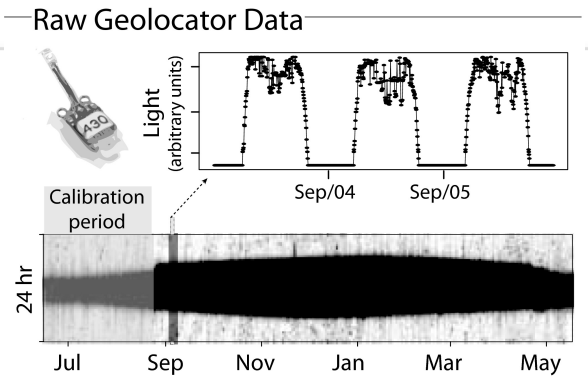
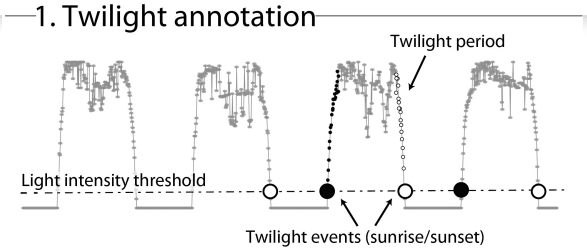
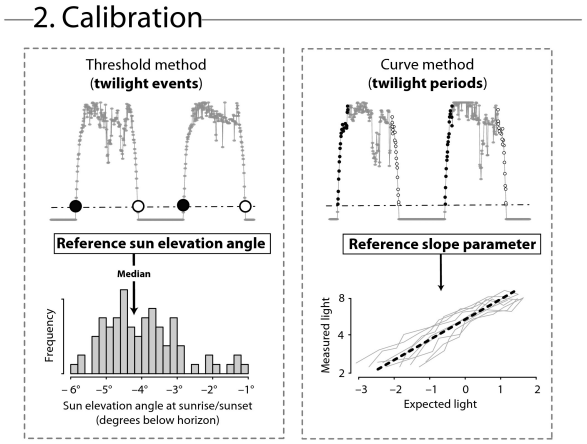
Solar Geolocators

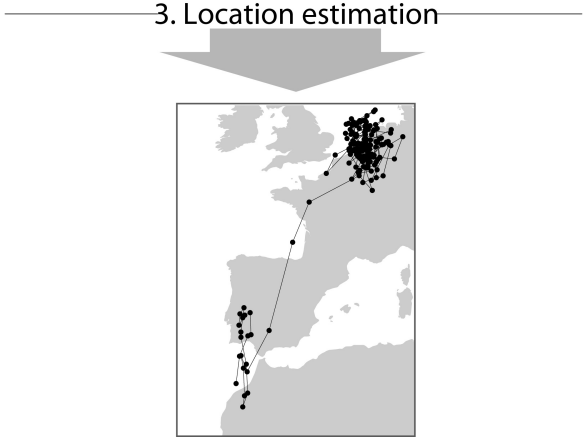
Solar geolocators

- Developed in 2007, trackers use photoperiod/ light levels as a proxy to determine geographic location of the animal
- Used in over 100 published studies
- Can have additional wet/dry and thermal sensor









Solar geolocators

- Works best for small migratory birds that otherwise can't use GPS tags due to weight restrictions
- Pros; very small, lightweight, cheap, longer battery life
- Cons; animal needs to be recaptured, location accuracy is very coarse, can't be used in closed environments

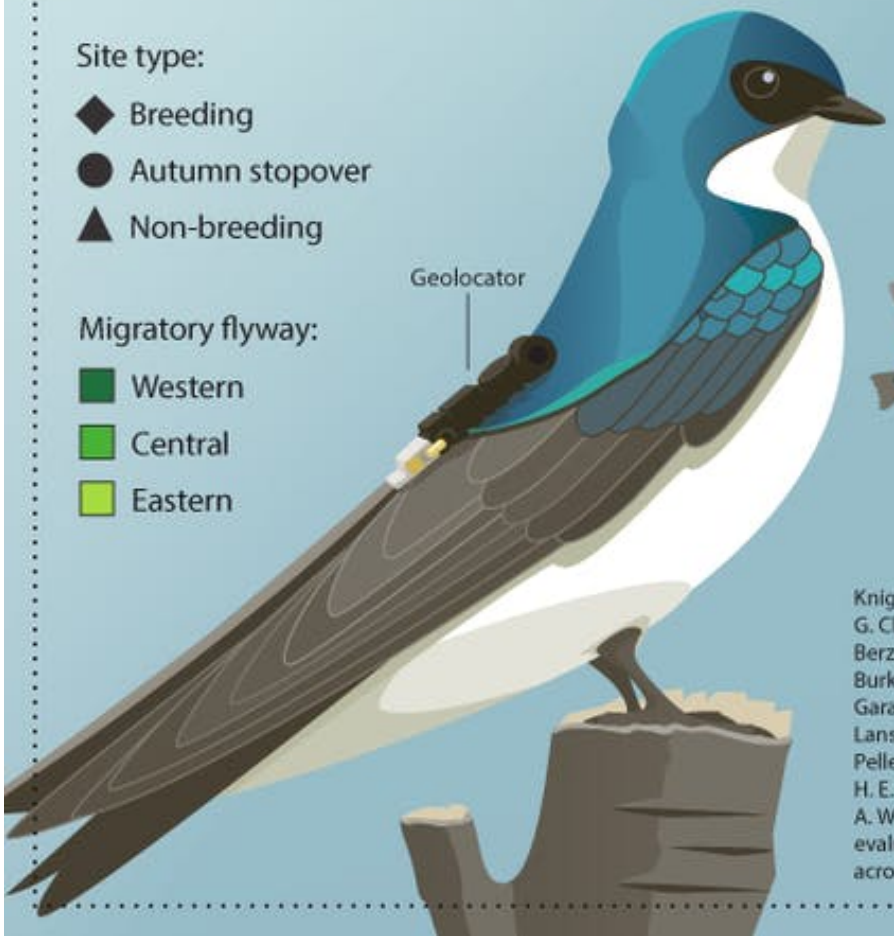
Constructing and evaluating a migratory network for Tree Swallows across the annual cycle

Site type:

- Breeding
- Autumn stopover
- Non-breeding

Migratory flyway:

- Western
- Central
- Eastern



Edges are weighted by proportion of individuals moving between sites multiplied by an index of relative abundance from the previous site. Edges do not represent actual migratory path.

Canada

USA

Mexico

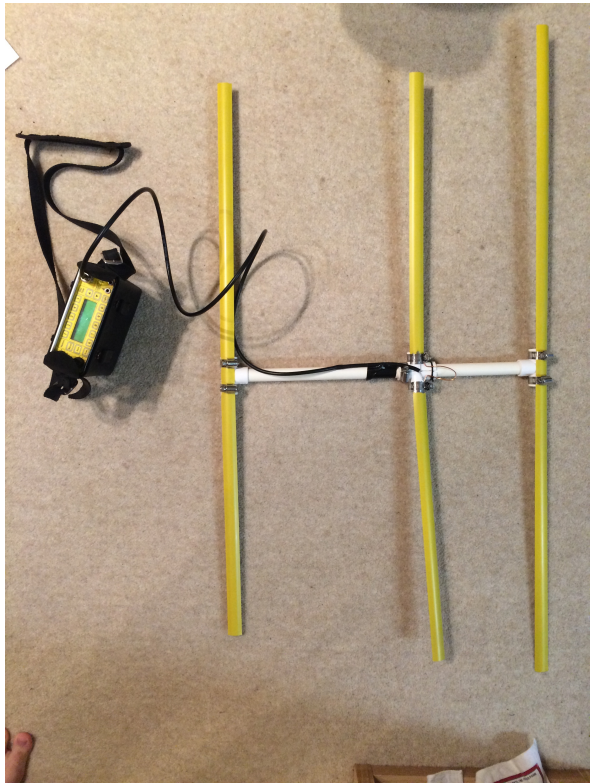
Cuba

Knight, S. M., D. W. Bradley, R. G. Clark, E. A. Gow, M. Bélisle, L. L. Berzins, T. Blake, E. S. Bridge, L. Burke, R. D. Dawson, P. O. Dunn, D. Garant, G. L. Holroyd, D. J. T. Hussell, O. Lansdorp, A. J. Laughlin, M. L. Leonard, F. Pelletier, D. Shutler, L. Siefferman, C. M. Taylor, H. E. Trefry, C. M. Vleck, D. Vleck, D. W. Winkler, L. A. Whittingham, D. R. Norris. 2018. Constructing and evaluating a continent-wide migratory songbird network across the annual cycle. ***Ecological Monographs***. In press.

@smknigh
@NorrisLab
@BirdStudiesCan

1) What kind of temporal resolution and spatial accuracy can you get?	2) What data can be collected (additionally to location)? how is the data transferred?	3) Does this limit what environments the technology can be used in?	4) Is it attached to the animal, how?	5) Cost and possible suppliers
• These devices record photo period and use sunset and sunrise times to predict the geographical position of the animal. • Location accuracy is not ideal, photoperiod only gives a general idea of areas travelled. • E.g. data can show bird overwintered in Florida but not which city or town	• The device has a light sensor, internal clock, battery and memory storage. • Data is stored within the small computer chip and remains on the device • Temperature and wet/ dry sensor also possible	• Because it is based on photoperiod, it doesn't work well in areas with dense vegetation or bad weather that obscures light	• Yes, usually as a backpack attached to the wings or legs of the animal • Devices are typically 0.3grams	• typically cost under $200 (USD?) • Lotek https://www.lotek.com/products/mk-geolocators/
What's the typical battery life/track duration?	**Do receivers/trackers/ meters need to be recovered?**	**Additional information**	**What taxa can it be used for?**	**When was the technology first developed?**
• Recording light levels doesn't require too much electricity or memory so devices can last longer than a year collecting 2 measurements per day	• Yes, the animal needs to be recovered • Typically 1/5 birds is recaptured	• Note: there is an R package FlightR available for reconstructing position from light data • https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/2041-210X.12765	• This is very popular for small migratory birds • Also used for seabirds where their long times at sea means they are often exposed to direct sun • Best used for small animals that migrate with high recapture rate, where other devices don't have sufficient battery or	• Boom in production and popularity of these devices from 2007. • Likely to become obsolete once GPS devices become miniaturised (i.e. ICARUS)

VHF telemetry



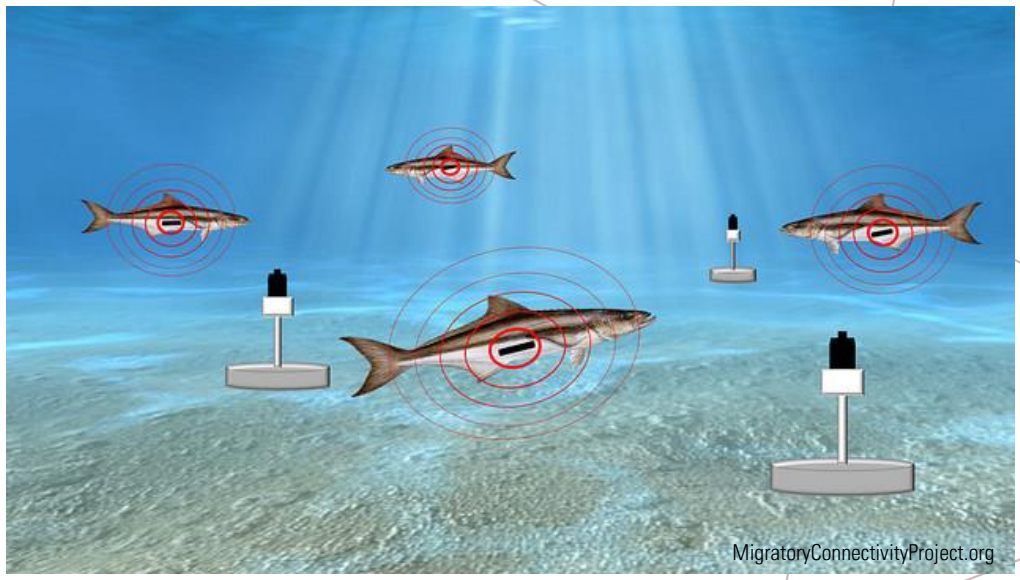

Telstra 4G
2:35 PM
55%
Legal
Set point 1
Clear
Set point 2

1) What kind of temporal resolution and spatial accuracy can you get?	2) What data can be collected (additionally to location)? how is the data transferred?	3) Does this limit what environments the technology can be used in?	4) Is it attached to the animal, how?	5) Cost and possible suppliers
• Temporal: • -Manual tracking • -Automatic tracking • • Spatial: • -More effort -> higher accuracy • -metres -> km •	• Mortality, temperature	• Signal is attenuated in freshwater & non-functional in saltwater. • Rocky areas will bounce signals around and complicate things.	• Collar • - Auto drop-off • Glue • Tape • Surgical implantation	• Holohil • SIRTrack/ Lotrack • Advanced Telemetry Systems
What's the typical battery life/track duration?	**Do receivers/trackers/ meters need to be recovered?**	**Skittles?**	**What taxa can it be used for?**	**When was the technology first developed?**
• Depends entirely on size/species. • 0.15g for a bat will last 10–20 days	• No, but recovered transmitters can be reused	• Yes.	• Terrestrial or semi-terrestrial • 2–5% of body weight	• 1960s • Advances continue to be made

Acoustic telemetry

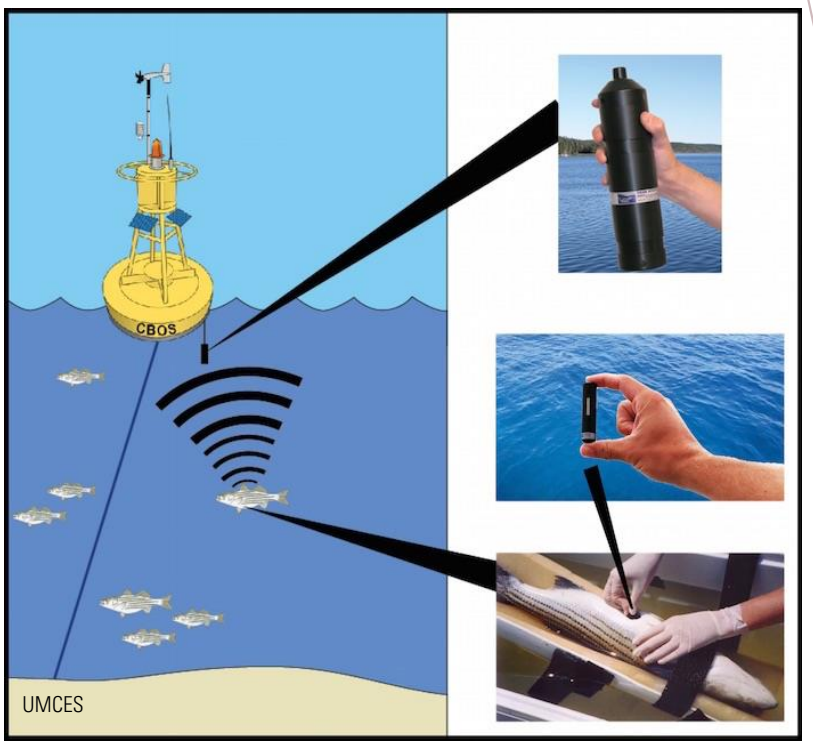
ACOUSTIC TELEMETRY

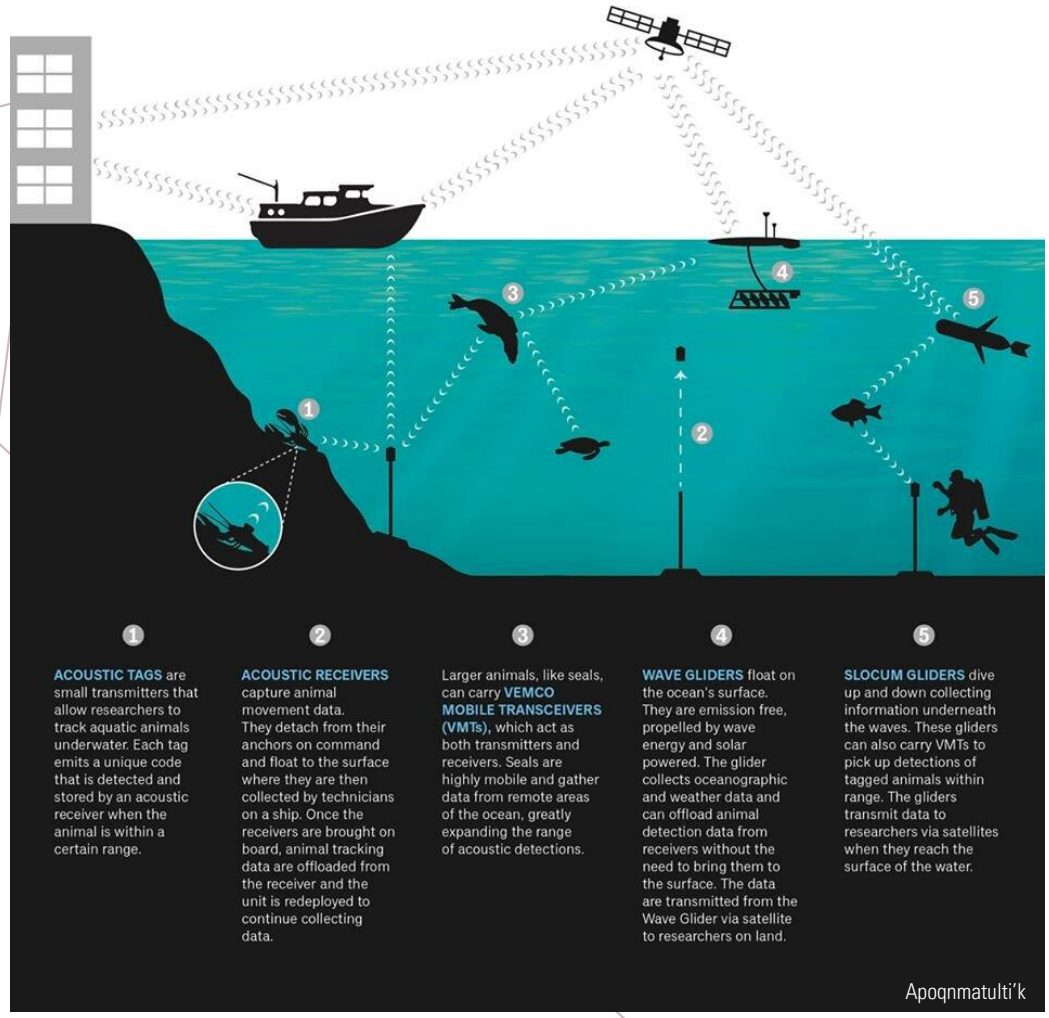
NOT BROUGHT TO YOU BY YOUR GRANDMOTHER'S HEARING AIDS



THE BASICS

- Relies on sound to detect and track tagged animals
- Studies have been using this technology since the 1960s
- Used underwater – both marine and freshwater environments





THE DETAILS

- Attachment methods
  - Internally implanted
  - Intragastrically inserted
  - Externally attached
- Receiver tracking stations
  - Stationary (passive)
  - Mobile (active)
    - Vessels
    - Larger organisms e.g. seals (Lidgard et al. 2014)
    - Autonomous underwater vehicles (Clark et al. 2013)
- Typically used for teleosts and elasmobranchs, now includes larger animals (e.g. seals) that are being fitted with transceivers (Lidgard et al. 2017)

DATA

- Temporal resolution
  - Pings every ~1.5-180 s
- Spatial accuracy
  - Must be within range of receiver (rarely > 800 m; Harcourt et al. 2019)
- Spatial and temporal coverage
  - Networks of compatible receivers = data linked across larger areas
  - Temporal scale can depend on type of tracking (passive vs. active)
- Additional data:
  - Some tags can also collect temperature and depth
  - Motion

RSAqua


Lotek

TECHNOLOGICAL DETAILS

Battery life

- Transmitters: a few days to a few years
- Receivers: typical battery life of 12-18 mos.

Manufacturers and cost

- Vemco (Canada)
- Lotek (Canada)
- Thelma Biotel (Norway)
- Sonotronics (USA)
- ~$200-500 for transmitters, ~$300-3500 for receivers (USD, Sonotronics)

1) What kind of temporal resolution and spatial accuracy can you get?	2) What data can be collected (additionally to location)? how is the data transferred?	3) Does this limit what environments the technology can be used in?	4) Is it attached to the animal, how?	5) Cost and possible suppliers
• Temporal resolution: Pings every ~1.5-180 seconds • Spatial accuracy: Must be within range of receiver (rarely > 800 m; Harcourt et al. 2019)	• Can be equipped with sensors to store or transmit info about the animal's internal and external env (Donaldson et al. 2014) • Some can include temp and depth sensors, motion sensors • Data either manually collected by retrieving receiver, remotely upload via hydrophone, or via satellite	Freshwater/marine	• Typically embedded, though can be externally attached as well	• Vemco (Canada) • Thelma Biotel • Sonotronics (USA) • Lotek (Canada) • Innovasea • BioSonics (USA) • Advanced Telemetry Systems • Aberdeen University (UK) • Custom Telemetry & Consulting Inc. (USA) • H.S. Electronics • ….many others • ~$200-500 for transmitters, ~$300-3500 for receivers (USD, Sonotronics)
What's the typical battery life/track duration?	**Do receivers/trackers/meters need to be recovered?**		**What taxa can it be used for?**	**When was the technology first developed?**
• For some receivers, 12-18 months (Vemco), but some can range to 9 years (IMOS) • As for tags, battery life is typically related to size (a few days to a few years)	• Tagged individuals no, but receivers traditionally, yes - data can now be telemetered via satellite from remote locations (Hussey 2015) • Receiver units either recovered or with some receivers there's the option to upload data remotely via a hydrophone (IMOS)		• typically used in teleosts and elasmobranchs • Also used in pinnipeds now (receiver or transceiver)	Development 1950s, used in studies since the 60s

GSM telemetry

GSM TELEMETRY (GLOBAL SYSTEM FOR MOBILE COMMUNICATIONS

- Used for mark-recapture studies
- Mobile phone tags attached to animals
- Sends a text every 2-3 days
- requires, that the tag is within radio contact of a GSM radio cell.
- Every 4 h the tag wakes from sleep mode, waits until it is dry and then attempts to register with a GSM network for a maximum of 95 sec

ARGOS transmitters

Overview

- Tags transmit to satellites which use the Doppler shift to calculate positions.
- This differs from GPS tags which receive positions from the triangulation of multiple satellites.
- Note: There are also “ARGOS GPS tags.” These typically are GPS tags that transmit the data via the ARGOS network (also collect ARGOS data as a backup)

Key disadvantages compared to GPS

- Often fairly large
- Imprecise (few hundred meters, or even over 1km)
- Work best closer to poles
- Few points per day

1) What kind of temporal resolution and spatial accuracy can you get?	2) What data can be collected (additionally to location)? how is the data transferred?	3) Does this limit what environments the technology can be used in?	4) Is it attached to the animal, how?	5) Cost and possible suppliers
• Low • Only a few points a day • Several hundred km accuracy (even over 1km) • Better near poles • • •	Temperature, acceleration, mortality, heart rate…. Downloaded remotely (uploaded to satellite, downloaded on computer)	• Yes • Open environments work best • Animals must spend a lot of time at the surface or above the water	• External (highly variable)	• **Cellular Tracking Technologies** • **Desert Star Systems** • **ES-PAS** • **GeoTrak** • **Icoteq** • **Lotek** • **Microsensory** • **Microwave Telemetry** • **MistyWest** • **North Star Science and Technology** • **Sea Mammal Research Unit Instrumentation Group (SMRU-IG)** • **Sextant Technology** • **SparkFun Electronics** • **Syrlinks** • **Telonics** • **Wildlife Computers** • **Xerius Tracking**
What's the typical battery life/track duration?	**Do receivers/trackers/ meters need to be recovered?**		**What taxa can it be used for?**	**When was the technology first developed?**
Highly variable • 11-670 days • 49-875 g	No? but some can be refurbished		• Anything largish that spends time at/above the surface (birds, mammals, reptiles, some fish)	• 1970s

GPS with Receiver Array

GPS with Receiver Array

VHF

(Stoner et al. 2008; Krone et al. 2009)

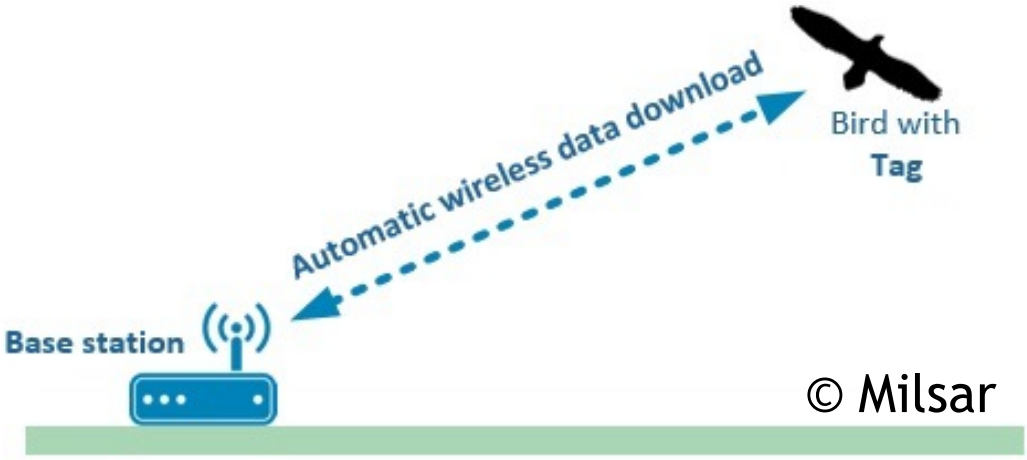
Radio Modem

© Milsar

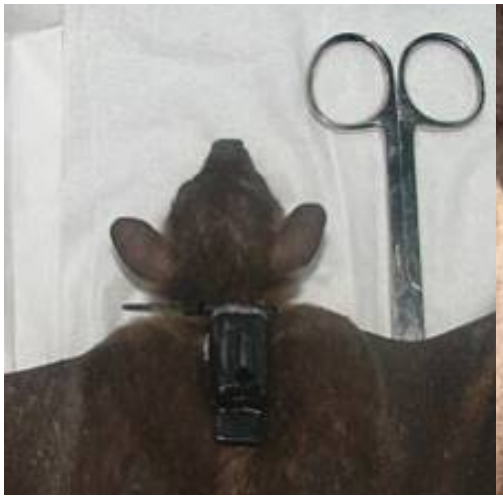
- local point-to-point communication
- minimizes overall complexity/ redundancy
- provides 2-way communication
  - confirmation of data
  - real-time-status updates
  - reconfiguration of the system

Mote

Radio Modem

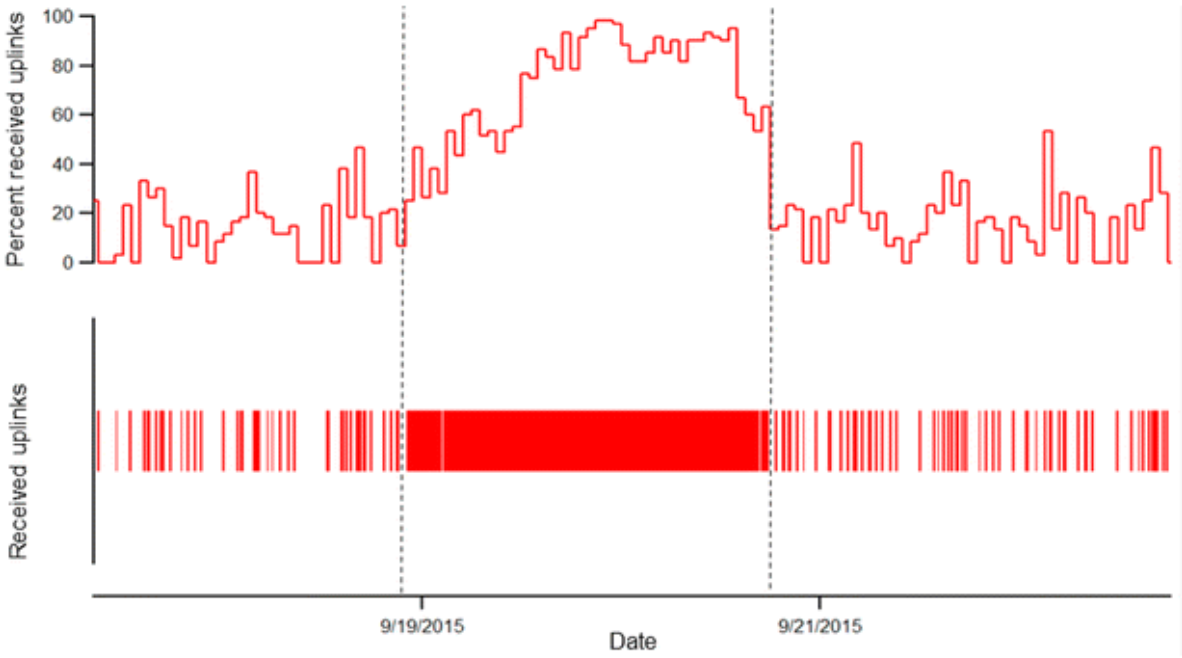


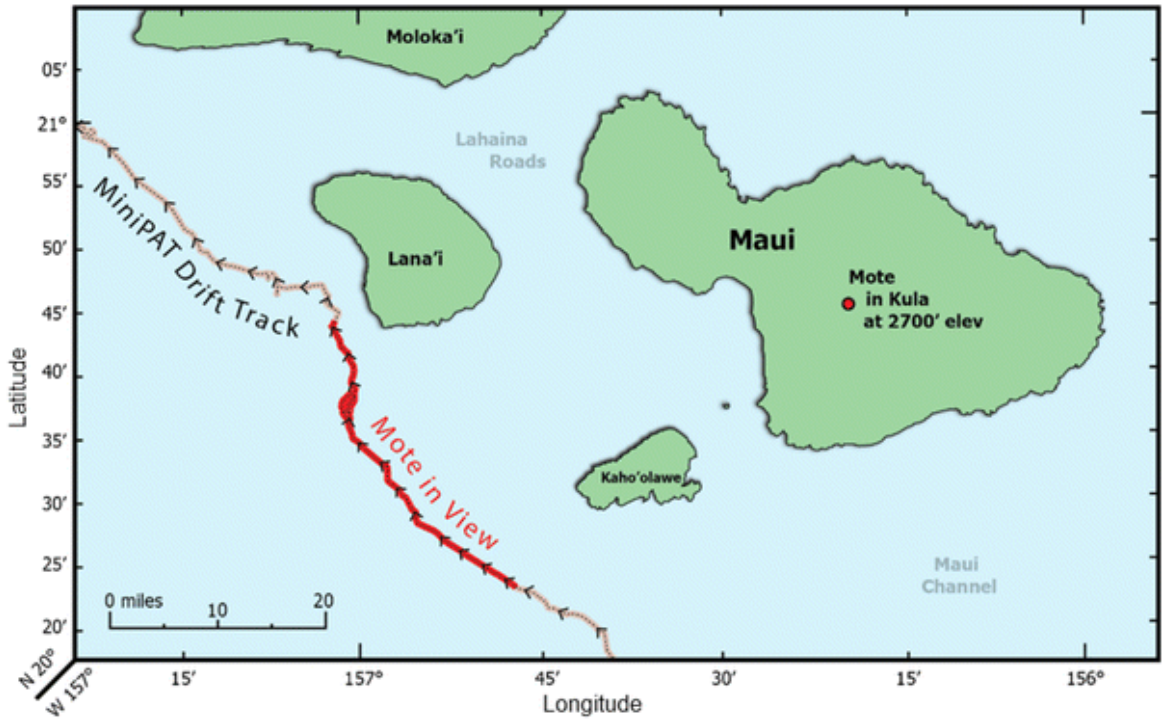
© Milsar



© Telemetry Solutions

Mote





Jeanniard-du-Dot et al. 2017

1) What kind of temporal resolution and spatial accuracy can you get?	2) What data can be collected (additionally to location)? how is the data transferred?	3) Does this limit what environments the technology can be used in?	4) Is it attached to the animal, how?	5) Cost and possible suppliers
• Locations can be as accurate as 5 m dependent on the number of satellites available to get a fix. • Generally within 30 m of true position • Measurements can be set to record almost continuously to intermittent periods (affects battery life) • Generally, to conserve battery life locations are collected at intervals of 15 or more minutes. • •	• Many options depending on budget (e.g. Depth, Altitude, Accelerometer, Temperature, Light, Speed) • Collection of additional data affects battery life • Some data may only be archived due to size of data transfer • Others can be transferred to permanent ground stations or through a satellite relay system (e.g. Argos/Iridium)	• Localised transferal via radio transmission • Ground stations are limited in their range • Work on line of site and dependant on location, power, and antennae size • Best for aerial species or those that have a known core range and generally for terrestrial species • Milsar base station has ~2 km range (designed for nesting birds) • Wildlife computers Mote system can extend to >200 km (Jeanniard-du-Dot et al. 2017) and increase detections from a sat tag by up to 400% • Telemetry solutions 30 km range (higher if base station used with drone/light aircraft) • Specialised GPS (e.g. Fastloc or Quickfix) required for marine species	• Dependant on species • Many terrestrial species use collars (e.g. cats, wolves, ungulates, elephants) • Tortoises/turtles usually have backpack tags glued on using epoxy • Harness or glue for birds • Harness for leatherback turtles, dugongs, Manatees • Pop-up systems or bolt on for other large marine animals	• From $100s for simple open-source build your own devices to ~$8000 for some marine tags. • Base station costs can range from hundreds for standard short range terrestrial to many 1000s of $ Suppliers: • WildlifeComputers • Telonics • CATS • SMRU • Milsar (€1000-1200) • TelemetrySolutions • Lotek • For more suppliers see: Argos community
What's the typical battery life/track duration?	**Do receivers/trackers/ meters need to be recovered?**		**What taxa can it be used for?**	**When was the technology first developed?**
• Duration dependent on the data being collected, settings, and the environment that the tag is deployed in. • Track duration tends to be species specific but can range from a few days to months or years (e.g. loggerhead turtles 50% tags transmit over 550 days) • Solar tags (sometimes used with birds can theoretically track entire life of an animal (e.g. a white stork was tagged with a GPS tracking device as a 3-year-old, nonreproductive juvenile in Germany in 1994 and was tracked until her death in 2006 (4 tags used over this period; Flack et al. 2015) • Stations can be self sufficient with solar or rechargeable if they are mobile (e.g. drone mounted	• Some Base stations can communicate with satellites or through mobile network (e.g. wildlife computers), others require manually downloading the data. GPS trackers do not need to be recovered, but may store additional archived data.		Almost anything dependent on size of the animal (animals under 240 g have issues), excluding ~81% of birds and 66% of mammals (Wilson et al. 2002))budget and the environment. Receiver Array is best for avian species, but also for those where you can guarantee the animal will come into range of the base station. Can also be used to increase the number of location estimates gained from tags that transmit via Argos or equivalent	GPS deployed 1973 First used in wildlife telemetry 1990s

GPS store-on-board


Borderlands Research Institute


Kauth et al. 2020

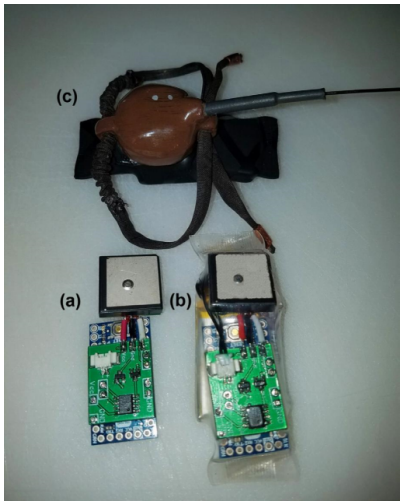

Foley & Siller-Zubiri 2020

How IT WORKS

- Location acquired from ~24 GPS satellites at 20000 km above earth (NAVSAR)
- Accurate to <30 m when 4+ satellites are in view
- Locations are stored on the tracking device
- Data can be downloaded via:

1. VHF or UHF receiver
2. When tags drop-off at a scheduled time
3. When the animal is recaptured

PROS and CONS



- Cheaper and lighter than remote download GPS
- Affordable 'off the shelf' customisable approaches

- Time lag for data download
- Risk of data loss if animal or drop-off tag not relocated
- Can't modify settings remotely

1) What kind of temporal resolution and spatial accuracy can you get?	2) What data can be collected (additionally to location)? how is the data transferred?	3) Does this limit what environments the technology can be used in?	4) Is it attached to the animal, how?	5) Cost and possible suppliers
• <30 m • High frequency	• Altitude, Speed, Temperature, Activity data • Can include VHF transmitter for locating the animal • Transferred via VHF or UHF • Manual transfer after drop-off and tag collected • Manual transfer after tag recaptured	• For location acquisition, limited to animals not in den, burrow, cave, shade, underwater or dense forest	• Collar • Harness	• $130 - $1000 USD • Lotek, Sirtrack, eOBS digital telemetry, telemetry solutions, telonics, tellus micro • Off the shelf GPS devices
What's the typical battery life/ track duration?	**Do receivers/trackers/meters need to be recovered?**		**What taxa can it be used for?**	**When was the technology first developed?**
• Trade-off with sampling rate (up to ~ 2 years) • Options for solar power	• Yes		• Weight limitations less than for remote transfer (min tag weight ~1 g) • Terrestrial, avian	1990s

Resources

Thomas Bindi, Holland John D., Minot Edward O. (2011) Wildlife tracking technology options and cost considerations. *Wildlife Research* **38**, 653-663. https://doi.org/10.1071/WR10211