Comisión Interamericana del Atún Tropical
Inter-American Tropical Tuna Commission

Incorporating results from tagging experiments into EPO regional stock assessments

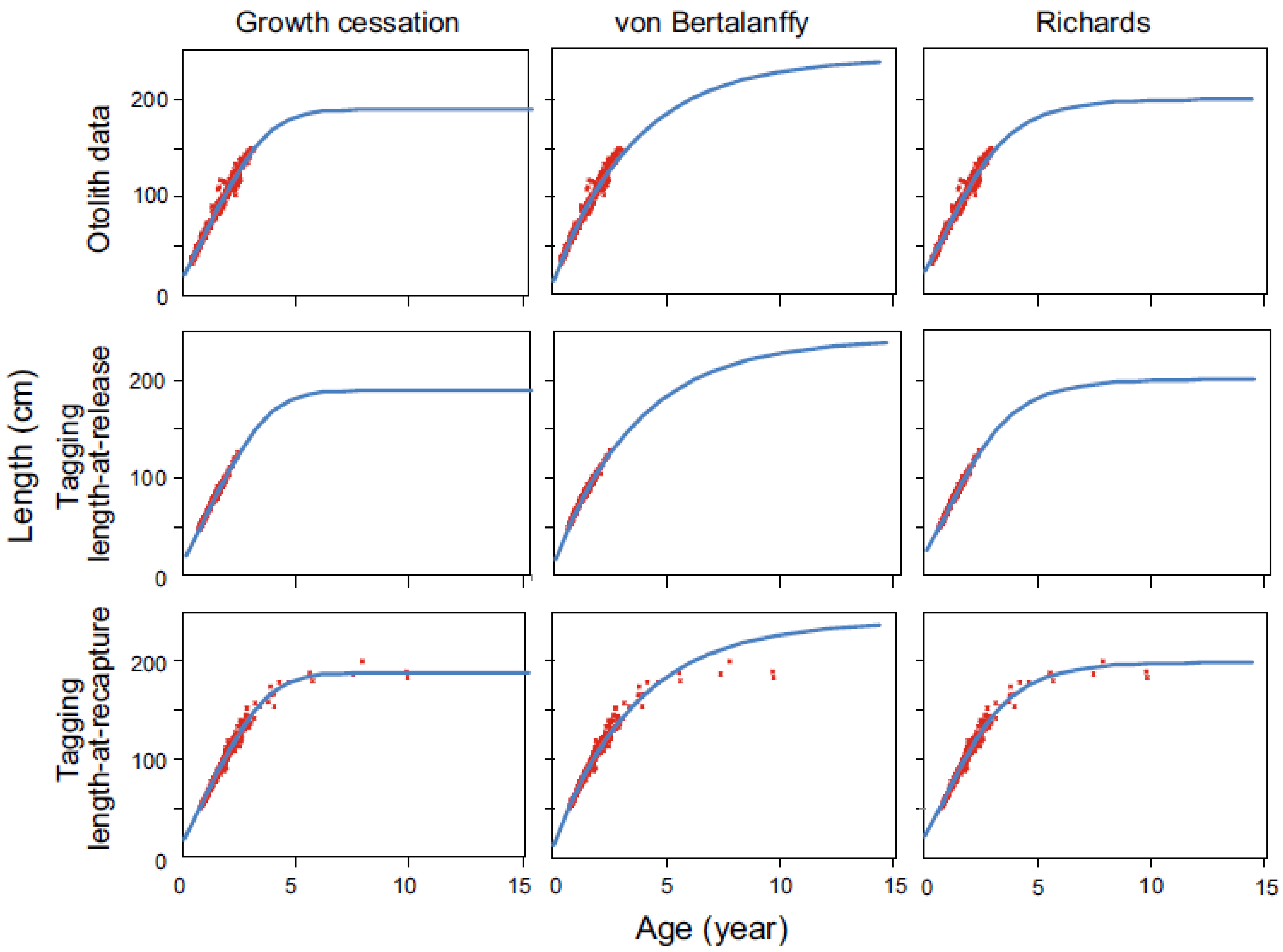
Outline

- Independent analyses
- Integrated assessment models
- Spatio-temporal modelling of tagging data

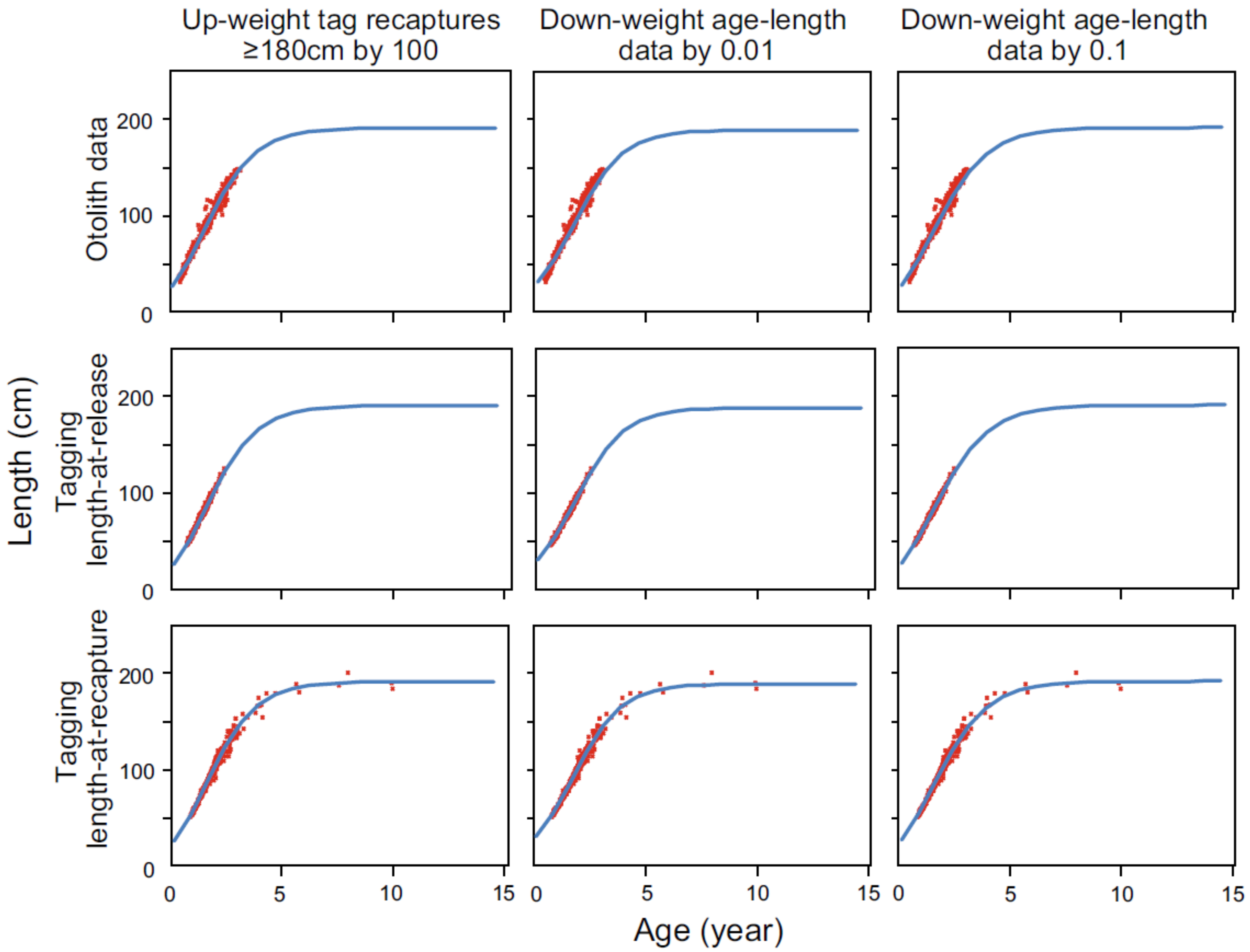
Independent analyses

- Analyze the data
- Include the results in a stock assessment as fixed parameters or priors
- Possible information
  - Absolute abundance/fishing mortality
  - Growth
  - Movement
  - Natural Mortality

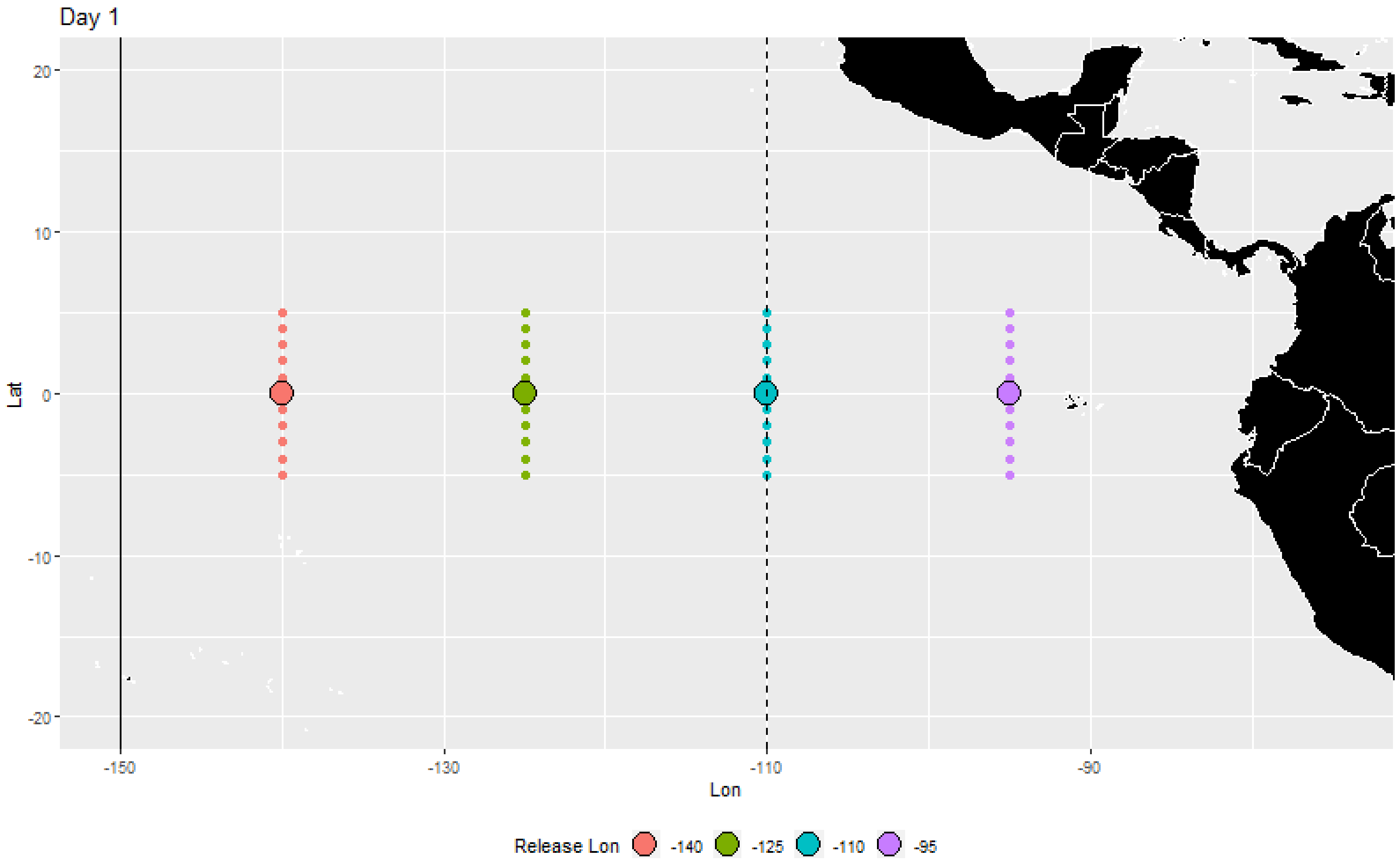
An improved growth curve using otolith and tagging data



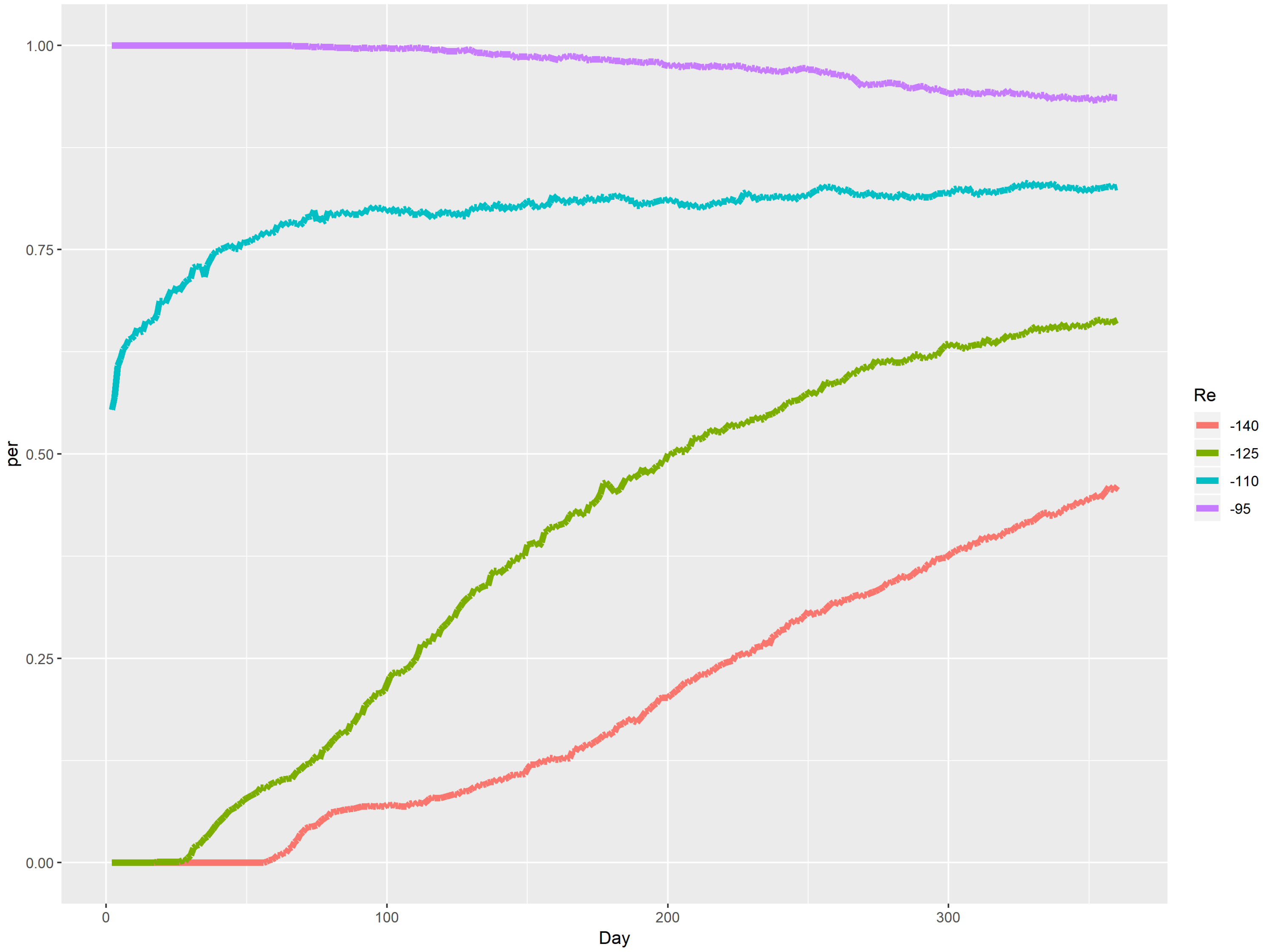
Richards in SS



Haikun’s movement



Haikun’s movement



Integrated assessment models

- Tag releases and recaptures at age (or length)
- Adjust for tag mortality
- Include priors for tag reporting estimates or estimate inside assessment

Stock Synthesis

- Data
  - Tag releases by group (area, sex, age, and year)
  - Tag recaptures by group, fishery (includes area), year
  - Mixing time
  - Accumulation time
  - -logL component for the distribution of recaptures across areas
    -logL component for the decay of tag recaptures from a group over time

Stock Synthesis

10.9 Tag Recapture Parameters

Specify if tagging data are being used:

Value	Label	Description
1	Tagging Data Present	0 = no read 1 = read following lines

COND = 1 Read the following long parameter lines:

#LO	HI	INIT	PRIOR	PRIOR SD	PRIOR TYPE	PHASE	...	LABEL
-10	10	9	9	0.001	4	-4	0	#TG loss init 1
-10	10	9	9	0.001	4	-4	0	#TG loss init 2
-10	10	9	9	0.001	4	-4	0	#TG loss init 3
-10	10	9	9	0.001	4	-4	0	#TG loss chronic1
-10	10	9	9	0.001	4	-4	0	#TG loss chronic2
-10	10	9	9	0.001	4	-4	0	#TG loss chronic3
1	10	2	2	0.001	4	-4	0	#TG loss overdisperion1
1	10	2	2	0.001	4	-4	0	#TG loss overdisperion2
1	10	2	2	0.001	4	-4	0	#TG loss overdisperion3
-10	10	9	9	0.001	4	-4	0	#TG report fleet1
-10	10	9	9	0.001	4	-4	0	#TG report fleet2
-4	0	0	0	0.001	2	-4	0	#TG report decay1
-4	0	0	0	0.001	2	-4	0	#TG report decay2

The tagging reporting rate parameter is transformed within SS during estimation to maintain a positive value and is reported according to the transformation:

$$\text{Tagging Reporting Rate} = \frac{e^{\text{input parameter}}}{1 + e^{\text{input parameter}}} \tag{35}$$

Spatio-temporal modelling of tagging data

- Deals with fine scale spatial variation
- Commonly used for modeling CPUE data
- TMB can be used to efficiently implement these types of models

Estimating abundance from tagging data

- Petersen
  - $\frac{r}{n_2} = \frac{n_1}{N}$
  - n_1 number of individuals tagged
  - n_2 sample size for the recovery data
  - r the number of tagged individuals recovered
  - N is the population size
- $\hat{N} = \frac{n_1 n_2}{r}$

Spatial estimates

Need to model movement of tagged individuals

- $\hat{N}_i = \frac{n_{1,i} n_{2,i}}{r_i}$
  - $n_{1,i}$ number of tagged individuals in area i
  - $n_{2,i}$ sample size for the recovery data in area i
  - r_i the number of tagged individuals recovered in area i
  - N_i is the population size in area i

Not all areas have tagged individuals so need to share information

Issues

- Need to model movement of tagged individuals
  - Advection diffusion model
  - e.g. Sibert et al. 1999. Can. J. Fish. Aquat. Sci. 56: 925-938.
- Need to share information on total abundance among space
  - Spatial-temporal model
  - e.g. Thorson et al. 2015. ICES J. Mar. Sci. 72: 1297–1310.
- The abundance of tagged fish changes over time
  - Multiple likelihood calculations for each area
  - e.g. Hilborn 1990. Can. J. Fish. Aquat. Sci. 47: 635–643.

Modelling “Assumptions”

- The total population is approximated using a spatio-temporal model
  - No explicit movement or fishing needed
- Movement of tags is the same in all areas

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Using spatio-temporal models of population growth and movement to monitor overlap between human impacts and fish populations

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Spatiotemporal variation in size-structured populations using fishery data: an application to shortfin mako (*Isurus oxyrinchus*) in the Pacific Ocean[1]

Mikihiko Kai, James T. Thorson, Kevin R. Piner, and Mark N. Maunder

Spatial delay-difference models for estimating spatiotemporal variation in juvenile production and population abundance

James T. Thorson, James N. Ianelli, Stephan B. Munch, Kotaro Ono, and Paul D. Spencer

Thank you!

Advection diffusion model of tagged individuals

Thorson et al. 2016. J. Appl. Ecol. 54: 577-587

$$\boldsymbol{n}_{1,t} = \boldsymbol{m}\boldsymbol{n}_{\boldsymbol{1},t-1} + \boldsymbol{R}_t$$

Where R_t are the tag releases

Movement function m typically includes both random and directed components, termed diffusion and advection, respectively. This function can be calculated from an instantaneous movement rate:

$$\frac{\partial}{\partial t}\mathcal{B} = (\mathbf{u}^{\mathrm{T}}\nabla + \nabla \cdot \Sigma\nabla)\mathcal{B} \qquad \text{eqn 7}$$

where $\mathbf{u}^{\mathrm{T}}\nabla\mathcal{B}$ represents advective movement (where ∇ is the gradient operator, which yields a vector of length two when evaluated at location s because $\mathcal{B}$ is a function defined in two-dimensional space, and $\mathbf{u}$ is a direction vector of length two), and $\nabla\cdot\boldsymbol{\Sigma}\nabla$ represents diffusive movement (where $\boldsymbol{\Sigma}$ is a 2×2 rotation matrix governing the rate of diffusion in different directions, and if $\boldsymbol{\Sigma} = \mathbf{I}$ then $\nabla\cdot\boldsymbol{\Sigma}\nabla$ reduces to the Laplacian operator).

Appendix S2. Movement matrix computation on a triangulated mesh.

Spatial model

- $\widehat{N}_i = exp(d_0 + \gamma_i)$

$$\gamma \sim \mathrm{MVN}(0, \sigma_\gamma^2 \cdot \mathrm{R}_{\mathrm{spatial}}) \tag{2}$$

where σ_γ is the marginal standard deviation (*SD*) of spatial variation γ and $\mathrm{R}_{\mathrm{spatial}}$ is spatial correlation for the random field:

$$\mathrm{R}_{\mathrm{spatial}}(s, s') = \mathrm{Matérn}\left(\frac{|(s - s')|}{\kappa}\right) \tag{3}$$

where s and s' are the location of two spatial stations, κ defines the rate at which correlations drop with increasing distance, and Matérn $(|(s-s')|)$ is the Matérn correlation function, which calculates the correlation between γ at stations s and s' given their distance $|s-s'|$. We

Likelihood: Poisson

$$-lnL = \sum_{t,i} -r_{t,i}\, ln[\lambda_{t,i}] + \lambda_{t,i}$$

$$\lambda_{t,i} = \frac{n_{2,t,i}}{N_{t,i}} n_{1,t,i}$$

$n_{1,i}$ number of tagged individuals in area i
$n_{2,i}$ sample size for the recovery data in area i
r_i the number of tagged individuals recovered in area i
N_i is the population size in area i

Spatio-temporal model

- Accounts for movement and catch
- Does not use the information on movement from the tagging data
- Does not explicitly use the information on catch
- $\widehat{N}_i = exp(d_{0,t} + \gamma_i + \gamma_{t,i})$

Improvements

- Removing tag recoveries from the tagged population;
- Covariates for N
- Using the advection-diffusion process to move the total population;
- Removing catch from the total population;
- Alternative likelihood functions;
  - zero inflation
- Including size information.