# Integrating Conventional Tagging Data into the Spatial Ecosystem and Population Model SEAPODYM 

Inna Senina, Patrick Lehodey

## Motivation



366545 releases 58207 recoveries


## Outline

- Modeling approach
- Method to integrate conventional tagging data
- Parameter estimation method
- Implementation and preliminary study
- Real data experiment with application to skipjack population


## Modeling approach to predict predator population dynamics



## Prior work on integrating tagging data into Eulerian models

- Sibert and Fournier. 1991. Evaluation of advection-diffusion equations for estimation of movement patterns from tag recapture data. In Interactions of pacific tuna fisheries. Proceedings of the first FAO expert consultation on interactions of pacific tuna fisheries, 3-11 December 1991, Noumea, New Caledonia. 336/1.
- Kleiber and Hampton. 1994. Modeling effects of FADs and islands on movement of skipjack tuna (Katsuwonus pelamis): estimating parameters from tagging data. Can. J. Fish. Aquat. Sci. 517.
- Sibert et al. 1999. An advection-diffusion-reaction model for the estimation of fish movement parameters from tagging data, with application to skipjack tuna (Katsuwonus pelamis). Can. J. Fish. Aquat. Sci.
- Adam and Sibert. 2002. Population dynamics and movements of skipjack tuna (Katsuwonus pelamis) in the Maldivian fishery: analysis of tagging data from an advection-diffusion-reaction model. Aquat. Living Resour.

Integrating conventional tagging data into SEAPODYM
$N(a, x, t)$ - population density at age $a, x \in \mathbb{R}^{2}, t \in\left[t_{0}, t_{n}\right]$ $R(k, a, x, t)$ - density of tags of $k$-th cohort, $t \in\left[\tau_{k}^{*}, t_{k}^{*}\right]$

$$
\begin{align*}
& \partial_{t} N+\partial_{a} N=-\operatorname{div}(\tilde{\mathbf{v}} N+\chi \nabla H \cdot N)+\nabla(D \nabla N)-(M+F) N  \tag{1}\\
& \partial_{t} R+\partial_{a} R=-\operatorname{div}(\tilde{\mathbf{v}} R+\chi \nabla H \cdot R)+\nabla(D \nabla R)+r(a, t, x)  \tag{2}\\
& N\left(a, x, t_{0}\right)=N_{0}(a, x) ; N(0, x, t)=H_{s} \cdot f\left(N_{a}\right), a>0  \tag{3}\\
& R\left(k, a, x, t_{0}\right)=0  \tag{4}\\
& \left.\mathbf{n} \cdot \mathbf{v}\right|_{\mathbf{x} \in \partial \Omega}=\left.\mathbf{n} \cdot \nabla N\right|_{\mathbf{x} \in \partial \Omega}=\left.\mathbf{n} \cdot \nabla R\right|_{\mathbf{x} \in \partial \Omega}=0 \tag{5}
\end{align*}
$$

## Definition of a cohort of tags <br> Data from tagging campaigns in 2006-2012



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## Parameter estimation approach

Model predictions

$$
\begin{aligned}
& C_{a t t i j}^{m}=q_{f} \cdot E_{t t i j} \cdot s_{f a} \cdot N_{t a i j} \cdot \delta x \cdot \delta y \\
& Q_{a t t i j}^{m}=\frac{C_{a t t i j}^{m}}{\sum_{a} C_{a t t i j}^{m}} \\
& R_{k a t i j}^{m}=R_{k a t i j} \cdot \delta x \cdot \delta y
\end{aligned}
$$

Likelihoods

$$
L=\prod_{t t i j}(L(\theta \mid C P U E) \cdot L(\theta \mid Q) \cdot L(\theta \mid R))
$$

Maximum likelihood estimate

$$
\theta_{\mathrm{mle}}=\underset{\theta \in(\underline{\theta}, \bar{\theta})}{\operatorname{argmin}}(-\ln L)
$$

## Implementation and preliminary work

- Rewriting adjoint code to minimize memory demand
- Program implementation of multi-cohort model
- Bugs fixing
- TWIN experiments


## Application for skipjack population

- Model run configuration
- Forcing SODA, VGPM, Levitus $\mathrm{O}_{2}$
- Resolution $1^{\circ} \times$ month
- Time period 2006-2008
- Initial conditions SODA reference run
- Data
- Fishing 7 WCPO fisheries (3xPL, 3xPS and LL)
- Tagging 12 cohorts recaptured through 2007-2008


## Sensitivity analysis



## Results

$$
L_{C P U E}^{-}+L_{L F}^{-}
$$

total skipjack (mt/sq.km) in 1/2007-12/2008



$$
L_{C P U E}^{-}+L_{L F}^{-}+L_{T a g}^{-}
$$

total skipjack (mt/sq.km) in 1/2007-12/2008


## Results

$$
L_{C P U E}^{-}+L_{L F}^{-}
$$



$$
L_{C P U E}^{-}+L_{L F}^{-}+L_{T a g}^{-}
$$



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## Conclusions and future plans

- Version of SEAPODYM with conventional tagging data
- Estimation of habitat and movement parameters
- Lower diffusion and higher advection rates
- Less cryptic biomass
- Model configuration until 2010 (more tagging data)
- OSSE - design of an observation system
- Need for code parallelization


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- Thanks to John Sibert for resolving AUTODIF issue for large GRADSTACKs and for the preliminary work on SEAPODYM-TAGEST application development
- Thanks to everyone for listening!

