



Killer whale conversations and conservation: eavesdropping with artificial intelligence

Dr Ruth Joy and Dr Kaitlin Palmer

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Killer whale conversations and conservation: eavesdropping with artificial intelligence

Killer whales, or orcas, are some of the most intelligent and socially complex animals on the planet. At **Simon Fraser University** in Canada, **Dr Ruth Joy** and **Dr Kaitlin Palmer** are part of the HALLO project, researching how the specific sounds these whales make to communicate can be used to track them as they move through the sea. By using deep learning AI techniques to identify which whales are making which sounds, they aim to alert nearby ships when certain endangered whale populations are nearby.



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Field of research

Statistical ecology

Research project

HALLO: Humans and Algorithms Listening to Orcas — training artificial intelligence systems to detect and identify underwater whale calls

Funders

Fisheries and Oceans Canada (DFO), Mitacs

Talk like a ... **statistical ecologist**

Acoustics — the study of the physical properties of sound, including its production, transmission and reception

Artificial intelligence (AI) — computer systems able to perform complex tasks that are similar to or beyond human capabilities, including decision-making, problem-solving and reasoning

Bioacoustics — the study of the production and reception of sound by living organisms

Deep learning — an AI method that teaches computers to process data in a way similar to the human brain, through the creation of deep neural networks

Echolocation — a method for detecting the location of objects by using reflected sound waves

Ecotype — within a species, a population that differs sufficiently from another to be classed as distinct, but not enough to be classified as a subspecies or different species

First Nations — the Indigenous Peoples of a land (that is, the earliest known inhabitants)

Hydrophone — a microphone that picks up sound waves underwater

Vocalisation — a sound produced by a voice (including animal voices)

sophisticated and ruthless hunting techniques and strong social bonds. Different groups show distinct cultures, with specific behaviours, specialisations and tendencies passed down through generations. Researchers are only just beginning to understand the depth and complexities of these cultural variations – at a time when many orca populations are facing existential threats.

Dr Ruth Joy and Dr Kaitlin Palmer, from Simon Fraser University,

are studying one such endangered population that inhabits the Puget Sound and Salish Sea, the waters between Canada's western coast and Vancouver Island in the province of British Columbia. These waters can get quite crowded. "Killer whales inhabit the same waters that we humans use for transporting goods, operating ferries, fishing and taking part in recreational activities," says Ruth. "This can pose some significant conflicts." The biggest threats that these marine

Orcas, or killer whales, instantly recognisable by their panda-like colouration and huge dorsal fins, are sometimes known as the 'wolves of the sea' due to their



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activities pose to killer whales are underwater noise, which disrupts their hunting and communication, and collisions with vessels.

An ecological threat such as this requires a huge collaborative effort to tackle it. Ruth and Kaitlin are part of the innovative HALLO project, which sees people from all over the world coming together to work on a solution to combat the threats facing orcas. “We work with people with backgrounds in biology, computer science and conservation, and people from industry, government, non-government bodies, academia and First Nations,” says Kaitlin. “It’s fantastic to see and hear different perspectives and to know that we are all working towards the same goals.”

HALLO: Humans and Algorithms Listening to Orcas

The goal of the HALLO project is to develop AI algorithms that can identify when killer whales are close by, through detecting their vocalisations. “Whales use sound to communicate, navigate and interact with their environment,” explains Kaitlin. “Through the study of whale acoustics, we can gain a deeper understanding of their behaviour, social structures and even migration patterns.” The HALLO project relies on collecting data from underwater listening devices, such as hydrophones, that skim over the water while listening for whales.

HALLO aims to develop tools that can detect killer whales in near-real-time and predict where they might be headed. “The research goal is to develop a whale movement forecasting system to warn nearby ships of whale presence,” says Ruth. “This could prevent potentially fatal ship strikes, both for killer whales and other whale species.”

Cultural differences in killer whales

Four distinct populations of killer whales

can be found in Southern British Columbia: southern resident killer whales, northern resident killer whale, west coast transient killer whales, and offshore killer whales. “These four ecotypes look different, sound different, and even have different whale cultures,” says Kaitlin. “For instance, the resident ecotypes only eat fish, specifically salmon, while the transients only eat marine mammals, and offshores tend to feed on sharks and open-ocean fish.” These different groups rarely interact or interbreed, so if one population is lost, it is lost forever – and its culture and role in the ecosystem with it.

The team’s research focuses on the southern resident population, which is by far the most at risk. “Their main prey, Chinook salmon, are also on the endangered species list in our province,” explains Ruth. Noise compounds the problem because killer whales use sound and echolocation to find food, so the noise masks the echoes returning from their prey. “This population is in deep trouble, with only 74 individuals left,” says Ruth. “One of the challenges of our research is telling these whales apart acoustically from the other groups of killer whales in the area.” The

populations’ different cultures and hunting techniques mean that the sounds they make are different too, though it is not always easy for humans to detect these differences. This is where AI comes in.

Algorithms and acoustics

The sound recorders deployed at sea capture a lot of information – and processing this quantity of information is not straightforward. “The sheer volume of data being collected easily exceeds the capacity of researchers to manually analyse these recordings for relevant vocalisations,” says Kaitlin. “In response to this challenge, there’s been a surge in the development of AI systems that can automatically recognise and classify various whale vocalisations within the datasets.” As well as speeding up the process dramatically, these systems can also become more accurate than human analysts. “These systems will allow marine researchers to turn their focus towards more complex aspects of whale behaviour, ecosystem dynamics, and conservation measures, leaving the tedious tasks to AI,” explains Ruth. ➡



A pod of Southern Resident killer whales in Boundary Pass © Lauren Laturnus

The HALLO team is using a specific type of AI system powered by deep learning. “Deep learning involves AI models ‘learning’ a particular task by being exposed to vast numbers of examples of what to identify, and then self-improving their identification process by being exposed to new data,” explains Kaitlin. “This leads to the construction of deep neural networks that are powerful tools for tasks like classifying whale sounds in complex acoustic soundscapes.”

As well as identifying whether a sound is coming from a killer whale or something else, a model can even classify which population a whale comes from – vitally important when one population is especially endangered. The team is building on this algorithm by incorporating behavioural knowledge to predict where the whales will move to in the immediate future. “When ships use this forecasting system, they can anticipate whales’ locations and avoid them,” says Ruth.

‘Hey Siri’ with extra steps

Sound classification in the form of speech detection has become one of the most commonplace uses of AI; it is found on most modern smartphones, for instance. “Our algorithm is a bit like a ‘Hey Siri’ for whales, as the AI is trained to detect and classify particular vocalisations,” says Kaitlin. “The tools are similar to those used by big tech companies in their voice recognition products.” However, while the HALLO algorithm is similar to human speech detectors, getting the training data needed for it is not as easy. “With humans, we can easily collect millions of speech samples by asking people to say specific

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When ships use this forecasting system, they can anticipate whales’ locations and avoid them.”

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things,” says Ruth. “This acts as training data for AI algorithms to learn what specific vocalisations and words sound like. But we can’t just ask whales to provide samples!”

Collecting whale call training data requires the use of underwater recorders, either placed in static positions where whales are likely to pass or following whales around with recording equipment. “We collect recordings from different times and locations to collate enough examples to make a good classifier,” explains Ruth. “Then, to create the training data itself, we ask the wider community to help us in classifying these sounds.” The team must also contend with all the other noises found in the ocean: boats, anchors, wind, other animals, and so on. “This results in somewhat ‘messy’ data, which can make it hard for our networks to learn the difference between killer whale sounds and other noises.”

Coding for conservation

The team envisions that its tool will be used to help conserve the critically

endangered southern resident killer whale population, potentially alongside a whole host of other populations, and species that inhabit different areas. “Right now, some commercial ships voluntarily slow down when passing through critical southern resident habitats at certain times of year, but we would like to make this behaviour more widespread by giving vessels a tool that means that they only need to slow down when whales are actually in the area,” says Kaitlin. “This would give whales year-round protection and mean the ships wouldn’t have to slow down unless they needed to.”

The team has had help in building its gigantic dataset by collaborating with not-for-profit organisations, governments, companies and academic institutions, who all agreed to share the killer whale vocalisation recordings they had on file. The HALLO team has been able to develop a catalogue of common southern resident calls, but now needs assistance in verifying these calls to ensure the quality of the data. “There aren’t many trained experts who can do this, but when this catalogue is publicly available online, anyone can start learning and, eventually, become an expert themselves,” says Ruth. This step is integral for fine-tuning the prediction models and integrating them into real-time detection systems. “We are continuing to build movement models to predict whales’ movements and are looking for opportunities to further this work,” says Kaitlin. “We want to play our part in effective conservation and in training the next generation of scientists in these important emerging fields.”

Ruth and Kaitlin’s top tip

Follow your passions, but also try to take classes that are outside your immediate interests. Making connections between different fields is both hugely rewarding and important for scientific success.

More resources

Find out more about the team’s work on the HALLO website. Resources include a call catalogue, where you can listen to southern resident killer whale calls, research publications, and blog posts about recent developments: orca.research.sfu.ca

Mongabay India’s Wild Frequencies mini-podcast explores the field of bioacoustics. The section starting at 19:40 of the first episode explores the vocalisations of marine mammals like whales and dolphins: india.mongabay.com/2024/07/podcast-wild-frequencies-find-wildlife-with-bioacoustics

In this TEDx talk, Dr Leslie New introduces the field of statistical ecology, including how struggling with maths at school by no means discounts a career in the field: www.youtube.com/watch?v=ZPagoo7MQow

About *statistical ecology*

Ecology is the study of living systems and the relationships between the organisms that inhabit them. Statistics involves collecting and analysing large quantities of numerical data. Statistical ecology brings these two practices together, by collecting and processing large datasets to generate insights into ecological systems.

Ruth and Kaitlin are applying statistical ecology principles to the field of bioacoustics, which involves the study of the sounds made by living organisms – in their case, the wide range of

vocalisations made by killer whales.

“The most rewarding thing about statistical ecology is the ability to use the fundamentals of maths and probability to further the conservation of an endangered species,” says Ruth. While Ruth focuses on statistics, Kaitlin’s specialisms cover acoustics and computer science. Other members of their team spend more time out in the ‘field’ – or rather, the ocean – collecting data and taking notes. “Our work is very interdisciplinary, which results in lots of collaboration,” says Kaitlin. “As they say, it takes a village!”

Increasingly efficient data collection techniques have led the field of statistical ecology to develop rapidly. “Statistical ecology and bioacoustics are exciting and somewhat new,” says Ruth. “In our own work, while we’ve focused on killer whale conservation, the datasets we have could also provide insights into these animals’ behaviour and communications.” Currently, data collection is outpacing data processing, which presents lots of opportunities for future statistical ecologists to work on finding answers from pre-existing datasets – especially when employing the ever-more powerful advances in AI.

Pathway from school to *statistical ecology*

Ruth and Kaitlin recommend studying biology, physics, mathematics (especially statistics) and, if available, ecology at school and beyond.

At university, courses or modules in biology, ecology, mathematical biology and statistics will prove useful for a career in statistical ecology.

Ruth and Kaitlin also recommend developing coding skills, such as through learning a common free programming language such as R or Python. Many online resources provide accessible introductions to these languages, both of which are commonly used in statistical ecology.

Explore careers in *statistical ecology*

The College of the Atlantic’s ‘Islands Through Time’ summer programme offers high school students the chance to study ecology and many other disciplines on offshore islands: www.coa.edu/summerprograms/summer-field-institute/islands-through-time

Simon Fraser University’s ‘Science Alive’ programme features a range of STEM workshops for high school students, many focused on coding: sciencealive.ca/high-school

The Science Alive programme is one of a collection of groups known as the SFU STEM Outreach Collective, many of which offer engaging STEM activities for Canadian high school students: www.sfu.ca/sfuwest/sfu-stem-outreach-collective.html

The Ecological Society of America has a statistical ecology section, which encourages research into statistical ecology and communication with related disciplines. Membership includes access to newsletters, notices and opportunities to connect with people working in the field: www.esa.org/stats/about

According to Glassdoor, the average ecologist salary in Canada is around C\$71,000.

Statistical ecology

with Dr Ruth Joy, Dr Kaitlin

Palmer and the HALLO project

Talking points

Knowledge & Comprehension

1. What is the conservation aim of the HALLO project?
2. What are the killer whale ecotypes found in Southern British Columbia, and how do they differ?
3. Why is developing sound classification algorithms more challenging for killer whale vocalisations than for human vocalisations?
4. Why is the southern resident population critically endangered, while the other killer whale ecotypes found in the area are doing relatively well?

Application

5. Based on Ruth and Kaitlin's article and your own knowledge, how would you define 'culture' in an ecological context? What questions would you ask to work towards a more precise definition?

Analysis

6. How does AI 'deep learning' compare to the human learning process? What similarities and differences can you identify?

Evaluation

7. More than 45,300 species around the world are threatened with extinction. Given funding for conservation is limited, to what extent do you think it is possible and/or ethically correct to decide which species (and ecotypes) are more 'worth' saving? What criteria might be used?
8. The rise of statistical ecology and related disciplines means that, increasingly, many research careers related to conservation involve more time at the computer than in the field. What do you think this means for:
 - a. The academic backgrounds/skills of people seeking careers in conservation?
 - b. The efficiency and impact of research related to conservation?

Activity

'Deep learning' involves AI systems learning in similar ways to people. Pair up with a classmate to try your own deep learning exercise!

Visit: www.orcasound.net/data/product/SRKW/call-catalog/srkw-orca-call-catalog.html

This website hosts examples of the most commonly encountered calls of southern resident killer whales. With your classmate, play through the sounds, reading the descriptions and examining how the sounds you hear relate to the spectrograms alongside each recording. Note that each vocalisation has its own reference number (from 'S01' to 'S46').

Now, choose one of you to be the researcher, and the other to be the participant.

1. Choose a subset of calls (e.g., S01-S10), which will be the focus of your experiment
2. The researcher opens this webpage, on a screen that the participant cannot see: orca.research.sfu.ca/call-library. This webpage gives further examples of each type of call.
3. The researcher chooses ten calls to play and, before playing them, writes down the reference number of each without the participant seeing.
4. When the researcher plays each call, the participant will use the first website to guess which type of call (reference number) is playing. The participant can either:
 - a. play the recordings but not look at the spectrograms (by minimising the screen so only the left-hand column of the website is visible).
 - Or b. looking at the spectrograms but not playing to the recordings.
5. Proceed with playing the sounds. For each call you play, record whether the participant guesses correctly or incorrectly, and how long they take to make a decision.
6. Tell the participant whether they were right or wrong after each decision. If they were wrong, tell them the correct answer.
7. Repeat the experiment using a different subset of calls and using the other method given in step 4.
8. Repeat the experiment by swapping researcher and participant roles and using a different subset of calls.

Analyse your results and display them graphically. Consider:

- Which method (of the two options in step 4) yielded more accurate results?
- Which method (in step 4) yielded faster results?
- How did the participant's accuracy change as the experiment progressed?

Consider how your learning process is likely similar or different to that of an AI algorithm. If you had designed an AI algorithm to do the same process, what types of results might you expect?



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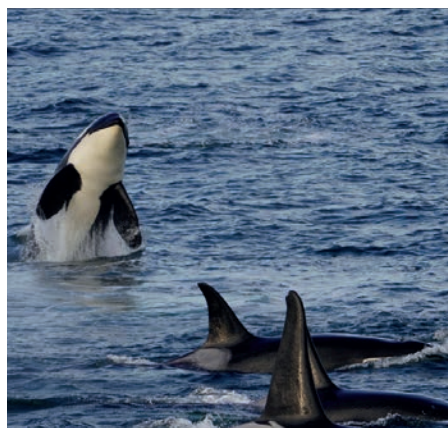


Photo montage

Top and middle row: A pod of Southern Resident killer whales in Boundary Pass © Lauren Latusus

Bottom: Dr Kaitlin Palmer and Dr Ruth Joy out on a hike

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