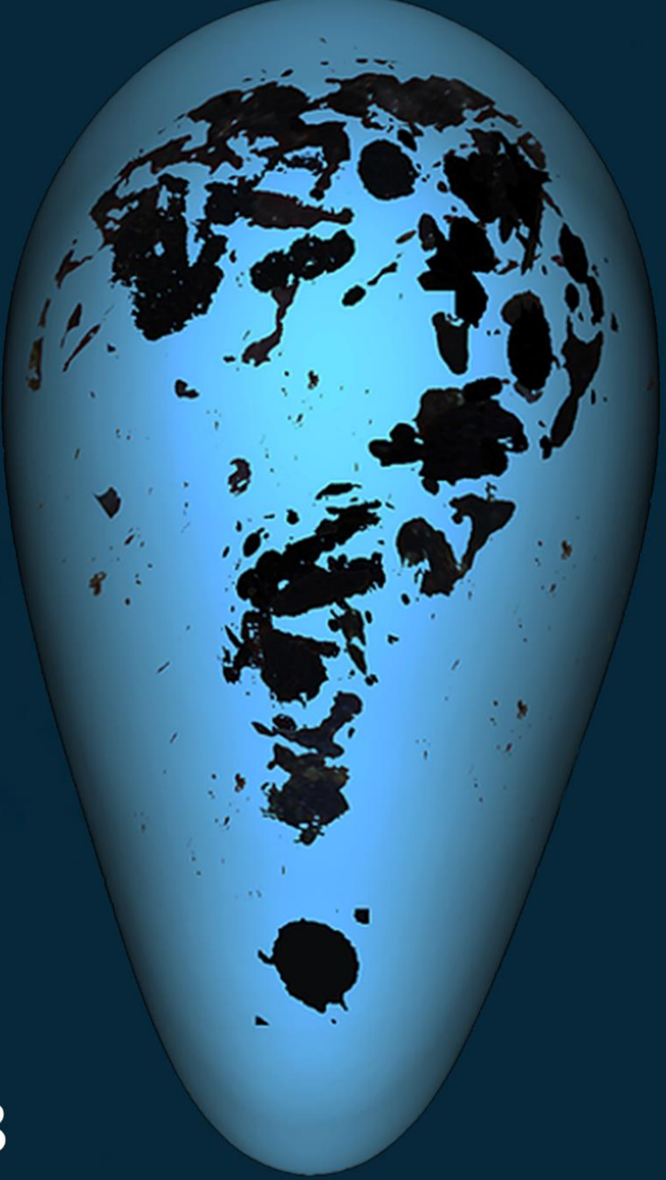
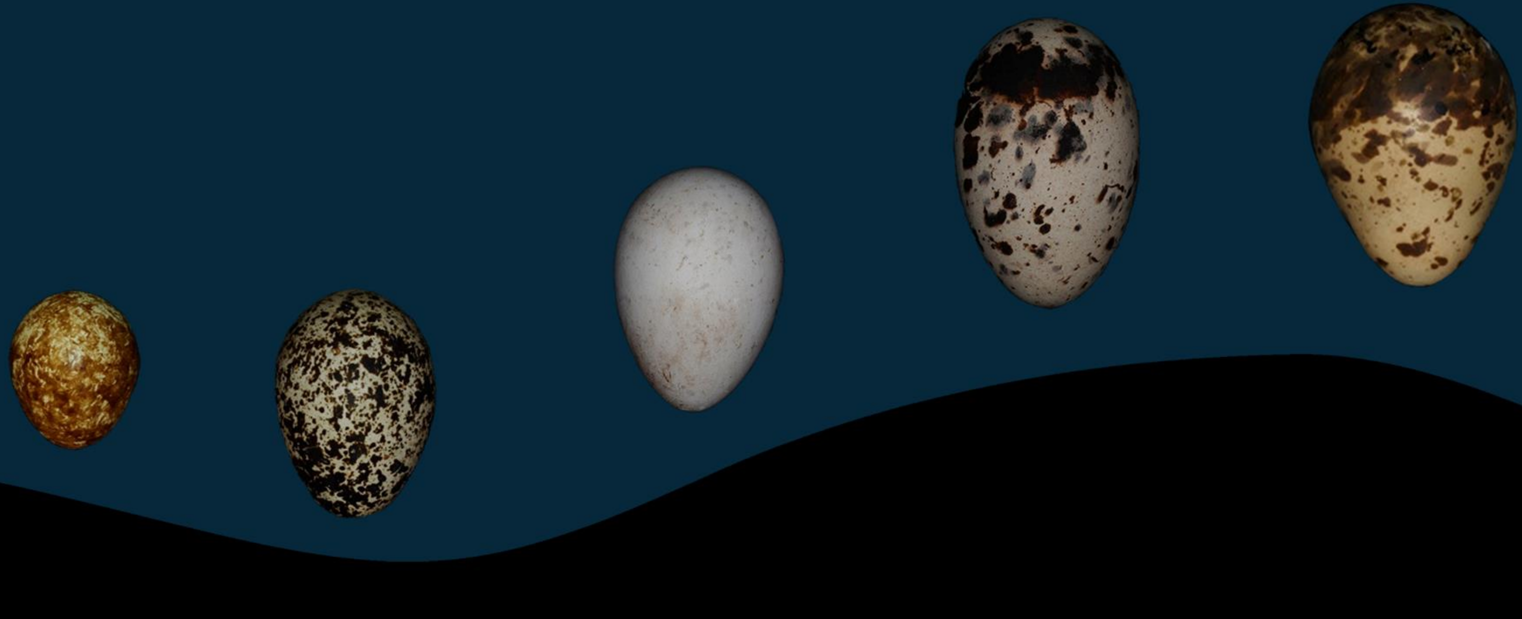
Resolving the Mysteries of the Avian Egg

CONFERENCE



Tuesday 20th March 2018

The University of Sheffield



PROGRAM AND ABSTRACT BOOKLET

Contents

This conference was organised by Professor Tim Birkhead and Dr Marie Attard at the University of Sheffield, United Kingdom.

Sponsored by:

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Synopsis: Bringing together innovating new research on the structure and function of the egg

In recent years and even months, there has been a flurry of important discoveries relating to the evolution, characterisation and development of different egg morphologies – including egg shape, size, colouration, pattern and shell surface structure.

With this one-day meeting, we aim to provide an opportunity for researchers to report new findings on the evolution, structure and adaptive function of avian eggs. The overall theme of the meeting is deliberately broad and our aim is to encourage discussion and provide different perspectives. The meeting features contributed talks, invited keynote speakers and a poster session covering all facets of egg form and function.

We also see this conference as an opportunity to bring together the egg research community and will welcome anyone involved in egg-related research, including postgraduates, academics, museum staff, ornithology societies and industry personnel.

Keynote Speakers

Douglas Russell

Douglas R. D. Russell is the Senior Curator at the Natural History Museum, London responsible for the Natural History Museum collection of Birds' eggs and Nests. Working as part of a team of ornithologists in the Bird Group at Tring for the last 17 years, Douglas has been involved in research on topics as diverse as the evolution of eggshell appearance, penguin sexual behaviours Edwardian's couldn't handle and the history of egg collecting.

Dr Jim Reynolds

Jim Reynolds is a lecturer in Ornithology and Animal Conservation at the University of Birmingham where he works on the reproductive biology and the nutritional ecology of birds in terrestrial and marine ecosystems. He is interested in how birds obtain the raw materials for egg production with a particular focus on the functional significance of pigmentation in eggshells. His work has highlighted how anthropogenic food can have profound effects on the breeding biology of birds, including the composition of eggs, the growth trajectories of chicks and population stability.

As a leading authority on avian reproduction, he has helped to advance techniques particularly at the nest to understand the process of incubation within various ornithological contexts. He is an Associate Editor of the British Ornithologists' Union journal *Ibis* and a co-editor of the Oxford University Press book entitled "Nests, eggs, and incubation: new ideas about avian reproduction".

Dr Mary Caswell Stoddard

Mary C. (Cassie) Stoddard is an evolutionary biologist and behavioural ecologist at Princeton University. She specialises on visual communication and signalling in birds, including egg mimicry among brood parasites and their hosts, and different strategies used by birds to help camouflage their eggs. The relationship between the structure and function of phenotypic traits in avian eggshells has also formed a key aspect of her research. Her recent findings to explain the shape of bird eggs were published in Science and received worldwide attention.

Her work incorporates techniques from physiology, mechanical engineering to comparative genomics. This research combines experiments in the lab and field, together with museum-based studies using extensive egg and nest collections.

Dr Charles Deeming

Charles Deeming is a principal lecturer at the University of Lincoln and specialises in avian and reptilian reproduction. His primary research explores the role of the nest within the incubation process and factors influencing the evolution and development of avian egg traits. He started working on aspects of bird incubation in the early 1980s and completed his postdoctoral studies on incubation effects on the sex and embryonic development of alligators. More recently, he has explored how egg shapes of birds, both past and present, might be associated with different nesting behaviours or incubation methods.

He has used his expertise to provide comprehensive scientific overviews of the diverse field of avian reproduction through his books, including “Avian incubation: behaviour, environment and evolution” and “Nests, eggs, and incubation: new ideas about avian reproduction”.

Delegate information

REGISTATION

All delegates must have registered online by 2nd March 2018 to attend. Registration is £15.

On the day of the event, participants are required to go to the registration desk at the venue between 9:30-9:50 to pick up their name badge and program.

The registration desk will only be open until 9:50. After this time, please speak to Professor Tim Birkhead or Dr Marie Attard should you require any assistance.

ORAL PRESENTATIONS

The oral presentations will be taking place upstairs in the ICOSS conference room.

POSTERS

Posters will be on display in the front foyer throughout the meeting from 9:50-17:00. Poster presenters are invited to hang their poster on their arrival and asked to remove their posters by 17:00. Posters will be displayed in the foyer downstairs.

CATERING

Tea, coffee and lunch will be provided. Please notify us of any dietary requirements.

INTERNET ACCESS

Wi-Fi is available on site through eduroam and will require your login name and password.

VENUE

Interdisciplinary Centre of the Social Sciences (ICOSS)
The University of Sheffield
219 Portobello
Sheffield S1 4DP
Web: https://www.sheffield.ac.uk/icoss/contact

LIABILITY

The University of Sheffield and conference organisers will not accept responsibility for damage or injury to persons or property during the meeting. Participants are advised to arrange their own personal health and travel insurance.

Programme

ICOSS Conference Room, The University of Sheffield

Tuesday 20 March 2018

TIME	EVENT
9:30-9:50	Registration and coffee
9:50	Welcome by Tim Birkhead
SESSION 1 (KEYNOTE) **CHAIR:** Tim Birkhead	
10:00	Douglas Russell, "21st Century Oology, museums and the legacy of collecting"
10:30	James Reynolds, "From egg description to developing a conservation program"
11:00	**MORNING TEA**
SESSION 2 (KEYNOTE) **CHAIR:** Nicola Hemmings	
11:30	Mary Stoddard, "The ecology and evolution of avian eggs"
12:00	Charles Deeming, "Avian egg shape is a reflection of terrestrial locomotory constraints rather than reproductive selection"
12:30	**LUNCH BREAK AND POSTER SESSION**
SESSION 3 **CHAIR:** Marie Attard	
14:00	Sjúrður Hammer, "Long-term trends of egg sizes of three seabirds and spatial variation of Great skua eggs"
14:20	Charles Deeming, "Pelvis morphology suggests that early Mesozoic birds and dinosaurs were too heavy to contact incubate their eggs"
14:40	Ian Hays, "How the egg rolls: A morphological analysis of egg shape in the context of displacement dynamics"
15:00	**AFTERNOON TEA**
SESSION 4 **CHAIR:** Duncan Jackson	
15:30	Marie Attard, "Egg shape mimicry in parasitic cuckoos"
15:50	Kiara L'Herpiniere, "Unscrambling the determinants of eggshell colour and spottiness in a continent-wide study"
16:10	Nicola Hemmings, "Extraordinary sperm to egg ratios in seabirds"
16:30	Tim Birkhead – Conference reflection
16:40	Close of meeting
17:00	Conference Drinks and Dinner (Optional. Pay for your own drinks/meal)

Poster Session

P1. The point of a Guillemot's egg

[1]Tim Birkhead, [1]Jamie Thompson, [1]Duncan Jackson, [2]John Biggins

[1]Department of Animal and Plant Sciences, University of Sheffield, UK
[2]School of Mathematics and Statistics, University of Sheffield, UK

The pyriform shape of the Common Guillemot's *Uria aalge* egg has long been considered to be an adaptation to prevent eggs rolling off the cliff ledges on which this species breeds. Rolling was thought to be prevented either by the egg spinning like a top, which is not the case, or by rolling in an arc, which it does but with little influence on whether the egg will fall from a ledge. We therefore sought alternative explanations for the pyriform shape of their eggs. Here, I will discuss one of two proposed possible explanations. Guillemot's breed in extremely dense colonies, which makes their eggs vulnerable to contamination by debris such as faeces. We present evidence that the pyriform shape of Guillemot eggs minimises the impact debris contamination has on eggshell gas exchange. Most contamination is on the pointed end of the egg; the pyriform shape thus keeps the blunt end of the egg, which has the highest porosity, relatively free of contamination. This may facilitate adequate gas exchange during incubation despite the Guillemot's egg being contaminated with debris, as well as aiding in the hatching process because the chick emerges from the blunt end of the egg.

P2. Are Common Guillemot eggs self-cleaning?

[1]Duncan Jackson, [1]Jamie Thompson, [1]Nicola Hemmings, [1]Tim Birkhead

[1]Department of Animal and Plant Sciences, University of Sheffield, UK

Unlike most birds, Common Guillemots *Uria aalge* do not make nests. Instead, their egg is laid directly onto a dirty cliff ledge, leaving them vulnerable to contamination with water, faeces and other debris throughout incubation. It has been suggested that Guillemot eggs are able to cope with this contamination because their shells self-clean – that is, keep themselves free from water and debris. Here, I answer whether the Guillemot egg is self-cleaning, and show the impact debris has on gas exchange across the eggshell. The role of shell accessory materials in defending against contamination by debris will also be discussed.

P3. Embryonic heart rate: Field methodology

[1,2,3] Kiara L'Herpiniere, [1,2] Elizabeth Sheldon; [1,2,3] Louis O'Neill, [2] Luke McCowan,[1,2] Callum McDiarmid, [2,4]James Savage, [2,3] Andy Russell, [1,2] Simon Griffith

[1]Department of Biological Sciences, Macquarie University, Australia
[2]Fowlers Gap Arid Zone Research Station, University of New South Wales, Australia
[3]Centre for Ecology & Conservation, University of Exeter, UK
[4]School of BEES, University College Cork, Ireland

Reliable in situ estimates of developmental stage, or incubation date, are valuable for many studies of behaviour and conservation. Embryonic heart rates have the potential to provide great insight into physiological variation and ontogenic status in early development. The availability of a relatively inexpensive, easy-to-use and portable piece of equipment, the Buddy digital egg monitor (Avitronics, Truro, UK), provides an opportunity to measure embryonic heart rate noninvasively in the field. The digital egg monitor has the potential to be very useful in studies of avian biology and to provide new insights into a range of questions. For example, quantifying variation in embryonic heart rate throughout development could allow the estimation of embryonic development and prediction of hatching time (useful for species for which nest access is difficult or overly disruptive); prediction of hatching success or identification of embryo mortality; examination of the extent to which a range of parental effects influence embryonic development and metabolism; and finally, determining the effects of environmental and climatic factors on embryonic heart rate and development may aid our understanding of the ways in which birds are likely to be affected by a changing climate. Here we have tested this equipment in the climatically harsh Australian outback on two separate models, the Chestnut-crowned Babbler (*Pomatostomus ruficeps*) and the Zebra Finch (*Taeniopygia guttata*). We characterise variation in embryonic heart rate concerning a range of abiotic and biotic variables and highlight the advantages and utility of the digital egg buddy for avian field biology.

P4. Seabird eggs as a higher trophic level indicator of contaminants in Irish marine waters

[1]Andrew Power, [1]Philip White, [1]Simon Berrow, [2]Brendan McHugh, [3]Stephen Newton, [1]Sinead Murphy, [2]Evin McGovern, [1]Ian O'Connor

[1]Marine and Freshwater Research Centre, Galway-Mayo Institute of Technology, Galway, Ireland
[2]Marine Environment & Food Safety Services, Marine Institute, Oranmore, Co. Galway, Ireland
[3]BirdWatch Ireland, Kilcoole, Co. Wicklow, Ireland

Contaminants such as persistent organic pollutants (POPs) are almost all exclusively synthesised chemicals that are highly resistant to natural degradation and are ubiquitous in marine environments. POPs have been shown to exhibit toxic properties causing endocrine dysfunction, mutagenesis, or reproductive and behavioural disturbances. Many of these contaminants bio-accumulate within organisms and bio-magnify within food webs with subsequent consequences for higher trophic level predators. Seabirds are integral, conspicuous and long lived components of aquatic ecosystems and have been used to infer diverse aspects of the health of the marine environment. Seabird eggs have been reported as one of the most ideal matrices for contaminant monitoring. We describe a pilot study to assess the feasibility of using seabird eggs as a POP indicator for the Irish marine environment. Three species were selected for this study; Common Tern *Sterna hirundo*, Northern Gannet *Morus bassanus* and Common Guillemot *Uria aalge*. Seabird eggs were collected in 2017 from three seabird colonies. Eggs will be tested for the presence of legacy and emergent POPs, heavy metals and mercury. Preliminary results indicate high levels of PCBs (Polychlorinated Biphenyls) in eggs collected. As part of the pilot study the impact of sampling on the breeding success of sampled birds is a critical component of the research. As such, non-destructive sampling techniques such as analysis of feathers and preen oil from adult birds of each species is also being investigated.

P5. Are cavity nests selecting for brighter eggs?

[1]Indira Rojas, [1]Daniel Hanley

[1]Biology Department, Long Island University Post, US

Investigating eggshells and nests evolution together can provide us with valuable information about their evolutionary mechanisms. Birds' eggs vary with respect to nesting habitat. For example, most cavity nesting birds lay white eggs; however, few studies have investigated the underlying evolutionary mechanisms of such changes. Here we address this question by incorporating data on nesting habits and quantitative data on avian eggshell coloration and brightness of eggshell color. The avian tetrahedral color space provides a context to study how birds perceive color, but does not incorporate brightness information. To overcome this challenge, we introduce a new opponent color space combining color information from two opponent channels with avian perceived brightness to define avian eggshell colors. Then, using Ornstein-Uhlenbeck models we supported the hypothesis that cavity nesting birds have adapted greater eggshell brightness. These patterns could be detected if cavity-nesting behaviors preceded egg color adaptations (e.g., white eggs in parrots and owls, lineages with white eggshells before and after adapting cavity nests). Therefore, we corroborated these findings by examining similar patterns within the families Turdidae and Mimidae, two families with a common ancestor that had a blue-green eggshell. We found that cavity nesting lineages within these two families have brighter eggs, which again supports the hypothesis that cavity nesting selects for brighter eggshells. These findings provide evidence that nests are acting as catalysts for the evolution of eggshell appearance. This novel approach will give researchers a new tool to study eggshell coloration, which could provide insights into the evolution of eggshell appearance.

P6. How is limb development timed and scaled?

[1]Holly Stainton, [1]Matthew Towers

[1]Biomedical Science, University of Sheffield, UK

Limbs of different avian species grow to markedly different sizes, however how this occurs and when these differences become apparent is largely unknown. In the larger chicken species, wing-span measures approximately 60cm and embryos have an incubation period of 21 days. In the smaller quail species however, wing-span measures approximately 30cm and has a correlating shorter incubation period of 14 days. One possibility to explain differences in wing sizes may be that patterning of the limbs occurs early in development and is followed by differential growth, alternatively, development may be scaled in proportion to the incubation period.

A previous study comparing embryonic development of the quail and chick supported the former theory, concluding that development of the chick and quail is equivalent until day 7 incubation (1). However, these results were based solely on observing the broad overall changes in morphology of chick and quail embryos over time. I have built on these studies by conducting a comprehensive analysis of embryonic development in the quail compared to the chick, I have compared differences in egg size, proximal to distal outgrowth of the wing over time, cell cycle rates, and also compared the expression of molecular markers which indicate development of the wing. The results of my analysis I have revealed that, in contrast to previously published data, differences in the development of the limb between the quail and chick occur as early as day 3 of embryonic development. This may be achieved by a species-specific program of development in relation to incubation time, resulting in accelerated development of the quail early in the incubation period.

1. Ainsworth SJ, Stanley RL, Evans DJ. (2010) Developmental stages of the Japanese quail. J Anat 216:3-15.

Keynote Abstracts

21st Century Oology, museums and the legacy of collecting

[1]Douglas Russell

[1]Department of Life Sciences, Natural History Museum, UK

The preservation of eggshell for study and display has been part of natural history collecting for at least 350 years. The Natural History Museum (NHM) holds several hundred thousand data-rich clutches, making it one of the largest research collections available. Holding approaching 52% of known extant species the NHM series is the most comprehensive collection of avian eggs available for study globally and, as such, is used regularly by researchers from all over the world. The oldest eggs in the NHM collection were collected in the 1700s but the vast majority dates from the mid-1800s to the early 1900s. The collection is global in nature and predictably strong in areas of former British colonial interest. Digitisation to increase access to collections and the dynamic development of new imaging and analysis techniques (e.g. Micro computed tomography and photospectrometry) have opened up new avenues of research – the importance of historical egg collections to science and society have never been greater.

From egg description to developing a conservation programme

[1]James Reynolds

[1]Centre for Ornithology, University of Birmingham, UK

At secondary school all I was taught about bird's eggs was that they were life support systems containing all of the nutrients required for avian life. At that stage of my biological career I could never have imagined where an interest in eggs would take me. There is far more to eggs than simply descriptions of their size, shape and number in species' accounts in handbooks; their description can provide critical insights into how birds breed in the modern urbanising world. Such is the case with Florida Scrub-Jays (*Aphelocoma coerulescens*), a corvid that is perhaps the most well-known cooperatively breeding species in the world. Despite this, it remains in a perilous ('Vulnerable') conservation position with a population of <10,000 birds that is restricted to peninsular Florida and continuing to decline. Although many birds occupy suburban areas, they clearly are sink habitats with source habitats being pristine (fire-maintained) oak scrubland. Suburbanisation is responsible for the steep decline in jay numbers. We found that careful food supplementation of birds at strategic times of their annual cycle can significantly change egg composition resulting in improvements in their breeding performance. As well as increasing clutch size, food supplementation also appears to increase fledging success, survival and the frequency of renesting. Therefore, when accompanying translocation of birds into suburban areas, food supplementation offers a potent conservation tool. Targeted feeding of jays by citizen scientists results in their persistence, and in local and rapid increases in bird numbers in suburban areas.

The ecology and evolution of avian eggs

[1]Mary Caswell Stoddard

[1]Department of Ecology and Evolutionary Biology, Princeton University, Princeton, NJ 08544

The eggs laid by birds come in an extraordinary variety of shapes, sizes, colors and textures, despite the fact that they serve the same essential function: to nourish and protect a chick until it hatches. To investigate the form and function of avian eggs, my lab uses a multidisciplinary approach, drawing on tools from math, computer vision, bioengineering and genomics. In this talk, I will show how analyzing eggs has revealed surprising insights into avian evolution and behavior. Egg shape, for example, is correlated with flight behavior, and eggshell pigmentation patterns encode the details of a coevolutionary battle between cuckoos and hosts. Overall, natural selection has tugged the egg phenotype in multiple directions to fashion a structure that can meet diverse mechanical, thermoregulatory and signaling demands.

Avian egg shape is a reflection of terrestrial locomotory constraints rather than reproductive selection

[1]Charles Deeming

[1]School of Life Sciences, University of Lincoln, UK

Mathematic descriptions of bird egg shape regularly feature in the literature but there are very few attempts to explain why or, more importantly, how such diversity of shapes arise. Egg formation takes place within an oviduct physically constrained by the size and shape of the pelvic girdle. An association between pelvic girdle shape and egg shape is not a new idea but it has not been fully investigated. Using linear measurements and geometric morphometric analysis pelvic girdle shape in around 150 species of bird mirrors taxonomic grouping but is also correlated with type of terrestrial locomotion. Foot-propelled swimmers have long, flat pelves that allow for insertion of muscles that move the femur backward and forwards. Grasping birds have shortened, angled pelves that allow the femur to be pulled downwards. Geometric morphometric analysis of egg shape revealed that elongation is related to absolute egg mass and proportion of yolk. By contrast, asymmetry is related to the proportion of shell and the mass of the egg relative to female body mass – the most pointed eggs are large relative to body mass. Analysis combining these data shows that egg and pelvic shape are correlated. Long, flat pelves provide space to allow long, relatively symmetrical eggs. Pelves with a short post-acetabulum and an increased angle are more cramped and restrict eggs to being shorter and often more asymmetrical. Egg size may reflect post-oviposition selection pressures but egg shape simply reflects the shape of the pelvic girdle, which is constrained by terrestrial locomotion.

Oral Presentation Abstracts

Long-term trends of egg sizes of three seabirds and spatial variation of Great skua eggs

[1]Sjúrður Hammer

[1]Faroe Marine Research Institute, Faroe Islands

Egg size may be a suitable ecological indicator as egg production is a demanding process. Some studies have shown long-term declines in seabird egg size for individual species and areas. What we are missing however are long-term studies of multiple species and on a wider geographical scale. With a compilation of egg measurements from field data and museum collections, this study investigates the long-term variation of over 10,000 Great Skua *Stercorarius skua* eggs across a wide spatial scale from 1809 to the present time as well as long-term trends in egg size of three seabird species breeding in the Faroe Islands. Great Skua egg size showed significant spatial and temporal variation. The temporal trend is apparent for Great Skuas eggs in the Faroes and similar trends were found in different areas suggesting either widespread environmental change, or feeding conditions have changed similarly over these areas. However, an examination of eggs of other seabird species such as Guillemot *Uria aalge* and Northern Fulmar *Fulmarus glacialis* eggs from the Faroes, showed different temporal trends from that in Great Skuas, suggesting not all species, respond similarly to changes in the marine ecosystem. Large-scale geographic differences of egg sizes at different colonies indicate a predictable latitudinal gradient in egg sizes, but trends at different colonies also suggest wide-ranging temporal changes, which are discussed in relation to changes in environmental conditions and fishing practices.

Pelvis morphology suggests that early Mesozoic birds and dinosaurs were too heavy to contact incubate their eggs

[1]Charles Deeming, [2]Gerald Mayr

[1]School of Life Sciences, University of Lincoln, UK
[2] Ornithological Section, Senckenberg Research Institute and Natural History Museum Frankfurt, Germany

Avian eggs are rare in the fossil record and none have been found in contact with adult skeletons, which would make assigning them to a species unambiguous. Such paucity of evidence hampers our understanding of the evolution of reproductive biology in early birds, particularly contact incubation, which is a defining feature of extant birds. Current views include the idea that contact incubation evolved first in theropod dinosaurs and persisted in early birds but such evidence is not universally accepted. We measured the distance between articulated pubes in 21 non-ornithurine birds, which defines a pelvic canal. The maximal egg breadth was estimated as 81% of the pelvic canal and using elongation ratios of Mesozoic bird eggs, we predicted egg mass. Data from modern birds allowed us to calculate the load mass an egg could endure before cracking. Body masses of fossil birds were predicted from data for humerus and femur lengths. Egg masses were small relative to body mass. For non-ornithothoracine, enantiornithine, Cretaceous ornithuromorph birds the bird's body mass was 187%, 127% and 179% of the load mass of the eggs, respectively. By contrast, eggs of extant birds of comparable sizes can support three times the mass of the adult. Available evidence for theropods also suggests that, like at least some Mesozoic birds, contact incubation was not possible because of the risk of crushing the eggs. Our results suggest that contact incubation evolved comparatively late in birds and was not inherited from a theropod ancestor.

How the egg rolls: A morphological analysis of egg shape in the context of displacement dynamics

[1]Ian Hays, [2]Iva Ljubicic, [3]Mark Hauber

[1]Animal Behavior and Conservation Program, Psychology Department, Hunter College, City University of New York, USA
[2]Department of Biology, The Graduate Center, The City University of New York, USA
[3]Department of Animal Biology, School of Integrative Biology, University of Illinois, Urbana, USA

Very little is known about how morphology effects the motion, stability and the resulting viability of avian eggs. The limited research that exists focuses on the pyriform or ‘pointed’ egg shapes found in the Alcidea family. This unusual shell form is thought to suppress displacement and prevents egg loss on the cliffside nesting habitat of the *Uria* genera. Unfortunately, these studies never isolated or quantify the specific morphological features (elongation, asymmetry and conicality) of these pyriform eggs, which limits their applicability to other taxa and hampers a robust proof of concept. We isolated each feature as a variable, produced models with incremental expressions of a single variable, and then all three variables simultaneously. Motion trials were conducted to test the individual and combinatorial effects of each morphological characteristic on displacement, on a range of inclines representative of the conditions found in nesting habitats. Increasing elongation (width over length) and asymmetry (distance of the apical width of the egg to the blunt end over length) significantly increased displacement, while conicality (pointed end of the egg geometrically mimicking a cone) decreased displacement in the single variable egg-models. In the multi-variable egg models, only conicality constantly suppressed displacement, while lower levels of asymmetry significantly increases displacement. Our findings broadly support previous studies' assertions of the adaptive value of the pyriform eggs, while providing data for future analysis of interactions between nesting habitat, behaviour and egg shape beyond the confines of the model species.

Egg shape mimicry in parasitic cuckoos

[1,2] Marie Attard, [3]Iliana Medina, [3]Naomi Langmore, [1,3,4]Emma Sherratt

[1]Zoology Department, University of New England, UK
[2]Department of Animal and Plant Sciences, University of Sheffield, UK
[3]Department of Ecology, Evolution and Genetics, Research School of Biology, The Australian National University, Canberra, Australia
[4] Department of Genetics and Evolution, School of Biological Sciences, The University of Adelaide, Adelaide, South Australia 5005, Australia

Parasitic cuckoos lay their eggs in nests of host species. Rejection of cuckoo eggs by hosts has led to the evolution of egg mimicry by cuckoos, whereby their eggs mimic the colour and pattern of their host eggs to avoid egg recognition and rejection. There is also evidence of mimicry in egg size in some cuckoo-host systems, but currently it is unknown whether cuckoos can also mimic the egg shape of their hosts. In this study, we test whether there is evidence of mimicry in egg form (shape and size) in three species of Australian cuckoos: the fan-tailed cuckoo *Cacomantis flabelliformis* which exploits dome nesting hosts, the brush cuckoo *Cacomantis variolosus*, which exploits both dome and cup nesting hosts, and the pallid cuckoo *Cuculus pallidus*, which exploits cup nesting hosts. We found evidence of size mimicry, and for the first time evidence of egg shape mimicry in two Australian cuckoo species (pallid cuckoo and brush cuckoo). Moreover, cuckoo-host similarity was higher for hosts with open nests than for hosts with closed nests. This finding fits well with the theory, since it has been suggested that hosts with closed nests have more difficulty recognising parasitic eggs than open nests, have lower rejection rates, and thus exert lower selection for mimicry in cuckoos. This is the first evidence of mimicry in egg shape in a cuckoo-host system, suggesting that mimicry at different levels (size, shape, colour pattern) is evolving in concert. We also confirm the existence of egg size mimicry in cuckoo-host systems.

Unscrambling the determinants of eggshell colour and spottiness in a continent-wide study

[1,2] Kiara L'Herpiniere, [1,2] Louis O'Neill, [1] Daisy Duursma, [2] Andrew Russell, [1] Simon Griffith.

[1]Department of Biological Sciences, Macquarie University, Australia
[2]Centre for Ecology & Conservation, University of Exeter, UK.

Pigmentation and maculation of avian eggs vary greatly, however the evolutionary drivers of this variation remain unclear. The leading hypotheses explaining this variation focus on structural integrity or signalling. In this study we combine both hypotheses to identify which is more significant in our continent-wide system. To do this we investigate Australian Magpie (*Cracticus Tibicen*) eggs, which is an ideal study species because of its continent-wide distribution and extraordinary diversity of egg patterns and colours. Here we use 283 clutches of eggs from across the whole Australian continent. We quantified the inter-clutch variation in egg pigmentation in relation to genetic divergence, environmental factors, and brood parasitism using a variety of methods to analyse eggs in terms of colouration and patterning, including spectroscopy and digital image analysis.

We found that egg colouration was mainly predicted by a selection of environmental parameters, particularly strongly by temperature. Subspecies showed only weak divergence, except for the Tasmanian subspecies which were bluer and more maculated than the rest, showing no effect of significant genetic divergence. The presence or absence of a brood parasite showed no significant difference, although the hypothesis should be explored further.

Although significant variation remains unexplained, our research suggests that environmental parameters contribute to the variation in background colour and patterning in Australian magpies. This research adds to the growing body of avian egg studies, and using a selection of different quantification methods has allowed to improve future study and collaboration in the field.

Extraordinary sperm to egg ratios in seabirds

[1]Nicola Hemmings

[1]Department of Animal & Plant Sciences, University of Sheffield

In this talk, I will present data showing that the number of sperm associated with eggs of single-egg clutch seabirds is more than an order of magnitude greater than predicted from the relationship between ovum size and sperm numbers in birds, and several hundred times greater than the estimated number necessary for a 50% likelihood of fertility. I will discuss how these findings are consistent with three unusual features of seabird reproduction: (1) single egg clutches, (2) prolonged sperm storage, and (3) a lag period between the end of yolk formation and ovulation. I hypothesise that the lag period evolved to provide sufficient time for sperm to be released simultaneously from storage and accumulate at the site of fertilization. High numbers of sperm may be an insurance against infertility in single-egg clutch species, and although numbers are far in excess of any safety margin, this may not matter if mechanisms exist to avoid any damaging effects of large sperm numbers to ova (i.e. pathological polyspermy).

For notes