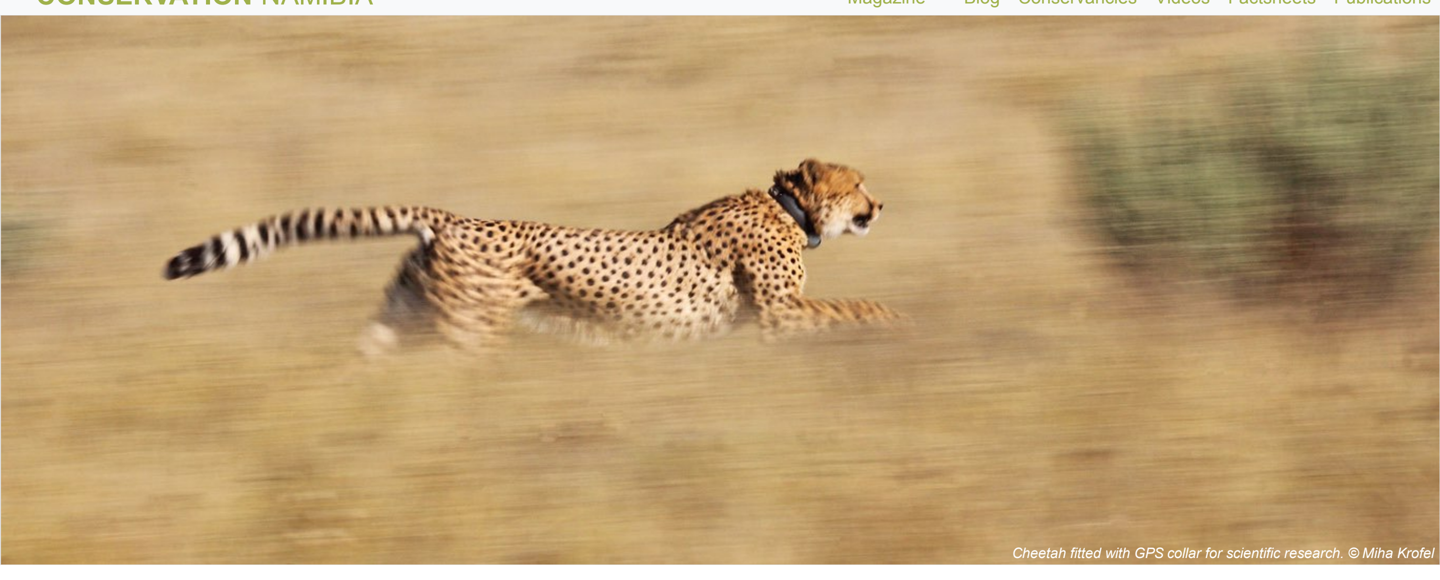

*Cheetah fitted with GPS collar for scientific research. © Miha Krofel*

# Want to do fieldwork in the 21st century?

*Pack your high-tech equipment to generate big data!*

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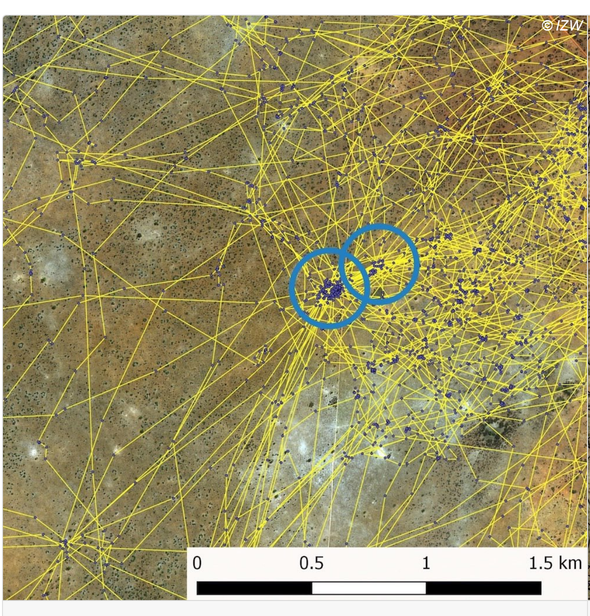
**Satellite tracking technology is used in everything from smartphones to smart watches – gadgets that can tell you where you are, how fast you are moving and even what kind of activities you are busy with throughout the day. They collect this surprising amount of data from built-in miniature sensors. These devices are getting more powerful but nevertheless smaller, lighter and easier to use every year. This rapidly advancing technology is now available for ecologists who want to know more about the behaviour and movements of the wild animals they study.**

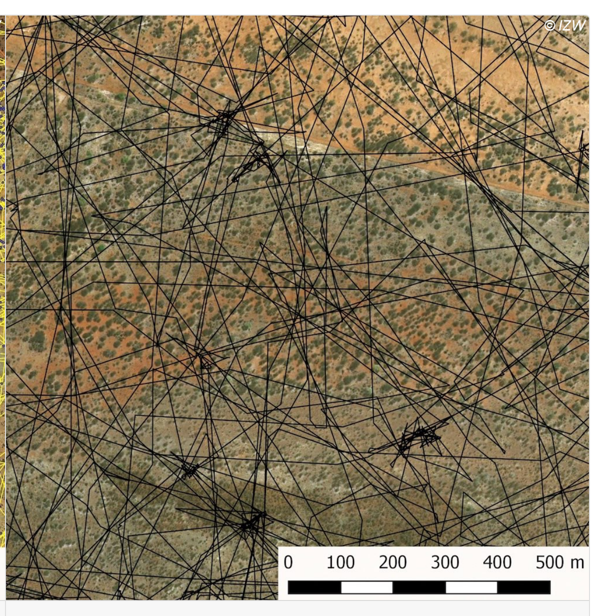
Using technology similar to smartphones and smart watches, ecologists can now almost continuously monitor their study animals' geographic location, behaviour, activity and body temperature. At the same time the device collects information about the area the animal is moving in, including air temperature, atmospheric pressure and water salinity. This not only provides insights into ecology but also into the weather, climate, atmosphere, natural catastrophes (e.g. earthquakes and tsunamis) and outbreaks of diseases, all of which may change animal behaviour. This new technology with its myriad of different applications has heralded the start of a golden age for "bio-logging" – a term scientists have coined for logging large amounts of biological data.

Ecologists choose the smallest possible bio-logging devices (or bio-loggers) to ensure that their study animals are not hampered in any way by carrying them. The heaviest part is the battery that powers various sensors, the GPS unit and the data uplink device. These components are becoming more efficient with every bio-logger generation; at the same time battery technology is progressing to deliver smaller batteries that produce more power. Consequently, battery size and the subsequent weight of the devices can be reduced, whilst also increasing the device's lifespan and data collecting capacity.

GPS tracking collars today gather more than ten times the amount of data than similar-sized collars that were developed only 10 years ago. This means we can study smaller animals than before, and collect more data to answer a huge variety of new research questions that we could not have dreamed of answering previously.




GPS locations of a male kudu show regular visits to two waterholes (blue circles), resulting in a cluster of GPS locations. In addition the map indicates that kudu prefer bushy habitat to open grasslands.



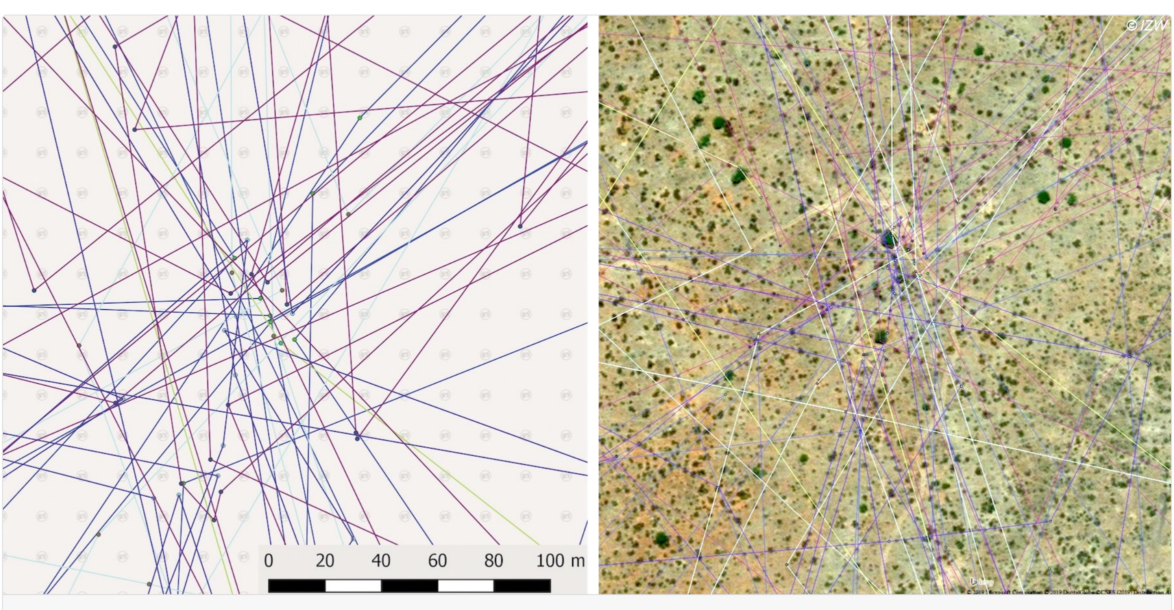

Movements of a female leopard – each cluster represents the site of a kill. Leopards typically spend 3-5 days near their kill, resting in the vicinity and repeatedly feeding on the prey. Kill sites were visited to identify the prey species to study prey preferences of leopards in Namibia.

The Leibniz Institute for Zoo and Wildlife Research (IZW) in Berlin, Germany, uses satellite telemetry on a variety of species in Namibia including cheetah, leopard, kudu and gemsbok. Our Cheetah Research Project is now 18 years old, making it our longest running study in Namibia. Studying cheetahs is especially important due to their precarious conservation status.

Historically, cheetahs were widely distributed throughout Africa and Asia. During the last few decades their distribution has been reduced to only 9% of their previous range, and scientists estimate that only 7,100 cheetahs are left in the wild. Namibia and Botswana are the global strongholds for this species: Namibia hosts approximately 1,500 adult and juvenile cheetahs, which are part of a larger population of around 3,000 occurring across both countries. Nearly 77% of the current cheetah range lies outside of protected areas, where cheetahs potentially come into conflict with farmers. This conflict is therefore one of the most important issues to address in order to conserve cheetahs.

One of the most promising approaches to solve human-wildlife conflicts is by analysing the population dynamics and movement ecology of the study species to develop solutions based on scientific findings. Leibniz-IZW takes this evidence-based conservation approach – we have fitted almost 200 cheetahs in Namibia with GPS collars (see header image), thereby generating more than 4 million GPS locations. In addition the new technology in our GPS collars produced 43 million data points that tell us more about what the cheetahs do at the places they visit.

We address a wide portfolio of research questions with these data such as i) determine space requirements and habitat use, ii) detect interactions among cheetahs and between cheetahs and other carnivores, e.g. leopards, iii) detect lairs with cubs to determine cub survival and reproductive success of females, iv) compare movements of territorial with non-territorial males, v) monitor marking behaviour of males and females, vi) investigate feeding ecology, vii) identify day-night and seasonal rhythms, viii) monitor human-wildlife conflicts, ix) fine-tune study design of density surveys using camera traps and x) increase success in capturing individuals for collecting biological samples.

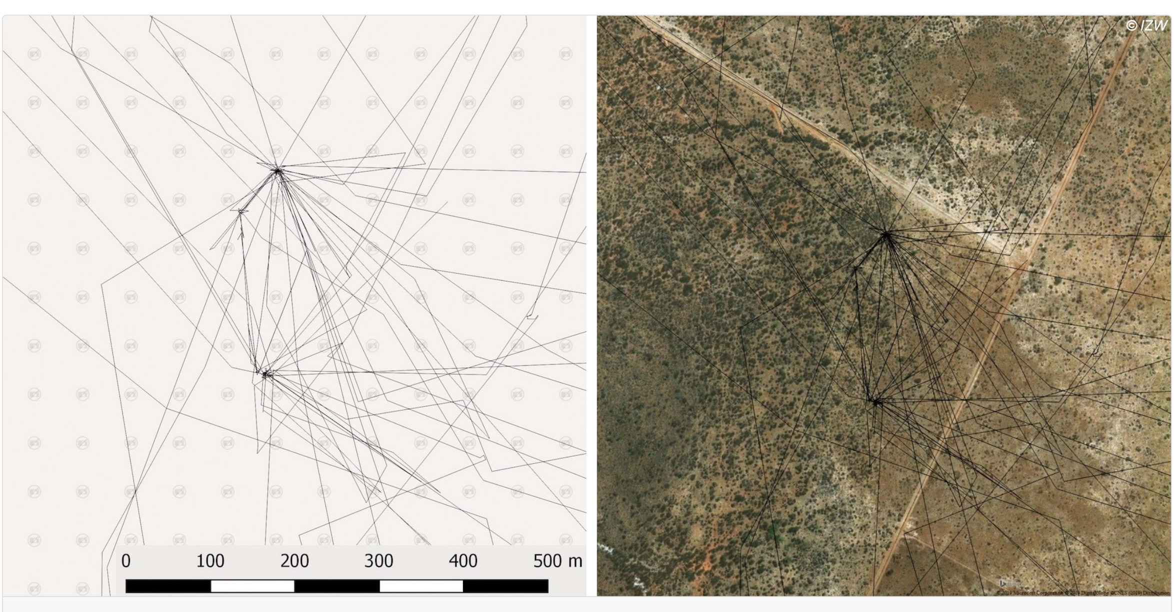



Movements of a territorial male cheetah (blue) and three non-territorial males (green, purple, light green), all visiting the same marking location. The territorial male visits the marking location much more frequently than the other males.

We usually set the GPS collars to record locations every 15 minutes, which they can do continuously for about two years before the battery runs flat. For most of our research questions and hypotheses this provides an ideal compromise between data resolution and collar longevity. Since cheetahs move at an average speed of 2-3 km per hour we miss almost nothing between two consecutive points.

Working with 43 million bits of information can be daunting, and we would not have been able to analyse all of this with the computer technology of the past. Fortunately there is a plethora of new tools and approaches to analyse this information, including artificial intelligence and deep learning algorithms. These advanced computer statistical models allow us to deal with our extremely high-resolution data and understand what it means in terms of cheetah behaviour and ecology.

Clusters of GPS locations are one of the most striking patterns revealed by these analyses. Such clusters indicate when an animal spends many consecutive hours or days in one location, when a specific animal is re-visiting the same location or when different animals are visiting and re-visiting the same location. Re-visitations can occur on different time scales depending on the biological determinants that trigger it. These clusters can indicate a lair of a female that recently gave birth, the death of an animal, territorial marking and/or communication at marking sites, visits to waterholes to drink, or feeding on a prey animal over several days. Information from these clusters thus provides scientific insights into and measurements of fascinating animal behaviour and ecological processes.




Movements of a female cheetah showing two distinct clusters. Each cluster represents the location of a lair. The female used the northern lair for the first 3 weeks after giving birth before taking her cubs to a new lair, probably to minimize predation risk and parasite infections.

We also use these clusters to streamline our other fieldwork. For instance, clusters that indicate marking locations can be used to better design studies on cheetah abundance or density using motion-sensitive camera traps. GPS clusters from collared territorial males tell us that these locations may be marking sites that may also be used by non-territorial males and females. We are therefore more likely to take photos of cheetahs when we place camera traps at well-used marking sites instead of other locations; more photos enable us to make better cheetah population estimates.

GPS clusters from collared females can be used to locate their lairs, thus allowing us to study cheetah reproduction. Visiting a lair when the mother is present, or just as she returns, can disrupt her natural behaviour and cause her to move her cubs unnecessarily. Consequently, we use the GPS collar data to monitor the mother's movements for at least several days before we visit her lair. Only when we know that the mother has left the lair and is likely to stay away for a while, we proceed to visit the cubs (see below) quickly to count them and determine their sex, and to collect non-invasive samples such as fur or faeces for genetic analysis.


Cheetah cubs in the lair.

The 21st century has heralded a new and exciting era for biological research. IZW is making the most of this new technology to increase our understanding of cheetah biology and behaviour. By arming ourselves with more detailed knowledge of this species we will develop evidence-based conservation actions that ensure its long-term survival.



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