Integrating tagging data in MFCL

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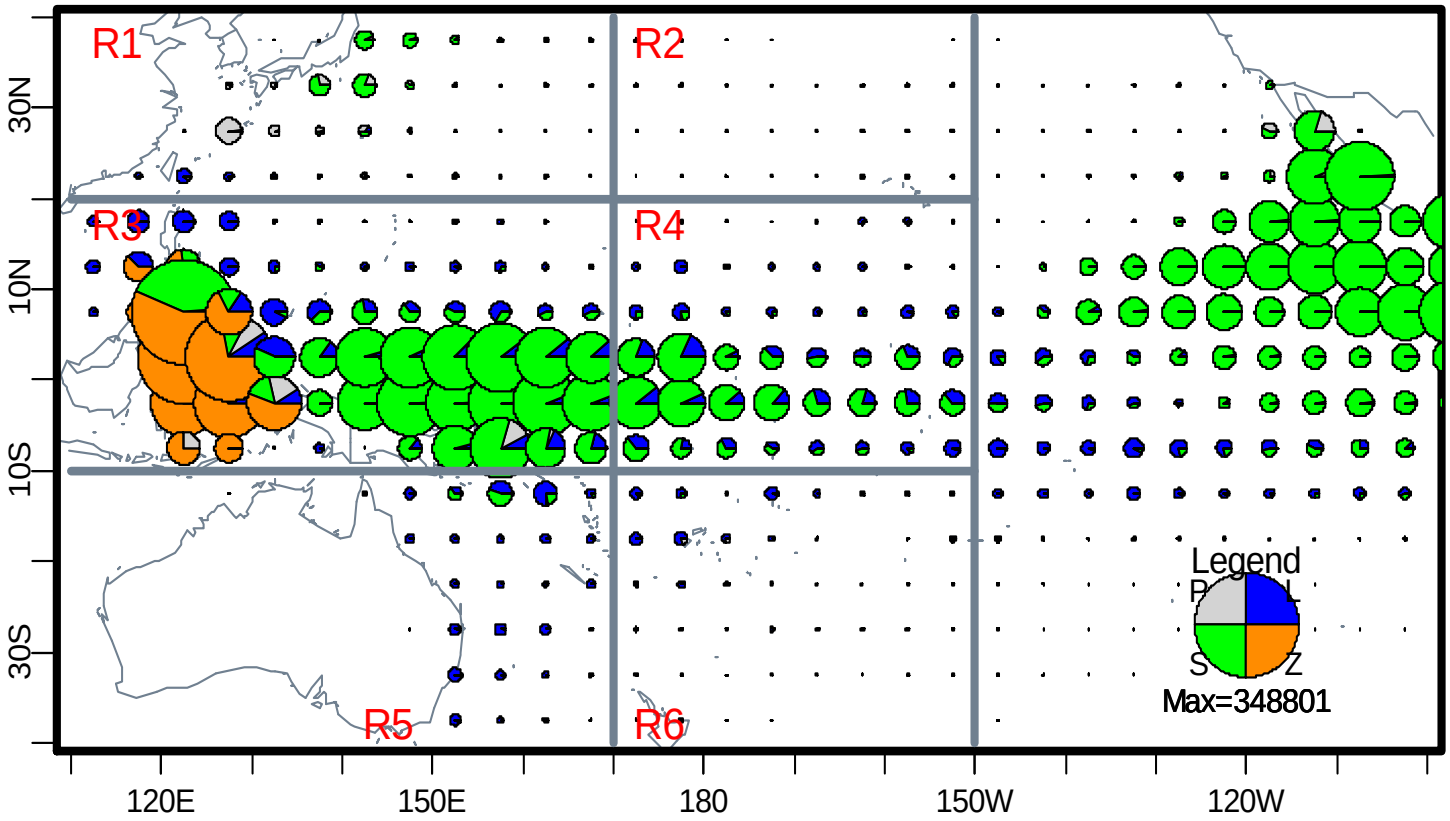
MFCL intro

- MFCL – spatially disaggregated, age structured population model.
- Catch, effort, size, and tagging data.
- Conventional tags – inform the model about:
  - Fishing mortality rate (fishery specific)
  - Movement
  - Natural mortality (age specific); e.g. SKJ.
  - But not growth (tag recovery size data not used).

Spatial structure



Region specific releases; fishery (defined by region/gear) specific recoveries.

Tags generally applied to smaller fish in population. PL method.

Model structure

- Observation models for data; catch, length composition, weight composition, and tagging.
- Observed catch assumed to be (essentially) known.

$$F_{atf} = s_{af} q_{tf} B_{r_f}^{\beta} E_{tf}^{\zeta} e^{\varepsilon_{tf}}$$

- Tag dynamics: tag mixing period, fishery specific reporting rates estimated.

Tag input data structure

- *.tag file
- Aggregated by release group: region/time (quarter) and by length interval.
- Recovery:
  - time & fishery of recapture
  - length interval at release (used to calculate age at release = tag cohort).

#
HEADER INFO
#
SPC tag release 1 -1
#
Region Year Month
1 1977 11
#Length interval of release
30 32 34 36 38 40 42 44 46 48 50 52 54
0 2 3 9 10 22 12 26 46 240 629 799 740
#
#Recovery
Length Fishery Year Month Number
46 3 1977 11 1
46 3 1978 5 1
48 3 1977 11 4
48 3 1978 5 2
48 3 1978 8 2
48 3 1978 11 1
48 3 1979 5 1
50 2 1978 5 2
50 3 1977 11 10
50 3 1978 2 1
50 3 1978 5 3
50 3 1978 8 2
50 3 1978 11 4
50 3 1979 5 1
52 2 1978 5 3
52 3 1977 11 10
52 3 1978 5 1
52 3 1978 8 8
52 3 1978 11 9
54 1 1978 11 1
54 3 1977 11 5
54 3 1978 5 3
54 3 1978 8 2
54 3 1978 11 6
54 3 1979 2 1
56 3 1977 11 1
56 3 1978 8 1

Tag population - initial

- Tags released are assigned to a *tag cohort (*c*)* – tag release group/age class.
- Each length interval (of release) assigned to an age.
  - Accumulate each age class (a) from multiple length classes.
- Pooled group – aggregate cohorts *(*c**)* from tag groups in a single group when attain a^{pool}. Maintain age structure.

Tag cohorts - releases

Tag group X

$$N_c^{\mathrm{rel}} \qquad N^{\mathrm{T}}_{c,t-1,r} e^{-Z^{\mathrm{T}}_{c,t-1,r}} \qquad Z^{\mathrm{T}}_{ctr} = \sum_{f \in f_r} F^{\mathrm{T}}_{ctf} + M_{a(c,t)}$$

Region 1

*T*rel

time \ age	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	5	55	55	14	3	0	0	0	0	0
6	0	2.122857	23.35143	23.35143	5.944	0	0	0	0	0
7	0	0	1.06685	11.73535	11.73535	0	0	0	0	0
8	0	0	0	0.593526	6.528788	0	0	0	0	0
9	0	0	0	0	0.347	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0

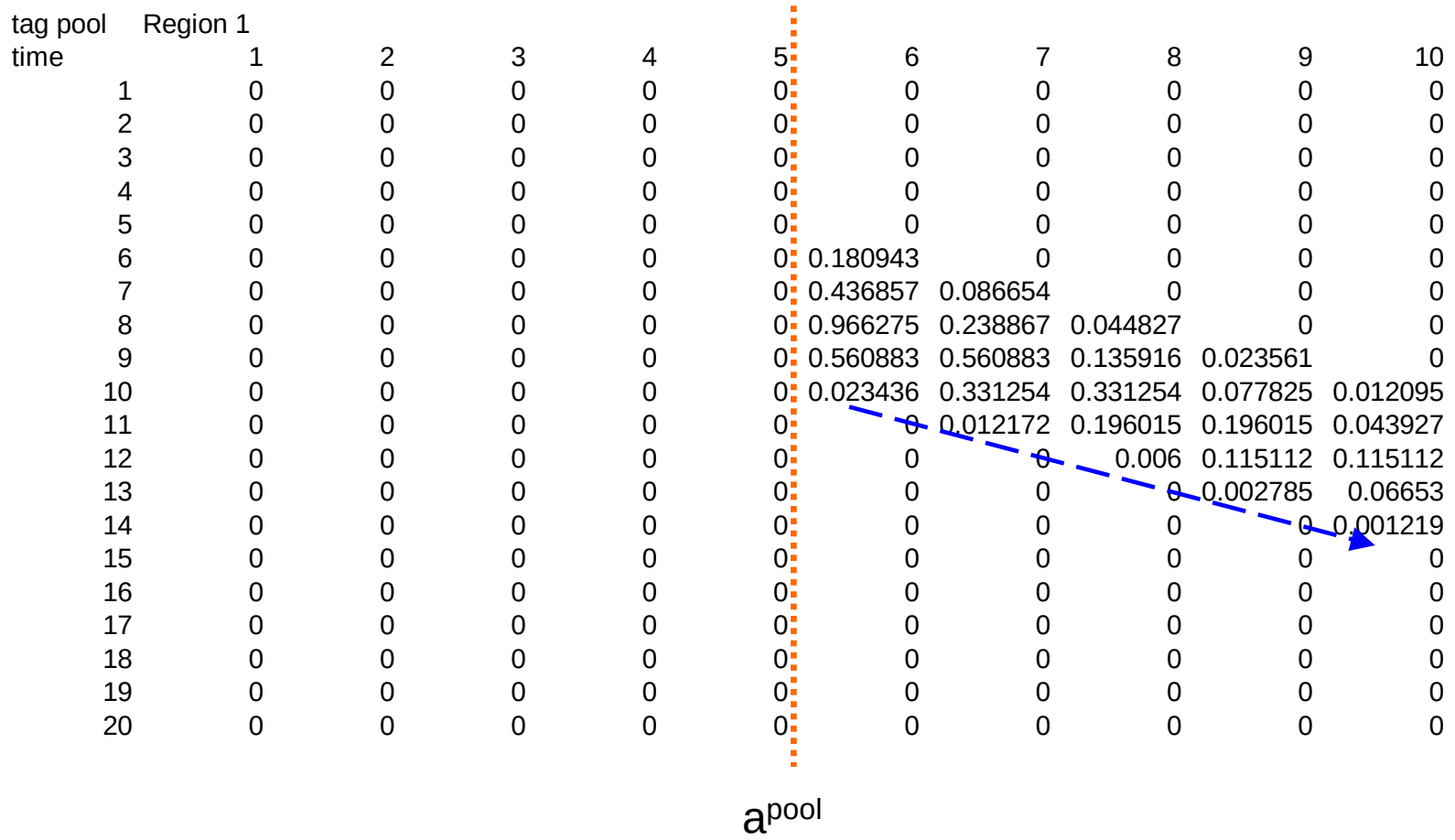
a^{pool}

Pooled tag group

Pooled tag group

Single release group

tag pool	Region 1									
time	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0.180943	0	0	0	0
7	0	0	0	0	0	0.436857	0.086654	0	0	0
8	0	0	0	0	0	0.966275	0.238867	0.044827	0	0
9	0	0	0	0	0	0.560883	0.560883	0.135916	0.023561	0
10	0	0	0	0	0	0.023436	0.331254	0.331254	0.077825	0.012095
11	0	0	0	0	0	0	0.012172	0.196015	0.196015	0.043927
12	0	0	0	0	0	0	0	0.006	0.115112	0.115112
13	0	0	0	0	0	0	0	0	0.002785	0.06653
14	0	0	0	0	0	0	0	0	0	0.001219
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0



Tag dynamics

- Mixing phase of X time periods
  - not included in likelihood
- Mixing phase fishing mortality = corrected tag returns during period

$$\mathrm{fn}_3(R^{\mathrm{Tobs}}_{ctf}, X_{tf}) \;\; ; \quad t^{\mathrm{rel}}_c \leq t < t^{\mathrm{rel}}_c + n^{\mathrm{mix}}$$

- Fishing mortality on tag cohort (post-mix)

$$F_{a(c,t),t,f} \;\; ; \qquad t \geq t^{\mathrm{rel}}_c + n^{\mathrm{mix}}$$

- Movement (equivalent to untagged fish)

Tag cohorts - movement

F	0.2	movement	0.3	tag-pool	5
M	0.3				

Region 1

time \ age	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	5	55	55	14	3	0	0	0	0	0
6	0	2.122857	23.35143	23.35143	5.944	0	0	0	0	0
7	0	0	1.06685	11.73535	11.73535	0	0	0	0	0
8	0	0	0	0.593526	6.528788	0	0	0	0	0
9	0	0	0	0	0.347	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0

Region 2

time \ age	1	2	3	4	5
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0.909796	10.00776	10.00776	2.547429
7	0	0	0.772547	8.498015	8.498015
8	0	0	0	0.522125	5.74337
9	0	0	0	0	0.329677
10	0	0	0	0	0
11	0	0	0	0	0
12	0	0	0	0	0
13	0	0	0	0	0
14	0	0	0	0	0
15	0	0	0	0	0
16	0	0	0	0	0
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0

$$N^{\mathtt{T}}_{ctr} = N^{\mathtt{T}'}_{ctr} - \left(\sum_{s \neq r} \nu^{rs}_{a}\right) N^{\mathtt{T}'}_{ctr} + \sum_{s \neq r} \nu^{sr}_{a} N^{\mathtt{T}'}_{cts}$$

$$N^{\mathtt{P}}_{tr} = N^{\mathtt{P}'}_{tr} - \left(\sum_{s \neq r} \nu^{rs}_{a}\right) N^{\mathtt{P}'}_{tr} + \sum_{s \neq r} \nu^{sr}_{a} N^{\mathtt{P}'}_{ts}$$

Predicted tag returns

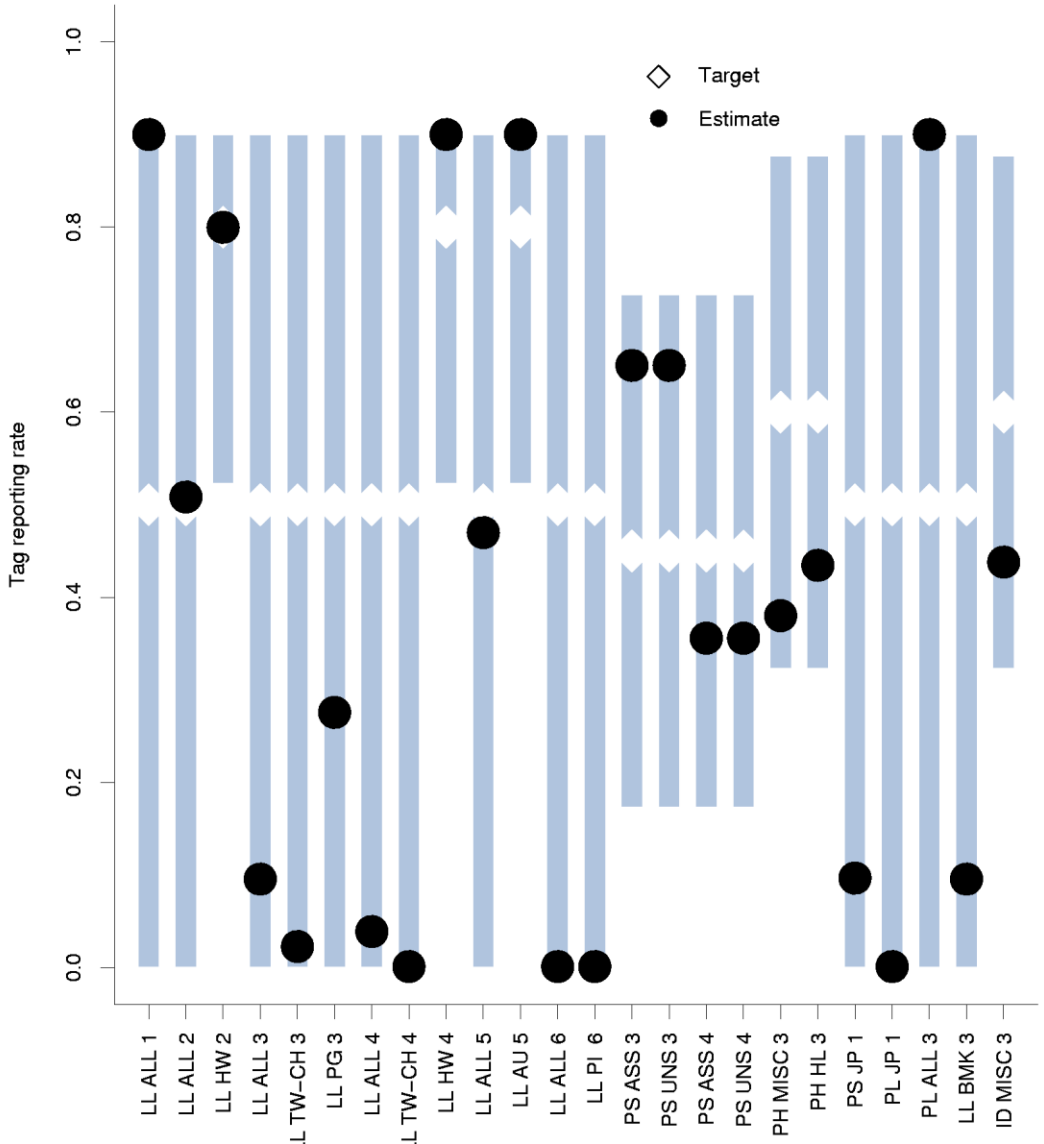
- Fishery specific reporting rate X_{tf} (can be temporally variant).
- Reporting rate priors; mean and penalty weight (*p*).
- Sharing reporting rates between fisheries.

Predicted recoveries by tag cohort (*c*), age (a), time (*t*), and fishery (*f*). From tag group and aggregated tag pool.

$$R_{ctf}^{\mathrm{Tpred}} = \frac{F_{ctf}^{\mathrm{T}} X_{tf}}{Z_{ctr}^{\mathrm{T}}} \left[1 - e^{-Z_{ctr}^{\mathrm{T}}}\right] N_{ctr}^{\mathrm{T}} \;;\; t \geq t_c^{\mathrm{rel}} + n^{\mathrm{mix}}$$

Aggregate predicted recoveries by fishery groupings (*g*) – aggregated tag returns, e.g. PS fishery.

Reporting rate



Penalty assigned to RR reflects standard deviation of RR.

$$\sigma \approx \frac{1}{\sqrt{2p}}$$

Observed tag returns

- Recoveries: length (at release), time, fishery at recovery.
- Assignment to tag cohort and age at recapture based on release cohort, length at release and time at liberty.
- Assignment to regions of release and recapture based on tag group and fishery of recapture (region).
- Length at recovery not included – no information about growth derived from tags.

Observed recoveries

Tag group X initial mixing period not included in likelihood

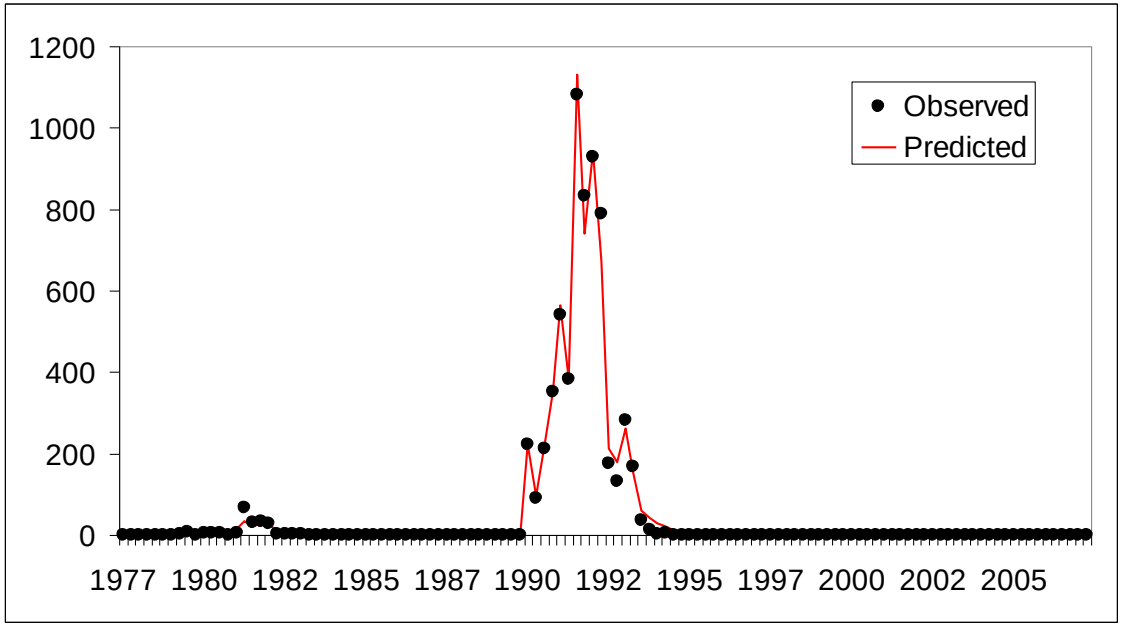
Region 1

time \ age	1	2	3	4	5	6	7	8	9	10
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	2	5	10	1	1	0	0	0	0	0
6	0	2	6	5	1	0	0	0	0	0
7	0	0	0	1	4	0	0	0	0	0
8	0	0	0	1	4	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0

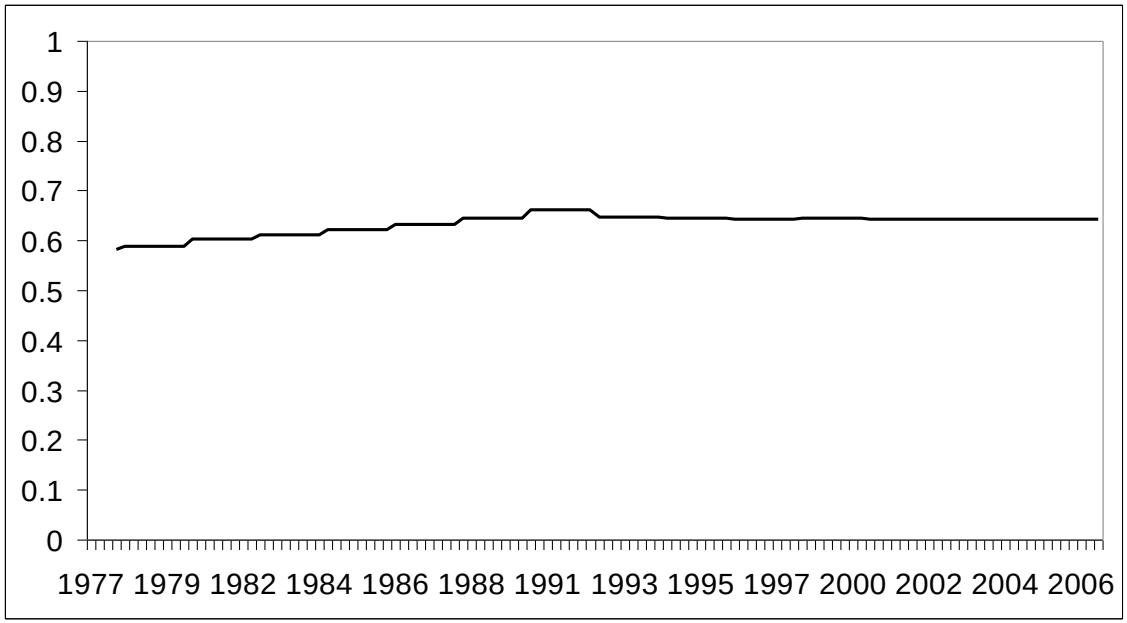
Region 2

time \ age	1	2	3	4	5
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	0	0	0	0	0
6	0	0	1	2	2
7	0	0	0	1	2
8	0	0	0	0	0
9	0	0	0	0	0
10	0	0	0	0	0
11	0	0	0	0	0
12	0	0	0	0	0
13	0	0	0	0	0
14	0	0	0	0	0
15	0	0	0	0	0
16	0	0	0	0	0
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0
20	0	0	0	0	0

Also observed tags within tag pool.



Aggregated tag recoveries by fishery/time (summed over tag cohorts).



Reporting rate; temporal variation via random walk.

Genuine variation in RR, spatial heterogeneity to tags, tag shedding, etc.

Likelihood contribution

- Objective function - options.

- Least squares.

$$\Theta^{\mathrm{T}} = \sum_{ctg} \frac{(R_{ctg}^{\mathrm{Tobs}} - R_{ctg}^{\mathrm{Tpred}})^2}{R_{ctg}^{\mathrm{Tpred}} + 0.01}$$

- Robust LS.
- Poisson
- Negative binomial (with added zeroes). Estimate variance parameter by fishery.

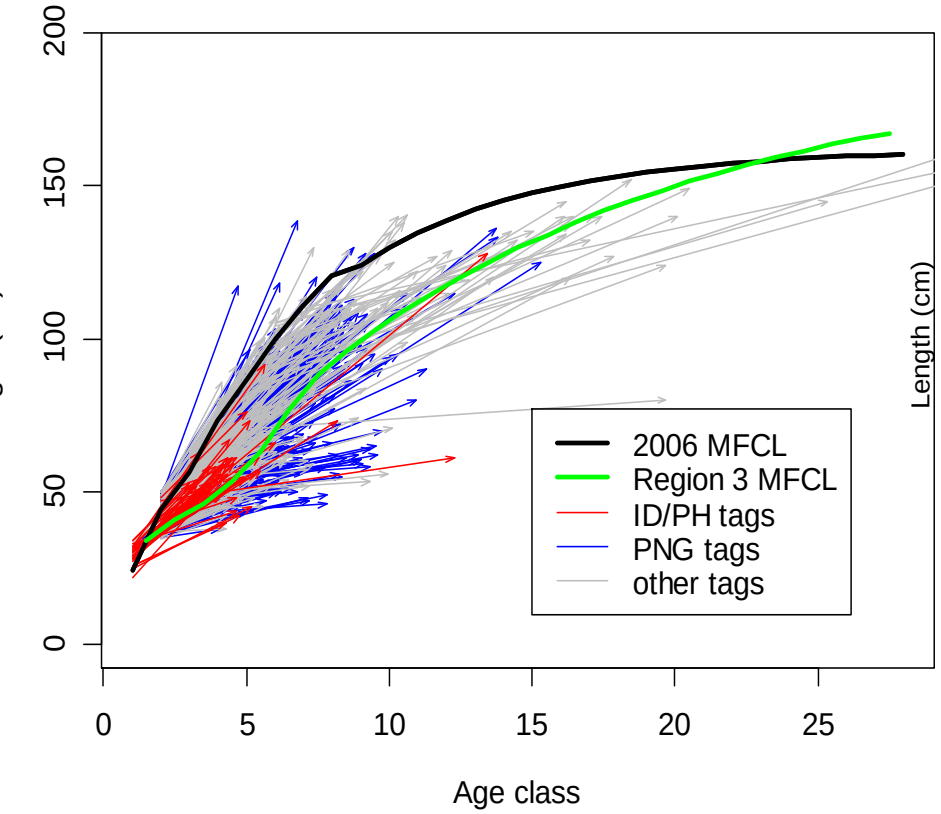
- Frequently small component of overall LL (dominated by catch, size data).
- Penalty from deviation reporting rate (m).

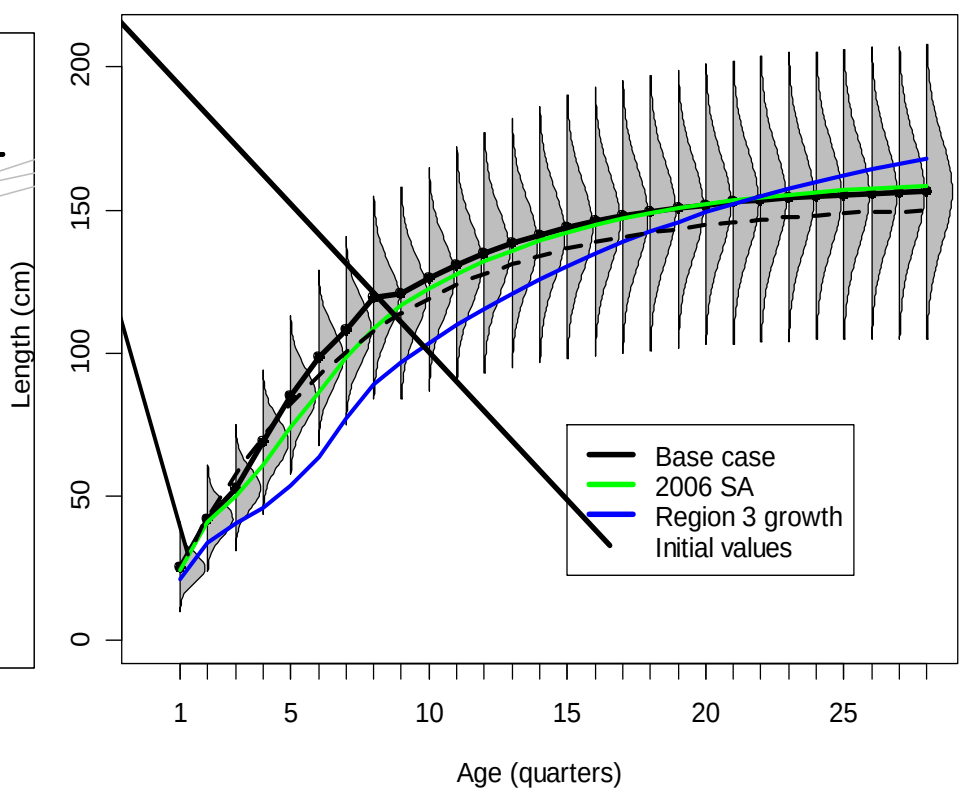
$$\Theta^{\mathrm{X}} = \sum_{f} p_f^{\mathrm{X}} (X_f - \mu_f)^2$$

Potential future developments

- Weighting of tag data in the LL.
- Penalise LL wrt tag movement.
- Tag programme specific reporting rate.
- Contribute to estimation of growth parameters (use length at recovery data).
- Estimate initial tag mortality rate, tag shedding rate (double tag).
- Tagger specific mortality/tag shedding.

Growth





Estimation of mean length and sd at age.