Measuring the environment

UCI – Environmental Science 101 July 2018

Measuring the environment

- Presence-absence
- Current abundance/biomass/standing stocks
- Population dynamics (demographic rates)
- Species interactions (with each other and the environment)
- Behavior and movement patterns

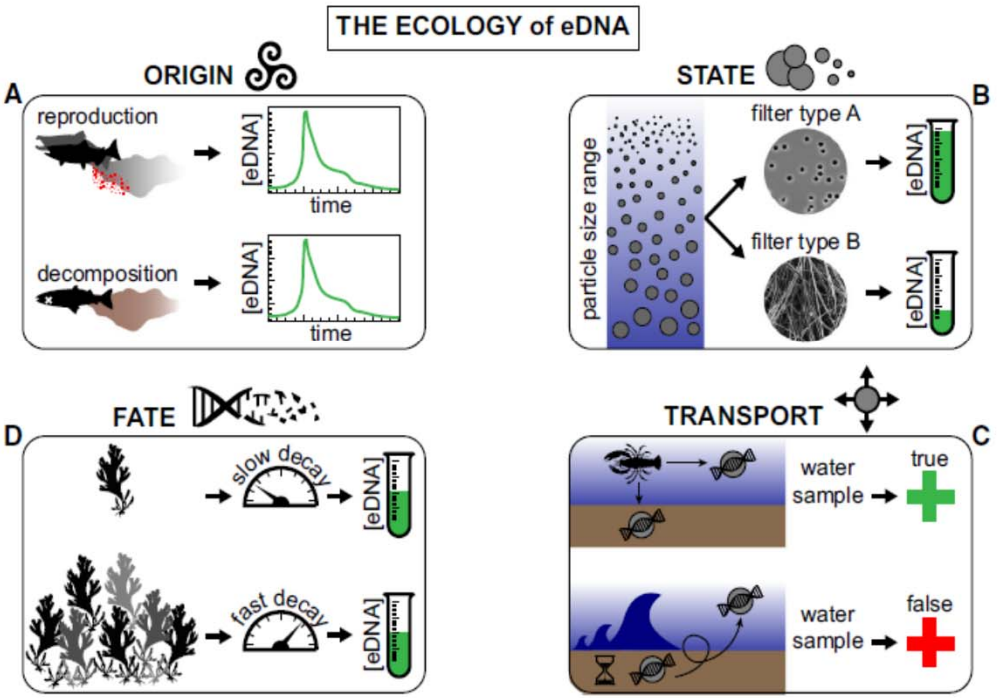
Do these change over time?

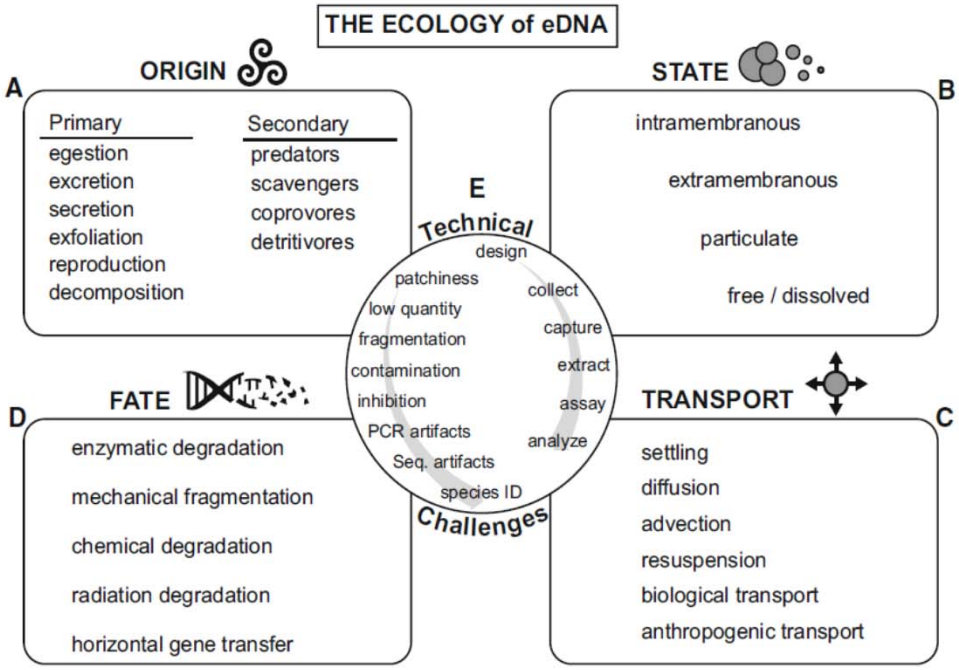
Do these change in relation to changes in the environment?

Presence-absence

Presence-absence

- eDNA: environmental DNA
- Scent marking stations, hair





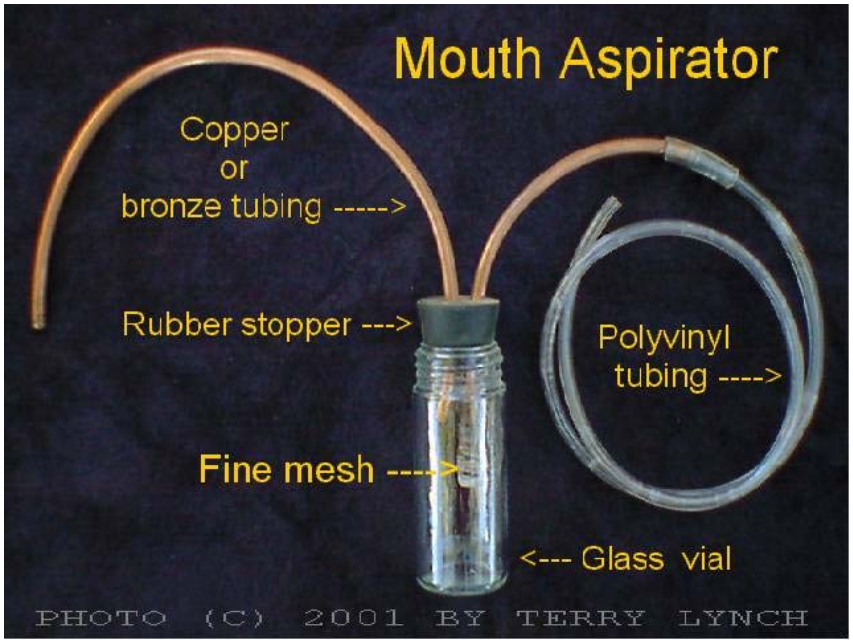
Source: Barnes and Turner Conservation Genetics *2016*

But some things are hard to see (or quantify)…

How can we measure important characteristics of organisms and ecosystems?

Terrestrial sampling: ground macroinvertebrates/cryptozoans

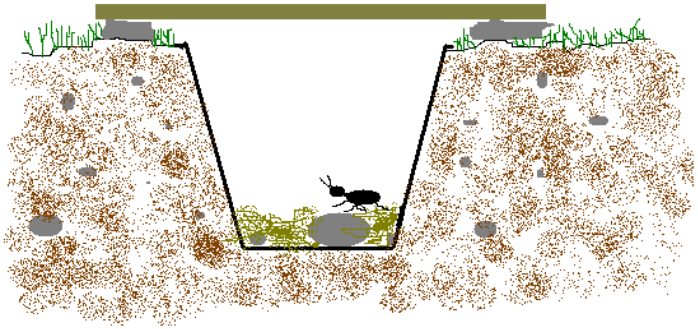
Source: https://www.srs.fs.usda.gov/compass/wp-content/uploads/2016/10/10.25._USE_Earthworms.jpg



Source: http://www.reocities.com/bioluminus/mouth_aspirator.jpg

Terrestrial sampling: pitfall traps

Source: https://upload.wikimedia.org/wikipedia/commons/b/b2/Barber_pitfall_trap.jpg



Source: http://www.bnhs.co.uk/youngnats/wp-content/uploads/2013/05/Pitfall-Trap.png

Source: https://c2.staticflickr.com/4/3693/13914326932_ed2efae39c_b.jpg

Terrestrial invertebrate sampling-foliage

http://baloun.entu.cas.cz/png/mtwilhelm/wp-content/uploads/Beating.jpg

https://cbs.umn.edu/sites/cbs.umn.edu/files/public/downloads/Sweep%20Coordination.JPG

Terrestrial invertebrate sampling-aerial

Source: https://lter.kbs.msu.edu/wp-content/gallery/collecting-data-high-resolution-images/insect.sampling.KBS.LTER.0001.jpg

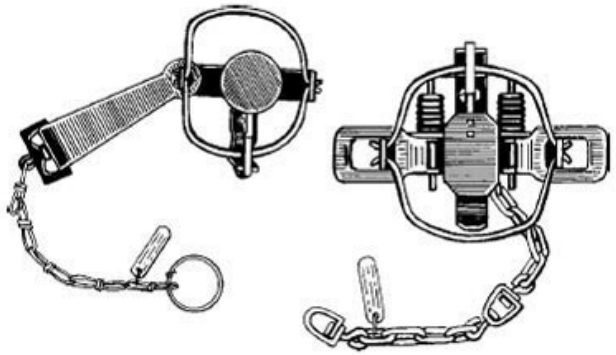
Source: http://www.evergreengrowers.com/

Source: http://mississippientomologicalmuseum.org.msstate.edu/images/traps/malaise3.jpg

Trapping methods

- Live traps
  - Box traps (bears, mice, etc)
  - Pitfall traps (drift fences)
  - Foothold
  - Foot, neck body snares

Foothold Traps



These are two types of foothold traps. At the left is a longspring trap, at the right is a coilspring trap.

Source: http://www.wild-about-trapping.com/images/photos/foothold_trap_types_pic.jpg

Source: http://2.bp.blogspot.com/-9vwgjj93uJk/VnRnv3_DM7I/AAAAAAAAAX8/qLBP4sDwQNs/s1600/100_0801.JPG

Trapping methods

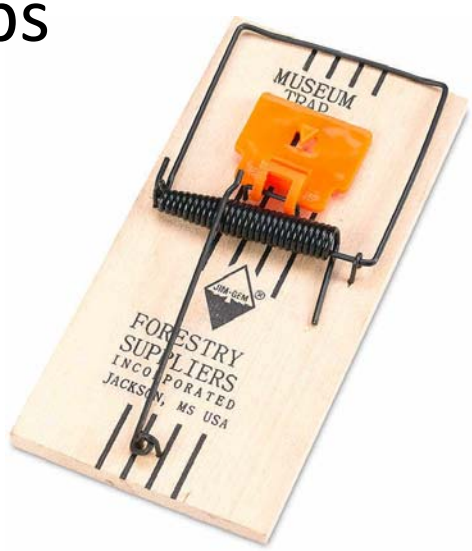
- Live traps
  - Drive corrals, Rocket nets
  - Mist nets, Hart trap (bats)
  - Dart collars

Source: https://todblog.files.wordpress.com/2007/02/canadagoosecapture.jpg

Source: https://aim0008-production.s3.amazonaws.com/idea_images/image_files/000/000/360/carousel/A_mist-net_used_to_capture_birds.png?1398864183

Trapping methods

- Killing traps
  - Snap traps
  - Killing box traps
  - Killing snares
  - Pitfall traps
  - Drowning sets



Source: http://www.forestry-suppliers.com/Images/Original/5128_35815_p1.jpg

Source: http://wdfw.wa.gov/living/species/graphics/rat12.jpg

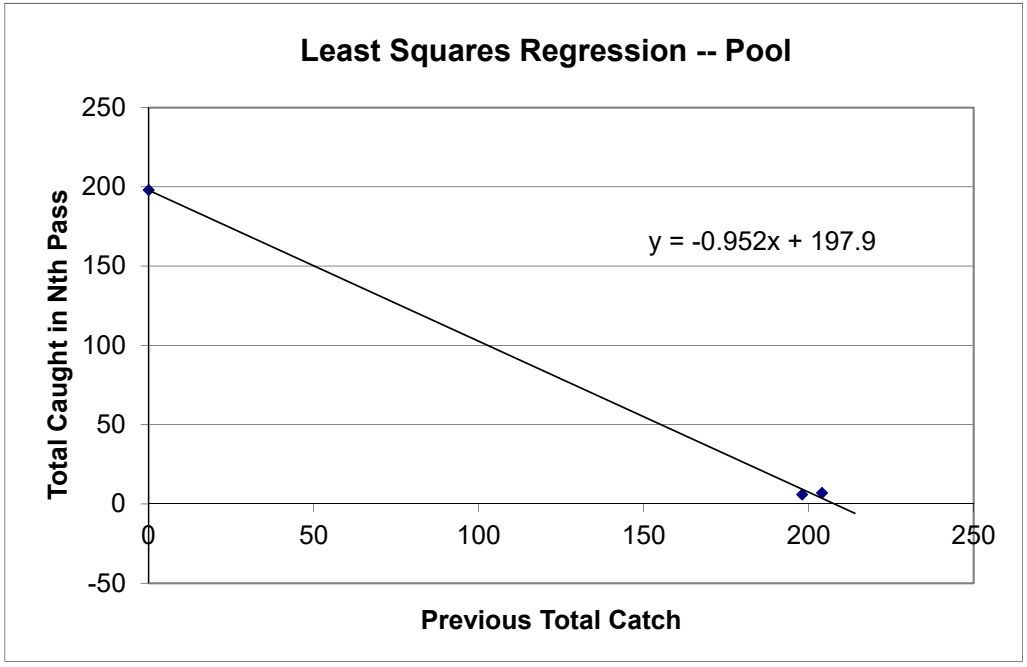
Estimating abundance: Removal sampling

- Assumptions
  - Each individual in population has an equal and independent chance of being captured, i.e., random sampling
  - The population is closed, that is no immigration or emigration; also no net birth/death occurring
  - Probability of capturing an animal is the same for each period of sampling

Removal sampling activity

Estimating abundance: Removal sampling

- Typically applied in areas with obvious borders or constraints to movement, e.g., aquatic systems



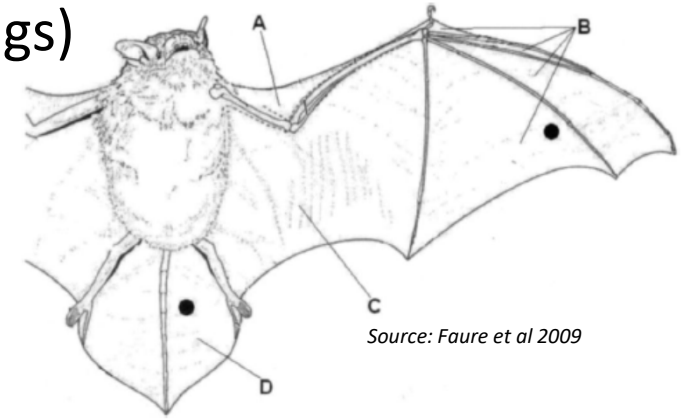
$0 = a + b*N$

$N = -a/b$

$N = 208$ fish

Marking Mammals

- Short term
  - Fur clipping or dyeing
  - Nocturnal lights
  - Powders/chemicals in food
  - Body attachment (ear tags, streamers)
  - Punch marking (small holes in bat wings)



Source: Faure et al 2009

Source: https://www.researchgate.net/post/Has_anyone_used_hair_dye_food_dye_to_temporarily_mark_small_mammals_in_the_field_Is_it_safe_are_there_any_recommended_brands

Marking animals

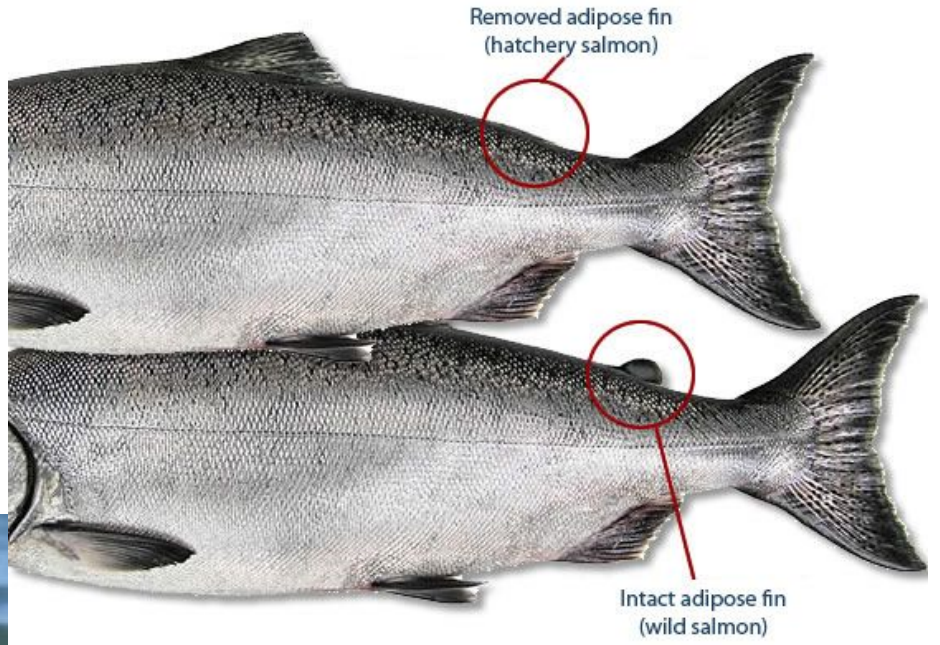
- Long term
  - Ear tags
  - Collars and bands
  - PIT tags
  - Radioactive markers (cobalt, gold, calcium, etc), fed or injected
  - Beta lights

Source: http://outdoorchannel.com/content/articles/columbian-white-tailed-deer-with-tags.jpg

Source: http://www.caryinstitute.org/sites/default/files/public/styles/detail/public/images/news/news_2014_03_ticks_mice.jpg?itok=6hLNA53U

Marking animals

- Permanent
  - Natural markings (e.g., horn shape, fin morphology)
  - Genetic markers
  - Mutilation (e.g., fin-clipping)
  - Freeze branding
  - Tattoos



Source: http://nnimgt-a.akamaihd.net/transform/v1/crop/frm/EzkFZxH3X6yqHujaBrFxTa/5a02d7b5-7aeb-496a-860e-07a856a5b3a8.JPG/r0_257_1604_1163_w1200_h678_fmax.jpg

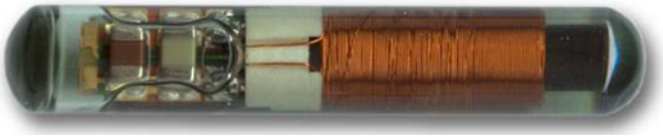
High(er) tech marking/tagging methods

- PIT tagging
- Coded wire tags
- Radio telemetry
- Acoustic telemetry
- Archival tags
- GPS tags

Active tags

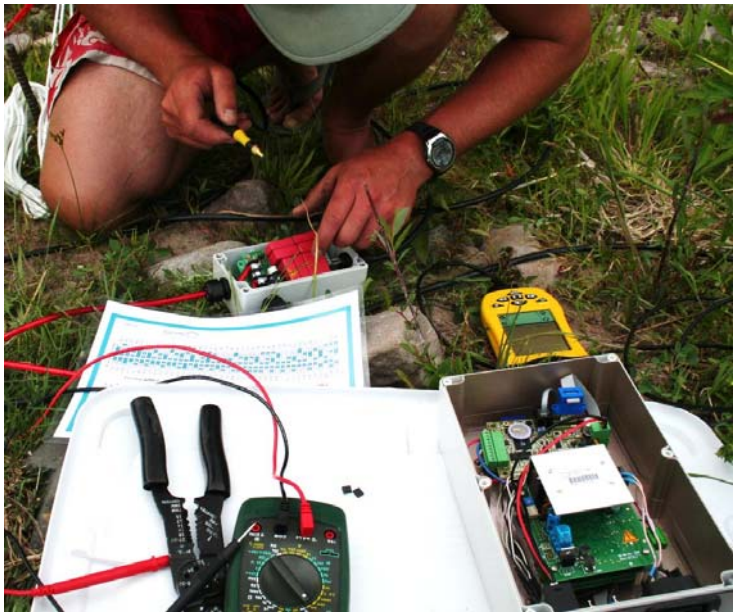
Fish movement and habitat use

- 23mm 134.2 kHz PIT tags, detection range 0.3-0.8 m
- Portable antenna
- 8 multiplexed stationary antennas (8.5-13 m wide, 2.3 scans/sec)



Fish movement

Portable antenna

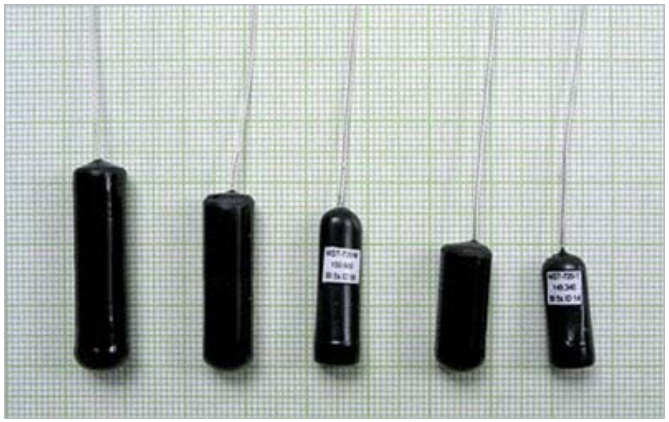


Stationary antenna

Radio telemetry

Source: http://dnr.wi.gov/topic/Fishing/Images/Lakemichigan/Radio_tag_2.jpg

Source: http://www.parksconservancy.org/assets/conservation/plants-and-animals/images/telemetry-1.jpg



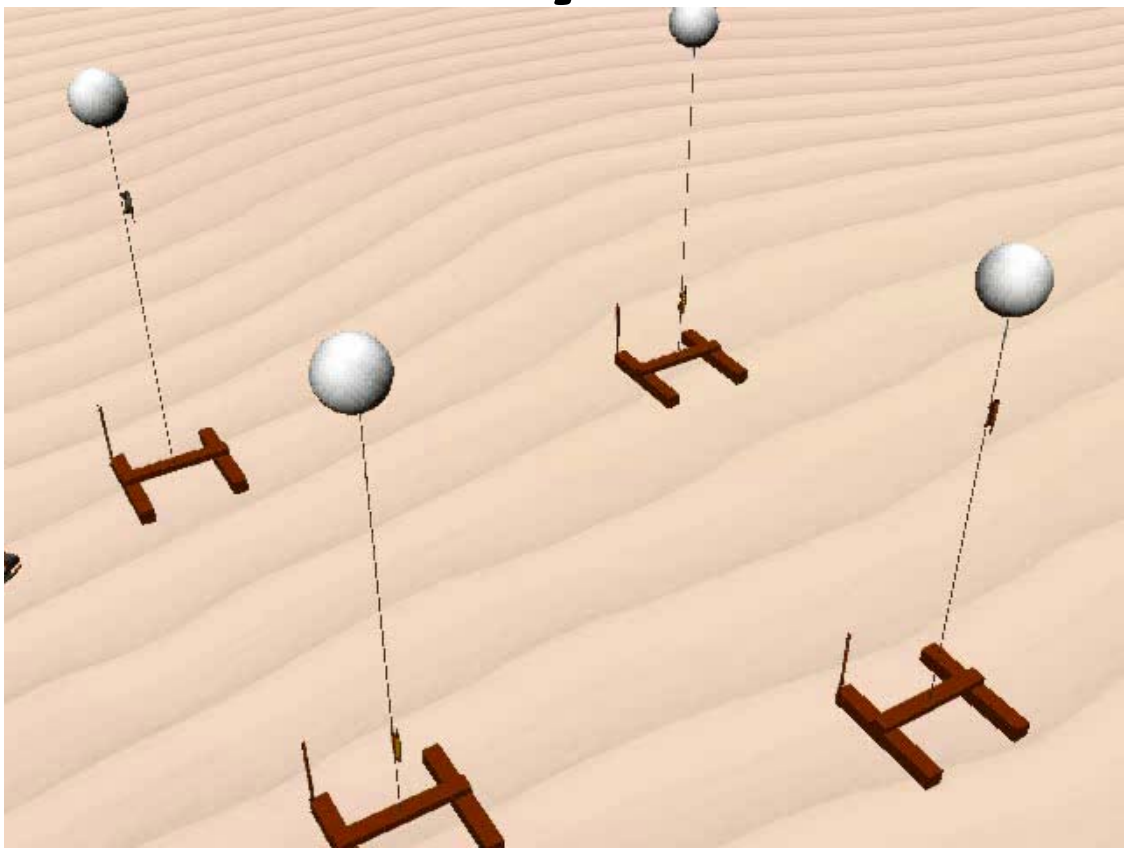
Source: http://www.lotek.com/mst-series-programmable-sensor-transmitters.htm

Radio telemetry

Source: https://www.researchgate.net/profile/Mark_Beere/publication/237434775/figure/fig3/AS:299471368933388@1448410946616/Figure-5-Helicopter-used-for-tracking-flights-showing-the-location-of-telemetry-antenna.png

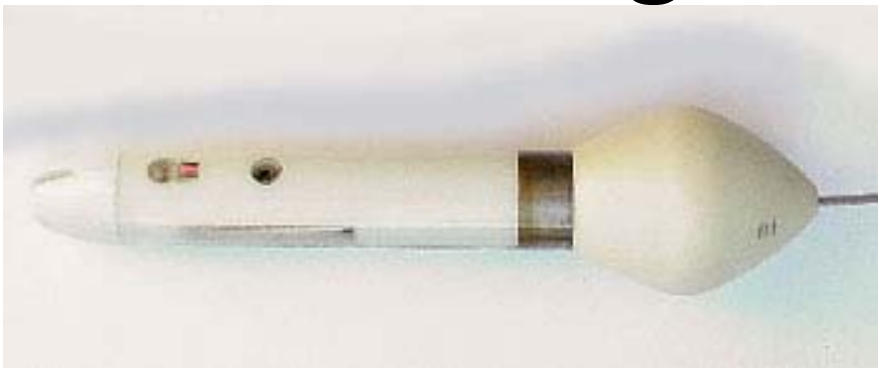
Source: http://cdn1.arkive.org/media/55/55361390-1C51-452D-9C10-6F8F87BF2D01/Presentation.Large/Aardvark-with-radio-collar-to-aid-tracking-for-research.jpg

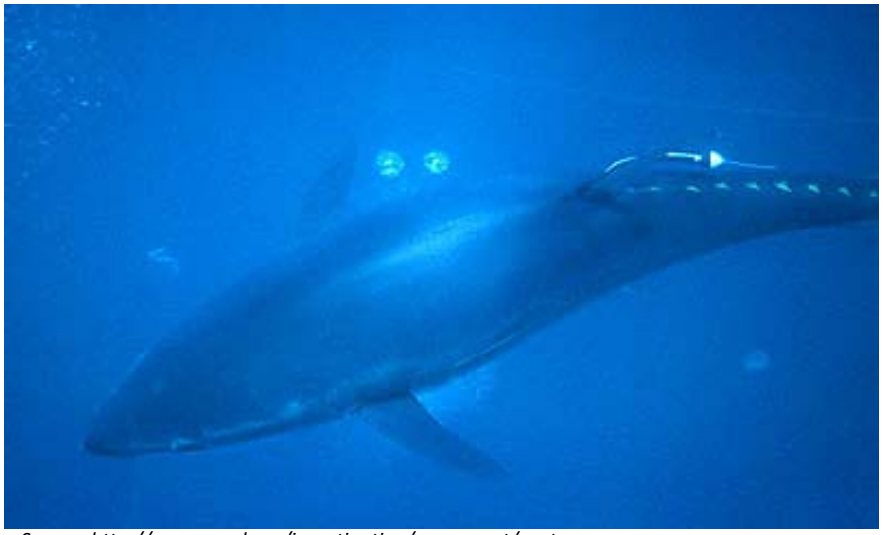
Acoustic telemetry



Source: http://www.htisonar.com/animations/pingconcept7.wmv

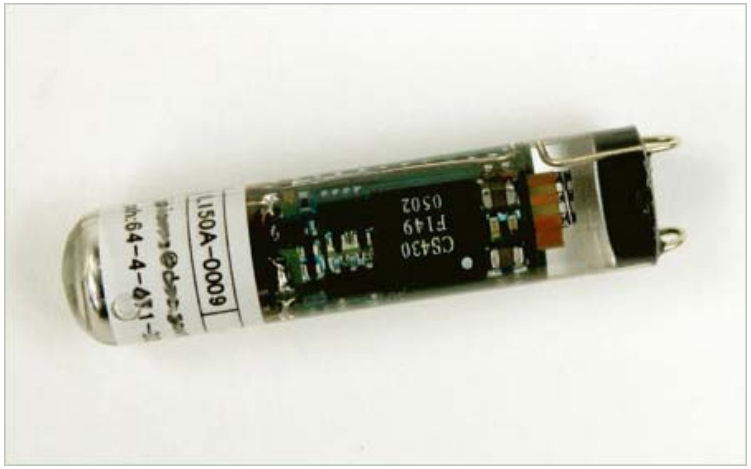
Archival tags



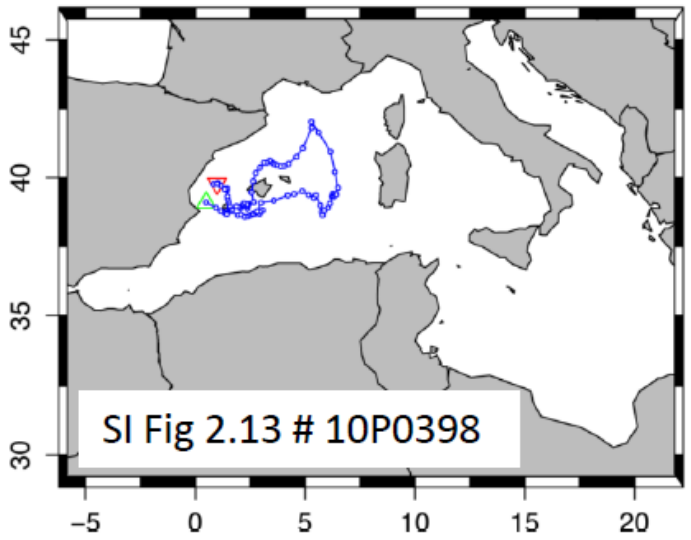


Source: http://www.coml.org/investigating/movement/psats

Source: http://www.coml.org/investigating/movement/archival_tags



Source: http://www.lotek.com/images/LAT1500-web.jpg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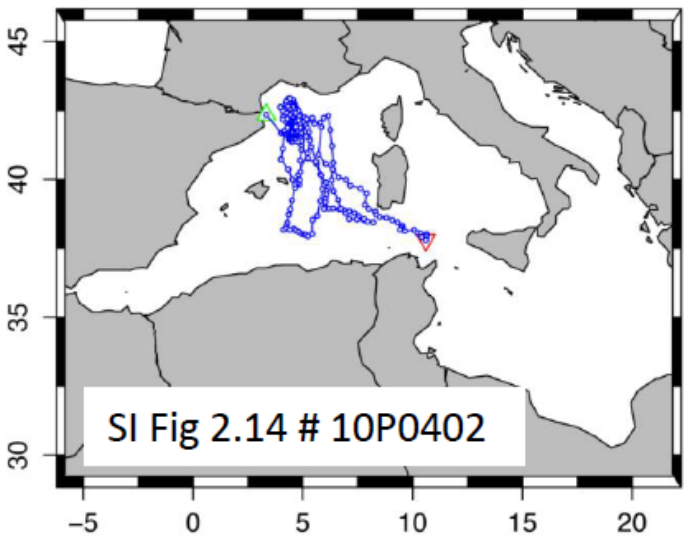
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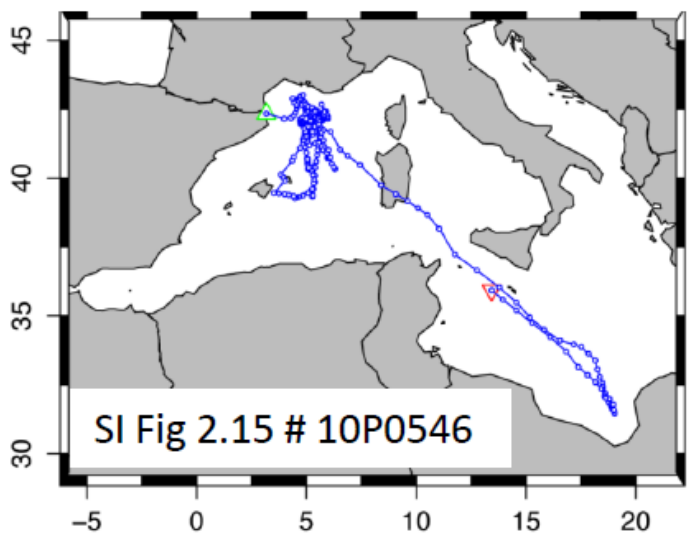
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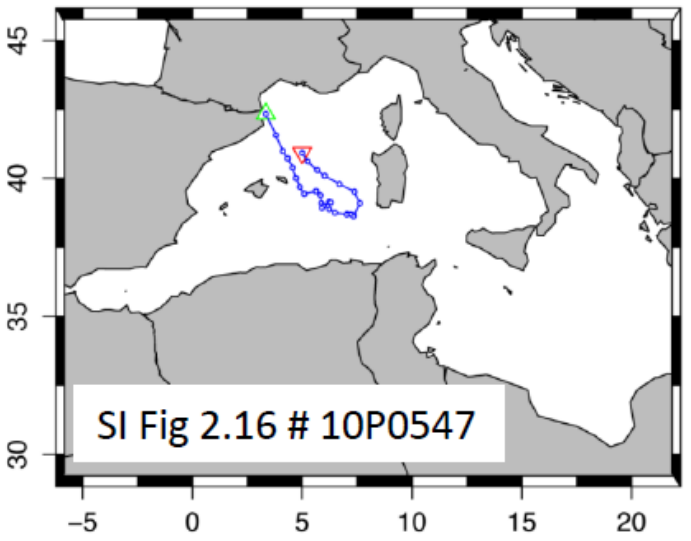
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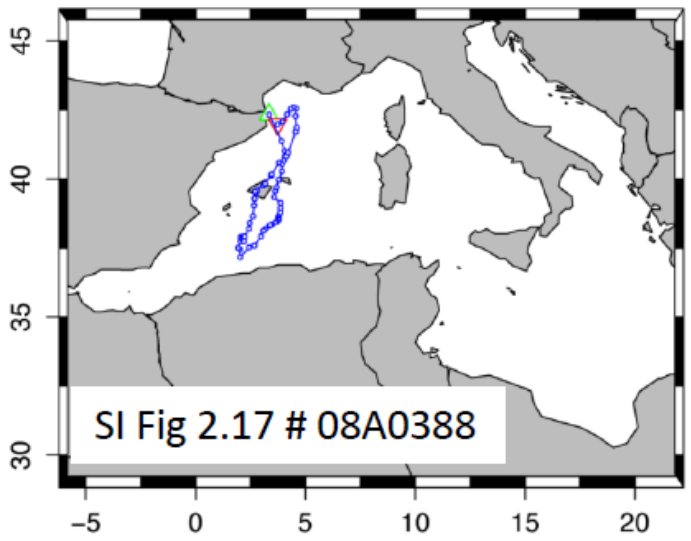
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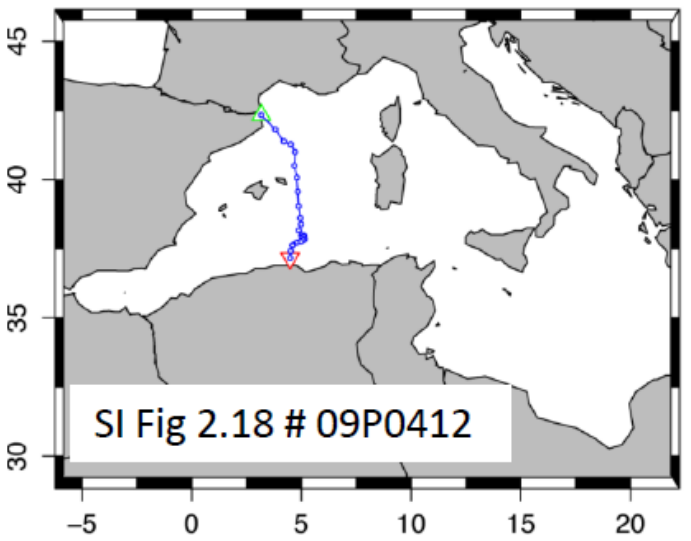
SI Fig 2.18 # 09P0412
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Estimating abundance: Mark-recapture

- Basic Assumptions
  - All individuals in population have an equal and independent chance of being captured during the time of sampling, i.e., random sampling
  - No change in ratio of marked to unmarked individuals; no significant births or immigration and no differential mortality between marked and unmarked individuals
  - Marked individuals distribute themselves homogeneously through the population, that is, are similarly likely to be captured in the second sample as unmarked individuals
  - The catchability of an individual should not be impacted by the act of capturing and marking it

Estimating abundance: Mark-recapture

Some of these assumptions may be violated—and many different models have been built to adjust

Capture-recapture is reliant on 2 probabilities:

- Survival probability, i.e., probability of surviving and returning to the sampling area
- Encounter probability, i.e., the probability of being encountered, conditional on being alive in the sample

Estimating abundance: Mark-recapture

Example recapture histories:

111 - captured and marked on the first occasion, alive and encountered on the second occasion, alive and encountered on the third occasion

110 - captured and marked on the first occasion, alive and encountered on the second occasion, and either (i) dead by the third occasion, or (ii) alive on the third occasion, but not encountered

101 - captured and marked on the first occasion, alive and not encountered on the second occasion, and alive and encountered on the third occasion

100 - captured and marked on the first occasion, and either (i) dead by the second occasion, (ii) alive on the second occasion, and not encountered, and alive on the third occasion and not encountered, (iii) alive on the second occasion, and not encountered, and dead by the third occasion

Roadside counts

- Can be used for both live and dead wildlife (e.g., roadkill)
- Provides a population index, typically effective for medium-large animals
- Should be standardized (effort, visibility, season)
- Can be combined with point surveys

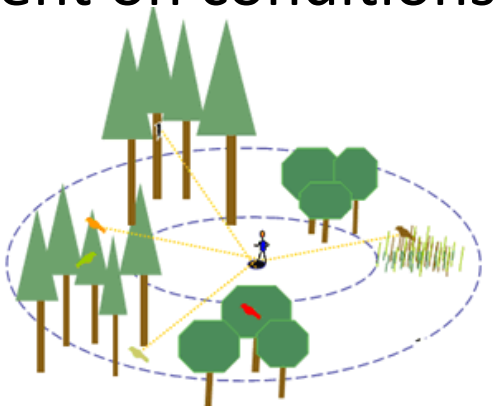
Source: https://en.wikipedia.org/wiki/Roadkill

- Not necessarily accurate or precise
- Potential variation between observers

Point surveys

- Trained observer records all sightings from a station over a set time interval
- Can be combined with transects/routes for replication

- Require trained observers
- Dependent on conditions, visibility

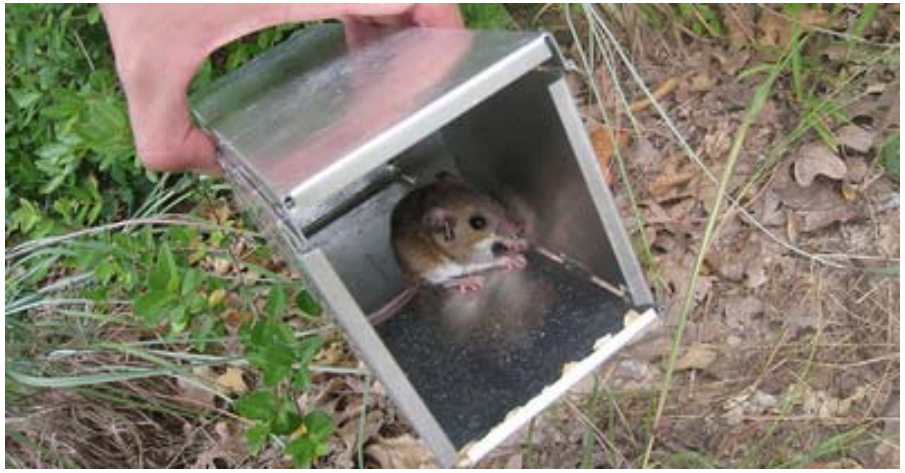


Source: https://www.pwrc.usgs.gov/Point/view/images/PointCountMethodDiagram.gif

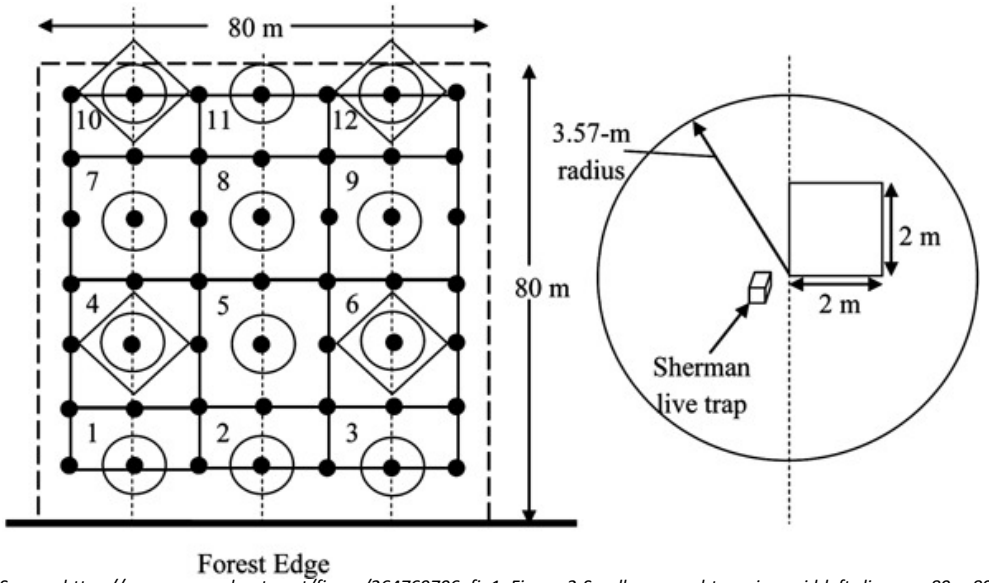
Source: https://www.tidalmarshbirds.org/?p=1705

Small mammals

- Typically trap arrays in grids or transects
- Can use removal or capture-recapture methods
- Can be index (animals/trap day, animals/transect length) or by area



Source: http://entogroup1.weebly.com/trapping-protocol.html



Source: https://www.researchgate.net/figure/264769706_fig1_Figure-2-Small-mammal-trapping-grid-left-diagram-80-m80-m-removal-or-reference-area

Camera trapping

- Mostly non-invasive method to detect small bodied or cryptic species
- Provide occupancy or relative abundance data

- Advantageous to use multi-camera cluster arrays to increase detection probability
- Require clear study designs, survey seasons, detectability, description of equipment and limitations

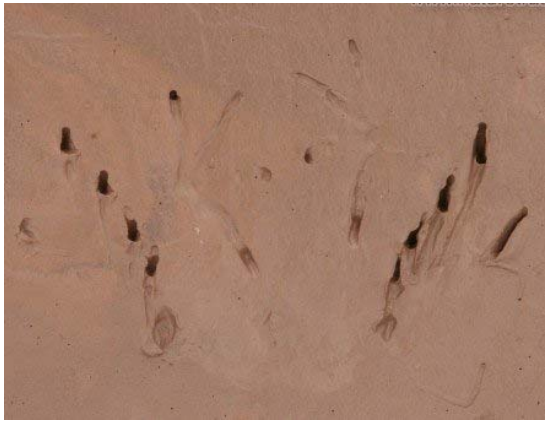
Source: http://www.discoverwildlife.com/sites/default/files/imagecache/800px_530px/gallery/Animal%20Portraits_Laila%20Bahaa-el-din_Giant%20Pangolin_800.jpg

Source: http://www.naturespy.org/wp-content/uploads/2014/05/20130514_191359-e1399312708303.jpg

Track counts

- Best used in areas/conditions that retain clear tracks
- Tracks may be challenging to identify
- Provide index of density and occupancy
- Can be calibrated with a relationship between animal numbers, spatial distribution, and track abundance or mean daily travel distance

Source: http://d1940xvrxfszyc.cloudfront.net/wp-content/uploads/2015/06/Raccoon-Tracks-1.jpg



Source: http://www.naturetracking.com/herp-tracks/#images-1/16/Bullfrog-Tracks-2.jpg

Pellet counts

- Works best where pellets are preserved
- Usually plot sampling, requires multiple visits with removal
- Provides index of density—but can be potentially converted to animal counts with defecation rate or other info

Source: http://www.summitpost.org/cottontail-rabbit-scat/276865/c-276861

Source: https://www.qdma.com/conduct-spring-pellet-count/

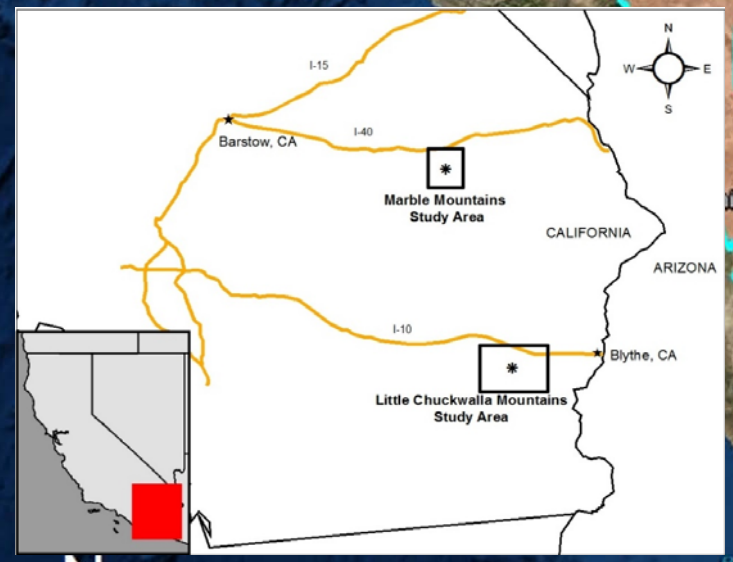
Monitoring Desert Mule Deer Using DNA-Based Capture-Recapture

Stephen Pfeiler
CSUCI Alumni
M.S. Student, Utah State
Wildland Resources

Fecal DNA-based Capture Recapture

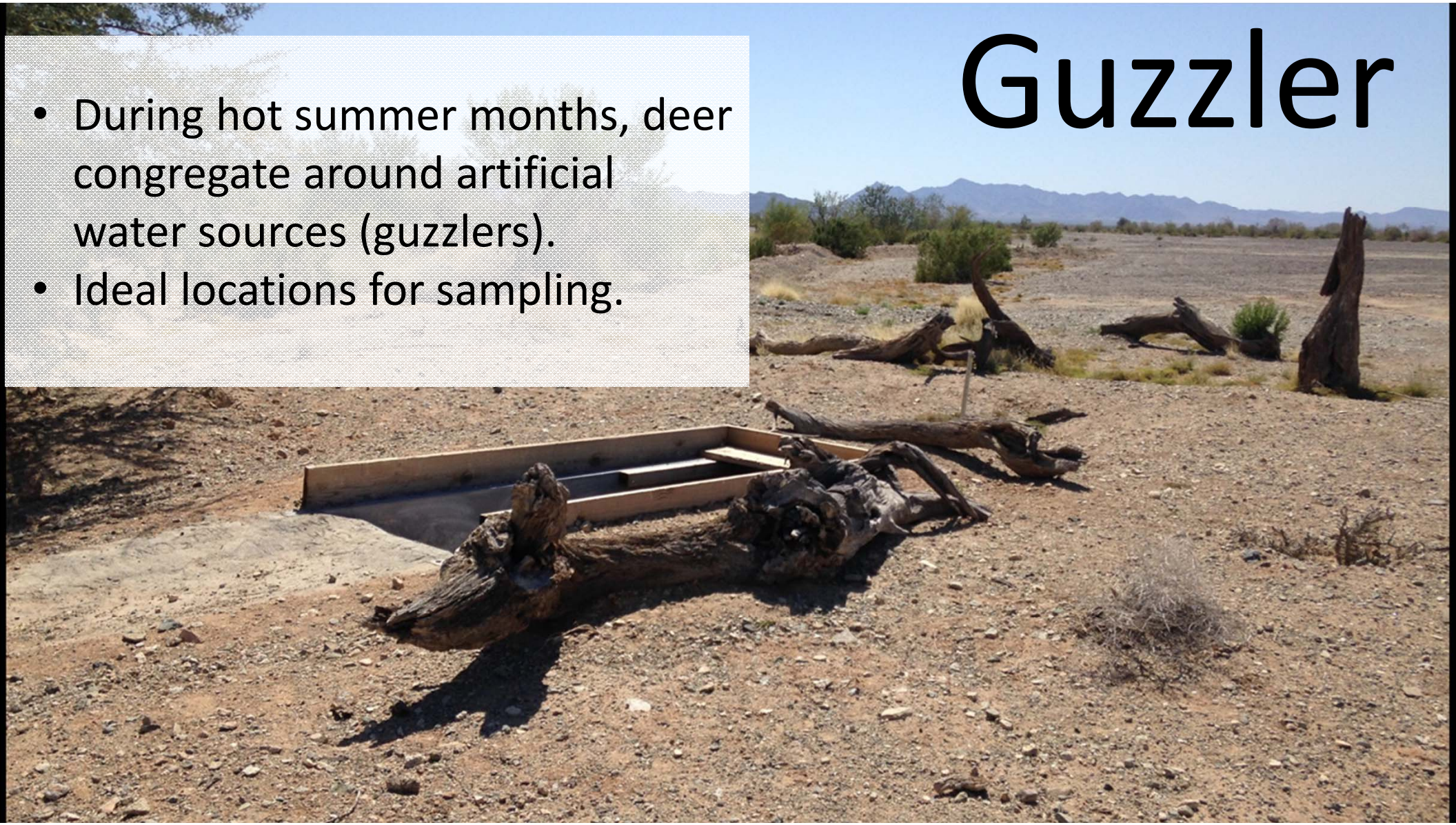
Sonoran Desert mule deer (*Odocoileus hemionus eremicus*)

- Behavior and habitat topography make traditional monitoring methods difficult and ineffective (e.g. ground counts and helicopter surveys).



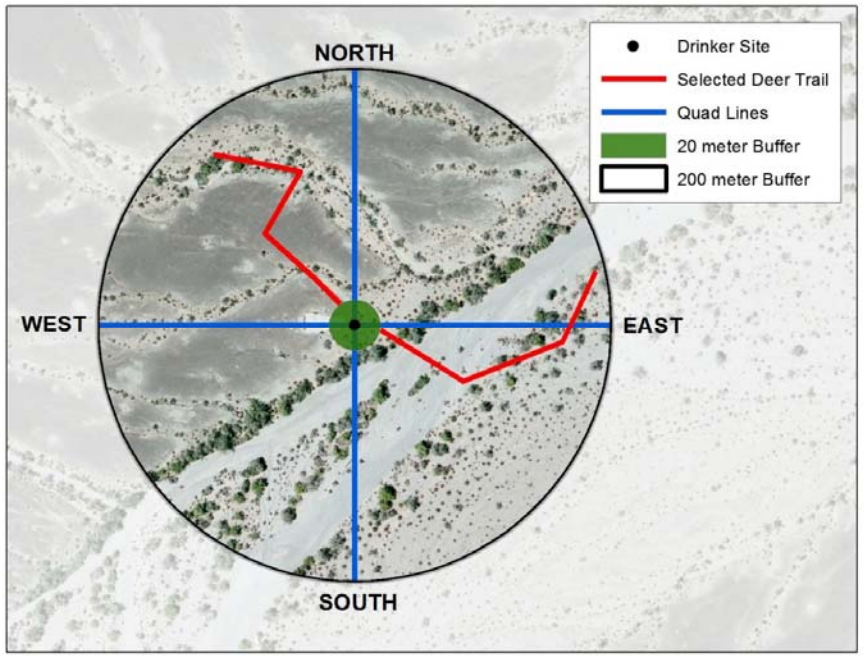
Guzzler

- During hot summer months, deer congregate around artificial water sources (guzzlers).
- Ideal locations for sampling.

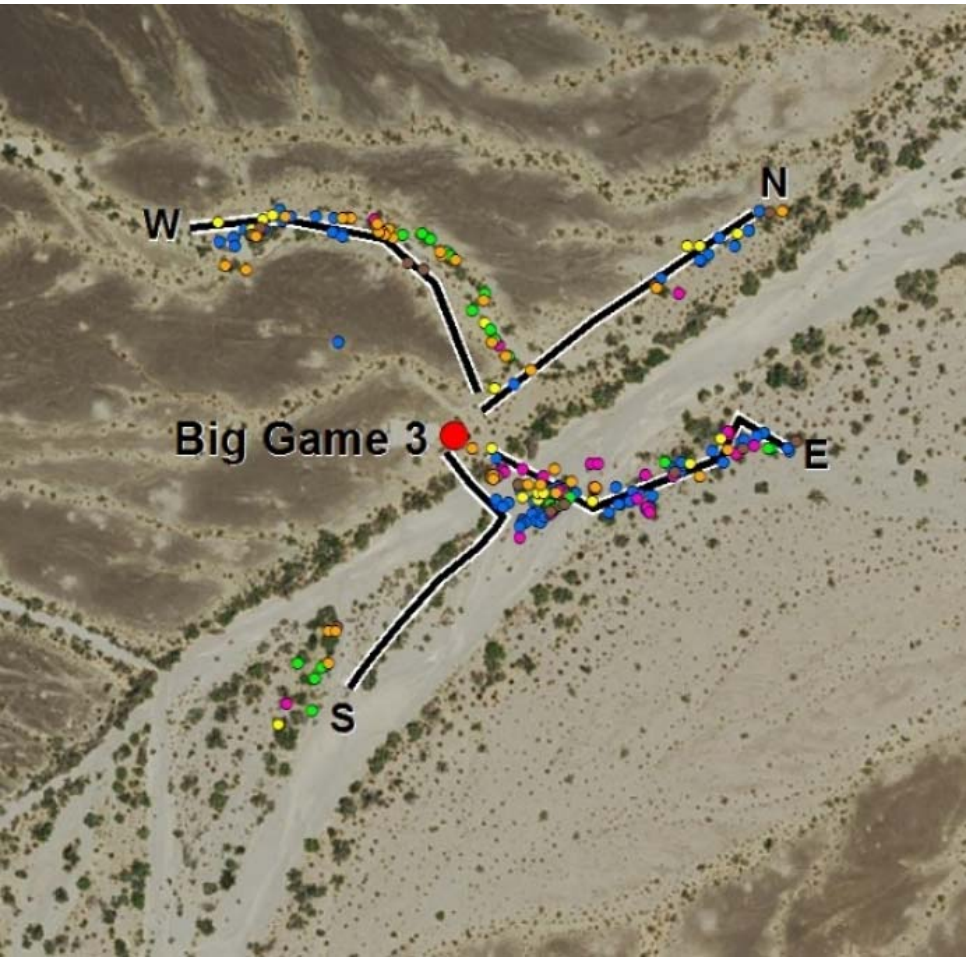


Sampling Design

- 2-4 Transects per drinker
- 250m long X 2m wide
- Each transect sampled
- Six sessions
- 5–7 day sampling intervals



1. DNA extracted from surface of fecal pellets.
2. Unique individuals are identified.
3. Capture histories along with capture and re-capture rates are constructed for each unique individual.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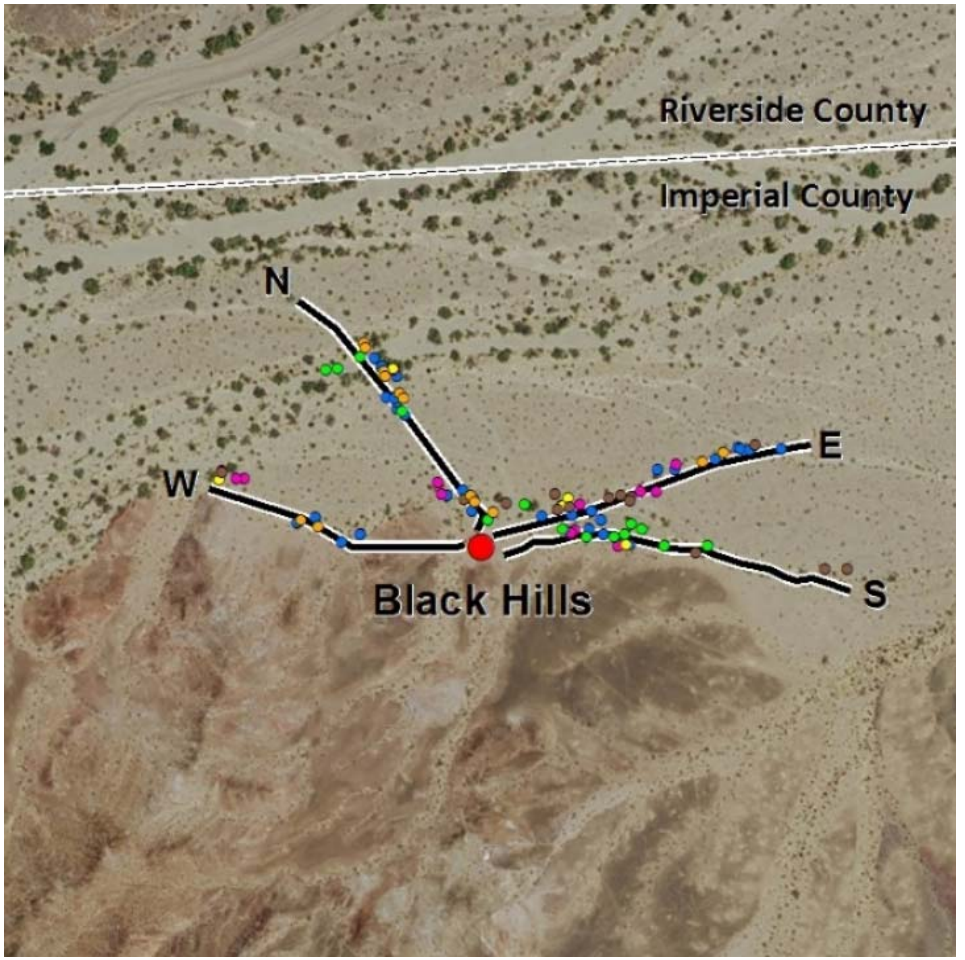
Riverside County
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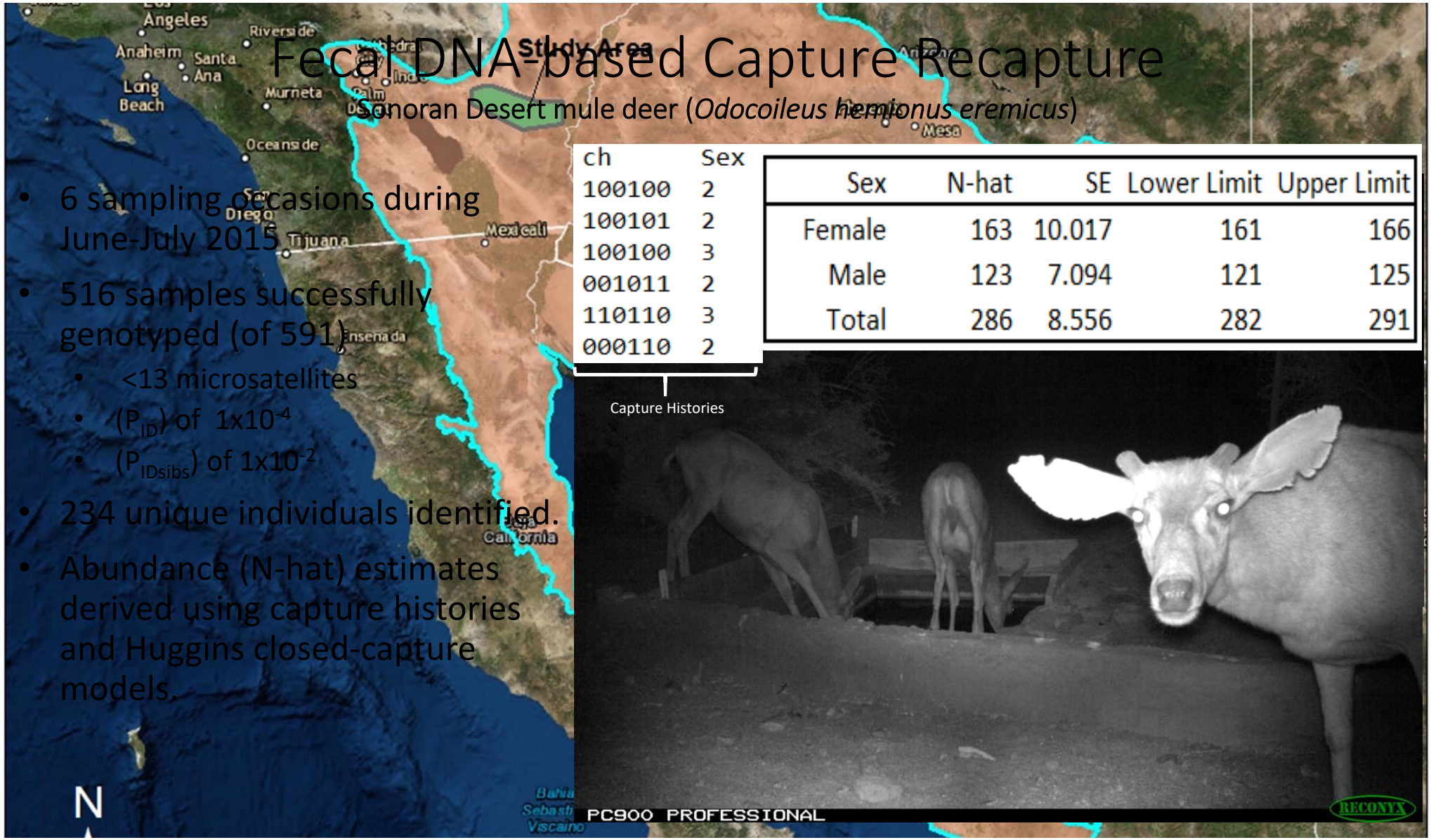
Fecal DNA-based Capture Recapture

Sonoran Desert mule deer (*Odocoileus hemionus eremicus*)

- 6 sampling occasions during June-July 2015
- 516 samples successfully genotyped (of 591)
  - <13 microsatellites
  - (P_{ID}) of $1x10^{-4}$
  - (P_{IDsibs}) of $1x10^{-2}$
- 234 unique individuals identified.
- Abundance (N-hat) estimates derived using capture histories and Huggins closed-capture models.



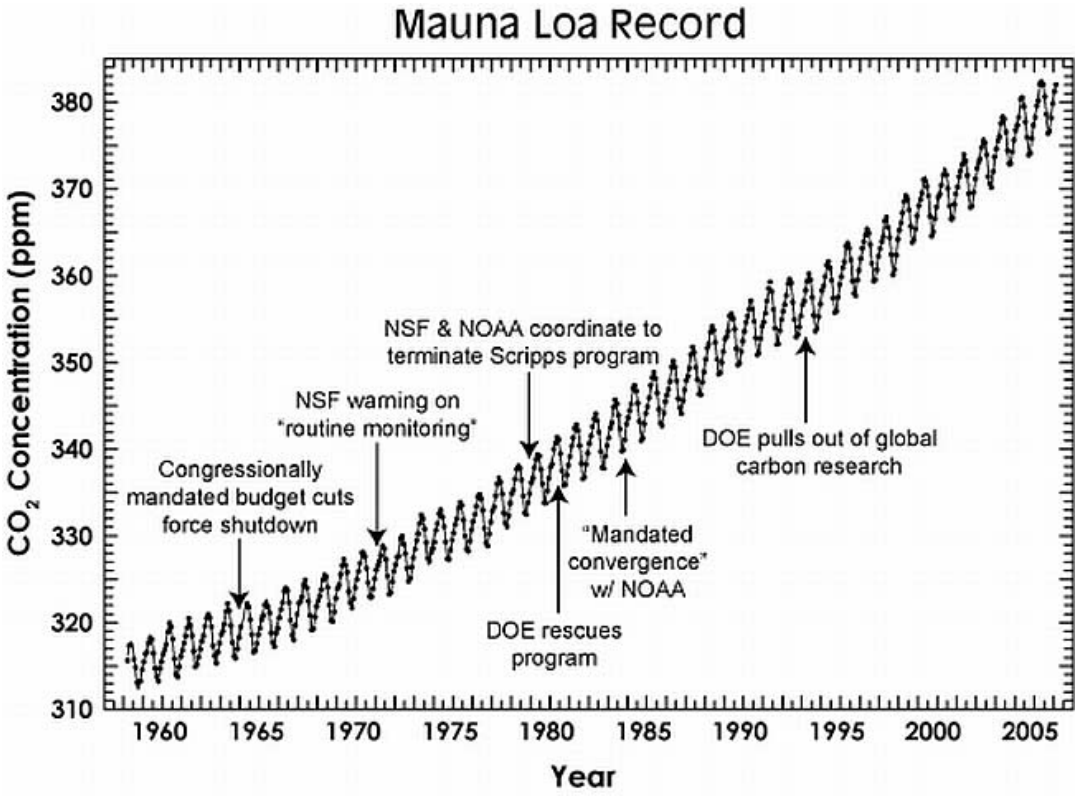
ch	Sex
100100	2
100101	2
100100	3
001011	2
110110	3
000110	2

Capture Histories

Sex	N-hat	SE	Lower Limit	Upper Limit
Female	163	10.017	161	166
Male	123	7.094	121	125
Total	286	8.556	282	291

Environmental change and long-term monitoring

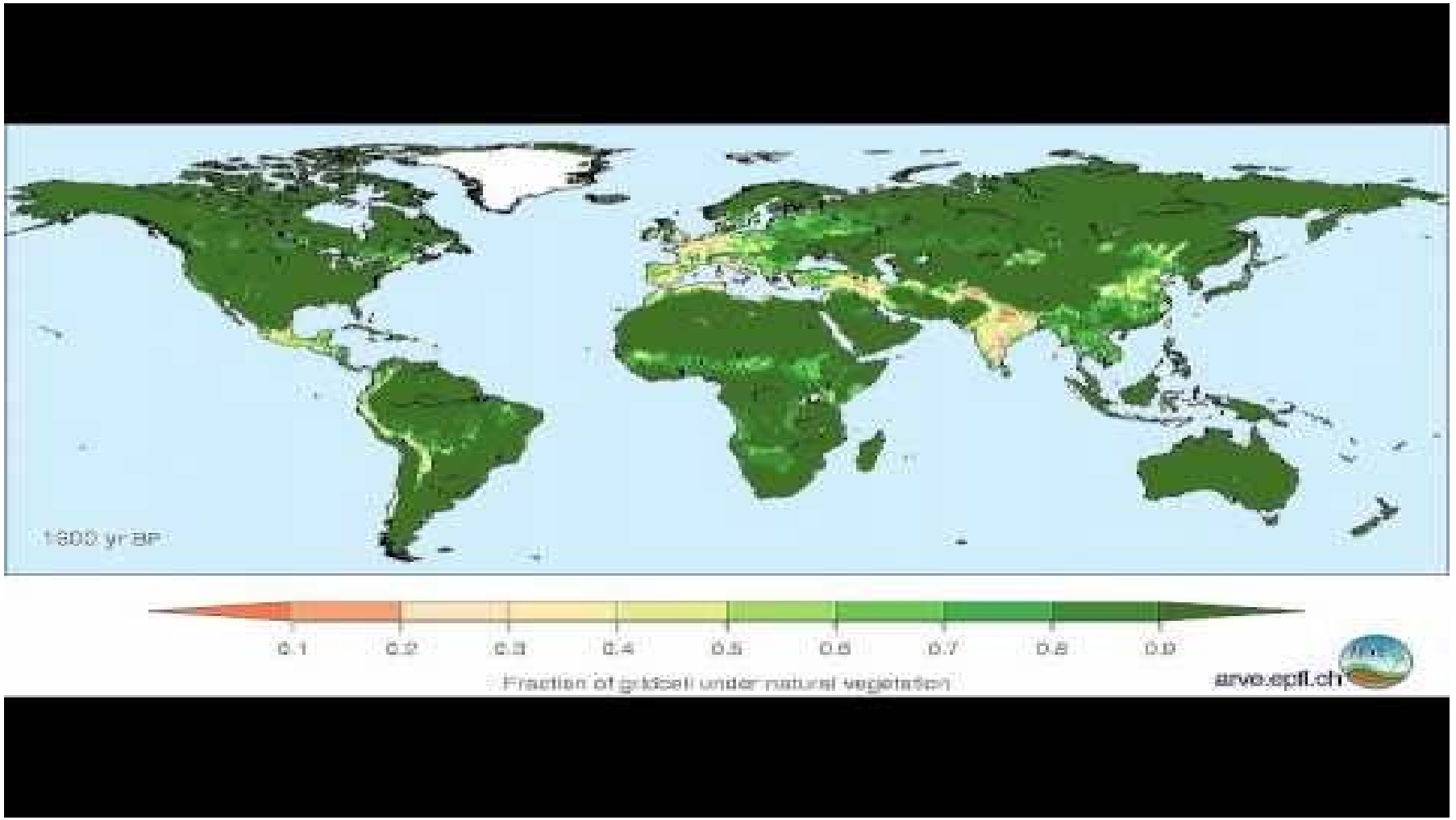
Long-term monitoring/historical records



Source: http://scrippsco2.ucsd.edu/history_legacy/keeling_curve_lessons

Sources of historical inference:

- Pollen
- Ice and sediment cores
- Pack rat middens
- Human records


1800 yr BP
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Fraction of gridcell under natural vegetation
arve.epfl.ch

Indications of environmental change

- Physical changes (human development, climate)

Source: http://waterandpower.org/Historical_DWP_Photo_Collection_LA_Public_Library/LA_Aerial_1887.jpg

Source: https://northvancouverhomes.files.wordpress.com/2013/06/p1060286.jpg

Source: https://upload.wikimedia.org/wikipedia/commons/b/ba/Los_Angeles_River_channelized.jpg

Indications of environmental change

- Physical change (human development, climate)
- Biological changes
  - Community structure and similarity
  - Species diversity and species introductions/invasions
  - Ecological succession
  - Ecosystem function (e.g., production of resources)
  - Ecosystem structure

Community structure

- **Dominant plant species:** those which are most influential, controlling structure and species composition by affecting physical and chemical factors
- **Stratification:** layering of species within the community
- **Dispersion:** layout of individuals; random, clumped, uniform
- **Trophic structure:** primary, secondary, tertiary consumers, primary producers
- **Temporal distribution**: diel to seasonal changes in species composition or activity

Species diversity

- α – local diversity (point, within habitat, within community)
- β – turnover of species among communities in region
- γ – regional diversity (basically, $\alpha + \beta$)
- Shannon Index: $\mathrm{H}' = -\sum p_i \log p_i$
  where p_i is the proportion of the total number of individuals that belong to species *i*
- Evenness (equitability): $J' = \frac{H'}{H^{max\prime}}$ where $\mathrm{H}_{\mathrm{max}}$ is H' where all species are equally abundant

Δ in Species

- Indicator species
- Focal species
- Keystone species

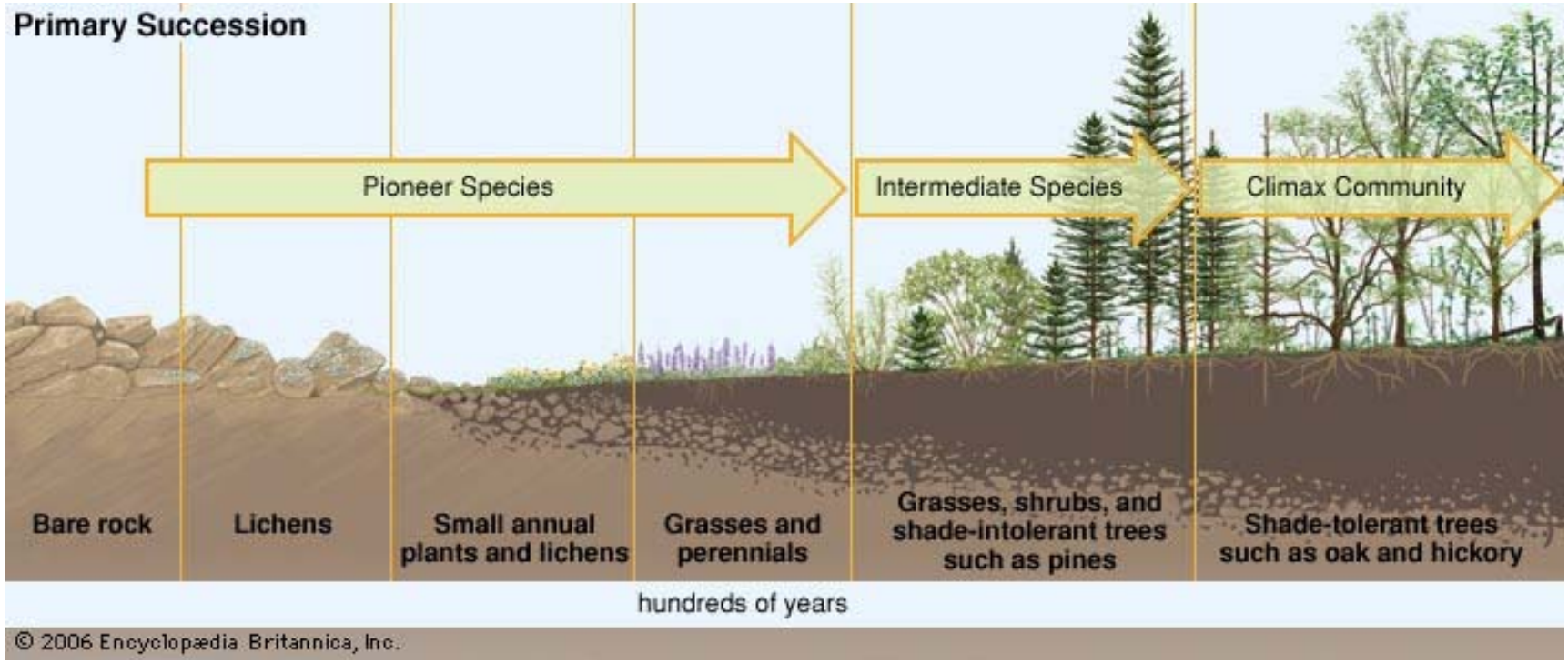
Source: https://www.sanelijo.org/sites/sanelijo.org/files/Least%20Bell%27s%20Vireo.jpg

Source: http://d2fbmjy3x0sdua.cloudfront.net/cdn/farfuture/jcw8wf0mNel5ooeWimkmZXWxPYhiXpxKnLYPbPyOCd0/mtime:1422549627/sites/default/files/Yellow_Warbler_s36-32-112_l_1.jpg

Source: http://www.eeb.ucsc.edu/pacificrockyintertidal/images/target_pisaster03.jpg

Source: https://www.montereybayaquarium.org/-/m/images/animal-guide/marine-mammals/sea-otter-mom-pup.jpg

Ecological Succession



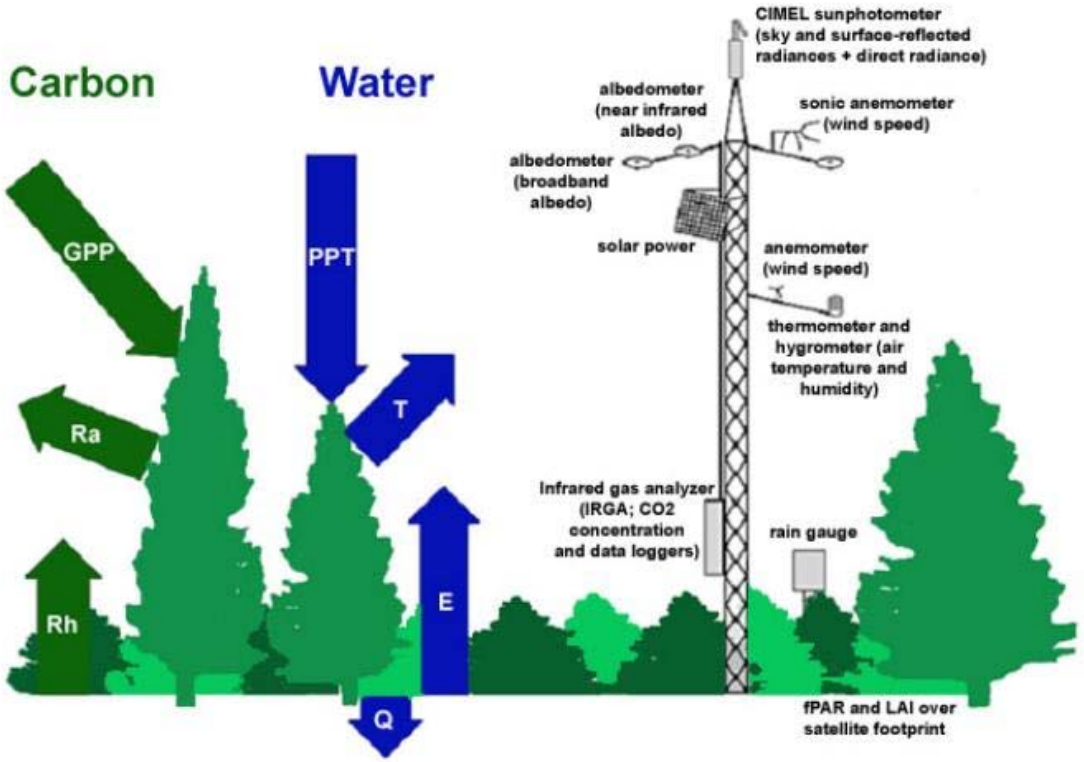
Source: https://media1.britannica.com/eb-media/97/95197-004-7F9B8F09.jpg

Production

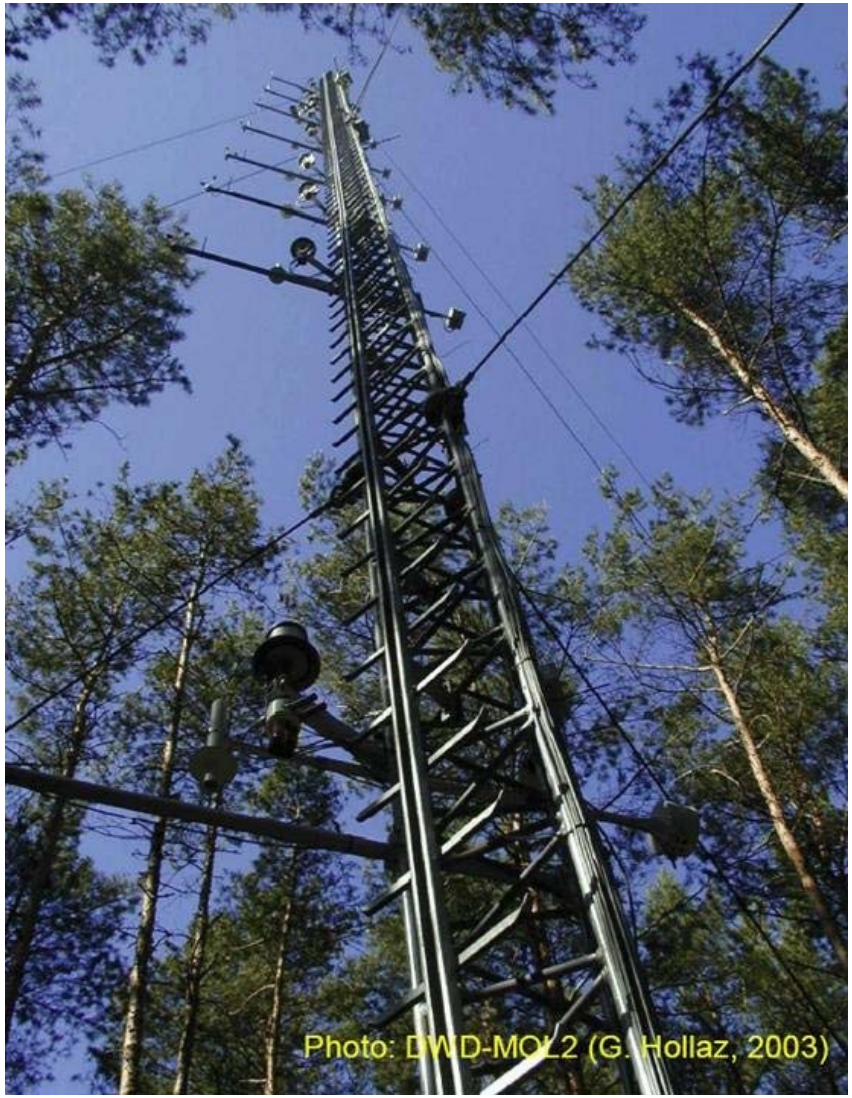
- **Biomass:** the weight of living organisms
- **standing crop**: the biomass present, typically expressed as weight of a species per unit area at a particular time
- **Production:** amount of biomass produced over a given time
- **Productivity:** rate of biomass production per unit time
- **gross primary production (GPP):** amount of organic matter photosynthesized by the autotrophic organisms in the ecosystem
- **net primary production (NPP):** amount of organic matter photosynthesized by the autotrophic organisms in the ecosystem minus the amount of biomass lost by the producers due to respiration
- **secondary production:** biomass accumulated in organisms feeding on primary producers

Long term monitoring

Figure 5. Configuration of a Typical Fluxnet Tower



Source: http://www.ntsg.umt.edu/sites/ntsg.umt.edu/files/imce/Fluxtower_Configuration.jpg



Citizen science

- Long history (think Newton and Darwin)
- Potential to collect diverse data, widely dispersed in space and time, e.g. “bioblitz”

www.citizenscience.org

- Some projects may not be suitable for volunteers, e.g., complex research methods or requiring arduous or repetitive work
- Lack proper training may risk introducing bias into the data
- Members may lie about data, particularly if bounties are awarded as an incentive to participate