Integrating electronic tagging data

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Outline

- Most current packages offer spatially explicit options
- Estimation of movement *usually* via (conventional) tag data
- Several other forms of tag:
  - archival (require recovery & reporting)
  - satellite (sends often detailed time/location data)
  - acoustic (detections from an array of receivers)
- Increasing array of electronic tag data being collected
- How can we include e-tag data in integrated assessments?

What assessment processes can they inform?

- **Archival**:
  - With reporting rates: mortality (F & M)
  - Migratory behaviour over time-at-liberty
- **Satellite**:
  - Often detailed movement history
  - If feasible to "condense" clear movement information
  - Tag and natural mortality information
- **Acoustic**:
  - Potentially information on total mortality ($F + M$)
  - Does require estimation of observation probability
  - With "spread" detection array movement information

Generic challenges

- Each data source would have different requirements
- Not feasible to do a single e-tag “module”
- Data “compression”:
  - Assessments (usually) spatiotemporally discrete
  - Archival/satellite “tracks” need discretising
  - Acoustic detections summarised at assessment scale
- Representation of uncertainty of “where” & “when”
- Integrating suitable covariates for movement models

Case studies

- **Southern bluefin tuna**:
  - Data: conventional/archival tags & catches
  - Parameters: M, F, seasonal movement & abundance
  - Scale: 2 seasons & 4 regions
- **South Pacific Striped Marlin**:
  - Data: conventional and satellite tagging data
  - Parameters: movement *only*
  - Scale: quarterly in time & 2 regions

Movement model

- Most use spatial transition matrix: $\mathbf{\Phi}$
- With R regions is an $R \times R$ matrix
- Closed system so rows sum to 1 ($\sum_i \Phi_{i,j} = 1$)
- For starting region r_0 set $\mathbf{u}_{r_0} = 1$, zero elsewhere
- Movement dynamics are simple:

$$\mathbf{u}_t = \mathbf{u}_{t-1}\mathbf{\Phi}$$

- Now $\mathbf{u}_t = \mathbb{P}\left(r_t \,\middle|\, r_0\right)$
- This will form basis for likelihoods for all e-tag data

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Movement likelihood structure

- This will vary depending on type of tag
- "Simplest" case is satellite tag
- General idea:
  - Have n_e individual tag histories $r_{t,i}$
  - Time sequence of regions, $r_{t,i}$, for tag i
- Likelihood product of probabilities of sequence of locations:

$$\Lambda^e = \prod_{i=1}^{n_e} \prod_{j=1}^{T_i} \mathbb{P}\left(r_{t_j,i} \,|\, r_{t_{j-1},i}\right)$$

- Conditional bit accounts for "track" history
- Wrinkle: it won't always be definitive "where" tag was...

Dealing with uncertainty of region in time

- For many cases, $r_{t,i}$ is going to be uncertain
- Fine-scale dynamics & imprecision of location key factors
- Tag imprecision: filtering algorithms can quantify uncertainty
- Fine-scale dynamics: again, uncertainty can be quantified
- Goal: combine to generate probability of region in time, $\pi_{t,i,r}$
- Integrate across this in modified likelihood:

$$\Lambda^e = \prod_{i=1}^{n_e} \prod_{j=1}^{T_i} \left(\sum_{k=1}^{R} \sum_{l=1}^{R} \mathbb{P}\left(k_{t_j,i} \,|\, l_{t_{j-1},i}\right) \mathbb{P}\left(l_{t_{j-1},i}\right) \pi_{t_j,i,k} \right)$$

- Efficient to recast as a Hidden Markov Model (HMM)

Archival and acoustic modifications

- Archival tags (with reporting rates):
  - Include survival and recapture probabilities
  - Survival included between position observations
  - Recapture/reporting probability at point of capture
  - Likelihood: spatial Brownie with track history bit
- Acoustic tags:
  - Needs survival and observation probabilities
  - Survival included between position observations
  - Observation probability at each position observation
  - Efficient to cast as an HMM
  - Observations: alive & detected in given region

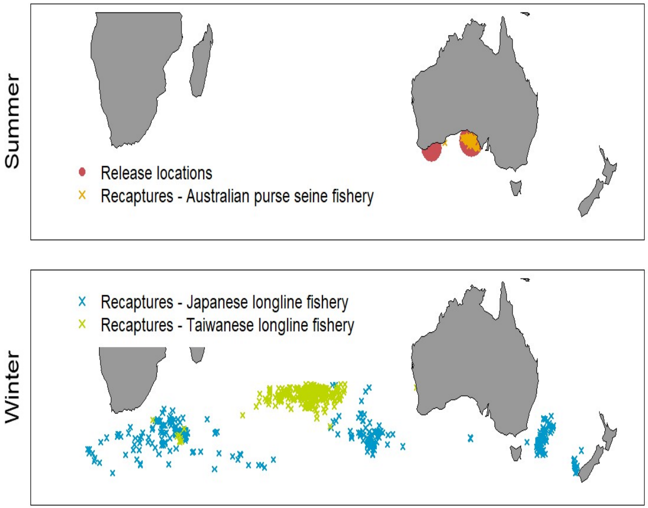
Southern bluefin tuna

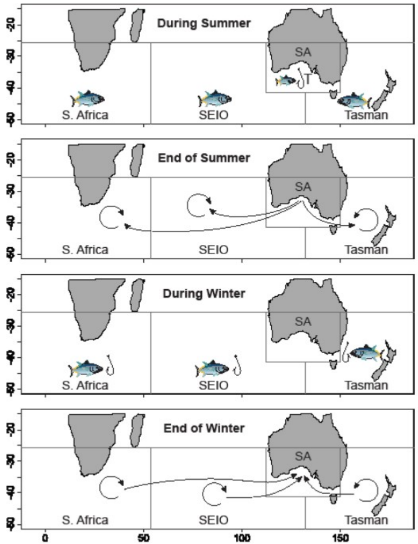
- Focus on simulation study exploring utility of archival tags[1]
- Data sources:
  1. Conventional tags
  2. Archival tags
  3. Catch-at-age
- Main questions:
  1. Do we need archivals to estimate M, F and Φ?
  2. How do the data sources inform the different parameters?

[1] Eveson, J. P., Basson, M., and Hobday, A. J. (2012) Using electronic tag data to improve mortality and movement estimates in a tag-based spatial fisheries assessment model. *CJFAS*, **69**:1–15

SBT spatiotemporal structure

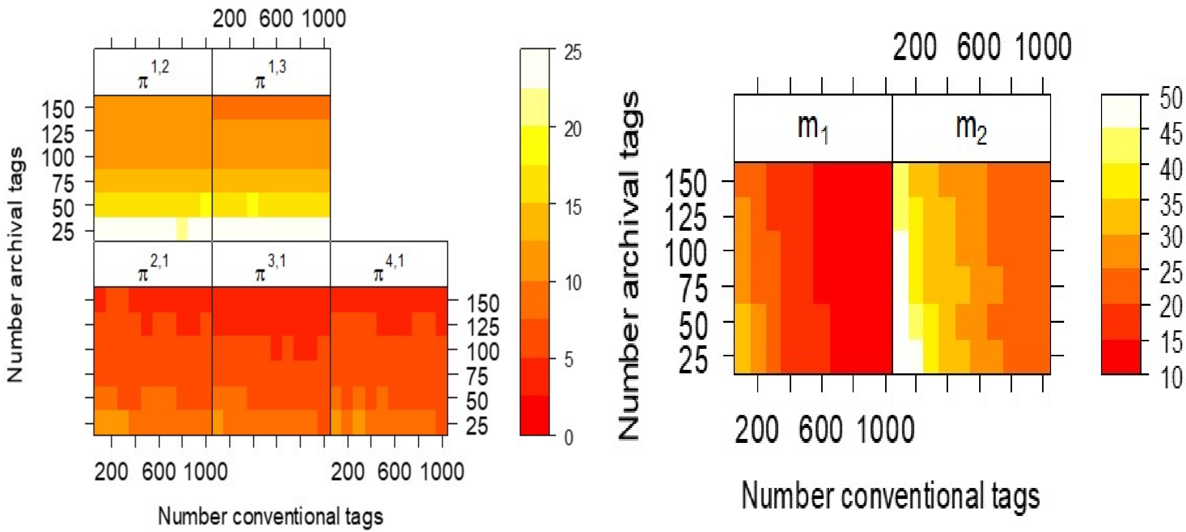
- Conventional tags (left) & spatiotemporal structure (right):





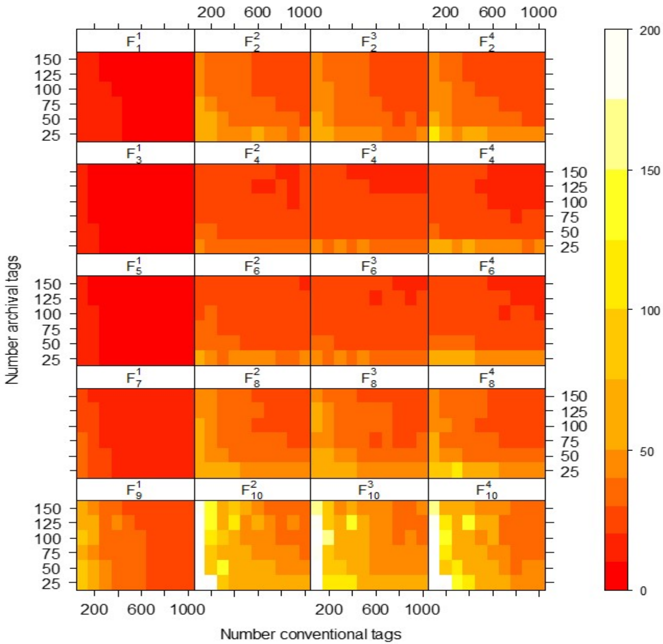
Data scenarios & CV of key parameters

- CV estimates for movement (left) & M (right):



Data scenarios & CV of key parameters

- CV estimates for F:

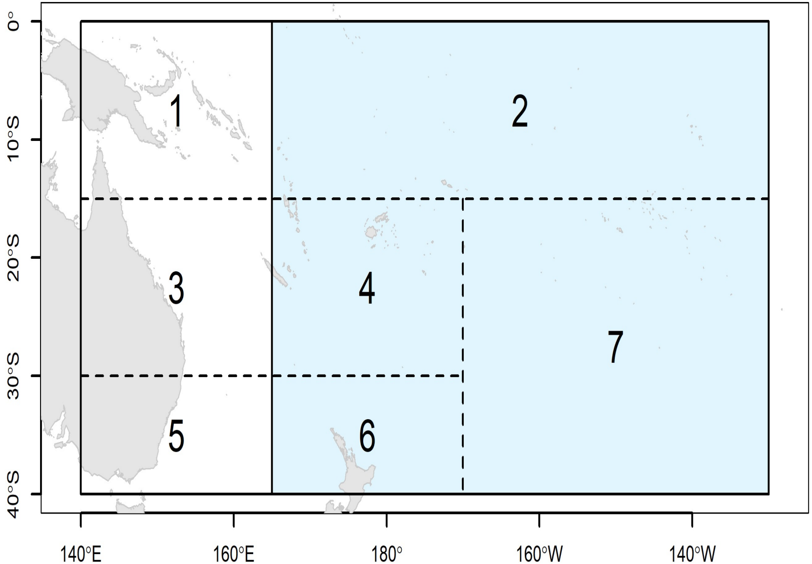


SBT case study summary

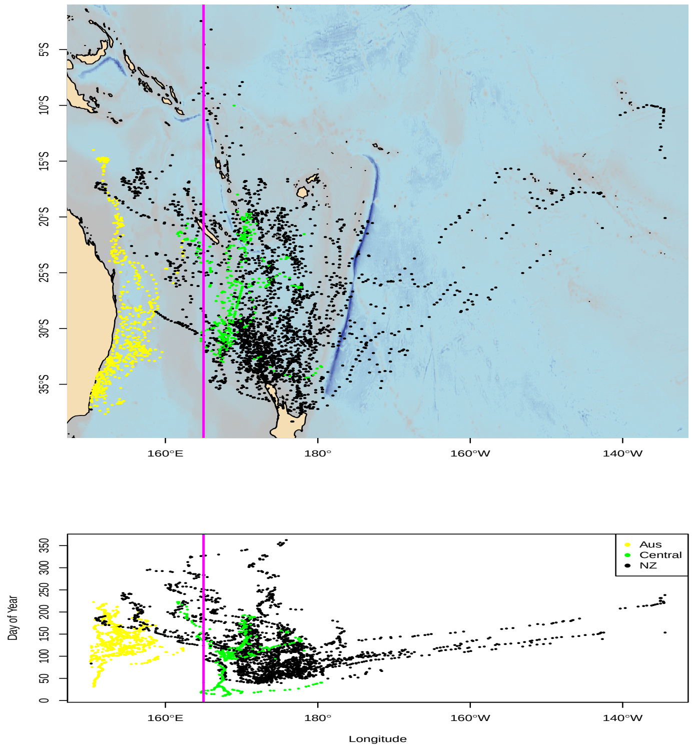
- Clearly archival tags *can* be informative
- Hard to estimate M, F & Φ without them
- Especially when releases are not spatially homogeneous
- Archivals are key to separating movement from mortality

South Pacific Striped Marlin

- Question: quarterly movement probability across 165E
- Spatial structure of the model:



Striped Marlin PSAT tracks (73 fish)



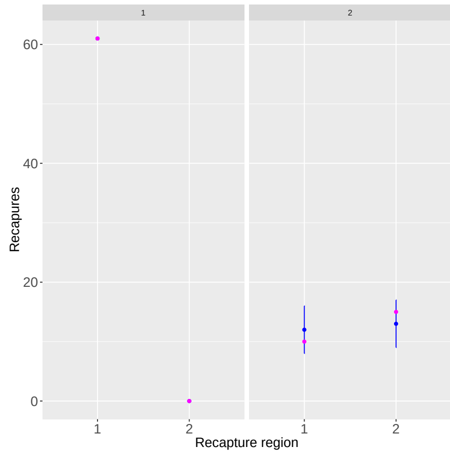
Striped Marlin Data

- PSATs:
  - 2 AU releases, 19 NZ releases 90+ days-at-liberty
  - 0 AU rel. go W$\rightarrow$E; *ca.* 30% NZ rel. cross E$\rightarrow$W boundary
- Conventional tags:
  - As with PSATs 90+ days-at-liberty (max. 4 years)
  - Use recaptures **only** (forget about M, F, shedding etc.)
  - Likelihood same as PSAT with 1 obs. post release
  - Minor tweak for relative rep./recap. rate by region

Release Area	Region 1	Region 2
Recapture Area		
Region 1	61	10
Region 2	0	16

Striped Marlin estimates

- Credible intervals (95%) for movement parameters:
  1. W$\rightarrow$E ($\Phi_{1,2}$): 0.001 (0–0.004)
  2. E$\rightarrow$W ($\Phi_{2,1}$): 0.14 (0.09–0.21)
- Predictive intervals for conventional tags:



Summary

- No technical impediment to including e-tag data
- Some obvious possible groupings:
  1. Archival tags with reporting rates
  2. Satellite and archival (without reporting rates) tags
  3. Acoustic tags
- Likelihood ingredients already in spatial models
- Obviously not immune to "wacky" dynamics or field work choices
- SBT example: conventional/archivals disentangle M, F & $\mathbf{\Phi}$
- STM example: conventional/PSAT make $\mathbf{\Phi}$ estimable

Thank You

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