the Institute of Zoology

The Institute of Zoology is the research division of ZSL, an international conservation charity working in over 60 countries worldwide. ZSL's strategy, *ZSL200*, was driven by IOZ, with the three Priority Areas of *ZSL200* mapping directly onto three of IOZ's Conservation Challenges (Biology and Recovery of Small Populations, Co-existence between People and Wildlife, Wildlife Health). IOZ's two remaining Conservation Challenges (Global Biodiversity Monitoring, Mitigating and Adapting to Climate Change) contribute cross-cutting knowledge to inform conservation practice across the three Priority Areas. The alignment between ZSL's Priority Areas and the IOZ's Conservation Challenges creates exceptional opportunities to translate science into conservation impact.

Collaborations with ZSL colleagues support IOZ research and impact in myriad ways across our five Conservation Challenges. For instance, our work on the Biology and Recovery of Small Populations continues to draw on the expertise of ZSL's animal keepers. In June, a ZSL bird keeper travelled to Sedgewick County Zoo, Kansas, to hand rear Sihek (*Todiramphus cinnamominus*) for reintroduction onto Palmyra Atoll in 2024 as part of our Extinct in the Wild initiative. ZSL zookeepers also assisted with the incubation and hand-reading of Endangered Mauritius kestrels (*Falco punctatus*), a focus of one of IOZ's Long-term Programmes, thus providing valuable support to the Mauritian Wildlife Foundation and National Parks and Conservation Service in the recovery of their threatened bird species.

Nestling sihek being hand-reared in the translocation quarantine facility at Sedwick County Zoo, Kansas. Photo: Thomas Manglona KUAM

Similarly, in our Conservation Challenge of Wildlife Health, IOZ researchers work with ZSL colleagues to better understand the impact of amphibian chytridiomycosis on the Critically Endangered mountain chicken frog (*Leptodactylus fallax*). Chytridiomycosis was first recorded in Dominica in 2002 and has since caused the population to plummet by over 99 per cent. The most recent survey, carried out in 2023 with participation from both IOZ and ZSL staff, recorded only 21 of the frogs alive in the wild. The Mountain Chicken Recovery Programme, an international collaboration bringing together expertise from across the Caribbean and Europe, includes caring for safety net breeding populations – including a new exhibit for the species at ZSL London Zoo.

IOZ-ZSL collaborations such as these have resulted in numerous published outputs during the year. These have included, for instance, an overview of the status of 84 animal and plant species currently assessed as Extinct in the Wild (EW), highlighting that most ex situ animal populations comprise less than 1000 individuals and are founded by few individuals, likely with low genetic diversity. The research showed that re-establishment of species in the wild has been successful for some species, but has currently only been attempted for about one-quarter of current EW species (Smith et al., 2023). Another collaboration, between IOZ researchers and ZSL's Conservation and Policy team, produced a review of the Living Planet Index to demonstrate its value to the field of biodiversity monitoring and highlight how it has been used to portray a compelling account of the changing status of global biodiversity through its application at policy, research and practice levels (Ledger et al., 2023).

The strength of our integration with ZSL is reflected in IOZ's research, impact, capacity building, and public engagement activities. For instance, over the 2022/23 academic year:

- One in every ten research papers by IOZ staff included a ZSL co-author (14 out of 147)
- Twenty-eight out of 183 (>15%) live research projects led by IOZ staff include 1–4 colleagues from across ZSL
- ZSL and IOZ colleagues collaborate closely in the development of ZSL policy and policy responses through joint membership of ZSL's Policy and Leadership Group
- ZSL colleagues contribute unique practitioner perspectives to IOZ's teaching and training, including through the delivery of lectures and modules to our MSc courses, supervision of MSc student projects, and co-supervision of PhD students
- IOZ staff and students participate in ZSL's Community and Learning activities and Careers events, and engage with over 1,600 secondary school students annually through 'ZSL in your Classroom' sessions

ZSL also provides financial support to IOZ, underwriting a significant proportion of our indirect costs. In 2022/23, ZSL covered 78% of these indirect costs, amounting to £717k (see Financial Summary).

The Living Planet Report 2022, produced by ZSL and WWF, focused on the global double emergency of climate change and biodiversity loss. The speed and scale at which biodiversity is changing as well as the impacts of this change are monitored using indicators such as IOZ's Living Planet Index.

Based on the largest dataset yet, the global Living Planet Index shows an average 69% decrease in monitored wildlife populations between 1970 and 2018. Particularly stark declines are shown in the Latin America and Caribbean region (94%) and in freshwater species (83%). The main drivers of wildlife population decline around the world are habitat degradation and loss, exploitation, the introduction of invasive species, pollution, climate change and disease.

Key Grants Awarded

The Institute of Zoology has seen significant funding successes this year, including £236,836 from Imperial College London for IOZ's research for the Leverhulme Centre for The Holobiont; £260,000 from Natural England for IOZ's Disease Risk Analysis and Health Surveillance for the Species Recovery Programme; £139,424 awarded from the National Institute of Biodiversity and Conservation (Ministry of Environment, Angola) to survey mammals in the Maiombe National Park, Angola; and £207,519 awarded from the Arcus Foundation to support IOZ's work to conserve the world's rarest ape, the Hainan gibbon (*Nomascus hainanus*). Details on other significant grants is given below.

Red Squirrel Conservation Strategy

Red squirrels are a declining species in England, now lost from the majority of their former range. Although there are no reliable historic estimates of red squirrel population change, it is thought that their range has contracted by 95% and they are classified as Endangered on the IUCN Red List. The causes of decline are multiple ranging from habitat loss and fragmentation to the disease squirrel pox. These factors present challenges to red squirrel recovery; however, with appropriate management support recovery should be possible. In partnership with Natural England, the University of Bern and the UK Squirrel Accord, IOZ will use adaptive management methodology to establish suitable recovery actions for the red squirrel. This year, IOZ was awarded £309,849 from Natural England to advance this work.

Illegal cheetah trade from the Horn of Africa

IOZ was awarded £137,417 from Colorado State University to collaborate on a USFWS-funded project to address illegal cheetah trade from the Horn of Africa. A major part of the project is using local ecological knowledge to gain a better understanding of species distributions. Two-way training and mentoring with local organisations, including government wildlife authorities, will be used to transfer locally relevant knowledge and tools. The project started in January 2023 with a workshop in Ethiopia to train government officers from Ethiopia, Djibouti, Eritrea, South Sudan and various regions of Somalia, and Kenya. The project aims to establish baseline information that can be used to target management interventions to safeguard cheetah in the region and establish lasting capacity for ongoing monitoring.

Vector-Borne RADAR project

The detection of Usutu virus (USUV) in wild birds in 2020 represents the first confirmation of a mosquito-borne viral zoonosis in the UK. A multi-disciplinary study, entitled Vector-Borne RADAR (Real-time Arbovirus Detection And Response), was funded by a collaboration between Defra, BBSRC, MRC, NERC and UKRI's 'Tackling infections' strategic theme in a call for One Health approaches to investigate vector-borne disease. The project aims to enhance surveillance for Usutu and West Nile virus in wild birds and mosquito vectors and to develop an early warning system for the detection of viral disease outbreaks in wild bird populations. This year IOZ was awarded £289,342 to advance this work.

Darwin Tree of Life

An international effort is underway to sequence the genome of every species in existence in order to understand the evolution of the diversity of life, explore the biology of organisms and ecosystems, aid conservation efforts and provide new tools for medicine and biotechnology. The genomic sequencing of species in the UK is led by the Wellcome Sanger Institute under the project Darwin Tree of Life. As a partner in this effort, IOZ has been awarded £170,740 from the Wellcome Sanger Institute to obtain tissue or blood samples from vertebrates in the UK for DNA extraction and whole genome sequencing.

Equality, Diversity and Inclusion

Throughout year, Equality, Diversity, and Inclusion has been a top priority for the Institute of Zoology as we have increased our support networks and procedures, amended plans to fit current needs, and welcomed a new full-time EDI and Science Review Boards Administrator. To better understand staff and student experiences, EDI forums were held for all IOZ staff and students. In addition, a ZSL-wide 'Wellbeing Survey' and a Science EDI Committee 'Student Wellbeing Survey' generated detailed and anonymous feedback relating to social, financial, physical and mental wellbeing. These surveys enabled the Science EDI Committee to identify and implement priority actions to enhance support for our community, including creating a monthly EDI book club, increasing participation in our Mentor Scheme, implementing financial support for PhD students, and organizing new social events.

IOZ's continued focus on safeguarding has resulted in the creation of situational awareness training, which will be rolled out in the 2023/24 academic year. Following last year's harassment and bullying training for supervisors, we led a three-hour session for students and early-career professionals to identify signs and impacts of harassment and bullying, evaluate power dynamics, and improve support and reporting procedures for harassment and bullying.

The ZSL Library has continued its 'Hidden History' blogs, supported multiple students and an independent researcher on work exploring ZSL's colonial past, and created displays for 'Women and Girls in Science' Day and 'South Asian Heritage' Month. IOZ staff and students also participated in a range of careers-in-science events, including sessions for students in ZSL's Education Access Scheme (in Camden and Westminster).

We are creating conversations around decolonizing science, both within our organisation and externally; for example, by organizing a decolonization workshop for over 40 University of Cambridge undergraduate students. We also held an IOZ staff and student meeting and questionnaire survey on the topic 'Starting a conversation about decolonization in ZSL science' to increase discussions around ethical work practices and co-creation of a decolonization strategy to help educate our staff and students. Adapting our working practices and communications around this will be one of our EDI priorities for 2023/24.

Our staff and students continue to benefit from ZSL's support initiatives, including training for Mental Health First Aid, Welfare Champions, and the Employee Assistance Programme.

Environment at the Institute of Zoology

Throughout the year, Institute of Zoology staff continued to resume international field research programmes that had previously been affected by Covid-19 restrictions. Staff and students had full access to the IOZ's Nuffield and Wellcome buildings as well as ZSL's Library and wider facilities, alongside the flexibility of remote working. To support our teaching activities, we invested in an upgrade of the Oak Lecture Theatre in ZSL's Community and Learning building, which includes a new AV system so that we can live-stream and record lectures. This will improve the delivery of our teaching to our WAB/WAH MSc students, as well improving integration with the Royal Veterinary College's platform. In the Wellcome building we have carried out extensive repairs to the roof on the second floor, redecorated facilities including some offices, the electrophoresis lab and the dry-samples storage room, and installed new central heating boilers. We have also upgraded the AV equipment in both the Nuffield and Wellcome buildings to support virtual meetings and hybrid working.

Lemur leaf frog (Agalychnis lemur) *in Central Panama. Photo: Gonçalo Rosa*

Rebounding populations, such as the Lemur leaf frog (Agalychnis lemur), offer a unique opportunity to characterize changes in immune phenotypes following disease outbreaks but also to assess the resilience of captive animals in coping with a naturalized pathogen in the wild. IOZ research on this species will support the development of a habitat and disease management strategy aimed at facilitating species recovery throughout its historical range via targeted habitat reclamation.

Theory of Change for the Institute of Zoology

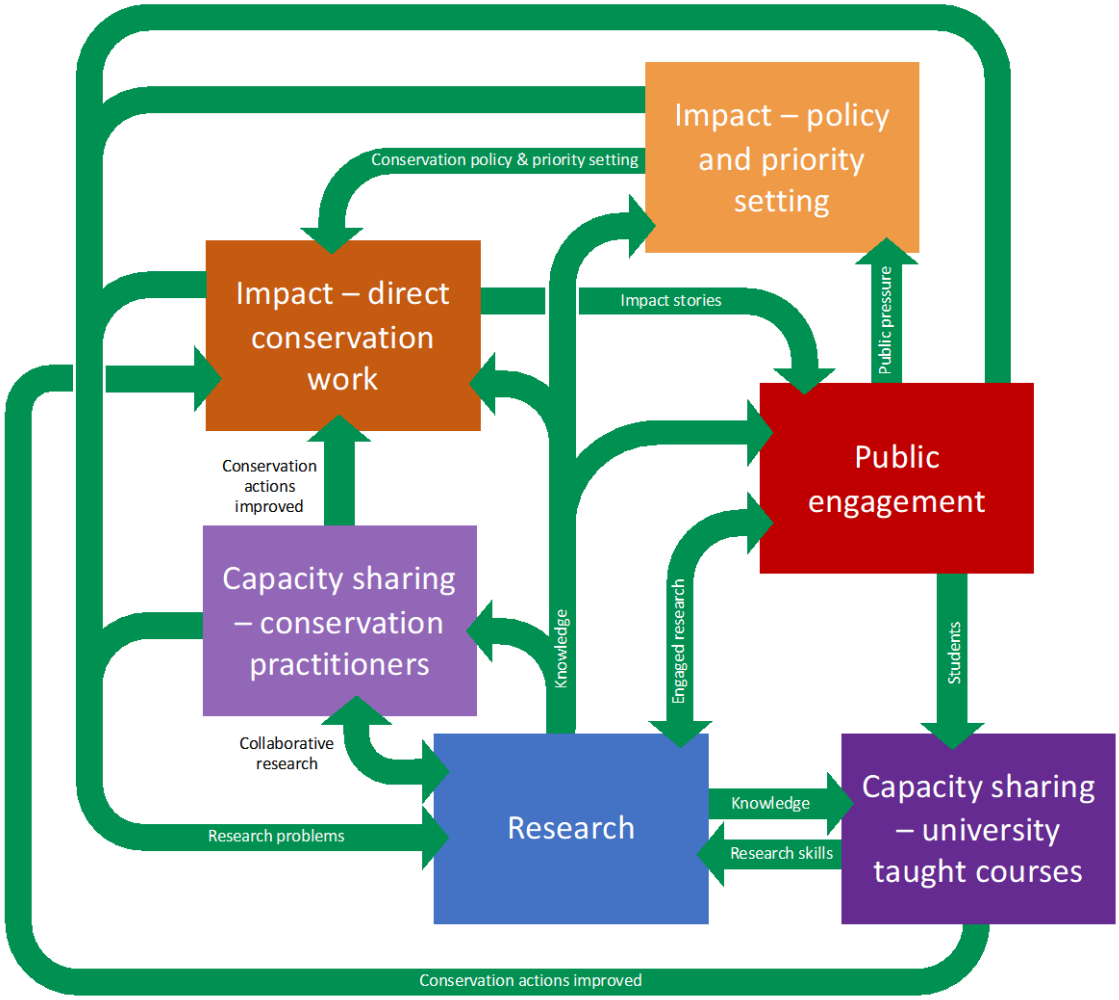
The Institute of Zoology achieves impact through four delivery areas: research, conservation impact, higher education teaching and practitioner training, and public engagement. IOZ's Key Performance Indicators (KPIs) have been developed to measure our progress in these activities. However, at the Independent Science Advisory Board meeting in autumn 2022 it was suggested that a Theory of Change (ToC) approach might help us to demonstrate IOZ's impact more clearly through a rationalised set of KPIs, as well as enable us to identify the blockers and enablers to achieving conservation impact.

Over the past year, two workshops were held with IOZ staff and students on the development and application of a ToC. In between these workshops, our draft ToC was presented to ISAB for their feedback and advice. This co-creation process identified the pathways we expect to see from our activities, as well as the outcomes that lead to conservation impact. The final workshop, held with additional participation from ZSL colleagues, led to a series of recommendations that have the potential to advance our work through wider collaboration with ZSL's Living Collections and Conservation and Policy teams, including the joint development of Communities of Practice to share knowledge and insights, cross-ZSL thematic groups, such as Amphibian Thematic Meetings, the development of ZSL mission funds that support the design of cross-organisational projects, and support for income diversification.

The ToC is split into four pathways which equate to IOZ's routes to delivery. The overview diagram below shows the relationship between these broad areas of work, with the detailed ToC exploring each area in depth.

In a practical sense, the ToC supports IOZ's Business Plan, and allows IOZ to map where our KPIs sit within the structure, and review them within this context. In addition, the organisation-level ToC can be used as a starting point for staff within IOZ to think through how their work is driving conservation, research and social impacts.

A priority for 2023/24 will be to use the ToC to review and rationalise our current IOZ KPIs. The ToC is a live document and is being critiqued and updated as needed.



Overview of IOZ's Theory of Change

Appendix A. Institute of Zoology Publications

(1 September 2022 to 31 August 2023)

Journal papers

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