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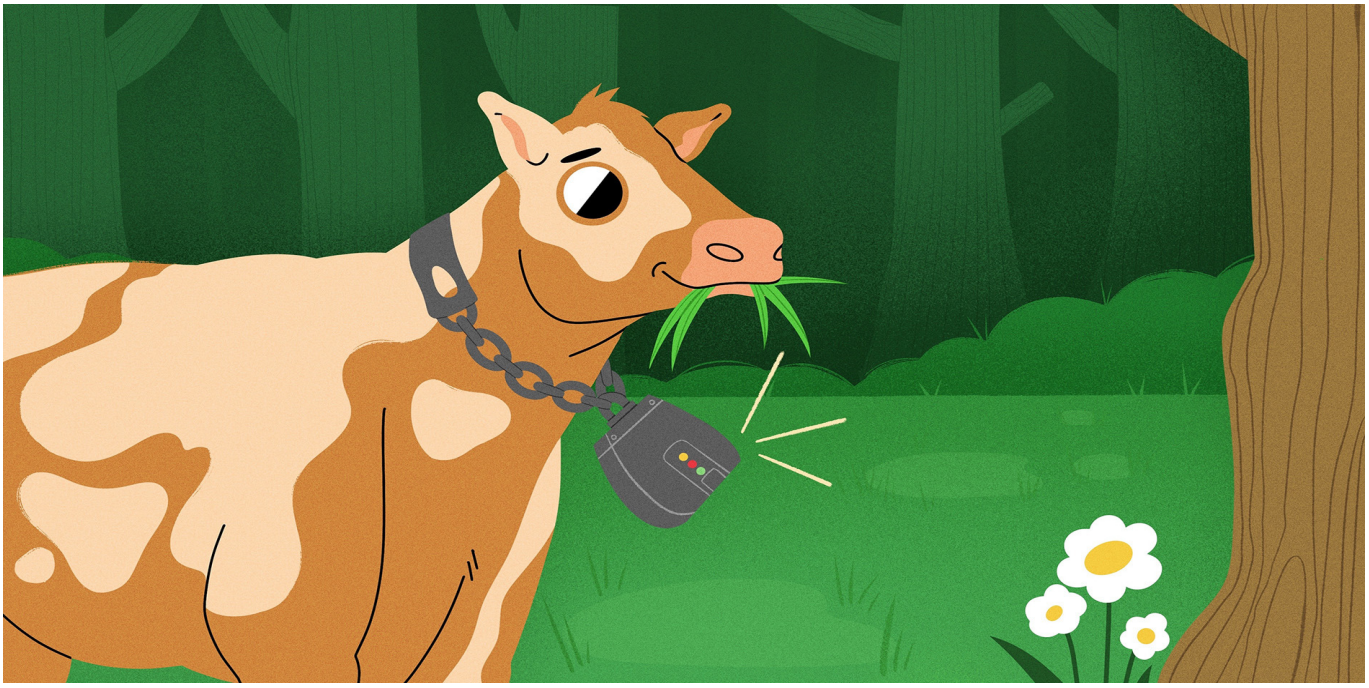

FOREST COWS SECRETS: CRACKING THE CODE WITH MOVEMENT SENSORS

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YOUNG REVIEWERS:

ANJU
AGE: 10

NOAH
AGE: 11

Have you ever wondered how we can watch animals in the wild without actually being near them? In Norway, cows roam freely in the deep forest during summer. While the cows enjoy the freedom, it can be tricky to keep them safe from carnivores like wolves and bears, as no shepherds or dogs protect the herds. Keeping an eye on the cows is important! Farmers and researchers use GPS to track animals, just as we do for phones or cars. However, GPS does not tell us much about what the animals are doing. That is where movement sensors come in. These sensors store information about the tiniest body movements and reveal what the animal is doing at any time. Is the cow's head up or down? Is it walking or running? Based on the data, we could distinguish 20 different behaviors! Now we can spy on

cows, see what they are up to in the forest, and help farmers better care for them.

HIDE-AND-SEEK IN THE NORWEGIAN FOREST

What happens when you want to watch something, but cannot, due to difficult conditions (shy animals, rocky or steep areas, far away from roads ...)? You use tools! In Norway, farmers have a limited number of fields they can use to produce food, both for humans and for **livestock**. In the summer, fields must be used to produce food for the long winter. Farmers do this by sending their animals out into the forest during the summer growing season (Figure 1). The cows get some sun and fresh air, eat grass and other plants, and their calves grow big and strong!

LIVESTOCK

Animals like cows and sheep that farmers raise for things like milk and meat.

However, the forest can contain very dense vegetation and rough terrain, and the cows are alone—no shepherd or guard dogs are with them. After not seeing humans for months, the cows can also become shy, making it difficult to approach them. Other difficulties these cows face can include hot and cold weather, diseases, accidents, and even **carnivores**! Very few researchers have studied how cows act in hard-to-reach, **remote areas** [1]. For farmers, it is very important to know if negative things happen to their cows that can affect the cows' health. Happy cows are the goal for everyone! Scientists and engineers have worked together to build tools to help both researchers and farmers watch the animals from back home [2, 3].

CARNIVORES

Animals that eat other animals to stay alive (for example: lions, tigers, wolves).

REMOTE AREA

A far away and isolated place that is not easy to reach.

DIFFERENT TOOLS USED TO SEE THE INVISIBLE

The cows we studied were equipped with collars (Figure 2) that contain small devices that allow us to watch them without actually being with them in the forest. The collars collect information using **sensors** and send it back to researchers in the form of numbers. One sensor is a GPS device, just like the one in your phone or in your parent's cars. GPS can be very useful for locating cows when they are far away in the forest, and it can tell us where the cows go every day and night. Another sensor is called a movement sensor (or accelerometer). It records how the cow is moving its head and neck, whether it is moving side-to-side, forward/backwards, or up and down. Your phone uses a similar technology to count your steps or to automatically switch the way your screen is turned when you turn your phone.

SENSORS

Just like our senses help us understand the world, sensors help machines understand what is going on. For example, GPS sensors reveal locations, and movement sensors (accelerometers) reveal different movement.

The movement sensors can detect even the tiniest movements up to 10 times per second. Each time, the collar stores three numbers, one for each direction the body is moving (forward/backwards, side-to-side, and up/down). The movement data comes out of the sensor as long lists of numbers for each direction. Finally, the collar contains a radio that communicates to a satellite in space, which can

Figure 1

This comic describes our first steps in our quest to spy on our forest cows. Step one: After equipping our cows, we followed them around and filmed what they were up to in the forest. Step two: We matched the behaviors we saw in our videos to the list of numbers we got from our movement sensors (Illustrations: Saskia H. Wulff).

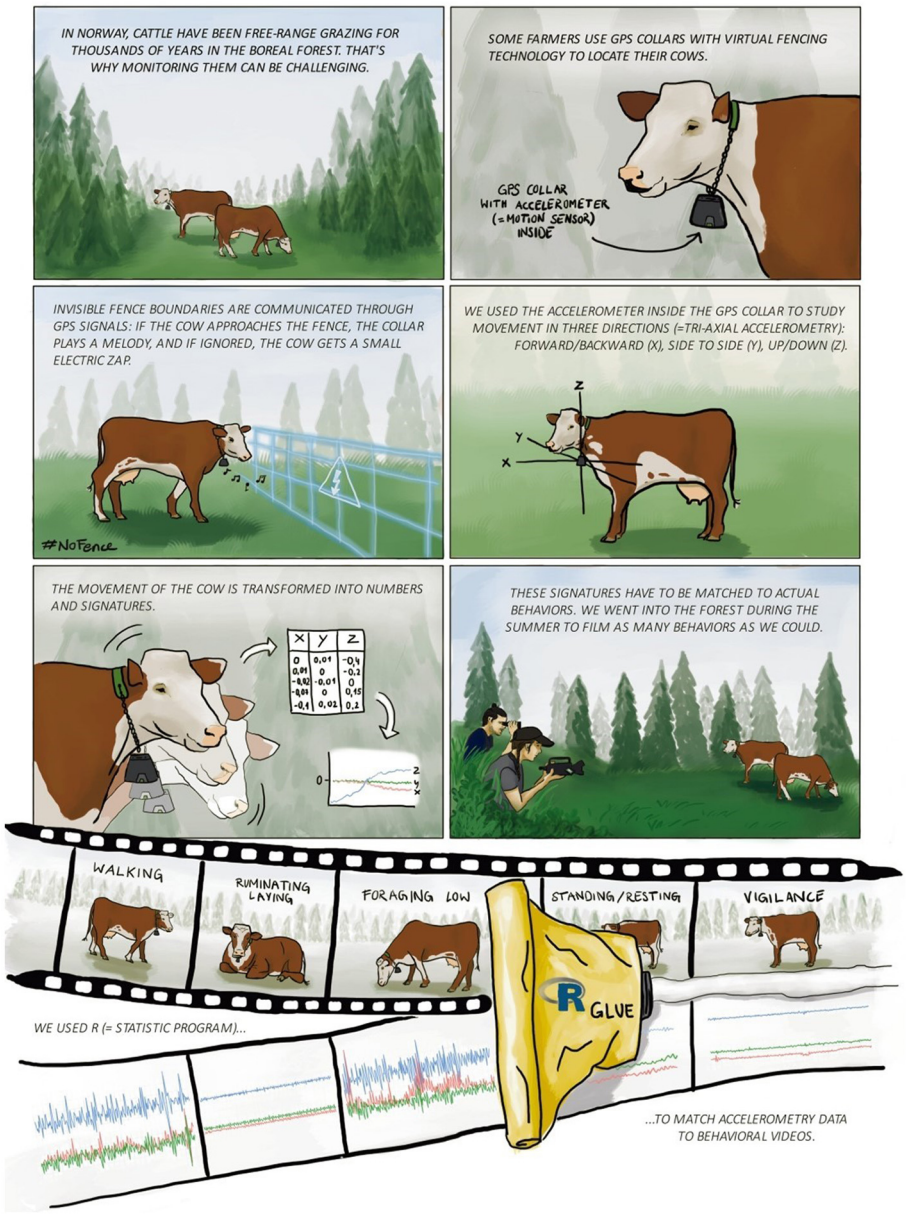

Figure 1

BEHAVIOR

How someone or something behaves. Just like how you might smile when you are happy or run when you are excited, animals have behaviors that can tell us about them.

MOVEMENT SIGNATURE

A movement signature is like a picture that shows how something moves in three different directions. It helps us figure out and understand how things move by looking at numbers.

send all of these numbers back to us in the lab (or to the farmer in his house) so we can analyze the data.

WHAT DO THESE NUMBERS MEAN?

Cows have many different body movements, also called **behaviors**, which include walking, eating, and sleeping. Every behavior has its own unique combination of the three numbers the collars records, and this is called a **movement signature**. We must figure out what the list of numbers returned by the collar means! But how do we even do this? In movies, solving a secret code requires a "key" that connects the secret signs to actual letters. In the same way, solving movement sensor data

Figure 2

Description of the cow collars and what they can do, from the product website (https://www.nofence.no/).

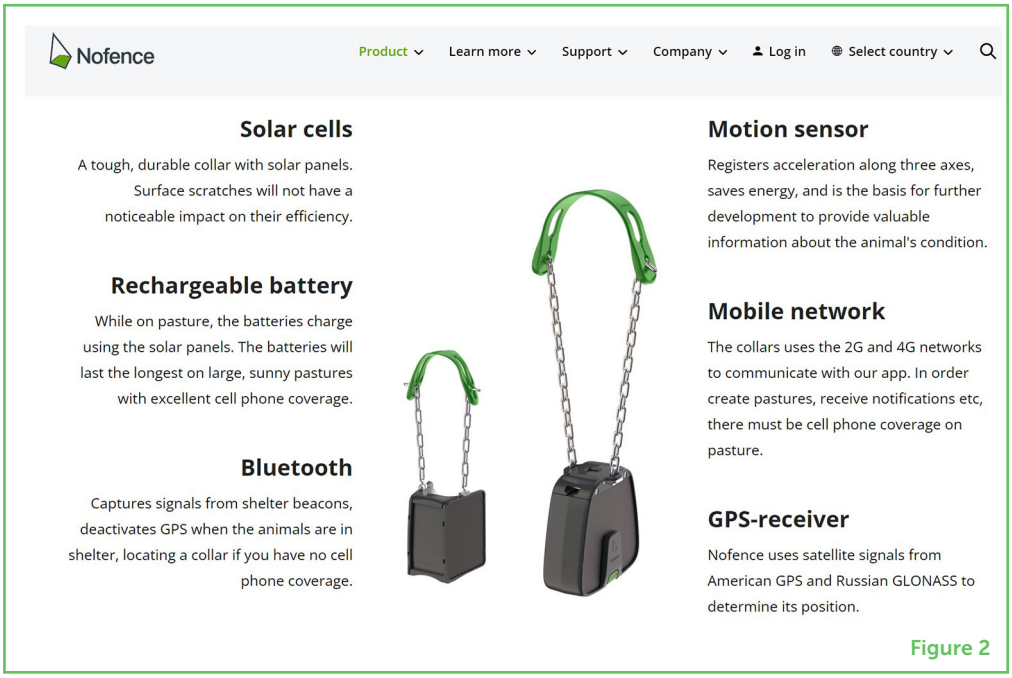

Figure 2

also requires a key that connects different combinations of numbers to specific behaviors. Our quest was to create this key for the forest cow movements. The first step of this quest was going into the forest to film the cows (Figure 1)!

After equipping our herds with our special collars, we snuck into the forest and filmed some of our cows, catching them doing many behaviors in many different situations. We wanted to film many situations: different cows, different breeds of cows, different times of the day, and different types of forests. Capturing this variety is important because cows can move in unique ways, and we wanted to understand how differences in cow movements would show up in the data from the collars. So, we gathered 41 h of videos and carefully watched all of it, writing down what the cows were doing (laying, standing, walking, feeding, fighting, running, etc.). We labeled a total of 42 behaviors [2]. What was the next stop on our quest? Matching our behaviors with movement data. We could do this because both our video and our collar data were linked to the date and time when the numbers were recorded.

MACHINE LEARNING

Just like you learn from doing things over and over, computers learn from lots of examples. They can figure out patterns and make decisions on their own. (see here).

This brought us to the final step of our quest to find the movement signatures: finding the combination of numbers linked to each behavior. We needed some help for this, as we had millions of rows of numbers and behaviors, and it would have taken us forever using just our own brains! So, we taught a computer how to do the job of creating the "key" to solve the mystery of the collar data (Figure 3). This process is called **machine learning**. Just like you learn from doing things over and over, computers can also learn from lots of examples. They can figure out patterns and make decisions on their

own. It is like a computer becoming really good at a chess game by playing it a lot—but with all kinds of stuff, like pictures, numbers, and words! Our job was to give the computer many examples of behaviors and the numbers that are connected to those behaviors, and then to test whether the computer could recognize special patterns that are repeated. Once this was done, we taught our program to run through all of our data, to assign a movement signature to a behavior. We could also test the computer by checking whether it could recognize what the cows were doing if we gave it movement data it had never seen before.

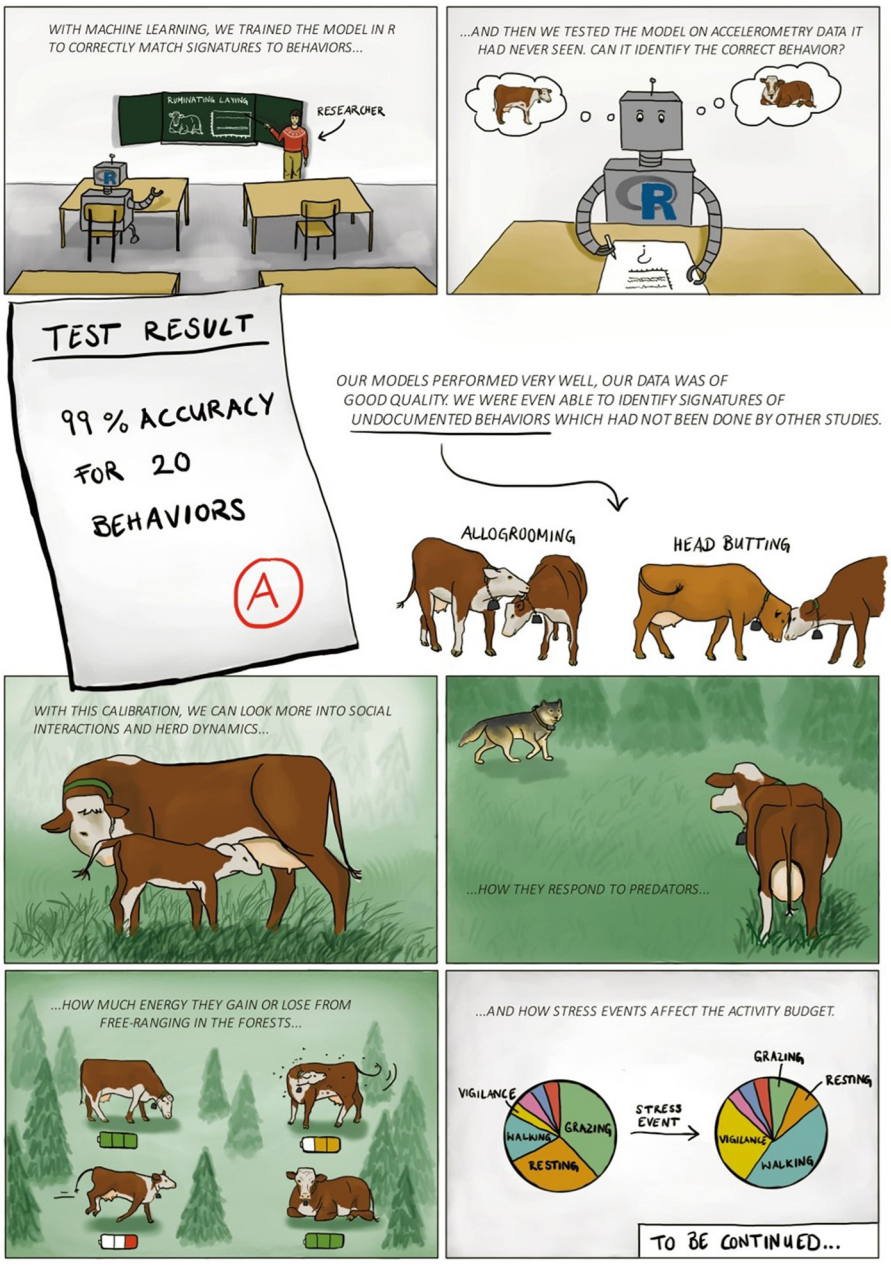

Figure 3

Here is the next step in the forest cow quest! Step three: We taught our computer to find patterns in the mysterious numbers from the movement sensors, and found that it could correctly identify up to 20 behaviors—some common ones (feeding, resting, walking) but also some more interesting ones (grooming other cows (also called allogrooming), head butting, feeding a calf). These very good results allow us to study how cows interact with each other, how they react to living with carnivores, or even how conditions can affect their energy levels (Illustrations: Saskia H. Wulff).

WHAT WERE THE COWS DOING IN THE FOREST?

What we ultimately wanted was to be able to use the numbers we got from the collars to say, for example: "These cows were busy eating from 9 a.m. until 11 a.m., then they rested for a bit, and then…". We were absolutely able to do that! The computer could tell us whether the cows were walking, resting, or feeding. This had been done before, but only on cows that stayed in the safe fields around their farms, so we expected that simple behaviors like these would be recognized. But, to our surprise, the computer could recognize up to 20 behaviors (Figure 2) [2]! Some of those included social behaviors, such as "our cows are bumping their heads against each other", "our cows are licking each other", "our mamma cows are feeding their calves". Recognizing these behaviors was new, and very exciting for our future projects. This kind of data can also help farmers take better care of their animals, keeping them happy while they are in the forest.

IMPORTANCE OF SPYING ON COWS

Cows are important for meat, milk, leather, soap, and many more products that humans use every day. Because the wellbeing of animals in our care is very important, we must make sure we are not causing cows unnecessary stress by releasing them into nature, even for a limited time. With the tools we created, we can identify what forest cows are doing without ever disturbing them, all with the help of a collar. In addition to making sure that the cows seem happy and are acting normally, the data from collars can help us study how the cows "chat" and hang out with each other, how different herds communicate, or how mothers and calves behave. It could also give us more information about how cows respond to carnivores in the wild, or how various conditions (diseases, insects, weather) impact their energy levels. On top of this, we might be able to identify a cow that is sick or injured, which would help the farmer take better care of his entire herd.

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ORIGINAL SOURCE ARTICLE

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YOUNG REVIEWERS

ANJU, AGE: 10
I live in Japan. I love reading animal-related books, ballet, and violin. I also enjoy walking and playing with my dog and participating in activities such as volunteering. I would like to learn more about animals, so I love to learn new subjects, especially biology. My dream is to become a veterinarian and have an international vet clinic to help animals and owners around the world.

NOAH, AGE: 11

I am 11 years old and live on the coast in the UK. In my free time I enjoy reading, drawing, helping in the kitchen, watching Dr Who and coding on my Raspberry Pi.

AUTHORS

LAURA J. NICCOLAI

Laura's journey began in Lyon, France, where she enjoyed learning all about animals, nature, and how humans fit into all of it. Now a Ph.D. student at Inland Norway University, she is unraveling the excitement of wildlife and human connections. Laura's Ph.D. focuses on figuring out how free-ranging cows coexist with forest carnivores, like wolves and bears. She is uncovering how these meetings influence cow behavior and wellbeing, which helps farmers care for their animals. Her path is an adventure that links animals, science, and communicating fascinating discoveries with everyone through fun comics! *laura.niccolai@inn.no

SASKIA H. WULFF

Saskia comes from Germany, where free-range cattle are a rare sight. During her studies, she learnt how nature conservation can be integrated into various forms of land use. She spent a few months in Norway helping researchers at Inland Norway University with various wildlife field work. At the end of her stay, Saskia illustrated the comic because she believes that everyone should be able to understand the exciting research results of Laura and her team. Now she is back in Germany, keeping an eye on the wild animals living there.

ERIK VERSLUIJS

Erik learned in the Netherlands how to manage nature and forests, and even went to South America to learn about tropical forests. However, after spending time in the hot Amazon, he decided to move to Norway where the winters are cold and snowy. Here, he studies ecology and learned about how moose choose where to go, how wolves live and hunt, and how wolves react to humans (spoiler: they run away or hide). Nowadays he works toward his Ph.D., looking at how cows use the forest and if wolves maybe change this. Also, Erik likes to work with smart computers.

MÉLANIE SPEDENER

Mélanie is from a village in Luxembourg, where cows graze on peaceful pastures close to human settlements. It was only when she moved to the endless forests of southeastern Norway that she learned about cows roaming freely in the forest, between wolves and bears, and between all the small trees that are supposed to grow into nice timber. Mélanie is doing her Ph.D. studies at the same school and in the same project as Laura and Erik, but she is focusing on interactions between cattle, trees, flowers and pollinators. Her bachelor's degree in forestry and master's in ecology are a perfect basis for that.

BARBARA ZIMMERMANN

Barbara was born in Switzerland. Her childhood dream came true when she studied biology at the University of Zurich. She has since been doing research on wildlife and livestock in many countries, and she works as a professor at Inland Norway University of Applied Sciences. Wildlife often generates conflicts between people.

Barbara is dedicated to dampening such conflicts by contributing new knowledge and informing the people involved.

ANNA HESSLE

Anna is from Sweden, where she lives on a cattle farm. For many years, she has been doing research on grazing cattle at the Swedish University of Agricultural Sciences in Skara. Anna is interested in finding out how much the animals eat and how fast they grow, how the meat from the animals tastes, how much money the farmer earns, and how nature is influenced by the grazing. Anna likes flowering grasslands and research that can easily be used by farmers.

MORTEN TOFASTRUD

Morten is an associate professor at Inland Norway University of Applied Sciences, department of Agricultural Sciences. Free-ranging grazing cattle and sheep in forests and mountains are very common in Norway, and studies of feeding behavior and production of these animals are Morten's favorite research topics. He is dedicated to finding solutions for improved grazing systems and at the same time meeting other social and ecological interests.

OLIVIER DEVINEAU

Dr. Olivier Devineau is an associate professor at Inland Norway University of Applied Sciences, where he teaches statistics and contributes to a variety of research projects in applied wildlife ecology, management, and conservation through consulting in data analysis and mentoring of graduate students. His career has previously taken him across several countries and languages, both in academia and in non-governmental organizations. He holds a Ph.D. in population biology and ecology from Montpellier University, France.

ALINA L. EVANS

Alina is from Alaska and moved to Norway after studying veterinary medicine. Working with cows in the forest is one of her favorite projects. She has a small farm in the forest with a few sheep and chickens and also enjoys training her Bohemian Shepherd for wildlife tracking in her free time.