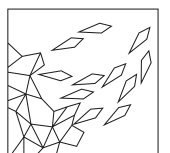
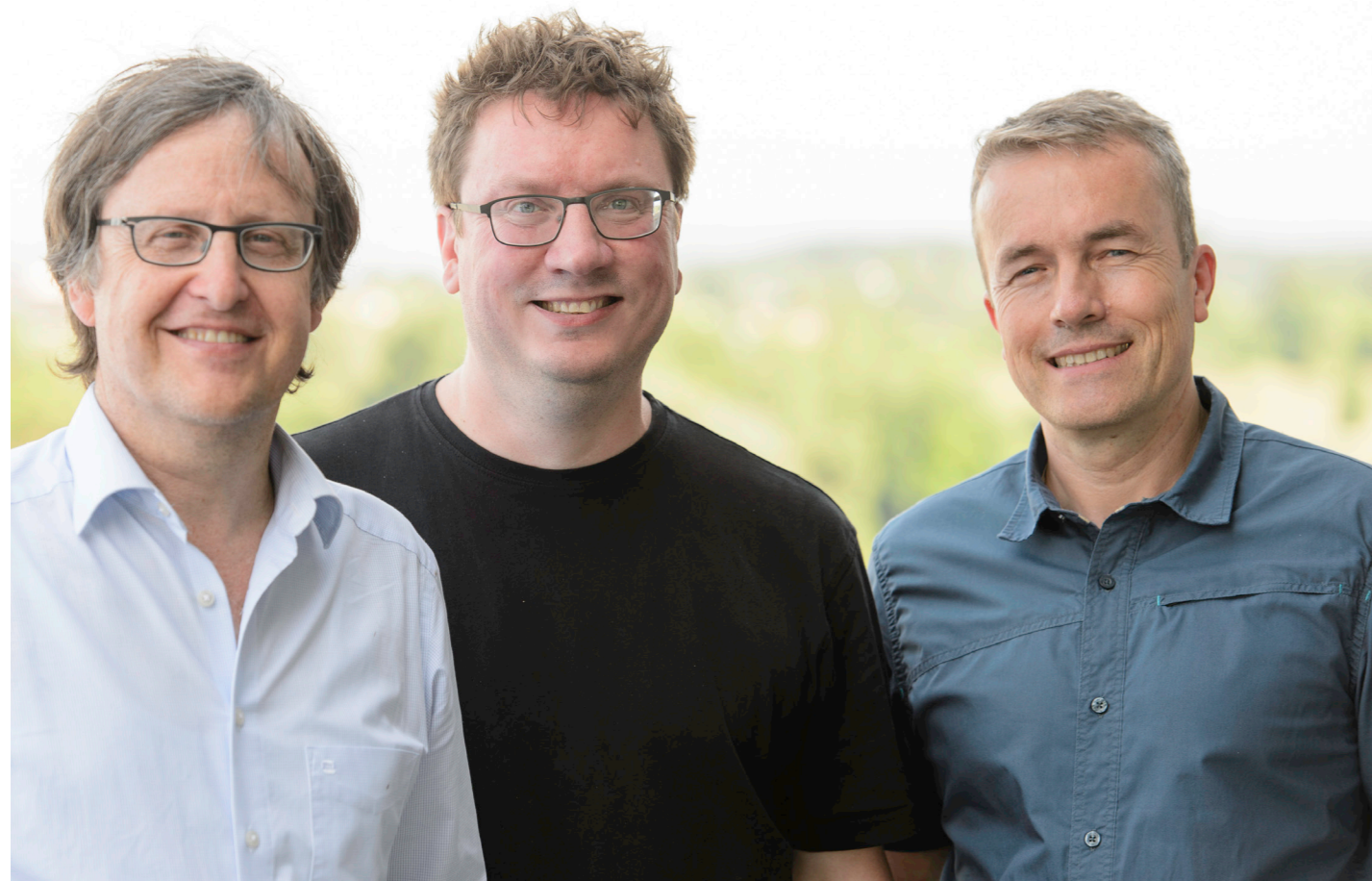


CASCB ANNUAL REPORT

2019 | 2020



FOREWORD



Two years ago, the Centre for the Advanced Study of Collective Behaviour came into being—marking the launch of what we at the time called “a globally unique environment for the quantitative analysis of behaviour.”

CASCB, we dreamed, would be a vibrant, internationally visible centre of research that plays a leading role in the future of collective behaviour research. Our greatest asset—our “interdisciplinary collective” of computer scientists, biologists, psychologists, physicists, economists, mathematicians and social scientists—pledged to step beyond the comfort zones of their disciplines in order to work together to pursue this common goal. Together, we integrate theory, experiment, and technology to transcend both disciplinary and conceptual boundaries.

While certainly ambitious, our mission is grounded in substantial evidence that we are at a time of unique opportunity to advance the study of collective behaviour. There are especially prescient opportunities to utilize and develop new ways of thinking, and new technologies that facilitate the integration of behavioural, physiological, neural, and ecological studies of collective phenomena, and to do so in a wide range of systems. We heard the sound of shifting gears in this emerging trans-disciplinary field—and CASCB was created to be an engine driving this change.

Two years in, where do we stand on this road? As we always say, it helps to quantify.

We are a tight-knit community of almost 100 scientists and professional staff. We have funded and made substantial progress on 29 research projects while publishing 116 scientific papers, including in the leading multi-disciplinary journals *Science* and *Nature*. Our interdisciplinary collective has also forged fresh alliances—economists with biologists, or psychologists with immunologists—that act as the hinges connecting our scientific

community. Our successful weekly seminar series has been a platform for 38 speakers, 21 of whom have visited us (albeit virtually in the last year) from institutions abroad. We hosted four conferences, two of which enjoyed the largest international delegations in the respective congress' history.

From the beginning, we underlined that emerging technologies would transform the study of behaviour from a qualitative to quantitative science. Our focus has been on developing a data and tech infrastructure that delivers on this promise. This includes virtual reality systems developed for experiments on both invertebrates and vertebrates—in the air, on land, and in water—and ultra-high resolution tracking facilities for both animal and human groups. A new Group Leader who will further pioneer these technologies in our Imaging Hangar is part of that investment.

It's important to reflect on what it takes for science to happen. Every proposal, every purchase, every protocol happens because of a collaboration between scientists and professional staff. Our team of six administrative and two technical officers provide the crucial background work to sustain our high-level performance, the program of events that gel our community, and the outreach that ensures our work has impact beyond our laboratories.

This has been a very difficult year, both here and across the globe. At the time of writing, Germany is in its second lockdown to control the spread of the coronavirus and a new, more transmissible strain threatens to strain our control efforts. Yet, Herculean collective effort has resulted in remarkable progress: our shared commitment to physically-distance ourselves, and the global collaboration that has led to the development of vaccines at unprecedented speed, has brought the pandemic's end within reach. Witnessing this collective action gives us the confidence that 2021 will be a challenging road, but one with clear signs of hope ahead.

co-speakers of CASCB

Urs Fischbacher

Iain Couzin

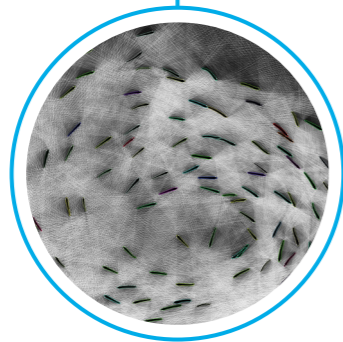
Oliver Deussen

TABLE OF CONTENTS



AT A GLANCE

- 08 Who, What, Where, Why & How of CASCB
- 09 CASCB in Numbers
- 10 What is Collective Behaviour?
- 12 Our Mission



HIGHLIGHTS

- 18 Underlying Principles
- 22 Quantitative Tools
- 28 Health and Society
- 32 One Virus, Many Helpers



RESEARCH

- 38 Cornerstones of Research
- 40 Large Projects:
 - Area A**
Studying individuals in the collective
 - Area B**
How behaviour aggregates in the collective
 - Area C**
Exploiting computational methods
- 50 Can VR revolutionize collective behaviour?
- 58 Can we predict where locust plagues will go?
- 66 Can we use collectives to monitor the planet?
- 72 Small and Medium Projects



CULTURE OF COLLABORATION

- 78 CASCB Seminar Series
- 90 Research Retreats
- 92 Conferences
- 96 Education
- 98 Public Engagement

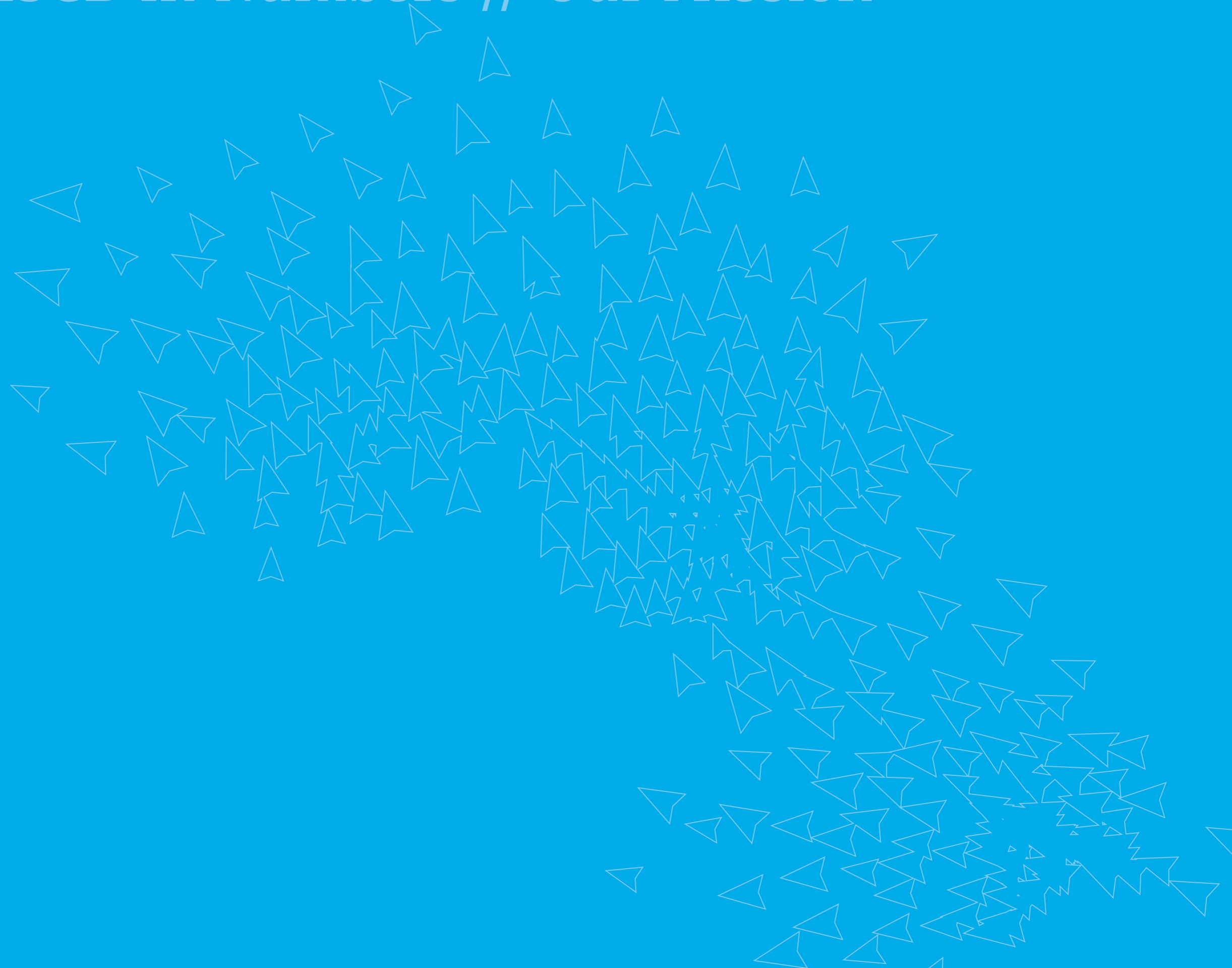


INFRASTRUCTURE AND PERSONNEL

- 108 Members
- 116 Doctoral Students
- 122 Global Partners
- 124 **Infrastructure**
 - ICARUS
 - Imaging Barn
- 130 Major Grants and Awards
- 134 Imprint



AT A GLANCE → Who, What, Where, Why & How of CASCB // CASCB in Numbers // Our Mission



Dive into Collective Behaviour in Konstanz

WHAT?

At the Centre for the Advanced Study of Collective Behaviour, we aim to create a global hotspot for the integrated study of collective behaviour across a wide range of species, including humans, and across scales of organization.

WHO?

As a collaboration between the University of Konstanz and the co-located Max Planck Institute of Animal Behavior, we harness substantial expertise in the local region across seven scientific disciplines to create a synergistic, interdisciplinary environment for the study of collective behaviour.

WHY?

Collective behaviour is everywhere:

Bird flocks, fish swarms, ungulate herds and human societies are just some examples of the broad sociality that exists in nature.

Collective behaviour is important:

Not only does its study provide fundamental insights into animal and human behaviour, it is also essential for managing issues of great socio-economic importance, such as pest plagues, virulent diseases, and speculative bubbles.

But the study of collective behaviour is challenging

Data-oriented research on collective behaviour requires the study of dynamic, multiscale, and interdependent feedback processes. And, it must account for differences in the actions, traits, and states of individuals, and changing conditions in their physical and social environments. In order to cope with this complexity, a new approach is needed that transcends discipline boundaries.

HOW?

Our research is interdisciplinary in scope – combining biology, social psychology, behavioural economics, sociology, physics, and computer science – but united in a quantitative approach that involves extensive collection and sophisticated analysis of empirical data. It is built on new tools – including an Imaging Hanger for the design of virtual and reactive environments, and a space-borne animal tracking system (ICARUS) – enabling the study of collectives in unparalleled depth.

Look at us grow



Research

116 Publications

31

Funded Projects

Awards

- 2 Highly Cited Researchers
- 1 James Heineman Research Award
- 1 Lagrange Prize
- 1 Junghe Akademie

Grants

- 3 Human Frontier Science Program
- 1 Emmy Noether
- 1 Gips-Schule
- 2 ERC
- 1 SFB-TRR

Teaching



5

Uni Courses

Collaboration

4 Conferences

5 Outreach Events

2 Research Retreats

21 Visiting Speakers

38

Research Seminars

Col|lec|tive

Be|hav|iour

Definition We define collective behaviour as the study of individuals in the context of how they influence and are influenced by others, taking into account the causes and consequences of inter-individual differences, such as in physiology, motivation, experience, and goals. It also includes the study of the individual and higher-order properties that can emerge as we move beyond dyadic (pairwise) interactions to consider the complexities that arise in the dynamic networks of communication that characterize both human and animal systems.



Our Mission

TO BUILD...

- a world-leading centre of collective behaviour research
- a culture of synergy and innovation

TO PURSUE...

- cutting-edge research from multi-scale analysis and modelling of collective behaviour to revealing dynamical feedbacks between social network structure and social transmission
- transdisciplinary approaches

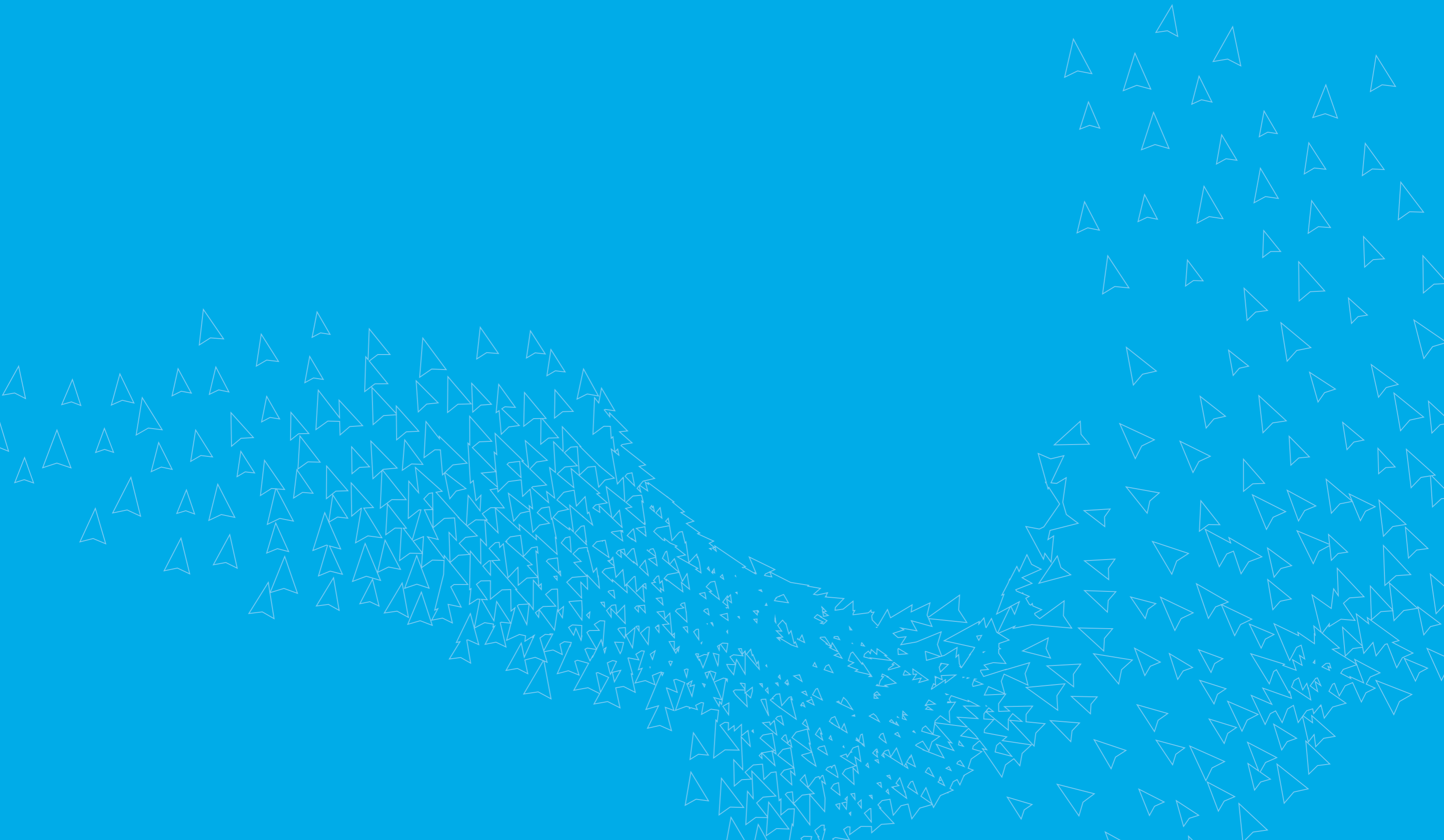
TO DEVELOP...

- a new generation of freely available, quantitative tools

TO APPLY

- concepts of collectives to real-world applications

HIGHLIGHTS → Underlying Principles // Quantitative Tools // Health and Society // One Virus, Many Helpers



Underlying Principles

→ THE HIDDEN INTELLIGENCE OF COLLECTIVES

For behaviour to be of any use, it needs to be modulated according to what's happening in the world around us. We see this in ourselves when we respond to a sudden noise: in a crowded street in broad daylight we might not notice the noise; but in an unfamiliar alley in darkness it might send our hearts racing. This context-dependent modification of behaviour—known as behavioural plasticity—has been very well studied in individual animals. What is much less known is how the process occurs in animal groups.

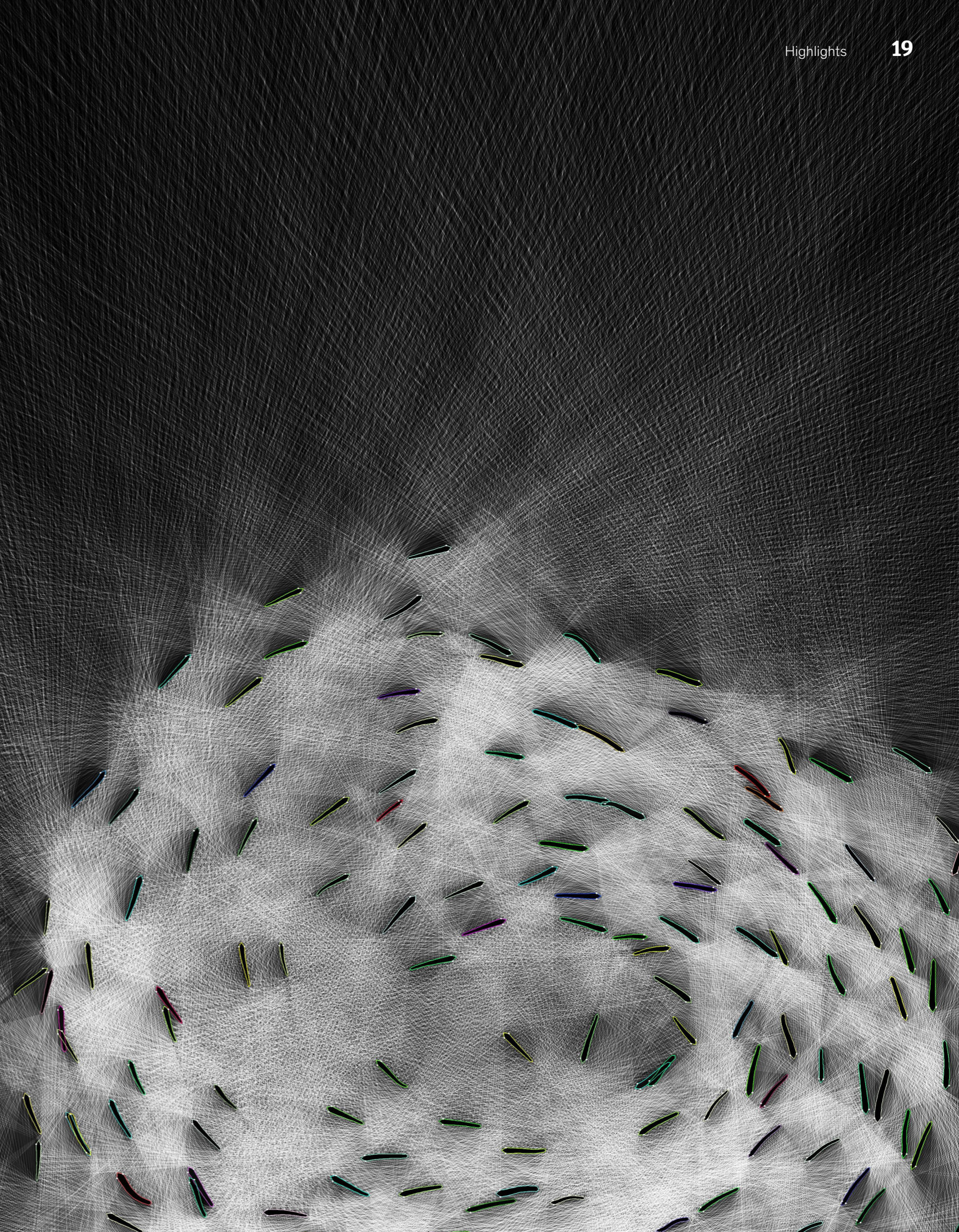
“When we start looking at how groups respond to their environment, it introduces a possibility that does not exist when you look at individual animals,” says senior author Iain Couzin, co-speaker of CASCB and director at MPI-AB. “When you form groups, you suddenly have a network system where social interactions exist, and we wondered whether this invisible architecture was in fact contributing to how groups can respond to changes in the environment.”

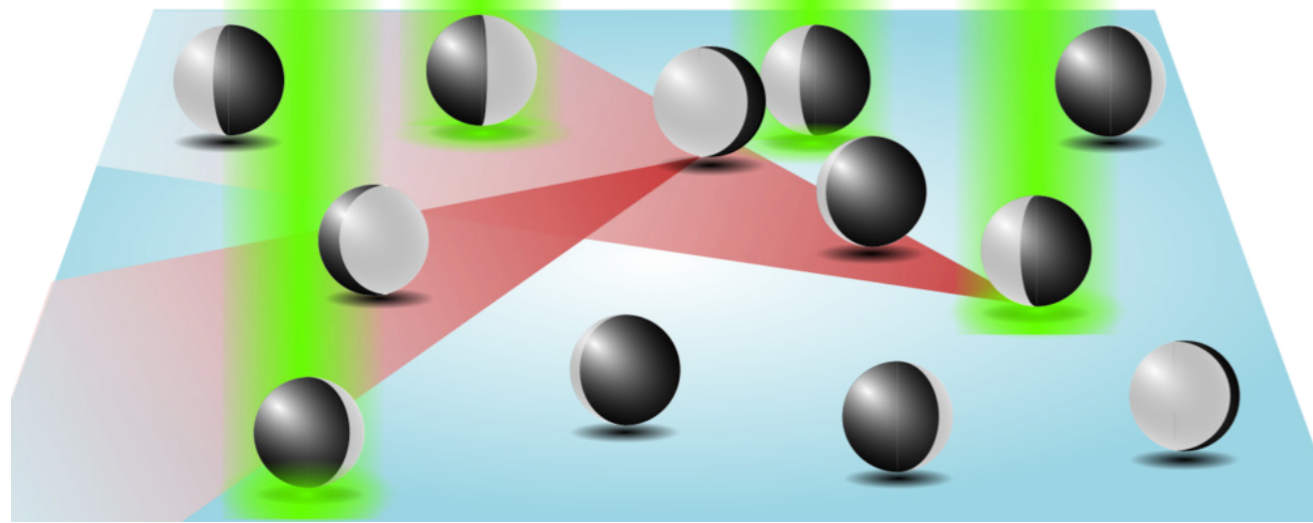
In a paper published in the Proceedings of the National Academy of Sciences, CASCB scientists provide the first evidence in support of this hunch: that information processing can occur—not only in the brains of individual animals—but in the physical structure of animal groups.

They examined how groups of juvenile golden shiner fish respond to danger in the environment. “Danger is one of the most important things that animals need to respond to if they are to survive,” says Couzin. When fish were exposed to danger, they changed the structure of the group, which increased the strength of the social connectivity among the individuals—ultimately allowing them to respond effectively and rapidly to changes in their environment, as a collective.

By demonstrating that animals can encode information about their environment in the architecture of their groups, the study provides rare insight into how animal collectives are able to behaviourally adapt to a changing world. “We have traditionally assumed that intelligence resides in our brains, in the individual animal,” says Couzin. “But we have found the first evidence that intelligence can also be encoded in the hidden network of communication between us.”

Paper: Sosna MG, Twomey CR, Bak-Coleman J, Poel W, Daniels BC, Romanczuk P, Couzin ID (2019) Individual and collective encoding of risk in animal groups. PNAS





→ VISION IS KEY TO GROUP FORMATION

Planet earth is a social place: bird flocks, fish schools, and bacterial swarms are just some examples of group living that we see in the natural world. A requirement for groups to form is that all members must continuously and reciprocally adapt their movements. However, knowing what information individuals are using to adapt their movements is challenging. Vision, sound, flow resistances, or chemical messengers can all play a role.

By designing experiments with artificial microswimmers, physicists led by Clemens Bechinger from CASCB were able to show that the formation of stable groups requires only few skills. “You need to see your peers over large distances and you need to adjust your speed accordingly,” says Bechinger. “That’s it.”

The microswimmers, which are glass beads of a few nanometers, were pioneered in Bechinger’s lab. They can be propelled to swim by light emitted from a laser beam. For this study, Bechinger equipped them with “vision.” The particles were stimulated to swim towards other particles when enough individuals appeared in their field of view. Using this procedure, the researchers observed that the particles spontaneously formed an artificial swarm.

Paper: Lavergne F, Hugo W, Tobias B and Bechinger C (2019) Group formation and cohesion of active particles with visual perception–dependent motility. *Science*.

→ ORDER AND DISORDER OF SWARMS

Animal groups exhibit the seemingly contradictory characteristics of being both robust and flexible. How they achieve this is not yet understood, but experiments by Bechinger’s group support the controversial hypothesis that a well-known concept in physics – a “critical point” – is behind the striking behaviour of collective animal systems.

Paper: Bäuerle T, Löffler RC, Bechinger C (2020) Formation of stable and responsive collective states in suspensions of active colloids. *Nature Communications*.

The experiments use glass Janus particles that are triggered to move by laser light.



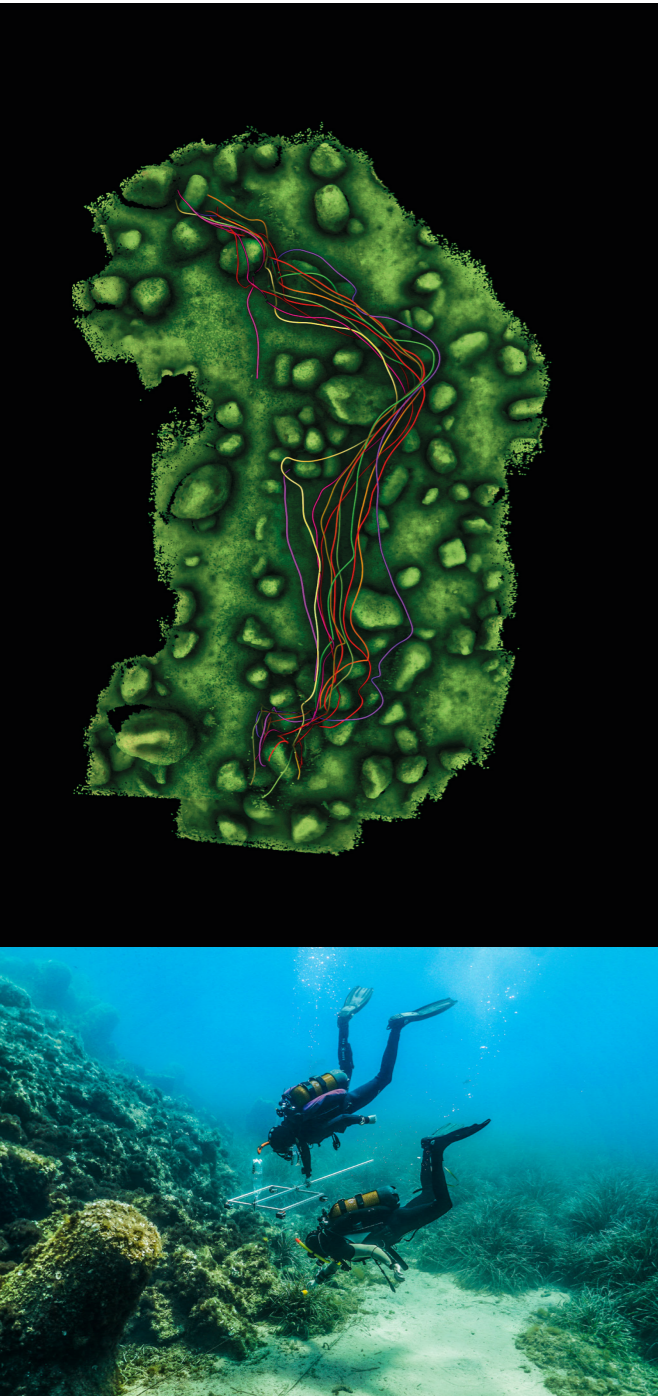
Quantitative Tools



→ IMPROVING MEASUREMENT OF ANIMAL BEHAVIOUR USING DEEP LEARNING

A team of collective behaviour researchers, led by PhD student Jake Graving, developed a deep learning toolkit for high-speed measurement of body posture in animals. DeepPoseKit can correctly measure body posture after being trained with only 100 examples and can be applied to study wild animals in challenging field settings. The tool provides an accessible system for non-experts to easily apply machine learning to their behavioural research.

Paper: Graving JM, Chae D, Naik H, Li L, Koger B, Costelloe BR, Couzin ID (2019) DeepPoseKit, a software toolkit for fast and robust animal pose estimation using deep learning. *eLife*.



Filming fish with at least two cameras enabled the masters' students to track animals and reconstruct their 3D environments.

→ BREAKING GROUND IN AQUATIC TRACKING

Anybody with a smartphone knows well the power and ubiquity of GPS tracking. Over the last decade, equipping animals with GPS trackers has become the state-of-the-art method for understanding the movement of animals on land, generating far reaching insights into behaviour, conservation, and the health of our planet. But there is one glaring limitation to this tech: GPS does not work underwater. Current alternatives such as audio telemetry do not have the accuracy to resolve movement and behaviour on a fine scale or with small animals such as fish. For a masters' project, Paul Nührenberg and Fritz Francisco developed a machine learning framework for fine-scale tracking of aquatic animals in the wild. Using video footage of animals captured with more than one camera, the tool can detect animals in the videos using deep learning, and also reconstruct the 3D environments through which they move. Senior scientist on the study, Alex Jordan, says the team hopes that the tool is general enough to be used in many aquatic studies. "It works at any scale, from microorganisms to whales, provided these can be recorded on camera," he says. "It's also open-source, with low cost infrastructure, so can be used everywhere by anyone."

Paper: Francisco FA, Nührenberg P, Jordan A (2020) High-resolution, non-invasive animal tracking and reconstruction of local environment in aquatic ecosystems. *Movement Ecology*.

Great tits can now be individually identified in the wild.



→ WORLD'S FIRST AI TOOL FOR IDENTIFYING INDIVIDUAL BIRDS

Even to an expert, one great tit looks a lot like the next. But research by CASCB biologists Damien Farine and Hanja Brandl demonstrates for the first time that artificial intelligence (AI) can be used to train computers to recognise individual birds in the wild—a task humans are unable to do. The tool will allow studies previously only possible in the laboratory—where people have tracked individuals using these methods for a number of years—to be replicated in the wild. "The ability to track wild birds without having to mark them represents perhaps the greatest single methodological advance in recent decades, at least since the miniaturization of GPS tags that can be carried by migrating birds," says co-author

Damien Farine, who conducted the work when he was a group leader at CASCB and MPI-AB.

In the study, researchers from institutes in France, Germany, Portugal, and South Africa collected thousands of labelled images of birds and then used this data to train and test AI models. This study represents the first successful attempt to do this in birds.

Paper: Ferreira A, Silva L, Renna F, Brandl H, Renault J, Farine D, Covas R, Doutrelant C (2020) Deep learning-based methods for individual recognition in small birds. *Methods in Ecology and Evolution*.

→ ROBOTS ANSWER AGE-OLD QUESTION

A fish school is a striking demonstration of synchronicity. Yet centuries of study have left a basic question unanswered: do fish save energy by swimming in schools? Now, CASCB scientists have provided an answer that has long been suspected but never conclusively supported by experiments: yes.

The researchers developed a 3D robotic fish that has a soft tail fin and swims with an undulating motion that mimics accurately the movement of a real fish. But unlike their live counterparts, the robots allow for direct measurement of the power consumption associated with swimming together versus alone.

“We developed a biomimetic robot to solve the fundamental problem of finding out how much energy is used in swimming,” says Liang Li, a postdoctoral fellow at the MPI-AB and first author on the study. “If we then have multiple robots interacting, we gain an efficient way to ask how different strategies of swimming together impact the costs of locomotion.”

The researchers studied robotic fish swimming in pairs versus alone. Running over 10,000 trials, they tested follower fish in every possible position relative to leaders – and then compared energy use with solo swimming.

“Our results provide an explanation for how fish can profit from the vortices generated by near neighbours without having to keep fixed distances from each other.”

**Iain Couzin, co-speaker of CASCB
and director at the MPI-AB**

The results showed a clear difference in energy consumption for robots that swam alone versus those that swam in pairs. The cause of this, they discovered, is the way that fish in front influence the hydrodynamics of fish behind. The energy consumed by a follower fish is determined by two factors: its distance behind the leader and the relative timing of the tail

beats of the follower with respect to that of the leader. In other words, it matters whether the follower fish is positioned close to the front or far behind the leader and how the follower adjusts its tail beats to exploit the vortices created by the leader.

It turns out that the secret to saving energy lies in synchronization. That is, follower fish must match their tail beat to that of the leader with a specific time lag based on the spatial position – a strategy the researchers called “vortex phase matching”. When followers are beside leader fish, the most energetically effective thing to do is to synchronize tail beats with the leader. But as followers fall behind, they should go out of synch having more and more lag as compared to the tail beat of the leader.

In order to visualize the hydrodynamics, researchers emitted tiny hydrogen bubbles into the water and imaged them with a laser – a technique that made the vortices created by the swimming motion of the robots visible. This showed that vortices are shed by the leader fish and move downstream. It also showed that robots could utilize these vortices in various ways. “It’s not just about saving energy. By changing the way they synchronize, followers can also use the vortices shed by other fish to generate thrust and help them accelerate,” says co-author Mate Nagy, who conducted the work when he was a postdoctoral fellow at the MPI-AB. But do real fish use the strategy of vortex phase matching to save energy? To answer that, the researchers created a simple hydrodynamic model that predicts what real fish should do if they are using vortex phase matching. They used AI-assisted analysis of body posture of goldfish swimming together and found, indeed, that the strategy is being used in nature.

Says senior author Iain Couzin, co-speaker at CASCB and director at MPI-AB: “We discovered a simple rule for synchronizing with neighbours that allows followers to continuously exploit socially-generated vortices. But before our robotic experiments, we simply didn’t know what to look for, and so this rule has been hidden in plain sight.”

Paper: Li L, Nagy M, Graving JM, Bak-Coleman J, Xie G, Couzin ID (2020) Vortex phase matching as a strategy for schooling in robots and in fish. *Nature Communications*.



The biomimetic robots have soft fins and swim in an undulating motion.

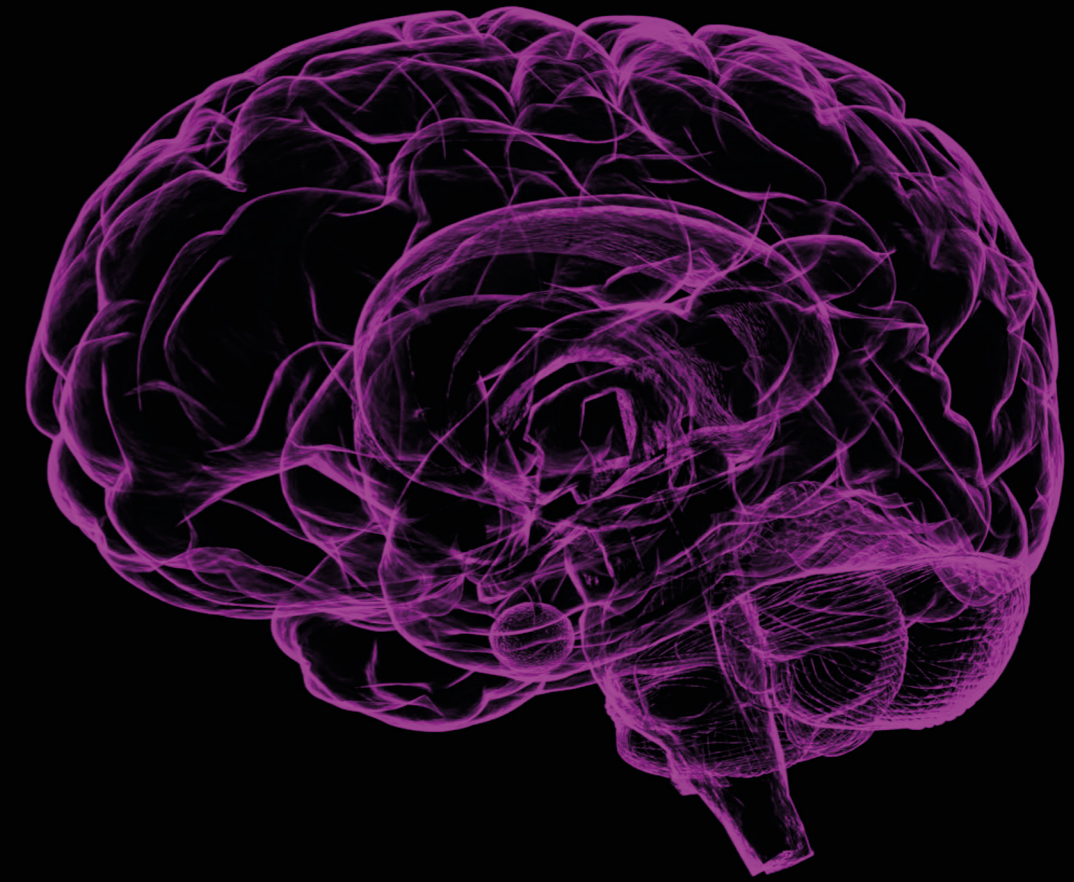
Health and Society

→ IMMUNE TO INFLUENCE

Psychologists Helge Giese, Hans Neth, and Wolfgang Gaissmaier provide the first rigorous look at how our attitudes towards vaccines are shaped by online forces. Turns out, social influence plays a small role.

Paper: Giese H, Neth H, Moussaïd M, Betsch C, Gaissmaier W (2019) The echo in flu-vaccination echo chambers: Selective attention trumps social influence. *Vaccine*.





→ LINKING STRESS TO HEART DISEASE

Stress, it seems, is not good for our hearts. When we're chronically stressed – like in a bad marriage or in a difficult job – it can cause an increased risk of coronary heart disease. If we experience it in a short, intense burst – like during a football game – it can lead to fatal heart attacks in patients with atherosclerosis. Now, CASCB psychologists have uncovered a potential new pathway linking stress to cardiovascular disease.

The team behind Petra Wirtz and Britta Renner has shown that RAAS—a system with hugely important consequences for heart functioning—becomes activated when we are in psychologically stressful situations. But even further, they have demonstrated that a simple saliva test for aldosterone is enough for detecting this.

In the past, blood samples were the best method for measuring aldosterone, and so the discovery that a much faster and easier saliva test works effectively opens up many more avenues for research. At CASCB, this will lead directly to research testing the effects of stress on the endocrine system in previously impossible situations, like large groups. “We plan to use our new method for testing aldosterone to understand the spread of stress in collectives,” says Wirtz.

Paper: Gideon A, Sauter C, Fieres J, Berger T, Renner B, Wirtz PH (2020) Kinetics and interrelations of the renin aldosterone response to acute psychosocial stress: a neglected stress system. *The Journal of Clinical Endocrinology & Metabolism*.

→ HOW OUR BRAINS ASSESS RISK

A growing body of neuroimaging research over the last 15 years has confirmed a remarkable fact: human brains become aligned when we hear or see the same thing.

The research group of psychologist Harald Schupp is building on this science, known as “inter-subject correlation”, to reveal the neural underpinnings of group processes. In a *NeuroImage* study, the researchers hooked up young adults to electroencephalogram (EEG) machines while watching real-life health advertisements about risky alcohol use. Their results demonstrated that EEG can be used to study brain synchronization as a measure of audience-wide responses as reliably as fMRI. “The benefit of EEG is that it can be used outside the laboratory and can be hooked up to a group of people simultaneously,” says Martin Imhof, a CASCB Affiliate Member, who is

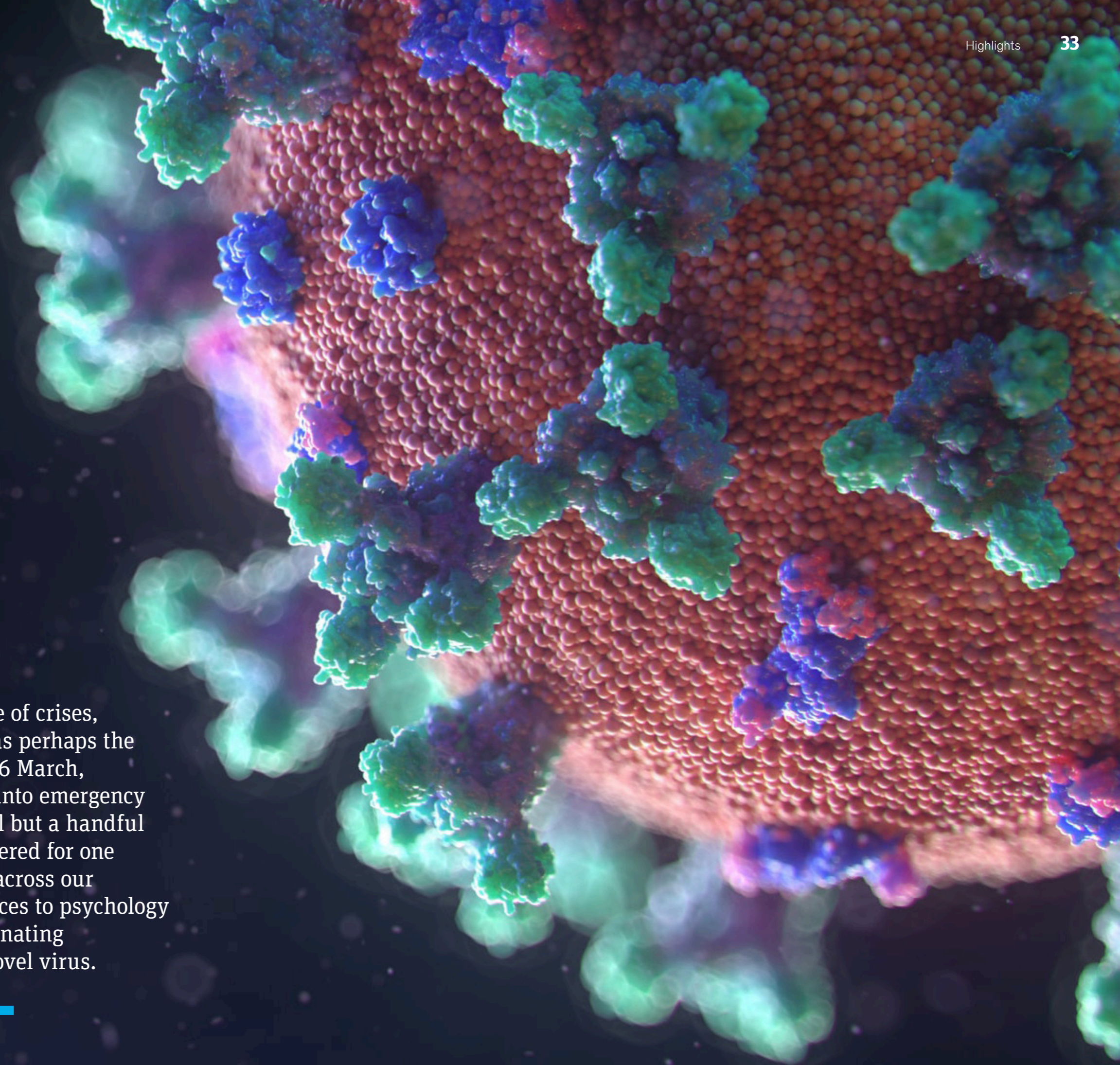
developing EEG as a tool to study collectives.

Their success in applying EEG to the study of brain synchronization will be used to determine if neural measures can identify effective group coordination. Ultimately, Schupp hopes that this approach will enable the prediction of successful or failed collective decisions based on a mechanistic understanding of group decision-making. “Examining inter-subject correlation with EEG is giving us an avenue to study group processes at a neural level,” says Schupp. “Can our brain show us when we are cooperating or when we are in competition? Answering this is our task for the next few years.”

Paper: Imhof MA, Schmälzle R, Renner B, Schupp HT (2020) Strong health messages increase audience brain coupling. *NeuroImage*.

One Virus...

2020 was a year with no shortage of crises, but the coronavirus pandemic was perhaps the defining global catastrophe. On 16 March, the University of Konstanz went into emergency operations, closing its doors to all but a handful of essential staff. With labs shuttered for one month, CASCB researchers from across our disciplines—from computer sciences to psychology to immunology—responded by donating time and expertise to fight the novel virus.



...Many Helpers



→ VISUALISING HOSPITAL BED CAPACITY

In April 2020, Oliver Deussen, co-speaker of CASCB, began working with the chief of pulmonology at Konstanz hospital to equip the medical staff with IT solutions to help pandemic preparedness. The pair identified a problem of how to gauge the availability of hospital beds around the country. Enter analytics expert Daniel Keim who created Coronavis: an on-line platform that shows the availability of free critical care beds with and without ventilators in all German hospitals.

→ PERCEPTIONS IN THE PANDEMIC

Since February 2020, the EUCLID study led by psychologist Britta Renner has been following the coronavirus situation in Germany and around the world. Via a survey available in 11 languages and 15 countries, plus visualization and analytics led by Daniel Keim, the study is assessing risk perceptions and behaviour in the context of the current Coronavirus outbreak.



→ ACCELERATING TESTING

A team of university molecular biology labs, including that of Marcus Groettrup, assisted a local medical diagnostics lab with testing for the novel coronavirus. The researchers contributed to “RNA preparation” by isolating viral RNA prior to PCR.



→ CROWDSOURCING HELP

Daniel Calovi is a co-creator (with Alfonso Pérez Escudero and Sara Arganda Carreras) of a site that matches volunteer scientists with researchers in need of help. By April, the site had gathered 40,000 volunteers and processed over 300 requests.

→ STUDENTS STANDING UP TO STRESS

Shut out of their labs, Lisa-Marie Walther and Alisa Auer redirected their PhD research to tackle one of the most pertinent issues of the pandemic: stress in response to the coronavirus crisis. They launched an online survey to elucidate the perceived stress felt by people in the pandemic and uncover helpful resources to allay the scourge of stress.



RESEARCH → Cornerstones of Research // Large Projects
// Featured Stories: predicting plagues...the power of VR...
disaster forecasting with collectives // Medium and
Small Projects





A

How does information, behaviour, and physiological state spread in collectives?

B

What are the consequences for collective outcomes?

C

How to analyze, predict, and model collective behaviour?

Cornerstones of Research

Our goal is to uncover the fundamental principles that underlie collective behaviour – in a range of organisms and across scales of organization – and to translate this knowledge into real-world solutions that will bring about positive impact world wide. Our scholars from biology, physics, psychology, sociology, economics, computer science, and maths step beyond the comfort zones of their systems in order to work together to pursue this common goal.

Our approach is to refract collective behaviour research through the prism of three structural elements:

- Studying the individual in the collective (Area A)
- And how this behaviour aggregates in the collective (Area B)
- Using theory-based empirical studies that exploit high tech computational methods (Area C)

To date, 31 projects have been successful for grants awarded by CASCB. Each proposes an innovative, interdisciplinary concept that illuminates the path to our research goal. Projects are financed via one of three funding lines: small (10K), medium (80K) and large (3 year Phd/PD salary) grants.

Large Projects

Area A

Studying individuals in the collective

→ CAN STRESS BE CONTAGIOUS?

We have all experienced a tangible “tension” in social situations. Surprisingly, there is little empirical work addressing the scientific basis of such processes, or their consequences. Traditionally, social transmission research has focused on the spread of behaviours, skills, opinions, or information within groups and populations. Departing from tradition, the CASCB project is pursuing a new line of inquiry that considers the social contagion of physiological states. If a physiological state—like stress—can spread, there are likely to be major consequences for collectives, both good and bad. A stressed individual could alert the group to a nearby threat but also reduce group functioning at the same time.

The pioneering nature of the study requires that paradigms are established de novo. The combination of human and non-human model species requires synergies and standardized approaches that allow comparability across systems. The goal is a synthetic, wholistic understanding of social contagion of stress in collectives—not just of one species—but in those that represent the diversity of life.

Area A



→ WE ARE ALL SOCIAL “INFLUENCERS”

Humans are social animals. Whether we know it or not, we pass on information, behaviours, and emotions to others. This “social transmission” is fundamental to how we function. This project with psychologists and biologists seeks to understand the four elements of social transmission and their complex interplay to gain insight into when collectives succeed or fail.



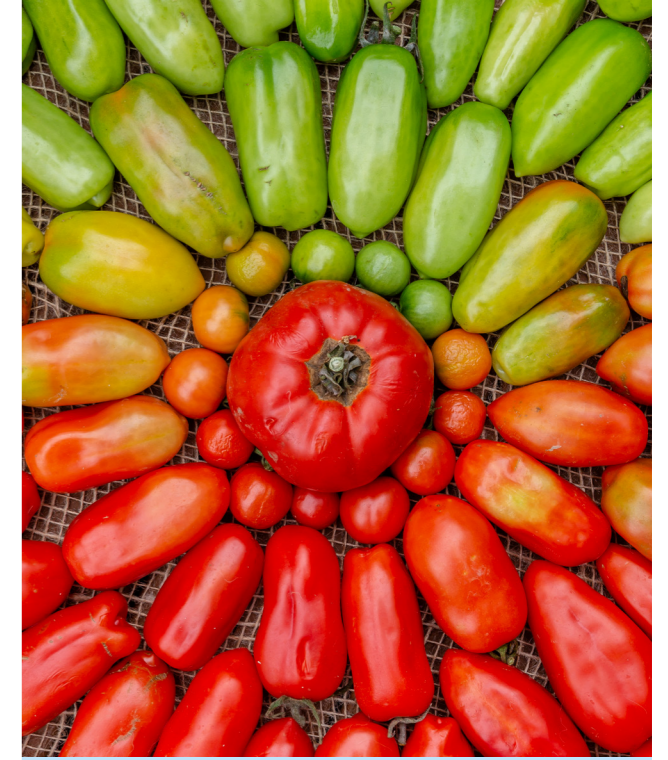
→ A TASTE FOR THE COLLECTIVE

Every single one of us eats, and most of this eating happens with others. Biologists and psychologists are harnessing the latest technological tools to find out how the social context influences eating behaviour in human and animal collectives. Using advanced technology to capture 3D body posture and vocal communication, they can explore in detail how the way we eat influences and is influenced by those around us.



→ LEARNING FROM THE BEST

Great tits are great problem solvers. In the 1920s, a population of tits in England learned to open milk bottles to steal cream. Before long, this was happening across the country, demonstrating the cultural spread of behaviour. CASCB researchers are working with great tits to uncover how factors like demographics and ontogeny of individuals precipitate cultural change.



→ INGREDIENTS OF INNOVATION

A lone creative who thinks outside the box might be the spark of innovation, but it is collective behaviour that provides the fuel to turn that spark into flames of success. Behavioural economics researchers are studying the prerequisites for innovation with game theoretic models of innovation and controlled behavioural experiments to test those predictions.

Area B

How behaviour aggregates in the collective

→ EXPLORING IN NUMBERS

Each year, billions of animals migrate to follow food, escape predators, or seek optimal climates. Migration research has largely focused on individuals, but movement decisions can be strongly influenced by social interactions. Using storks, bats, and locusts as model systems, CASCB biologists will address the role of social influence in migration.

Area B



→ LIFTING THE CURSE OF CAUSALITY

A great challenge in the study of collectives is determining causality: who is influencing who in the group. At CASCB, biologists and computer scientists will use virtual reality (VR) to fully control an animal's social environment, opening powerful avenues of inquiry into decision-making, and the physiological and neural mechanisms of collective behaviour.



→ THE NEUROSCIENCE OF COOPERATION

Can our brain show us when we are cooperating or when we are in competition? CASCB psychologists hope to find out. Using state-of-the-art mobile electroencephalography (EEG) technologies to measure brain waves of team mates engaged in games, their project will assess the neural underpinnings of collective failures and successes.



→ GIVING VOICE TO COLLECTIVE MOVEMENT

Deciding what to do and where to go as a group can be challenging, so many animals use shouts or calls to pass information on to others. Studying meerkats in Africa, CASCB biologists will deploy state-of-the-art tools in machine learning and GPS tracking to record movements and vocalizations from entire groups of wild animals—providing the most detailed look yet at how vocalizations mediate collective movement.

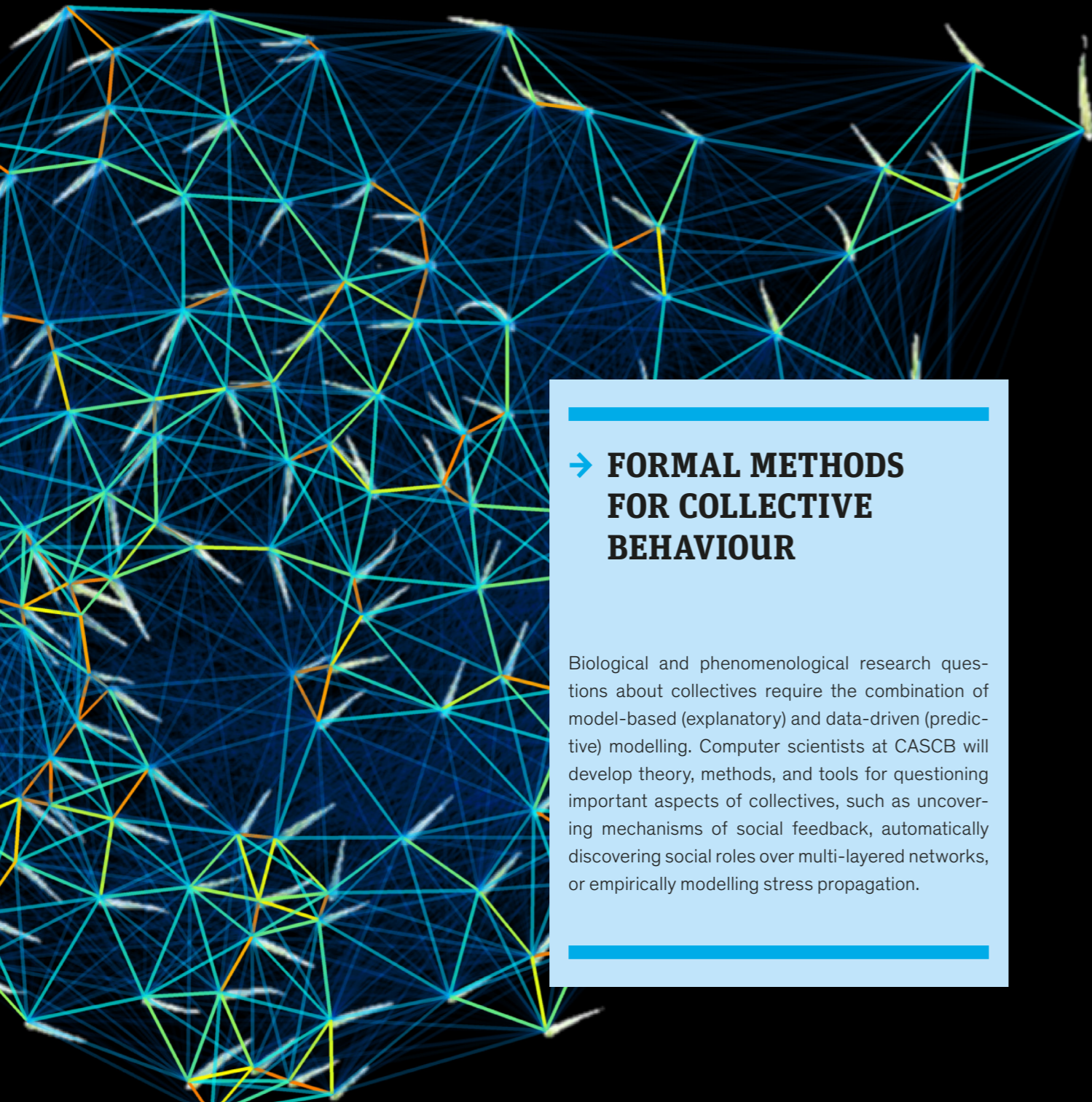


→ TRACKING ANIMALS TO HELP OUR PLANET

In October 2020, the global animal tracking project ICARUS started operations. By equipping animals with tags that communicate data with the ISS, Martin Wikelski has pioneered a revolutionary bio-logging system in which animals can act as a distributed array of sensors to monitor the health of our planet.

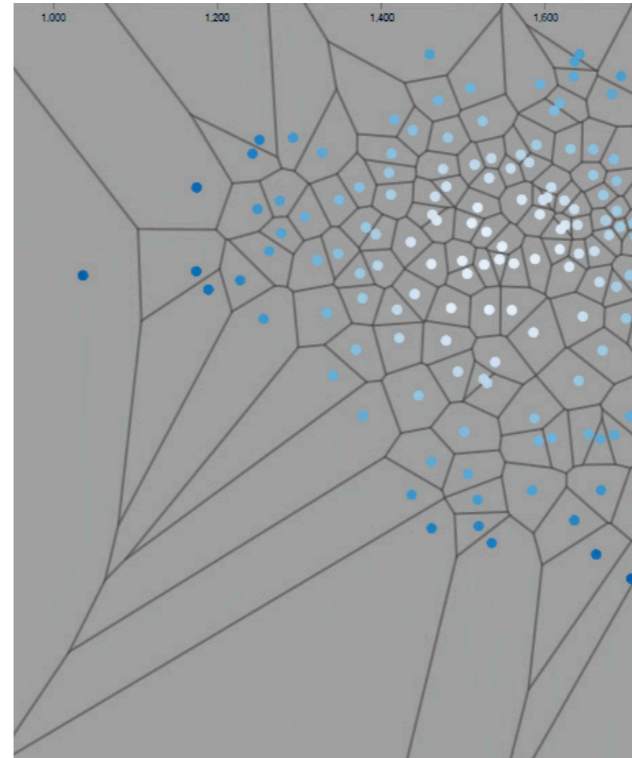
Area C

Exploiting computational methods



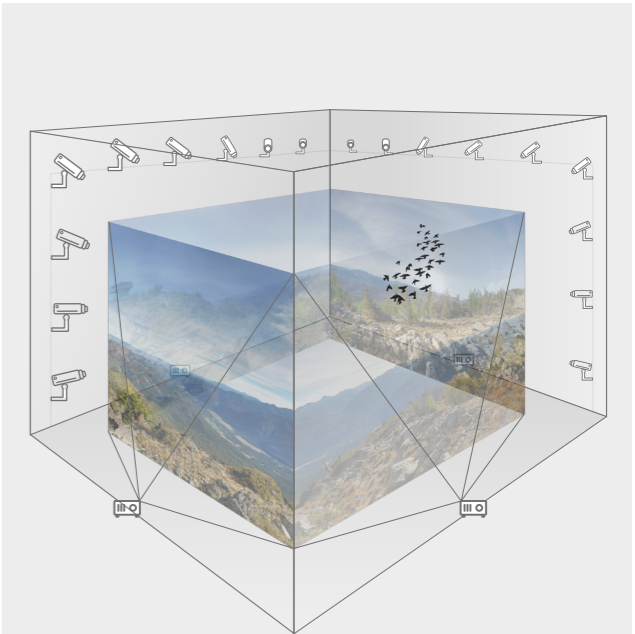
→ FORMAL METHODS FOR COLLECTIVE BEHAVIOUR

Biological and phenomenological research questions about collectives require the combination of model-based (explanatory) and data-driven (predictive) modelling. Computer scientists at CASCB will develop theory, methods, and tools for questioning important aspects of collectives, such as uncovering mechanisms of social feedback, automatically discovering social roles over multi-layered networks, or empirically modelling stress propagation.



→ VISUAL ANALYTICS TELLS A THOUSAND WORDS

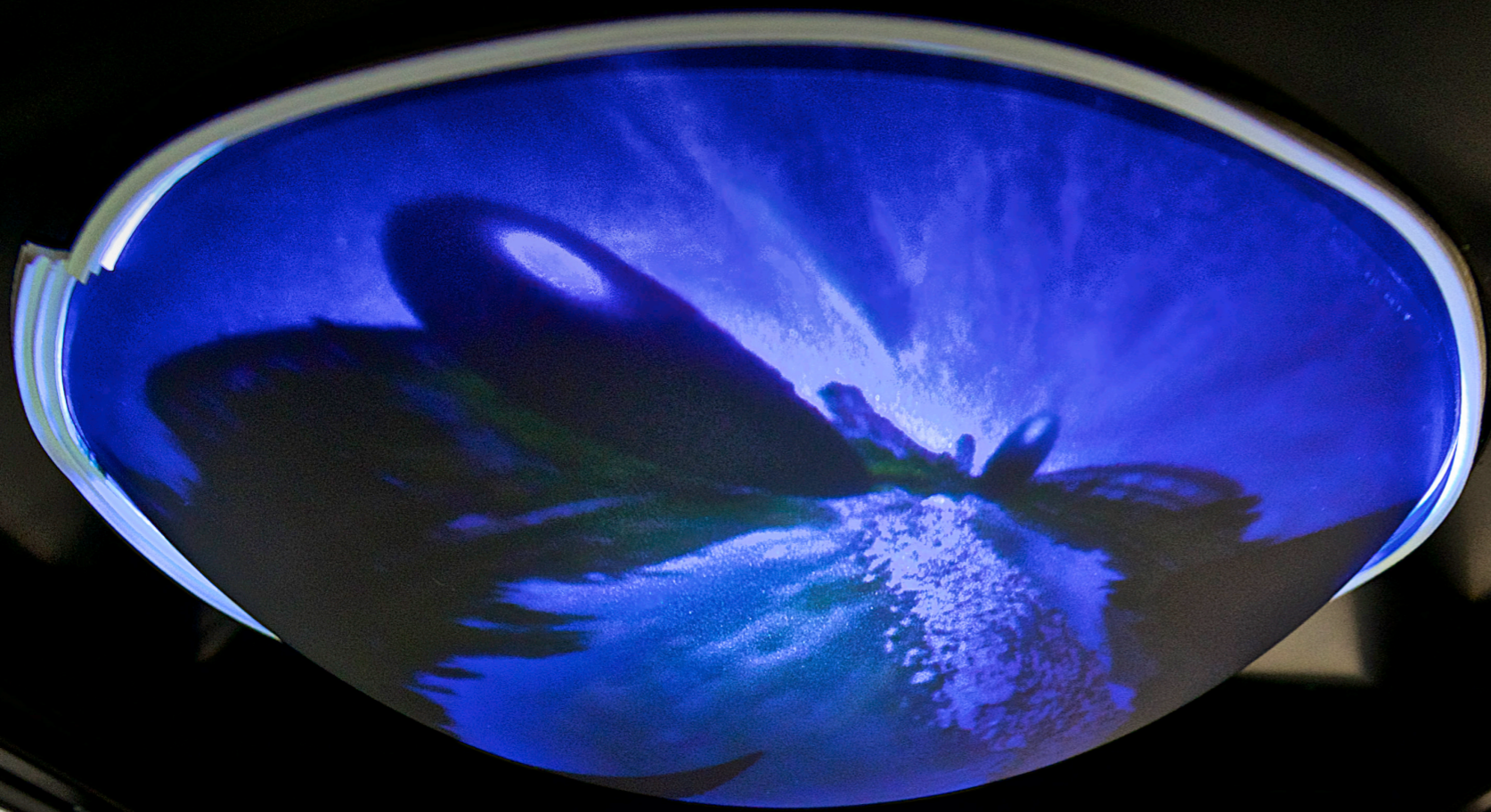
Finding interesting patterns in large data sets remains a challenge for collective behaviour. The machine learning (ML) methods commonly used to explore such data are often complicated by numerous input parameters, which makes for long runtimes. Computer scientists will develop ML methods that enable biologists and psychologists to interactively explore their large datasets, enabling a deeper understanding of their results.



→ BUILDING THE VIRTUAL ANIMAL KINGDOM

Studying collective behaviour under controlled conditions requires artificially recreating an animal's social environment. Enter the Imaging Hangar. In this globally-unique facility, individuals and their interactions are tracked through computer vision to build a "social network", which is continuously analysed by a graph database system. Next, computer graphics adapt the virtual environment in realtime, creating a reactive, naturalistic environment for the study of collectives.

Can VR revolutionize collective behaviour?



Virtual reality is best known as a gimmick for entertainment, but, as we argue in the pages below, the technology is poised to revolutionize the study of collective behaviour. CASCB has developed a suite of core facilities that allows researchers to apply virtual environments in experiments. Our FishVR, FlyVR, and most recently, LocustVR, allows individuals across three model systems to be embedded in a synthetic world in which they can interact with virtual organisms. Networking multiple of these VR systems together allows many real animals to coexist in the same virtual world. Finally, our Imaging Hangar within the Centre for the Visual Computing of Collectives, which will be completed in spring 2021, will enable us to immerse larger animal groups, such as birds and bats, into reactive virtual environments.

How VR became a key to unlocking animal behaviour

Biologists, computer scientists, and engineers at CASCB are collaborating to push the limits of virtual reality to understand decision-making in animal collectives

When you think about virtual reality, you probably think about who it's for: gamers, lovers of tech, or people with a desire to make the outside world disappear. Or maybe you think about that headset, with its sweaty interior and ease of inducing motion sickness. Isn't it just a niche product only used for entertainment?

And yet, were you to look beyond the headset, you would find that the technology for creating an ultra-realistic immersive world has given rise to a thriving offshoot that's far removed from the glare of game arcades. For the last two decades, biologists have been using VR as a tool to reveal fundamental principles about the neuronal circuitry underpinning behaviour in animals. And in the CASCB, behavioural biologists are joining forces with computer scientists to push the limits of this technology to gain insights into decision-making in animal collectives that were previously inaccessible.

"Virtual reality is a game changer for the study of animal collective behaviour," says Iain Couzin, co-speaker at CASCB and director at the MPI-AB.



The FishVR system, which places a single fish in a virtual environment, can be networked together so that multiple fish can be interacting in the same virtual environment.



The LocustVR system in CASCB is the world's first virtual reality system to study freely walking locusts.

→ SO WHAT IS ANIMAL VR?

What we call “VR” is technically defined as an immersive environment where the sensory organs (such as visual or auditory) of the user are artificially stimulated to alter the perception of reality. While we usually think of people using VR, animals can also be placed in virtual environments. But in place of a headset, the animal’s whole body is within the space.

In the last few years, the technology used for animal VR has reached a high water mark where the virtual world and the real world are closer than ever before. In state-of-the-art platforms, animals are embedded in a photorealistic environment in which they can interact with virtual organisms, or inspect and move around virtual obstacles, just as they do in the real world. Graphics are projected into the volume to create a virtual world in full 3D with depth cues. To ensure the illusion is preserved, the animal’s movement is tracked and the graphics are updated accordingly.

In the collective behaviour research program in Konstanz, Couzin and other CASCB researchers

are bringing this powerful technology to bear on the fundamental question of how animal groups make decisions. By placing fish, locusts, and flies in virtual environments, they are beginning to decipher the invisible pathways of communication in animal collectives—something that by Couzin’s admission is “not only hard to observe directly, it is practically impossible without VR.”

→ THE ADVANTAGE OF VR TECHNOLOGY

The advantages that VR brings to studying collective behaviour are twofold. First, it allows for quickly running different experimental scenarios. If a researcher wants to know how fish adjust their behaviour to the orientation of the school, they would, in the old days, have had to observe the school for as long as it took until it changed direction.

“Sometimes that could take days,” says Daniel Calovi, a CASCB postdoctoral researcher who is using VR to study how visual stimuli control behaviour in fish. But in a virtual environment, the hologram of the fish school could be programmed to change direction at



the touch of a button. “You could run this experiment as many times as you need in a day,” he says.

Second, VR addresses a major bottleneck in the study of collective behaviour, what Couzin calls “the curse of causality.” The complexity of social feedbacks in animal groups makes it extremely difficult to infer the causality—who is influencing who—in processes like decision making. But with VR, it is possible to systematically explore all the conditions of interest. “Virtual reality offers a means of controlling causality,” says Couzin.

One way is to decouple elements that are normally coupled, such as making an animal that looks dominant act like a subordinate. “Usually, it’s hard to separate how an animal looks from how it behaves, but with VR we can control these variables in precise ways that are not possible in the real world,” says Couzin.

→ THE CRUCIAL COLLABORATION

If VR is the art of calculated deception, then the magician behind the sleight-of-hand is computer

graphics—in particular, the powerful graphics cards and fast algorithms born from the booming video game industry. “From what the computer graphics industry can achieve for humans, we are close to perfect,” says Oliver Deussen, a professor of computer graphics and co-speaker of CASCB. “Combined with some cool projection systems you can really start fooling humans about reality.”

But of course, it’s not enough to design a realistic virtual world for us. The animals must perceive it to be real. Considering solely vision, many animal species show a range of properties that differ from our own. For instance, the human visual system merges a stream of images into a continuous percept when presented with a refresh rate of at least 30 images per second, whereas this happens at 200 images per second in insects.

“Almost every part of a VR system is designed for humans,” says Stephan Streuber, who develops VR tools for the study of human collectives at CASCB. “If we are to push animal VR to the next level, we should first understand animal perception and take that into account when designing VR systems.” Extending the value of VR beyond a small handful of well-characterized animals will require a radical rethinking of

current hardware and software solutions. “We are at a point now where coordinated action between biologists, computer scientists, and engineers is needed to transform the sophisticated tech we have to fit different species,” says Hemal Naik.

→ KONSTANZ CONNECTION

At CASCB, this transformation is already taking place. Neurobiologist Einat Couzin-Fuchs has teamed up with computer graphics expert Deussen to harness VR to study the once-in-a-generation plague, which swept East Africa in 2020. Using data and movies of locusts that Couzin-Fuchs and her team captured from the plagues in Kenya, the computer scientists are generating a virtual swarm that replicates the “full social” experience of a locust band. Meanwhile, biologists Alex Jordan and Paul Nührenberg are collaborating with computer scientist Mariam Mahmoud on a virtual video game that will help unravel the complex web of cause and effect in behaviour of social groups of fish.

What’s more, a forthcoming facility, known as the Imaging Hangar, will offer unprecedented infrastructure for the design of novel experiments in collective behaviour involving virtual environments. The research space, housed within a purpose-built research building for visual computing of collectives at the University of Konstanz, will be a place where computer scientists and biologists work together to develop dedicated hardware for display, sensing, and real-time processing for extending VR studies to new species.

“This exceptional facility will allow biologists to collaborate with domain experts in computer vision, computer graphics, and perception and latency, to design the next generation of VR solutions.”

Iain Couzin, co-speaker at CASCB and director at the MPI-AB.

The insights gleaned from using VR to unlock the mechanisms behind collective behaviour have far reaching benefits. In the field of robotics, for example, such insights might help engineers in the development of technologies that can be applied to problems demanding more effective and efficient solutions, such as self-organizing robots, self-navigating drones, and micro-robots for disaster relief. In the shorter term, the work being pursued by Konstanz researchers in this area will pave the way for further studies using this technology. “One of the reasons VR is still relatively rare in the animal sciences is that it’s expensive and technologically daunting,” says Couzin. “But the funding we have to conduct this research in Konstanz will take this technology forward to make it more available and useful for the community.”

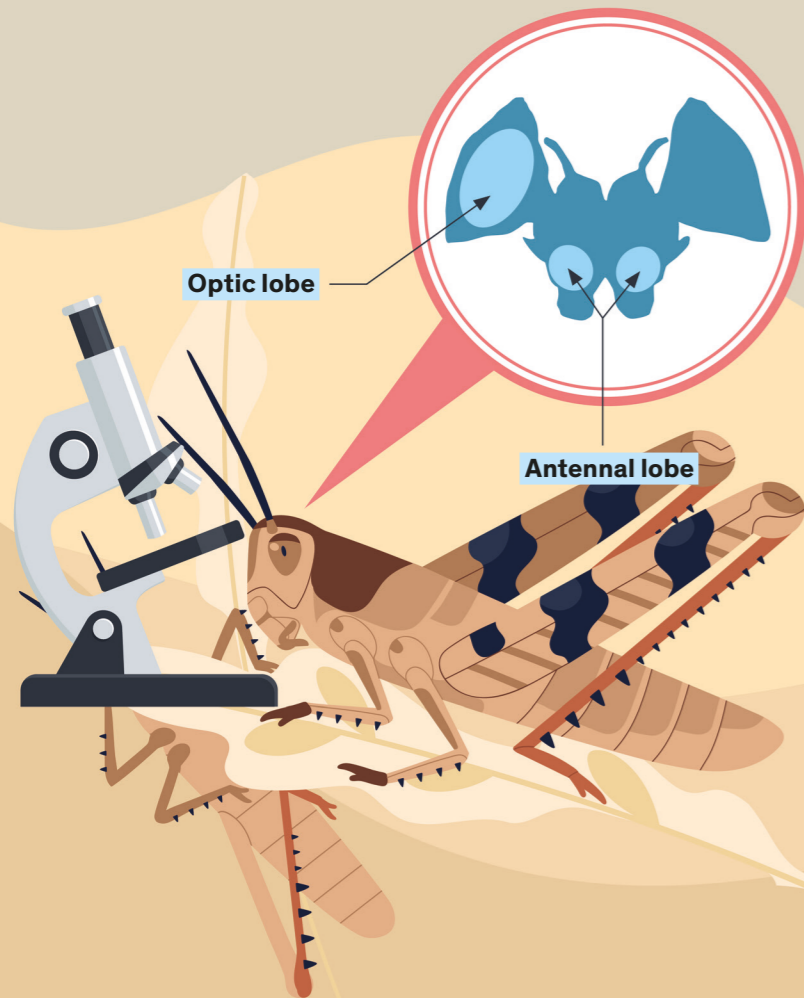
Paper: Naik H; Bastien R; Navab N; Couzin ID. *Animals in Virtual Environments. IEEE Transactions on Visualization and Computer Graphics.*



Can we predict where locust plagues will go?

Locust swarms affect one in ten people on the planet—yet there is currently no reliable way to predict where they move. This means that efforts to control plagues, which destroy crops and threaten the livelihoods of people, often come days after bands have already moved on. Einat Couzin-Fuchs and her team are working to change that. With a powerful arsenal of tools—from brain imaging to high-resolution tracking to virtual reality developed in CASCB—the scientists have begun a project that aims to generate fundamental insight into the question: where does a locust decide to move?

A step ahead of the swarm

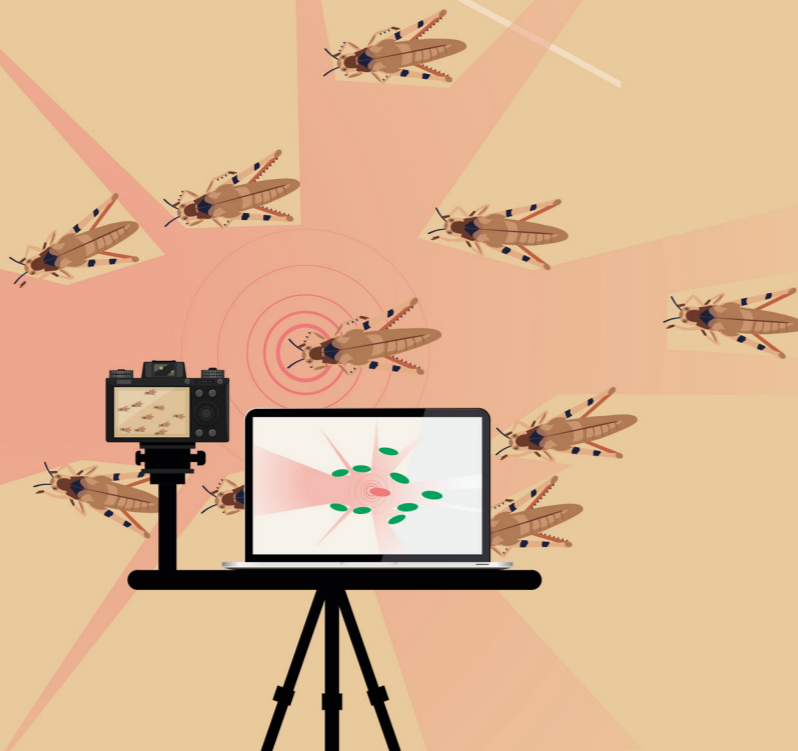


→ 1. FROM BRAIN TO DECISION

A locust in a swarm is embedded in a complex sensory world. The information they take in can be “social” (obtained from other locusts) or “non-social” (such as the smell of nearby plants). The neurobiologists are recording brain neurons that code certain smell and visual patterns to understand how sensory experiences are processed into movement decisions. “At the brain,” says Inga Petelski, “the smell of grass is perceived differently when a locust is in a dense swarm.”

→ 2. FOLLOW THE LOCUST?

Unlike other swarming insects, like ants or bees, locusts are selfish. Insects are not necessarily related to one another in a swarm, so they have no interest in helping each other to find food. This makes for interesting dynamics of how locusts acquire and use information. In laboratory experiments, PhD students Yannick Günzel and Inga Petelski are filming locust interactions and using machine learning tools to identify the visual field of each insect to make predictions of why and when a locust will follow others.

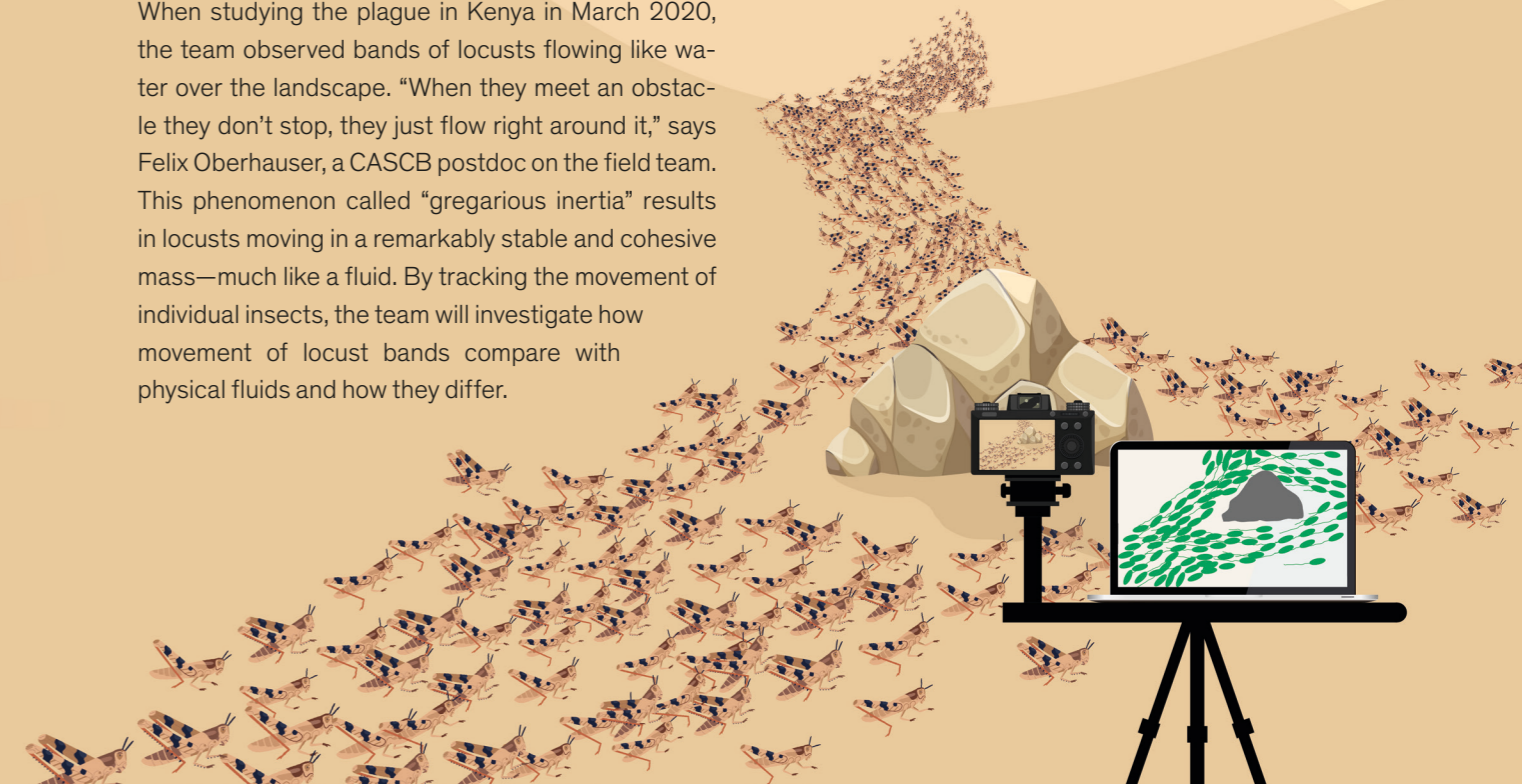


→ 4. WHERE DO PLAGUES GO?

“If we really want to control locusts, we have to know where they will go,” says Couzin-Fuchs. While predicting the global movement of plagues is still out of reach, some suggestions have been proposed. Scientists think that groups are moving in persistent directions towards large features in the landscape, like mountains, or according to celestial cues. The team plans to bring quantitative clarity to this picture. They will attach tracking devices to locusts in swarms, following groups while they split and merge over days.

→ 3. GO WITH THE FLOW

When studying the plague in Kenya in March 2020, the team observed bands of locusts flowing like water over the landscape. “When they meet an obstacle they don’t stop, they just flow right around it,” says Felix Oberhauser, a CASCB postdoc on the field team. This phenomenon called “gregarious inertia” results in locusts moving in a remarkably stable and cohesive mass—much like a fluid. By tracking the movement of individual insects, the team will investigate how movement of locust bands compare with physical fluids and how they differ.



“I couldn’t imagine the scale until I saw it with my own eyes.”



→ INTERVIEW

In February 2020, neurobiologist Einat Couzin-Fuchs travelled with a team of scientists to the locust outbreak in East Africa to do something rarely done with natural plagues: basic scientific research. She describes their field trip to Kenya: what her team saw, what they are doing, and her hopes for how science can contribute to controlling out-breaks.

Dr Couzin-Fuchs, you just recently returned from the locust outbreak in Kenya. What do the swarms look like now?

It looks like water flowing over the land. I heard about the plague proportions, but I couldn’t imagine the scale until I saw it with my own eyes. Some areas were just fully infested, with only toxic plants left behind after the locusts had moved through. The insects move most during the morning and afternoon hours. You see them moving in streams towards new vegetation patches that they will climb over and eat during the hotter hours.

Are all the insects on the ground at the moment?

Yes, right now all the locusts in Kenya are juvenile hoppers. Their wings are not yet mature to fly but this will soon change as they approach their last larval stage before adulthood. These are the second generation of locusts from the current plague. The first generation of adults arrived in Kenya in late January, when they mated and laid eggs. Eggs are laid 8cm underground and so are harder to control with insecticides.



What will the hoppers do next?

Within a week or two they will become adults and fly to invade new areas to mate and reproduce. That is why it's so important to control the plagues now. Each adult lays 100 eggs, which means that each generation can be up to 100 times bigger.

What is happening to control the plagues now?

Ground teams are working to locate and spray the hoppers. They drive alongside the road and walk through fields depositing insecticides.

“Our main goal for research was to understand what are the rules governing the movement of locusts in the swarms.”

What does that mean for people living there?

It is a serious humanitarian crisis. The locals rely on their cattle for survival and tremendously suffer from the loss of vegetation by the locusts. In addition, the chemical used for controlling the outbreak, malathion, has strong undesirable side effects on all other insects and their predators, like birds and reptiles. Mammals, including humans, are also affected as the chemical taints crops, milk, and meat from the area.

You have a team of researchers studying the plagues in Kenya now. What are they doing?

Three other junior researchers from Konstanz travelled with me to Kenya. After we arrived the first step was to find the hopper bands. We received help from

the Food and Agriculture Organization (FAO) of the United Nations, local scientists, and the local villagers. Our main goal for research was to understand what are the rules governing the movement of locusts in the swarms. Believe it or not, despite the scale of damage these plagues bring, this is still an open question. There are only a couple of groups working on understanding the basic biology of the phenomenon.

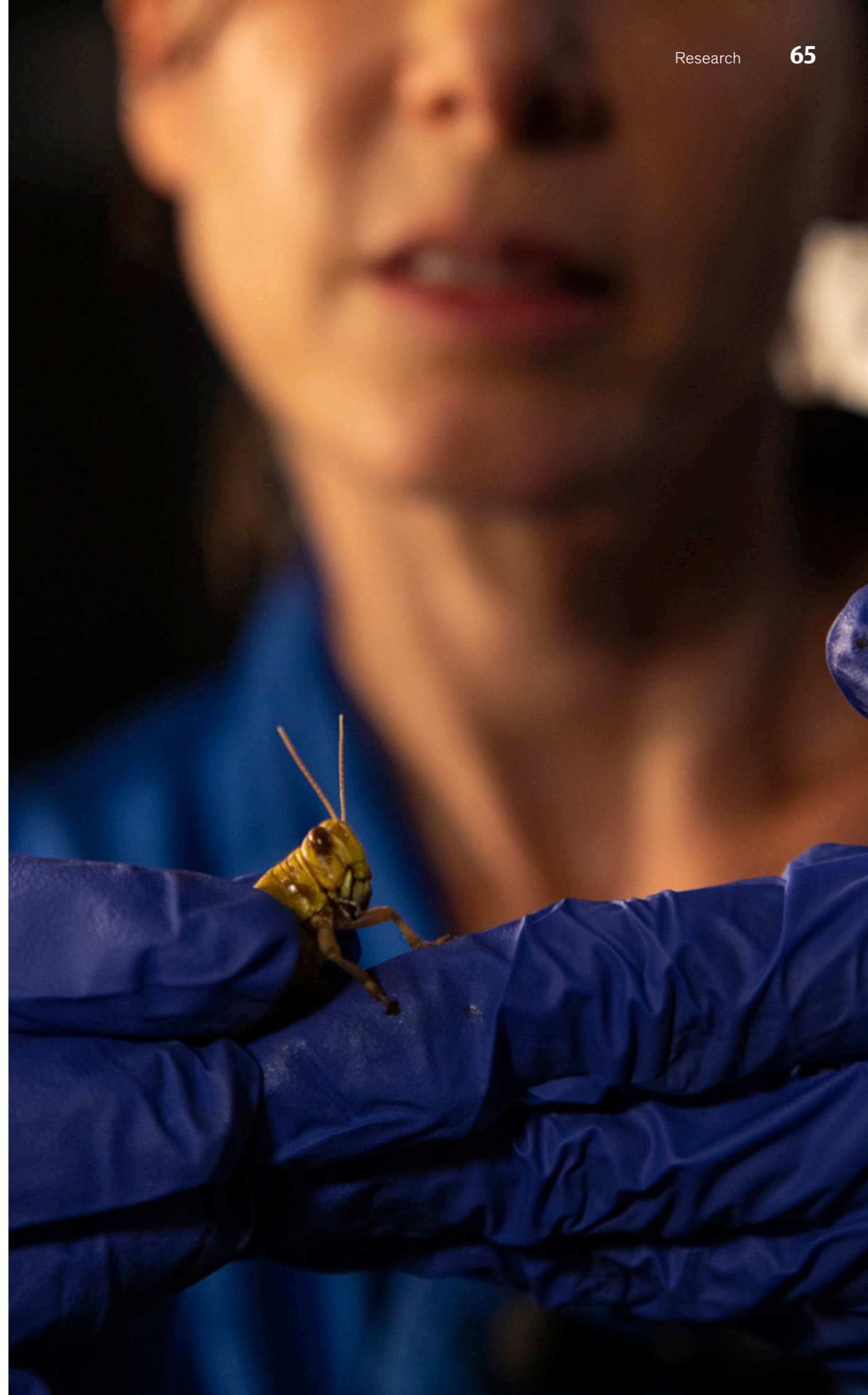
We set up cameras to film them in various topologies and ran experiments to manipulate the hopper streams. We also blocked out their ability to see or smell so we could study what information they use for movement decisions. I only saw the first trials when I was there and am looking forward to hearing what the team finds out next.

What did you find out about how and where they move?

The hoppers start migrating in the morning and it seems that they initially align their movement with the sun. The stunning thing is that they just keep moving. In these quantities, it seems all that matters is that enough surrounding individuals move. While it's too early to say for sure, it seems from our experiments that the hoppers rely almost exclusively on visual cues from their neighbours. This is why the resulting swarm moves so consistently in a single direction.

What are the next steps for your research on the swarms?

The rest of the team is still there and will keep doing experiments to monitor and test the rules of movement. We developed contacts with the local ground teams and we are hoping to combine their data on where swarms are located with our scientific techniques for movement predictions. Having the coordinates of where the insect groups are over time could allow for the development of predictive models to analyze where they will move next. We are trying to establish exchange of information so that in future science could assist in more efficient control.



Can we use collectives to monitor the planet?

Imagine if the science of collective behaviour could improve the health of our planet. That aspiration isn't as fanciful as it might sound. The myriad animals that roam across every corner of our globe could, if tracked, act as a distributed array of sensors that communicate information back to us about the health of wildlife and habitats. Our researchers use high-resolution GPS trackers that also sample 3D acceleration and magnetometer data, temperature, pressure, altitude, and humidity. The data collected can reveal detailed information about the behaviour of animals, as well as local and global environmental changes. As a result, animal collectives could become sentinels, informing humans regarding important changes on our planet.

In 2016, a series of earthquakes hit central Italy without warning. These became part of the study by CASCB researchers, which sought to test if collective animal groups can forecast earthquakes.





Animals might anticipate earthquakes

Even today, nobody can reliably predict when and where an earthquake will occur. However, eyewitnesses have repeatedly reported that animals behave unusually before an earthquake. In an interdisciplinary project, CASCB computer scientist Daniel Keim, economist Winfried Pohlmeier, and biologist Martin Wikelski have investigated whether cows, sheep, and dogs can actually detect early signs of earthquakes.

Experts disagree about whether earthquakes can be exactly predicted. Nevertheless, animals seem to sense the impending danger hours in advance. For example, there are reports that wild animals leave their sleeping and nesting places immediately before strong quakes and that pets become restless. However, these anecdotal accounts often do not stand up to scientific scrutiny because the definition of unusual behaviour is often too unclear and the observation period too short.

In order to be able to use animal activity patterns as a kind of early warning system for earthquakes, the animals would have to show measurable behavioural changes. Moreover, if they do indeed react to weak physical changes immediately before an earthquake, they should react more strongly the closer they are to the epicentre of the quake.

→ 18,000 EARTHQUAKES AND 13 SENSITIVE ANIMALS

In a study published in *Ethology* in 2020, a team including CASCB computer scientist Daniel Keim, economist Winfried Pohlmeier, and biologist Martin Wikelski investigated whether animals really do this. On an Italian farm in an earthquake-prone area, they attached accelerometers to the collars of six cows, five sheep, and two dogs that had already displayed unusual behaviour before earthquakes. The researchers then recorded their movements continuously over several months.



During this period, official authorities reported about 18,000 earthquakes in the region. In addition to many small and hardly noticeable quakes, there were also 12 earthquakes with a strength of 4 or higher on the Richter scale.

The researchers then selected the quakes that triggered statistically relevant earth movements on the farm. These included strong quakes up to 28 km away as well as weaker quakes, the epicentres of which were very close to the farm. However, instead of explicitly looking for abnormal behaviours in the period before these events, the researchers chose a more cautious approach. They first marked all behavioural changes of the animals that were unusual according to objective, statistical criteria. "In this way, we ensure that we not only establish correlations retrospectively but also that we really do have a model that can be used for predictions," says Wikelski. However, this effect was clear only when the researchers looked at all animals together. "Collectively, the animals seem to show abilities that are not so easily recognized on an individual level," says Wikelski.

The data—measured as body acceleration of each farm animal (indicating activity level)—were evaluated using statistical models drawn from financial econometrics. "Because every animal reacts differently in size, speed and according to species, the animal data resemble data on heterogeneous financial investors," explains co-author Pohlmeier, CASCB principal investigator and professor of econometrics at the University of Konstanz. The scientists also considered other disturbance factors such as natural changes in animal activity patterns over the day.

→ UNUSUAL BEHAVIOURAL PATTERNS BEFORE AN EARTHQUAKE

In this way, the researchers discovered unusual behavioural patterns up to 20 hours before an earthquake. "The closer the animals were to the epicentre of the impending shock, the earlier they changed their behaviour. This is exactly what you would expect when physical changes occur more frequently at the epicentre of the impending earthquake and become weaker with increasing distance," explains Wikelski. However, this effect was clear only when the researchers looked at all animals together. "Collectively, the animals seem to show abilities that are not so easily recognized on an individual level," says Wikelski.

→ EARTHQUAKE EARLY WARNING SYSTEM

Real-time data measured by the researchers and recorded since December 2019 show what an animal earthquake early warning system could look like: a chip on the collar sends the movement data to a central computer every three minutes. This triggers a warning signal if it registers a significantly increased activity of the animals for at least 45 minutes.

The researchers have once received such a warning. "Three hours later, a small quake shook the region," says Wikelski. "The epicentre was directly below the stables of the animals."

However, before the behaviour of animals can be used to predict earthquakes, researchers need to observe a larger number of animals over longer periods of time in different earthquake zones around the world. For this, they want to use the newly established global animal observation system ICARUS on the International Space Station ISS, which commenced operations in October 2020.



On an Italian farm in an earthquake-prone area, Martin Wikelski attached accelerometers to the collars of six cows, five sheep, and two dogs.

Small and Medium Projects

Small project 2019 Digital Societies Conference

Thomas Hinz, professor and cluster principal investigator at the history and sociology department, co-organized the 2019 Digital Societies Conference at the University of Konstanz to bring together substantive empirical research, methodological discussions and theoretical contributions on digitalization with respect to all aspects of social life. A range of sessions, including "Polarization of Opinions", "Network Modelling" and computational contributions to social science directly related to CASCB research areas and projects. Cluster members and students attended the conference for free.

#interdisciplinarity #networks #quantitative #events

Small project Deep reductions for modelling collectives

Denis Repin, a visiting doctoral student in Tatjana Petrov's Theoretical Computer Science group, explored how deep learning can facilitate model reduction for highly-dimensional stochastic reaction networks, and how the proposed model reduction technique can be used for efficient modelling of collective dynamics. The proposed outcome is a proof-of-concept case study based on a collaboration with experimental biologist Morgane Nouvian on the defence behaviour of honey bees as continuous-time reaction networks.

#modelling #networks #deeplearning

Small project Individual to group behaviour of mutant zebrafish

Early-career researchers Dan Bath, Katherine Conen and Jacob Davidson from the Collective Behaviour group work together to perform collective motion experiments on several lines of zebrafish mutants to find out how a group's motion changes when a fraction of the group exhibits altered social behaviour, and how individual 'social interaction functions' of mutant fish differ from wildtype zebrafish.

#collectivemotion

Small project Modern machine learning methods for mapping honey bee nests

Ben Koger and Michael L. Smith are going to revolutionize the over 50-year-old method of mapping nest contents of honey bee colonies by integrating advances in computer vision and machine learning. Their novel method will expand the ability to collect high-resolution imaging data on natural nests at reduced risk of colony stress and nest damage, and make it possible to ask questions in largely unexplored areas of social insect biology, e.g. spatial organization.

#computervision #machinelearning #socialinsects #novelmethods

Small project 2020 Early Career Social Learning Researchers Workshop

Michael Chimento and Sonja Wild of the Social Learning group of Lucy Aplin plan to co-organize a Workshop for the Society of Early Career Social Learning Researchers to take place in Konstanz in 2020. While the society is dedicated to the study of social learning in humans and non-human animals, the 2020 workshop will focus on social networks and data science, two of the research themes of the CASCB and highly relevant to early career researchers studying human and animal behaviour. The workshop has been postponed due to the coronavirus pandemic.

#earlycareer #events #networks #sociallearning #interdisciplinarity

Medium project Deep learning of priors for bayesian inverse problems in image analysis

This collaboration around professors Bastian Goldlücke and Stefan Volkwein aims to bring together existing expertise in computer science and applied mathematics with regard to deep learning for inverse problems and stochastic nonlinear optimization. The project is designed to build up core methodology that will ultimately be useful for different applications within the cluster, such as efficient low-level imaging and image processing systems in the Imaging Hangar. It will start by assessing the viability of the approaches before branching into other aspects of optimizing deep models by using advanced mathematical methods.

#deeplearning #coremethodology #inverseproblems #imageanalysis

Small project Desert locust field study

This small project grant enabled the research group around Einat Couzin-Fuchs to extend their lab-based research with a short-term trip to Kenya to study recent massive locust outbreaks. In Kenya, the group succeeded with novel field experiments and high-resolution video recordings of locust swarms. Apart from the acquisition of uniquely valuable data, the trip sparked new insights and questions for the group, attracted considerable media coverage and helped to establish on-going collaborations with local scientist in locust-infested areas. → See page 58.

#fieldstudy #collectivemotion #globalrelevance #insects #pestcontrol #tracking

Medium project Collective transmission of physiological states and behaviour in fish

Postdoc Aneesh Bose successfully drew together a highly interdisciplinary and complementary group of biologists and psychologists for this 1-year project. His proposed research aims to elucidate the modes of stress transmission between individuals in fish collectives and to bring techniques (e.g. behavioural and physiological stress assays) in aquatic systems up to speed with those in terrestrial systems. This project adds highly relevant methods and research questions to the cluster's large starting project A1 ("Stress").

#crossspeciesapproach #stress #transmission #interdisciplinary

Small and Medium Projects

Medium project A software framework for multisensory environments

With funding for this project, postdoc Hemal Naik has set out to develop a software framework that will allow effective use of experimental facilities with multiple sensors for tracking posture and movements. The framework will standardize the process of synchronized data collection, data sharing (formats), and data manipulation (processing). Such standardization will promote collaborative development and will support technology or methods transfer between different local motion tracking facilities i.e. Imaging Barn, Imaging Hangar, or the human tracking facility at the psychology department.

#software #tracking #datacollection
#dataanalysis #standardization #decisionmaking

Medium project Active sensing and collective motion in groups

The study of active sensing groups is an exciting new field and offers ample prospect for the development of readily-usable methodological tools for breaking technical barriers. Postdoc Thejasvi Beleyur proposed to bring together methods from the fields of echolocation, acoustic tracking, computer vision, and collective behaviour. By creating usable workflows to study active sensing in groups of bats, the project aims to provide novel insights into how individuals in active sensing groups manage to detect each other, and to pioneer in quantifying their collective behaviour.

#quantitative #collectivemotion #bats
#activesensing #acoustictracking #computervision

Small project Information-sharing and social generalization in collective risky decision-making

Postdoc Wataru Toyokawa from Wolfgang Gaissmaier's group works with evolutionary biologists and cognitive and decision scientists to understand time-depth mechanisms underlying the conflicts between collective wisdom and maladaptive herding in information-sharing systems. In a computational approach to this question, the project aims to create an innovative theoretical framework, which incorporates both social learning and information-sharing.

#quantitative #interdisciplinary #sociallearning
#decisionmaking

Small project Financial support for the conference Computational Methods in Systems Biology (CMSB)

Tatjana Petrov, Stefano Tognazzi, Matej Hajnal (Dept. Computer and Information Science) and Jacob Davidson (Dept. Collective Behaviour) co-organized the 18th International Conference on Computational Methods in Systems Biology (CMSB) with the aim to bring together researchers from across biological, mathematical, computational, and physical sciences interested in the study, modelling, simulation, advanced analysis, and design of biological systems. The Konstanz conference was fully virtual and free of charge for all delegates to attend.

#events #quantitative #interdisciplinarity
#systemsbiology

Small project Movement analysis toolkit

Cluster PhD student Eren Cakmak proposed this project to extend an existing movement analysis software package ("MoveKit") with more machine learning methods like spatio-temporal clustering techniques, network analysis methods, covariance estimators, and ensemble methods, with a focus on the development of machine learning methods for the analysis of tracked spatio-temporal data. The vision is that the movekit package will be used throughout the whole cluster and bring researchers from the various disciplines together, and may one day be the sci-kit for spatiotemporal data analysis.

#software #movementanalysis #machinelearning
#spatiotemporalclustering

Small project TedX Conference

Upon the initiative and direction of Angela Albi, a dedicated organizing team consisting of PhD students and postdocs from various disciplines at CASCB and the MPI-AB succeeded in applying for an event of the famous TedX format to be produced in Konstanz. Due to Covid-19, the event will take place largely online in March 2021 under the title "Kaleidoscope - patterns in nature and society". The team plans to bring together ideas from collective behaviour research with other contemporary work in art, music, technology, and sciences. With funding from CASCB, the team will be able to cover their expenses especially for video production and editing.

#events #interdisciplinarity #outreach
#community

Small project Honeybee mass stinging behaviour: data-informed parameter inference for population Markov chains

Trying to unravel the mechanisms of social feedback in honeybee defence through a mechanistic model which explicitly models each bee and its communication via pheromones, Zukunftskolleg Fellow Morgane Nouvian and PhD student Matej Hajnal have been collaborating to start building a tool which would allow easier interaction with experimentalists through a graphical user interface (GUI) and by transparently incorporating the mechanistic assumptions on the one side and data on the other. Specifically, the tool aims to implement several different methods for parameter search (refinement, sampling, Bayesian inference, regression), and explore how they can be combined for improving performance.

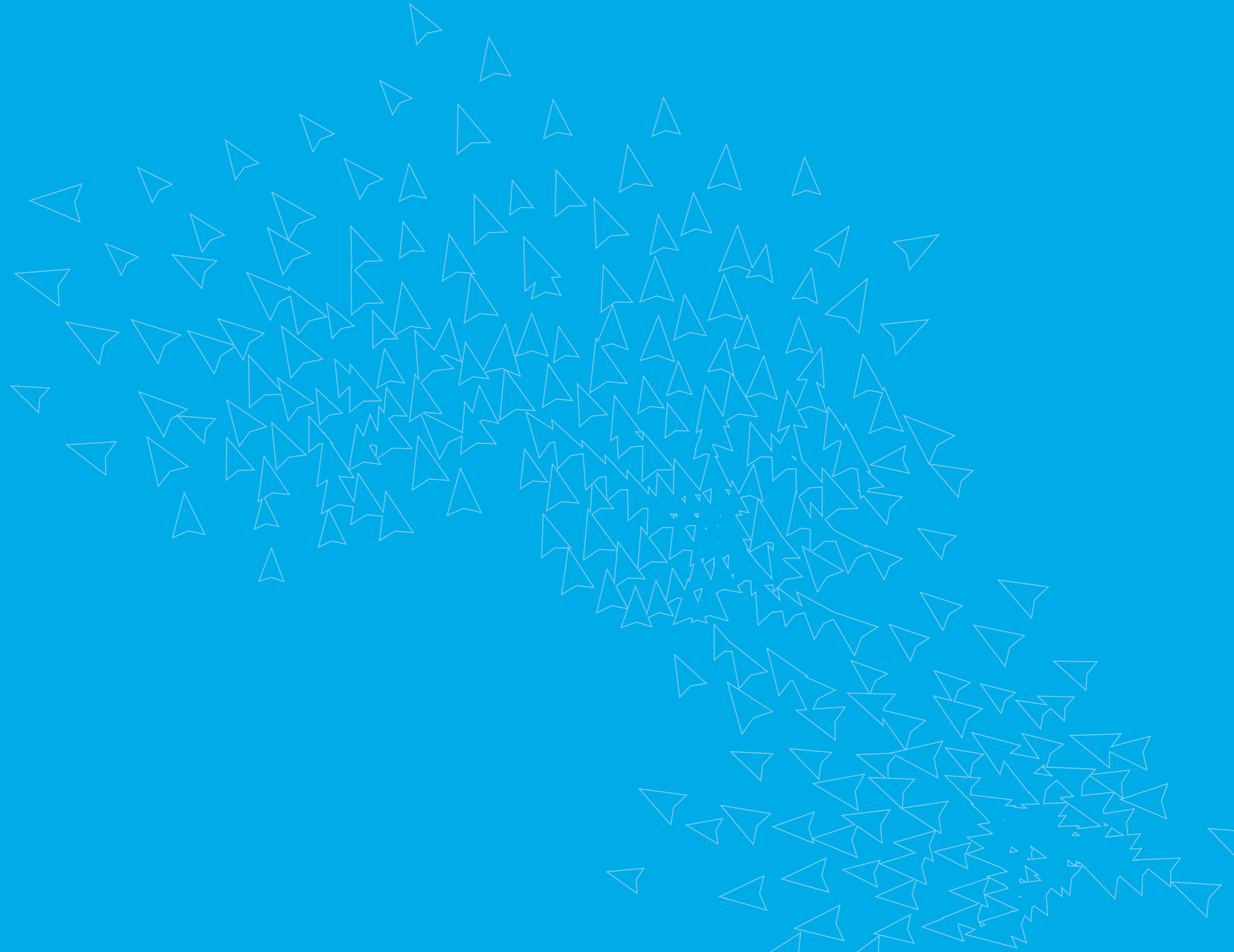
#modelling #software #parametersearch
#socialfeedback #socialinsects

Small project Combining drone-based behavioural observation with long-term data for deeper insights into collective processes

Biologist and cluster affiliate Blair Costelloe and PhD candidate Ben Koger seek to establish a fully functional drone-based research program in collaboration with the Guassa Gelada Research Project (GGRP), which is a long-term study of gelada monkeys (*Theropithecus gelada*) in central Ethiopia. Within the scope of this grant, the team will evaluate the feasibility of using drones to monitor gelada movement and behaviour during a field trip and develop drone-based observation protocols for geladas that are compatible with established data collection activities.

#movementecology #drones #methods
#collaboration #conservation

CULTURE OF COLLABORATION → Seminar Series //
Research Retreats // Conferences // Education // Public
Engagement



CASCB Seminar Series

A cornerstone of our centre's program, our weekly seminar series invites speakers locally and from around the globe to present a one-hour talk and engage more deeply with our members by meetings and social events afterwards. In line with our mission to foster a culture of open science and promote the science of collective behaviour in the broader community, CASCB seminars are recorded and made freely available on our website and streaming channel.



Youtube Channel: Collective Behaviour



Wintersemester 2020/21



Nir Gov

Weizmann Institute of Science

The origin of collective transport by ants and emergent problem solving behaviour



Sarah Geber

University of Zurich

COVID Norms: monitoring and analyzing behaviour



David Sumpter

University of Uppsala

How to best study collective behaviour?

“This amazing talk had everything—a history of the field, some thoughts on its future, and advice for young researchers!”

Vivek Hari Sridhar
Doctoral student, MPI-AB



Alexander Baugh

Swarthmore College

Sex is stressful. Is stress sexy?
The role of glucocorticoid hormones in modulating sexual behaviour



Orit Peleg

University of Colorado Boulder

Collective ecophysiology and physics of honey bee swarms



Manfred Hartbauer

University of Graz

Alternative treatments of gregarious locusts



Michael Griesser

University of Konstanz

Collective behaviours in personalized groups: why family living matters

Summersemester 2020



Serena Ding

Imperial College London

C. elegans as a window into the genetics of individual and collective behaviour



Pawel Romanczuk

Humboldt University of Berlin

Collective information processing: interplay of self-organization and function in collective (biological) systems



Valentina Di Santo

Stockholm University

Climate change and locomotion: Insights into energetics and biomechanics of fishes



Jens Pruessner

University of Konstanz

Physiological synchrony across systems and species



Marcus Gröttrup

University of Konstanz

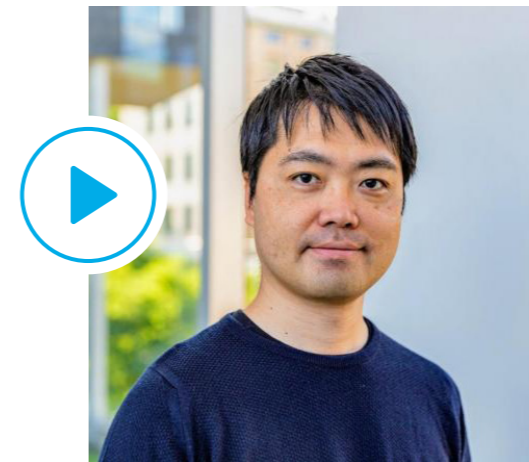
The influence of social stress on T cell responses against viruses, tumor cells, and on behaviour of mice



Dina Dechmann

Max Planck Institute of Animal Behavior

Ephemeral resource adaptations in bats



Hirokazu Shirado

Carnegie Mellon University

Disastrous effects of human networks in emergency coordination experiments

“We met with Hiro to discuss technical problems in online group research. It reassured us that our approach to dealing with online-group research problems (in particular, drop-outs and invalid responses) is feasible and cutting-edge.”

Ariana Strandburg-Peshkin,
CASCB PI

Helge Giese,
Group Leader Social Psychology

Wintersemester 2019 | 20



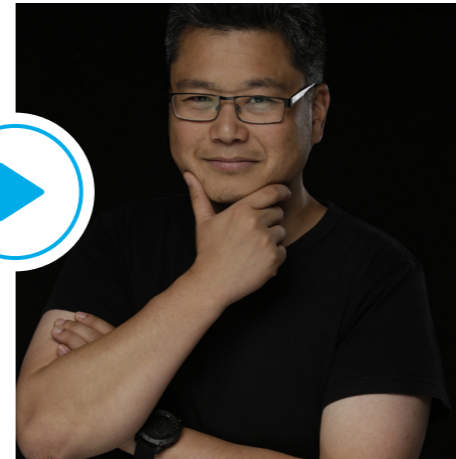
Mélissa Berthet

École Normale Supérieure

What do titi monkeys' calls mean?

“After Melissa’s talk, we held a round table discussion on animal linguistics with participants from the wider university. This very fruitful exchange formed the basis of a collaborative grant proposal with members of the Zukuftskolleg.”

Alex Jordan,
CASCB PI



Shinichi Nakagawa

University of New South Wales

A behavioural ecologist meets meta-analysis and falls in love...



Mirco Tribastone

IMT Lucca

Automatic simplification of large-scale reaction networks



Academic Staff Development

PhD Info Session:
Carina Dambacher & Silke Hell



Anja Weidenmüller

University of Konstanz

Temperature homeostasis in bumblebee colonies



Barbara König

University of Zurich

The evolutionary significance of social interactions – a case study in house mice



Fábio Daura Jorge

Federal University of Santa Catarina
Florianópolis Campus

Effects of an unusual foraging specialization in a dolphin population



Ulrik Brandes

ETH Zurich

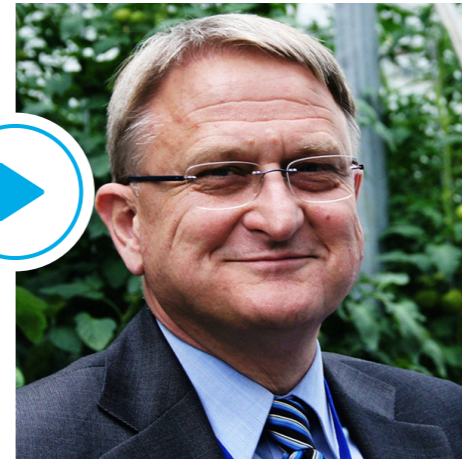
Groups in social networks



Naomi Leonard

Princeton University

Resilience and the dynamics of spreading processes



Winfried Pohlmeier

University of Konstanz

Estimating peer effects from network data



Thomas Hinz

University of Konstanz

Xenophobic events as a collective phenomenon?



Fumin Zhang

Georgia Institute of Technology

Bio-inspired autonomy for mobile sensor networks



Charles Efferson

University of Lausanne

The promise and the peril of using social influence to reverse harmful traditions



Clemens Bechinger

University of Konstanz

Active particles with social interactions



Meg Crofoot

University of Konstanz and Max Planck Institute of Animal Behavior

The collective ecology of animal societies

Summersemester 2019



Alex Jordan

Max Planck Institute of
Animal Behavior

Limitations on our interpretations
of animal behaviour, and how
machines might help



Tatjana Petrov

University of Konstanz

Data-informed parameter synthesis
for stochastic population models



Oliver Deussen

University of Konstanz

Non-photorealistic rendering:
how to display and abstract objects
for humans



Einat Couzin-Fuchs

University of Konstanz

Active perception: the role of
motion in insect olfaction



Fernando Peruani

Université de Nice Sophia Antipolis

Intermittent behaviour across
scales in biology



Harald Schupp

University of Konstanz

Brain synchronization: functional
neuroimaging as a tool to study group
processes



Wolfgang Gaissmaier

University of Konstanz

From individual decisions to
collective behaviour



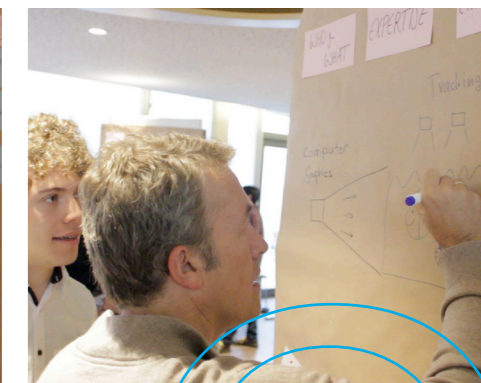
Mark Laidre

Dartmouth College

Architectural foundations of
collective behaviour in nature's
housing market



Research Retreats



→ OCTOBER 2019

INAUGURAL ANNUAL RETREAT, REICHENAU

EVENT: 2 days; 80 people

As the first official get-together in our first year of operation, the “Inaugural CASCB” Annual Retreat was all about getting to know one another in a casual setting. The venue, on the beautiful island of Reichenau, provided the perfect backdrop for informal socializing and relaxing nature walks. Science was also high on the agenda, and collaborators on large projects met in groups to take a strategic look at their research plan: what had been done? what were the challenges? what do they need to succeed? Brainstorming sessions also took place to bring focus on how support measures can better work for CASCB researchers. Early career development, science communication, and tools for analysis were just some topics discussed.

→ MARCH 2020

MINI RETREAT, KONSTANZ

EVENT: 1 day; 50 people

A 15th-century historic building was the setting of the “CASCB Mini Retreat”, held a mere weeks before large gatherings were disallowed in Germany. The focus here was on large projects, and teams presented their work to date and sought feedback.

Conferences

→ ASAB SUMMER 2019, 26-28 AUGUST “NEW FRONTIERS IN ANIMAL BEHAVIOUR”

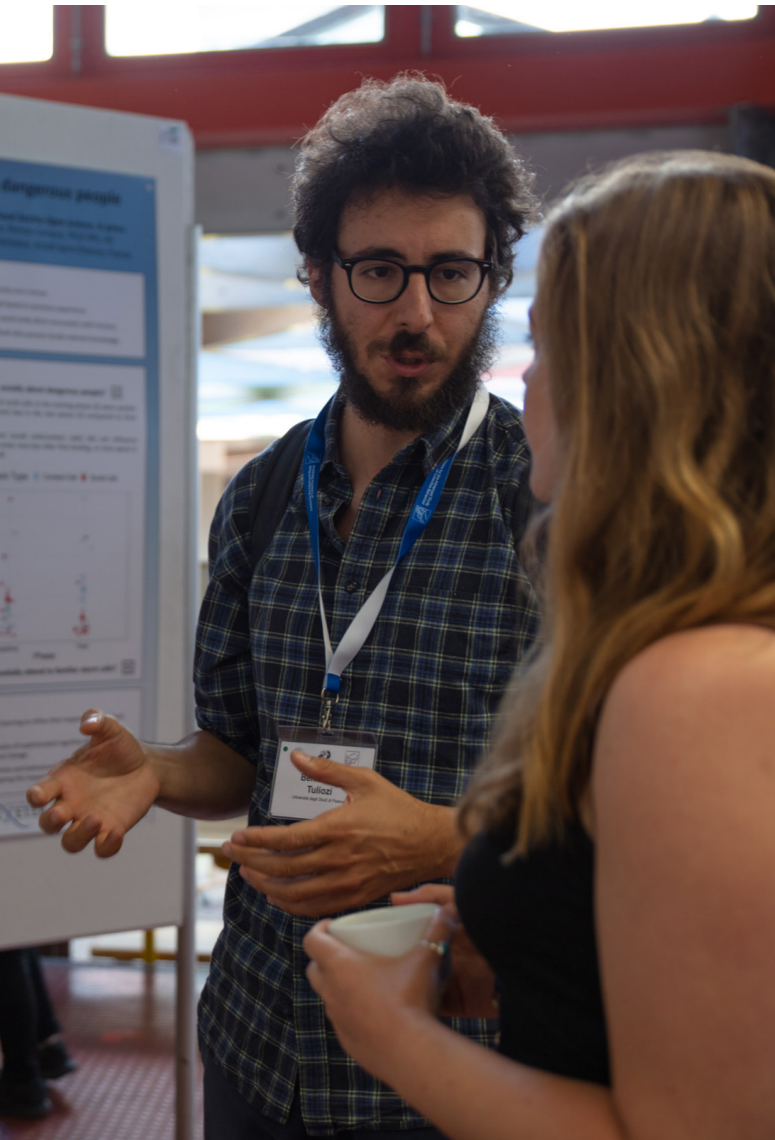
In 2019 CASCB co-hosted its first major conference, the Association for the Study of Animal Behaviour Summer Conference, together with our partners in the Max Planck Institute of Animal Behavior. Five hundred animal behaviour scientists gathered in Konstanz to share their research findings, with an emphasis on the new tools that are driving the transition of animal behaviour from a largely observational to a more quantitative science.

On top of the usual mix of talks, plenaries, and posters, ASAB 2019 offered an optional full-day workshop session held before the formal opening. These workshops—covering deep learning, tracking animals from video (lab and field), bio-logging, bio-acoustics techniques, genomic techniques, and automation and classification techniques—gave participants hands-on experience with implementing these tools in their own research and were taught by experts who have experience with these technologies. Roughly half of the entire delegation participated in these workshops, which is testament to the value of this training at such a timely moment when the field is pivoting to relying on these emerging technologies.



→ AS 2019, 25 – 27 SEPTEMBER

The 2nd Academy of Sociology (AS) conference was held in Konstanz with CASCB PI Thomas Hinz leading the organizing committee. The “Digital Societies” theme included empirical research, methodological discussions, or theoretical contributions on digitalization with respect to all aspects of social life.



→ I, SCIENTIST 2020, 16 – 19 SEPTEMBER

Created by a team of Konstanz professionals, I,Scientist is a professional development conference that seeks to drive conversation and develop opportunities on three levels: gender, career paths, and networking.



→ CMSB 2020, 23 – 25 SEPTEMBER

The Computational Methods in Systems Biology conference brings together researchers from across biological, mathematical, computational, and physical sciences who are interested in the study, modelling, simulation, advanced analysis, and design of biological systems. PI Tatjana Petrov's team led the organization of the all-virtual event that had the highest attendance in the conference's history.



Education

Our range of university courses are equipping scholars with foundational knowledge and next-generation tools for the quantitative study of behaviour.

→ QUANTITATIVE METHODS IN MARINE ECOLOGY

The pristine waters of STARESO field station in Corsica, Italy, is the location for this field based course. Masters' students are immersed in a modern curriculum for ecology, spanning animal behaviour, evolutionary theory, and hands-on training in underwater field work, animal tracking, programming, and deep learning.

Instructors:

Alex Jordan and Ariana Strandburg-Peshkin (Biology)

→ ANIMAL BEHAVIOUR

This introductory lecture series focuses on animal behaviour and explaining the mechanisms that generate behaviour including locomotion and decision-making.

Instructors:

Iain Couzin, Alex Jordan and Damien Farine (Collective Animal Behaviour)

→ CURRENT TRENDS IN COMPUTATIONAL MODELLING OF COLLECTIVES

Targeted at masters' students, this interdisciplinary seminar course is designed for students to become familiar with literature on modeling collective systems.

Instructors:

Tatjana Petrov and Stefano Tognazzi (Computer and Information Science); Jacob Davidson (Biology)

→ ANIMAL SOCIALITY

With an exciting range of invited speakers, this seminar-course introduces students to cutting-edge original research on animal societies and trains them to discuss current results and hypotheses.

Instructors:

Gisela Kopp and Ariana Strandburg-Pehskin (Biology)

→ COLLECTIVE ANIMAL BEHAVIOUR

This advanced masters' course (VTK) focuses on the quantitative analysis of collective animal behaviour and how theoretical models lead to predictions about the benefits individuals gain by forming groups.

Instructors:

Iain Couzin, Alex Jordan and Damien Farine (Collective Animal Behaviour)



A photograph showing a woman in a bright yellow sweater using a VR headset. She is holding the device with both hands, and her eyes are focused on the screen. In the background, a man with glasses and a red jacket is looking towards the camera. The scene is set in a well-lit indoor space, possibly a museum or a public event.

Public Engagement

CASCB's approach to public engagement is inspired by the collectives we study: our activities range in scale from small gatherings to large public events, and they seek to transcend geographical lines to reach people around the globe.

The captivating dynamic and visual nature of collective behaviour gives us a powerful opportunity to engage the public in the science behind the complex patterns that interacting individuals create. We seize this opportunity—translating our research into compelling stories by hosting events, working with the media, and creating content for University of Konstanz and Max Planck websites that thousands visit each month. In our first two years of operation, we held a standing-room only talk by acclaimed

popular science writer Lee Dugatkin and hosted a world-premiere of an animation about CASCB stork research that was nominated for a RIF award. But even as the coronavirus pandemic has kept many of us at home, we continue to find ways to draw people far and wide into the incredible science of collectives. In 2021, we are proud to be hosting an all-virtual TEDxKonstanz event.

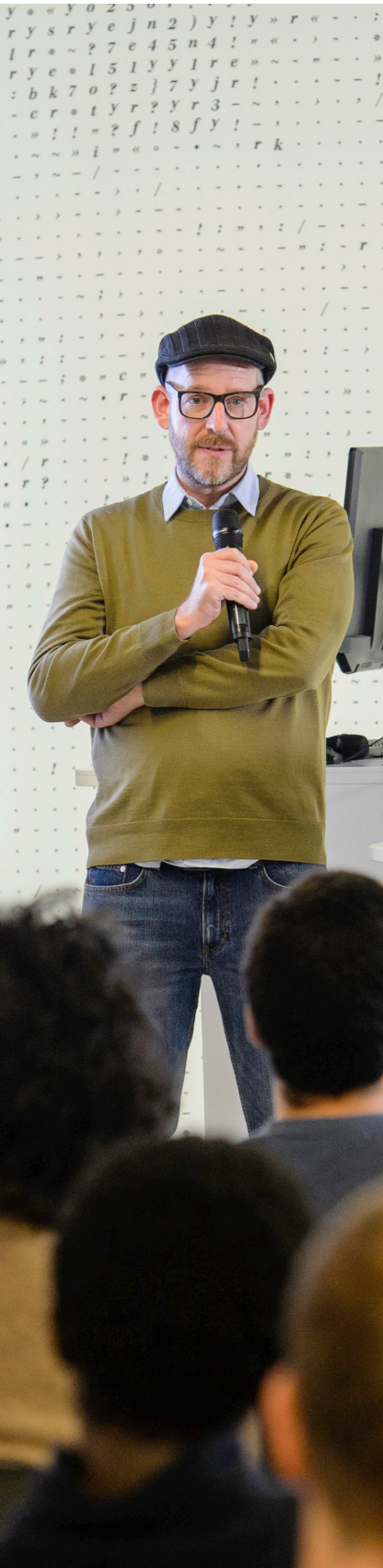
→ A STORK'S STORY OCTOBER 2019

On a day that had all the trappings of a perfect day for flying — clear skies, a gentle breeze with the crisp bite of autumn — it felt particularly fitting to be celebrating the world's most iconic long-distance flier at the University of Konstanz library, a modern space that was transformed into a science festival for World Migratory Bird Day.

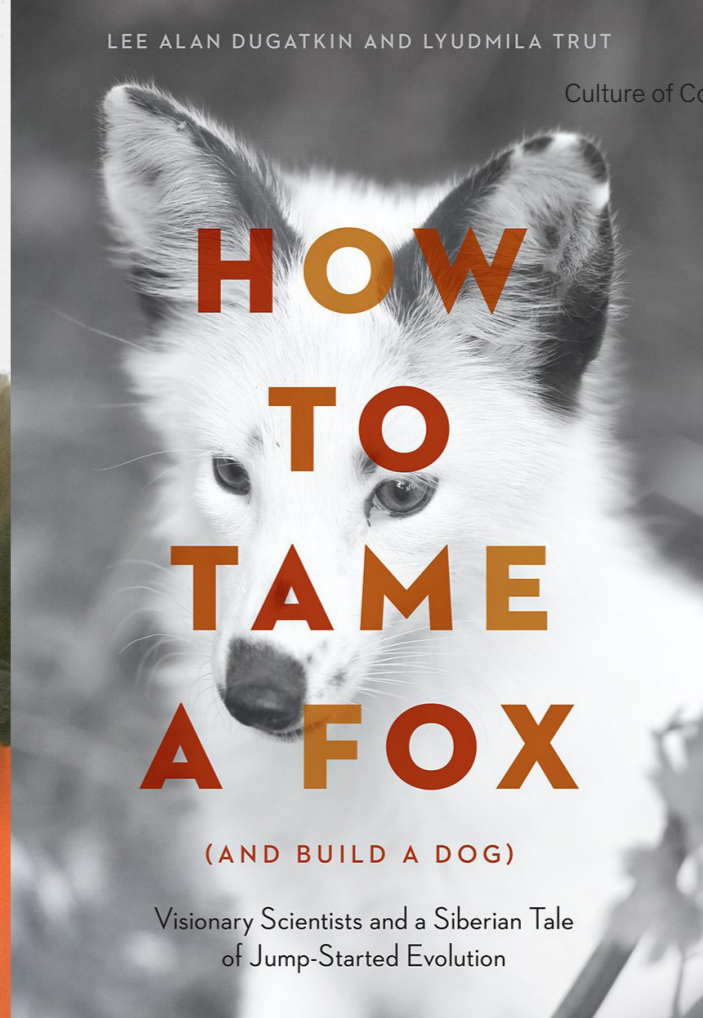
Hosted by CASCB and our friends at MPI-AB, the Konstanz event was held in honour of a very special migratory bird: the white stork (*Ciconia ciconia*). The famous species, often seen roosting on roofs or circling above the skies of Konstanz, has been the focus of years of research by CASCB and MPI-AB scientists Martin Wikelski, Wolfgang Fieldler, and Andrea Flack. But on October 12, the celebrated bird stepped into a brighter spotlight as the star of an animated short film “A Stork’s Journey” created by comic creator Karrie Fransman and London-based firm PositiveNegatives.

The event welcomed guests into the university library, where a movie theatre of sorts had been prepared: colourful pillows were scattered on stairs, beanbags were nestled against walls, and rows of chairs were laid out in front of a large screen. Here, “A Stork’s Journey” was shown for the first time to audiences anywhere in the world. The film brings to life the latest scientific breakthroughs about storks—including insight into their conservation needs—that have resulted from the global tracking work of CASCB and MPI-AB scientists.

To put the film into context, the audience heard from the film’s producer Benjamin Dix as well as the scientists behind the research. The event continued with hands-on demonstrations of the technology behind the science. Stations included displays of the tags used to track storks; 3D printed backpacks used for fine-scale tracking of very small birds; virtual reality headsets used for visualizing and interpreting the highly complex data that is collected for storks; and a short movie made about the least known migrant, the Amur Falcon.



Biologist Nora Carlson and computer graphics expert Patrick Paetzold showed off their collaboration on lightweight 3D printed backpacks used to track birds.



→ **FOX TALE CAPTIVATES
KONSTANZ
FEBRUARY 2019**

On 25 February, prize-winning book author Lee Alan Dugatkin delivered the public talk: “How to Tame a Fox (and Build a Dog)” to a packed audience at the University of Konstanz. Dugatkin, a Professor of Biology and Distinguished University Scholar at the University of Louisville, is an acclaimed author of numerous popular science books. For his Konstanz lecture, Dugatkin retraced the story told in his 2017 book *How to Tame a Fox (and Build a Dog)*—a story of jump-started evolution and the most astonishing breeding experiment ever undertaken.

Following the talk, Dugatkin met with fans of his book, signing English and German editions that were whisked away by school students and members of the public.

Dugatkin says: “I hope my talk reached all people: the public, aspiring young scientists, and seasoned researchers studying evolution, behaviour, or the history of science. The six-decade-long study on domesticating foxes in Siberia has everything from cutting-edge science to political intrigue to human-animal love stories. But perhaps more than anything else, it shows that when smart people with a passion for science pair that with almost super-human perseverance, we can unwrap the mysteries of the world we live in.”

Yannick Günzel and Felix Oberhauser show off the locust experimental arena during filming by P.M. Wissen.



→ LOCUST RESEARCH SWARMS ONTO THE SCREEN

When news got out that Einat Couzin-Fuchs was taking a team of biologists to study the East African locust plagues in early 2020, the media swarmed to cover the story of how science was using fundamental knowledge as a weapon against plagues. In February, the CASCB team was joined in the field by journalist Gioia Forster from the German Press Agency DPA, who published a feature article describing how the scientists were conducting experiments on the visual and olfactory senses of the insects. When the team returned to Konstanz in March, TV crews for the broadcasters ARTE and P.M. Wissen visited to film how lab work, including behavioural assays, brain imaging, and virtual reality experiments, was bolstering the data gathered in the field. The documentary aired on ARTE on October 19 and P.M. Wissen on December 11, 2020.



Xenius:
Nützliche Heuschrecken
arte.de

Wie bewegt sich ein Heuschreckenschwarm?
pm-wissen.com

INFRASTRUCTURE AND PERSONNEL → Staff and
Student Roll Call // Global Partners // Infrastructure //
ICARUS // Imaging Barn



Members

Collective behaviour in Konstanz is trans-disciplinary at its core. Our community is made up of researchers from seven disciplines — biology, computer science, economics, psychology, maths, physics, and sociology — and from two institutions — the University of Konstanz and the Max Planck Institute of Animal Behavior. What unites us is a drive to move beyond the boundaries of disciplines in order to collaborate on our shared interest: studying individuals in the context of who they influence and are influenced by, and harnessing tools to process, analyse, and visualize the resulting data.



Ellen Aikens

CASCB
Post-doctoral researcher
Animal Migration



Lucy Aplin

CASCB PI
Cognitive Ecology, MPI-AB



Carla Avolio

Communications Officer,
CASCB



Armin Bahl

CASCB PI
Neurobiology, Uni Konstanz



Clemens Bechinger

CASCB PI
Physics, Uni Konstanz



Michael Berthold

CASCB PI,
Bioinformatics and
Data Mining, Uni Konstanz



Felicia Afriyie

Diversity, Equal Opportunity &
Career Officer, CASCB



Hanja Brandl

CASCB
Post-doctoral researcher
Collective Behaviour



Daniel Schardosim Calovi

CASCB
Post-doctoral researcher
Collective Behaviour



Blair Costelloe

CASCB Affiliate
Collective Behaviour, MPI-AB



Iain Couzin

CASCB Co-speaker
Collective Behaviour,
Uni Konstanz and MPI-AB



Einat Couzin-Fuchs

CASCB PI
Neurobiology, Uni Konstanz



Margaret Crofoot

CASCB PI,
Ecology of Animal Societies,
MPI-AB



Grace Davis

CASCB Affiliate
Ecology of Animal Societies,
MPI-AB



Dina Dechmann

CASCB PI,
Animal Migration, MPI-AB



Oliver Deussen

CASCB Co-speaker
Visual Computing,
Uni Konstanz



**Kiran
Dhanjal-Adams**

CASCB
Post-doctoral researcher
Ecology of Animal Societies



Fabian Dvorak

CASCB
Post-doctoral researcher
Applied Research in Economics



Bastian Goldlücke

CASCB PI
Computer Vision and Image
Analysis, Uni Konstanz



Susanne Goldlücke

CASCB PI
Microeconomic Theory,
Uni Konstanz



Daniela Göpfrich

Administrative Manager,
CASCB



Damien Farine

CASCB PI
Collective Behaviour, MPI-AB



Urs Fischbacher

CASCB Co-speaker
Applied Research in
Economics, Uni Konstanz



Andrea Flack

Group Leader,
Animal Migration, MPI-AB



Michael Griesser

CASCB Affiliate
Biology, Uni Konstanz



Marcus Groettrup

CASCB PI
Immunology, Uni Konstanz



**Michael
Grossniklaus**

CASCB PI
Databases and Information
Systems, Uni Konstanz



Wolfgang Gaißmaier

CASCB PI,
Social Psychology and Decision
Sciences, Uni Konstanz



Giovanni Galizia

CASCB PI
Neurobiology, Uni Konstanz



Helge Giese

Group Leader
Social Psychology and Decision
Sciences, Uni Konstanz



Mathias Günther

Imaging Barn, Technician,
CASCB



Thomas Hinz

CASCB PI
Empirical Social Research with
a Focus on Survey Research,
Uni Konstanz



Edward Hurme

CASCB
Post-doctoral researcher
Animal migration

**Martin Imhof**

CASCB Affiliate
General and Biological
Psychology, Uni Konstanz

**Alex Jordan**

Group Leader
Collective Behaviour, MPI-AB

**Urs Kalbitzer**

CASCB Affiliate
Ecology of Animal Societies,
MPI-AB

**Morgane Nouvian**

CASCB Affiliate
Zukunftskolleg, Uni Konstanz

**Chase Nuñez**

CASCB Affiliate
Ecology of Animal Societies,
MPI-AB

**Felix Oberhauser**

CASCB
Post-doctoral researcher
Collective Behaviour

**Daniel Kaping**

General Manager,
CASCB

**Daniel Keim**

CASCB PI
Data Analysis and
Visualisation, Uni Konstanz

**Christoph
Kleineidam**

Professor of Neurobiology,
Uni Konstanz

**Tatjana Petrov**

CASCB Junior Professor
Modeling Complex Self-
Organised Systems, Uni Konstanz

**Winfried Pohlmeier**

CASCB PI
Economics and Econometrics,
Uni Konstanz

**Jens Pruessner**

CASCB PI
Clinical Psychology,
Uni Konstanz

**Gisela Kopp**

CASCB Affiliate
Zukunftskolleg, Uni Konstanz

**Stefan Leue**

Chair of Software and
Systems Engineering,
Uni Konstanz

**Hemal Naik**

CASCB
Post-doctoral researcher
Visual Computing

**Harald Reiterer**

Director Human-Computer
Interaction, Uni Konstanz

**Britta Renner**

CASCB PI
Psychological Assessment and
Health Psychology, Uni Konstanz

**Sercan Sayin**

CASCB
Post-doctoral researcher
Neurobiology



Hanna Schäfer

CASCB
Post-doctoral researcher
Data Analysis and Visualization



Falk Schreiber

Chair, Practical Computer
Science with focus on
Computational Life Sciences,
Uni Konstanz



Harald Schupp

CASCB PI
Head of General and Biological
Psychology, Uni Konstanz



Katinka Wendt

Administrative Officer,
CASCB



Martin Wikelski

CASCB PI
Animal Migration, MPI-AB



Alexandra Wild

Science Manager,
CASCB



**Ariana
Strandburg-Peshkin**

CASCB PI
Ecology of Animal Societies,
MPI-AB



Stephan Streuber

CASCB Junior Professor
Virtual Reality, Uni Konstanz



Stefano Tognazzi

CASCB
Post-doctoral researcher
Modeling Complex
Self-Organised Systems



Sonja Wild

CASCB
Post-doctoral researcher,
Cognitive Ecology



Petra Wirtz

CASCB PI
Work and Health Psychology,
Uni Konstanz



**Isaac Kazuo
Uyehara**

CASCB Affiliate
Collective Behaviour, MPI-AB



Stefan Volkwein

Professor, Numerics,
Uni Konstanz



**Anja
Weidenmüller**

CASCB
Post-doctoral researcher
Neurobiology, Uni Konstanz



“I’m most proud to have started my own PhD project. The cluster provided me with perspective from fields that differ from my own, which helped me think about the big picture of my research.”

Bernadette Denk

Doctoral student,
Clinical Neuropsychology



PhD Students at CASCB

Our PhD students are a unique cohort. Hailing from disparate disciplines of biology, psychology, and computer science, these young researchers are tasked with leading projects into the uncharted territory that is interdisciplinary research. As they probe the unknown, they forge connections to other projects and researchers, creating the collaborations that power our engine of discovery.

In 2020, we launched a platform for our PhD students that could help accommodate their individual and collective needs. Led by Felicia Afriyie, our dedicated officer for Diversity, EO and Careers, the regular meeting allows students to network, hone skills outside their discipline, and be heard in their needs and wishes.

This has been given particular urgency in the wake of the coronavirus pandemic, which has impacted young scientists in their projects, studies, and personal well-being. “The situation has generated uncertainty and unforeseen needs for our PhD students,” says Afriyie. “But unprecedented crises like these can also encourage new perspectives, and I’ve been impressed by how quickly many have adjusted their studies to adapt. As an interdisciplinary centre, we are dedicated to supporting students with measures tailored to their specific needs. Our goal is to be there for them every step of the way.”



“I study visual analysis of dynamic network data, and during the last year I have learned that no matter how smooth the presentation is in rehearsal, PowerPoint is still non-deterministic.”

Eren Cakmak

Doctoral student,
Visual Analytics



“Discovering that a construction site is impacting my study animals has posed a challenge. But I’m buoyed by the collaborative atmosphere, especially our “stress dinners” pre-COVID.”

Dennis Horvath

Doctoral student,
Biology



“The literal miracle of progress is having started with an older video system and now testing the new lab, seeing all the possibilities with the new tracking system, having the prospect of no more endless hours of manual coding.”

Jana Straßheim

Doctoral student,
Psychological Assessment and
Health Psychology



“One of the most challenging but also most rewarding experiences was building up a pipeline for measuring online multi-human EEG, using a totally new and innovative technical equipment, namely wireless, portable EEG systems.”

Karl-Philipp Flösch

Doctoral student,
General and Biological Psychology



“Analyzing our preliminary data and seeing that our developed standardized paradigm for investigating stress transmission in humans is promising was one of the key moments for me this year.”

Lisa-Marie Walther

Doctoral student,
Biological Work and Health Psychology

“The highlight of my work so far has been seeing the first swarm of virtual locusts implemented together with my colleague in biology. I'm excited to use VR to study social behaviour in animals.”

Mariam Mahmoud

Doctoral student,
Visual Computing



“The most outstanding highlight was the adventure of our fieldwork on the locust plague in Kenya! The cluster's support – scientifically and on a personal level – has proven extremely helpful throughout this time, making it a complete success.”

Yannick Günzel

Doctoral student,
Neurobiology



“During my PhD, I have learned that most problems can be solved by talking to your co-workers, by taking a quick coffee break or by staring at your favorite fish tank for a while - or of course, by any combination of these options. Luckily for me, all of them are easily accessible at CASCB.”

Paul Nührenberg

Doctoral student,
Max Planck Institute of Animal Behavior

“Even though I started my PhD right before the COVID-19 lockdown, I've been able to enjoy some cool tech at CASCB, like the 'nvidia DGX-2' and 'nvidia DGX A100' in the Collective Computational Unit as well as the VICON system of the Imaging Barn.”

Urs Waldmann

Doctoral student,
Computer and Information Science



Global Partners

We are primarily based at the University of Konstanz, but we partner with the Max Planck Institute of Animal Behavior located a few minutes off campus. Our extended community is broader still: we have leading scientists from Berlin, Tübingen, Switzerland, the US, the UK, France, Australia and more.

2019 and 2020 Highlights

1 YINS is co-directed by Nicholas Christakis, a sociologist and physician who has conducted extensive research on social networks and human behaviour and health. Couzin and Christakis maintain research collaborations, one of which resulted in the 2019 Nature review “Machine Behaviour”, which argues that behaviour of artificial intelligence systems should be studied rigorously and across disciplines.

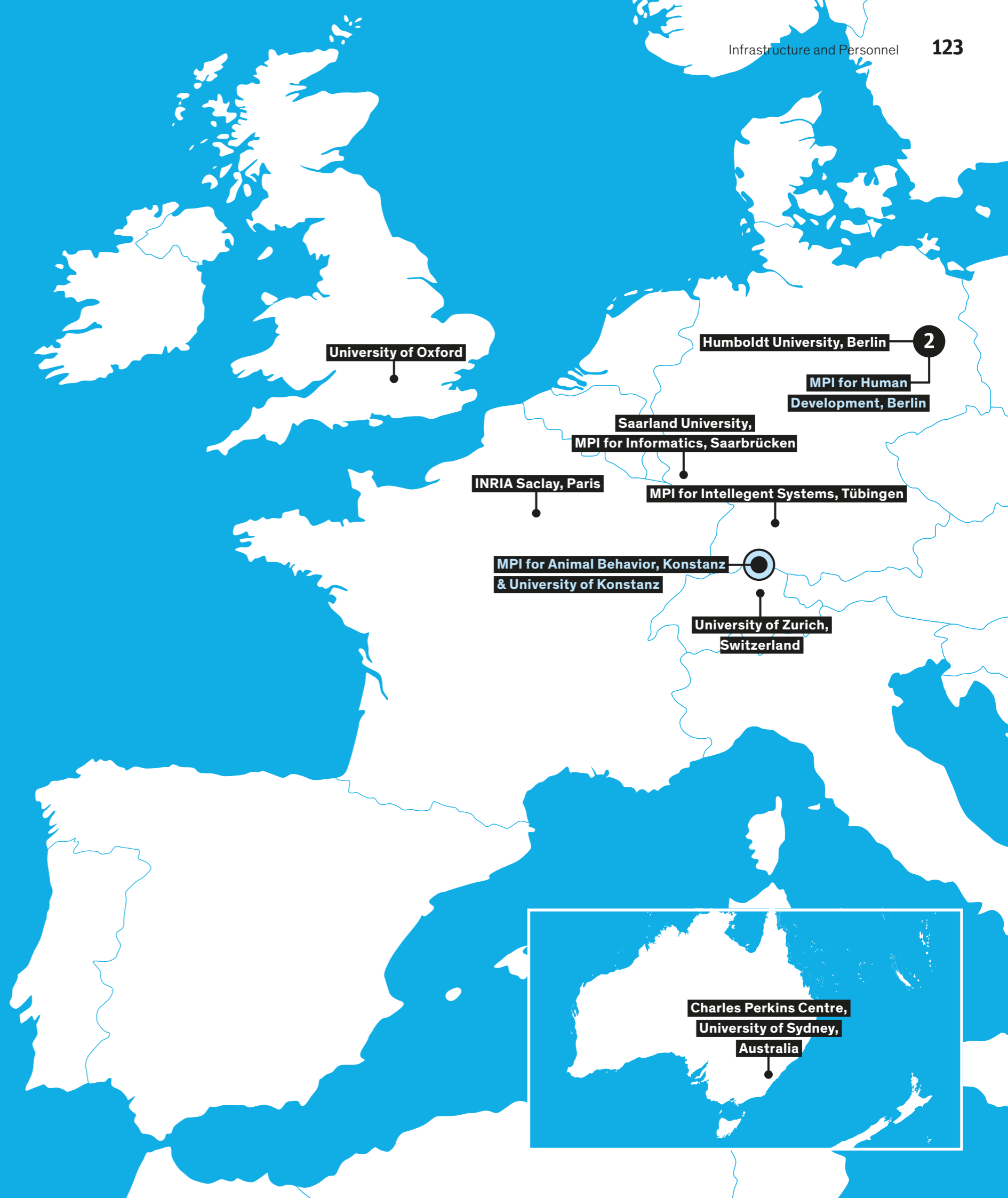
Paper: Rahwan I et al. (2019) Machine behaviour. Nature.

2 Ralph Hertwig, a psychologist and director at the MPIHD, established the centre as a premier location for studying human decision-making in social and non-social environments. Gaissmaier, Hertwig and members of their team collaborate on group decision-making and aggregation.

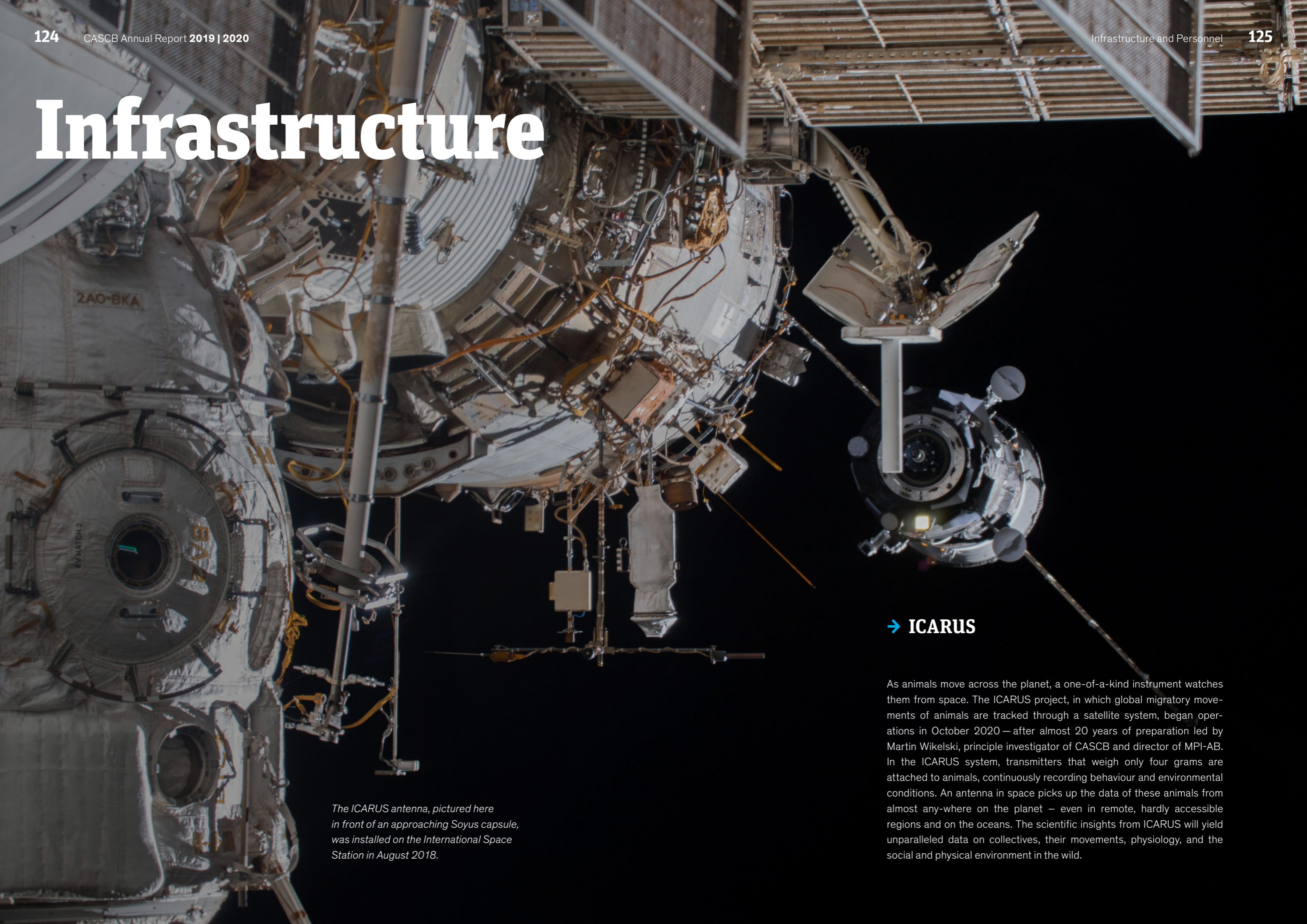
Paper: Popovic NF et al. (2020) Acute Stress Reduces the Social Amplification of Risk Perception. Scientific Reports.

Paper: Schulze C et al. (2020) Maximizing as satisficing: On pattern matching and probability maximizing in groups and individuals. Cognition.

Paper: Giese H et al. (2019) The echo in flu-vaccination echo chambers: Selective attention trumps social influence. Vaccine.



Infrastructure



The ICARUS antenna, pictured here in front of an approaching Soyuz capsule, was installed on the International Space Station in August 2018.

→ ICARUS

As animals move across the planet, a one-of-a-kind instrument watches them from space. The ICARUS project, in which global migratory movements of animals are tracked through a satellite system, began operations in October 2020 — after almost 20 years of preparation led by Martin Wikelski, principle investigator of CASCB and director of MPI-AB. In the ICARUS system, transmitters that weigh only four grams are attached to animals, continuously recording behaviour and environmental conditions. An antenna in space picks up the data of these animals from almost any-where on the planet — even in remote, hardly accessible regions and on the oceans. The scientific insights from ICARUS will yield unparalleled data on collectives, their movements, physiology, and the social and physical environment in the wild.

Imaging Barn

→ WHAT IS THE IMAGING BARN?

The Imaging Barn is a collaborative project between CASCB at the University of Konstanz and the MPI-AB near Radolfzell. Housed within a traditional 18th-century barn at the MPI-AB campus, it is a core facility for studying the dynamics of highly naturalistic interactions, such as when animals or people meet, eat, or make decisions together.

STATE-OF-THE-ART FACILITIES

The Imaging Barn is a **15 m x 7 m x 6 m** enclosure for freely moving animals equipped with ultra-high resolution tracking and projection technology.

+ 30
INFRARED MOTION-CAPTURE CAMERAS FROM VICON
 (used in movie and game productions)

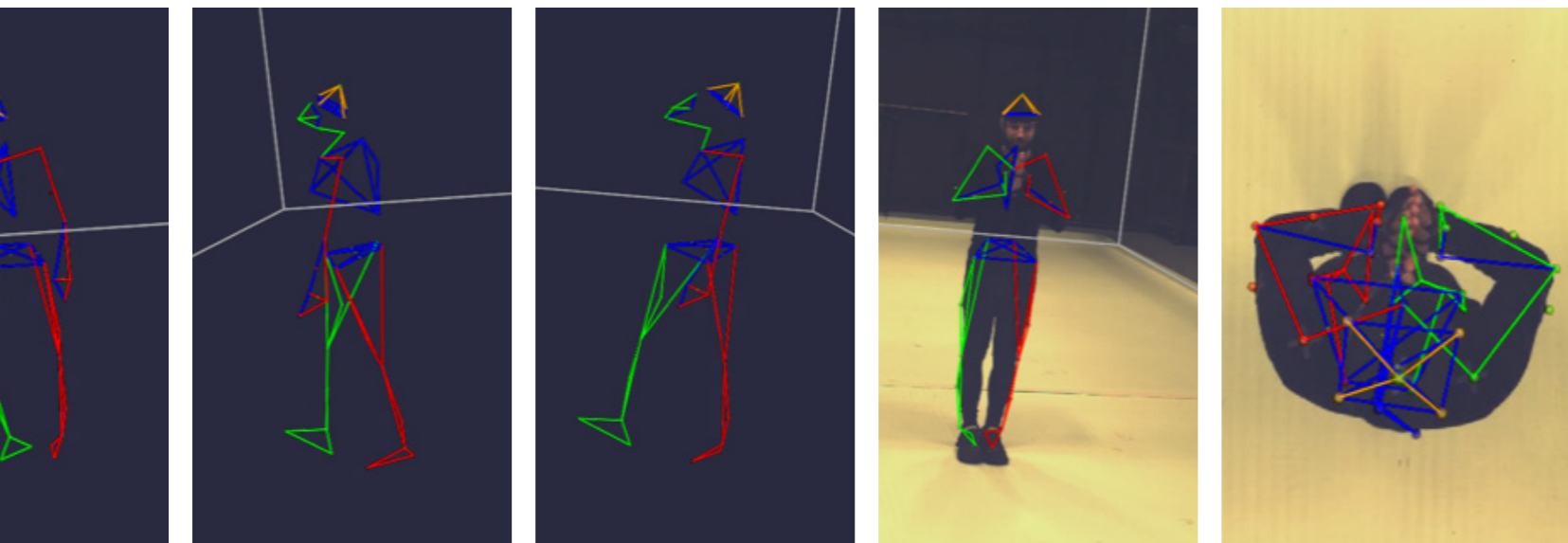
+ 6
RGB CAMERAS
 to develop computer vision

+ ACTIVE AND PASSIVE ACOUSTIC POSITION TRACKING

+ A POTENTIAL PLATFORM FOR VIRTUAL REALITY

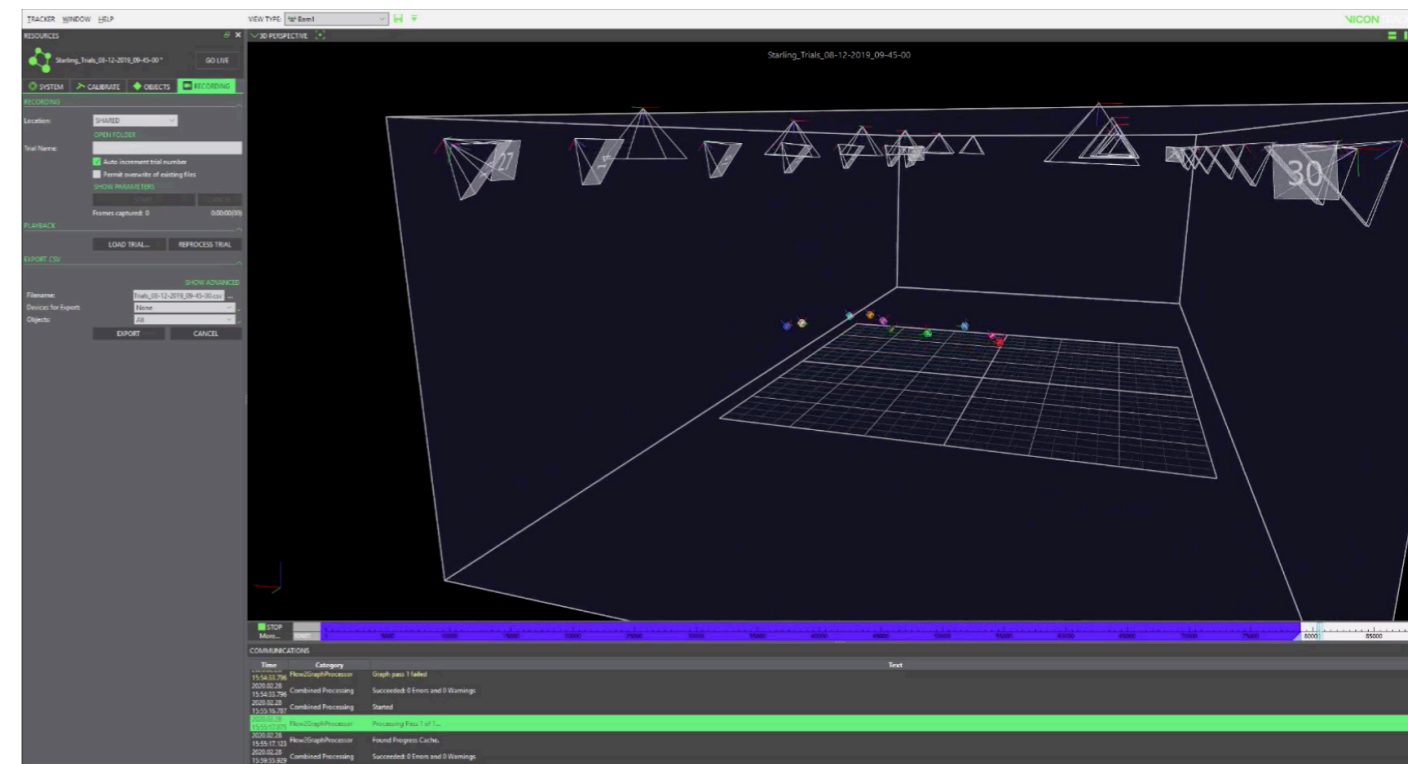
Research Report

Facility Manager, Mathias Günther, spent 2020 improving the Imaging Barn to make it an even more efficient and user-friendly facility for researchers interested in high-resolution tracking. With support from computer vision expert Urs Waldmann and biologist Hemal Naik, Günther rearranged the VICON system to push it to its physical limits. This included optimizing the camera positions and settings, which improved the recording of the spatio-temporal position of small fast-moving objects. Furthermore, the trio developed software, a data analysis toolbox, and a comprehensive wiki. The result is an even more “plug and play” experience for all scientists interested in realizing their project ideas. “More than ever, the Imaging Barn is ready for your project,” says Günther.



→ PROJECT A: STRIKE A POSE

Urs Waldmann is using the Imaging Barn on a project that seeks to accurately reconstruct the 3D human poses of people from real images. He recorded videos and collected the spatial position of 17 human joints, like elbows, ankles and hips, from three human subjects while acting common scenes – such as talking on the phone or eating. From this dataset, he will run computer vision algorithms, like 'Learnable Triangulation of Human Pose' that locate the joints on the videos without knowing the spatial positions.



→ PROJECT B: ARE HUMANS TOO NOISY FOR WILDLIFE?

Nora Carlson aims to understand what happens when human noise disrupts the calls that birds need to breed and coordinate movement. In the Imaging Barn, flocks of starlings are tracked with visual and auditory tools: the VICON system determines positions of individual birds, and an acoustic array captures all sounds. By knowing which individuals are calling when and from where, she hopes to uncover behavioural changes under human-made noise.

Major Grants and Awards

AWARDS

 <p>Lucy Aplin National Geographic Explorer</p>	 <p>Damien Farine Global Highly Cited Researcher, Web of Science Group (2019, 2020)</p>
 <p>Iain Couzin Lagrange-CRT Foundation Prize (2019)</p>	 <p>Aneesh Bose International Society for Behavioural Ecology Pitelka Award (2020)</p>
 <p>Andrea Flack Minerva Stiftung James Heineman Research Award (2019)</p>	 <p>Giovanni Galizia Henriette Herz-Preis (2020)</p>
 <p>Britta Renner Elected Vice President of German Nutrition Society (2019) and Vice-Chair of the Scientific Advisory Board on Agricultural Policy at the Federal Ministry of Food and Agriculture, Germany (2019)</p>	 <p>Martin Imhof Science Award of the Werner und Erika Messmer Foundation (2020)</p>
 <p>Giovanni Galizia Fellow of the Wissenschaftskolleg in Berlin (2019-2020)</p>	 <p>Gisela Kopp Die Junge Akademie Fellow (2020)</p>
 <p>Iain Couzin Global Highly Cited Researcher, Web of Science Group (2019, 2020)</p>	 <p>Martin Wikelski, ICARUS project "Brücken für die deutsch-russische Hochschul- und Wissenschaftszusammenarbeit"</p>

GRANTS

 <p>Lucy Aplin Israeli Science Foundation grant for "From conformity to diversity" for 5 years (2020)</p>
 <p>Armin Bahl → Emmy Noether Junior Research Group for 6 years (2020) → Zukunftskolleg Research Fellow for 5 years (2020)</p>
 <p>Clemens Bechinger → ERC Marie Skłodowska-Curie Actions, Innovative training Networks (ITN) grant for "Active Matter: From Fundamental Science to Technological Applications" for 4 years (2019) → European Union ITN Network Active Matter grant for 2 years (2020)</p>
 <p>Iain Couzin → Office of Naval Research grant for "Individual Differences and Bio-Inspired Design of Vehicle Group Dynamics" for 5 years (2019) → Marie-Curie Research and Innovation Staff Exchange grant for "iNavigate" for 4 years (2019) → ERC Marie Skłodowska-Curie Actions, Innovative training Networks (ITN) grant for Advanced Simulation, Analysis and Interpretation of Network Structures in Biological Data "SmartNets" for 4 years (2020)</p>
 <p>Meg Crofoot Alexander von Humboldt Professor for 4 years (2019)</p>
 <p>Dina Dechmann Human Frontier Science Program Research Grant for "Regrowing the brain: evolution and mechanisms of seasonal reversible size changes in a mammal" for 3 years (2019)</p>

**Oliver Deussen**

Transregional Collaborative Research Center SFB-TRR 161 "Quantitative Methods for Visual Computing" funding renewal for 4 years (2019)

**Damien Farine**

→ ERC Starting Grant for "the ecology of collective behaviour" for 4 years (2020)
→ SNSF Eccellenza Professorship "The building blocks of animal societies" for 4 years (2020)

**Helge Giese and Ariana Strandburg-Peshkin**

University of Konstanz Zukunftskolleg Interdisciplinary Collaborative Project Grant "The communication network in collective decision-making: How does group structure affect decision dynamics and outcomes?"

**Helge Giese and Wolfgang Gaissmaier**

DFG Project Grant "Contagious Risk Perception: The Social Dynamics of Risk Perception, Communication, and Behavior" for 3 years (2019)

**Alex Jordan**

→ Human Frontier Science Program Young Investigator Grant for "The dynamics of information flow in a social network of mutually shading plants" for 3 years (2019)
→ Japan Society for the Promotion of Science grant for "Studies on the evolution of mating systems and parental care patterns of the cichlid fishes in the ancient African lake: ecological, cognitive and neurophysiological approaches" for four years (2020)
→ Fundação para a Ciência ea Tecnologia grant for "Genetic toolkits and the molecular evolution of social behaviour: teleost fish as a comparative study model" for four years (2020)
→ National Science Foundation grant for "Characterization and dissection of DNA methylation and animal color changes in an African cichlid" for 3 years (2020)

**Daniel Keim**

→ DFG grant for "Uncertainty and Trust-Aware Integration of VGI and Spatio-Temporal Traces for Understanding Animal Behavior" for 3 years (2019)
→ EU Horizon 2020 grant for "Sustainable Data Lakes for Extreme-Scale Analytics" for 3 years (2019)

**Morgane Nouvian**

Zukunftskolleg Research Fellow for 5 years (2019)

**Britta Renner**

DFG Research Training Group grant "Sustainable Food Systems" for four years (2020)

**Falk Schreiber and Martin Wiecki**

Ministry of Science, Research and the Arts (MWK) of Baden-Württemberg grant for "Movebank 2.0"

**Ariana Strandburg-Peshkin**

→ Zukunftskolleg Research Fellow for 5 years (2019)
→ Human Frontier Science Program Research Grant for "Communication and the coordination of collective behavior across spatial scales in animal societies" for 3 years (2019)

**Stephan Streuber**

Zukunftskolleg Research Fellow for 5 years (2019)

**Stefan Volkwein**

DFG grant for "Multiobjective Optimization of Non-Smooth PDEs – Switches, State Constraints, Model Reduction" for 3 years (2019)

IMPRINT

Centre for the Advanced Study of
Collective Behaviour

University of Konstanz
Postbox 687
78464 Konstanz

+49 7531 88-4191
cascb@uni-konstanz.de
exc.uni.kn/collective-behaviour

Project Management and Editing

Carla Avolio
Daniel Kaping
Alexandra Wild

Writing

Carla Avolio

Copy Editing

Daniela Göpfrich
Katinka Wendt

Design

Abschnitt eins

PHOTO CREDITS

Page 08 – 09: Simon Gingins
Page 14 – 15: University of Konstanz
Page 18 – 19: Colin Twomey
Page 20: Lavergne et al. (2019) Science
Page 22 – 23: Graving et al. (2019) eLife
Page 24: Paul Nührenberg and Fritz Francisco
Page 25: André Ferreira
Page 27: Christian Ziegler
Page 28 – 29: Ehimetalor Akhere Unuabona
on unsplash.com
Page 31: Raman Oza on pixabay.com
Page 32 – 33: Fusion Medical Animation,
on unsplash.com
Page 34: Martin Sanchez on unsplash.com
Page 35: Polina Tankilevitch on pexels.com,
crowdfight COVID-19;
Lisa-Marie Walther and Alisa Auer
Page 40 – 41: Miguel Henriques on unsplash.com
Page 42: Normal Rockwell WikiArt
Page 43: Sonja Wild (image of bird);
Michal Klajban on Wikimedia
Commons
Page 44 – 45: Soumadeep Das on pexels.com
Page 46: Simon Gingins (game players)
Page 47: Ariana Strandburg-Peshkin
(meerkats); Max Planck Institute of
Animal Behavior (earthquake)
Page 48: Rosenthal et al. (2015) PNAS
Page 49: Eren Cakmak (visual analytics)
Page 58 – 59: Einat Couzin-Fuchs
Page 62 – 63: Einat Couzin-Fuchs
Page 65: Christian Ziegler
Page 66 – 71: Max Planck Institute of
Animal Behavior
Page 78 – 79: Gustavo Alarcon-Nieto
Page 80 – 89: Portraits courtesy of speaker
Page 93 – 95: Gustavo Alarcon-Nieto
Page 96 – 97: Alex Jordan
Page 104 – 105: Christian Ziegler
Page 108 – 115: Portraits courtesy of staff member
Page 124 – 125: ROSCOSMOS

All other photos by Centre for the Advanced Study
of Collective Behaviour, University of Konstanz

CASCB SCIENTIFIC ADVISORY BOARD

Gene Myers

Max-Planck Institute of
Molecular Cell Biology and Genetics,
Bioinformatics

Joshua Shaevitz

Princeton University,
Biophysics

Naomi Leonard

Princeton University,
Computational Mathematics

Leonida Fusani

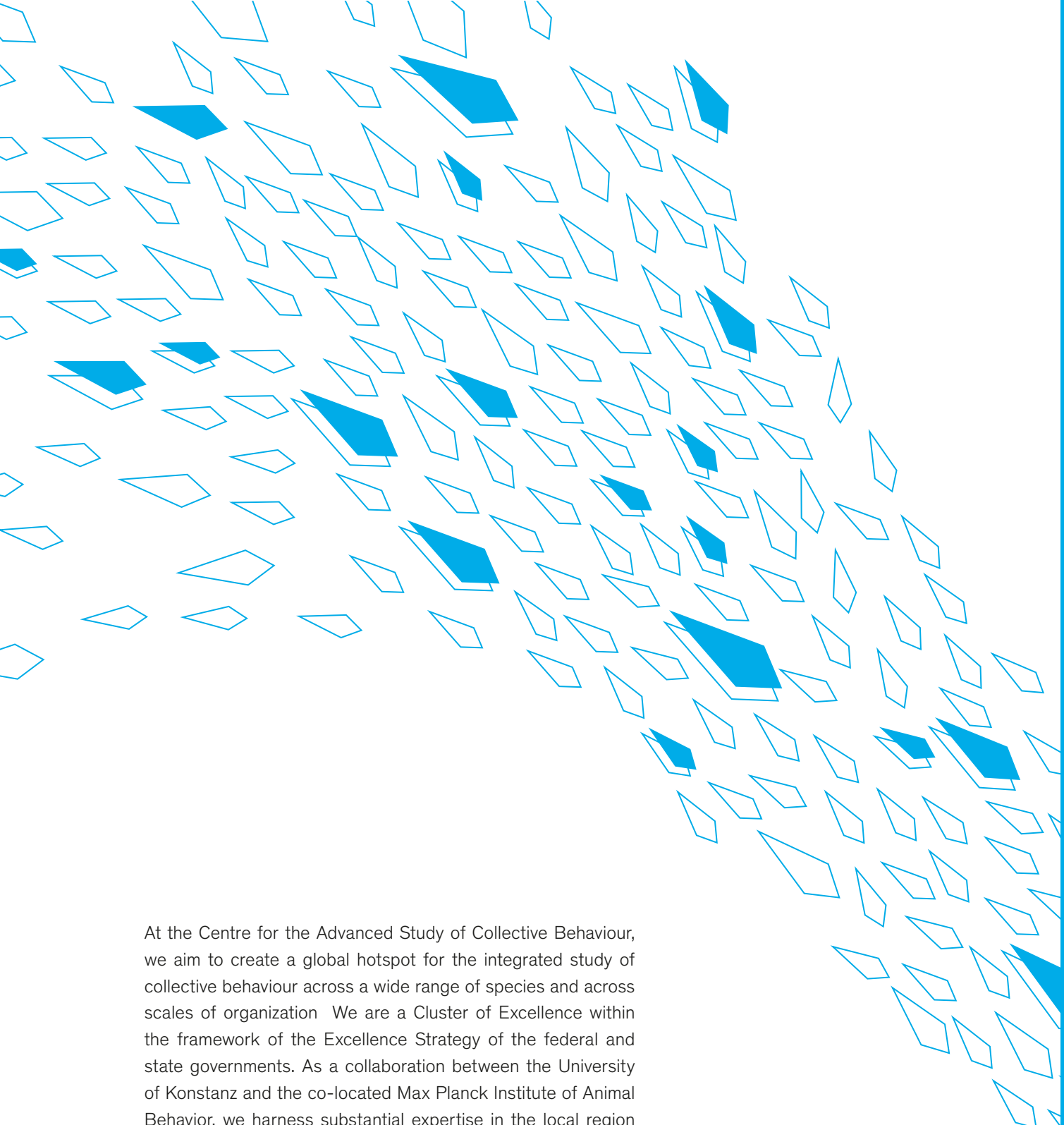
Universität Wien,
Animal Physiology

Karl Sigmund

Universität Wien,
Game Theory

Jutta Schneider

Universität Hamburg,
Animal Behaviour



At the Centre for the Advanced Study of Collective Behaviour, we aim to create a global hotspot for the integrated study of collective behaviour across a wide range of species and across scales of organization. We are a Cluster of Excellence within the framework of the Excellence Strategy of the federal and state governments. As a collaboration between the University of Konstanz and the co-located Max Planck Institute of Animal Behavior, we harness substantial expertise in the local region to create a synergistic, interdisciplinary environment for the study of collective behaviour that will be unmatched by any institution around the world. Combining transdisciplinary research with emerging technologies, we are creating a crucible in which the ideas and methods of tomorrow will be forged. Whether you are a researcher, business, or member of the public, we invite you to discover the people and ideas in this hub for collective behaviour.

uni-konstanz.de/collective-behaviour