Accelerometers: investigating animal´s activity

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What do we know about the collared animals?

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- Characteristics of the animals

  species, sex, age class, ...

- Positions of the animals

  at special times -> movement models

- Environmental information

  habitat type, NDVI (Normalized Density Vegetation Index), temperature, remote sensing data...

But you still don’t know what the animal is doing there !

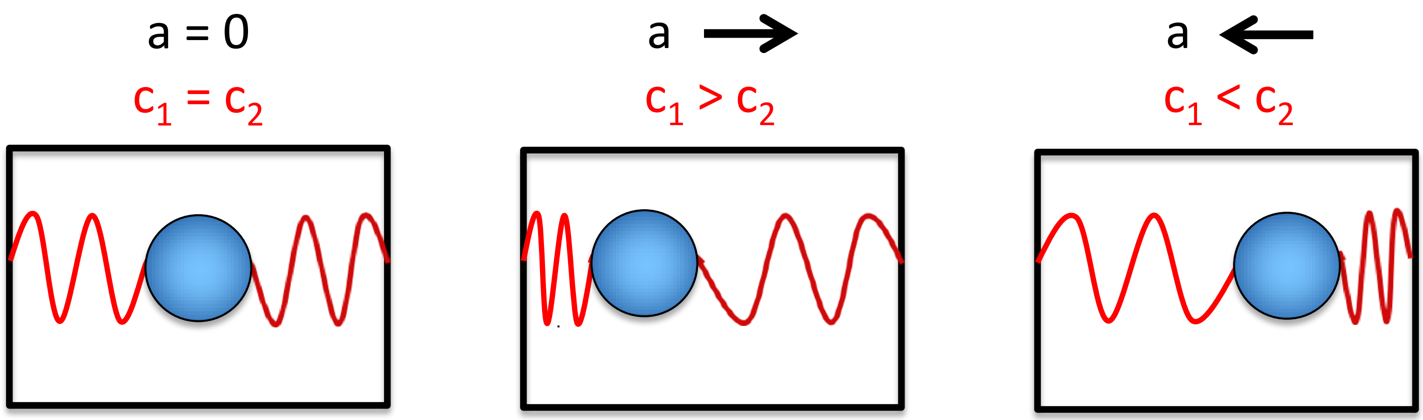
Behaviour = fast and direct reaction to environmental changes
= direct interaction to other animals (conspecifics & other species)
= indicator of animal wellbeing or stress

Do you really want renounce such important information ?!

How to measure wildlife behaviour without affecting it?

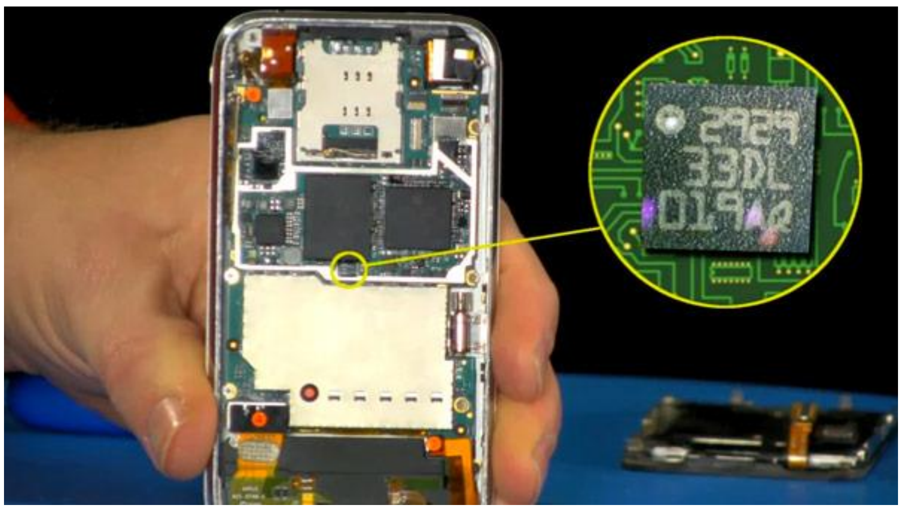
How an accelerometer works

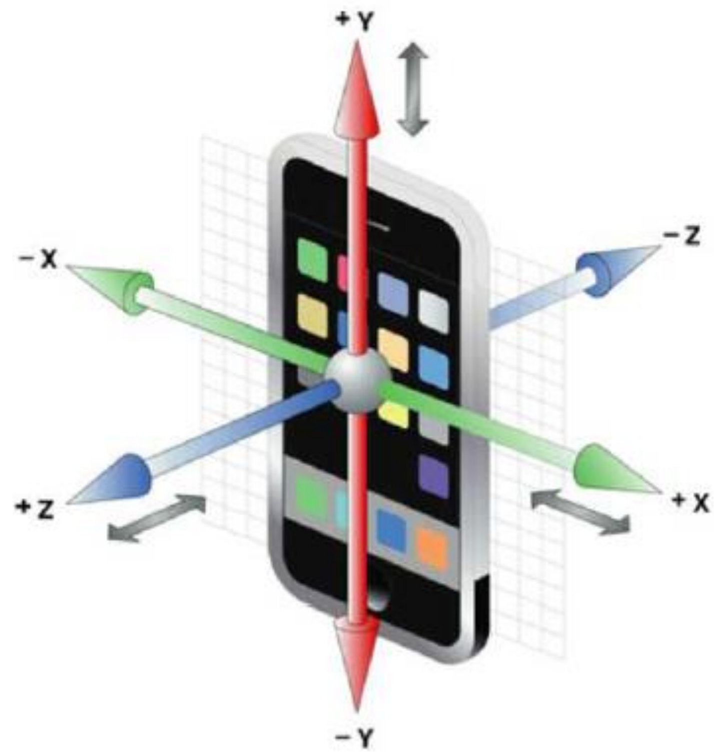
- a spring-like piezo-electronic sensor that measures the rate of change of velocity with respect to time (acceleration)
- sensor is deformed by inertial acceleration (due to movement of the device)



How an accelerometer works

- a spring-like piezo-electronic sensor that measures the rate of change of velocity with respect to time (acceleration)
- sensor is deformed by inertial acceleration (due to movement of the device) AND by gravitational acceleration (g)

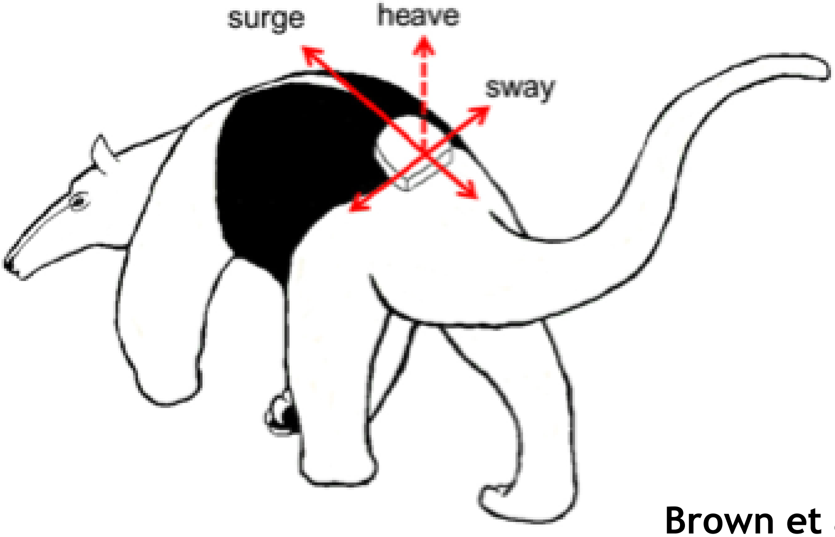




1 g = $9.81\ ms^{-1}$

Different types of acceleration measurement

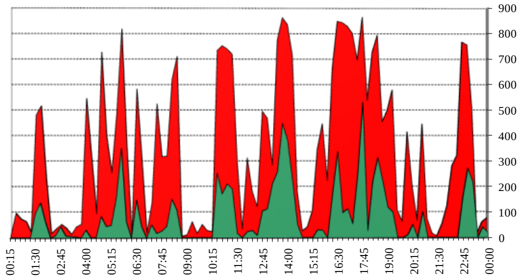
- can be user-programmed to sample frequencies from 0.5 to 10,000 Hz
- can be set to record continuously or in repeated bursts (e.g., every 2 min)
- can weigh 0.7 g (without a battery) and measure 9.5 × 15 × 4 mm
- consume very little digital memory with each measurement, so data collection and data storage on-board is possible for up to several months or years, depending on the sampling schedule
- possibility to download the data from a reasonable distance (up to 500 m or by airplane)



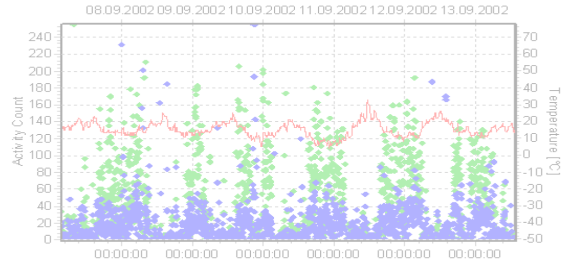
Brown et al. (2014) Animal Biotelemetry

Different types of acceleration measurement

Ethosys, Esys



Vectronic, Lotek



E-obs, WAS, Vectronic

Different types of acceleration measurement

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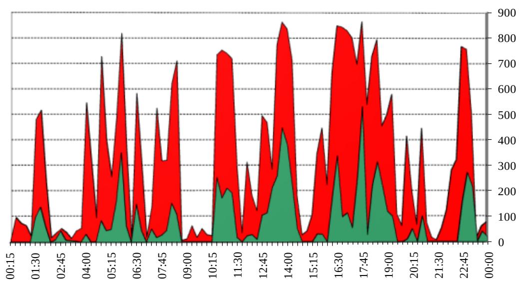
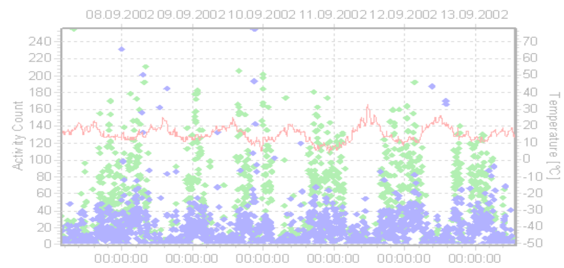


Vectronic, Lotek



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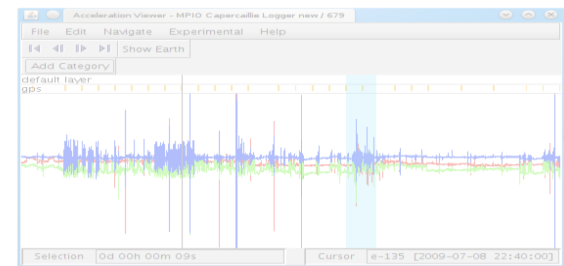
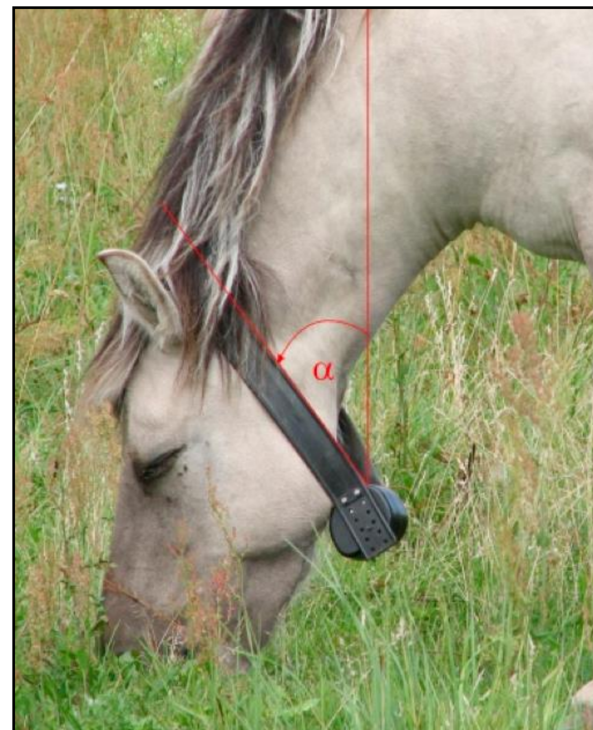


- Scheibe et al. (1998) Appl Anim Behav Sci 55
- www.esys.de ALT-Pedometer

- **sensor:** one in all dimension
- plus head position sensor (up or down)
- **measure:** existence of vibrations within a second given as zero or one
- **storage interval**: 1-60 min
- **data:** total numbers of measures per storage interval
- no data gaps
- **output:** ASCII-files



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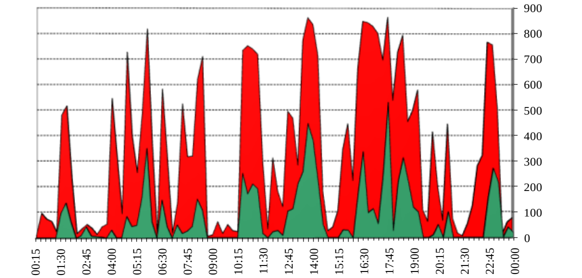
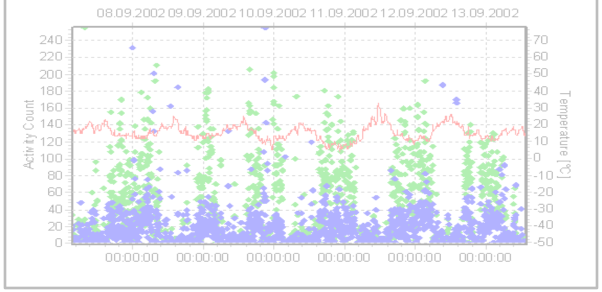
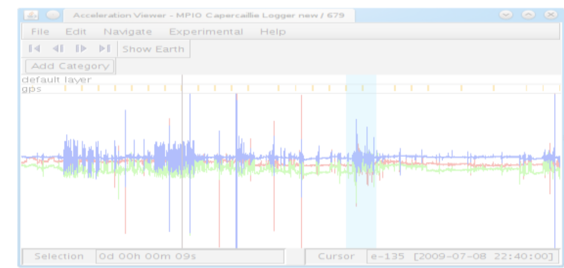


Vectronic, Lotek



E-obs, WAS, Vectronic



- Scheibe et al. (1998) Appl Anim Behav Sci 55
- www.esys.de ALT-Pedometer

- **column 1**: date & start time of measuring interval
- **column 2 & 3:** measured behaviour [number of seconds per measuring interval]
- **storage capacity**: about 4,000 data sets
- **battery capacity:** 3 years (sheep, horse)
- transmission per radio
- without GPS-tool

Original data

date/time	activity	activity head down
05.02.05 08:40	784	56
05.02.05 08:55	36	0
05.02.05 09:10	664	0
05.02.05 09:25	734	1
05.02.05 09:40	138	44
05.02.05 09:55	43	0
05.02.05 10:10	199	23
05.02.05 10:25	868	0
05.02.05 10:40	753	0
05.02.05 10:55	796	28
05.02.05 11:10	900	12
05.02.05 11:25	820	460
05.02.05 11:40	618	0
05.02.05 11:55	762	0
05.02.05 12:10	73	19
05.02.05 12:25	62	32
05.02.05 12:40	609	52
05.02.05 12:55	863	0
05.02.05 13:10	508	4
05.02.05 13:25	80	11

Different types of acceleration measurement

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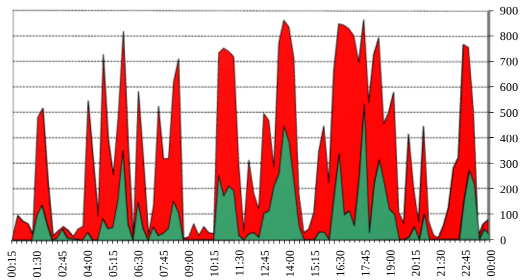
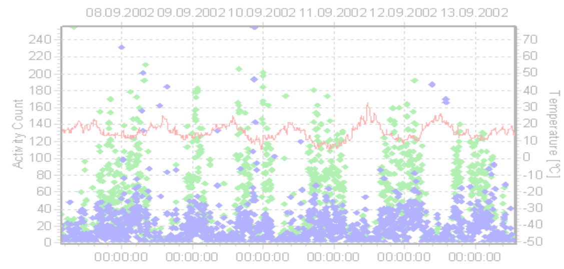
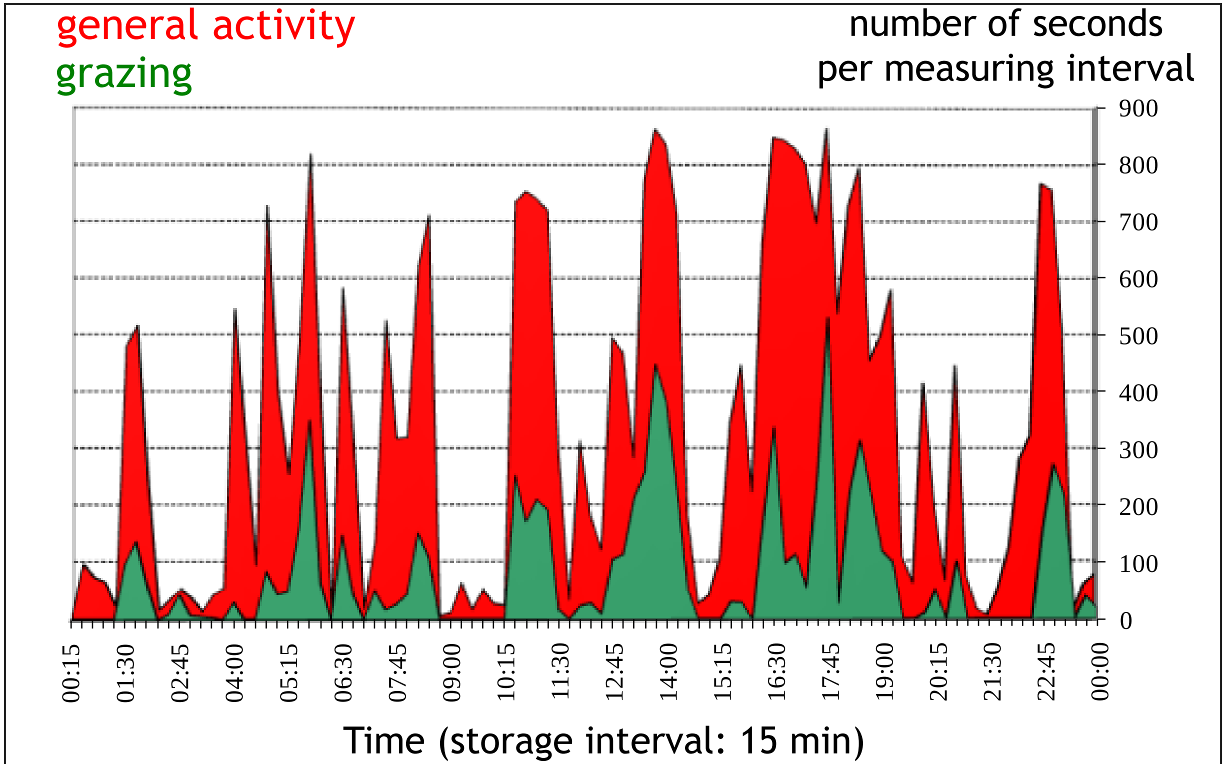
Ethosys, Esys



Vectronic, Lotek

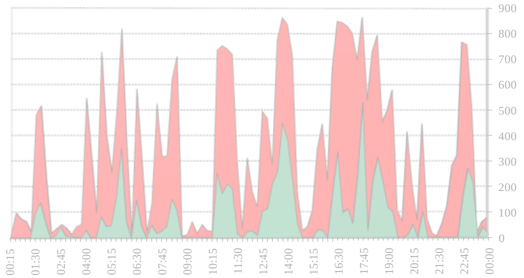


E-obs, WAS, Vectronic

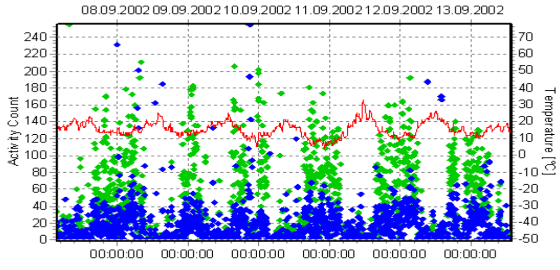


Different types of acceleration measurement

Ethosys, Esys



Vectronic, Lotek



E-obs, WAS, Vectronic

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Different types of acceleration measurement

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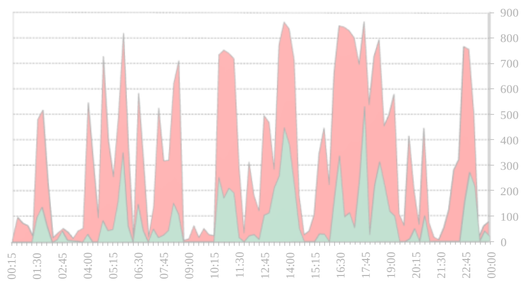
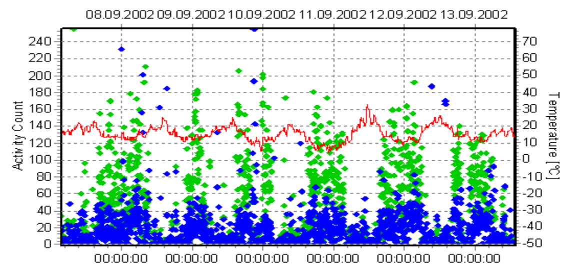
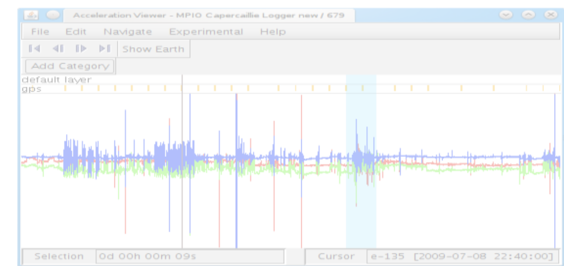


Vectronic, Lotek

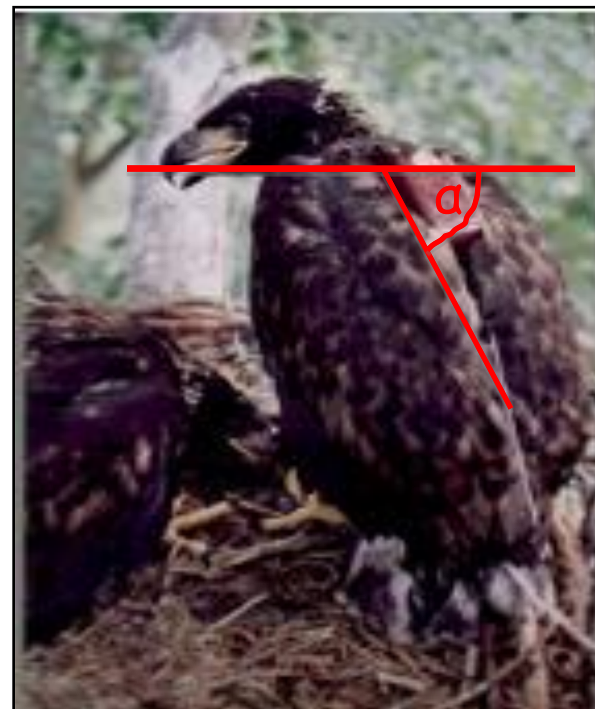


E-obs, WAS, Vectronic



www.vectronic-aerospace.com
www.lotek.com

- two uni-directional sensors (x and y)
- angular adjustment tool
- **measure**: difference in acceleration between two consecutive measurements (6-8 per sec)
- **storage interval**: minimum: 64 sec and up (with steps of 8 seconds)



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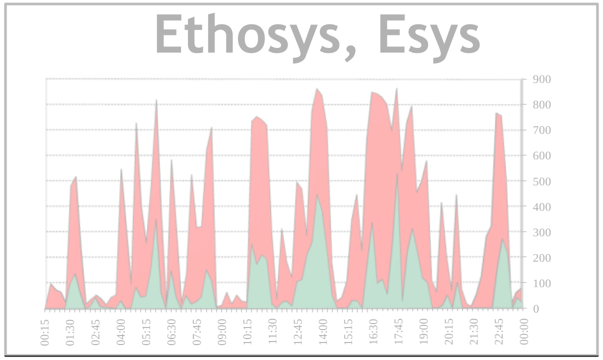

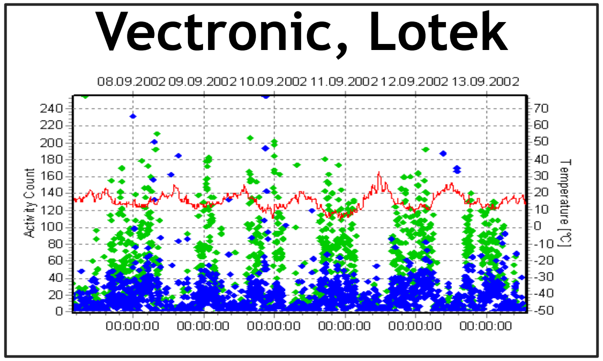

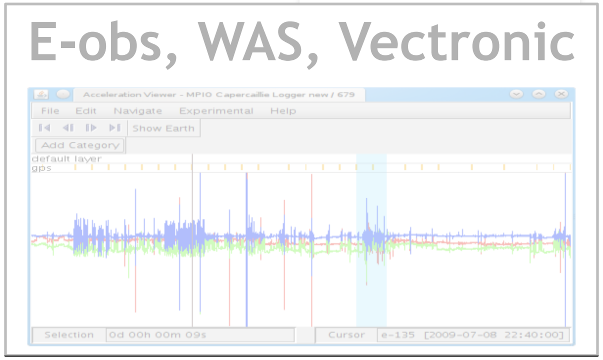

www.vectronic-aerospace.com
www.lotek.com

- **data:** means (given within a relative range of 0-255) per storage interval (2-5 min)
- **output**: company specific files (*.ADF)
- older versions: data gaps during GPS-positioning

Original data

DATE	TIME	ACTIVITY_X	ACTIVITY_Y	TEMP
29.07.03	11:00:00	3	2	30
29.07.03	11:05:00	0	0	30
29.07.03	11:10:00	0	0	30
29.07.03	11:15:00	0	0	29
29.07.03	11:20:00	0	0	29
29.07.03	11:30:00	0	1	29
29.07.03	11:35:00	0	0	30
29.07.03	11:40:00	0	0	30
29.07.03	11:45:00	0	0	31
29.07.03	11:50:00	0	0	31
29.07.03	11:55:00	0	0	31
29.07.03	12:00:00	0	0	32
29.07.03	12:05:00	0	0	32
29.07.03	12:10:00	3	2	32
29.07.03	12:15:00	18	7	32
29.07.03	12:20:00	0	0	32
29.07.03	12:25:00	0	0	33
29.07.03	12:30:00	0	0	33
29.07.03	12:40:00	0	0	33
29.07.03	12:45:00	7	3	33
29.07.03	12:50:00	25	10	31
29.07.03	12:55:00	11	4	30
29.07.03	13:00:00	5	2	31
29.07.03	13:05:00	0	0	31
29.07.03	13:10:00	0	0	31
29.07.03	13:15:00	0	0	31
29.07.03	13:20:00	4	1	32
29.07.03	13:25:00	0	0	30
29.07.03	13:30:00	0	0	29

Different types of acceleration measurement

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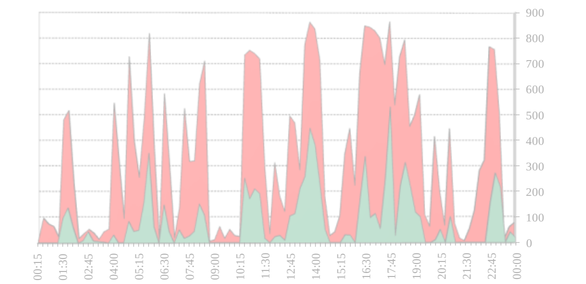
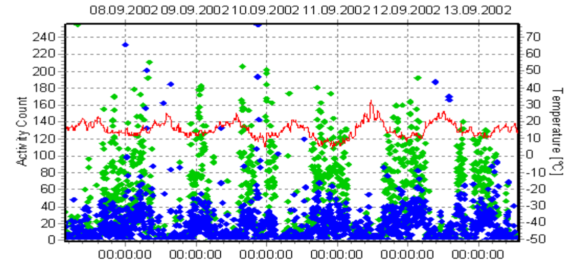
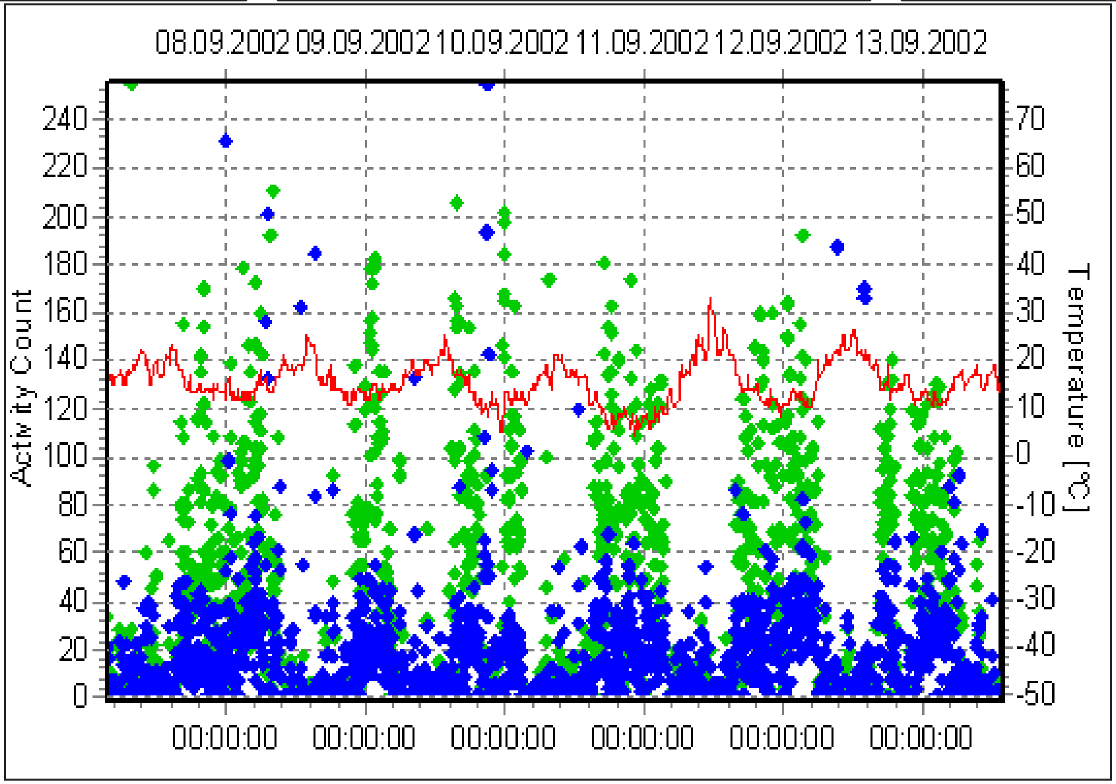
Ethosys, Esys



Vectronic, Lotek



E-obs, WAS, Vectronic



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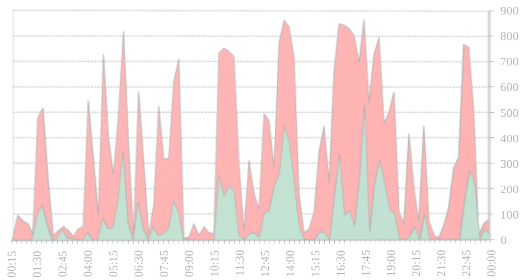

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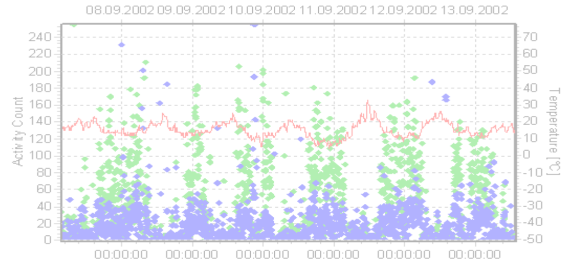

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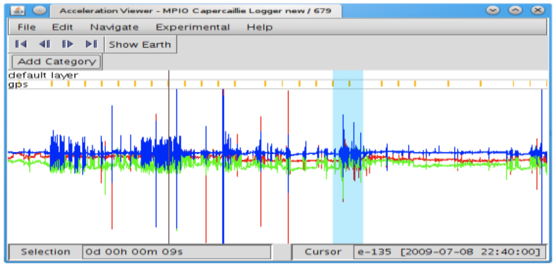

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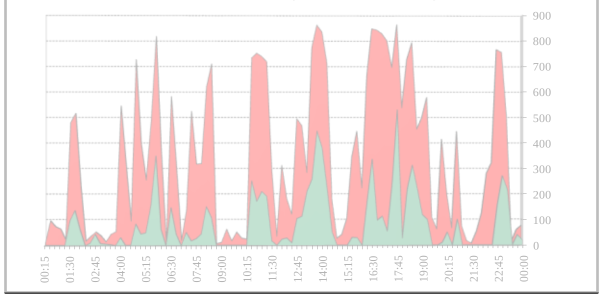
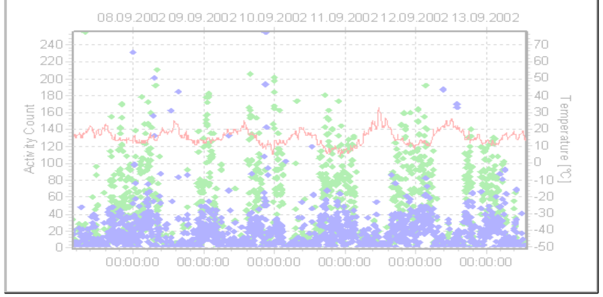


Vectronic, Lotek



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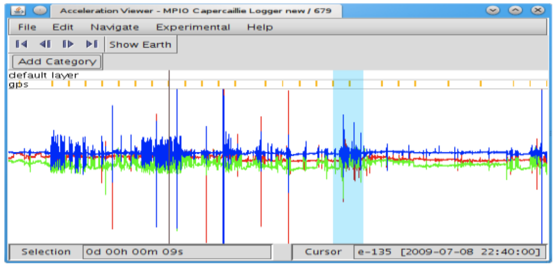
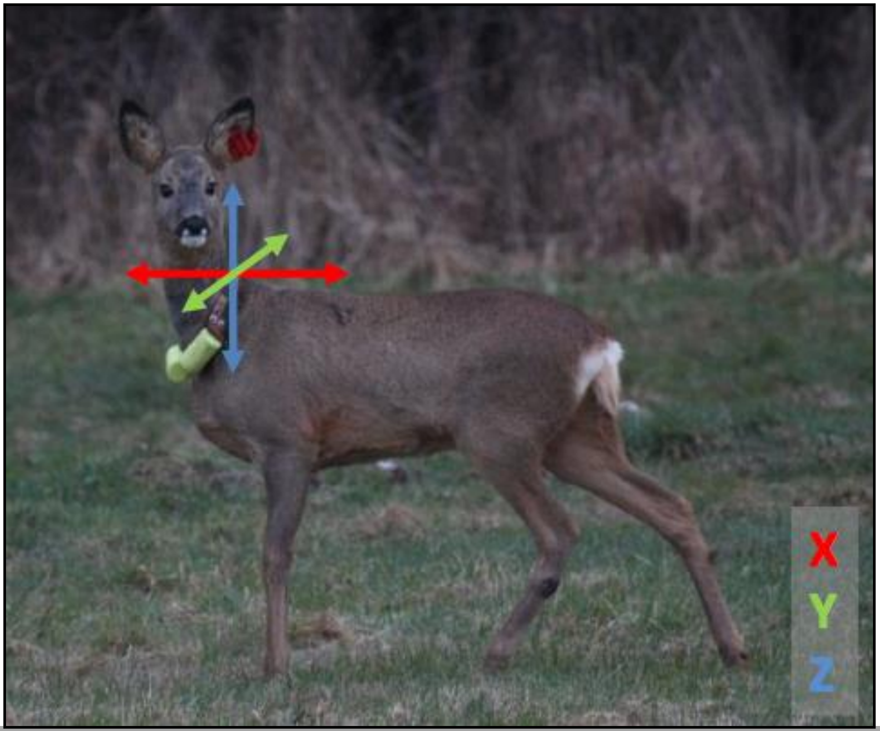


Scheibe & Gromann (2006) BRMIC
www.e-obs.de
www.esysautomation.com

- 3 uni-directional sensors (x, y and z)
- **measure**: linear accelerations in the three axes of space within a time interval (10-1,000 msec)
- **data**: absolute values within the record interval (10-1,000 msec)
- no threshold tool



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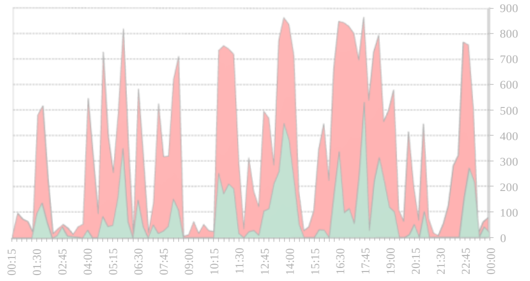

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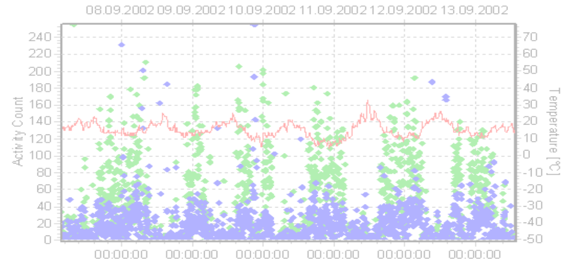

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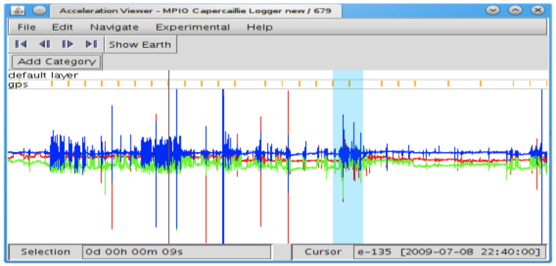


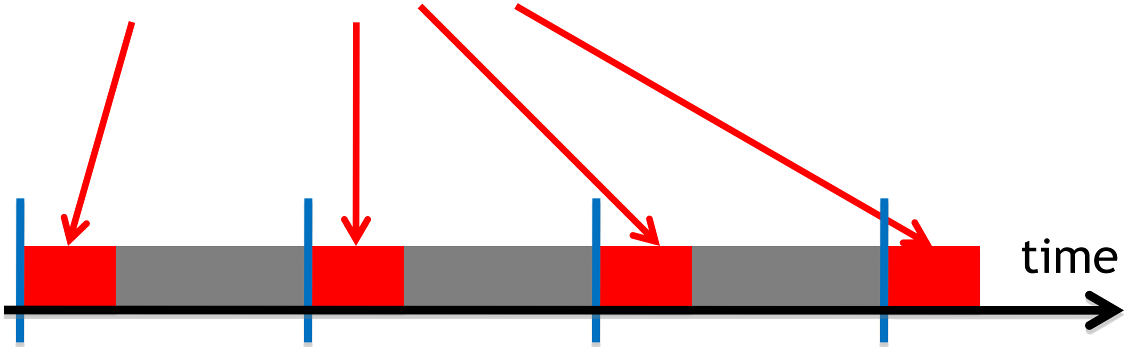
You want to know the behaviour of every 5 minutes

You have to be able to identify the single behaviour within the record time

Attention: minimal duration of behaviour you want to measure should be longer than the time between the records

User defined record time = “burst” (e.g., 10 seconds)

time between the records (e.g., 4 min & 50 sec) without measurements !



User defined sample interval (e.g., 5 minutes) (often connected to the GPS-fixes)

What can we do with these data ?

Brown *et al. Animal Biotelemetry* 2013, 1:20
http://www.animalbiotelemetry.com/content/1/1/20

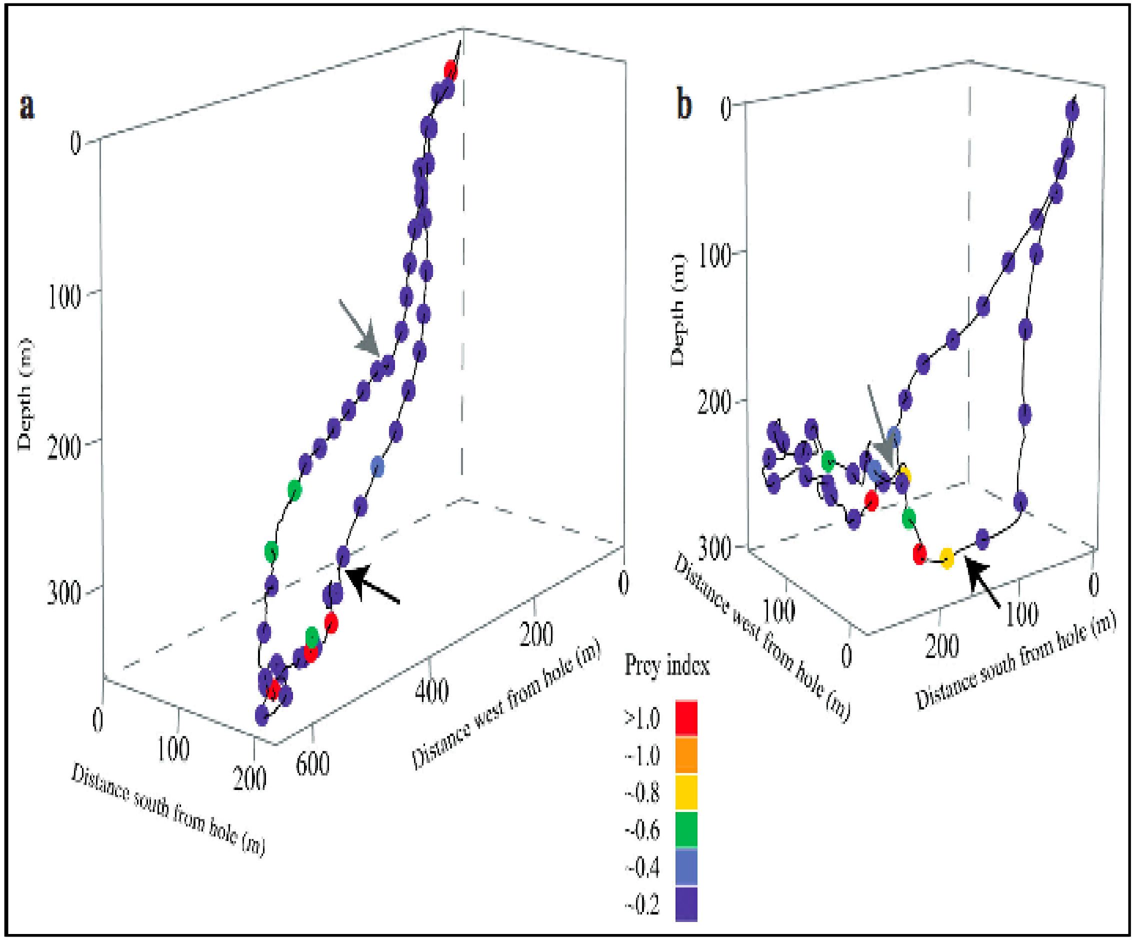
Animal Biotelemetry

REVIEW Open Access

Observing the unwatchable through acceleration logging of animal behavior

Danielle D Brown[1*], Roland Kays[2,3,4], Martin Wikelski[4,5,6], Rory Wilson[7] and A Peter Klimley[8]

3D-path reconstruction (under water)



Calculation of:

- The rotation angles around the lateral and longitudinal axes and estimate the gravity-based acceleration (3D-vector calculation)

Output:

- Reconstruction of path or dive positions and their connection to environment

Mitani et al. (2004) Marine Ecology Progress Series, 281
Shiomi et al. (2010) Aquatic Biology, 8

Calculation of energy expenditure

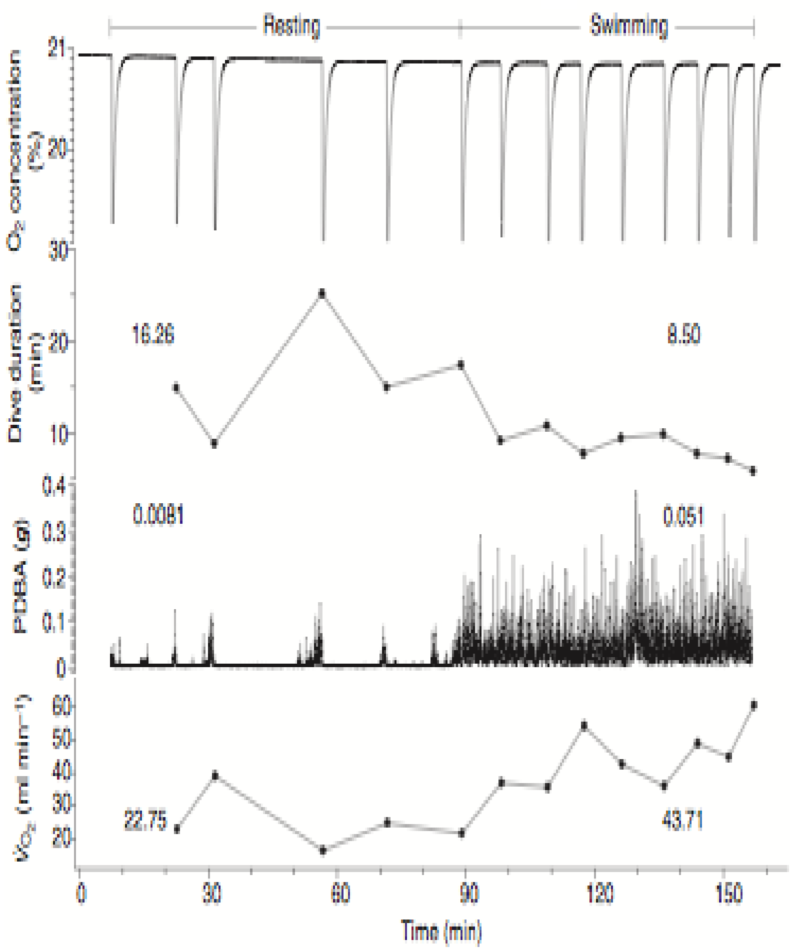


Fig. 4. Example of combined respirometry and accelerometry recording during a typical trial with one turtle. Traces (from top to bottom) show the O_2 concentration inside the chamber, dive duration, partial dynamic body acceleration (PDBA) and $\dot{V}_{O_2}$. The downward deflections in the top trace reflect breathing events. Dive duration was calculated as the time elapsed between two consecutive breathing events. PDBA was calculated from turtle body acceleration (surge and heave), recorded in parallel with respirometry using a bi-axial acceleration logger. $\dot{V}_{O_2}$ for single dive cycles was calculated from the area under the curve associated with each breathing event in a continuous plot of apparent $\dot{V}_{O_2}$ against time. However, in our analysis, we did not use a single dive cycle resolution but divided each trial into two periods with contrasting activity level (indicated by the bars at the top) and calculated $\dot{V}_{O_2}$ over these periods. For each trace two numbers are given, representing the calculated values for the resting and swimming period of that particular trial, included in the analysis.

<u>Calculation of:</u>

- Accelerometry (allows quantification of the movement) by overall or partial dynamic body acceleration (ODBA/PDBA) and calibration within different conditions (mostly in lab)

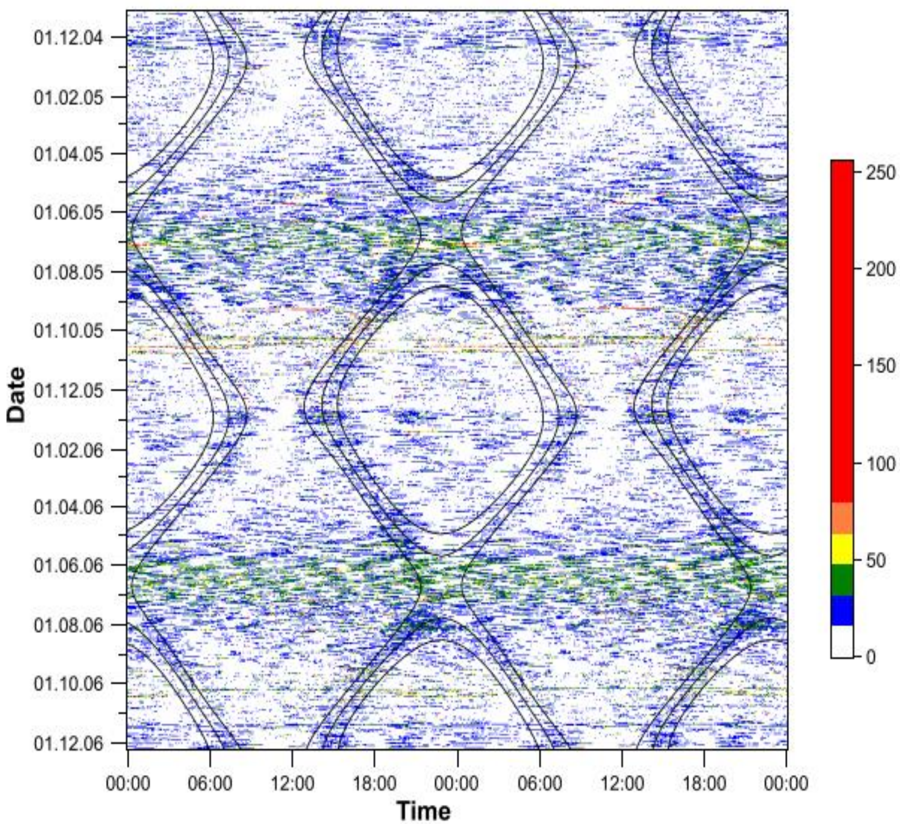
<u>Output:</u>

- Metabolic rates

Qasem et al. (2012) PLoS ONE 7(2)
Enstipp et al. (2011) The Journal of Experimental Biology 214

Daily and annual activity pattern analysis

Male moose (*Alces alces*), Scandinavia



Calculation of:

- means / medians
- day-night relation = diurnality index
- number, length and duration of daily activity or resting phases

Output:

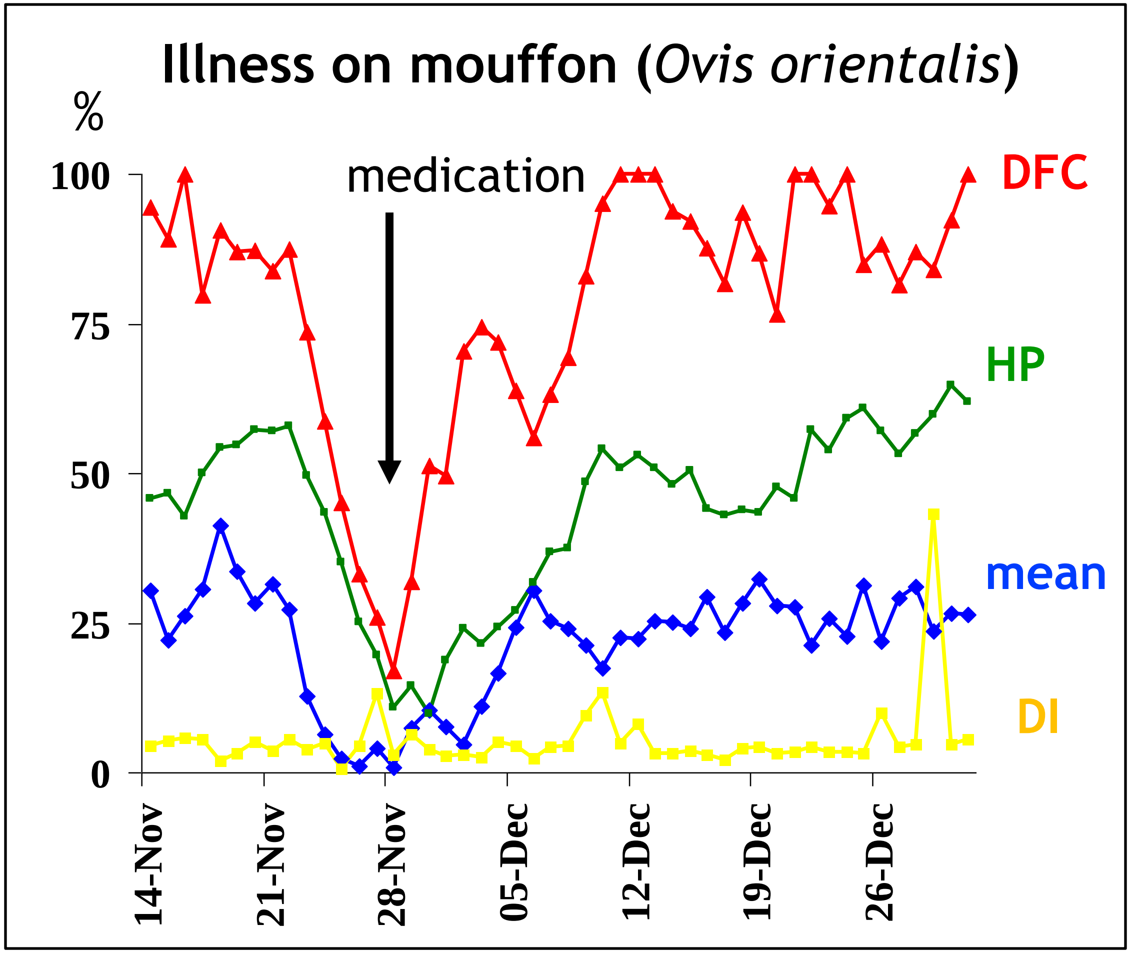
- general activity pattern
- activity relation to dawn & dusk
- adaptation to seasons and habitats
- influence or timing of certain events (e.g., reproduction, migration, hunt, calving, denning…)

Software:

- Activity Pattern (Vectronic)
- Python or R-package

Berger et al. (1999) Appl. Anim. Behav. Sci. 64 -> Przewalski horses
Berger et al. (2002) Biol. Rhythm Res. 33 -> red deer
Krop-Benesch et al. (2013) Italian Journal of Zoology -> roe deer

Detection & evaluation of disturbances / stress



Calculation of:

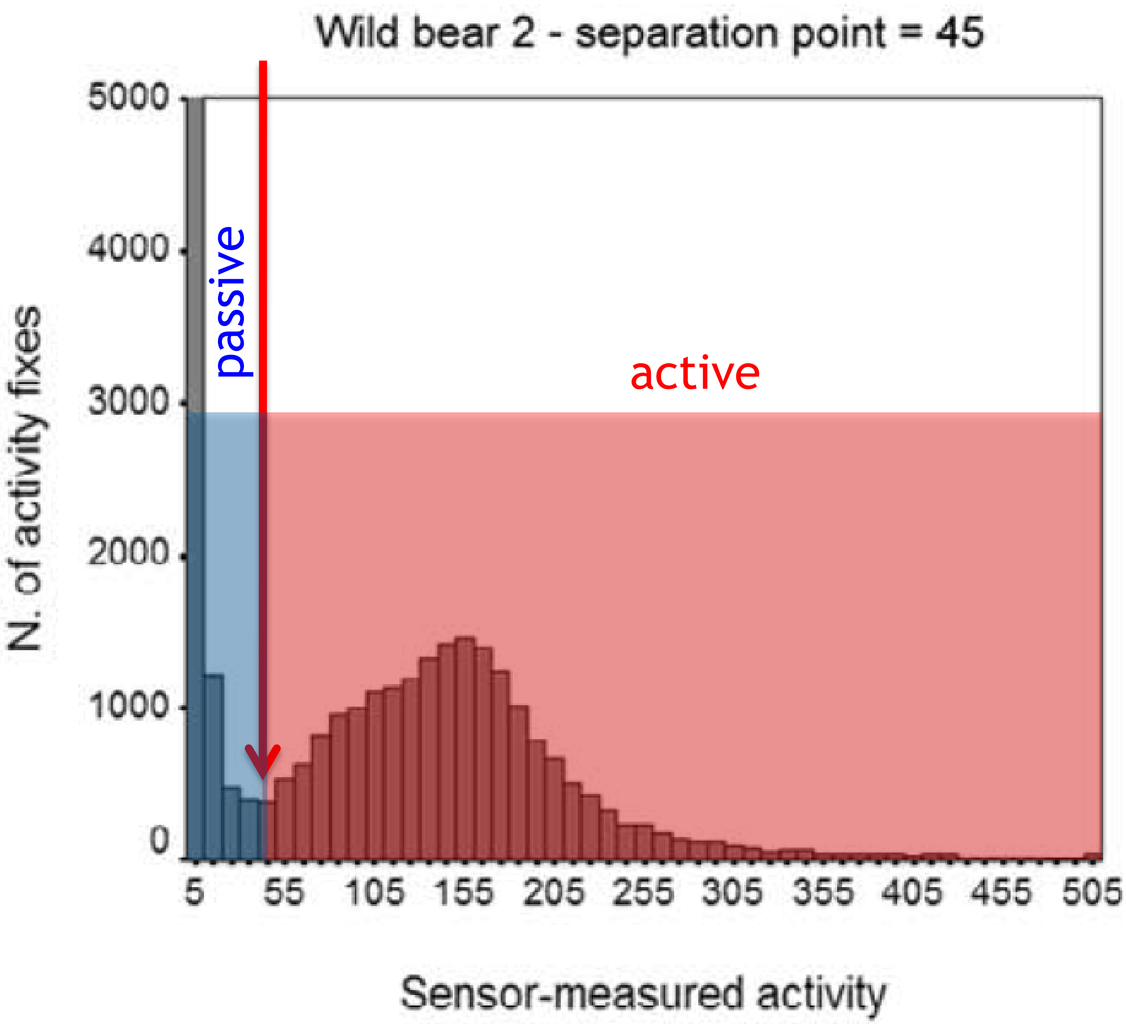
- daily mean (mean)
- diurnality index (DI)
- autocorrelation
- power spectrum
- Degrees of Functional Coupling (DFC)
- Harmonic Parts (HP)

Output:

- coupling between the internal circadian rhythm and external environmental periodicities
- detection of disturbances and stressing conditions in wildlife on a daily level

Berger A et al. (2003) Behaviour Research Methods, Instruments & Computers 35 (3)

Detection of different behaviours (1-2D)



Calculation of:

- plot the frequency distribution of activity classes
- define the separation point = activity class with the lowest frequency between the 2 modes (need: bimodal pattern)

Output:

- individual threshold to discriminate active and passive behaviour

Gervasi et al. 2006 Wildlife Society Bulletin 34 (5)

Detection of different behaviours (1-2D)

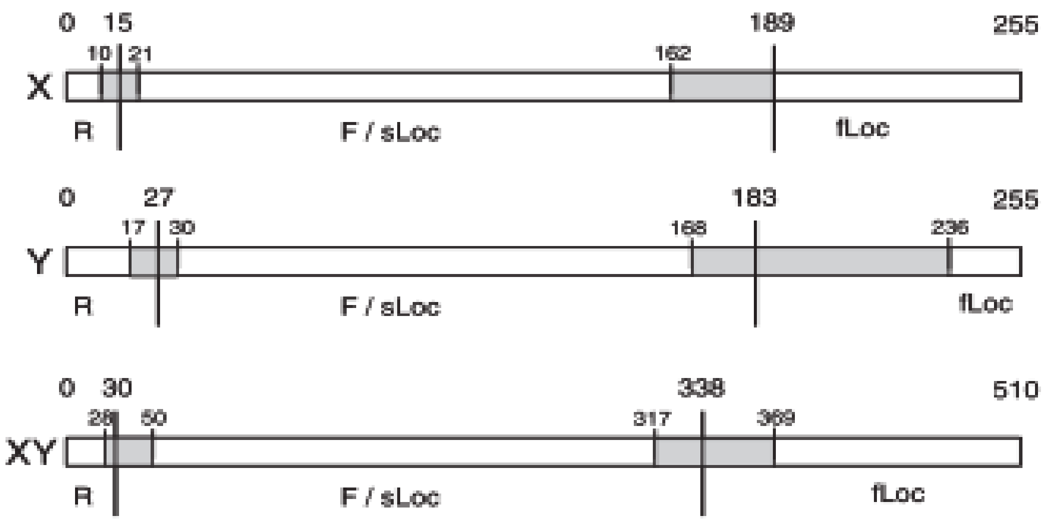


Figure 2. Threshold values (thick vertical lines) to separate resting (R) from feeding/slow locomotion (F/sLoc) and the latter from fast locomotion (fLoc) for x-values, y-values and the sums of x- and y-values as determined by recursive partitioning, and overlapping zones (grey bars) after 5,000 bootstraps. White bars denote 95% confidence intervals after 5,000 bootstraps. Thresholds are built from pooled data of four individuals (compare with Table 1).

Calculation of:

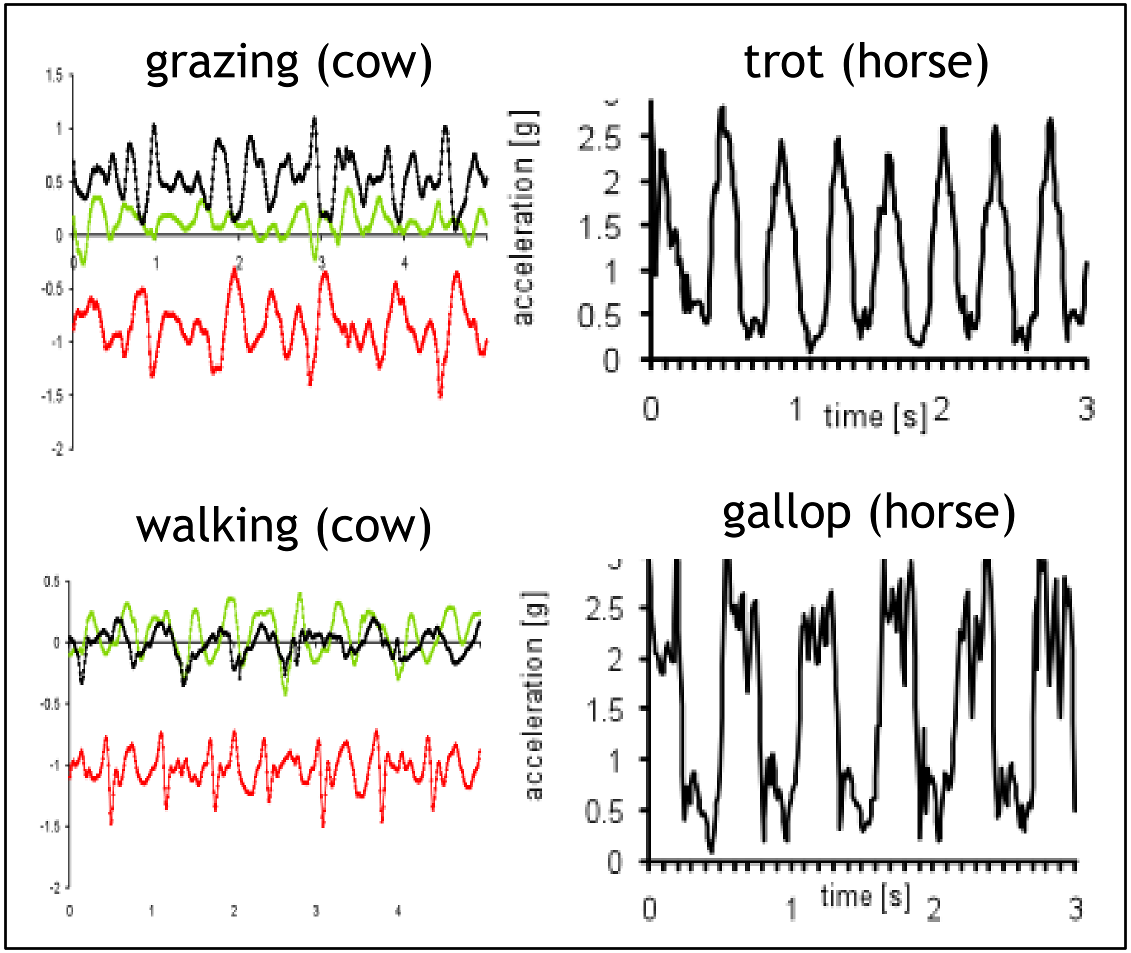
- comparison of observed behavioural categories and acceleration values at the same time
- ANOVA

Output:

- determination of thresholds to differ activity states

Löttker et al. (2009) Wildlife Biology 15

Detection of different behaviours (3D)



Calculation of:

- periodogram
- frequency distribution
- fractal dimension
- ODBA (overall dynamic body acceleration)
- moving window of pattern analysis

Output:

- differentiation of several behaviours (fine scale)
- only possible for behavior of characteristic pattern in space and time

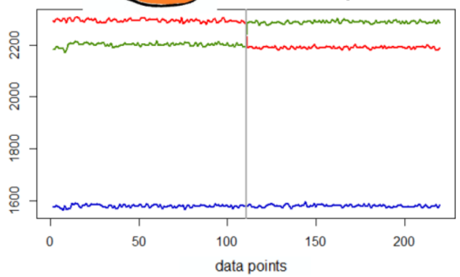
Shepard et al. (2008) Endangered Species Research, Vol. 10: 47–60
Scheibe & Gromann (2006) Behaviour Research Methods, Instruments & Computers 38 (3)

Detection of different behaviours (3D)

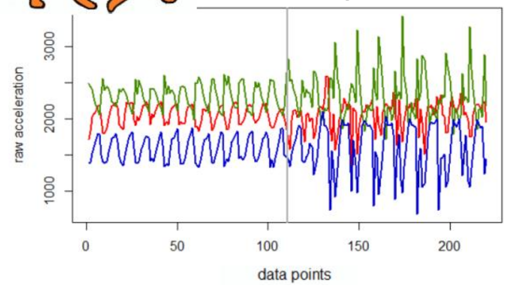
Leibniz Institute for Zoo and Wildlife Research
IN THE FORSCHUNGSVERBUND BERLIN E.V.

Member of the Leibniz Association

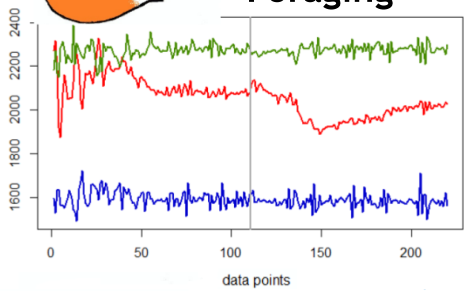
Resting



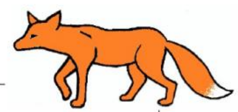
Trotting

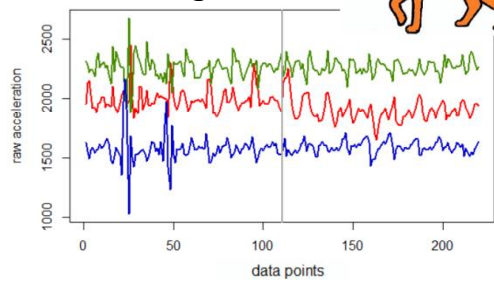


Foraging

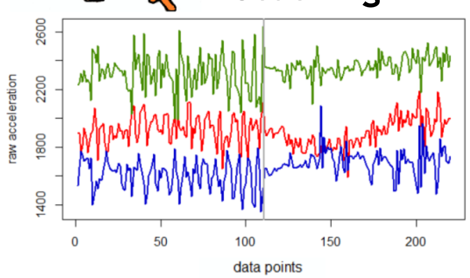


Walking

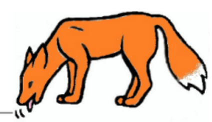


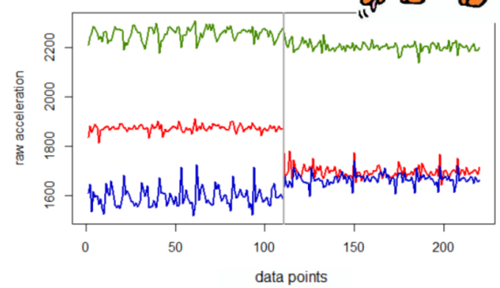


Stocking

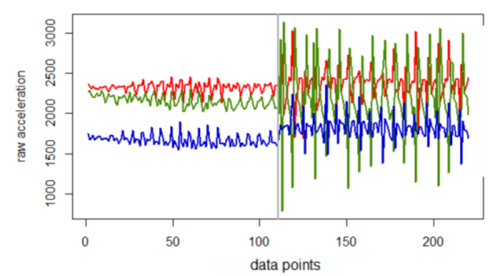


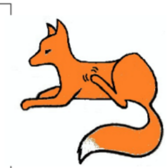
Drinking





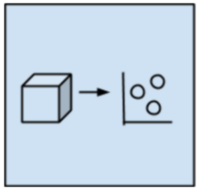
Grooming





Detection of different behaviours (3D)

used (supervised) machine learning methods

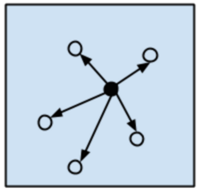


Linear Discriminant Analysis (LDA)

LDA is a dimensionality reduction algorithm in order to find a linear combination of features (predictors) that characterizes or separates the different classes (behaviours). LDA is for homogeneous variance-covariance matrices.

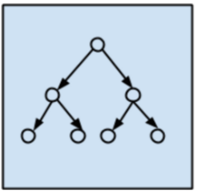
Quadratic Discriminant Analysis (QDA)

QDA is similar to LDA but is used for heterogeneous variance-covariance matrices. Quadratic discriminant analysis calculates a Quadratic Score Function.



K-Nearest Neighbor (KNN)

An object is classified by a majority vote of its neighbors, with the object being assigned to the class most common among its k nearest neighbors (k is a positive integer, typically small). If k = 1, then the object is simply assigned to the class of that single nearest neighbor.

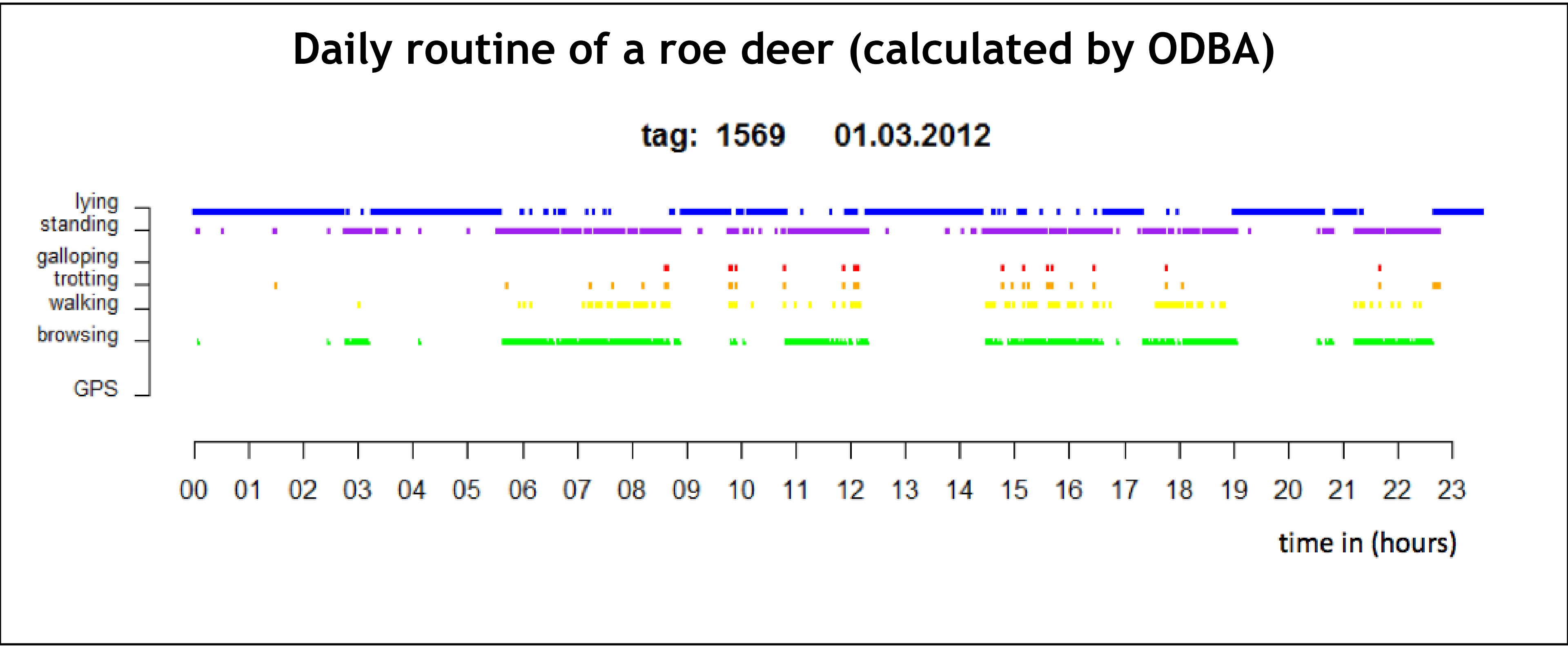


Classification and Regression Tree (CART)

Decision tree methods construct a model of decisions made based on actual values of attributes in the data. Decisions fork in tree structures (nodes and leaves) until a prediction decision is made for a given record.

There are a lot more! (Artificial Neural Network Algorithms, support vector machine, random forest ….)

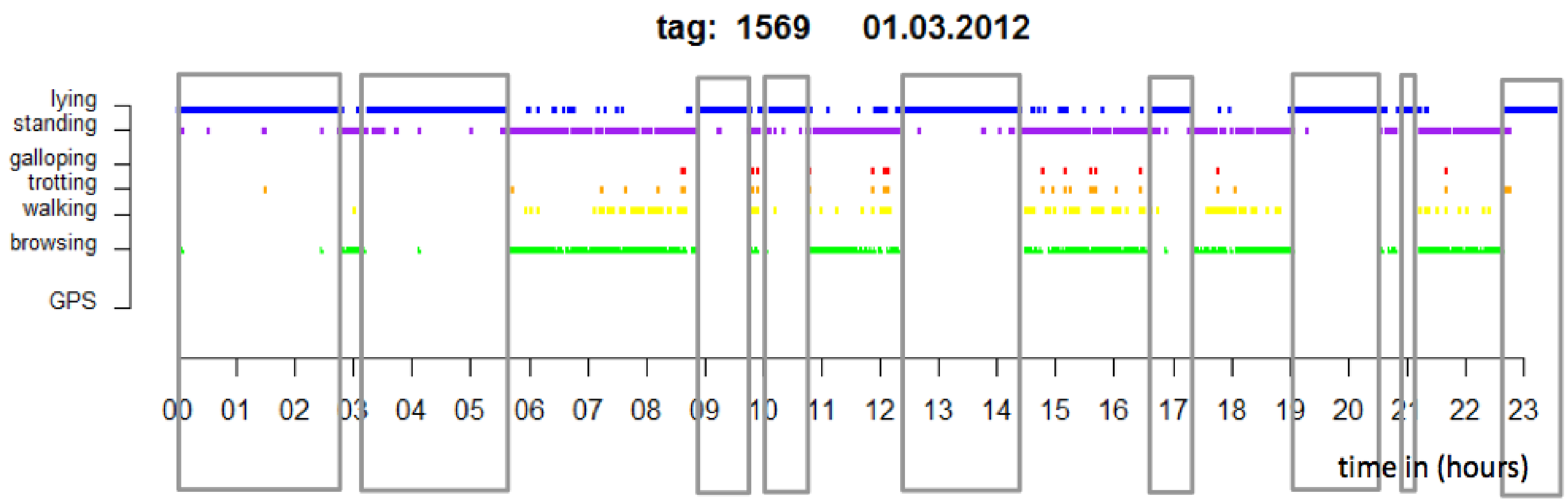
Development of functional habitat maps



Kröschel et al. (2017)

Development of functional habitat maps

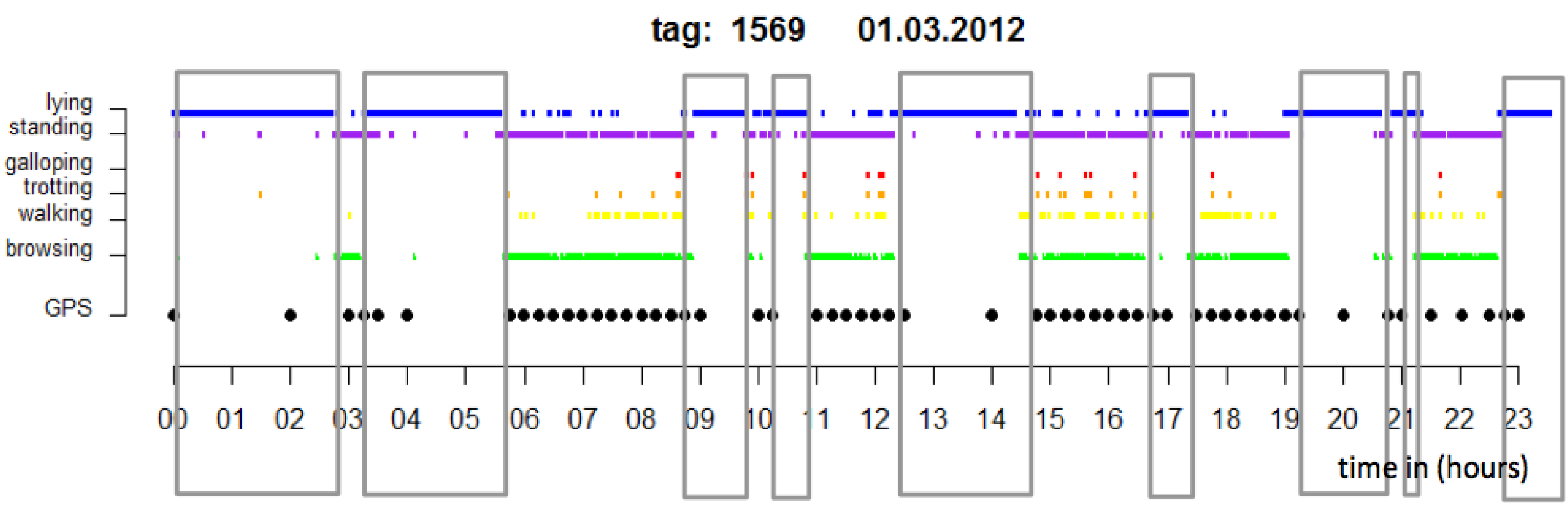
Classification of active & passive phases



Kröschel et al. (2017)

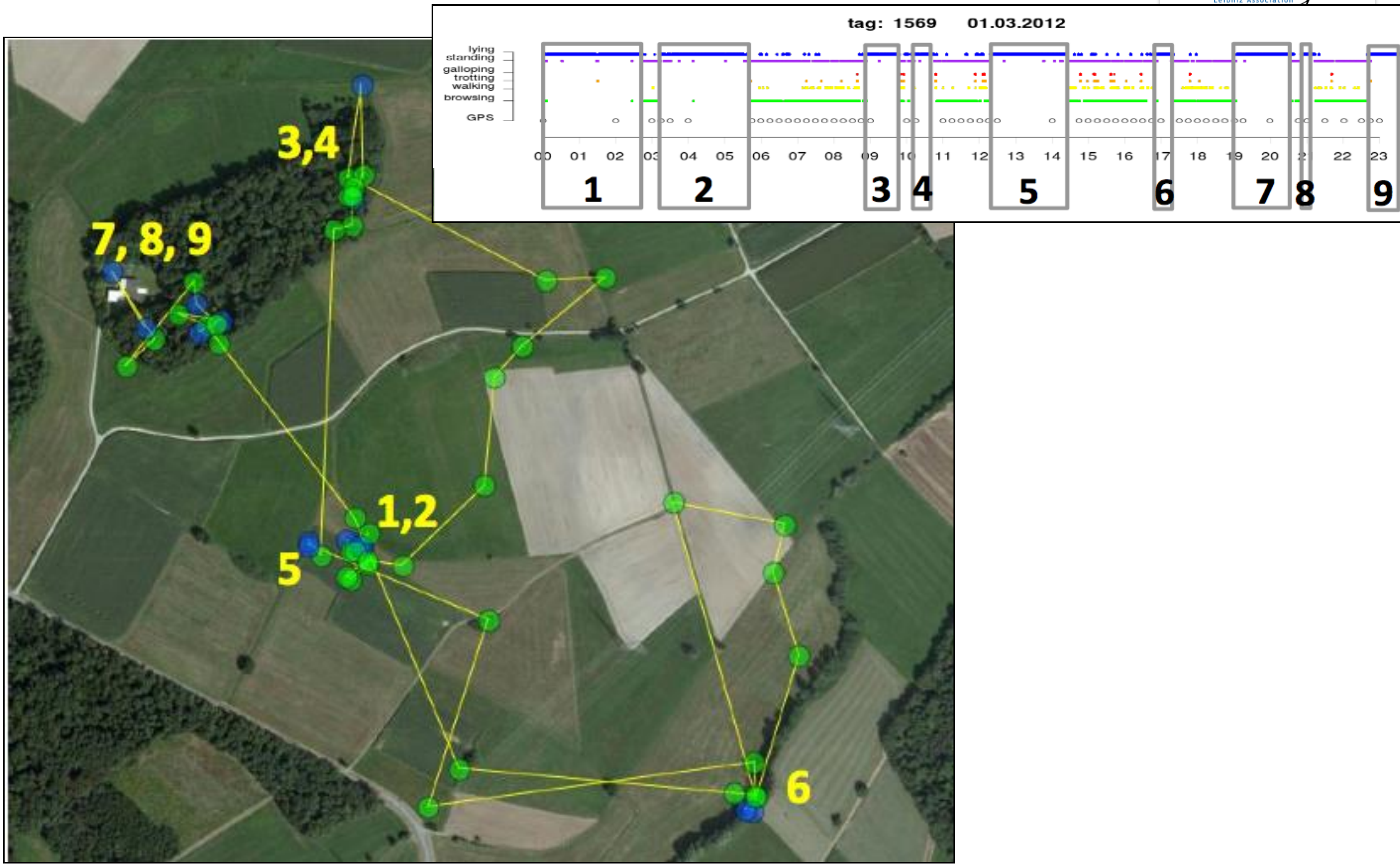
Development of functional habitat maps

Join behaviour and GPS-positions



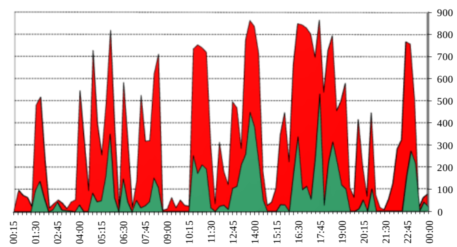
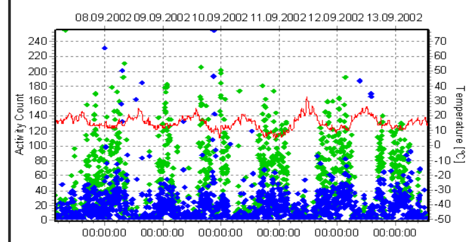
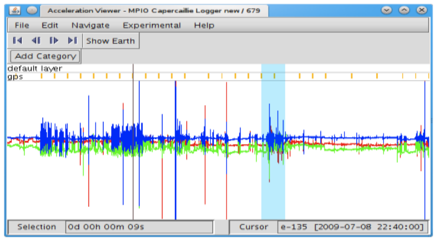
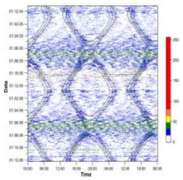
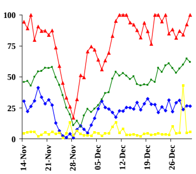
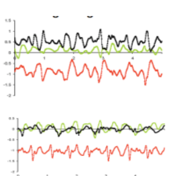
Kröschel et al. (2017)

Development of functional habitat maps

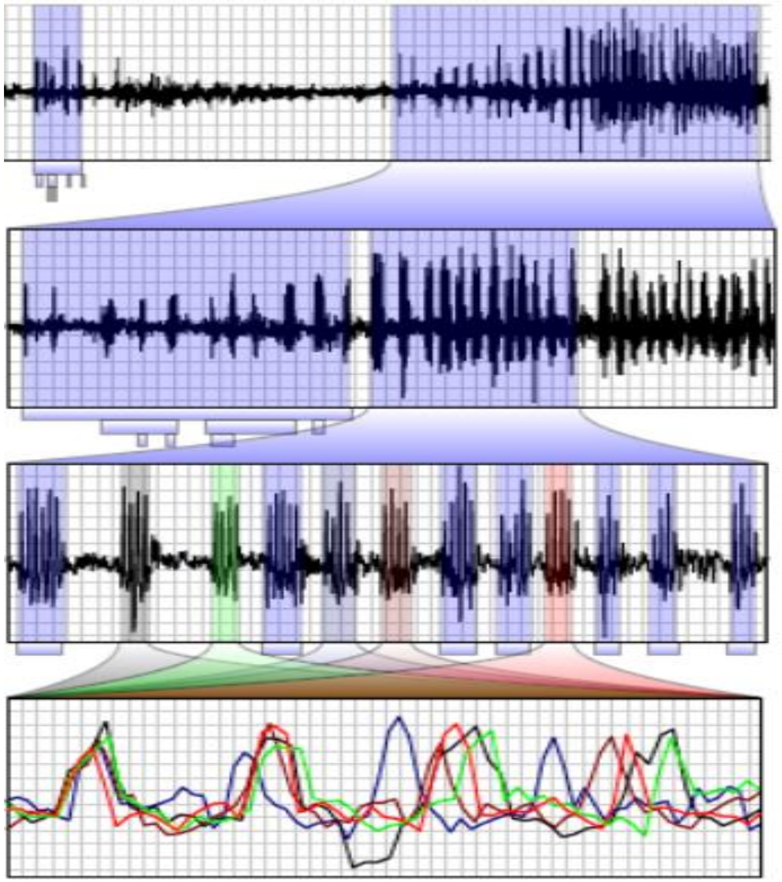


Kröschel et al. (2017)

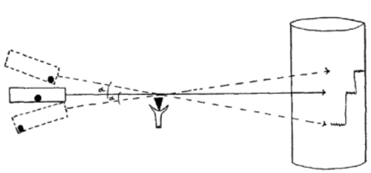
Which measurement suits to which analysis ?

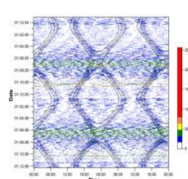
	Ethosys, Esys 	Vectronic, Lotek 	E-obs, WAS, Vectronic 
 Annual basic pattern			
 Stress detection			 In general possible but not done yet
 To differ behaviours	 Only general activity & grazing	 Only resting and very fast locomotion	
 Functional habitat maps	 Only general activity/ grazing & VHF	 Only resting and very fast locomotion	

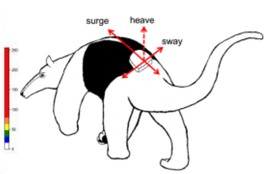
Outlook

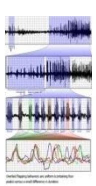


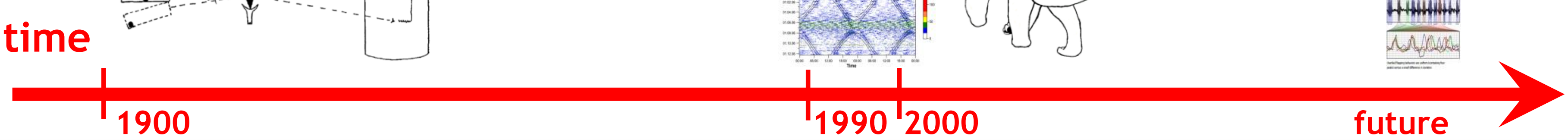
- 3D-accelerometers & other sensors (light, temperature, sound, humidity…)
- continuous measurements
- on-board behaviour classification by unsupervised pattern detection algorithms
- real-time data viewing via web



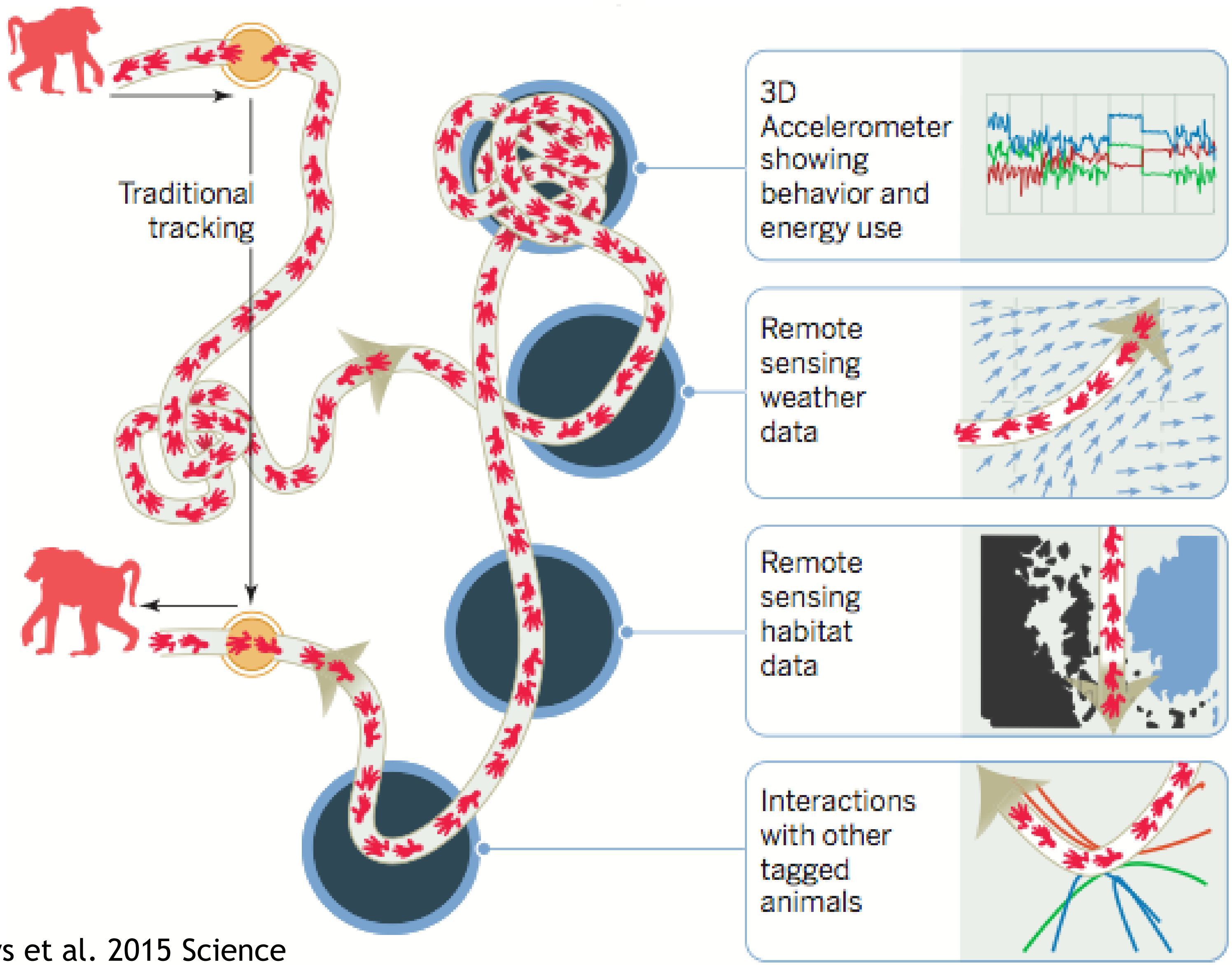








Outlook



Kays et al. 2015 Science

Take home messages

- Be clear about your study question !

- AFTER, choose your measuring/analyzing methods according to your study question !
  (do literature search and communicate with the community because the market is growing rapidly)

- IF you need to measure special behaviours, behaviour disturbances, energy consumptions, or functional habitat maps to answer your study question, the use of accelerometers is highly recommended !

- If you are rather a spatial data analyst, ask specialists in activity data analysis (maybe me :-)) -> These analyses are learnable!