Incorporating electronic tagging in stock assessment

Spatially-explicit integrated assessment models and experimental design

Indian Ocean Tuna Tagging Symposium – IOTC
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1) NOAA-SWFSC; 2) SPC; 3) IATTC; 4) NOAA-PIRO

Presentation Structure:

Current state of spatially explicit integrated assessment models and electronic tagging

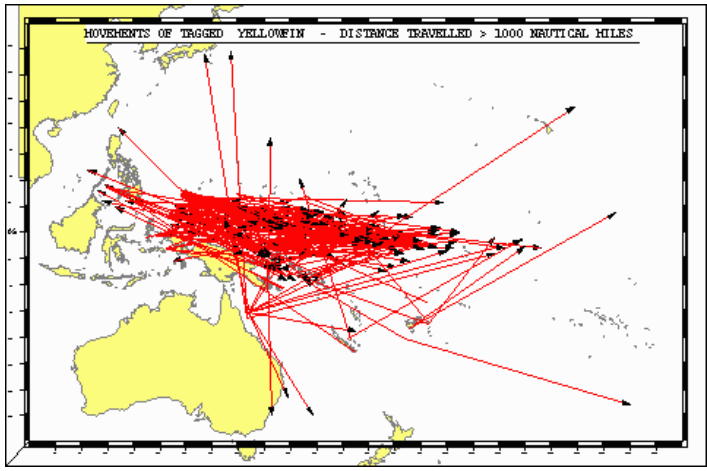
- Spatially-explicit integrated assessments
- Tagging of HMS
- ET movement analysis
- Assumptions
- Experimental design
- Conclusions and opportunities

Stock Assessment (SA) models

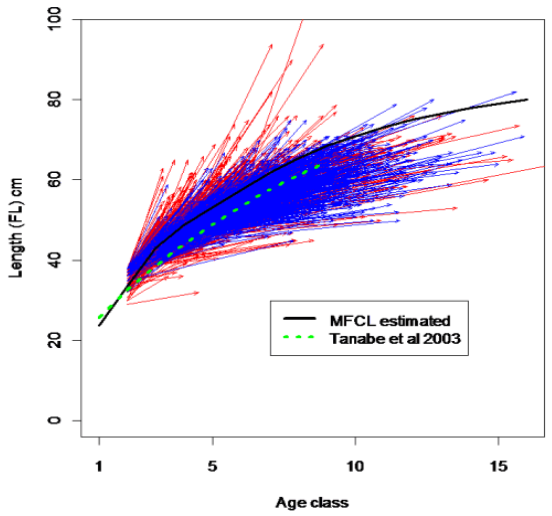
- Integrated models
  - Composite likelihoods
  - Maximize information content of data
  - Many examples
- Spatially-explicit integrated models
  - Composite likelihoods, maximize info content
  - Allows for spatial stratification & movement
  - Inspection of spatial domain subsets
  - MULTIFAN-CL, Stock Synthesis, CASAL, etc.

Decades of tagging data for HMS assessment *

- Skipjack Survey and Assessment Programme (SSAP, 1977-1981)
  - Conventional tagging (CT)
  - Ground-breaking for HMS
- Regional Tuna Tagging Programme (RTTP, 1989-1992)
  - CT
  - Underpinned development of MULTIFAN-CL
- Pacific Tuna Tagging Programme (PTTP, 2006-present)
  - Both CT and electronic tagging (ET)
- Indian Ocean Tuna Tagging Programme (IOTTP)
- ICCAT - GBYP
- Other examples, including sub-projects of above programmes



Top: RTTP - yellowfin recaptures *
Bottom: Growth rates *

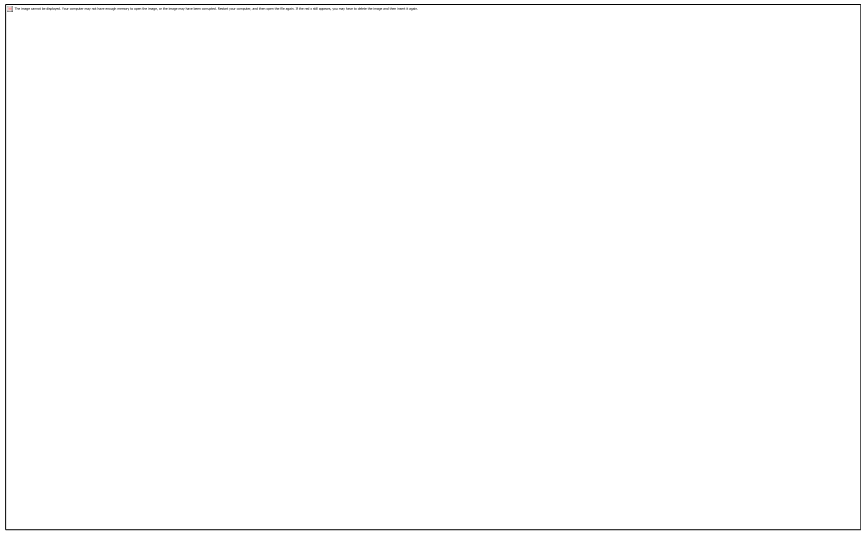


* Source: SPC Pacific Tuna Tagging (http://www.spc.int/tagging/en/programs)

Electronic tagging (ET)

Electrically powered (battery, solar, etc), multiple sensors (temperature, light, etc), flash memory

- Extensive datasets
- Information content per tag much higher than CT
- Movement & behavior (spawning)
- Many, many millions already spent
- Not currently used in SA, why?
  - SA frameworks built for CT, not ET
  - Unbalanced experimental design
  - Proprietary and not accessible
  - Assumptions



Block et al. 2011. *Nature* (475) 86-90

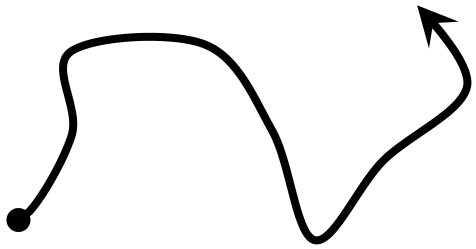
Examples of ET and S.A. – Pop. Dy.

- Outside SA model – block transfer, PSAT and CT (Evans et al. 2012)
  - Testing 3 hypotheses about swordfish movement process (bounded & unbounded diffusion, site fidelity)
- Integrated: Spatial Brownie-Peterson (hybrid abundance-mortality model)
  - Designed with CT in mind (Eveson et al. 2009)
  - Adapted for IAT (Eveson et al. 2012)
    - Instantaneous block-transfer (end of each quarter)
    - Assumes fish move independently of one another
- Integrated: MAST (Taylor et al. 2011)
  - IAT, PSAT, CT – plus CPUE, age, etc.
    - Instantaneous block-transfer (end of each quarter)
- Integrated: SEAPODYM (Lehody et al. 2008, Senina et al. 2008)
  - Ecosystem model
  - Continuous space-time
  - Probability densities, not trajectories

Tagging data - movement

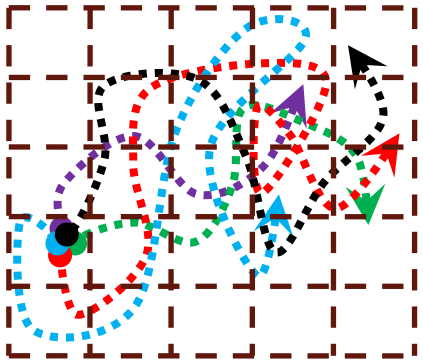
- Individual base models (Sibert et al. 2003, etc.)
  - Intermediate positions
- Scaling up from individuals to populations
  - Advection-diffusion-reaction (ADR) models (Sibert et al. 1999)
- Population-level movement models
  - Block-transfer (Beverton & Holt 1957)
    - Straight-forward, but can rapidly become highly parameterized
  - Continuous space-time (Skelam 1951)
  - Movement process…

Lagrangian



- focus on individual path
- state variables: latitude / longitude

Eulerian



- focus on collective
- state variables: abundance field

Movement and process models

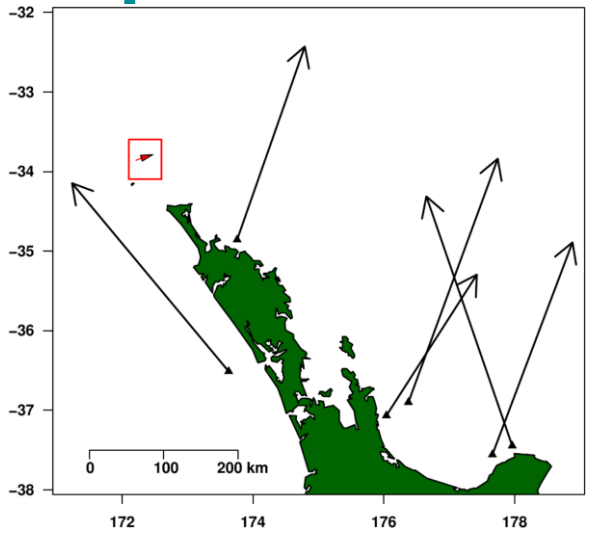
- Movement models (Patterson et al. 2009, Nathan et al. 2009)
  - Biological states (eg. spawning, migrating, foraging)
  - Correlated random-walks (default), Levy-walk (scale-free), attraction point (Orenstein-Uhlenbeck)
- Process models
  - Markov process
  - Bayesian
- Underpins incorporation of movement dynamics important to stock assessment (eg. spawning) – inside or outside SA model?
- Challenging…

Problems and Questions

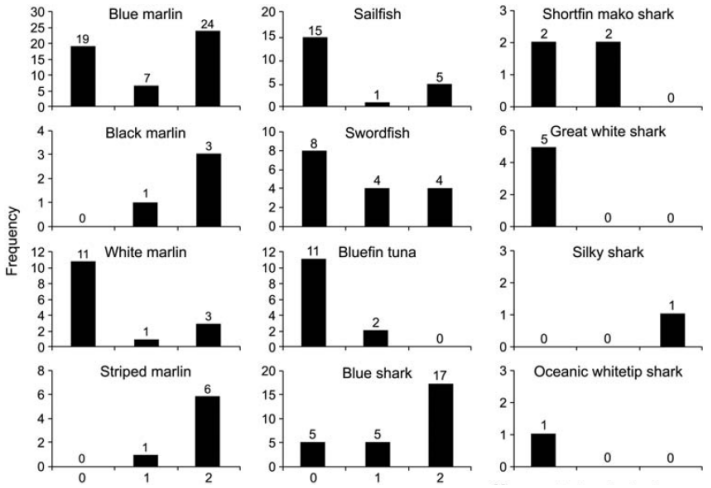
- Modeling movement outside model useful, but misses value of full integration
- Movement is a continuous process, are block-transfer models sufficient?
- Movement process: not a one-solution fits all problems situation
  - Independence: schooling vs. non-schooling fish
  - Fidelity: regular or irregular movement patterns
  - Requires SA model flexibility
- What processes are germane to SA?
- Stratifying and scaling models with tagging data

Mixing and behavior assumptions

- Assumption: tagged fish mix randomly with and behave like untagged population
- Behavior modification
  - Free-tagged striped marlin behaved differently than hook & line caught (Sippel et al. 2011)
    - Experimental control
  - Observed across multiple taxa (Hoolihan et al. 2011)
- Fish condition factors
  - SBT (Hampton 1986)
    - Initially diminished condition post-tagging
  - Feeding probability effected by tagging
    - SBT - Bestley et al. 2008
    - Striped marlin - Sippel et al. 2011



Controlling for capture effects (Sippel et al 2011)

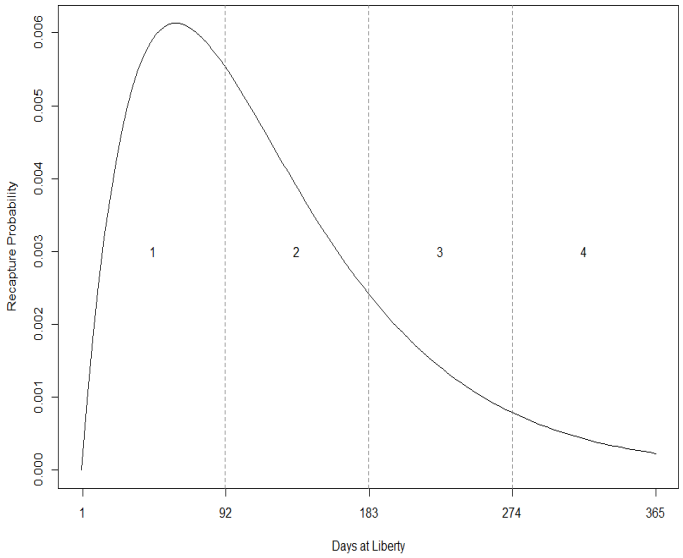


Perturbed behaviour scores - Hoolihan et al. 2011

Experimental design

- ET seldom conducted with SA in mind
  - Opportunistic deployments
  - Unbalanced sampling
  - Inadequate sample size
  - Data gaps
- Consequences
  - Movement parameters imprecise, biased, or not estimable
  - Costly to collect more data to fill in gaps (under/over sampling)

* Sample size requirements increase geometrically (not arithmatically) with more SA space-time strata



Hypothetical probability of recapturing a tagged fish (or tag transmitting) with respect to time at liberty, assuming quarterly time strata (denoted by numbers and vertical lines).

ET data management and access

- Problems
  - Data volumes
  - Many different data formats
  - Long-term legacy data availability
  - Access to data
- Data management solutions
  - Tagbase (Lam and Tsontos 2011, open-access http://code.google.com/p/tagbase/)
  - CSIRO (Hartog et al. 2009, proprietary development)
  - IOTTP (Julien Barde)
- Data access still challenging…
  - Existing data widely distributed and proprietary

Conclusions

- ET and integrated spatial assessments evolving in parallel, but independently
- Opportunities
  - Expand upon ET research designed for SA
    - More balanced deployments (better for ecology too)
    - Ideal vs. practical – simulate ideal and modify based on experience (SEAPODYM functionality being developed for this)
    - Experimental controls in tagging
    - New tags designed for needs of SA (pop-off CT)
  - Movement and process models appropriate to SA with ET
  - Tagging data shared more like fishery data for SA

Acknowledgments

Contributors:

Participants in IATTC Electronic Tagging and Stock Assessment Symposium 2011

Paige Eveson, Ben Galuardi, Tim Lam, Vardis Tsontos, Felipe Carvalho, Alex Aires-da-Silva, Simon Hoyle

Funding:

Methods and data repositories

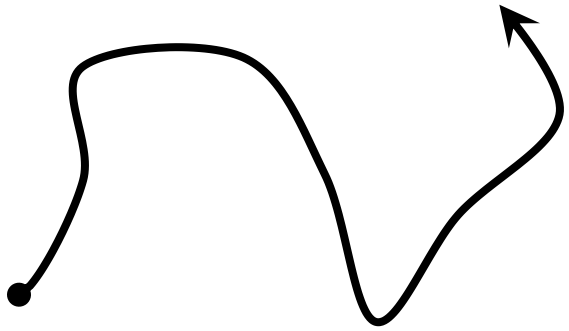
- Method development environments (open-source)
  - ADMB: well suited to non-linear and highly parameterized problems (www.admb-project.org)
    - Already underpins SS3, MULTIFAN-CL
  - R: good for data manipulation and visualisation (www.r-project.org)
    - Packages: R2admb, PBSadmb, etc.
- 'Holotype' reference datasets (both real and simulated)
  - Reference to characteristics of important behavior (spawning)
  - Simulate 'ideal' and 'realistic' data
- Propose central locale for reference methods and data
  - www.fisheriesstockassessment.com (Mark Maunder's page) ???

Model inputs and structure

- Biological data
  - Growth-curves and size data, aging, sex, etc.
- Fishery data
  - Catches, abundance indices (CPUE)
  - Generally longest time-series
  - Abundance indices problematic (difficult to standardize)
- Tagging data
  - Estimate abundance, mortality, growth, movement
  - Not commonly used, particularly movement (sample size, movement process)
  - Shorter, but less confounded time-series than CPUE
  - Key assumptions: random mixing, survivorship/behavior not impacted by tag, independent movement, 100% reporting
- Stratification: commonly quarterly over multiple spatial domains

Movement Models

Lagrangian



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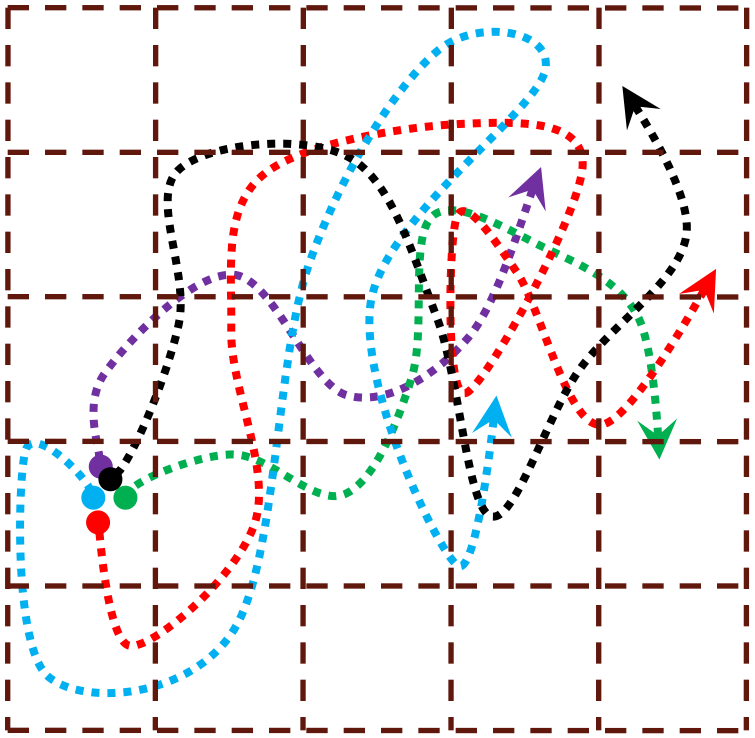

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Stock assessment models

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- Other examples, including sub-projects of above programmes

- Diffusion models, continuous time-space (Skellam 1951)
- Bulk-transfer (Beverton & Holt 1957)

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