

# Introduction to movement

## Biologia della Conservazione 25/26

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# Overview

- ▶ Discretionary course for master level students enrolled in “Biologia Ambientale” degree at the University of Rome Tor Vergata. It is worth **2 CFU** for a total of 16 hours
- ▶ All the material and the literature used will be in English
- ▶ No specific prior knowledge is required, but rudiments of basic GIS will definitely help. Students will be extensively exposed to various software and web-tools. Problem-solving skills and a good knowledge of your own computer OSs structure and function will definitely be useful
- ▶ Classes are Wednesday and Thursday (09:00-11:00) in “Aula televisore” (Laboratori di Ecologia Sperimentale ed Acquacoltura)

## Hardware set up

- ▶ To visualize and analyse data we will be using **R** and **RStudio**

```
> sessionInfo()
```

R version 4.5.1 (2025-06-13)

Platform: x86\_64-pc-linux-gnu

Running under: Ubuntu 24.04.3 LTS

Figure 1: The R version, hardware, and OS I am using on my personal computer. We will be using R and RStudio throughout the course, so please go ahead and install them on your computers. We will add specific libraries little by little.

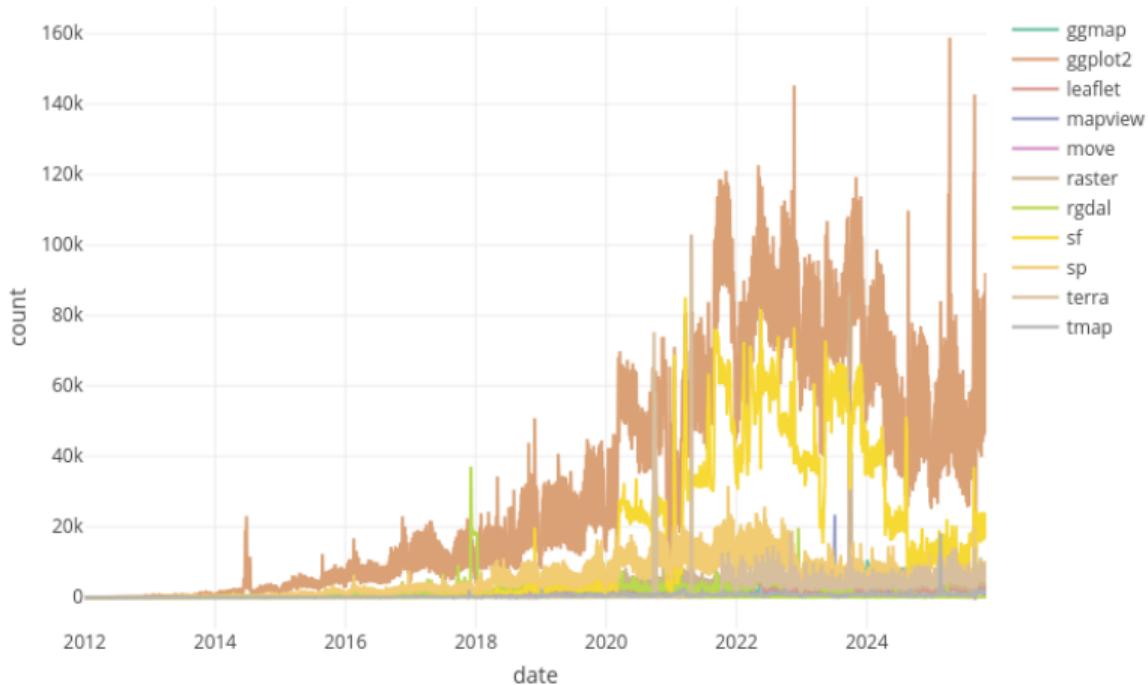


Figure 2: Trend of “movement related” packages downloaded from CRAN

A tag to track

# A tag to track

- ▶ Animal Tracking is a discipline allowing to gather information about the biology, ecology, behavior and life history of animals starting from data on their position in the natural environment.

Major requirements:

- ▶ the capability to uniquely identify individuals, populations or species (Costa, Foody, Jiménez, & Silva, 2015);
- ▶ the availability of position data for that individual (population or species) and a geographic reference system that helps minimizing errors when making calculations (Guisan & Zimmermann, 2000)
- ▶ the availability of reliable environmental data!

# Tagging systems

- ▶ A tag is a label!
- ▶ A tagging system is a way of labeling “something” to provide that something with an unique identifier. People have been tagging animals (wild and captive) for hundreds of years
- ▶ An animal tag can be as simple as a piece of metal or plastic with a number carved on it or with a standardized meaning



Figure 3: A male *Cyclura carinata* with colored bead tags. Photo credits: Giuliano Colosimo.

# Passive Integrated Transponders (PIT)

- ▶ These tags are widely used for wildlife fauna, especially in long-term capture-mark-recapture studies. They uniquely identify individuals. They generally do not carry any other information but the individual's ID. They are based on the RFID (Radio-Frequency-Identification) system. When the tag is within reach of a specific radio frequency, it emits a signal containing an alpha-numeric code unique to the animal it has been implanted.



Figure 4: A Passive Integrated Transponder by Trovan®. Photo credits: Giuliano Colosimo.

# Patterns tagging

## Toes and nail clipping

Table 1. All codes possible by clipping one, two, or three toes. The codes available only for animals with five fore toes are printed in bold.

ONE	A#2	B#3	AI#3D	AJ#4C	BB#D5	BB#C3	C#3A1	CA#3B4	DD#A5	AI#D5	A#B#C3
TOE	A#B#3	B#D#	AI#A#D#5	AJ#A#C#3	BB#B#A#1	BB#B#C#4	C#C#3A#1	CA#C#3B#4	DD#D#A#5	AI#R#C#1	A#B#H#C#4
A#	A#B#	B#D#	AI#A#B#3	AJ#A#C#4	BB#B#A#2	BB#B#C#5	C#C#2A#1	CA#C#2B#4	DD#D#A#4	AI#R#C#2	A#B#H#C#3
A1	A#B#5	B#D#5	AI#A#B#3	AJ#A#C#4	BB#B#A#3	BB#B#C#6	C#C#2A#2	CA#C#2B#5	DD#D#A#3	AI#R#C#3	A#B#H#C#2
A2	A#C#1	B#D#5	AI#A#B#3	AJ#A#D#1	BB#B#A#4	BB#B#C#7	C#C#3A#1	CA#C#3B#5	DD#D#B#R	AI#R#C#4	A#B#H#O#2
A3	A#C#2	B#D#5	AI#A#B#3	AJ#A#D#2	BB#B#A#5	BB#B#C#8	C#C#3B#1	CA#C#3D#4	DD#D#B#R	AI#R#C#5	A#B#H#O#1
A4	A#C#3	B#D#5	AI#A#B#3	AJ#A#D#3	BB#B#A#6	BB#B#C#9	C#C#3B#2	CA#C#3D#5	DD#D#B#R	AI#R#C#6	A#B#H#O#0
A5	A#C#4	B#D#5	AI#A#B#3	AJ#A#D#4	BB#B#A#7	BB#B#C#10	C#C#3B#3	CA#C#3D#6	DD#D#B#R	AI#R#C#7	A#B#H#O#-1
B1	A#C#5	C#C#4	AI#A#C#2	AJ#A#D#5	BB#B#C#3	BB#B#C#11	C#C#3B#4	CA#C#3D#7	DD#D#A#2	AI#R#C#0	A#H#C#1
B2	A#D#1	C#C#5	AI#A#C#2	AJ#A#B#1	BB#B#C#4	BB#B#C#12	C#C#3B#5	CA#C#3D#8	DD#D#A#3	AI#R#C#1	A#H#C#2
B3	A#D#2	C#C#5	AI#A#C#2	AJ#A#B#2	BB#B#C#5	BB#B#C#13	C#C#3B#6	CA#C#3D#9	DD#D#A#4	AI#R#C#2	A#H#C#3
B4	A#D#3	C#C#5	AI#A#C#2	AJ#A#B#3	BB#B#C#6	BB#B#C#14	C#C#3B#7	CA#C#3D#10	DD#D#A#5	AI#R#C#3	A#H#C#4
B5	A#D#4	C#C#5	AI#A#C#2	AJ#A#B#4	BB#B#C#7	BB#B#C#15	C#C#3B#8	CA#C#3D#11	DD#D#A#6	AI#R#C#4	A#H#C#5
C1	A#D#5	C#C#5	AI#A#C#2	AJ#A#B#5	BB#B#C#8	BB#B#C#16	C#C#3B#9	CA#C#3D#12	DD#D#A#7	AI#R#C#5	A#H#C#6
C2	A#B#5	C#D#5	AI#A#D#3	AJ#A#C#3	BB#B#C#9	BB#B#C#17	C#C#3B#10	CA#C#3D#13	DD#D#B#R	AI#R#C#4	A#H#D#2
C3	A#B#5	C#D#5	AI#A#D#3	AJ#A#C#4	BB#B#C#10	BB#B#C#18	C#C#3B#11	CA#C#3D#14	DD#D#B#R	AI#R#C#5	A#H#D#1
C4	A#B#5	C#D#5	AI#A#D#3	AJ#A#C#5	BB#B#C#11	BB#B#C#19	C#C#3B#12	CA#C#3D#15	DD#D#B#R	AI#R#C#6	A#H#D#0
C5	A#B#5	C#D#5	AI#A#D#3	AJ#A#C#6	BB#B#C#12	BB#B#C#20	C#C#3B#13	CA#C#3D#16	DD#D#B#R	AI#R#C#7	A#H#D#-1
D1	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#5	BB#B#C#13	BB#B#C#21	C#C#3B#14	CA#C#3D#17	DD#D#A#1	AI#R#C#1	C#D#A#1
D2	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#6	BB#B#C#14	BB#B#C#22	C#C#3B#15	CA#C#3D#18	DD#D#A#2	AI#R#C#2	C#D#A#2
D3	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#7	BB#B#C#15	BB#B#C#23	C#C#3B#16	CA#C#3D#19	DD#D#A#3	AI#R#C#3	C#D#A#3
D4	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#8	BB#B#C#16	BB#B#C#24	C#C#3B#17	CA#C#3D#20	DD#D#A#4	AI#R#C#4	C#D#A#4
D5	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#9	BB#B#C#17	BB#B#C#25	C#C#3B#18	CA#C#3D#21	DD#D#A#5	AI#R#C#5	C#D#A#5
D6	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#10	BB#B#C#18	BB#B#C#26	C#C#3B#19	CA#C#3D#22	DD#D#A#6	AI#R#C#6	C#D#A#6
D7	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#11	BB#B#C#19	BB#B#C#27	C#C#3B#20	CA#C#3D#23	DD#D#A#7	AI#R#C#7	C#D#A#7
D8	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#12	BB#B#C#20	BB#B#C#28	C#C#3B#21	CA#C#3D#24	DD#D#A#8	AI#R#C#8	C#D#A#8
D9	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#13	BB#B#C#21	BB#B#C#29	C#C#3B#22	CA#C#3D#25	DD#D#A#9	AI#R#C#9	C#D#A#9
D10	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#14	BB#B#C#22	BB#B#C#30	C#C#3B#23	CA#C#3D#26	DD#D#A#10	AI#R#C#10	C#D#A#10
D11	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#15	BB#B#C#23	BB#B#C#31	C#C#3B#24	CA#C#3D#27	DD#D#A#11	AI#R#C#11	C#D#A#11
D12	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#16	BB#B#C#24	BB#B#C#32	C#C#3B#25	CA#C#3D#28	DD#D#A#12	AI#R#C#12	C#D#A#12
D13	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#17	BB#B#C#25	BB#B#C#33	C#C#3B#26	CA#C#3D#29	DD#D#A#13	AI#R#C#13	C#D#A#13
D14	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#18	BB#B#C#26	BB#B#C#34	C#C#3B#27	CA#C#3D#30	DD#D#A#14	AI#R#C#14	C#D#A#14
D15	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#19	BB#B#C#27	BB#B#C#35	C#C#3B#28	CA#C#3D#31	DD#D#A#15	AI#R#C#15	C#D#A#15
D16	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#20	BB#B#C#28	BB#B#C#36	C#C#3B#29	CA#C#3D#32	DD#D#A#16	AI#R#C#16	C#D#A#16
D17	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#21	BB#B#C#29	BB#B#C#37	C#C#3B#30	CA#C#3D#33	DD#D#A#17	AI#R#C#17	C#D#A#17
D18	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#22	BB#B#C#30	BB#B#C#38	C#C#3B#31	CA#C#3D#34	DD#D#A#18	AI#R#C#18	C#D#A#18
D19	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#23	BB#B#C#31	BB#B#C#39	C#C#3B#32	CA#C#3D#35	DD#D#A#19	AI#R#C#19	C#D#A#19
D20	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#24	BB#B#C#32	BB#B#C#40	C#C#3B#33	CA#C#3D#36	DD#D#A#20	AI#R#C#20	C#D#A#20
D21	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#25	BB#B#C#33	BB#B#C#41	C#C#3B#34	CA#C#3D#37	DD#D#A#21	AI#R#C#21	C#D#A#21
D22	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#26	BB#B#C#34	BB#B#C#42	C#C#3B#35	CA#C#3D#38	DD#D#A#22	AI#R#C#22	C#D#A#22
D23	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#27	BB#B#C#35	BB#B#C#43	C#C#3B#36	CA#C#3D#39	DD#D#A#23	AI#R#C#23	C#D#A#23
D24	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#28	BB#B#C#36	BB#B#C#44	C#C#3B#37	CA#C#3D#40	DD#D#A#24	AI#R#C#24	C#D#A#24
D25	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#29	BB#B#C#37	BB#B#C#45	C#C#3B#38	CA#C#3D#41	DD#D#A#25	AI#R#C#25	C#D#A#25
D26	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#30	BB#B#C#38	BB#B#C#46	C#C#3B#39	CA#C#3D#42	DD#D#A#26	AI#R#C#26	C#D#A#26
D27	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#31	BB#B#C#39	BB#B#C#47	C#C#3B#40	CA#C#3D#43	DD#D#A#27	AI#R#C#27	C#D#A#27
D28	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#32	BB#B#C#40	BB#B#C#48	C#C#3B#41	CA#C#3D#44	DD#D#A#28	AI#R#C#28	C#D#A#28
D29	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#33	BB#B#C#41	BB#B#C#49	C#C#3B#42	CA#C#3D#45	DD#D#A#29	AI#R#C#29	C#D#A#29
D30	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#34	BB#B#C#42	BB#B#C#50	C#C#3B#43	CA#C#3D#46	DD#D#A#30	AI#R#C#30	C#D#A#30
D31	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#35	BB#B#C#43	BB#B#C#51	C#C#3B#44	CA#C#3D#47	DD#D#A#31	AI#R#C#31	C#D#A#31
D32	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#36	BB#B#C#44	BB#B#C#52	C#C#3B#45	CA#C#3D#48	DD#D#A#32	AI#R#C#32	C#D#A#32
D33	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#37	BB#B#C#45	BB#B#C#53	C#C#3B#46	CA#C#3D#49	DD#D#A#33	AI#R#C#33	C#D#A#33
D34	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#38	BB#B#C#46	BB#B#C#54	C#C#3B#47	CA#C#3D#50	DD#D#A#34	AI#R#C#34	C#D#A#34
D35	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#39	BB#B#C#47	BB#B#C#55	C#C#3B#48	CA#C#3D#51	DD#D#A#35	AI#R#C#35	C#D#A#35
D36	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#40	BB#B#C#48	BB#B#C#56	C#C#3B#49	CA#C#3D#52	DD#D#A#36	AI#R#C#36	C#D#A#36
D37	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#41	BB#B#C#49	BB#B#C#57	C#C#3B#50	CA#C#3D#53	DD#D#A#37	AI#R#C#37	C#D#A#37
D38	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#42	BB#B#C#50	BB#B#C#58	C#C#3B#51	CA#C#3D#54	DD#D#A#38	AI#R#C#38	C#D#A#38
D39	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#43	BB#B#C#51	BB#B#C#59	C#C#3B#52	CA#C#3D#55	DD#D#A#39	AI#R#C#39	C#D#A#39
D40	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#44	BB#B#C#52	BB#B#C#60	C#C#3B#53	CA#C#3D#56	DD#D#A#40	AI#R#C#40	C#D#A#40
D41	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#45	BB#B#C#53	BB#B#C#61	C#C#3B#54	CA#C#3D#57	DD#D#A#41	AI#R#C#41	C#D#A#41
D42	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#46	BB#B#C#54	BB#B#C#62	C#C#3B#55	CA#C#3D#58	DD#D#A#42	AI#R#C#42	C#D#A#42
D43	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#47	BB#B#C#55	BB#B#C#63	C#C#3B#56	CA#C#3D#59	DD#D#A#43	AI#R#C#43	C#D#A#43
D44	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#48	BB#B#C#56	BB#B#C#64	C#C#3B#57	CA#C#3D#60	DD#D#A#44	AI#R#C#44	C#D#A#44
D45	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#49	BB#B#C#57	BB#B#C#65	C#C#3B#58	CA#C#3D#61	DD#D#A#45	AI#R#C#45	C#D#A#45
D46	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#50	BB#B#C#58	BB#B#C#66	C#C#3B#59	CA#C#3D#62	DD#D#A#46	AI#R#C#46	C#D#A#46
D47	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#51	BB#B#C#59	BB#B#C#67	C#C#3B#60	CA#C#3D#63	DD#D#A#47	AI#R#C#47	C#D#A#47
D48	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#52	BB#B#C#60	BB#B#C#68	C#C#3B#61	CA#C#3D#64	DD#D#A#48	AI#R#C#48	C#D#A#48
D49	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#53	BB#B#C#61	BB#B#C#69	C#C#3B#62	CA#C#3D#65	DD#D#A#49	AI#R#C#49	C#D#A#49
D50	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#54	BB#B#C#62	BB#B#C#70	C#C#3B#63	CA#C#3D#66	DD#D#A#50	AI#R#C#50	C#D#A#50
D51	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#55	BB#B#C#63	BB#B#C#71	C#C#3B#64	CA#C#3D#67	DD#D#A#51	AI#R#C#51	C#D#A#51
D52	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#56	BB#B#C#64	BB#B#C#72	C#C#3B#65	CA#C#3D#68	DD#D#A#52	AI#R#C#52	C#D#A#52
D53	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#57	BB#B#C#65	BB#B#C#73	C#C#3B#66	CA#C#3D#69	DD#D#A#53	AI#R#C#53	C#D#A#53
D54	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#58	BB#B#C#66	BB#B#C#74	C#C#3B#67	CA#C#3D#70	DD#D#A#54	AI#R#C#54	C#D#A#54
D55	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#59	BB#B#C#67	BB#B#C#75	C#C#3B#68	CA#C#3D#71	DD#D#A#55	AI#R#C#55	C#D#A#55
D56	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#60	BB#B#C#68	BB#B#C#76	C#C#3B#69	CA#C#3D#72	DD#D#A#56	AI#R#C#56	C#D#A#56
D57	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#61	BB#B#C#69	BB#B#C#77	C#C#3B#70	CA#C#3D#73	DD#D#A#57	AI#R#C#57	C#D#A#57
D58	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#62	BB#B#C#70	BB#B#C#78	C#C#3B#71	CA#C#3D#74	DD#D#A#58	AI#R#C#58	C#D#A#58
D59	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#63	BB#B#C#71	BB#B#C#79	C#C#3B#72	CA#C#3D#75	DD#D#A#59	AI#R#C#59	C#D#A#59
D60	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#64	BB#B#C#72	BB#B#C#80	C#C#3B#73	CA#C#3D#76	DD#D#A#60	AI#R#C#60	C#D#A#60
D61	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#65	BB#B#C#73	BB#B#C#81	C#C#3B#74	CA#C#3D#77	DD#D#A#61	AI#R#C#61	C#D#A#61
D62	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#66	BB#B#C#74	BB#B#C#82	C#C#3B#75	CA#C#3D#78	DD#D#A#62	AI#R#C#62	C#D#A#62
D63	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#67	BB#B#C#75	BB#B#C#83	C#C#3B#76	CA#C#3D#79	DD#D#A#63	AI#R#C#63	C#D#A#63
D64	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#68	BB#B#C#76	BB#B#C#84	C#C#3B#77	CA#C#3D#80	DD#D#A#64	AI#R#C#64	C#D#A#64
D65	A#C#5	C#D#5	AI#A#D#3	AJ#A#C#69	BB#B#C#77	BB#B#C#85	C#C#3B#78	CA#C#3D#81	DD#D#A#65	AI#R#C#	

- ▶ More modern approaches rely on the use of morphometric cues to identify individuals!
- ▶ These techniques are more complex, but somewhat similar to the FaceID technology on your phones

## Results : individual identification of Lesser Antillean Iguanas

- ▶ Matching individual pictures in I3S

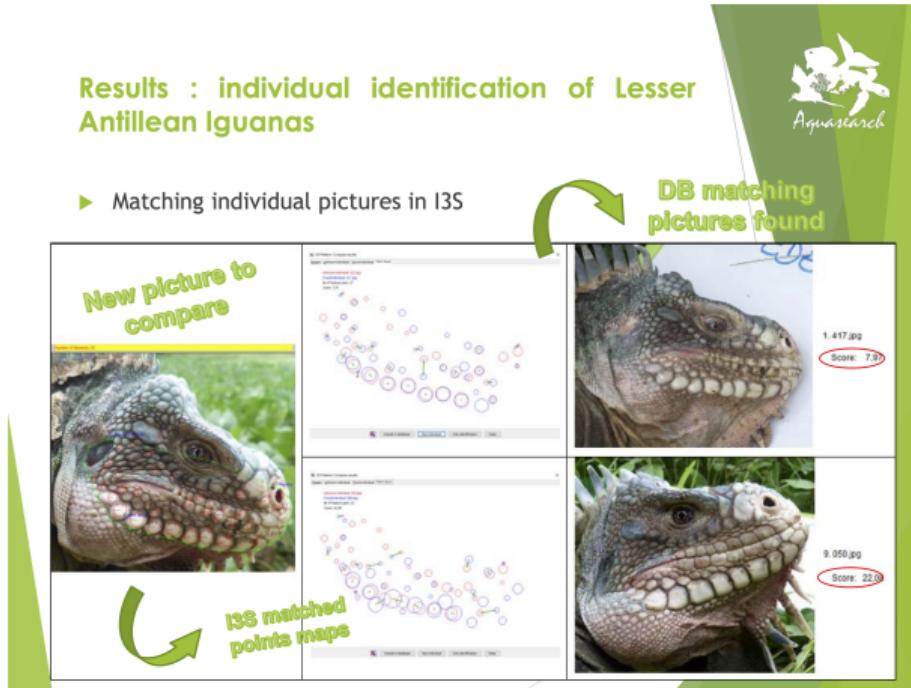


Figure 7: Development of a photo recognition software to identify iguanas in the wild. Image courtesy of Nathalie Duporge. A nice example and protocol of the use of photographies for the identification of unique individuals is presented in

# Molecular tags

- ▶ From the **USGS** website:
  - ▶ Molecular tagging is a new application of molecular genetic techniques to traditional mark-recapture methodology designed to address situations where traditional methods fail. In such studies, non-invasively collected samples (such as feces, feathers, or fur) are used as a source of DNA that is then genotyped at multiple loci such that each individual animal can be uniquely identified. Thus, each individual's DNA represents a unique tag analogous to a band or other mark used in traditional mark-recapture studies.



Figure 8: Selected species and locations for which genetic tagging for demographic insights into population density, growth rates, direct measures of connectivity, or human–wildlife conflict has been successfully applied. Projects using genetic tagging are biased toward mid-large sized mobile mammals. After Lamb et al. (2019)

- ▶ Small devices transmitting specific radio frequencies have been, and still are, widely used to track animals. Telemetry (tele = far, metron = measurement) is a technique that allows to retrieve real time data and information using an array of wireless data transfer protocols.



Figure 9: Barrell transmitter implanted in a female Turks and Caicos Rainbow Boa (*Chilabothrus chrysogaster*). Photo credits: Giuliano Colosimo.



Figure 10: Radio-telemetry has been, and still is, widely used to retrieve information about the whereabouts of tagged individuals. Photo credits: Giuliano Colosimo.

# Satellite tags



Figure 11: A male *Conolophus marthae* equipped with a Wireless Sensor Node (WSN). This tag allows to identify the individual and to collect important information such as GPS location, temperature and UV light. Photo credits: Giuliano Colosimo.

- ▶ Eventually, data can be organized and analyzed to produce informative animations
- ▶ Example 1
- ▶ Example 2
- ▶ Example 3

# Coordinate Reference Systems (CRS)

# Coordinate Reference Systems (CRS)

- ▶ A coordinate reference system allows us to use coordinates to locate features on a map. It is a rather important component of tracking, especially when dealing with animals that move significant distances.
- ▶ One of the main issue is that ultimately what we try to do is to represent locations measured on a 3D surface (the earth) to a 2D map. This introduces distortions and errors.
- ▶ Another issue is represented by the fact that the earth is not smooth surface. We can visualize the problem [here!](#)
- ▶ We recognize two big classes of coordinate systems:

# Geographic coordinates

- ▶ The earth is represented by a spherical or ellipsoidal surface. The geometric representation of the earth that is used is called *datum*. Distances between points cannot be measured out with geographical coordinates.
- ▶ Latitude: denoted by the Greek letter phi ( $\phi$ ). It is given as an angle that ranges from  $-90^\circ$  at the south pole to  $90^\circ$  at the north pole, with  $0^\circ$  at the Equator.
- ▶ Longitude: denoted by the Greek letter lambda ( $\lambda$ ). It is given as an angle that ranges from  $-180^\circ$  to  $180^\circ$  from east to west and the  $0^\circ$ .

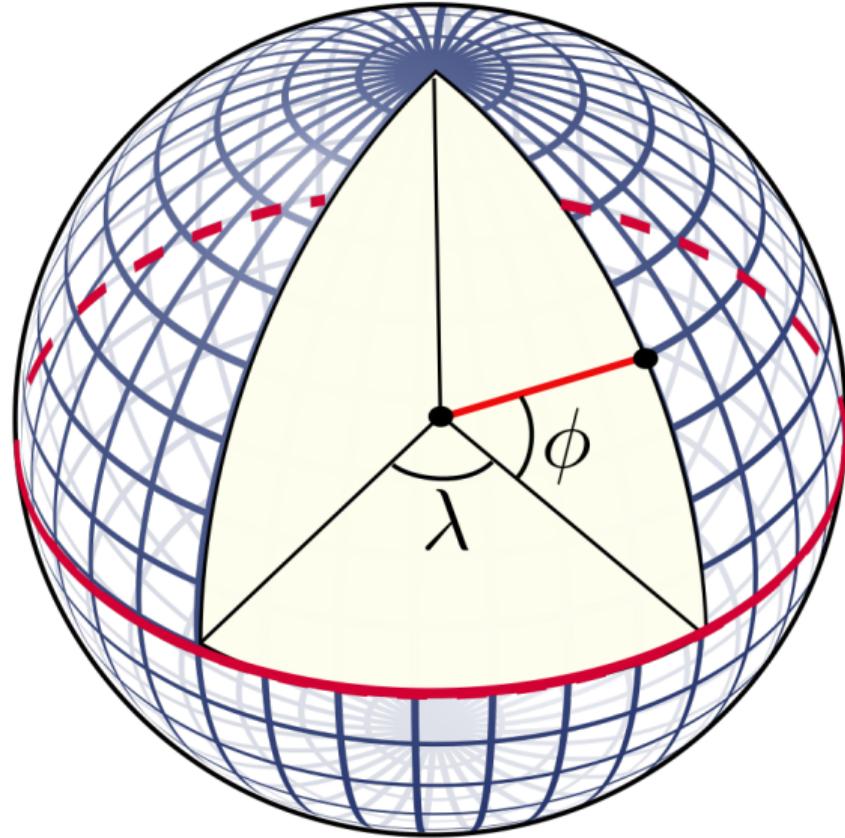


Figure 12: Angles (degrees; longitude and latitude), pointing out locations on a spherical or ellipsoidal surface. [Image source](#).

- ▶ Measured on a two-dimensional flat space (e.g. in meters; x and y), related to an ellipsoid by projection. In the transition from geometric coordinates to projected ones, a deformation of the images occurs.

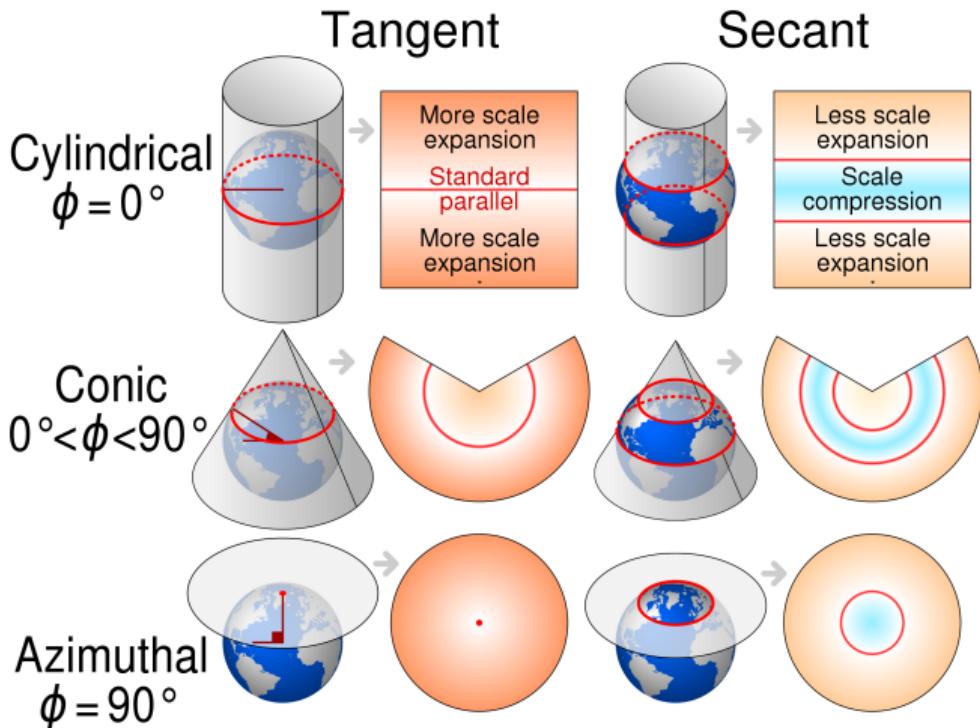


Figure 13: There is no system of projections that is not affected by errors and distortions. [Image source](#).

# Telemetry e GPS

- ▶ The term telemetry (tele = far, metron = measurement) refers to an ensemble of techniques that allow to retrieve real time data and information using an array of wireless data transfer protocols.
- ▶ The acronym GPS stands for Global Positioning System GPS
  - ▶ NAVSTAR = NAVigation System with Timing And Ranging
  - ▶  $n \geq 4$  satellites
  - ▶  $m \geq 1$  receivers
  - ▶ Pseudo-ranges
- ▶ Check [this](#) out. Downloaded from the [Wikipedia page](#).

# How does positioning with range works?

## Positioning with ranges

● Point of interest (unknown)



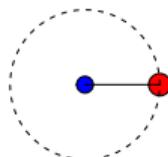
## Positioning with ranges

- Point of interest (unknown)
- Reference point (known)

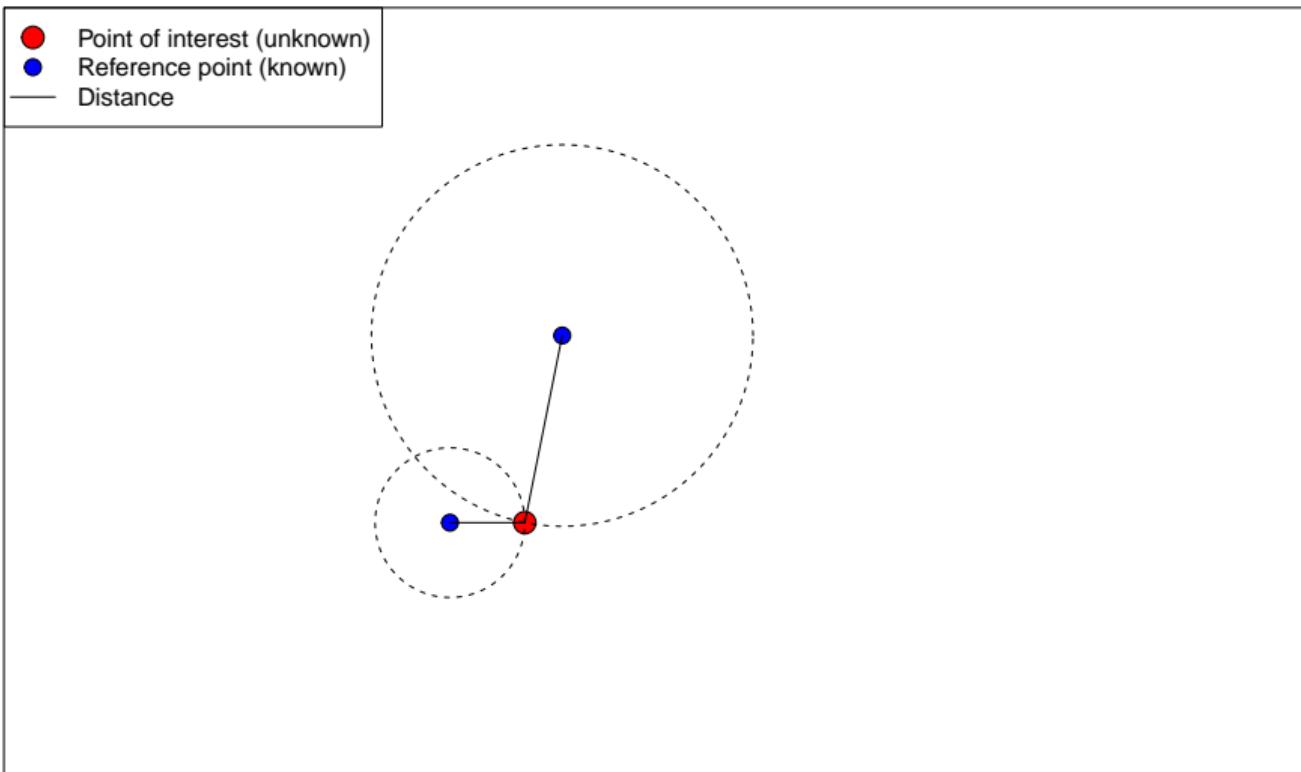


## Positioning with ranges

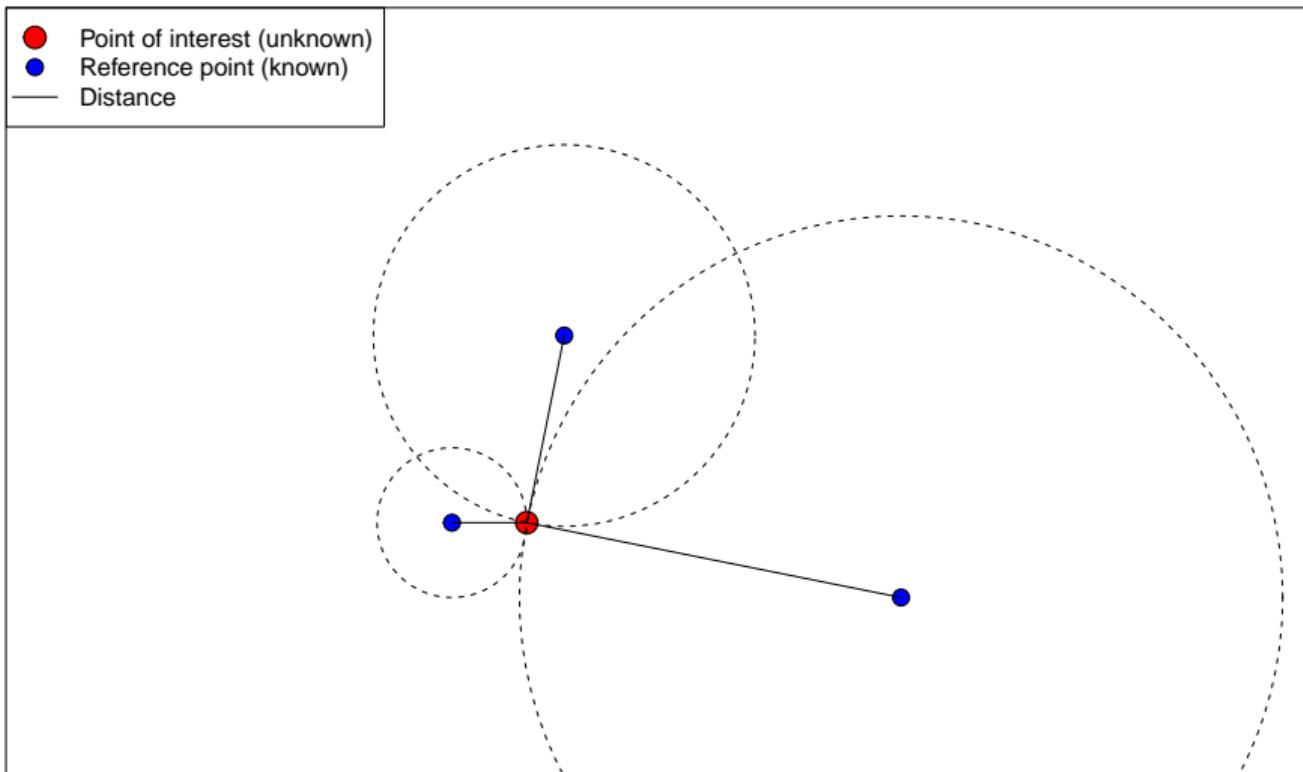
- Point of interest (unknown)
- Reference point (known)
- Distance



## Positioning with ranges



## Positioning with ranges



- ▶ As you know, distance is a function of time and speed. We can assume with a certain degree of confidence that the speed of our radio signal is fairly constant ( $3 * 10^5$  Km/s). If our estimate of time is error-prone, the associated estimate of distance may also be affected by errors. That is why the distance is actually called pseudo-distance.
- ▶ To minimize this error a forth reference point (satellite) is necessary!
- ▶ The GPS receiver knows the position of the satellite because it is the satellite itself that sends it by communicating its orbit in a navigation message (ephemeris)

# Movement data

# Lagrangian data

- ▶ Usually we think of and work with movement data where the position of an animal is collected through a device attached to the animal. This device should allow, in principle, to know where the animal is at any time: Lagrangian data!
  - ▶ Radio tracking
  - ▶ Satellite tracking
  - ▶ GPS
  - ▶ Geo-Locators
- ▶ The methods differ mainly in their precision

## Eulerian data

- ▶ Eulerian methods violate the unbiased sampling assumption in the spatial domain
  - ▶ Camera traps
  - ▶ RFID Tags
  - ▶ Microphon arrays
  - ▶ Rings and band
- ▶ The data they provide allow often in specific systems quite a reliable reconstruction of paths

# What is movement?

- ▶ Movement is defined as **locations through time**. We can think of movement as a spatio-temporal object. Therefore, a proper definition of space and time is fundamental to analyse data in the proper way

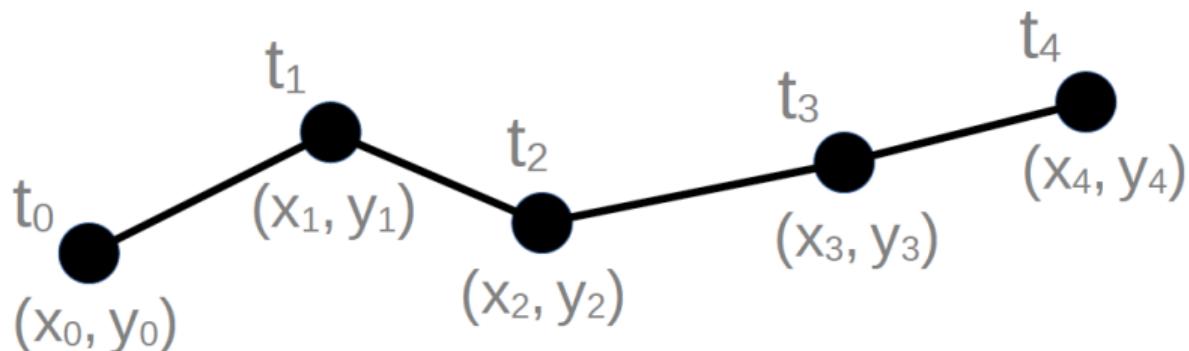


Figure 14: Brief example of how “movement” could be formalized

# Space problem

- ▶ We have already talked about the space problem...

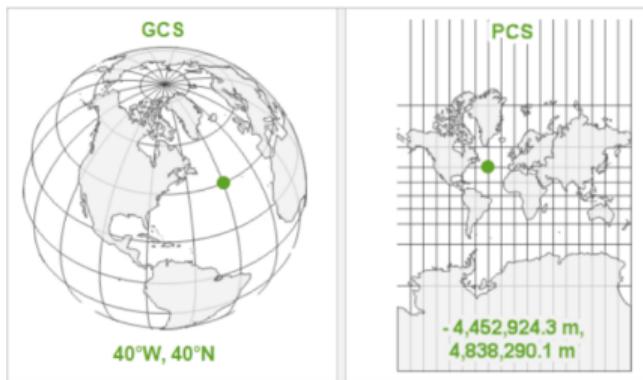


Figure 15: Image from [ESRI website](#)



Figure 16: Image from [ESRI website](#)

## Time problem

- ▶ Time settings are crucial
- ▶ You need to know what your device uses as time
- ▶ Many handheld GPS use and report local time, others use UTC
- ▶ Time in R is relatively easy to work with

```
Sys.time()
```

```
[1] "2025-11-05 05:16:26 CET"
```

```
(t <- as.POSIXct("2022-09-12 14:00:00",
                  "%Y-%m-%d %H:%M:%S", tz="CET"))
```

```
[1] "2022-09-12 14:00:00 CEST"
```

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