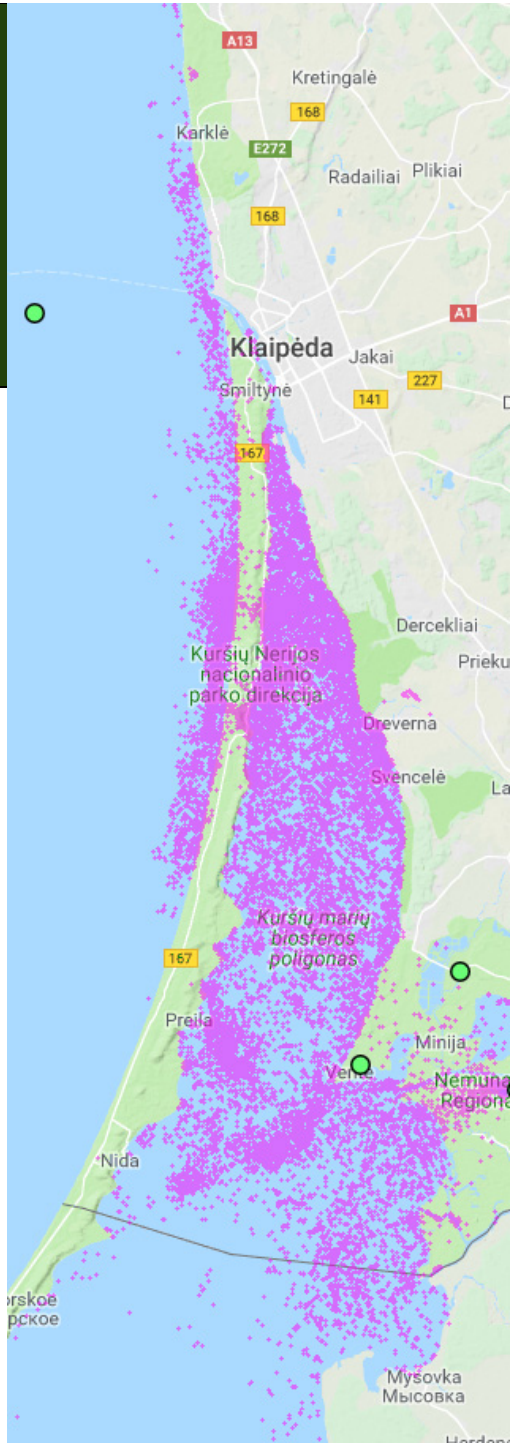
Ornitela

Bird tracking technology – at the frontier of possibilities

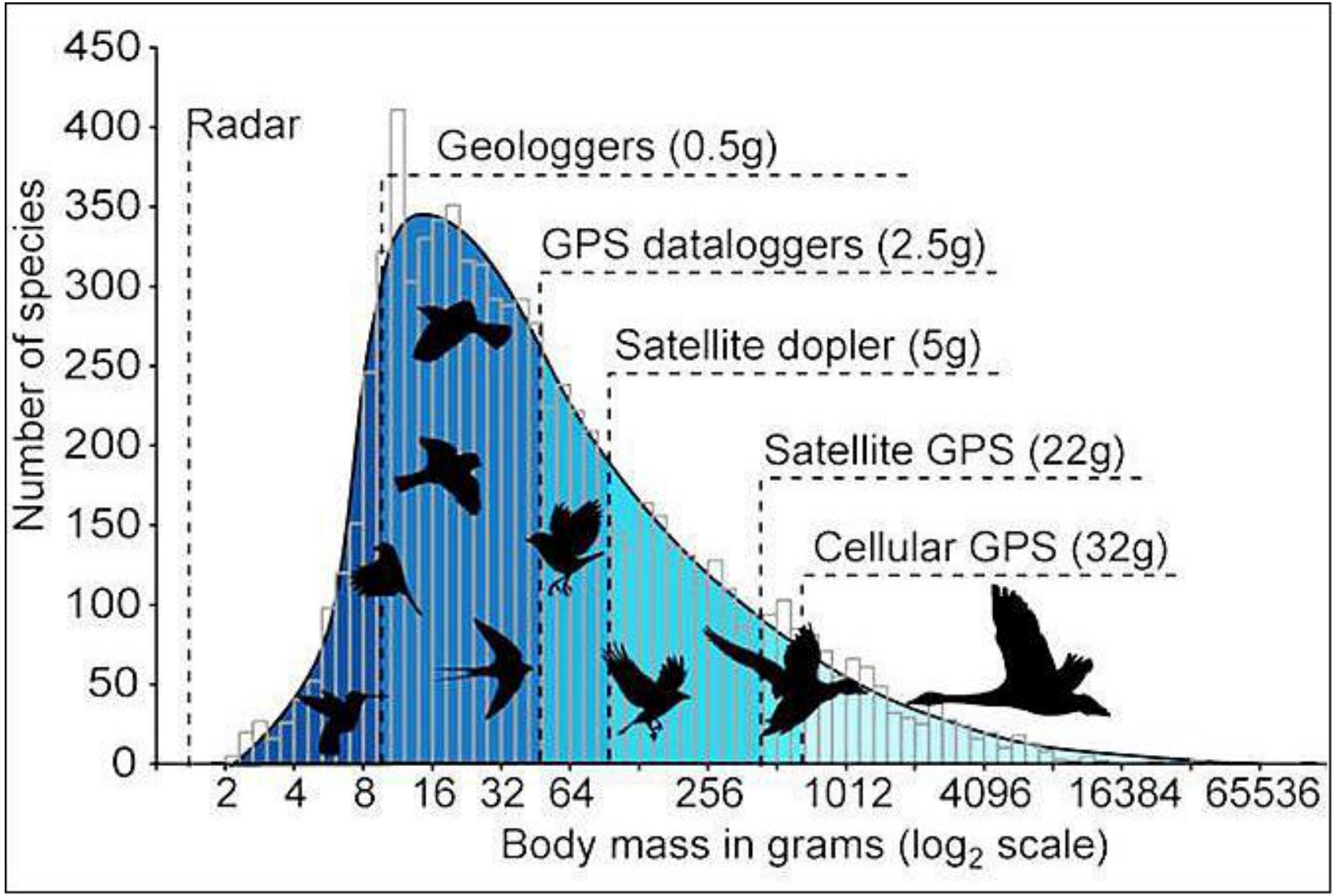


Mindaugas Dagys

Ornitela

Program LifeWatch Biodiversity Day, 28 October 2021

Bird telemetry equipment 10 years ago



Source: Bridge et al. 2011. Technology on the Move: Recent and Forthcoming Innovations for Tracking Migratory Birds. *BioScience* 61: 689–698

VHF radio tracking

One of the first animal tracking methods

Used since the 1960s

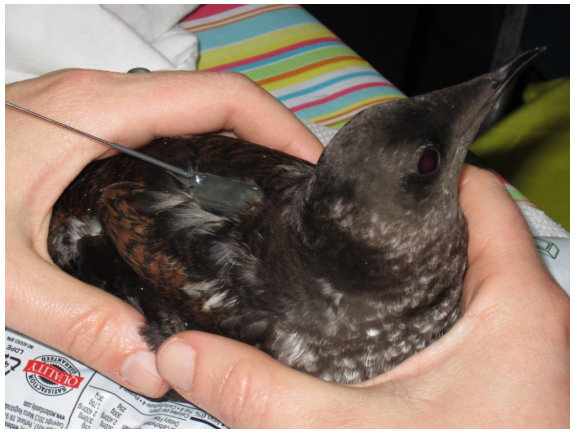
Radio transmitters from ~0.5 g in weight

Manual tracking

Directional Yagi antenna and data receiver

Labour intensive process

Relatively short range tracking (up to several km)



Source: Advanced Telemetry Systems (ATS) https://atstrack.com/

Motus Wildlife Tracking System

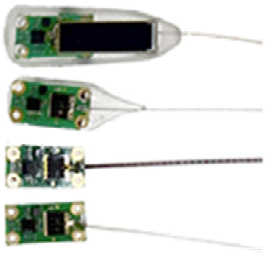
Motus
Wildlife Tracking System

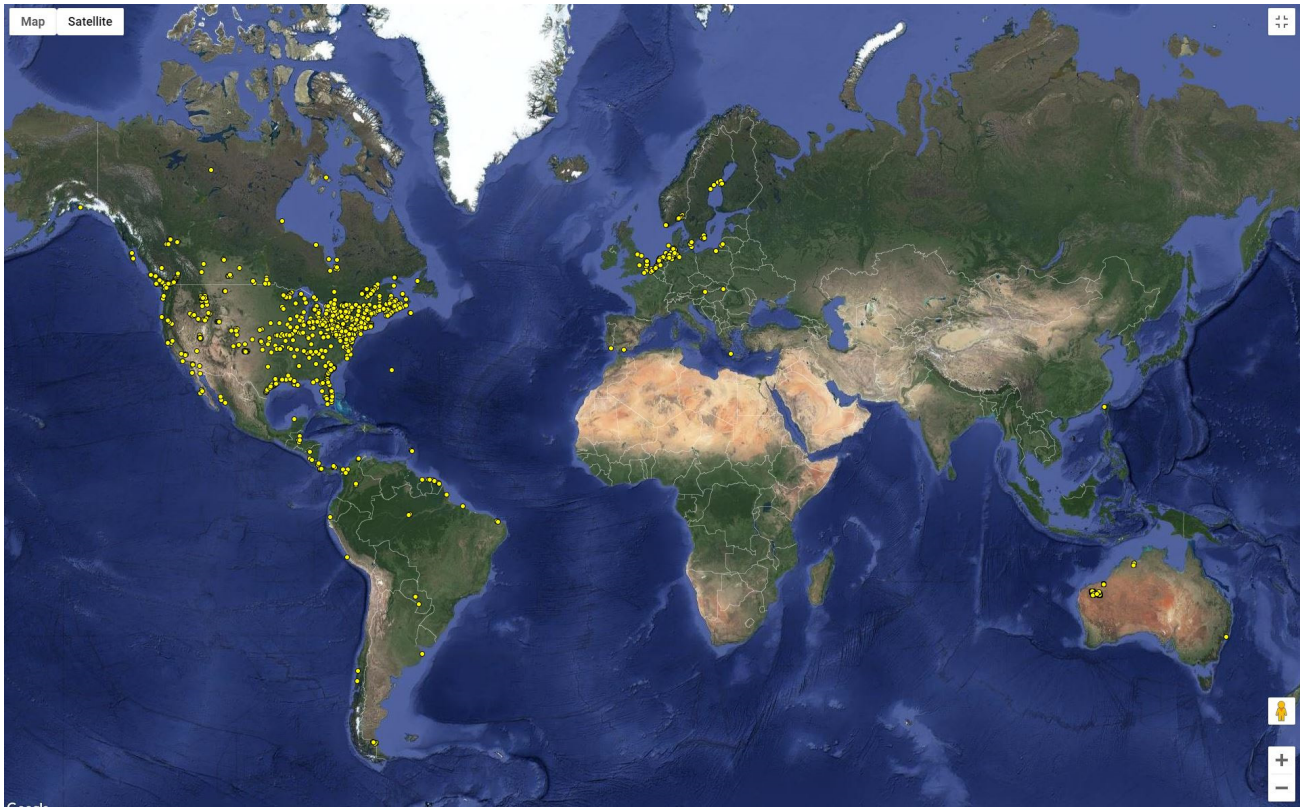
Motus tags

Digitally encoded radio transmitter

Weight from 0.15 g

Accuracy depends on antenna network

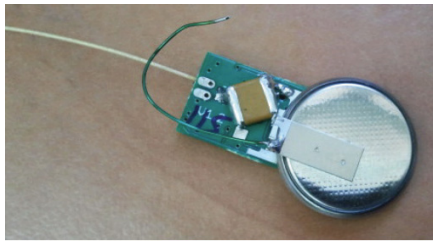




Source: Motus Wildlife Tracking Systems https://motus.org/

Area-based automatic tracking systems: ATLAS

ATLAS



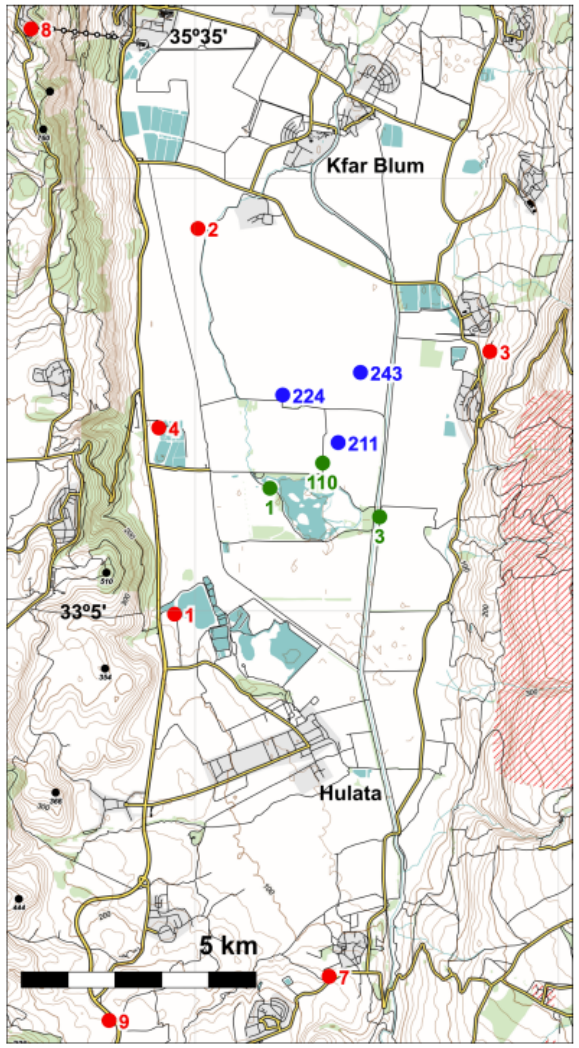
Advanced Tracking and Localization of Animals in real-life Systems

Area-based with ground stations (antennas) around the area

High frequency, high accuracy (5–15 m; ~GPS)

Time-Of-Arrival positioning principle (reverse GPS)

Radio transmitters from ~1 g in weight



Source: Weiser et al. 2016. Characterizing the Accuracy of a Self-Synchronized Reverse-GPS Wildlife Localization System
Source: Toledo et al. 2014. Lightweight low-cost wildlife tracking tags using integrated transceivers

Light level geolocators (GLS), Multi-sensor geolocators

Light level geolocators

Light intensity, temperature

Weight from 0.3 g

Accuracy ~100 km

Have to be recovered

Multi-sensor geolocators

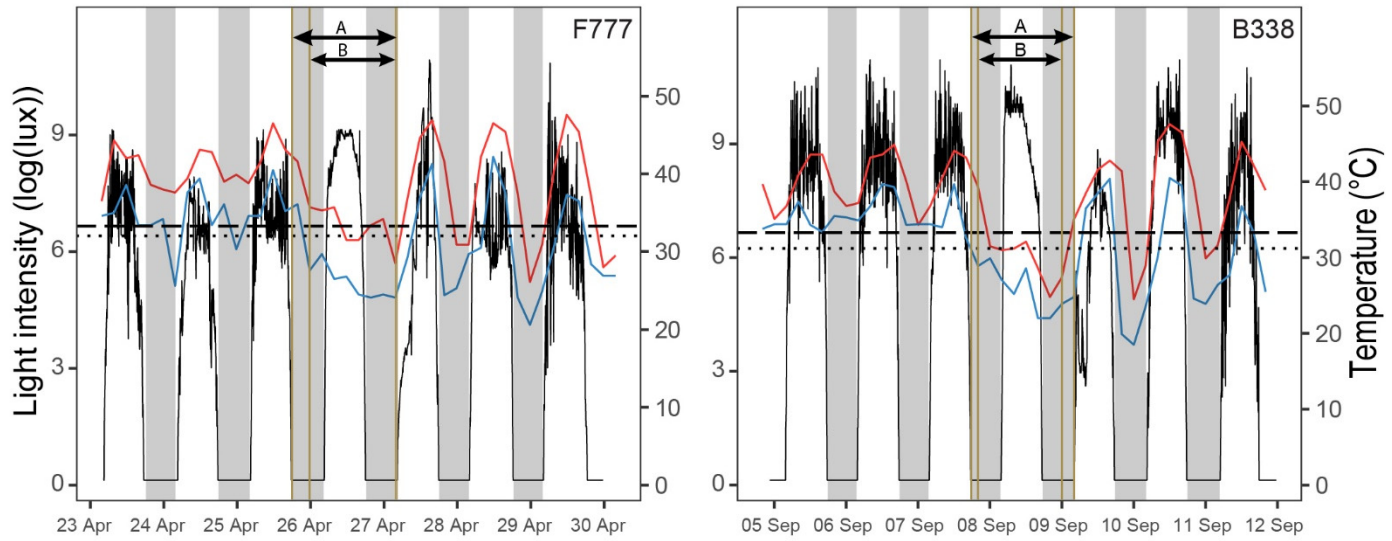
Light intensity, temperature, acceleration, pressure

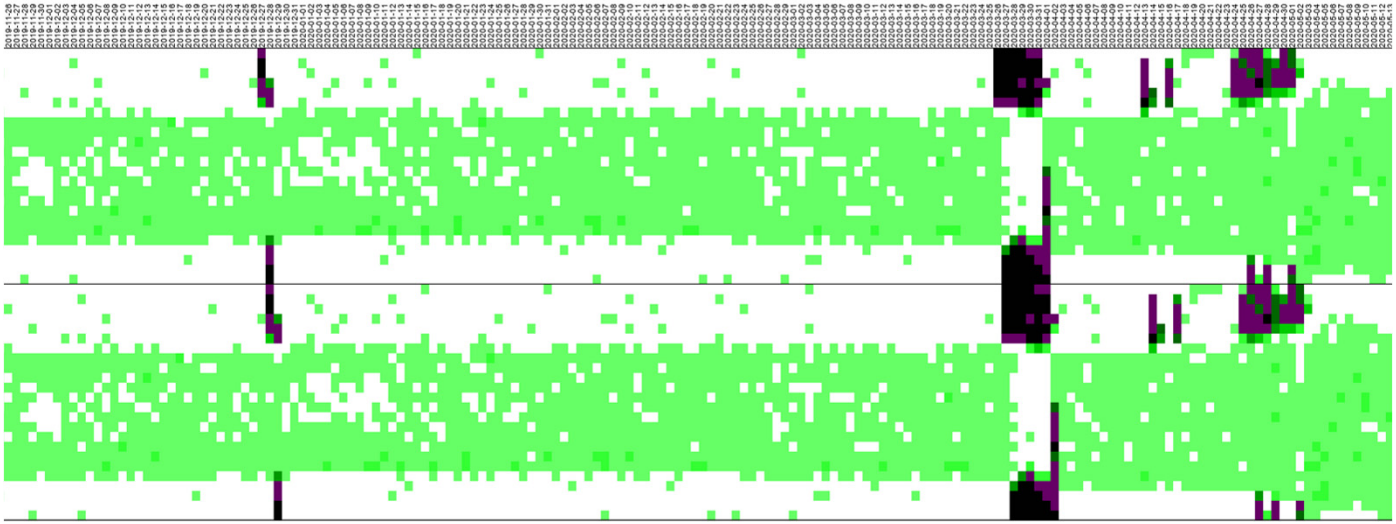
Weight from ~1 g

Accuracy ~100 km (50 km)

Have to be recovered

Light level geolocators (GLS), Multi-sensor geolocators





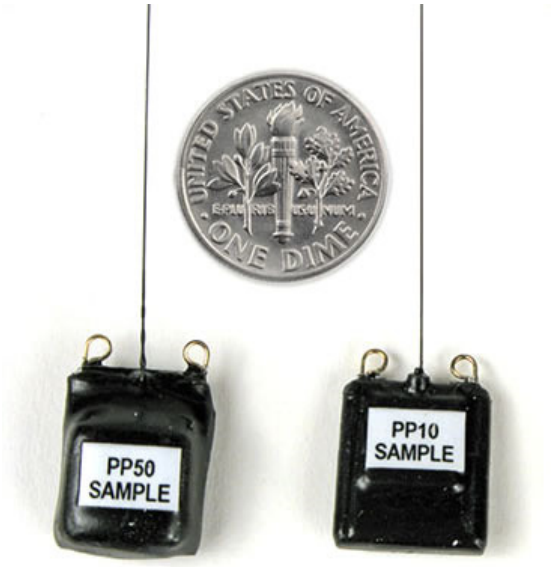
Archival GPS loggers

Weight from 1 g

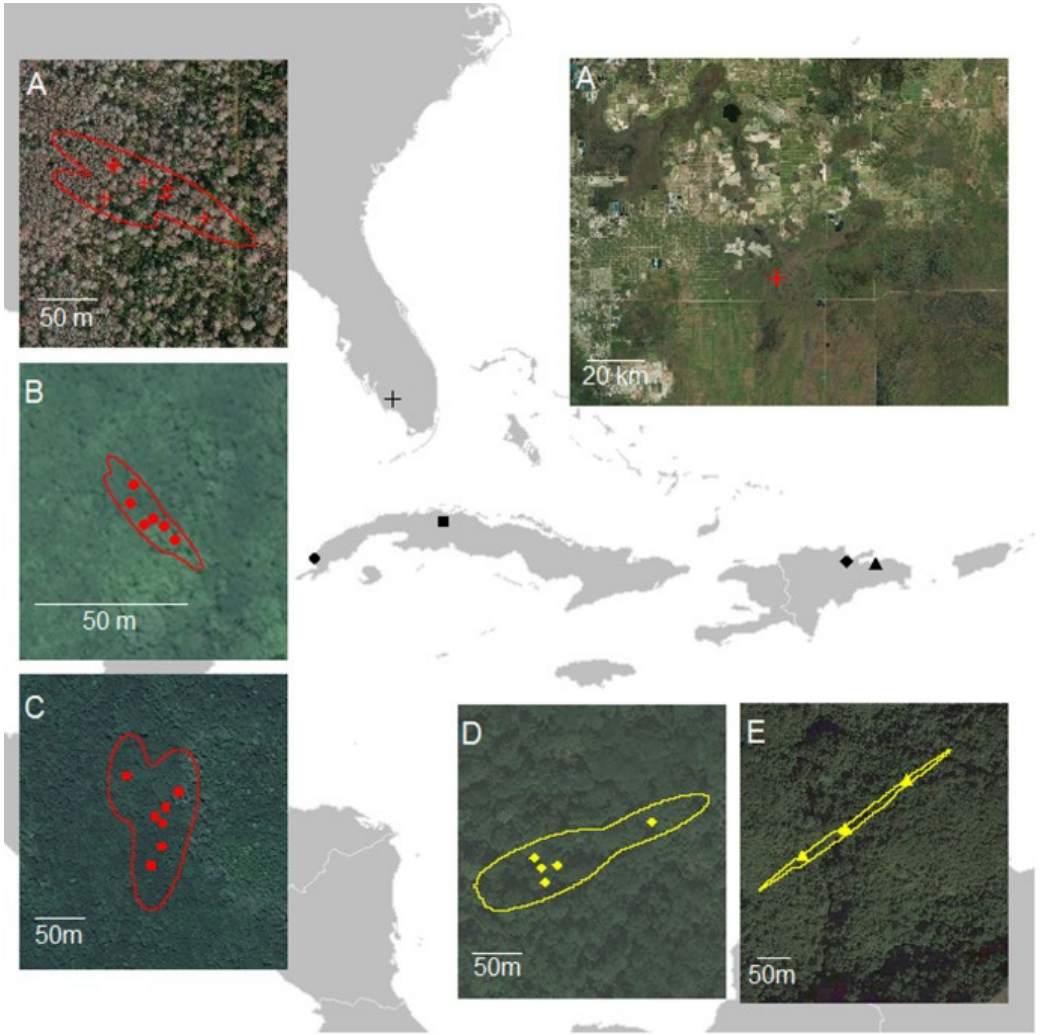
GPS accuracy

Programmable schedule

Have to be recovered



Source: Lotek Wireless Inc.
https://www.lotek.com/products/pinpoint-gps-store-on-board/



Hallworth, M., Marra, P. Miniaturized GPS Tags Identify Non-breeding Territories of a Small Breeding Migratory Songbird. Sci Rep 5, 11069 (2015). https://doi.org/10.1038/srep11069

ARGOS satellite system (Kinéis)

Launched in 1978, used for animal tracking since the late 1980s

Global coverage

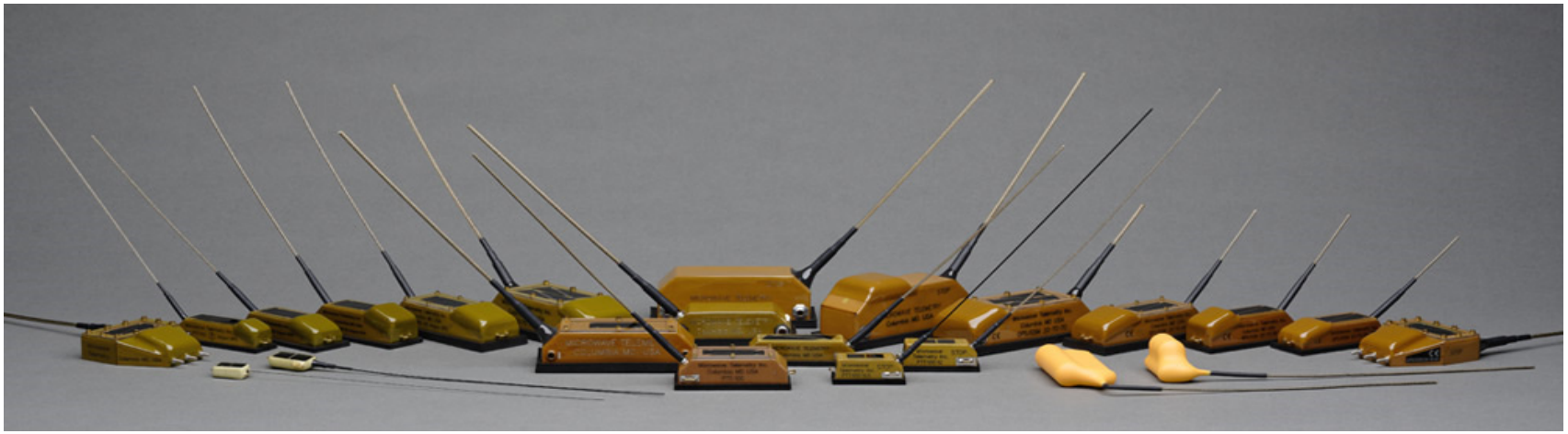
Constellation: 8 polar orbiting satellites at 850 km altitude

PTT – Platform Transmitter Terminals

Ground stations (3 main, ~70 total)

Doppler shift-based position estimation

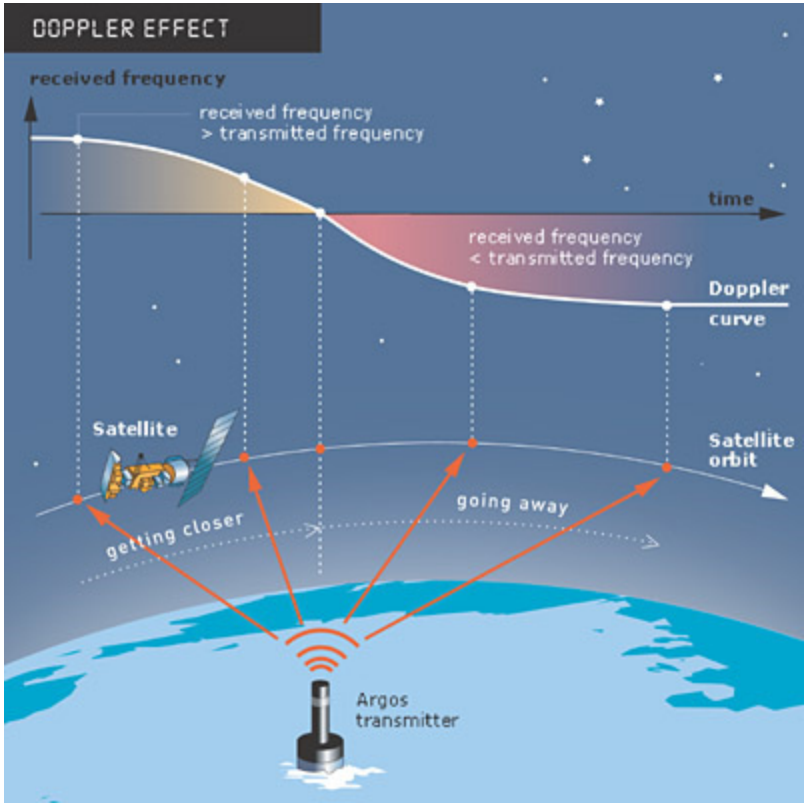
Transmitter weight from 2 g (Doppler), 17 g (GPS)

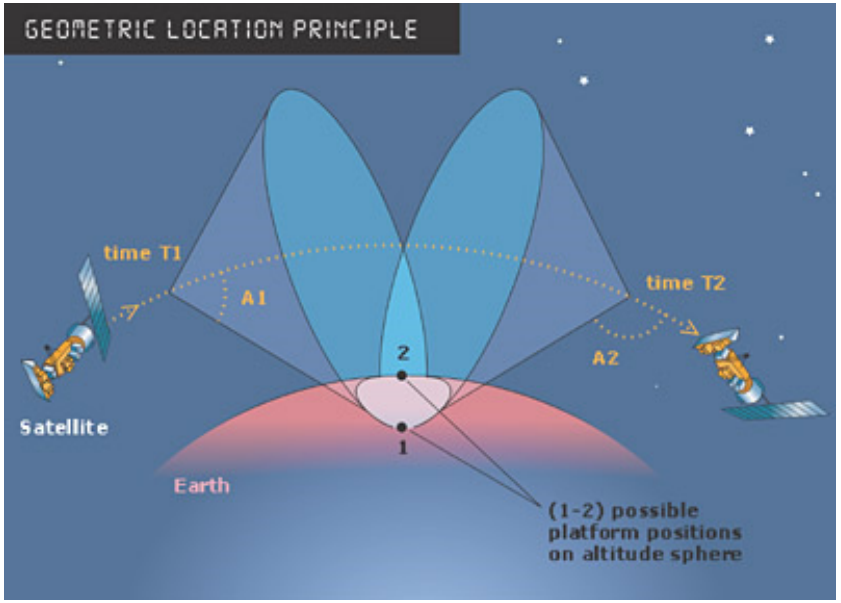


Source: Microwave Telemetry, Inc. https://www.microwavetelemetry.com/

Source: CLS group https://www.cls-telemetry.com/argos-solutions/kineis/

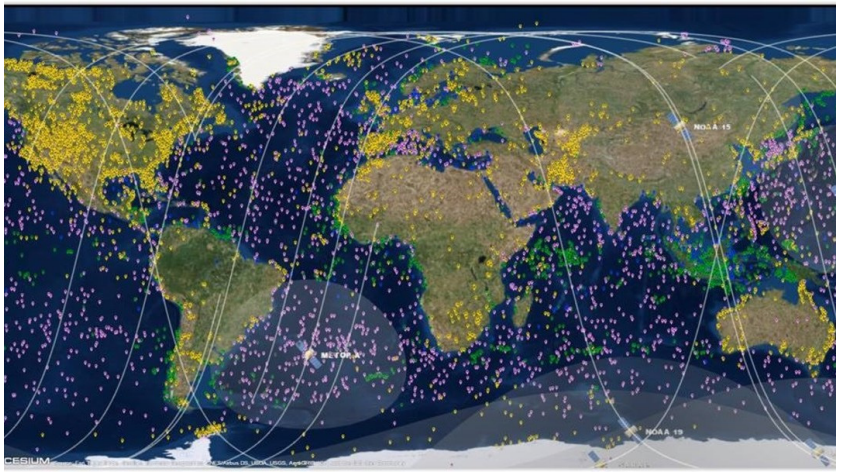
Position estimation: Doppler shift (ARGOS)





ARGOS accuracy classes:

Class 3: <250 m
Class 2: 250–500 m
Class 1: 500–1500 m
Class 0: >1500 m
Class A, B, Z



Source: ARGOS 2016. Argos User's Manual http://argos-system.org

ICARUS project/initiative

Initiated in 2002; operational since 2020

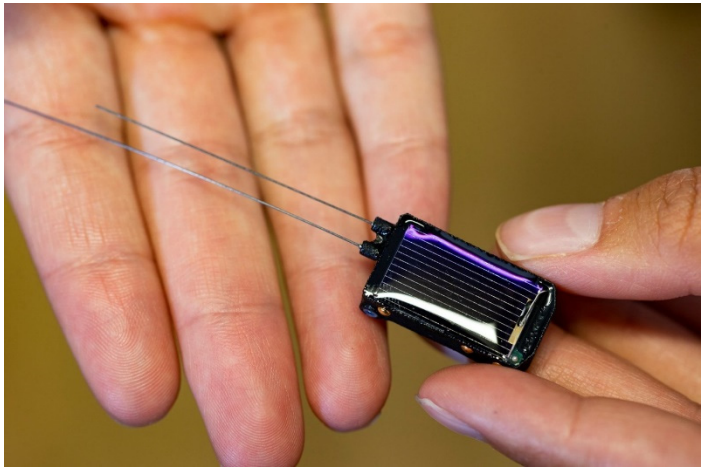
Based on International Space Station; 408 km altitude

Limited coverage – from 55° N to 55° S

Transmitter weight from 5 g

All transmitters use GPS for position estimation

High volume data to be downloaded via UHF



Source: ICARUS Global Monitoring with Animals https://www.icarus.mpg.de/en

GPS-GSM transmitters

Data download via GSM network

Use GPS positioning

Available since the late 2000s

SMS → GPRS, 2G → 3G → 4G

High data volumes

Two-way communication (settings, firmware updates)

Low data transfer fees

Limited GSM coverage in some regions

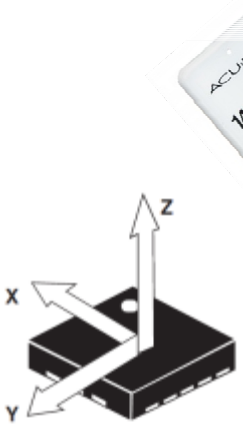
Sunset of older GSM protocols (2G, 3G)

Transmitters from ~6 g

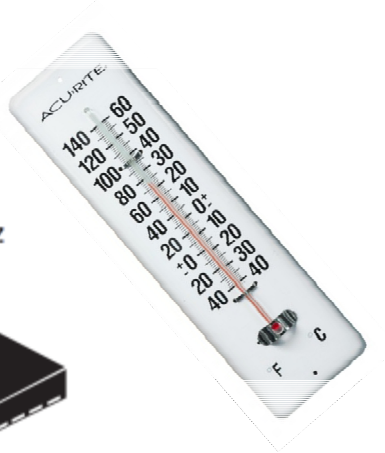
Optional sensors:

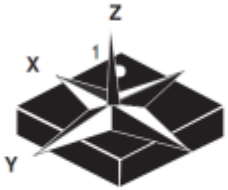
- Accelerometer
- Magnetometer
- Gyroscope
- Barometric altimeter
- Depth sensor
- Fast-response temperature sensor
- Salinity sensor

GPS-GSM transmitters



Acceleromter



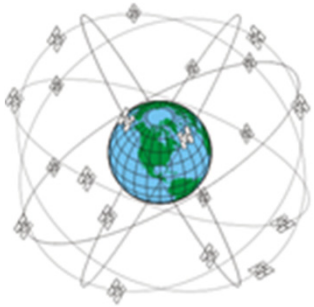


Magnetometer

GPS-GSM transmitters: connectivity

Sources: http://www.gsmworld.com, http://maps.mobilewordlive.com

Position estimation: GNSS



GPS

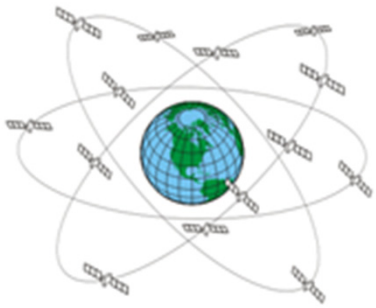
- 6 Orbital planes
- 24 Satellites + Spare
- 55^0 Inclination Angle
- Altitude 20,200km

USA
Launch: 1978
Available: 1994

GLONASS

- 3 Orbital planes
- 21 Satellites + 3 Spares
- 64.8^0 Inclination Angle
- Altitude 19,100km

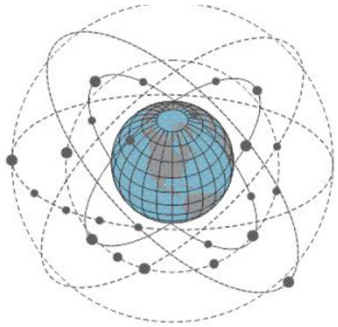
Russia
Launch: 1982
Operational: 1995



Galileo

- 3 Orbital planes
- 27 Satellites + 3 Spares
- 56^0 Inclination Angle
- Altitude 23,616km

EU
Launch: 2011
Operational: 2016



BeiDou

- 6 Orbital planes
- 27 Satellites (+8)
- 55° Inclination Angle
- Altitude 21,500km

China
Launch: 2000
Operational: 2018

GNSS positioning:

Signal time-of-arrival principle

Trilateration/triangulation

GPS Almanac (constellation health)

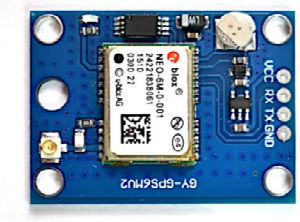
GPS Ephemeris (position of the satellite)

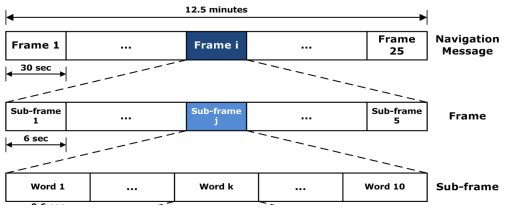
At least 4 satellites for a 3D position

On-board position calculation (GPS module)

Position calculation on server side

- nanoFix, Fastloc, etc.





Source: GPS and GNSS for Geospatial Professionals. PennState College of Earth and Mineral Sciences. https://www.e-education.psu.edu/geog862/

Position estimation: GNSS – accuracy

Position error sources:

Satellite clock inaccuracies

Ionosphere density effect

Receiver clock inaccuracies

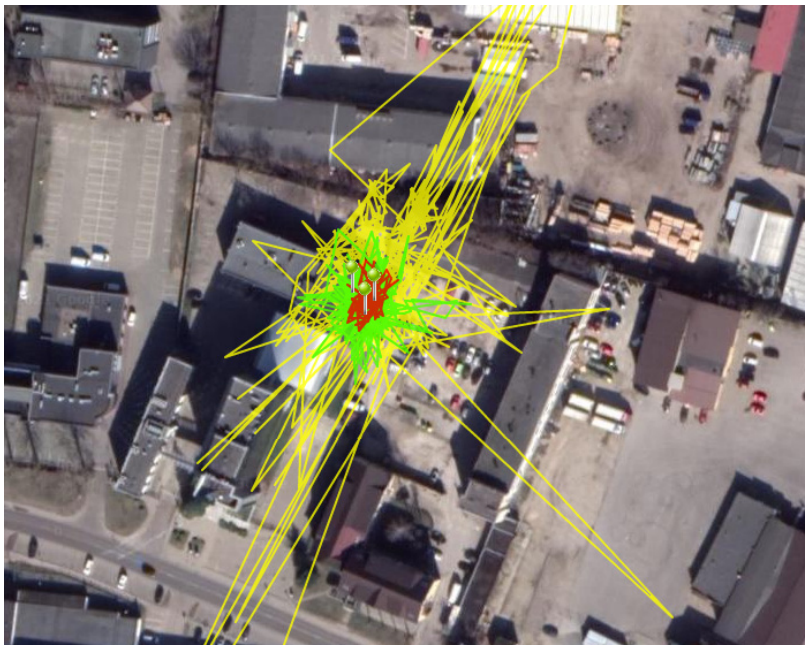
Satellite orbit errors

Lower atmosphere

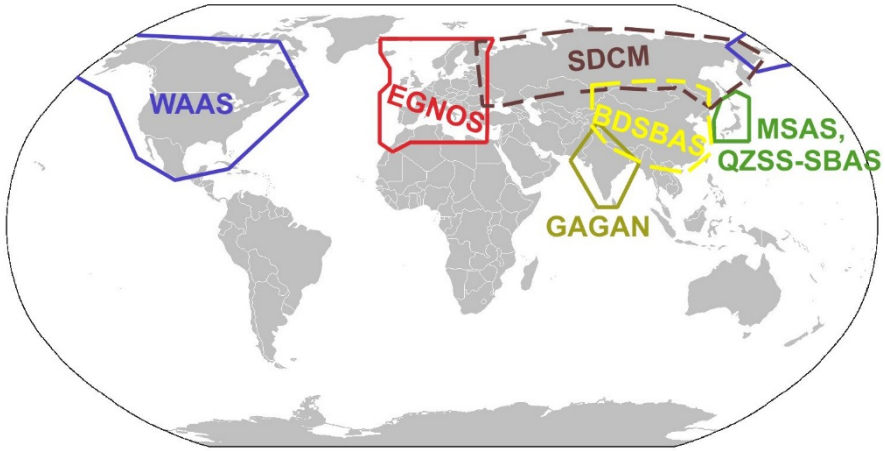
Signal reflections (multipath)

Satellite geometry during a fix

Dilution of precision (DOP): HDOP, VDOP



GNSS augmentation systems



Other variables that affect performance:

GPS antenna

Transmitter design

Attachment method and position

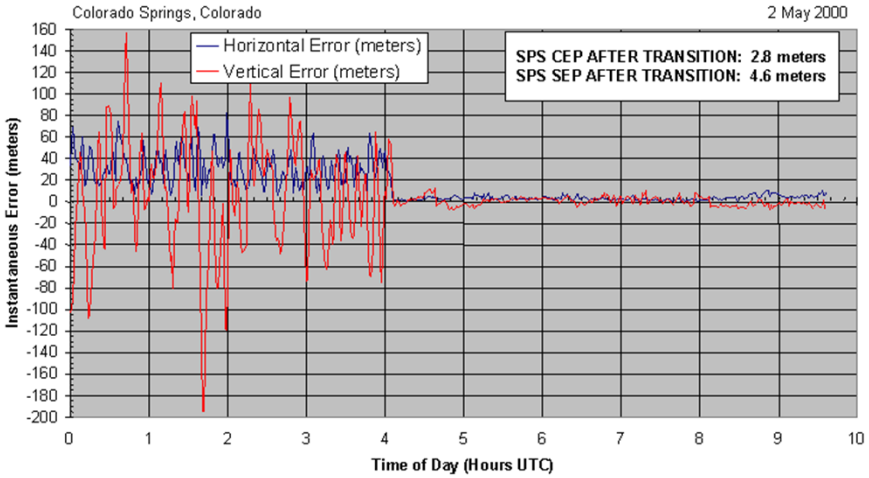
Bird behaviour

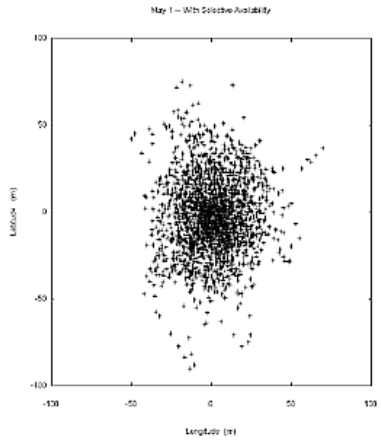
Habitat

Position acquisition frequency

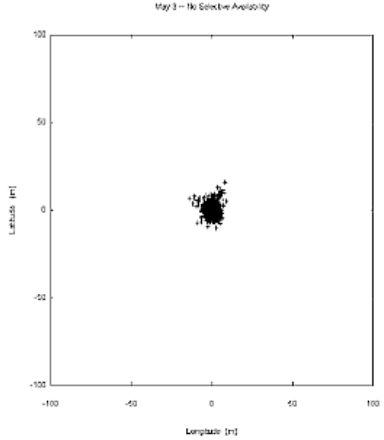
Position estimation: GNSS – intentional distortions

Selective Availability (until May 1, 2000)





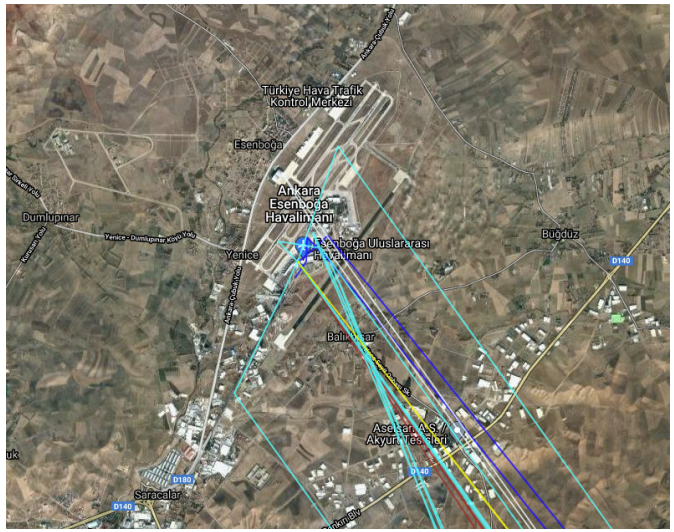
May 1, 2000



May 3, 2000

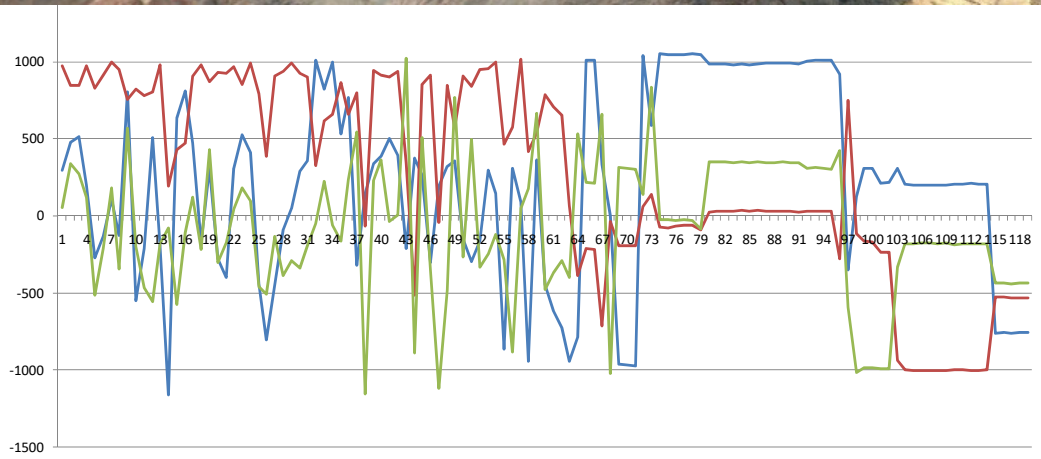
Sources: GPS Support Center, Air Force Space Command, NOAA National Geodetic Survey; https://www.gps.gov/systems/gps/modernization/sa/data/

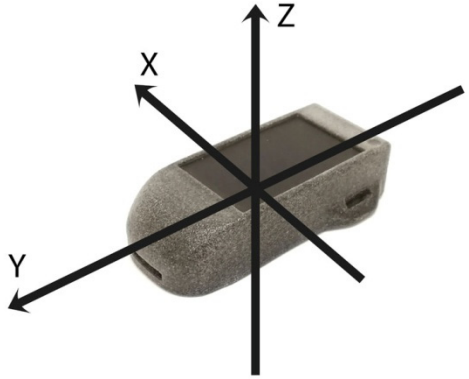
GPS jamming and spoofing



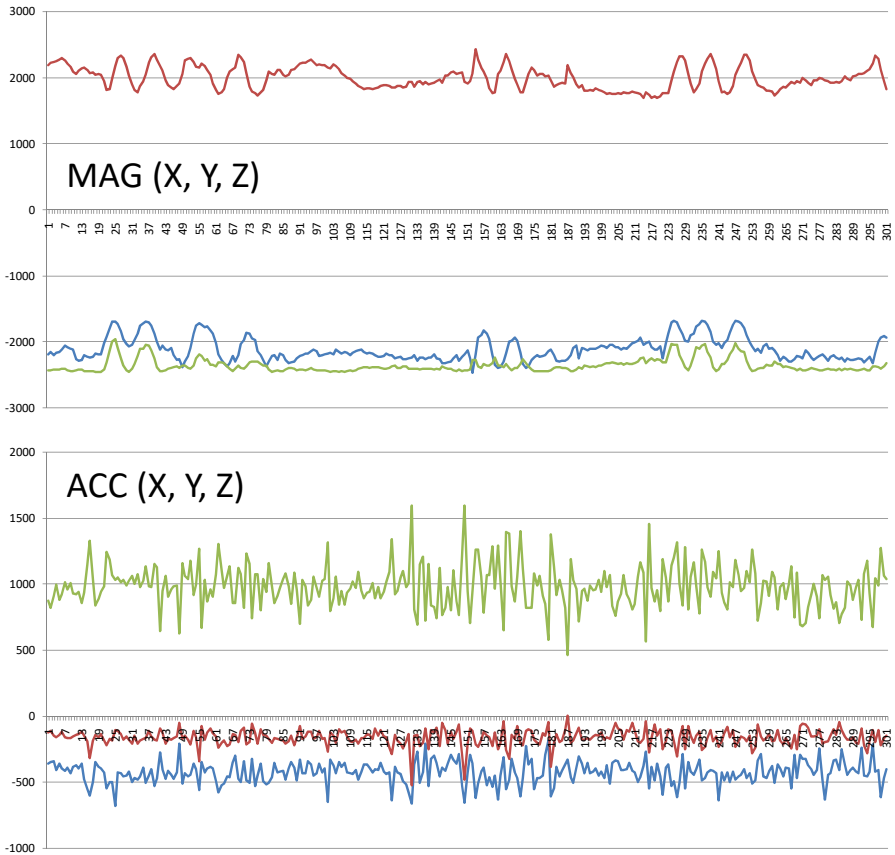
GPS-GSM transmitters: data

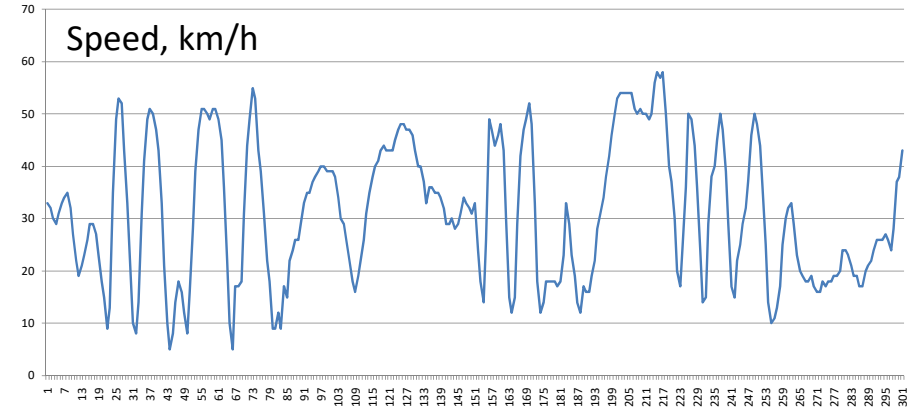
1	UTC_datetime	gps_fix_tim	hdop	Latitude	Longitude	Altitude_m	speed_km_h	direction_deg	temperature_C	light	mag_x	mag_y	mag_z	acc_x	acc_y	acc_z
32	2018-11-12 07:41	16310	1.6	46.212029	7.239785	1123	28	154	25	321	284	-493	-147	42	-115	1232
33	2018-11-12 07:52	81070	0.9	46.213413	7.241768	1351	33	344	24	861	32	-115	-17	106	-71	1137
34	2018-11-12 08:01	16320	1	46.229038	7.239245	1397	0	67	20	1965	335	165	40	253	128	1007
35	2018-11-12 08:11	16290	1.5	46.230644	7.23734	1445	0	203	20	1313	315	-142	68	157	511	866
36	2018-11-12 08:21	16320	1.5	46.230492	7.237377	1486	0	147	25	757	464	8	32	145	632	776
37	2018-11-12 08:31	16350	1.1	46.219574	7.231367	1596	17	139	25	1553	464	-49	51	102	-128	1088
38	2018-11-12 08:41	16320	1	46.220772	7.22781	1730	0	49	22	529	626	116	-82	115	619	790
39	2018-11-12 08:51	16310	1	46.220806	7.227813	1737	0	224	23	0	759	75	-315	131	891	408
40	2018-11-12 09:01	16330	1	46.220627	7.227888	1743	0	58	24	56	751	102	-287	62	887	448
41	2018-11-12 09:11	16320	1	46.220879	7.227842	1720	0	127	26	775	763	76	-291	61	870	480

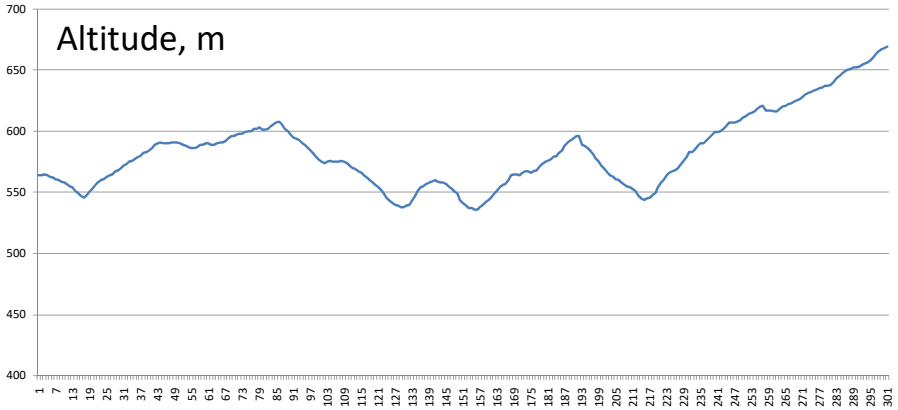




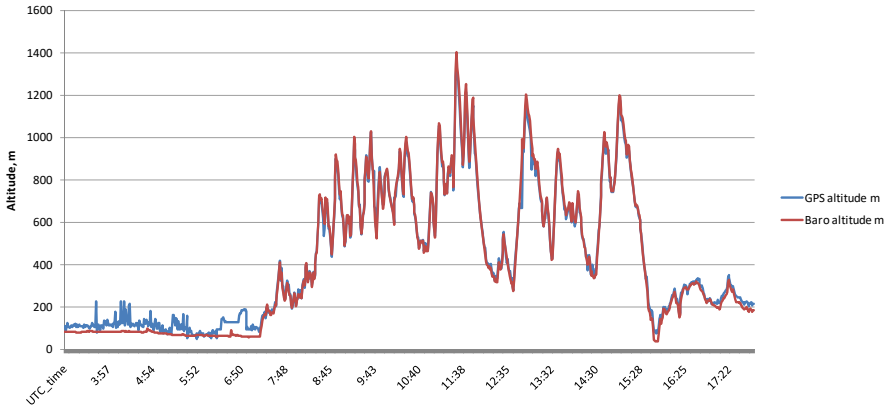
GPS-GSM transmitters: data

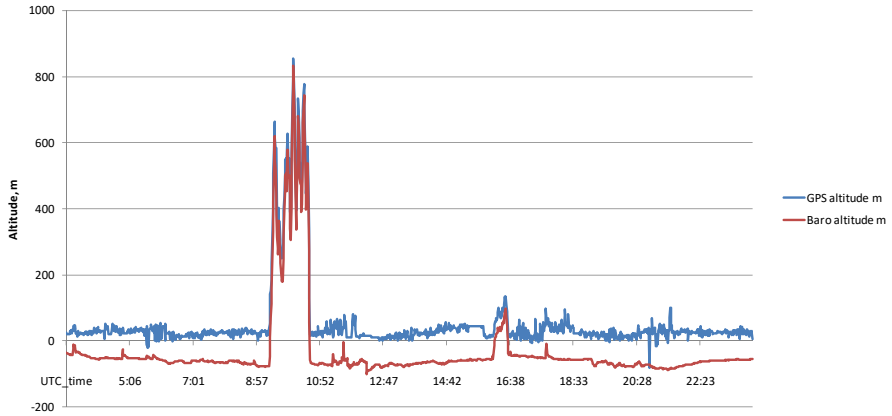




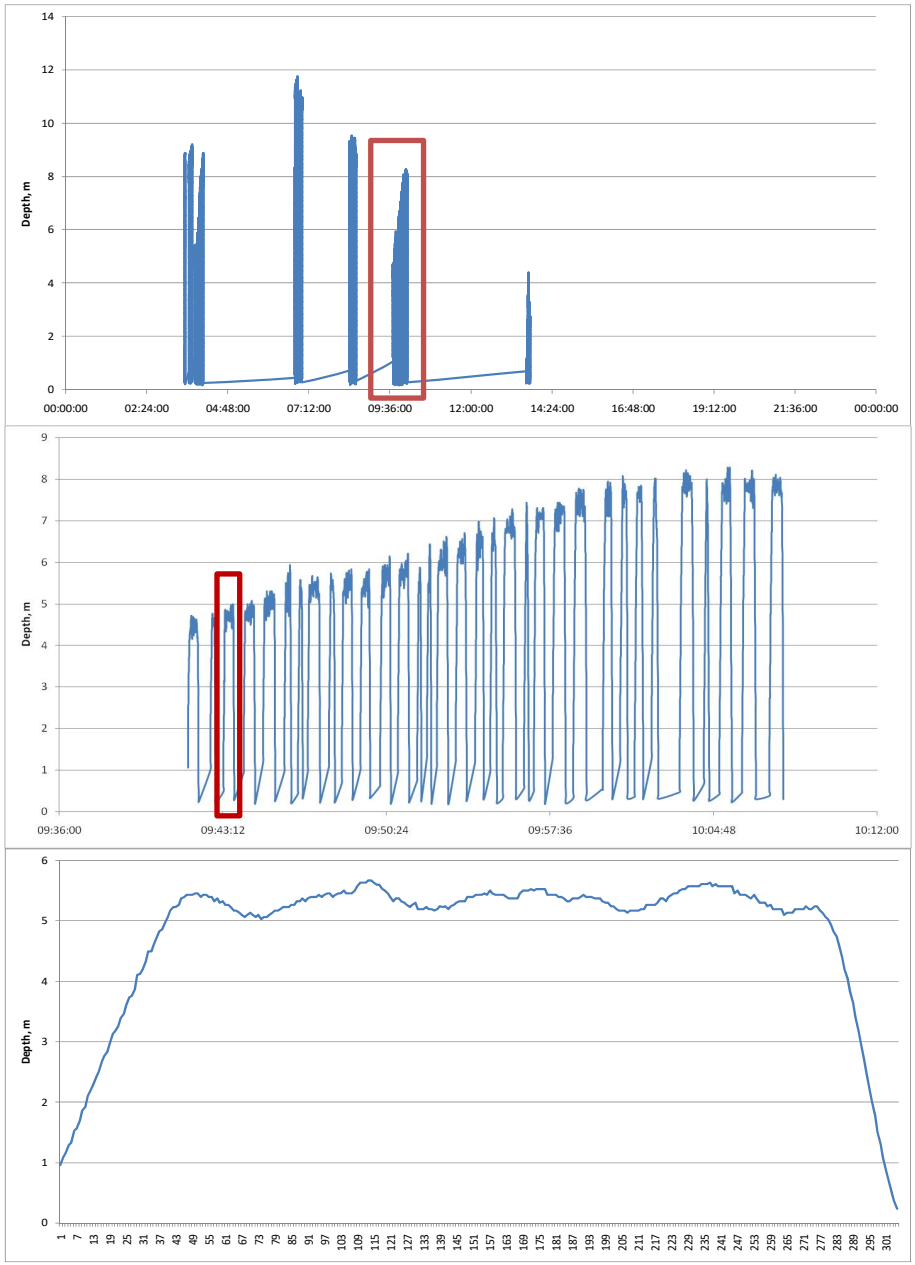


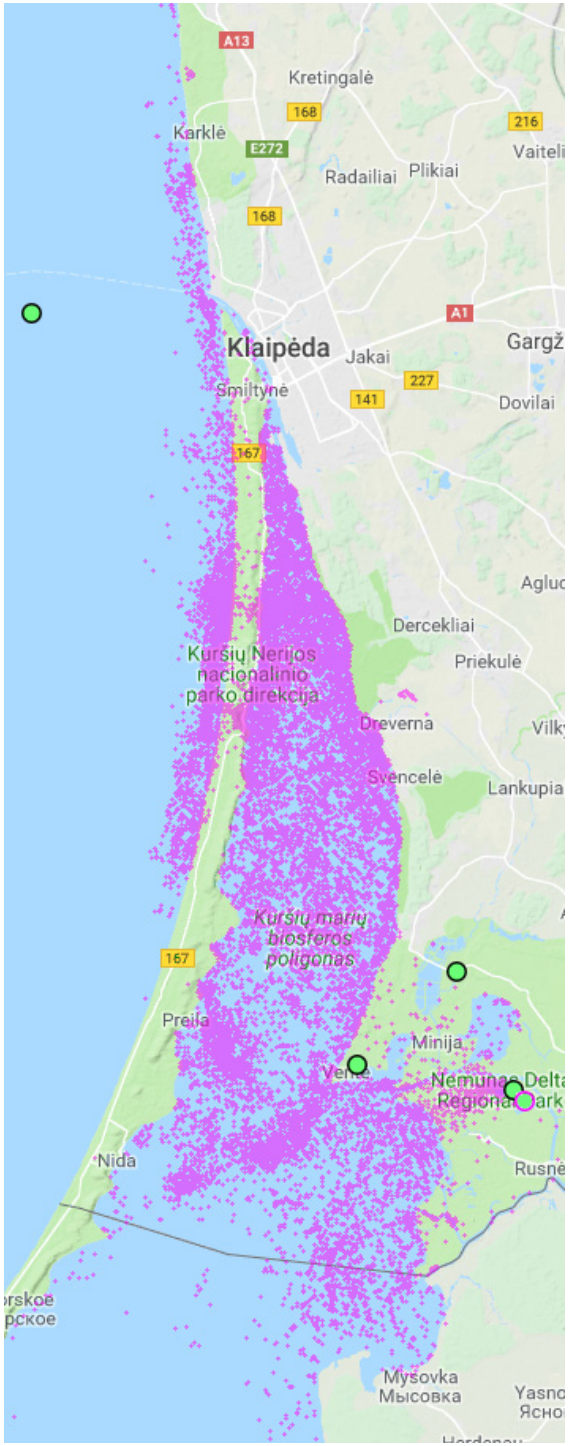
GPS-GSM transmitters: data – altitude



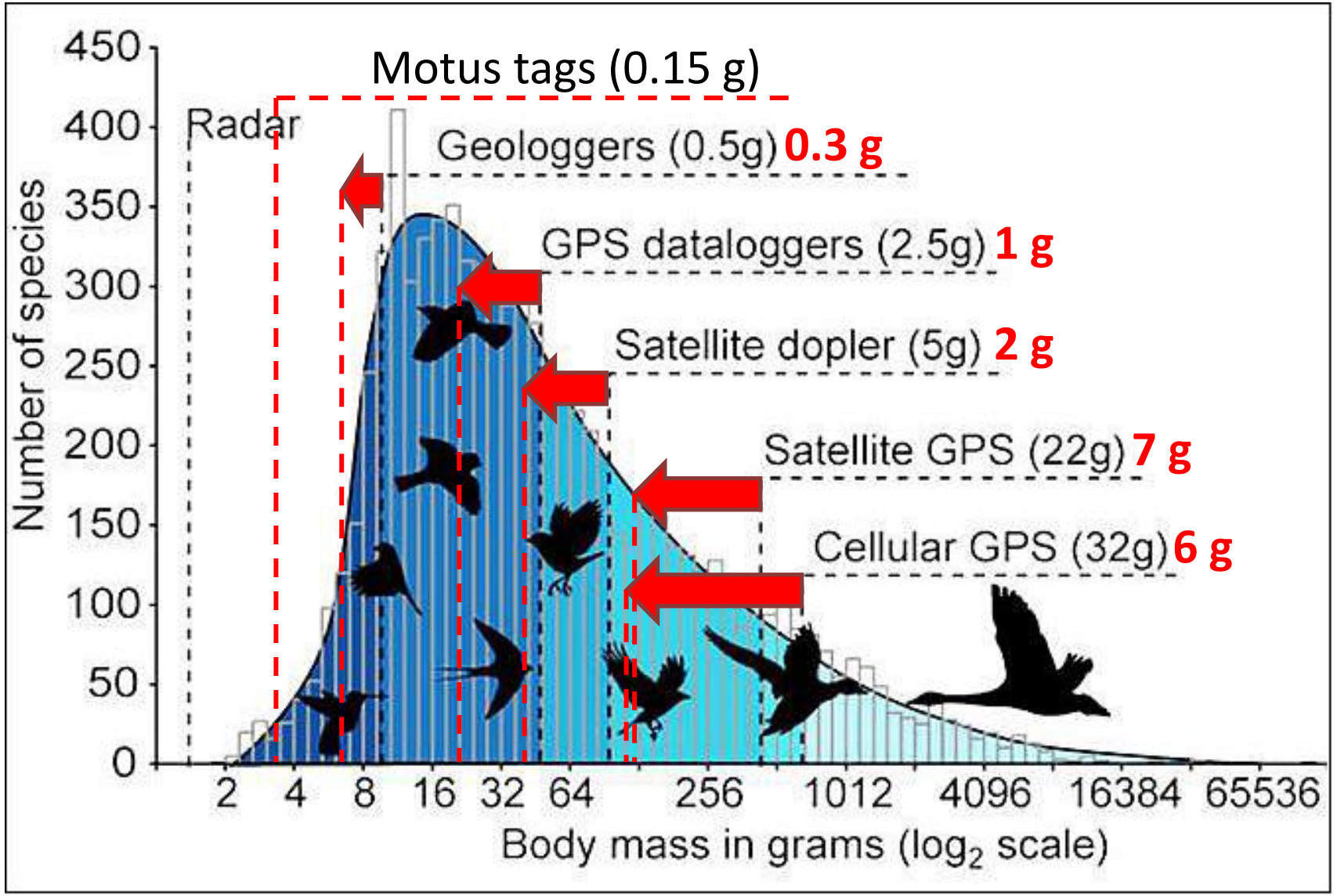


GPS-GSM transmitters: data – depth





Bird telemetry equipment progress in 10 years



Source: Adopted from Bridge et al. 2011. Technology on the Move: Recent and Forthcoming Innovations for Tracking Migratory Birds. *BioScience* 61: 689–698

Bird tracking – what‘s next?

Power supply improvements

More efficient solar cells

Higher energy density batteries

Improved energy management

Alternative power sources:

- Piezoelectric (movement)
- Thermal gradient

Connectivity

GSM: 2G and 3G sunset

GSM: 4G IoT expansion

Smaller and lighter GSM modules

Iridium

Transmitter networking

On-board data processing

Behavioural classification

Identification of certain events

Early alert systems (death, poisoning, etc.)

Additional sensors

Sound, video

Heart-rate, ECG

Other physiological parameters

ARGOS / Kinéis

25 nano satellites by 2023

Improved accuracy to 150 m

2-way communication as standard

Higher data throughput

ICARUS initiative

More widely available

Smaller tags: 2 g and even smaller

Dedicated satellites?

Drop-off systems

- Predictable
- Programmable
- On demand

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dagys@ornitela.eu