

# Jacob M. Graving

Max Planck Institute of Animal Behavior  
University of Konstanz, Department of Biology  
Centre for the Advanced Study of Collective Behaviour  
Universitätsstr. 10  
Konstanz, Germany 78464

✉ jgraving@gmail.com

🌐 jakegraving.com

🐦 twitter.com/jgraving

🔗 github.com/jgraving

## Research Interests

Computational models of individual and collective behavior, Bayesian statistical inference, deep learning, causal inference, probabilistic programming, nonlinear dynamics

## Experience

2020–present

### Research Scientist

Advanced Research Technology Unit  
Max Planck Institute of Animal Behavior

- Head of a central machine learning research group focused on developing advanced, general-purpose methods for the measurement and analysis of animal behavior in laboratory and field environments using computer vision, deep learning, and modern statistical methods, such as Bayesian causal inference.

## Education

2021

### Dr.rer.nat., Biology (0,0 “summa cum laude”)

Department of Collective Behaviour, Max Planck Institute of Animal Behavior

Department of Biology, University of Konstanz

Centre for the Advanced Study Collective Behaviour, University of Konstanz

International Max Planck Research School (IMPRS) for Organismal Biology

Thesis Title: “Deep Learning and Computer Vision Methods for Measuring and Modeling Animal Behavior”

Supervisor: Iain Couzin

2015

### M.Sc., Biology

Department of Biological Sciences, Bowling Green State University

- Focus: Ethology, Neuroscience

2013

### B.Sc., Biology

Department of Biological Sciences, Bowling Green State University

## Relevant Publications

In Prep

Koger, B., Deshpande, A., Kerby, J.T., **Graving, J.M.**, Costelloe, B. R., Couzin, I.D. Multi-animal behavioral tracking and environmental reconstruction using drones and computer vision in the wild. In prep. Code: <https://github.com/benkoger/overhead-video-worked-examples>

- Helped develop a data collection pipeline using state-of-the-art deep learning and computer vision algorithms combined with aerial drone imaging to measure detailed behavioral data from groups of individuals, and synchronously reconstruct accurate 3D models of the natural environment

In Review

Bath, D.E., **Graving, J.M.**, Walter, T., Sridhar, V.H., Vizcaíno, J.P., Couzin, I.D. Collective detection and processing of distributed information by fish schools. In revision. Code: [https://github.com/jgraving/bayesian\\_beta\\_regression](https://github.com/jgraving/bayesian_beta_regression)

- Collaborated with researchers from multiple disciplines to test the collective intelligence of large schools of fish using computer vision, deep learning, and Bayesian inference

- Developed and applied a generative Bayesian statistical model using JAX, Numpyro, and Tensorflow Probability to analyze an extremely large and complex time series data set (approx. 3 billion observations across 400+ experimental conditions)

**Graving, J.M.,** Heins, C., Couzin, I.D. Probabilistic self-supervised deep learning reveals the structure of high-dimensional data *bioRxiv*: <https://doi.org/10.1101/2020.07.17.207993>. Code: <https://github.com/jgraving/selfsne>

- Developed a generalist self-supervised deep learning model to compress high-dimensional data and reveal its structure, including unsupervised action recognition of stereotyped dynamical motifs in high-dimensional body posture data measured from animals ( <https://youtu.be/JlbSdKzvLfk>), as well as single cell transcriptomic data and natural images.

2020

Li, L., Nagy, M., **Graving, J.M.**, Bak-Coleman, J., Guangming X., Couzin, I.D. (2020). Vortex phase matching as a strategy for schooling in robots and in fish. *Nature Communications* 11, 5408 <https://doi.org/10.1038/s41467-020-19086-0>

- Collaborated with researchers from multiple disciplines to test theoretical predictions from robotic experiments for how schooling fish collectively optimize their swim patterns to maximize energy savings in flow environments
- Measured and analyzed detailed body posture data of schooling fish using computer vision and deep learning, as well as mechanistic and statistical models of behavior to show that fish adopt optimal swimming patterns

2019

**Graving, J.M.,** Chae, D., Naik, H., Li, L., Koger, B., Costelloe, B.R., Couzin, I.D. (2019). DeepPoseKit, a software toolkit for fast and robust animal pose estimation using deep learning. *eLife*, 8. <https://doi.org/10.7554/elife.47994> *bioRxiv*: <https://doi.org/10.1101/620245> Code: <https://github.com/jgraving/deepposekit>  
Press: Quanta Magazine, Nature Methods, Nature News & Views, eLife Science Digests

- Led the development of a general-purpose few-shot deep learning toolkit for measuring the body posture of animals using TensorFlow (<https://youtu.be/hCa2zaoUWhs> ; <https://youtu.be/dSjaphoGHAY>).
- Supervised Daniel Chae, a visiting Bachelor's student from Princeton University, to develop a keypoint annotation GUI and custom data augmentation methods

## Teaching

2019

### ASAB 2019 Summer Conference, University of Konstanz

- Led a seminar on “Machine Learning in the Behavioral Sciences” with over 400 participants
- Co-organized a practical workshop on “Quantifying Behavior with Machine Learning” with 27 participants

2016–2020

### University of Konstanz, Department of Biology

- Co-organized an intensive research course for Master's students on the collective animal behavior research
- Served as project advisor for 5 Master's students
- Led lectures and workshops on the topics of “Measuring Animal Behavior with Computer Vision”, “Analyzing Behavioral Data”, and “Introduction to Programming in Python”

## Skills

*Languages:*

*Applications:*

*Libraries:*

Python

Bayesian inference, causal inference, statistical analysis, data visualization, machine learning, deep learning, computer vision, and image processing

JAX, Numpyro, Stan, TensorFlow, PyTorch, scikit-learn, OpenCV

## References

**Iain D. Couzin**

Director, Max Planck Institute of Animal Behavior  
Professor, University of Konstanz  
Department of Collective Behaviour  
icouzin@ab.mpg.de  
+49 7531 88 4928

**Gordon Berman**

Associate Professor  
Emory University  
Department of Biology  
gordon.berman@emory.edu  
+1 404-727-0071

**Martin Wikelski**

Director, Max Planck Institute of Animal Behavior  
Professor, University of Konstanz  
Department of Migration  
wikelski@ab.mpg.de  
+49 7732 1501 25

**Oliver Deussen**

Professor  
University of Konstanz  
Visual Computing Group  
oliver.deussen@uni-konstanz.de  
+49 (0) 7531 88-2778