MERCATOR OCEAN INTERNATIONAL

Analyzing and modeling juvenile sea turtle dispersal

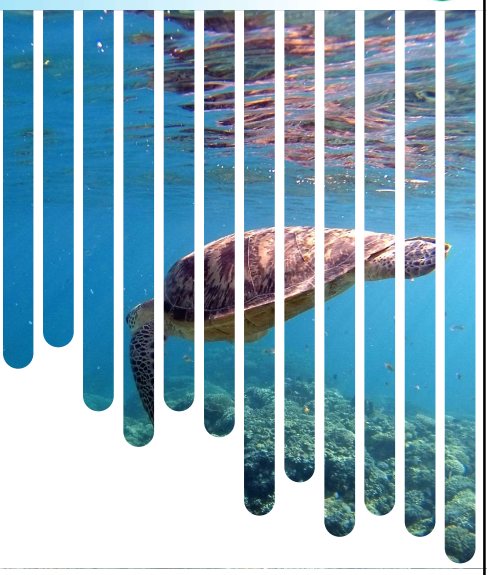
Marine Ecosystem Analysis and Prediction Task Team (MEAP-TT)

Tony Candela & Julien Temple-Boyer

February 20, 2024

1

Summary of the presentation



2

Introduction

Where juvenile sea turtles go?

3

The sea turtles, an endangered species

Green
(Endangered)

Flatback
(Data deficient)

Kemp's Ridley
(Critically Endangered)

Leatherback
(Vulnerable)

Hawksbill
(Critically Endangered)

Loggerhead
(Vulnerable)

Olive Ridley
(Vulnerable)

MEAP-TT Meeting 4

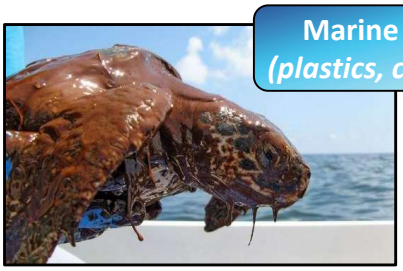
4

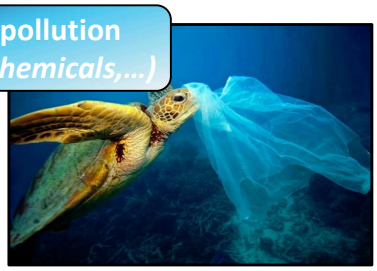
Main risks and threats

Eggs and females consumption

Interactions with fisheries

Marine pollution *(plastics, chemicals,…)*





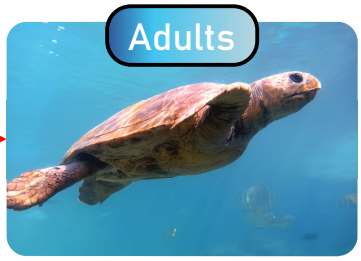
MEAP-TT Meeting 5

5

Understanding the "Lost Years"

Hatchlings

Adults



MERCATOR OCEAN INTERNATIONAL

General movement

$V_t = V_c + V_s$

Motivation for swimming

$0 < h = h_f\, h_T < 1$

$\|V_s\| = (1-h)V_O(a)$

STAMM

Gaspar & Lalire (2017)
Lalire & Gaspar (2019)

MEAP-TT Meeting 6

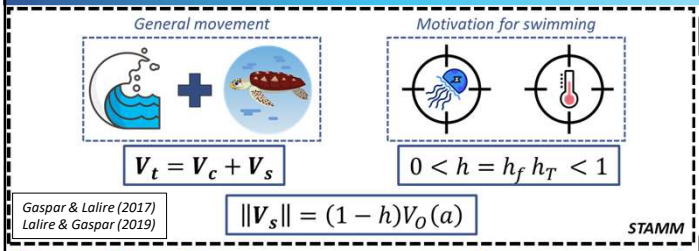
6

Modeling juvenile sea turtle dispersal

Sea Turtle Active Movement Model (STAMM)

7

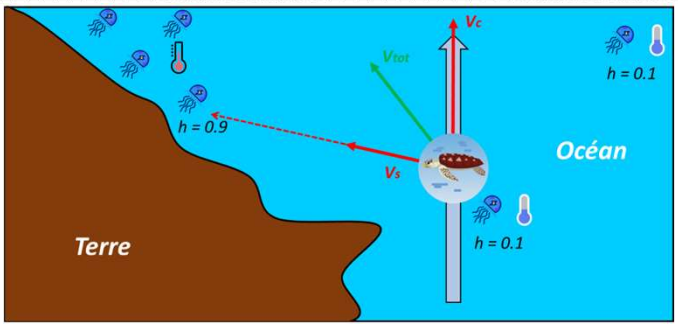
Modeling juvenile sea turtle dispersal.



STAMM: Sea Turtle Active Movement Model

OBJECTIVE

*To simulate **juvenile** sea turtle dispersal under the combined effect of **ocean currents** and a habitat-driven **swimming activity**.*



Ocean data from global ocean models as forcing fields

MERCATOR OCEAN INTERNATIONAL

→ *Ocean currents*

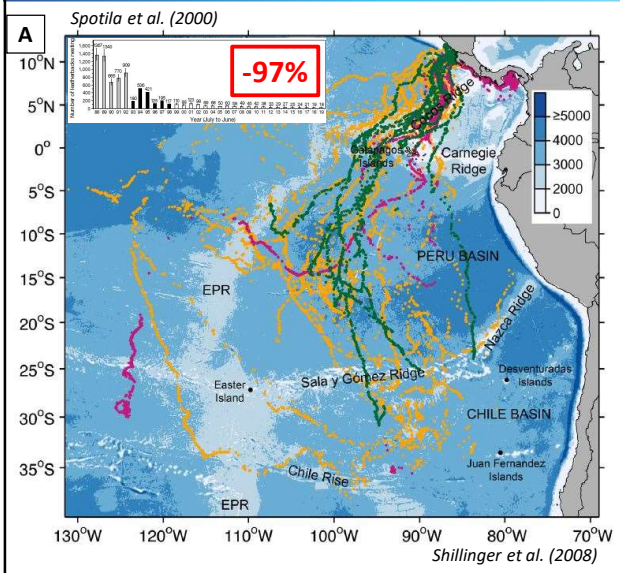
→ *Sea Temperature*

→ *Prey density (or proxy)*
(data from lower trophic levels)

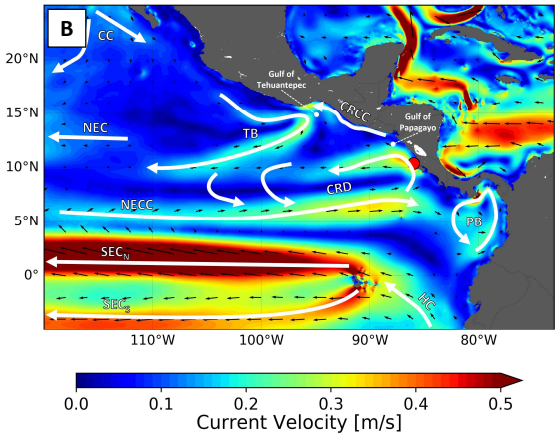
MEAP-TT Meeting 8

8

Case study: Eastern Pacific Leatherbacks



A highly fragile population with a surprising and counter-intuitive migration pattern.



STAMM & LMG

Try to explain migrations of adults through the simulation of juvenile dispersal.

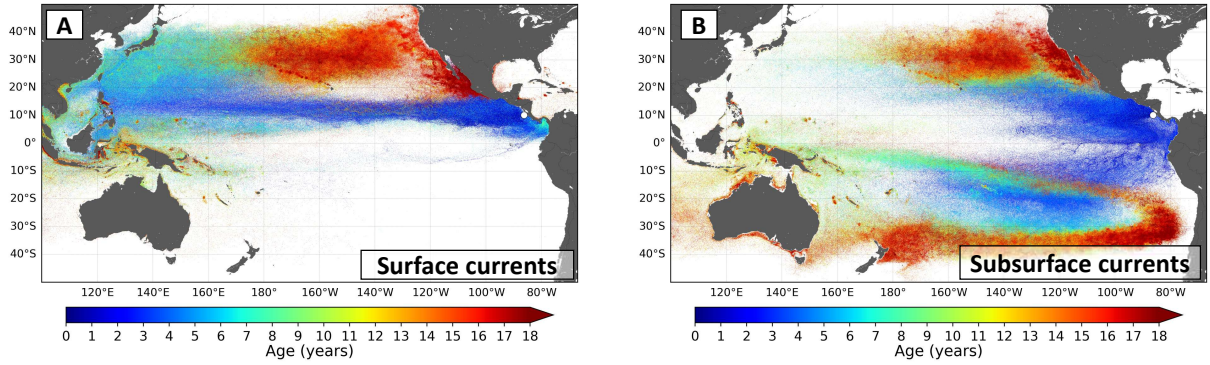
LMG

(Learn Migration Goal)

"Adult sea turtles tend to exploit favorable foraging areas that they discovered during their juvenile stages."

Testing different hypotheses

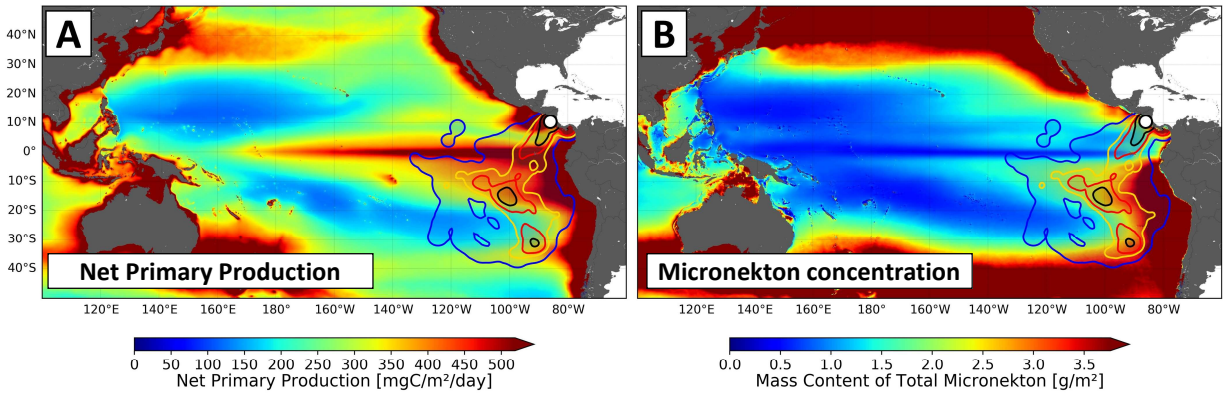
Testing different dispersal hypotheses to highlight dispersal features



Here, the diving behavior of young individuals should be important enough to bring some pieces of explanation about the migration observed with the adults.

Connection between trophic levels

Fields of concentration from lower trophic levels are used as proxy for prey density.



Here, the micronekton concentration represents a better approximation of leatherback turtle diet and could also explain the location of foraging areas of adults.

Investigating the model evolution

Analyzing sea turtle tracking data

Quick dive into primitive equations

Equation of lagrangian motion of a trajectory :

$$\frac{d\boldsymbol{X}}{dt} = \boldsymbol{V}_{drift} + \boldsymbol{V}_{swim}$$

Major question : How to describe V_{swim} as realistic as possible ?

Current state of the model : Turtles swim toward habitat gradient and habitat condition determines the velocity norm.

$$\boldsymbol{V}_{swim}(x,y,t) = V_0[1 - h(x,y,t)]\begin{pmatrix}\cos\theta \\ \sin\theta\end{pmatrix}$$

$\theta = \theta_{\nabla h}$ + random effect (Von Mises circular distribution)

Habitat definition : product of thermal niche and food proxy availability

$$h = h_T \cdot h_F$$

$$h_T(x,y,t) = e^{-2\left(\frac{T(x,y,t)-T_1}{T_2-T_1}\right)^2}$$

$$h_F(x,y,t) = \min\left(1, \frac{F(x,y,t)}{F_0}\right)$$

T : temperature field (SST)
F : food proxy field (micronekton, npp)

A relatively simple model, but a challenge regarding changes possibilities. The use of turtle tracking data is fundamental to make improvements.

Using ocean model data to study tracking data in North Pacific

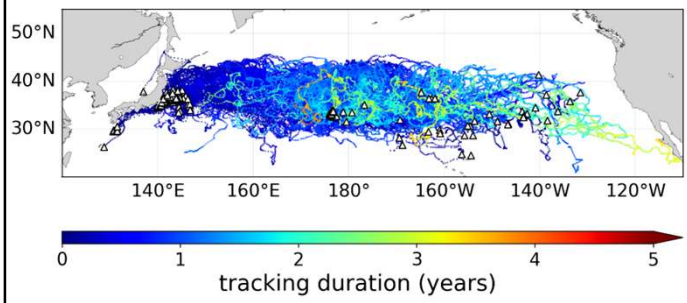
Understanding the behavior of sea turtles relays on swimming velocity estimates, by interpolating ocean data on tracking data positions:

$$\frac{dX}{dt} = V_{drift} + V_{swim} \quad \rightarrow \quad V_{swim} = \frac{dX}{dt} - V_{drift}$$

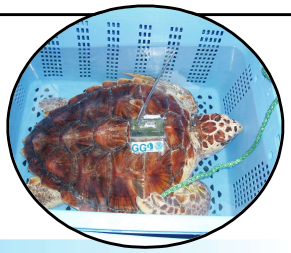
$\frac{dX}{dt}$: derived from tracking positions

V_{drift} : estimated with physical models and reanalysis

Reanalysis quality determine results and interpretation. Use of surface current and stokes drift reanalysis.



We use and analyze a dataset of 232 juvenile loggerhead trajectories, In collaboration NOAA PIFSC Marine Turtle Research.



Analysing swimming velocities

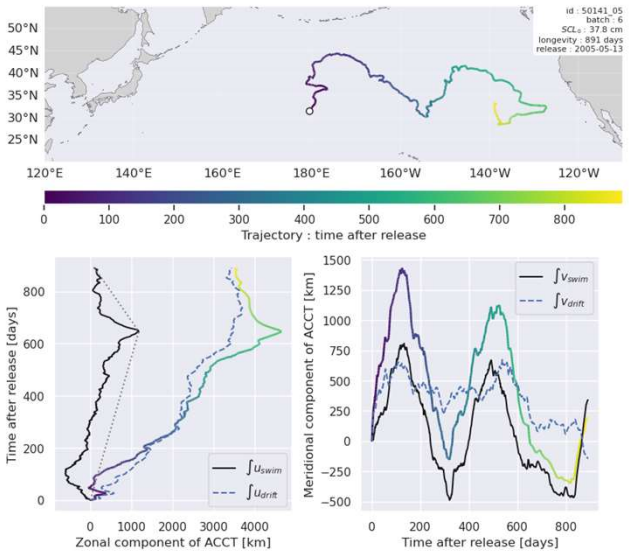
Estimated swimming velocities tend to be **very noisy** :

→ Construction of **integrated signal** to be analysed :

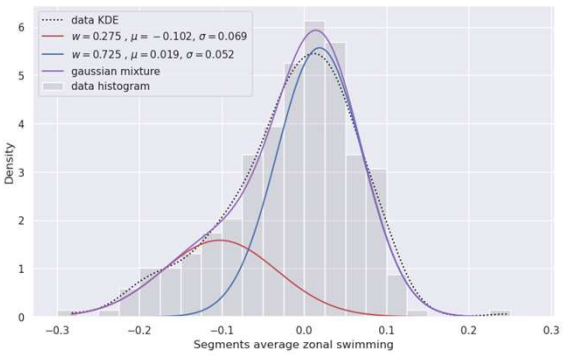
$$X_{swim}(t) = \int_0^t V_{swim}(\tau)d\tau$$

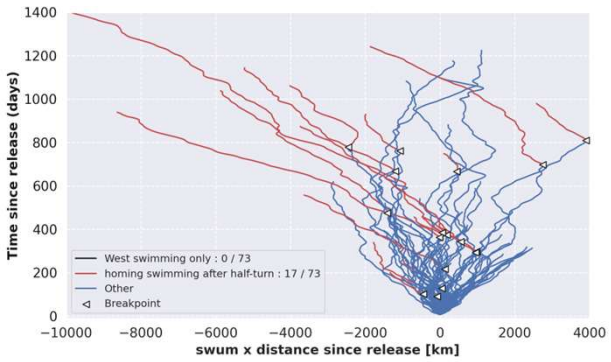
→ Represents the purposed active movement

→ The integrated series are a step forward to understand the turtle's behavior



Observing zonal swimming

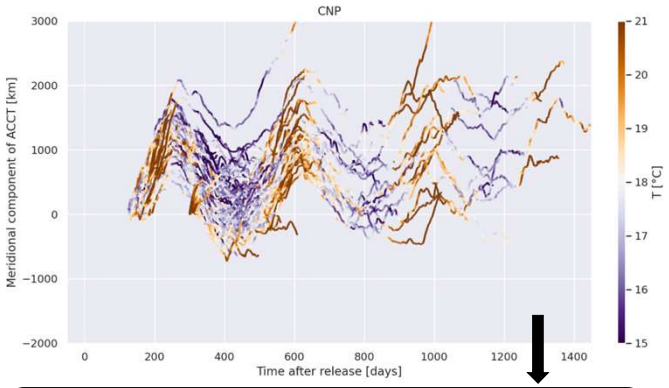


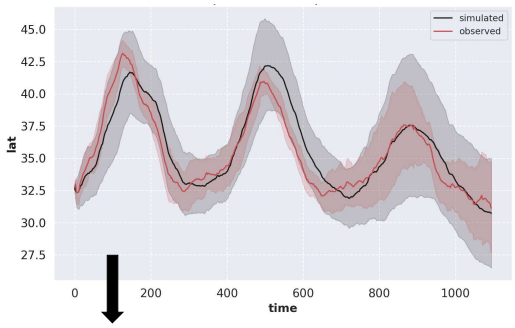


Analyze of $\int u_s(t)dt$ (zonal):
- **Using gaussian mixture models informs on velocities pattern of westward migratory behavior.**
- **Such behaviors may be linked to reproductive migration and are not modeled in STAMM yet.**

17

Observing meridional swimming





Analyze of $\int v_s(t)dt$ (meridional):
- **Periodic behavior, likely under influence of day length or the temperature.**
- **Such cycle is not well represented in the model yet**

However, some modeling experiments with purely thermal defined habitat gave improved interesting results to be confirmed.

$$h = e^{\frac{1}{2}\left(\frac{T-T_0}{\sigma}\right)^2}$$

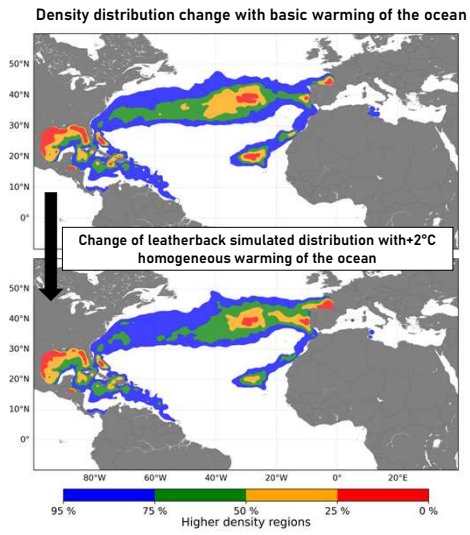
18

Conclusion

19

STAMM : a unique model under improvement

- A unique and evolving tool to model juvenile sea turtle dispersal.
- Model actively used the last few years (publications and collaboration).
- Tracking studies analysis offers leads for improvements. With specific attention to ocean biology models.
- Developments occurred in order to make the code more accessible (soon available on EDITO project).
- Production of distribution density maps which can be used helping in the decision-making process regarding sea turtle conservation measures or MPA implementation.



20

Thank you

For your attention