MULTIFAN-CL

- Longevity
- Valuable features for tuna dynamics

Longevity of MULTIFAN-CL

- December 2021, Dave Fournier retired, since project focus is to:
  - consolidate recent new features
  - undertake enhancements of existing features, and
  - complete documentation
- MFCL project has long-been under-resourced, is now even more so, with only 1 staff engaged with maintaining the software, with some software administrative support provided by Fabrice Bouyé
- project currently is able to support the ongoing requirements of OFP stock assessments as they explore alternative model configurations and for projection simulations for MSE
- Reasonably regular and comprehensive testing of development versions is done preceding merges to the repository "master" branch
- Other important support functions, such as maintaining user's documentation, are sorely neglected
- can continue this through a smooth transition phase to using the next-gen-mod (3-4 years ?)

Current MULTIFAN-CL work plan

- YFT2020 Peer Review recommendations:
  - variability in weight-at-length can be taken into account
  - specify the number of spline knots when defining selectivity and where they are located with respect to age (length)
  - account taken of age-reading error when fitting to conditional age-at-length data
  - add the ability to specify overdispersion in CPUE as an additive rather than multiplicative factor
  - integrate the calculation of M-at-age from the sex-ratio data into MULTIFAN-CL unless a sex-specific assessment is used- User's Manual documentation
- MSE projections capability for effort-conditioned fisheries
- Upgrade the simulation generation of pseudo-observations of tagging data for the catch-conditioned model
- Test the multi-sex model capability for: the catch-conditioned method and for projections

1. Space partition

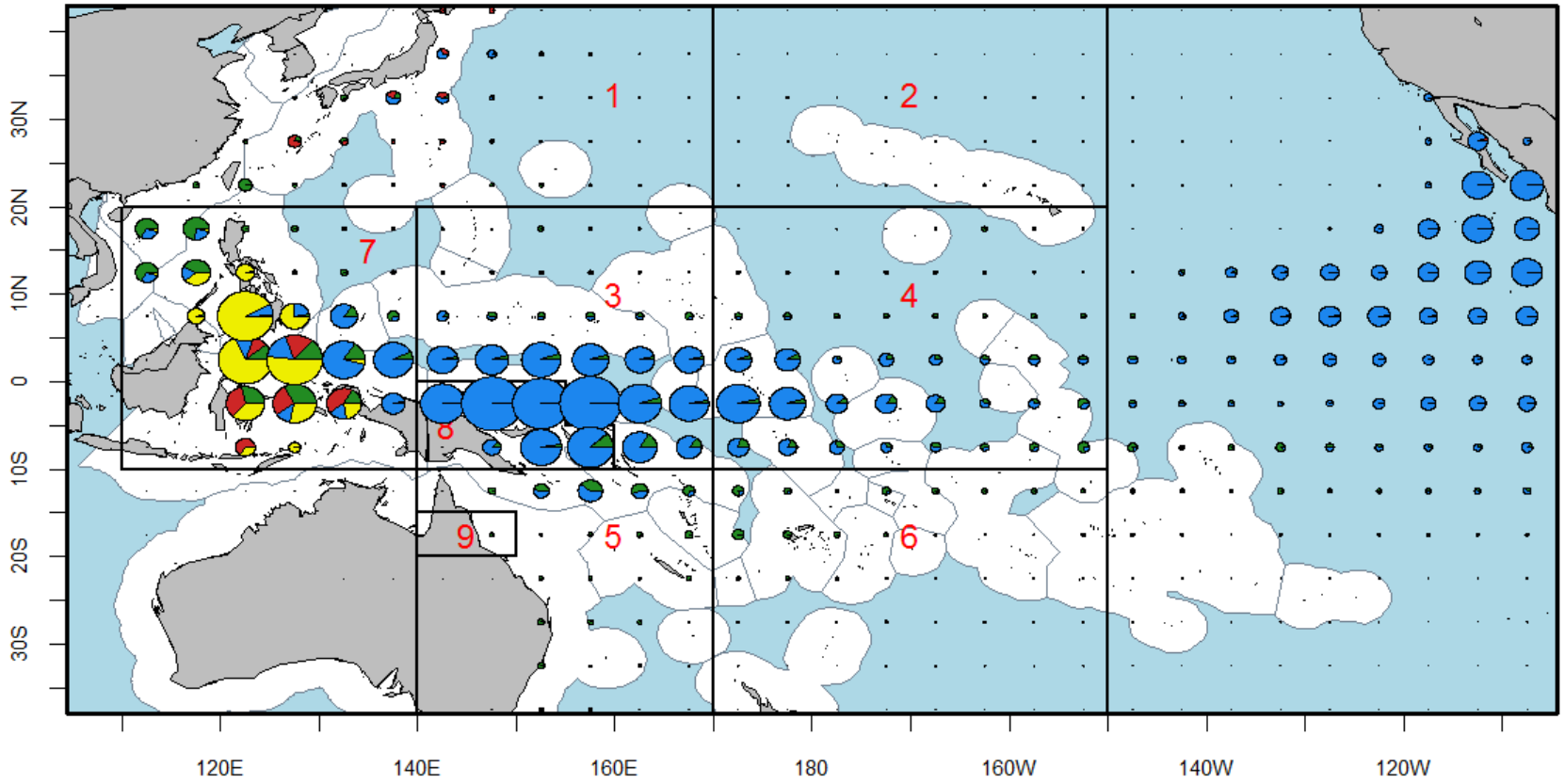
Rationale:

- to explicitly describe spatial processes that lead to heterogeneity within the fish stock
- to account for heterogeneity in fleet structure or management measures

In summary - to explicitly describe the variable effects of fishing mortality on the stock by area

Spatial complexity in WCPO

Heterogeneity:
- fisheries
- biology



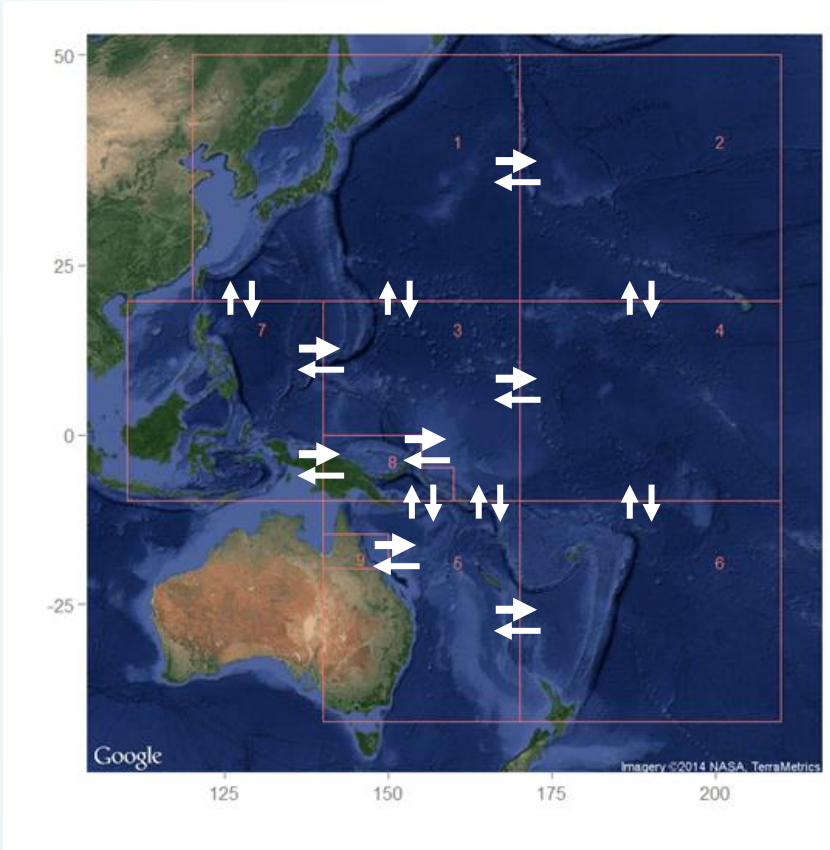
Movement parameterisation

- Temporal:
  - Flexibility for number of movements per year (e.g. each quarter)
  - Flexibility for grouping (shared) movements for particular time periods, e.g. 1 2 2 1 rather than 1 2 3 4
- Spatial:
  - coefficients estimated are region boundary-specific, so flexibility for:
    - number of regions
    - adjacent regions

Movement processes in MULTIFAN-CL cont.

Movement matrix in respect of regions

e.g. yellowfin tuna



Destination region
R2 R3 R4 R5 R6 R7 R8 R9

Region of origin # Incidence matrix

R1----------	**1**	**1**	0	0	0	**1**	0	0
R2----------		0	**1**	0	0	0	0	0
R3----------			**1**	**1**	0	**1**	**1**	0
R4----------				0	**1**	0	0	0
R5----------					**1**	0	**1**	**1**
R6----------						0	0	0
R7----------							**1**	0
R8----------								0

- Flexibilty in respect of the vectors of movement coefficients in respect of: spatial structure, temporal assumptions

Region structure

Incidence matrix

	2	**3**	**4**	**5**
1	0	0	1	1
2		0	1	1
3			1	1
4				0

nvar = 12 coefficients; m_{ij}

i	***j***
1	4
1	5
2	4
2	5
3	4
3	5
4	1
4	2
4	3
5	1
5	2
5	3

Movement processes cont.

- Fully implicit solution → movement can occur to all regions (including non-adjacent) in a single time step
- guarantees numerical stability

$$\mathbf{N_{at}} = \mathbf{B_a^{-1}} \cdot \mathbf{N'_{at}};$$

$$\mathbf{B_a} = \begin{bmatrix}
1+\nu_a^{12}+\nu_a^{13}+\nu_a^{14} & -\nu_a^{21} & -\nu_a^{31} & -\nu_a^{41} & 0 & 0 & 0 \\
-\nu_a^{12} & 1+\nu_a^{21}+\nu_a^{25} & 0 & 0 & -\nu_a^{52} & 0 & 0 \\
-\nu_a^{13} & 0 & 1+\nu_a^{31}+\nu_a^{34} & -\nu_a^{43} & 0 & 0 & 0 \\
-\nu_a^{14} & 0 & -\nu_a^{34} & 1+\nu_a^{41}+\nu_a^{43}+\nu_a^{45}+\nu_a^{46} & -\nu_a^{54} & -\nu_a^{64} & 0 \\
0 & -\nu_a^{25} & 0 & -\nu_a^{45} & 1+\nu_a^{52}+\nu_a^{54}+\nu_a^{57} & 0 & -\nu_a^{75} \\
0 & 0 & 0 & -\nu_a^{46} & 0 & 1+\nu_a^{64}+\nu_a^{67} & -\nu_a^{76} \\
0 & 0 & 0 & 0 & -\nu_a^{57} & -\nu_a^{67} & 1+\nu_a^{75}+\nu_a^{76}
\end{bmatrix}$$

Movement processes cont.

- Options for age dependency of the movement coefficients:

$$\nu_a^{rs} = \phi_0^{rs} \exp\left(\phi_1^{rs} (\kappa_a)^{\phi_2^{rs}}\right)$$

  - linear-dependence ϕ_1^{rs}
  - non-linear-dependence ϕ_2^{rs}

2. Tag partition

Tagged population model

- Each release event represents a “parallel” **tagged** population

tagnum_fish(**1,tag_events**,1,nregions,1,nperiods, 1,nage)

- shares most of the dynamic processes with the model (**un-tagged**) population
- **Identical movement and growth processes**
- The exception process is recruitment: where for the tagged population a **“cohort”** is a release event comprising a “recruitment” in numbers at length

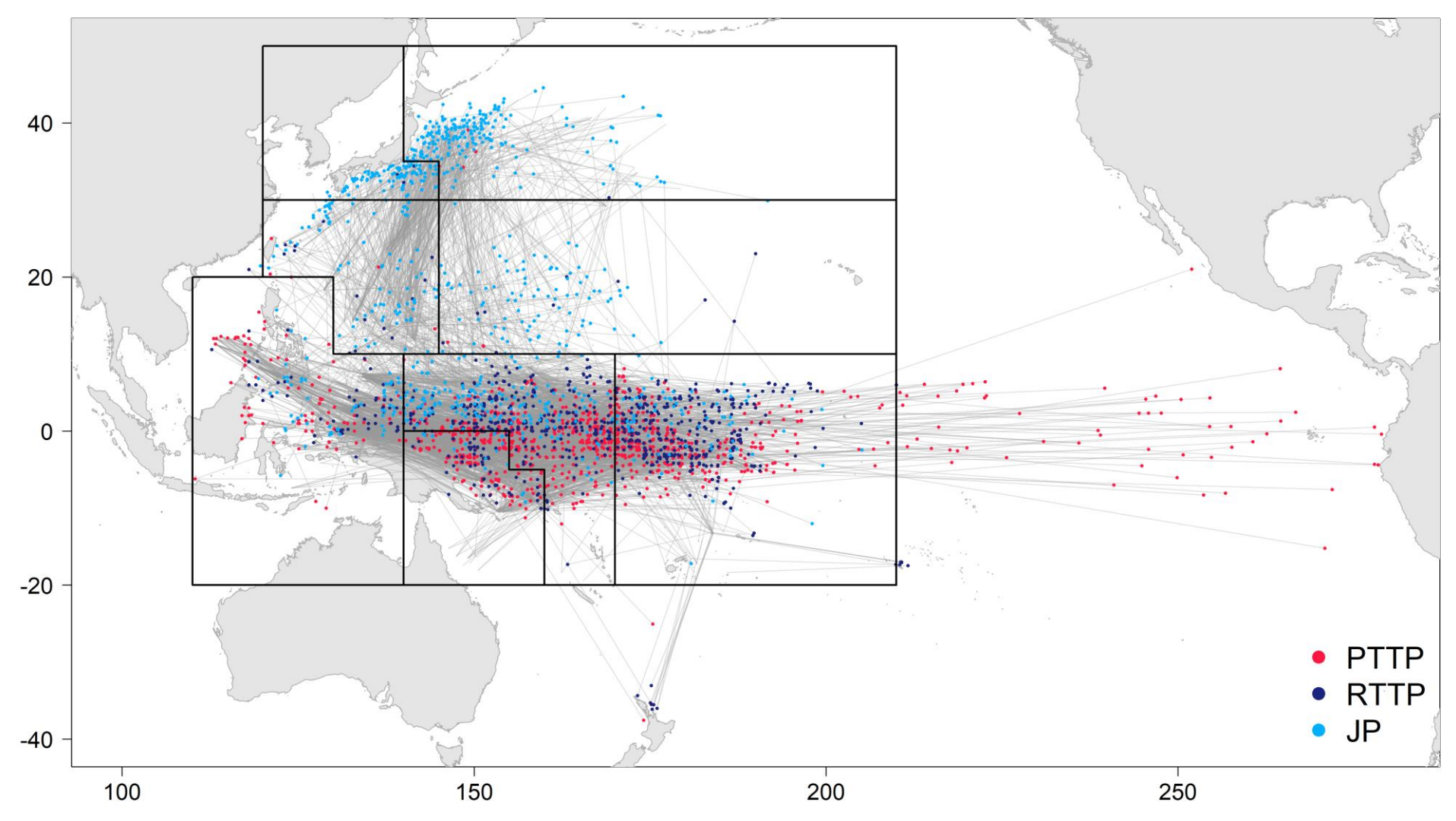
Tagged population model

- MULTIFAN-CL is age-structured. Tag releases are **length-specific** – transformed to be **age-specific** via the estimated growth function
- A **mixing period** is specified for assumed random mixing of tagged population
- Grouping of recaptures: specified fisheries for which recaptures can be aggregated

Tag population dynamics - release

- Tags released are assigned to a ***tag cohort*** *(c)* – being a tag release **group**
- **Pooled group** – aggregate cohorts *(c*)* from tag groups in a single group when attain a^{pool}. Age structure is maintained

Tag movements - SKJ



269 release groups 329,811 releases 56,092 recaptures