An individual-based modeling approach for Pacific saury migrations

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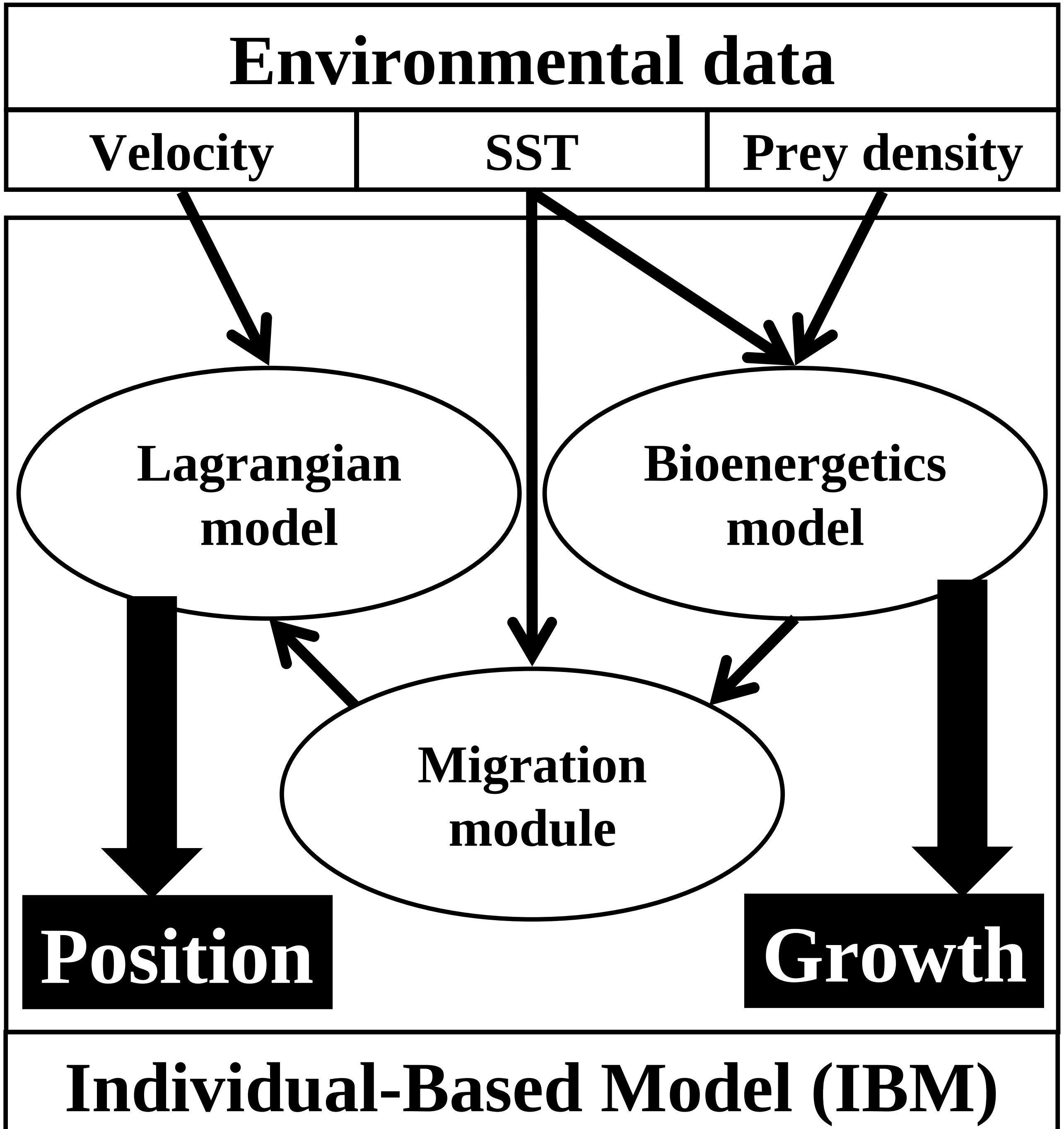
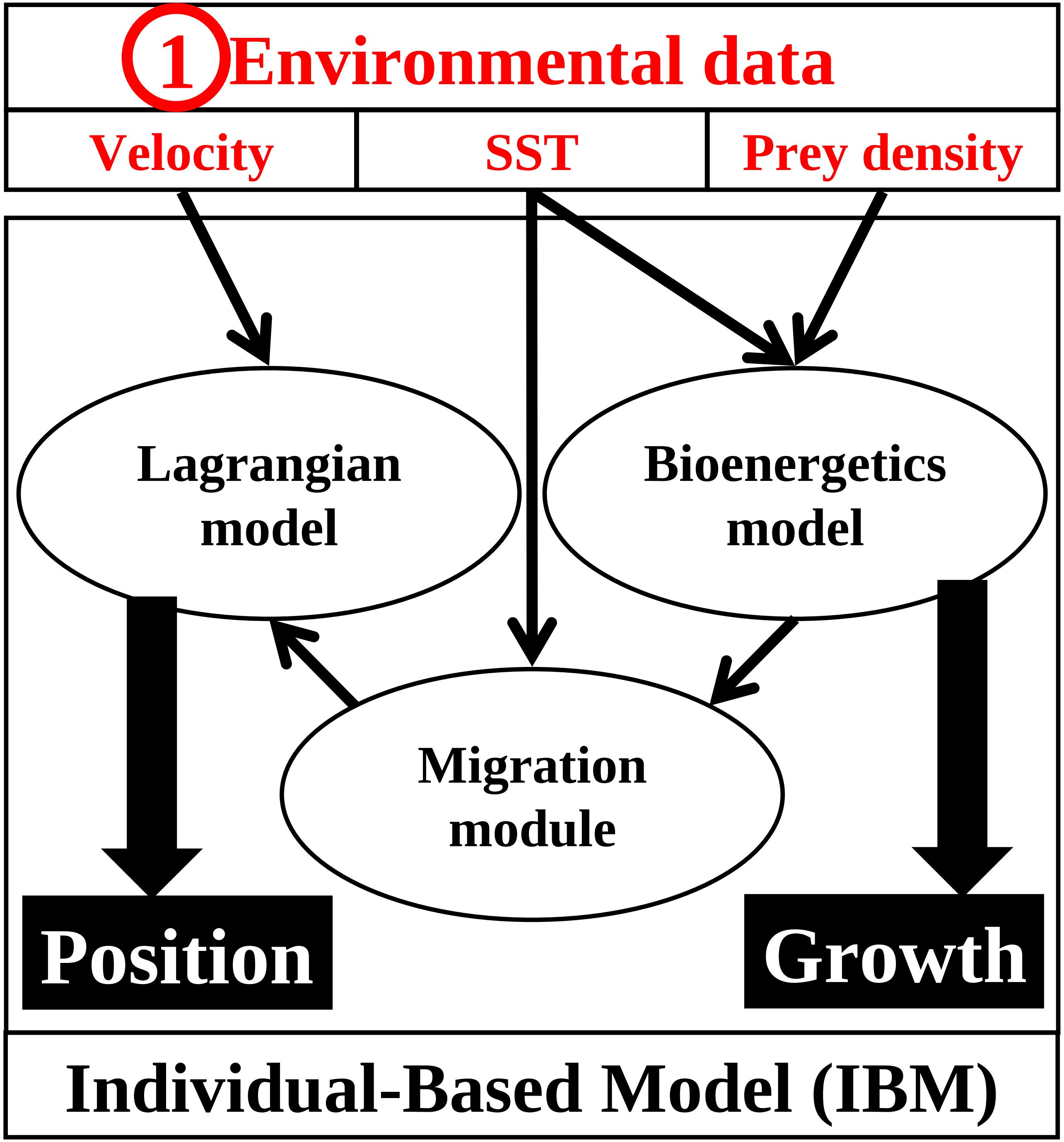
Today's Contents


Environmental data
Velocity
SST
Prey density
Lagrangian model
Bioenergetics model
Migration module
Position
Growth
Individual-Based Model (IBM)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① Environmental data

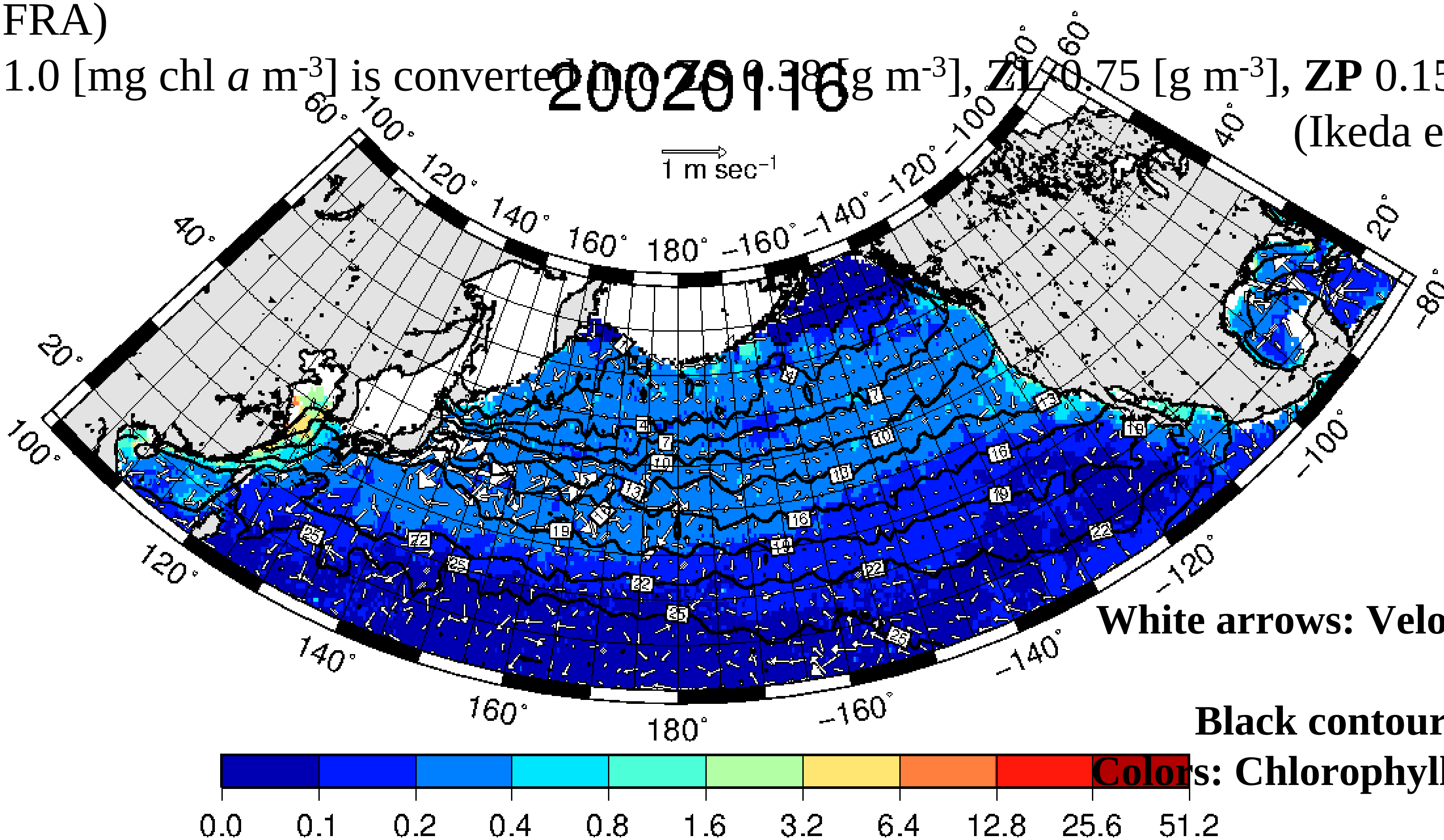
Velocity: Ambe08 ($1/3^o$) (D. Ambe, FRA)

estimated from satellite altimetry and drifting buoy

SST: MODIS/Terra ($1/12^o$) (T. Kameda, FRA)

Chlorophyll *a*: SeaWiFS ($1/12^o$) (T. Kameda, FRA)

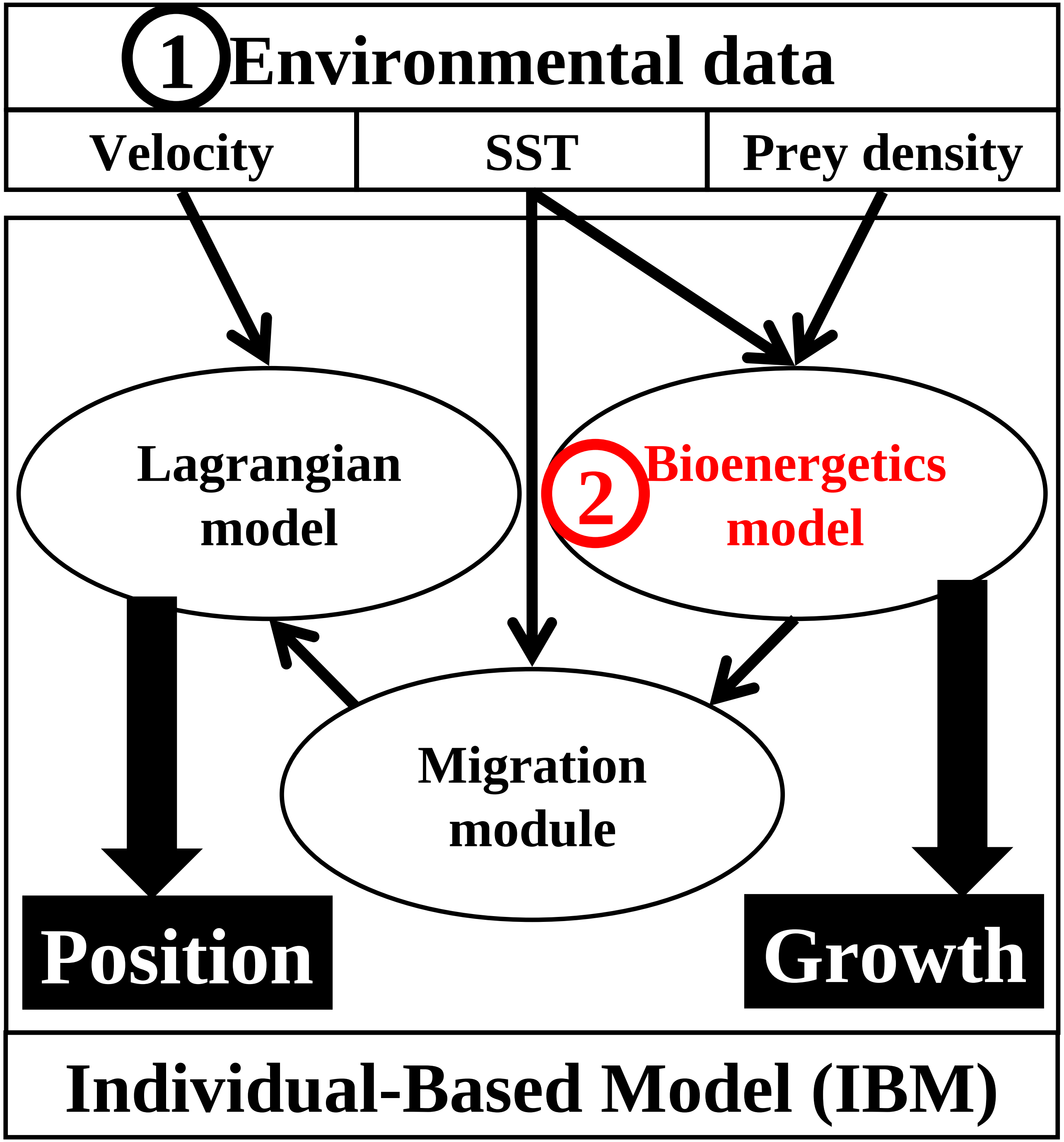
1.0 [mg chl *a* m^{-3}] is converted into **ZS** 0.38 [g m^{-3}], **ZL** 0.75 [g m^{-3}], **ZP** 0.15 [g m^{-3}] (Ikeda et al., 2008)



White arrows: Velocity (m sec^{-1})

Black contours: SST (^oC)

Colors: Chlorophyll *a* (mg m^{-3})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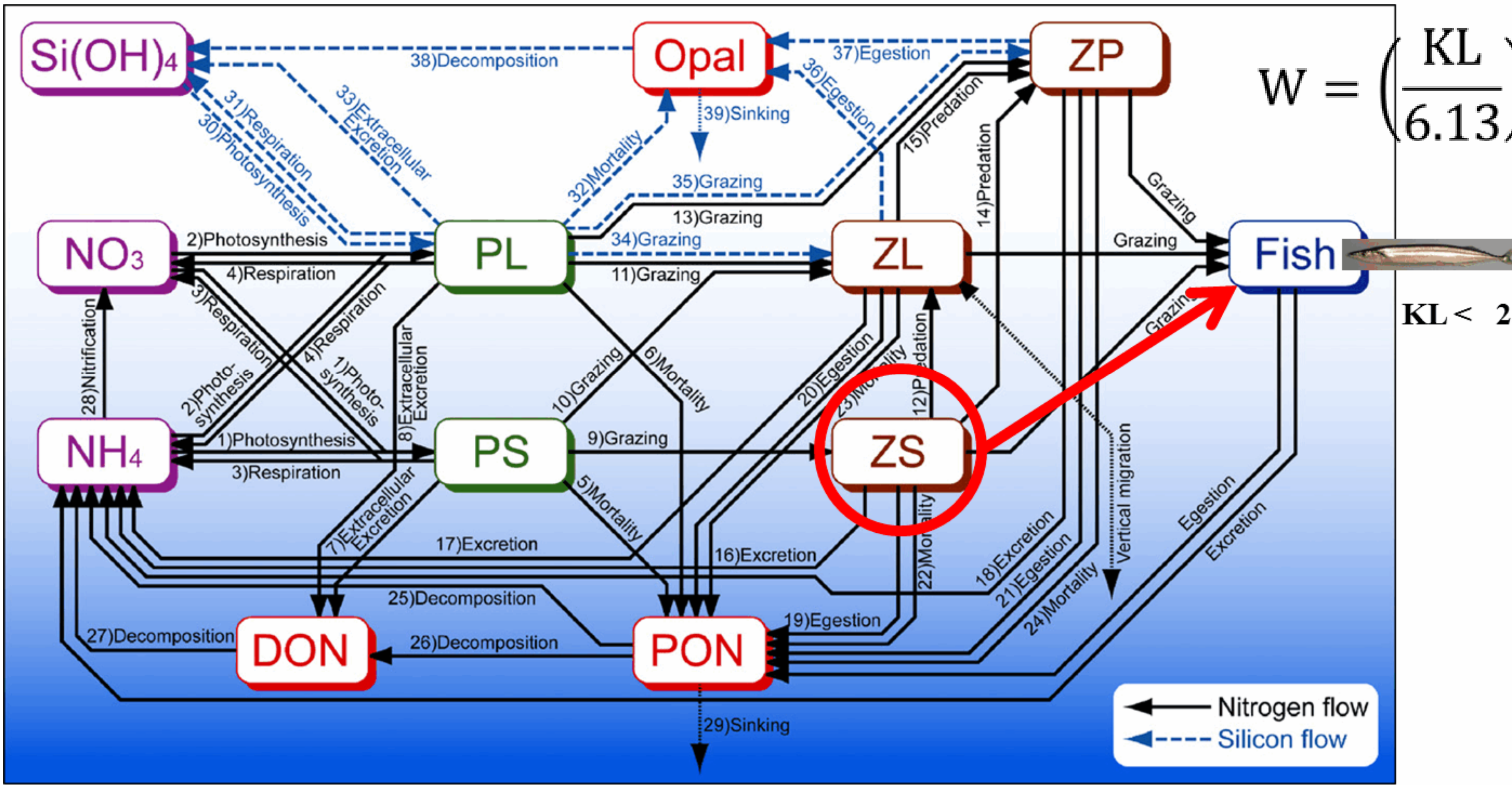
② Bioenergetics model

NEMURO.FISH

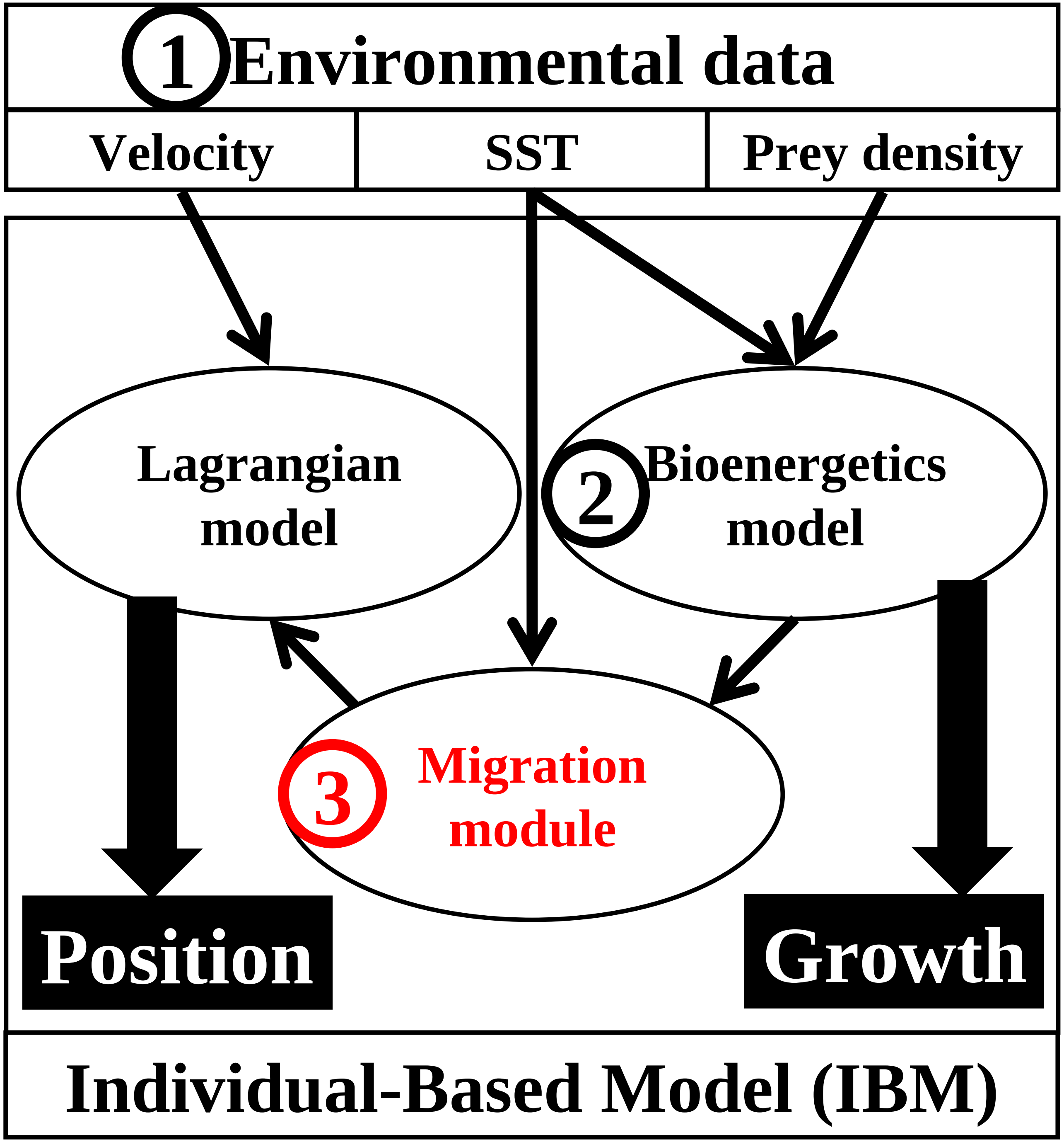
<u>**N**</u>orth Pacific <u>**E**</u>cosystem <u>**M**</u>odel for <u>**U**</u>nderstanding <u>**R**</u>egional <u>**O**</u>ceanography <u>**F**</u>or <u>**I**</u>ncluding <u>**S**</u>aury and <u>**H**</u>erring



$$W = \left(\frac{KL}{6.13}\right)^3$$

KL < 2.5

Ito et al. (2004), Megrey et al. (2007), Mukai et al. (2007)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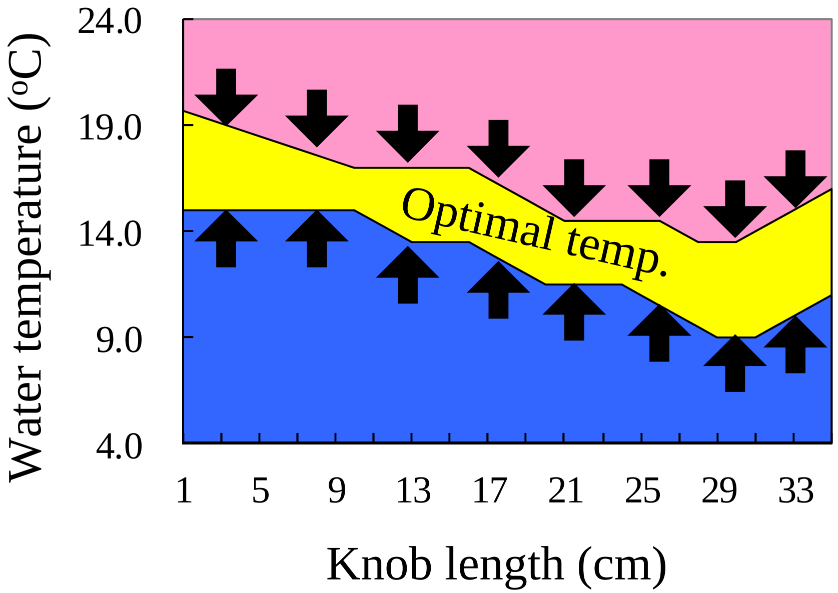
③ Migration module

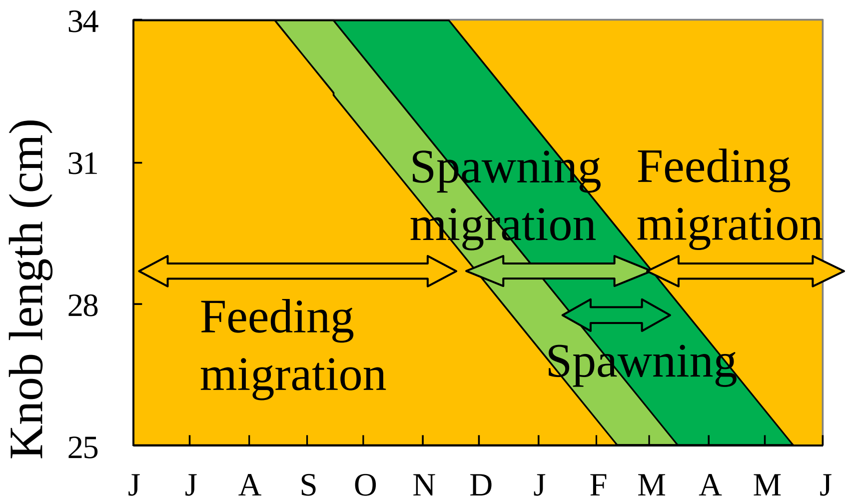
Feeding migration

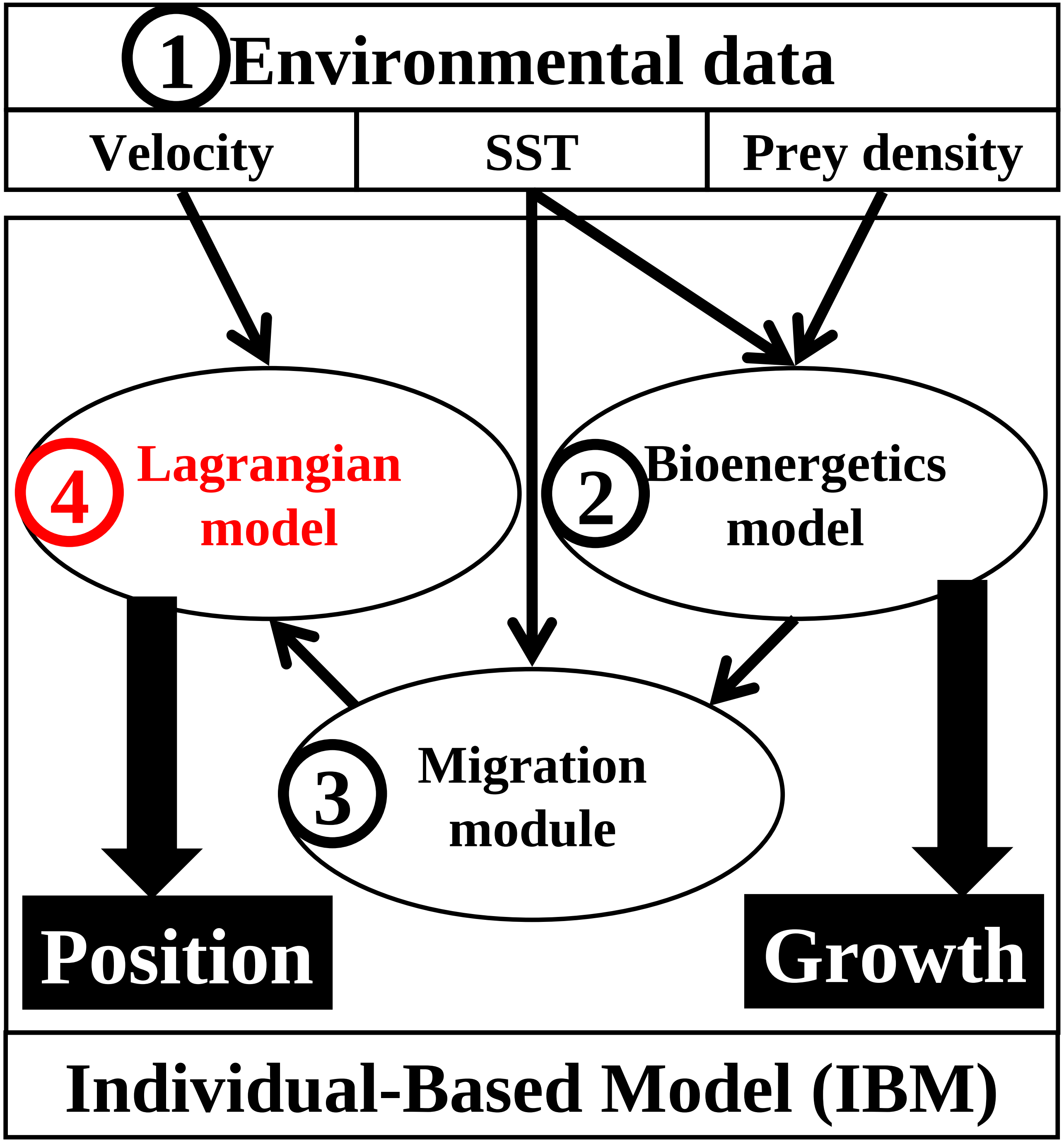
Saury search for local optimal habitats.
(1) Optimal temperature for fish
(2) Maximum growth for fish



Spawning migration

Spawning migration starts 1 month before the spawning beginning date, depending on knob length (> 25 cm), and the duration is 2 months.
(1) Spawning temperature (17 – 25 ºC)
(2) Maximum growth for larvae

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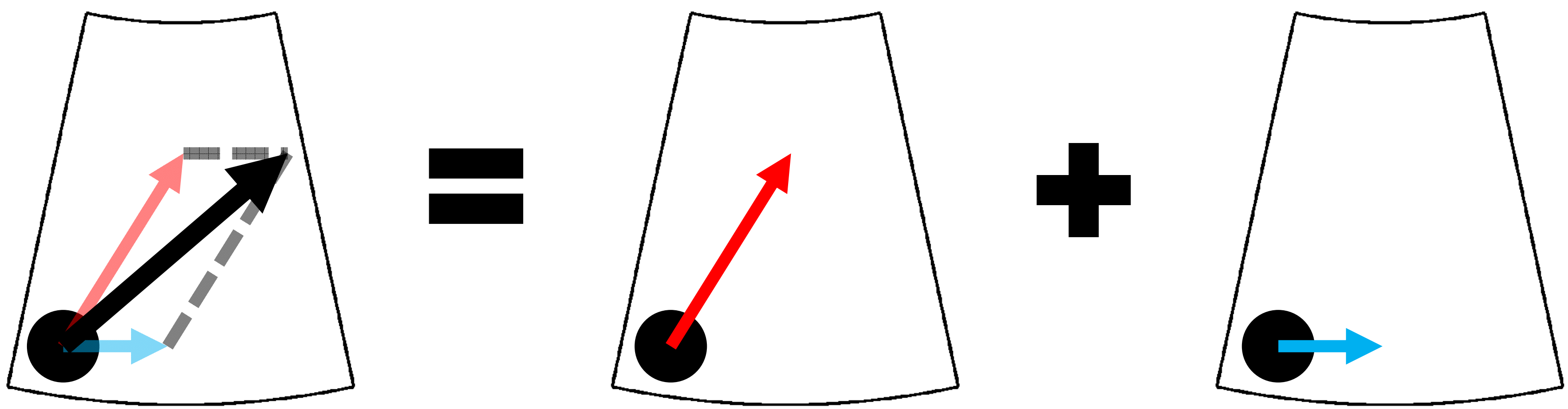
④ Lagrangian model

$$\boldsymbol{X}_{n+1}(x,y) = \boldsymbol{X}_n(x,y) + \boldsymbol{V}_n(x,y) \times dt$$

$$\boldsymbol{V}_n(x,y) = \boldsymbol{V}_{swimming}(x,y) + \boldsymbol{V}_{advection}(x,y)$$



Fish movement **Swimming** **Advection**

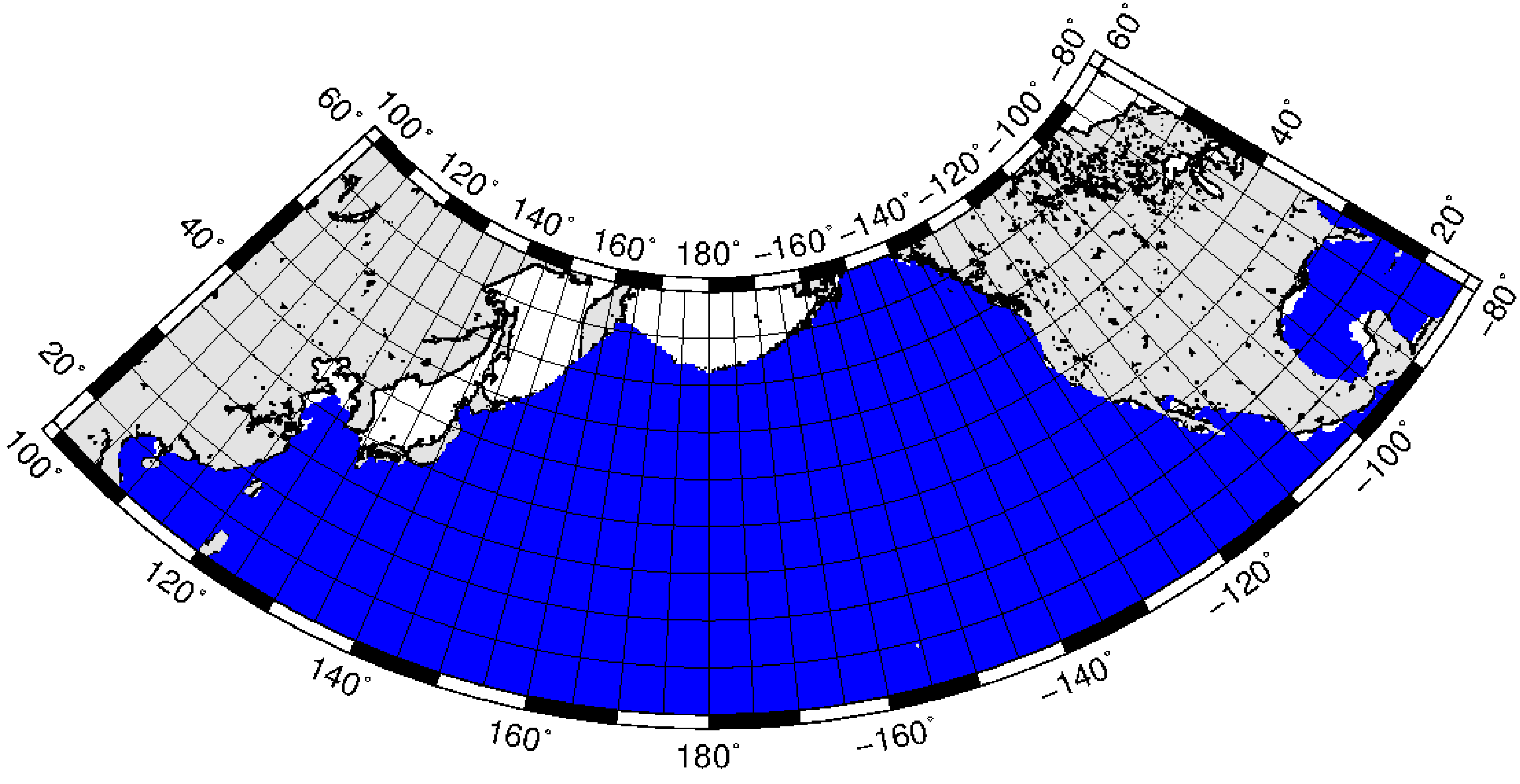
Swimming direction = (Migration module)

$$\text{Swimming speed} = \begin{cases} 12.3 \times W^{0.33} & ,\text{when } T > 12°C \\ 2.0 \times W^{0.33} \times \exp(0.149 \times T) & ,\text{when } T \leq 12°C \end{cases}$$

(Ito et al, 2004)

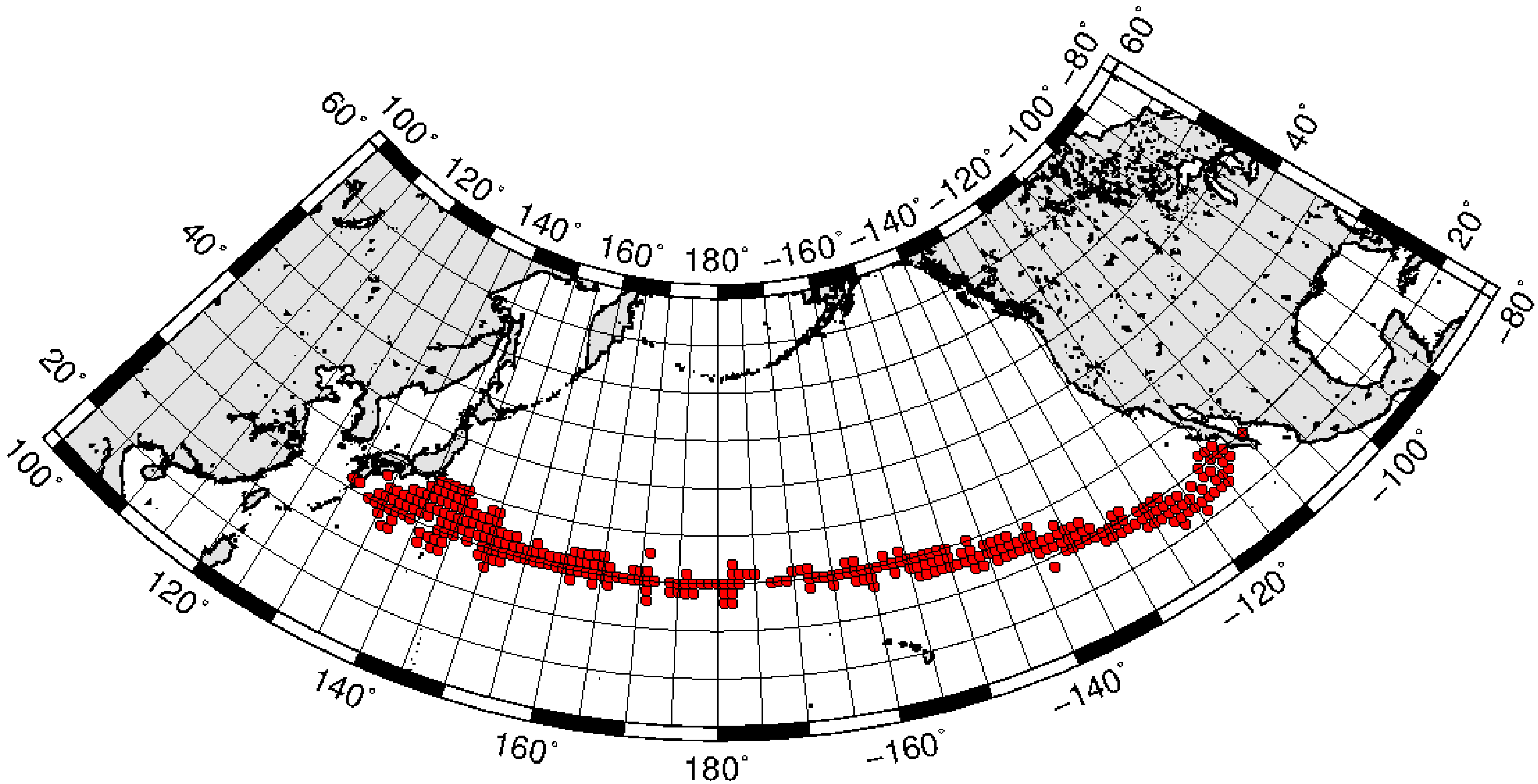
Model implementation

- Domain: 105°E – 80°W, 15°N – 60°N
- Resolution: 526 × 136 (1/3°)
- Run time: 2002.02.01 – 2004.02.01 (2 years, Δt = 1 hour)



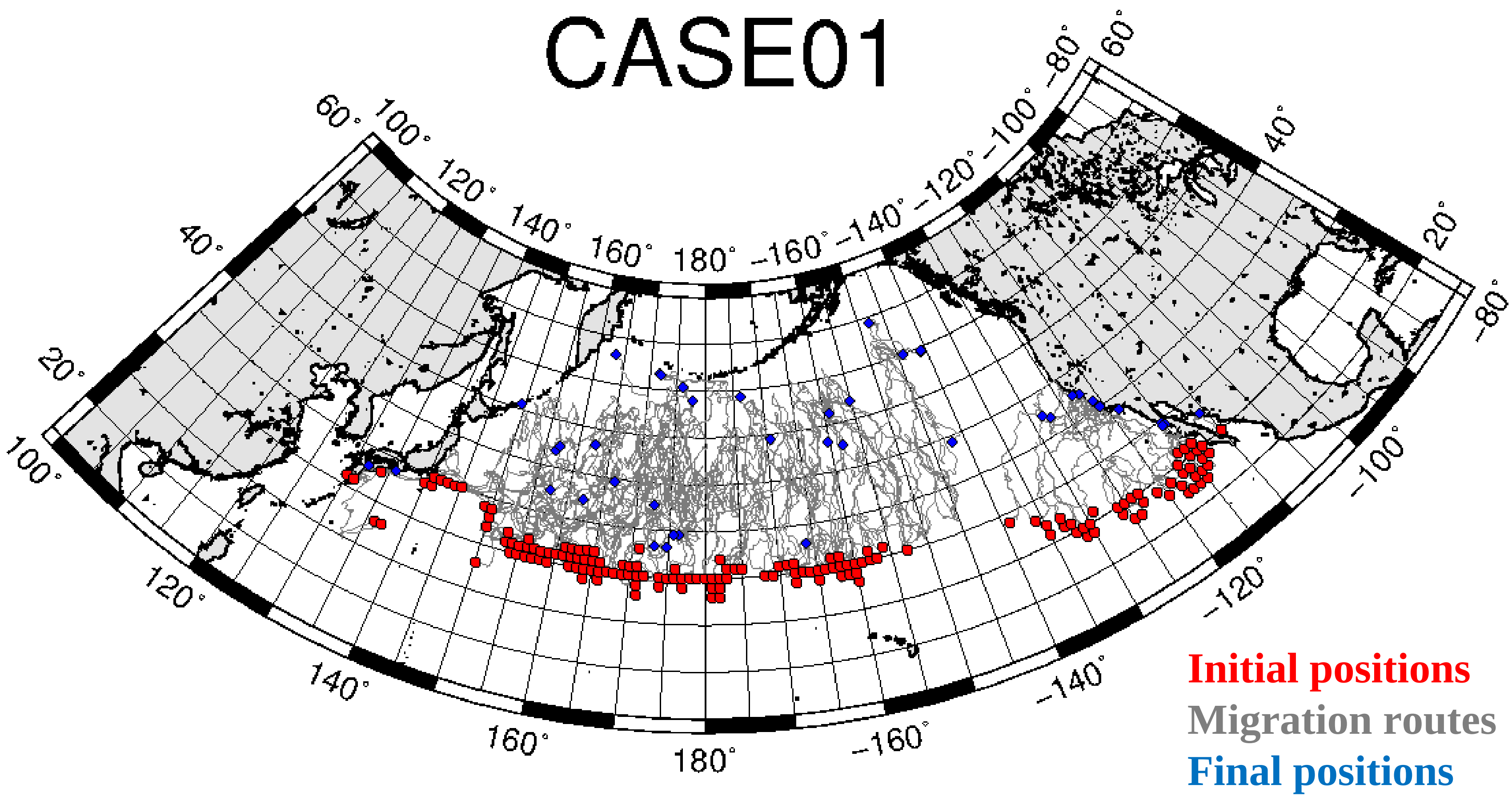
Initial positions

- Initial date: 2002.02.01
- Put eggs in the area between 130°E and 110°W of $18.5 \le T \le 20.0$ °C based on Iwahashi et al. (2006)
- Total 324 particles



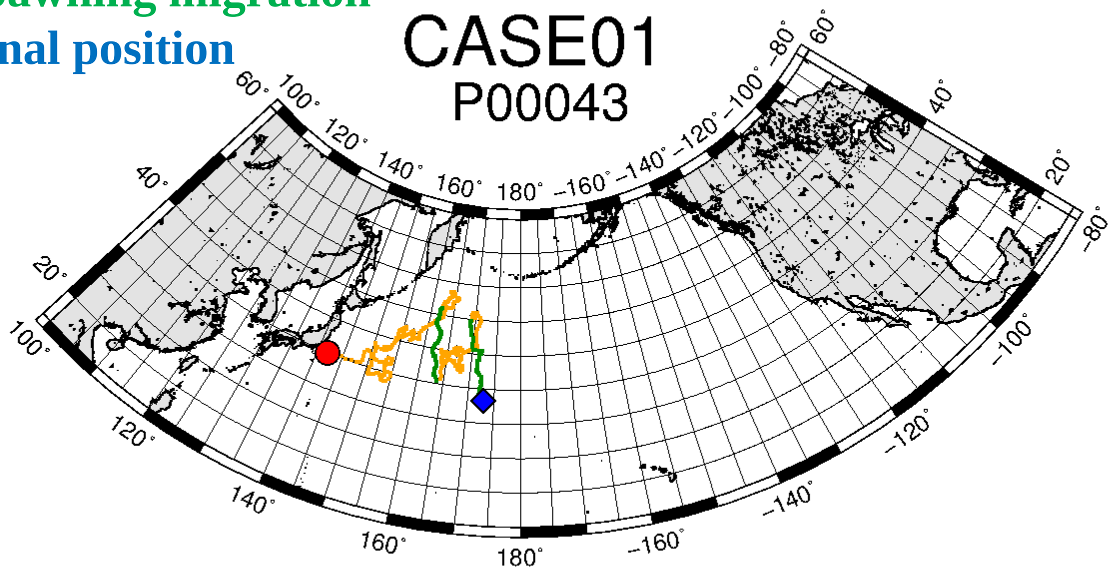
Standard CASE01

- **166** particles not reached to 25 cm-knob length in 1 year (eliminated in figure).
- **34** particles returned at least once to near (within 5 degree of) the initial position during twice spawning migrations.

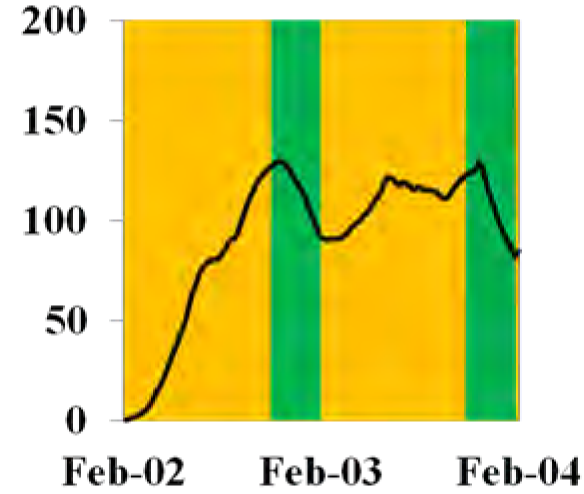


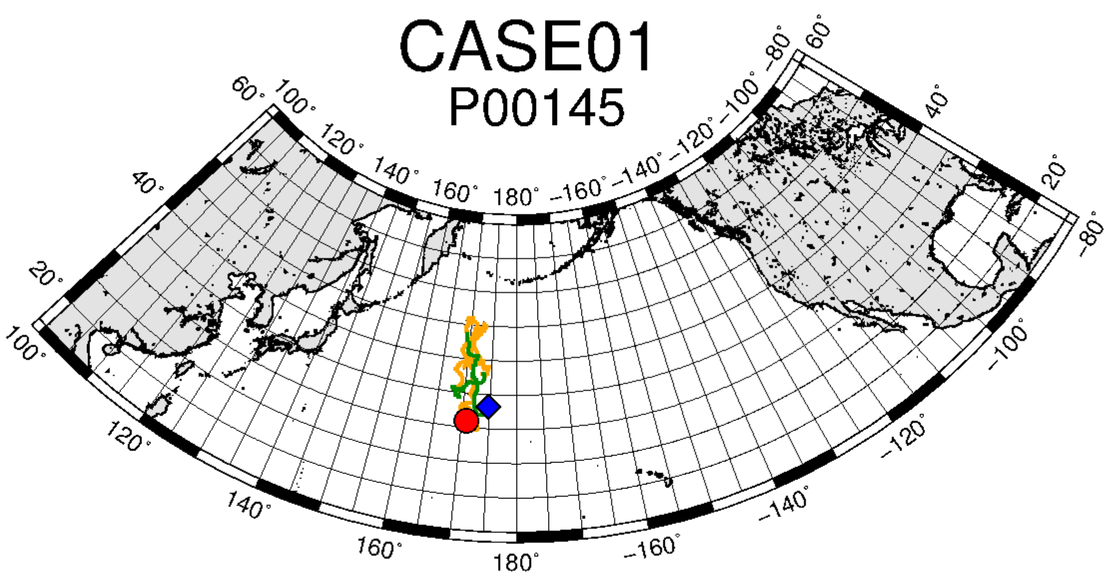
Initial position
Feeding migration
Spawning migration
Final position

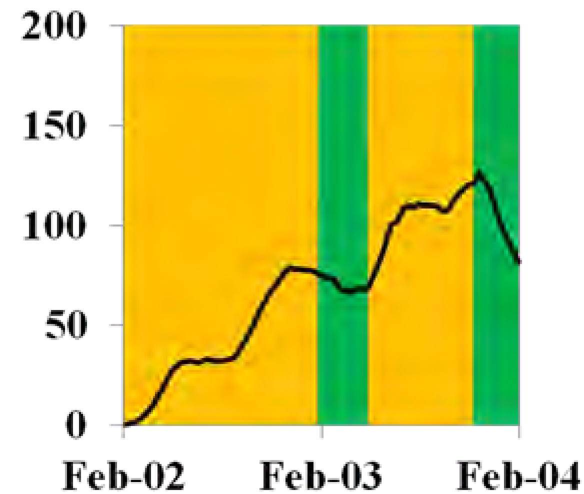
CASE01 examples

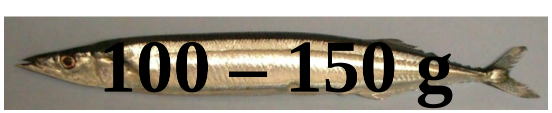


Weight (g)









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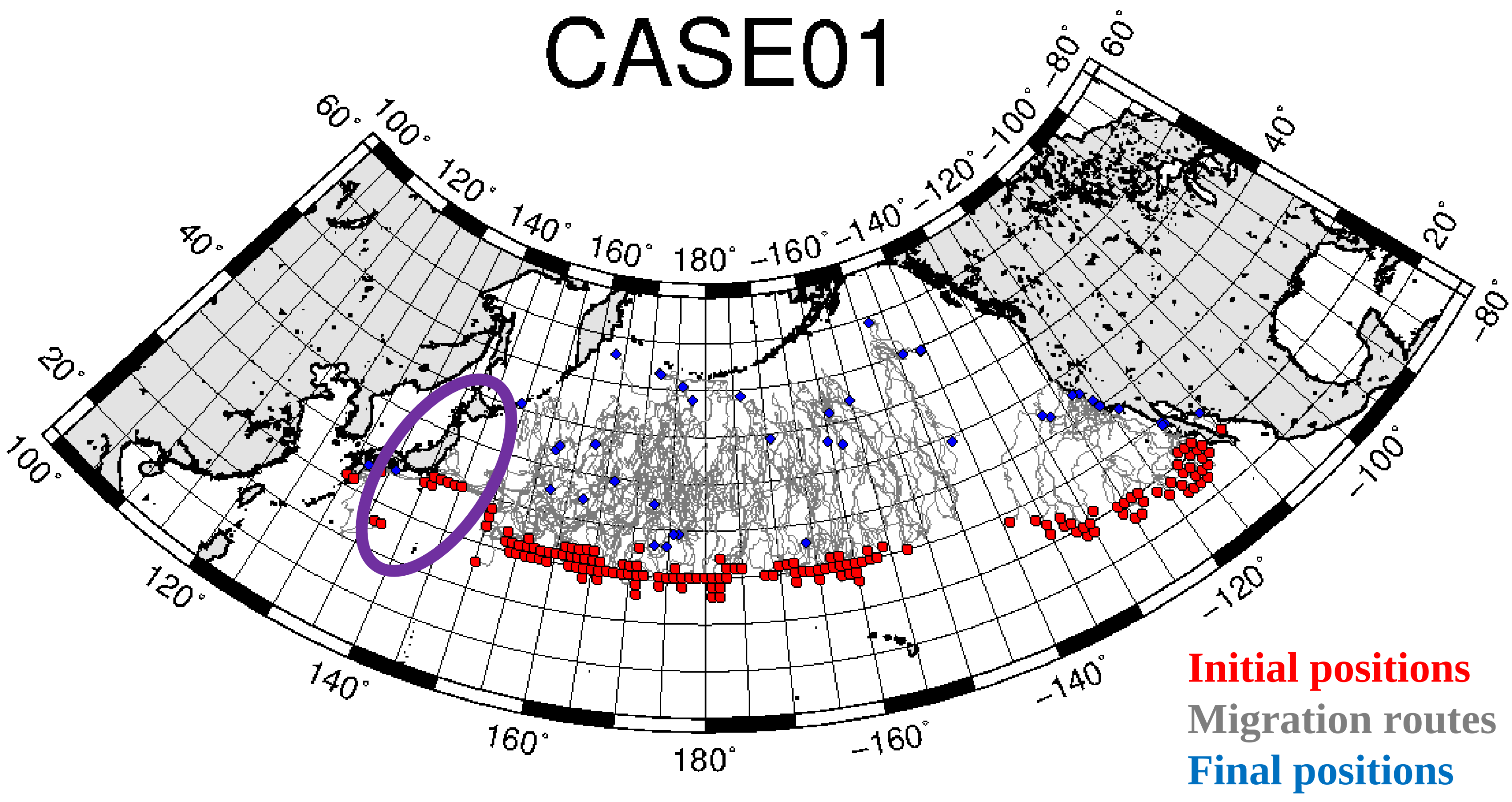
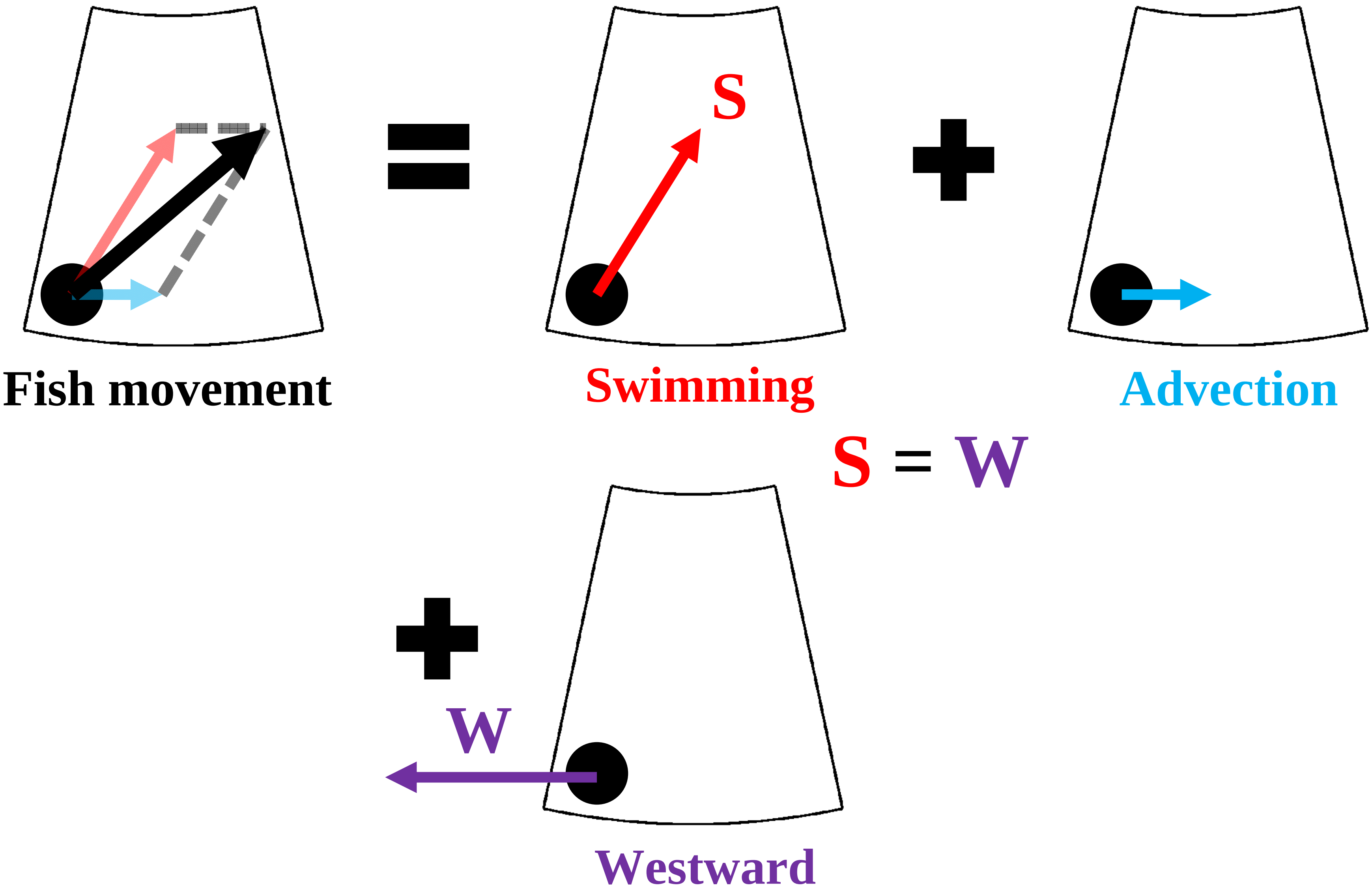
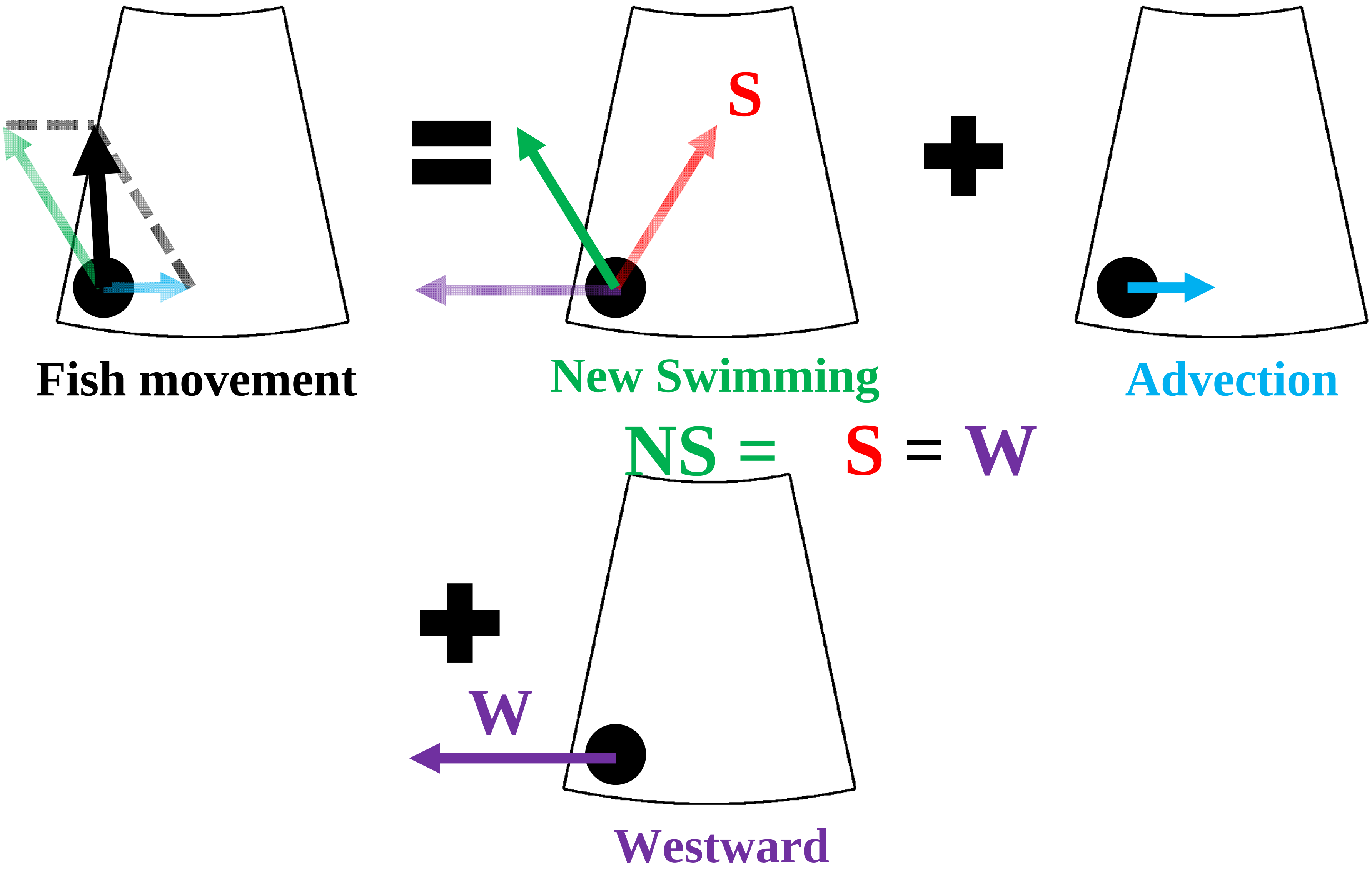


Artificial Westward Migration

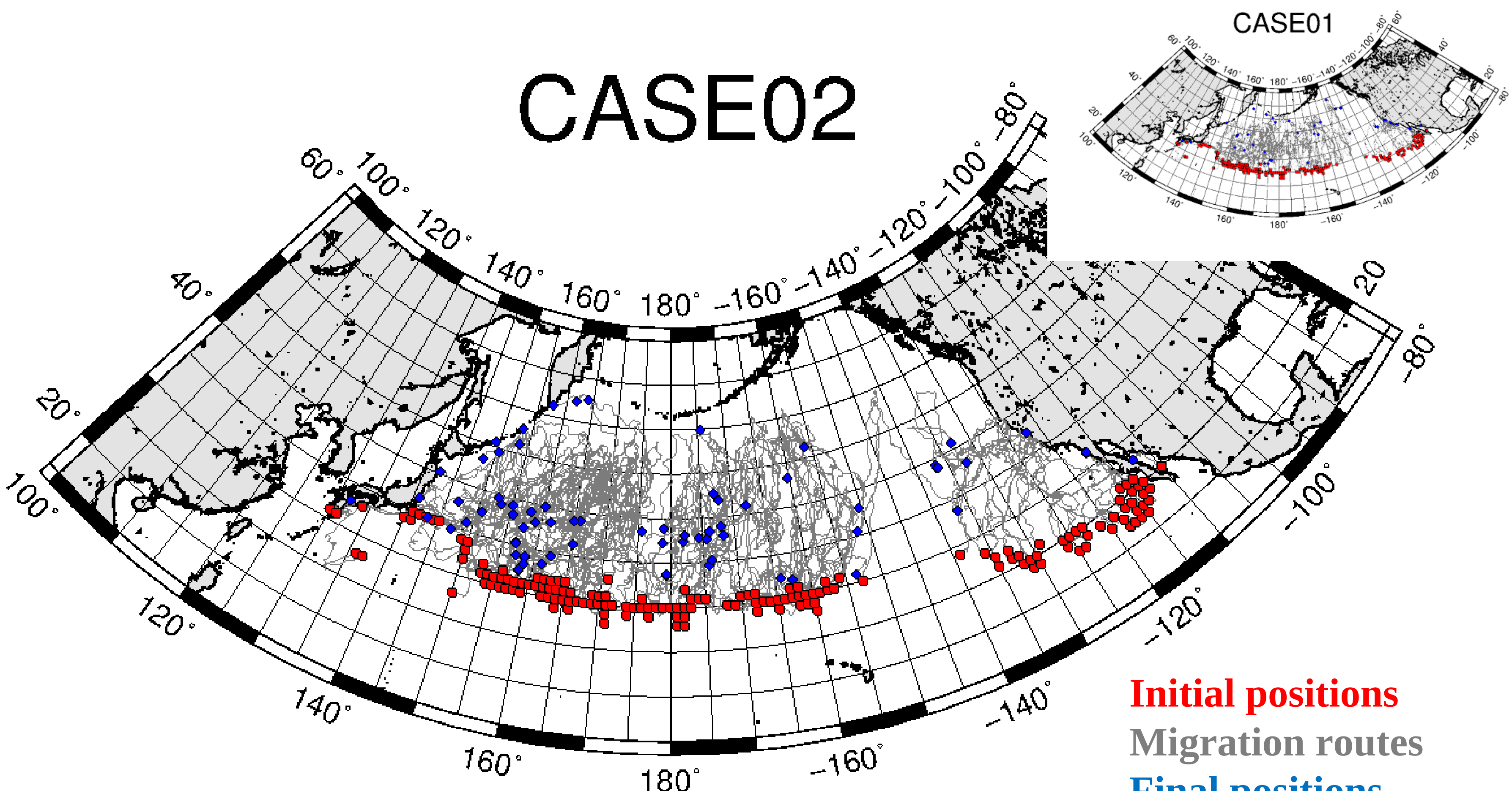


Artificial Westward Migration



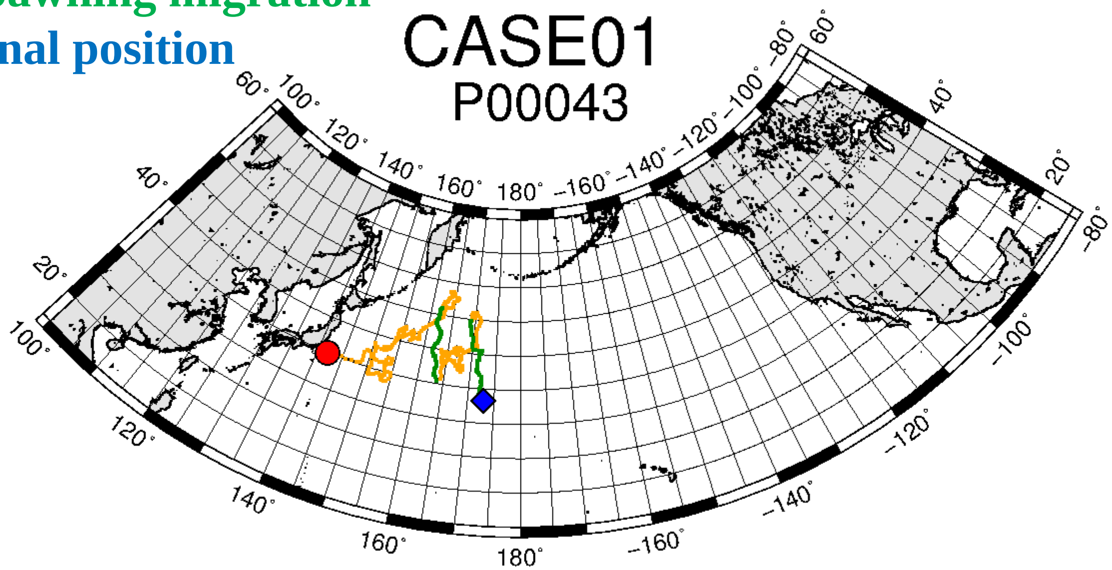
CASE02: CASE01 + Artificial Westward Migration

- **166** particles not reached to 25 cm-fork length in 1 year (eliminated in figure).
- **86** particles returned at least once to near (within 5 degree of) the initial position during twice spawning migrations.

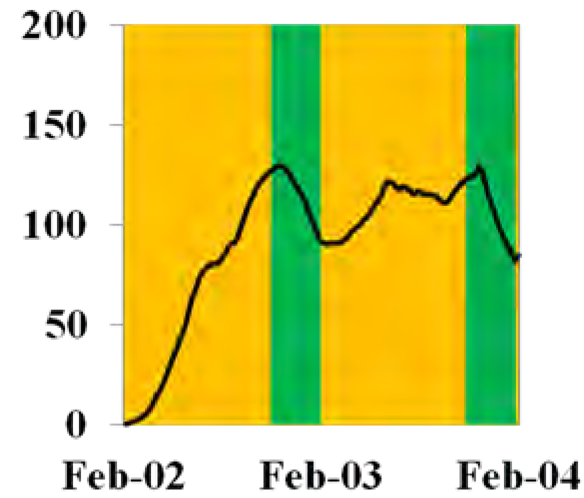


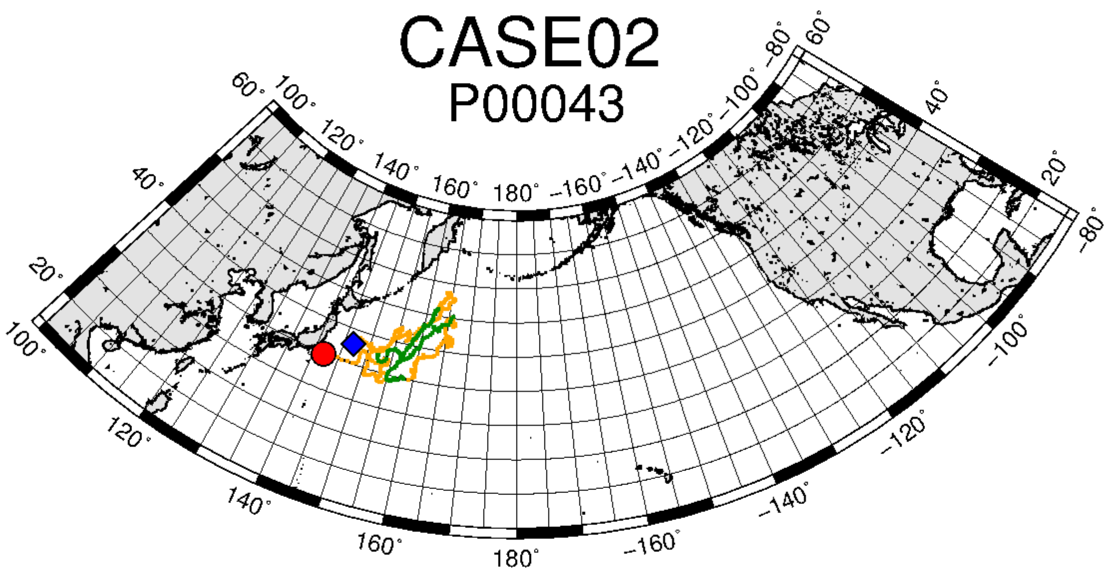
CASE01 vs CASE02

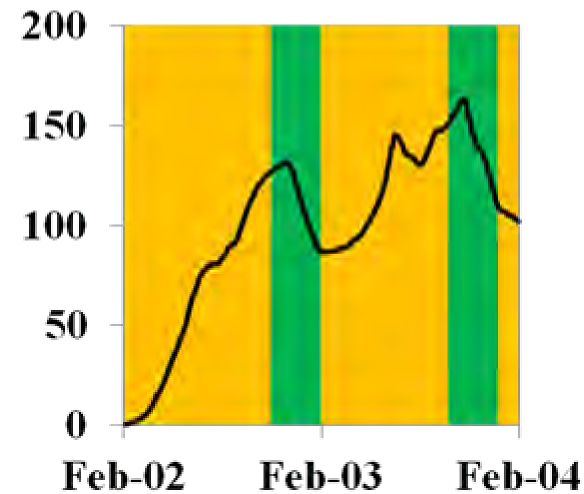
Initial position
Feeding migration
Spawning migration
Final position

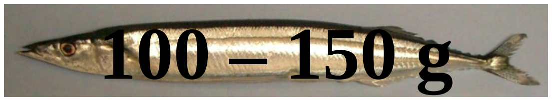


Weight (g)



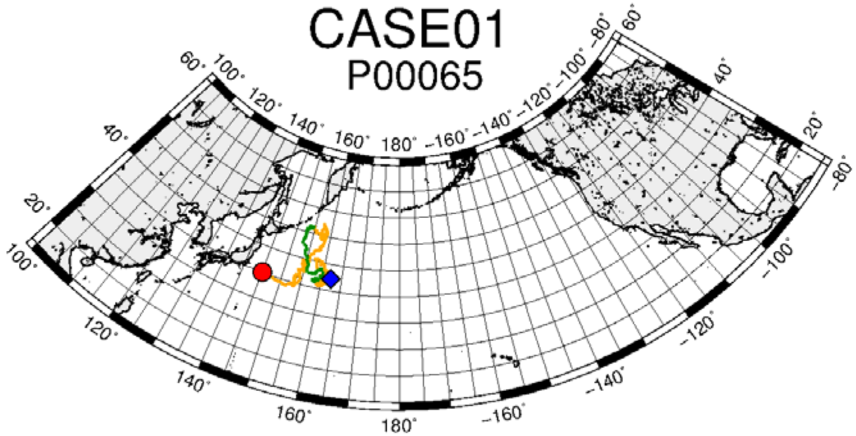


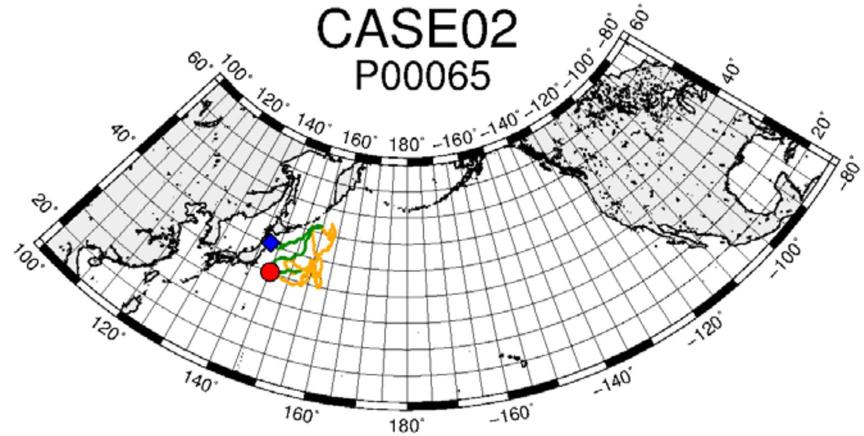


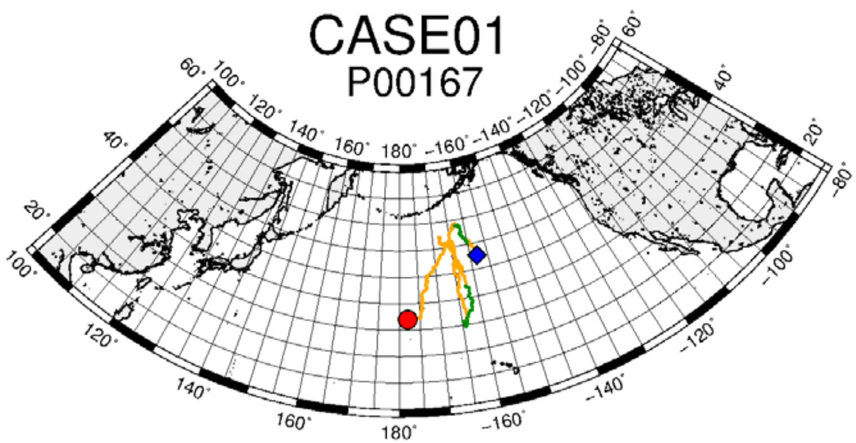


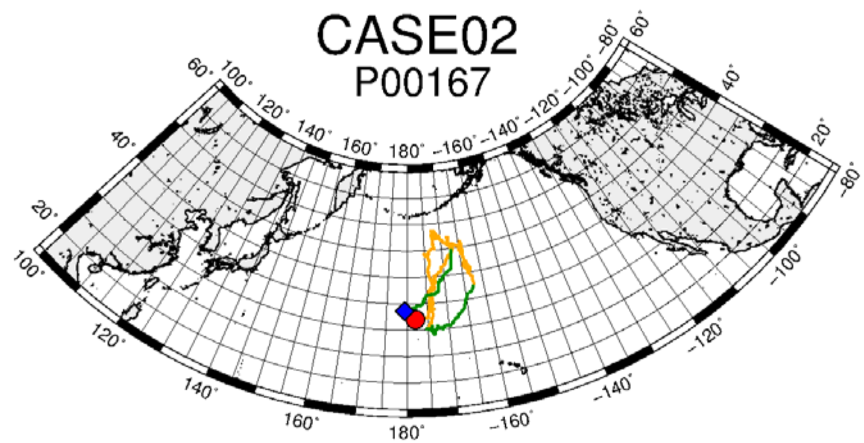
CASE01 vs CASE02

Initial position
Feeding migration
Spawning migration
Final position



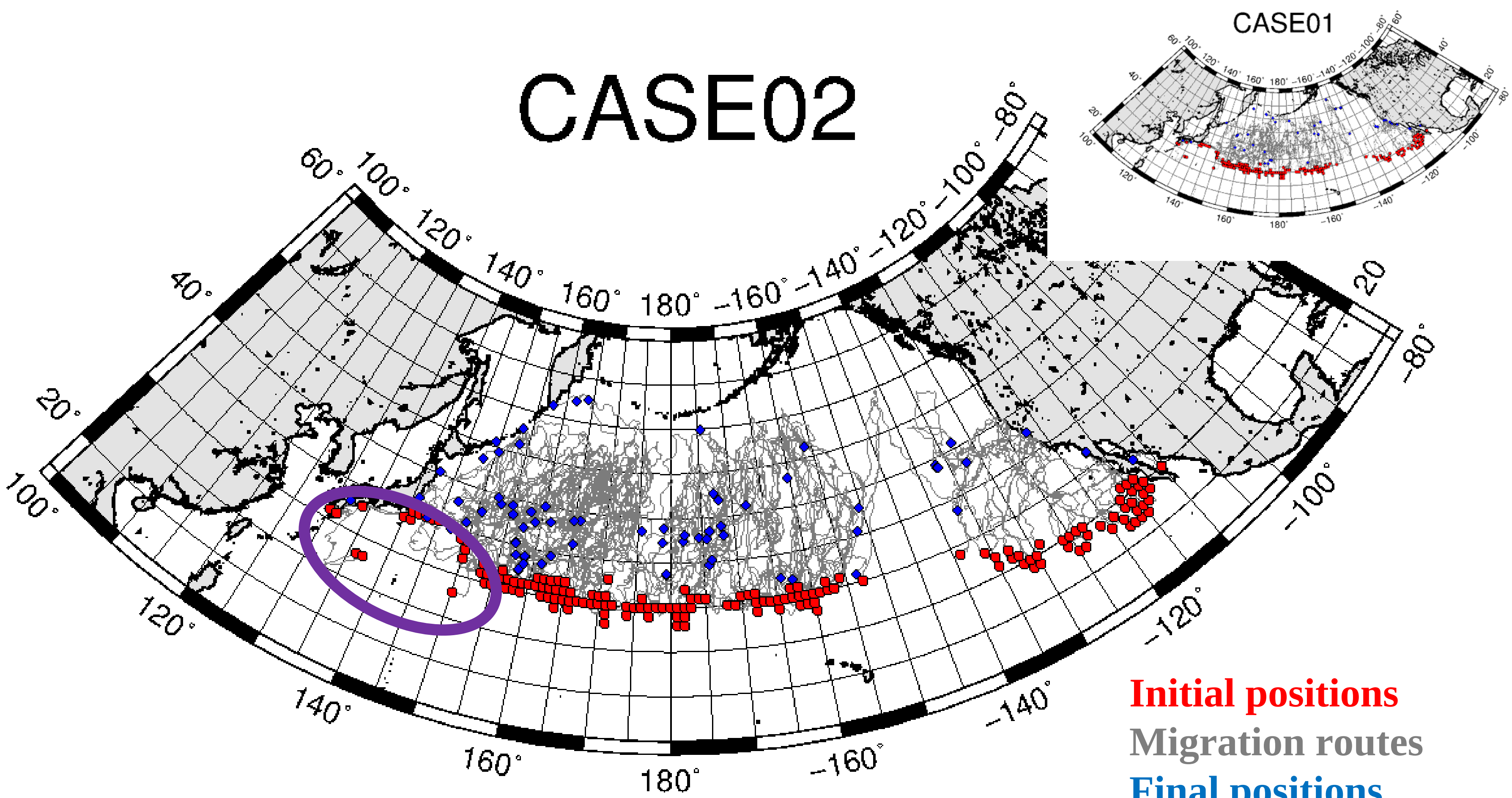




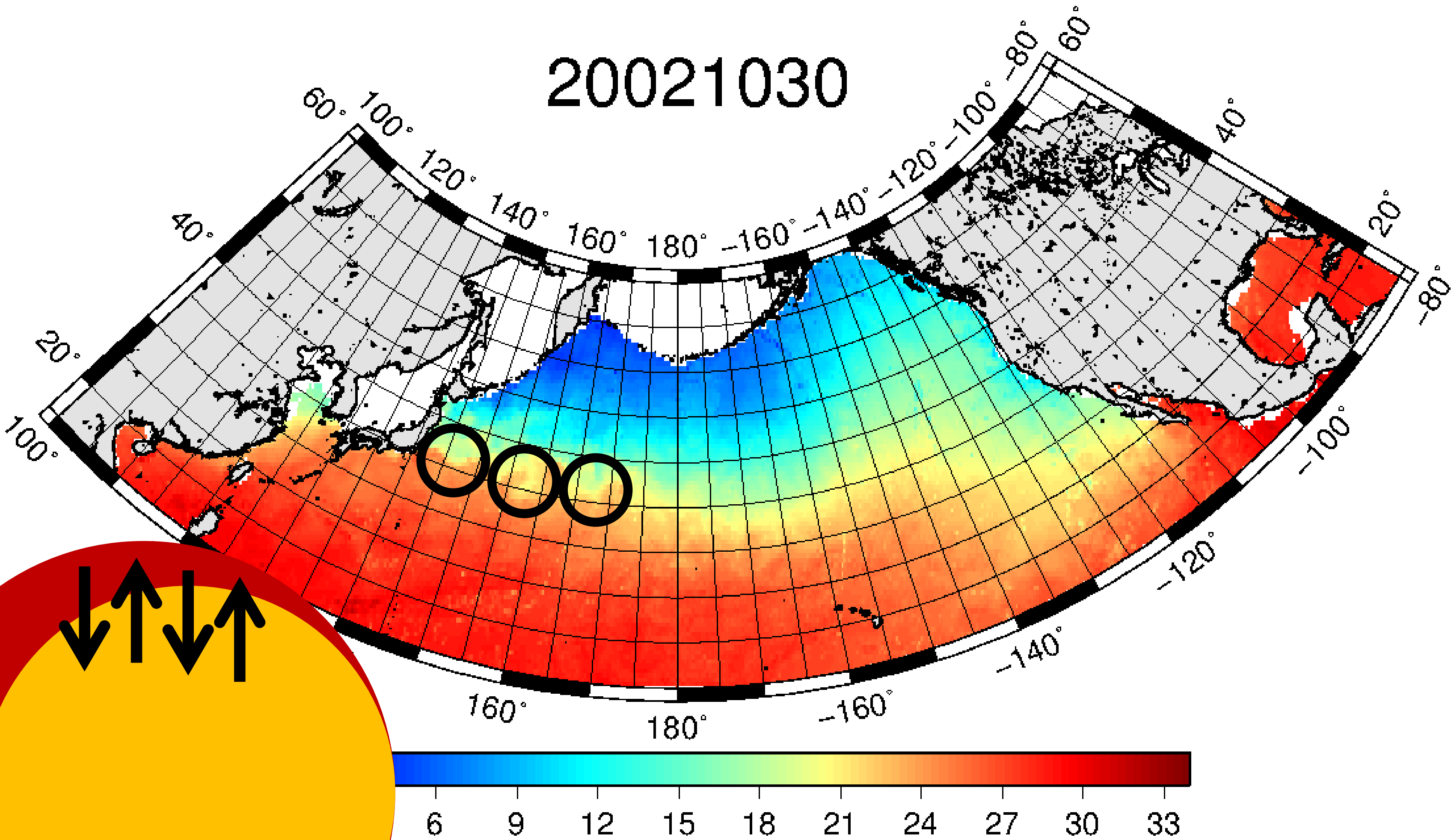


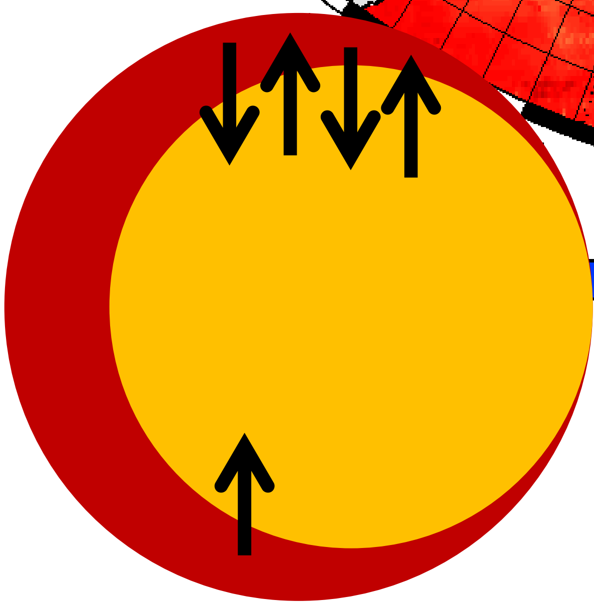
CASE02: CASE01 + Artificial Westward Migration

- **166** particles not reached to 25 cm-body length in 1 year (eliminated in figure).
- **86** particles returned at least once to near (within 5 degree of) the initial position during twice spawning migrations.



Eddy capture



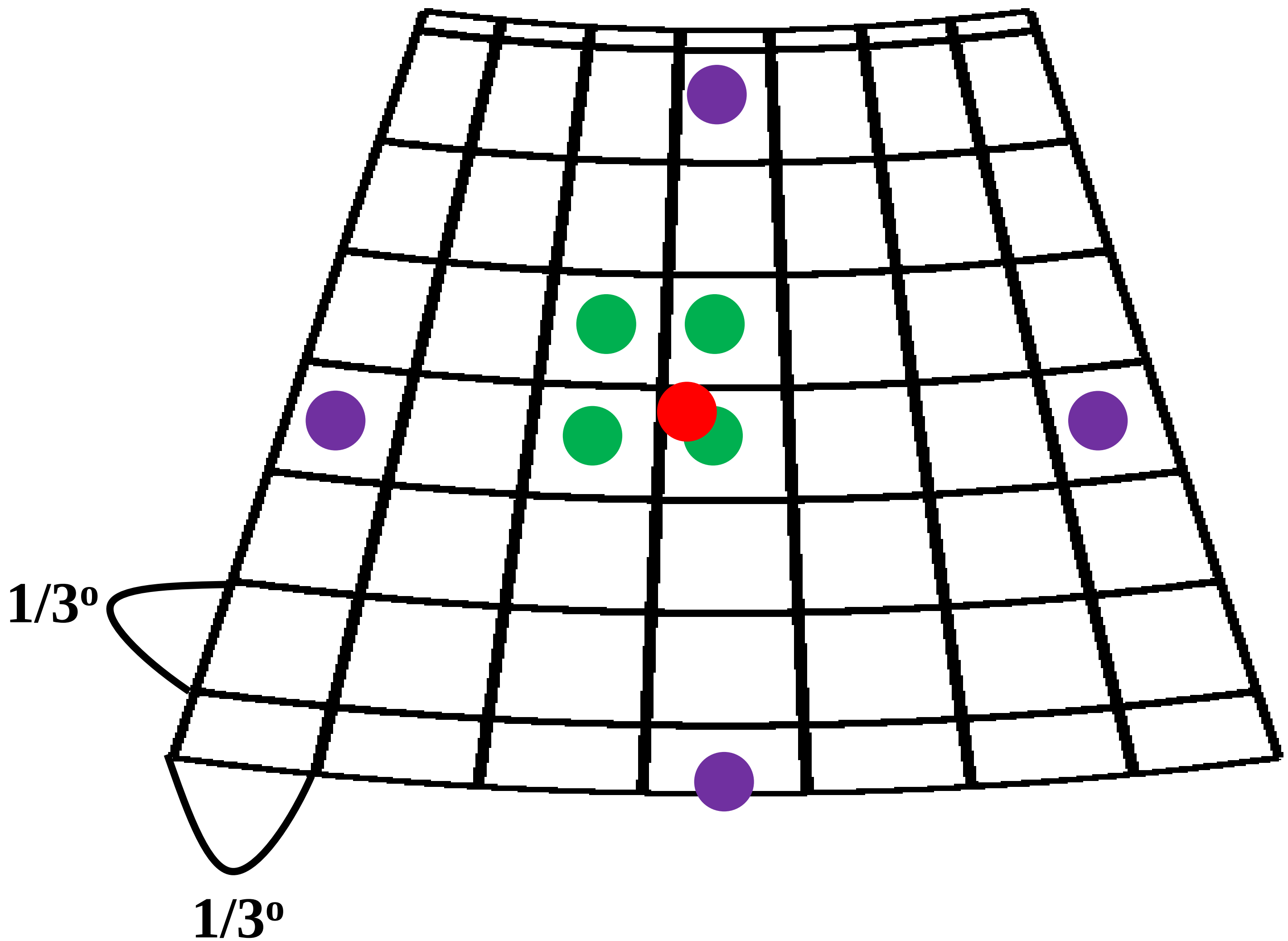


Move toward the **colder** **side**

BUT captured by Eddies

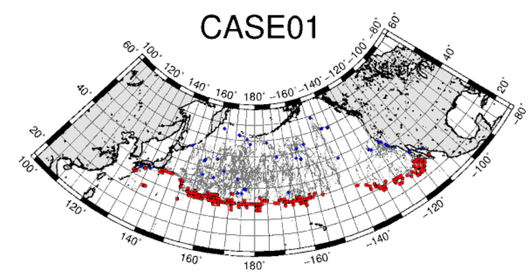
Expanded Search Scope

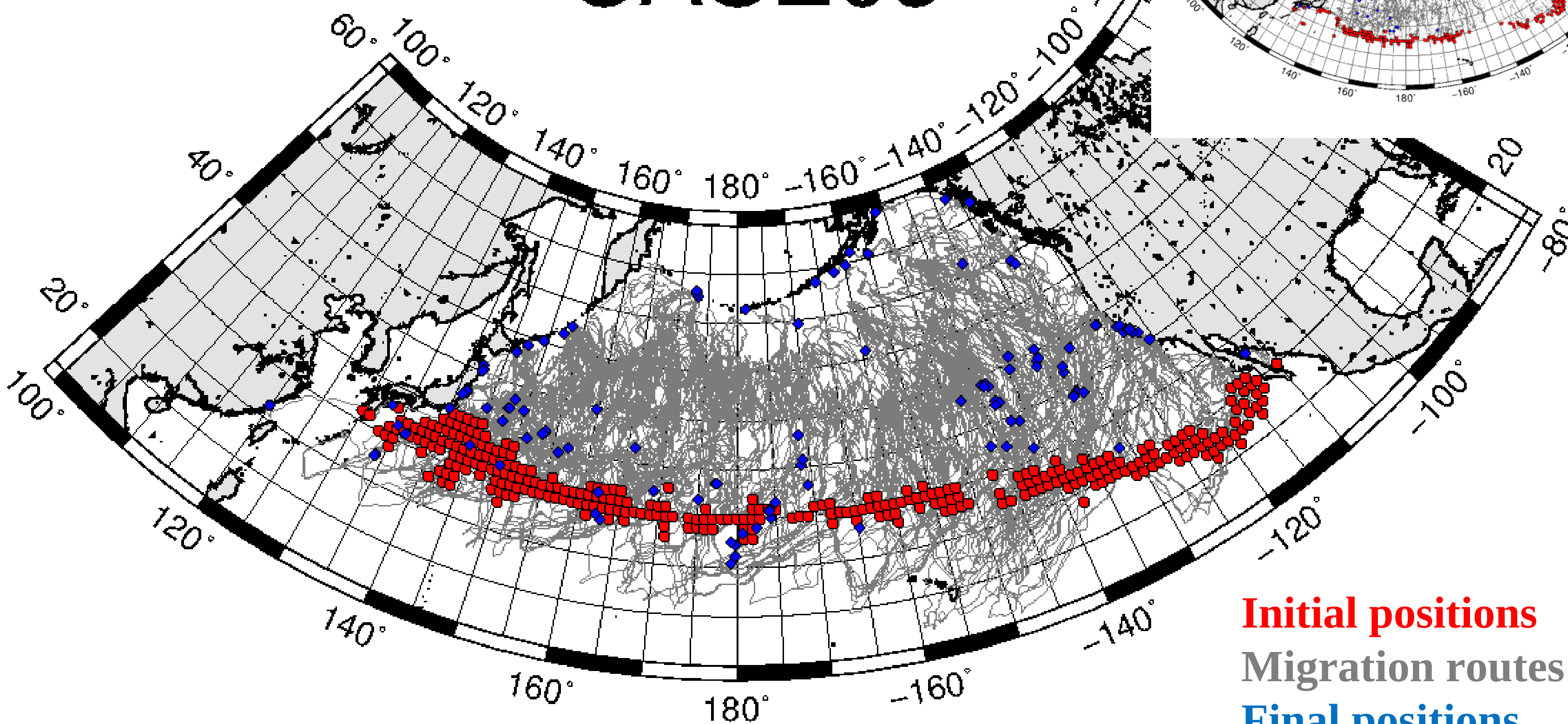
Adjacent 4 grids → 4 grids which are 3 grids far from fish



CASE03: CASE01 + Expanded Search Scope

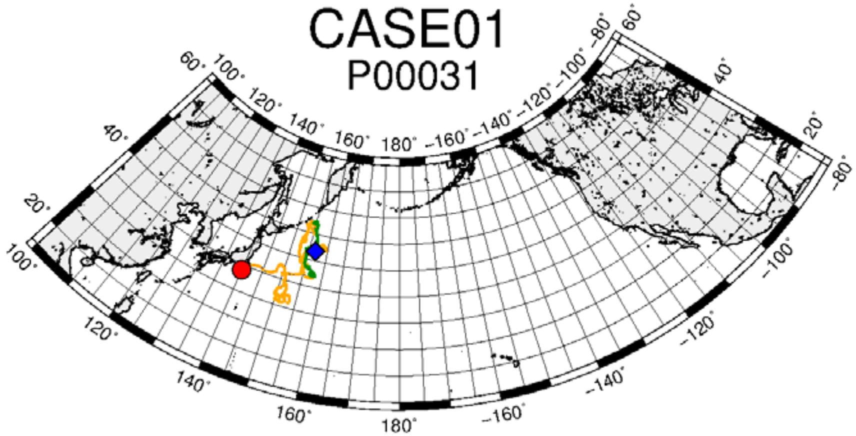
- **19** particles not reached to 25 cm-knob length in 1 year (eliminated in figure).
- **3** particles went out of the model domain (eliminated in figure).
- **138** particles returned at least once to near (within 5 degree of) the initial position during twice spawning migrations.

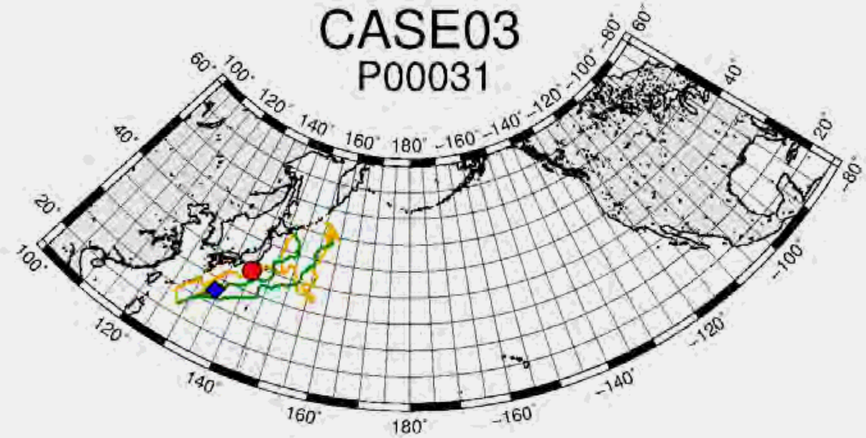


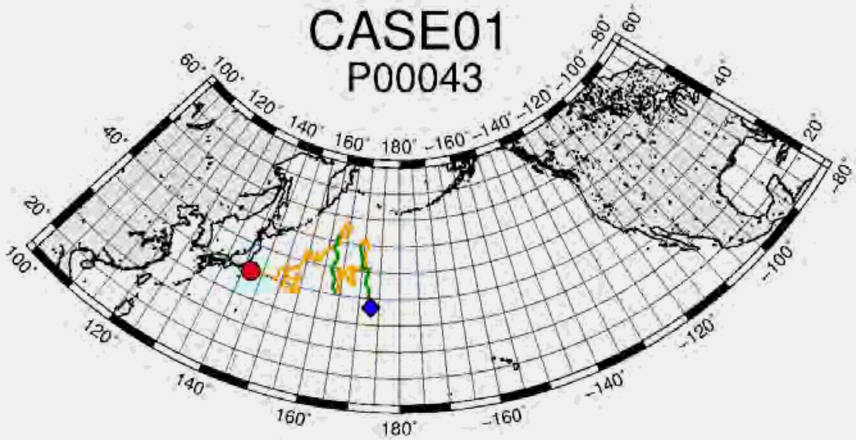


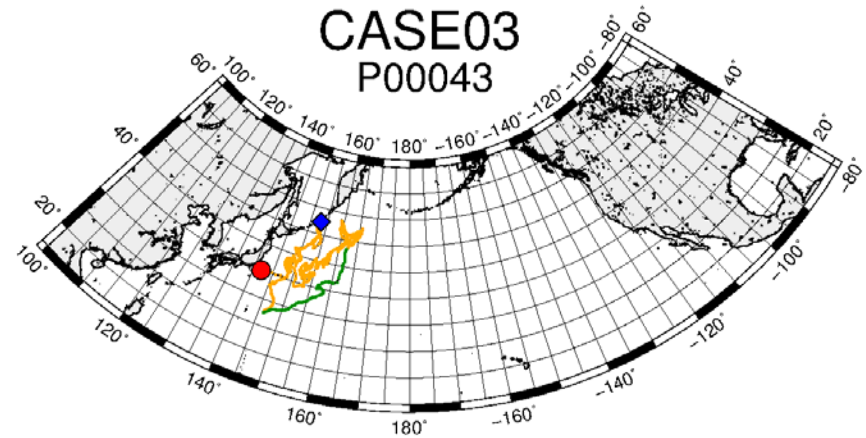
Initial position
Feeding migration
Spawning migration
Final position

CASE01 vs CASE03



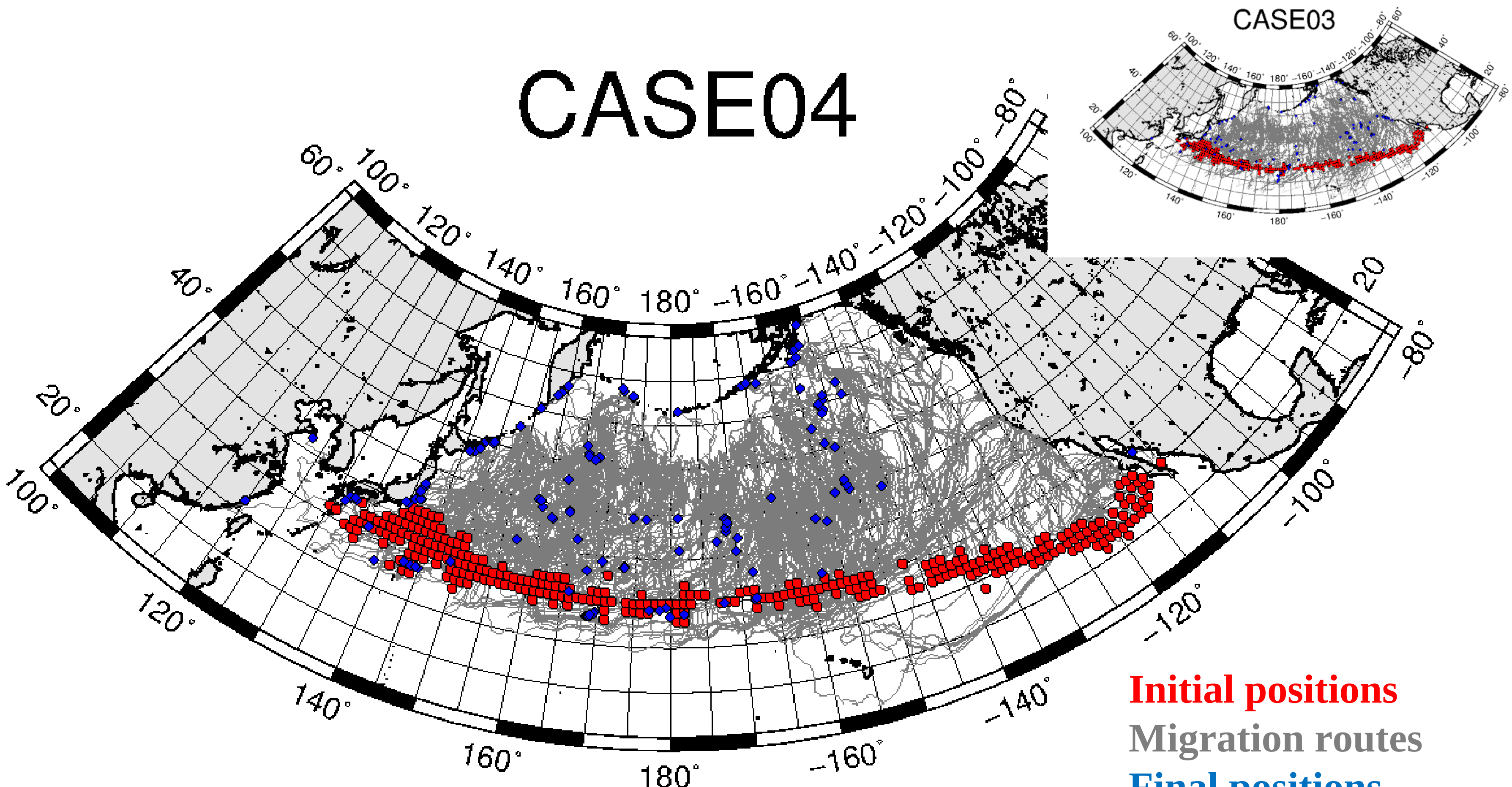






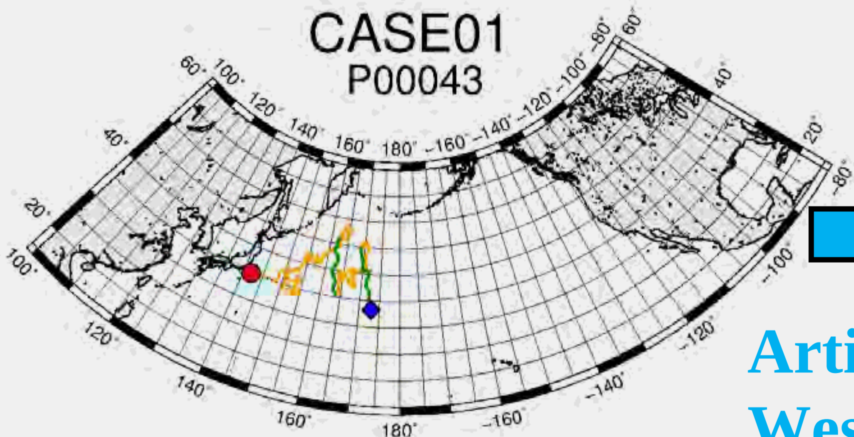
CASE04: CASE03 + Artificial Westward Migration

- **19** particles not reached to 25cm-total length in 1 year (eliminated in figure).
- **151** particles returned at least once to near (within 5 degree of) the initial position during twice spawning migrations.

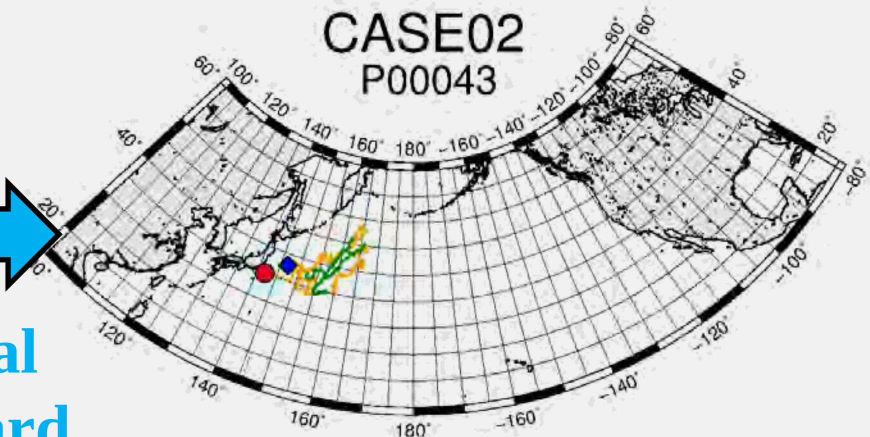


Initial position
Feeding migration
Spawning migration
Final position

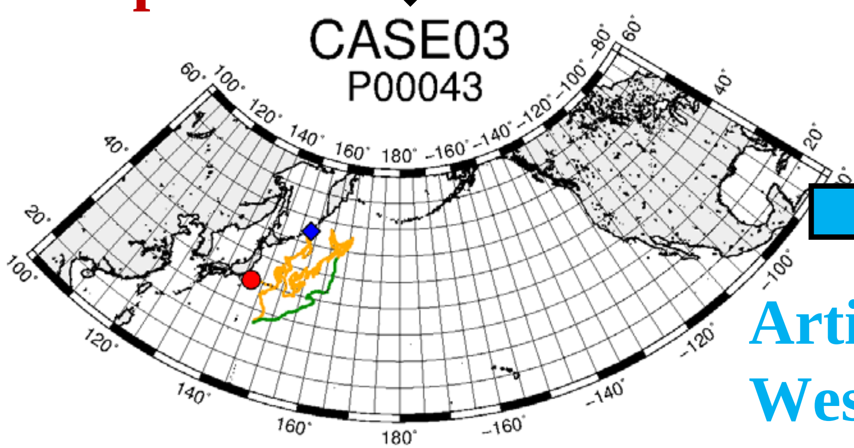
CASE01 vs CASE02 vs CASE03 vs CASE04



Artificial Westward Migration

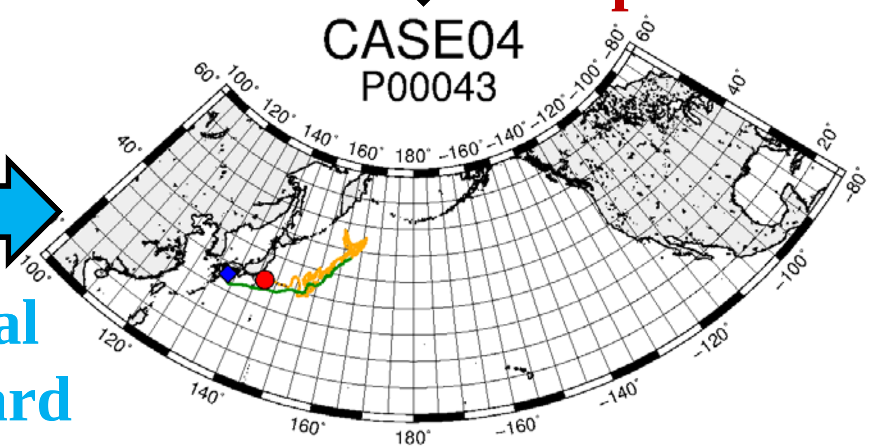


Expanded Search Scope



Artificial Westward Migration

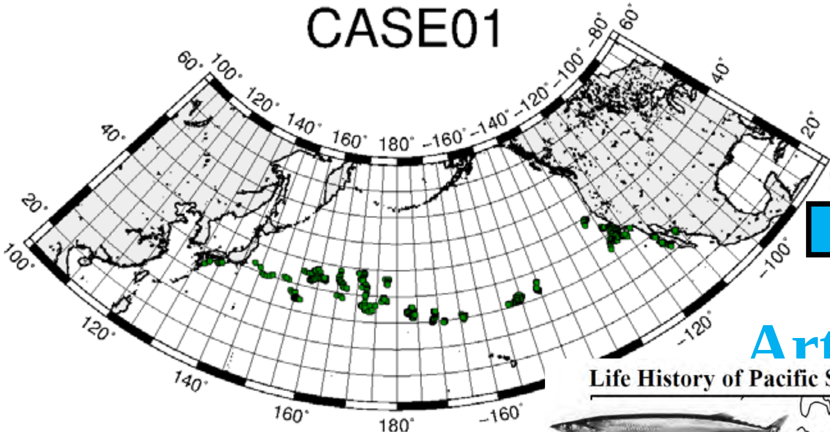
Expanded Search Scope



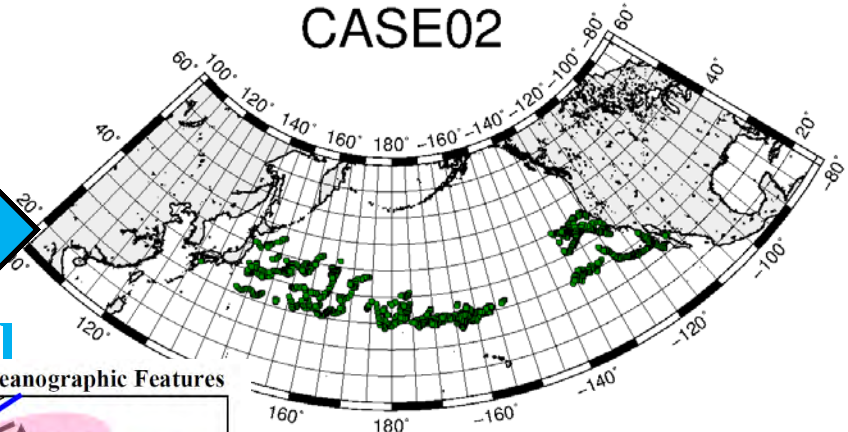
Total spawning positions for two years

Ito et al. (2004)
& Ito et al. (PICES2010)

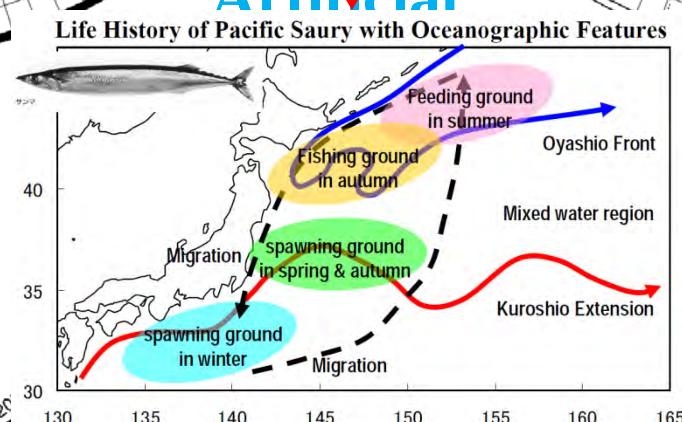
CASE01



CASE02

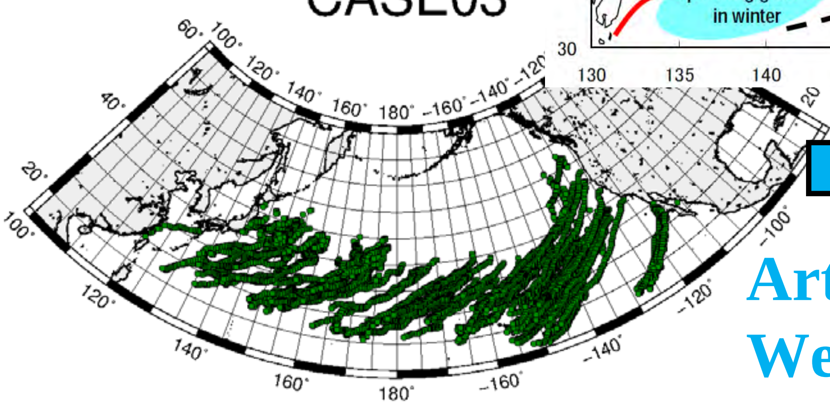


Expanded Search Scope

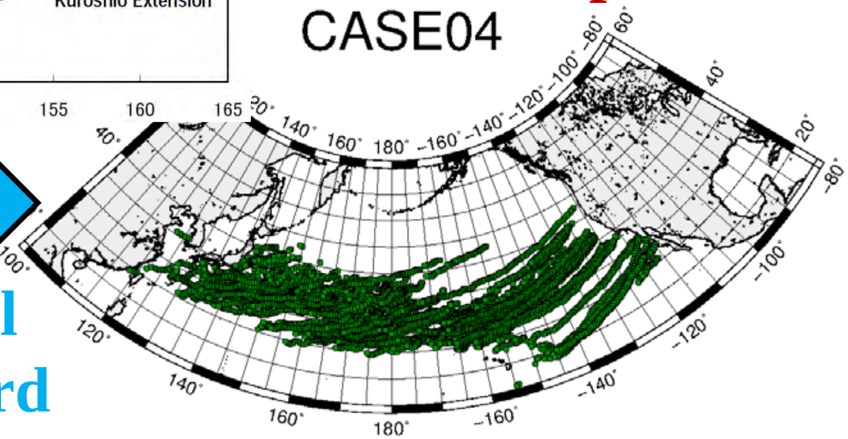


Expanded Search Scope

CASE03

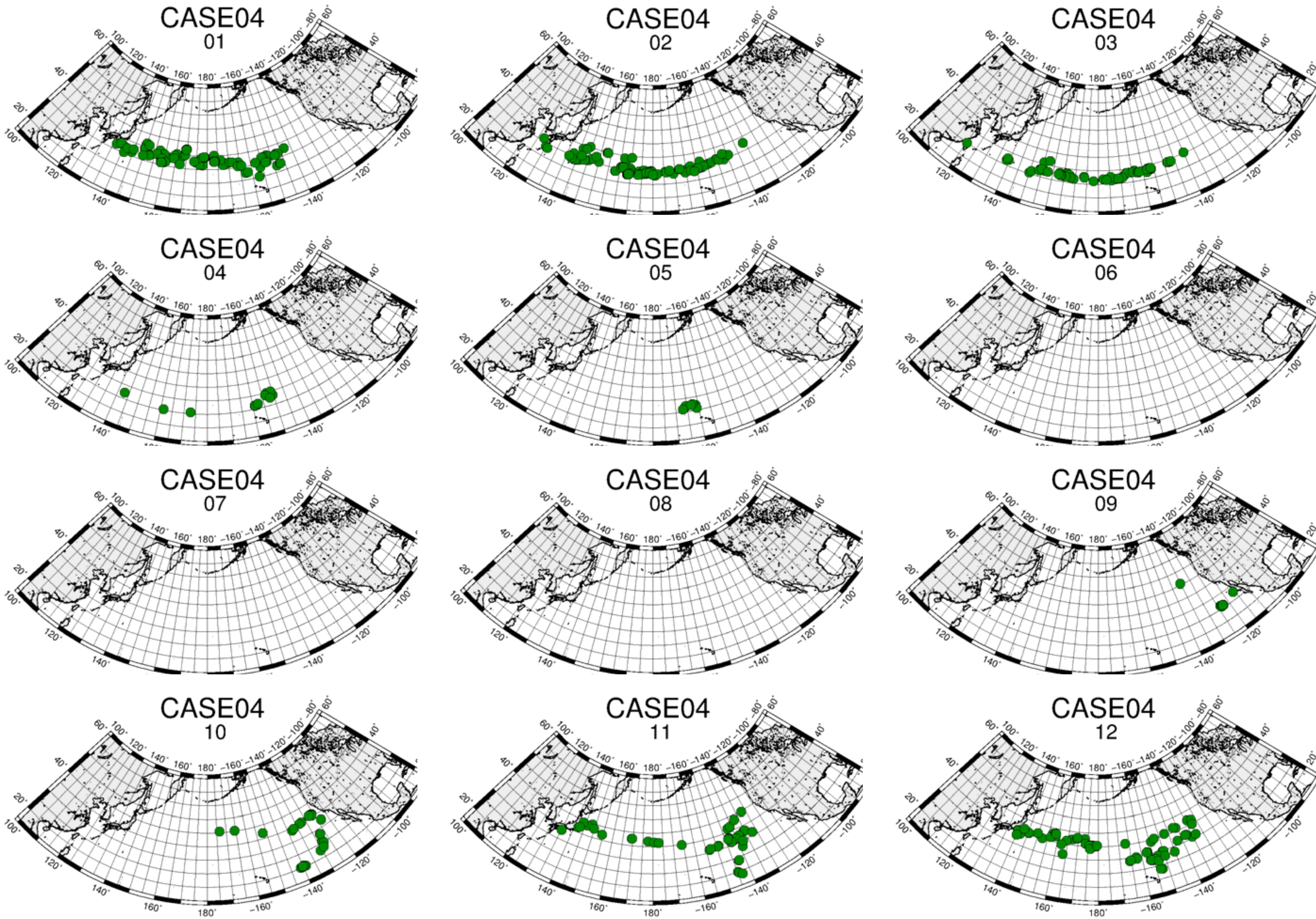


CASE04



Artificial Westward Migration

Spawning positions on 1st day of each month



Conclusions

- A two-dimensional Individual-Based Model coupled with fish bioenergetics model has been developed to simulate the migration and growth of Pacific saury.

- Fish movements was controlled by feeding and spawning migrations with passive transport by ocean current.

- To release from eddies, we expanded the scope of search for optimal habitats.

- The condition of an artificial westward migration was needed during spawning migration to form spawning ground around Japan.