Quantifying tag reporting rates for the tuna fleets of the Indian Ocean

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The theory

Factors determining recapture probability

- Tag shedding rate (Type I and II)
- Tag-induced mortality rate (Type I and II)
- Natural mortality rate
- Exploitation rate
- Tag detection rate
- Tag reporting rate
- Tag recording rate

Factors determining recapture probability

- Tag shedding rate (Type I and II)
- Tag-induced mortality rate (Type I and II)

- Tag detection rate
- Tag reporting rate
- Tag recording rate

Definition of reporting rate

- Not so obvious!
- Here we define reporting rate as the probability that a tag is

  (1) detected and

  (2) reported and

  (3) recorded correctly,

  given that it is caught.

Relative reporting rate

- A commercial fleet, *com* catches 100 fish, and reports 5 tags.
- A reference fleet, *ref* catches 200 fish and reports 20 tags.
- We might conclude that the reporting rate of the commercial fleet is half that of the reference fleet:

$$\frac{5/100}{20/200} = \frac{200 * 5}{100 * 20} = \frac{C_{ref}T_{com}}{C_{com}T_{ref}} = \frac{1}{2}$$

- That's rather unsatisfying. We only know the relative reporting level….

Absolute reporting rate

- But what if we knew the reporting rate of the reference fleet, r_{ref}?

(Paulik 1961; $r_{ref} = 1$) (Kimura 1976)

$$r_{com} = \frac{T_{com} C_{ref}}{T_{ref} C_{com}} = \frac{T_{com}\ C_{ref}\ r_{ref}}{T_{ref}\ C_{com}}$$

- This is also quite unsatisfying! Don't we have to assume that tags are mixed to use these models?

Problems

- Hang on, aren't tags distributed unevenly in time / space / among species / sizes of fish?
- How would I compare and consolidate recapture and catch observations from different strata made by different fleets?
- What if I have multiple cross-fleet observations that offer contradictory information about reporting rate?

E.g. $T_{com} = 5$ $C_{com} = 100$

$T_{com} = 60$ $C_{com}=1000$

- Oh and aren't these just point estimates? I want to express uncertainty in my reporting rate estimates....

The solution? Bayesian modelling of mark rates, *m* (Carruthers and McAllister 2010)

$$m = \frac{T_{pop}}{N_{pop}} = \frac{T_{ref}}{r_{ref} C_{ref}} = \frac{T_{com}}{r_{com} C_{com}}$$

- The probability of reporting *R*, seeded tags from those seeded *S*, given the reference reporting rate:

$$R_{ref} \sim dbin(r_{ref}, S_{ref})$$

- The tag recapture likelihood function:

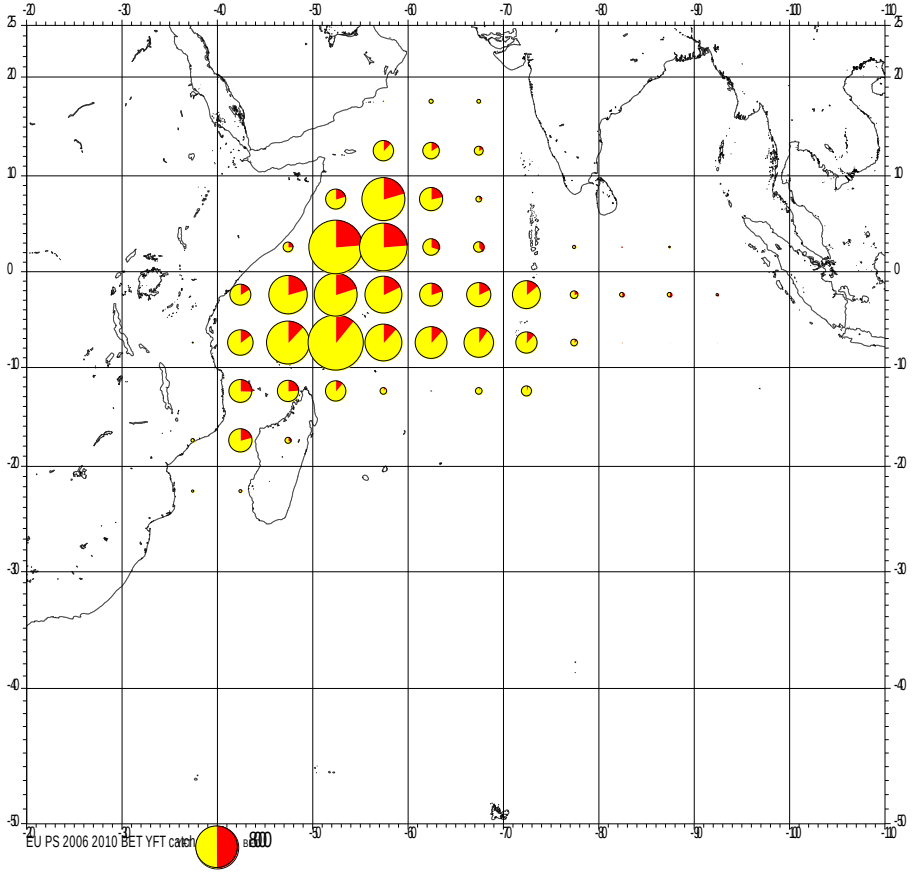
$$T \sim dnegbin(1 - mr, C)$$

- The (uninformative) priors:

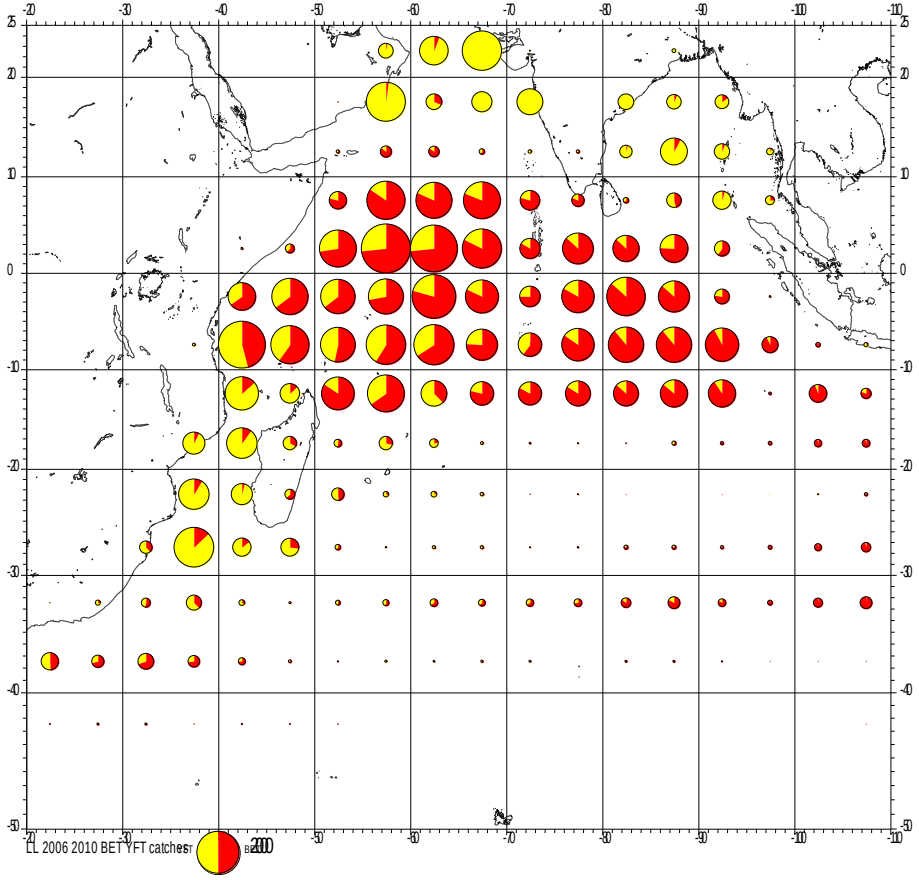
$$m \sim dbeta(1,1)$$
$$r_{com} \sim dbeta(1,1)$$

The data

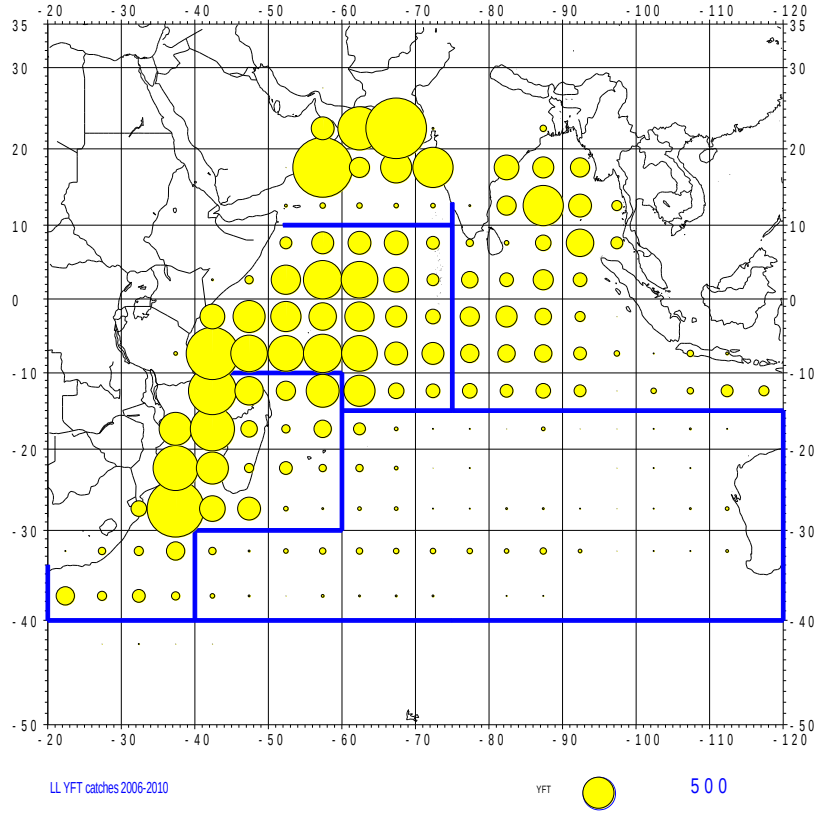
Purse seiners



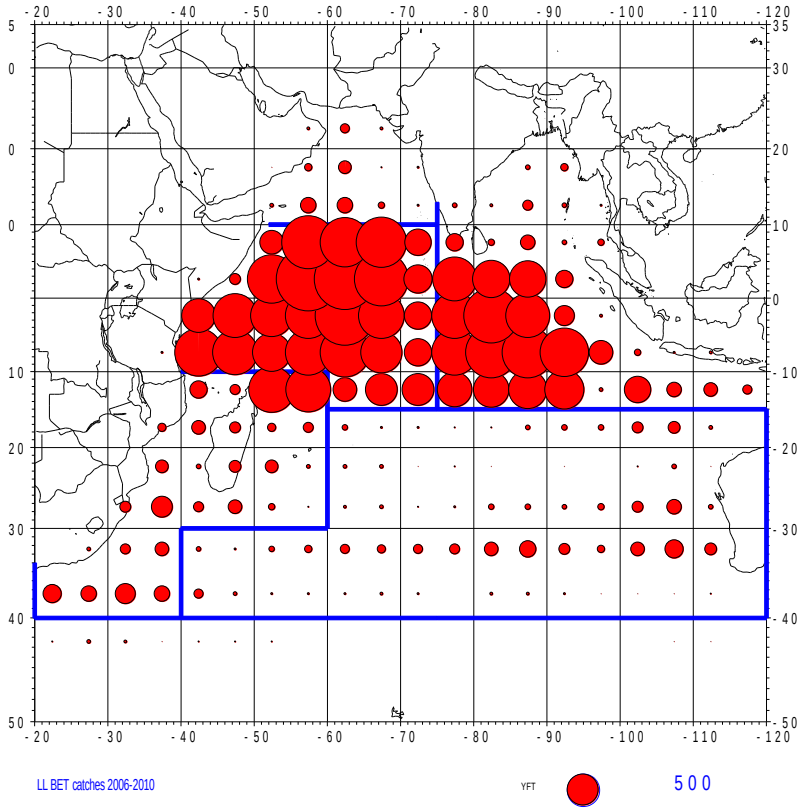
Longliners



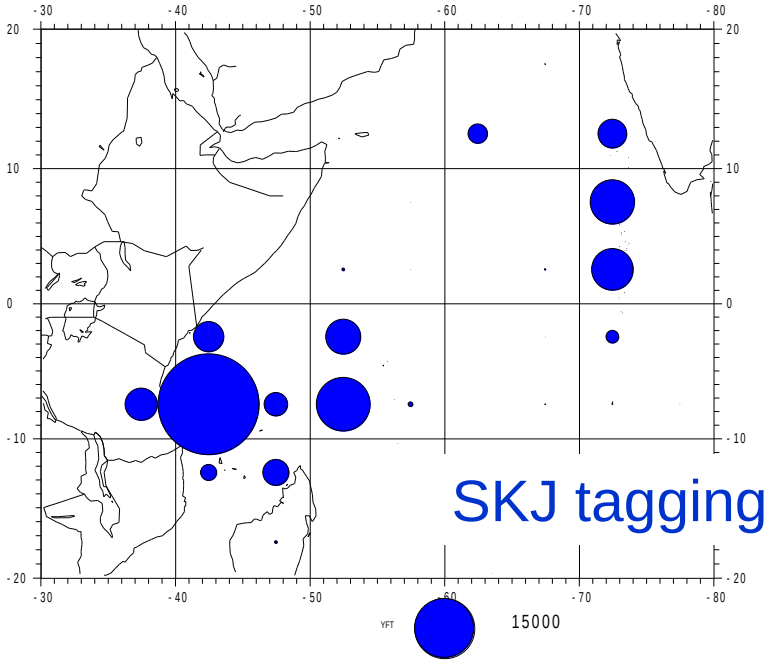
YFT BET 2006-2011

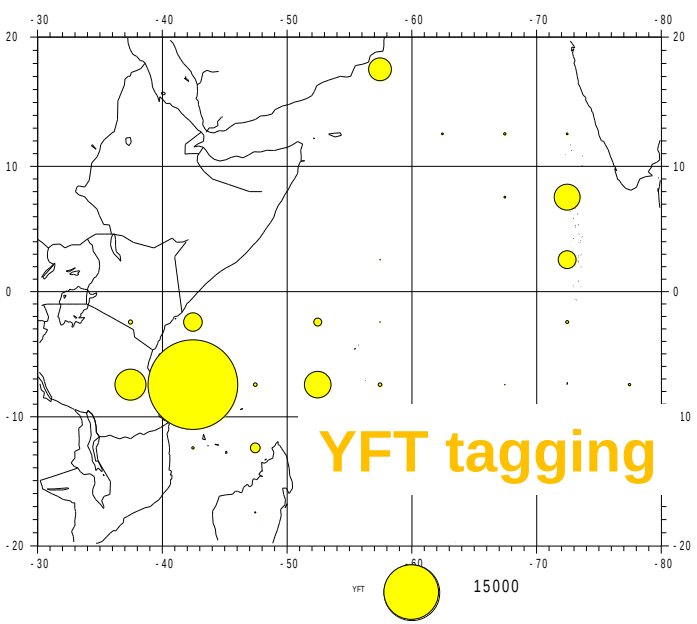


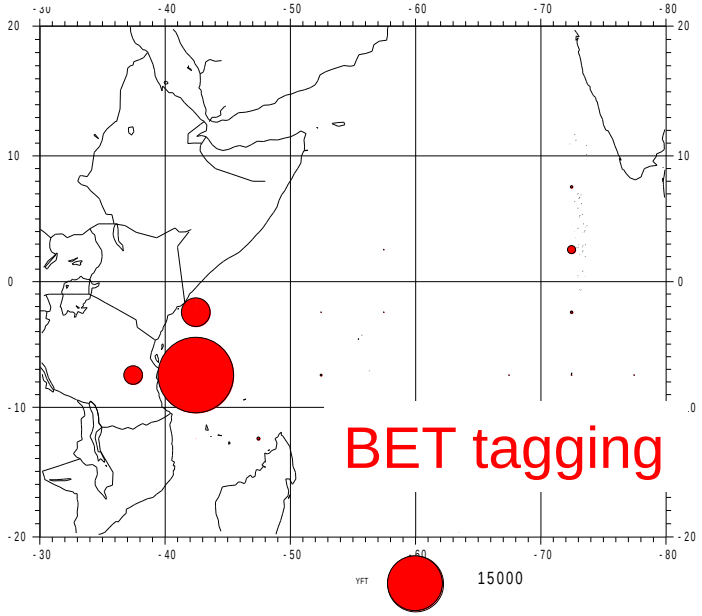
Yellowfin catches by 5° squares caught by longliners during the period 2006-2010, and declared to the IOTC (various LL fleets do not declare their fishing zones).



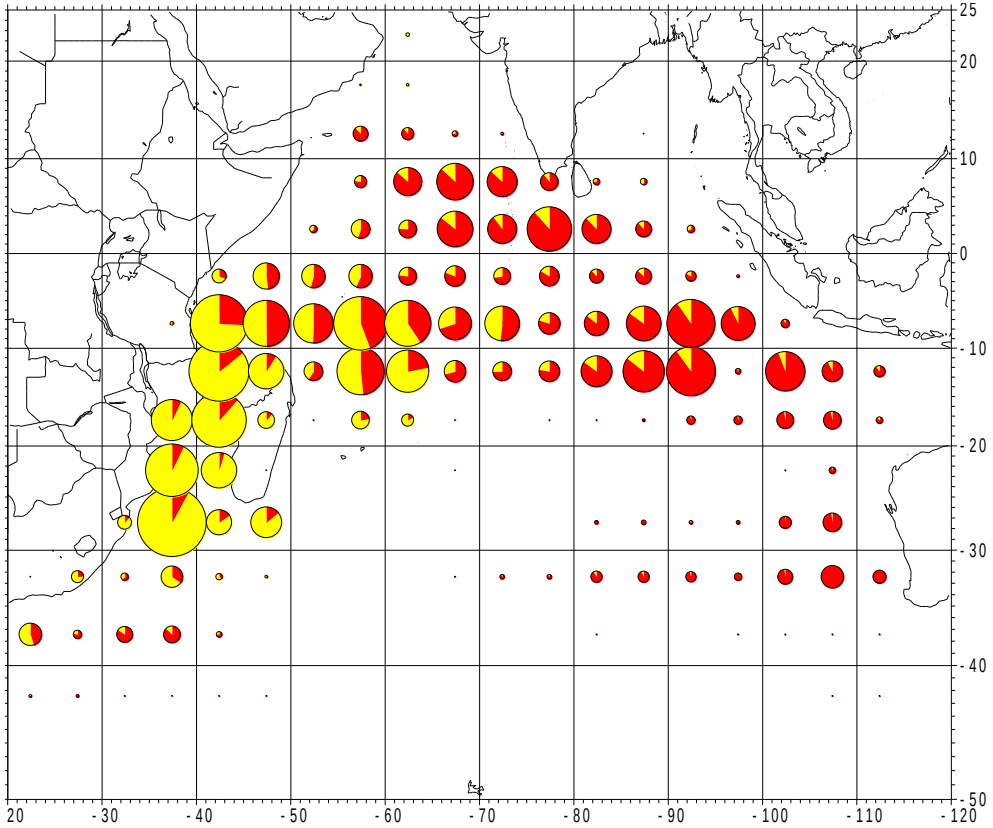
Bigeye catches by 5° squares caught by longliners during the period 2006-2010, and declared to the IOTC.


SKJ tagging
YFT
15000


YFT tagging
YFT
15000


BET tagging
YFT
15000

Japanese longliners

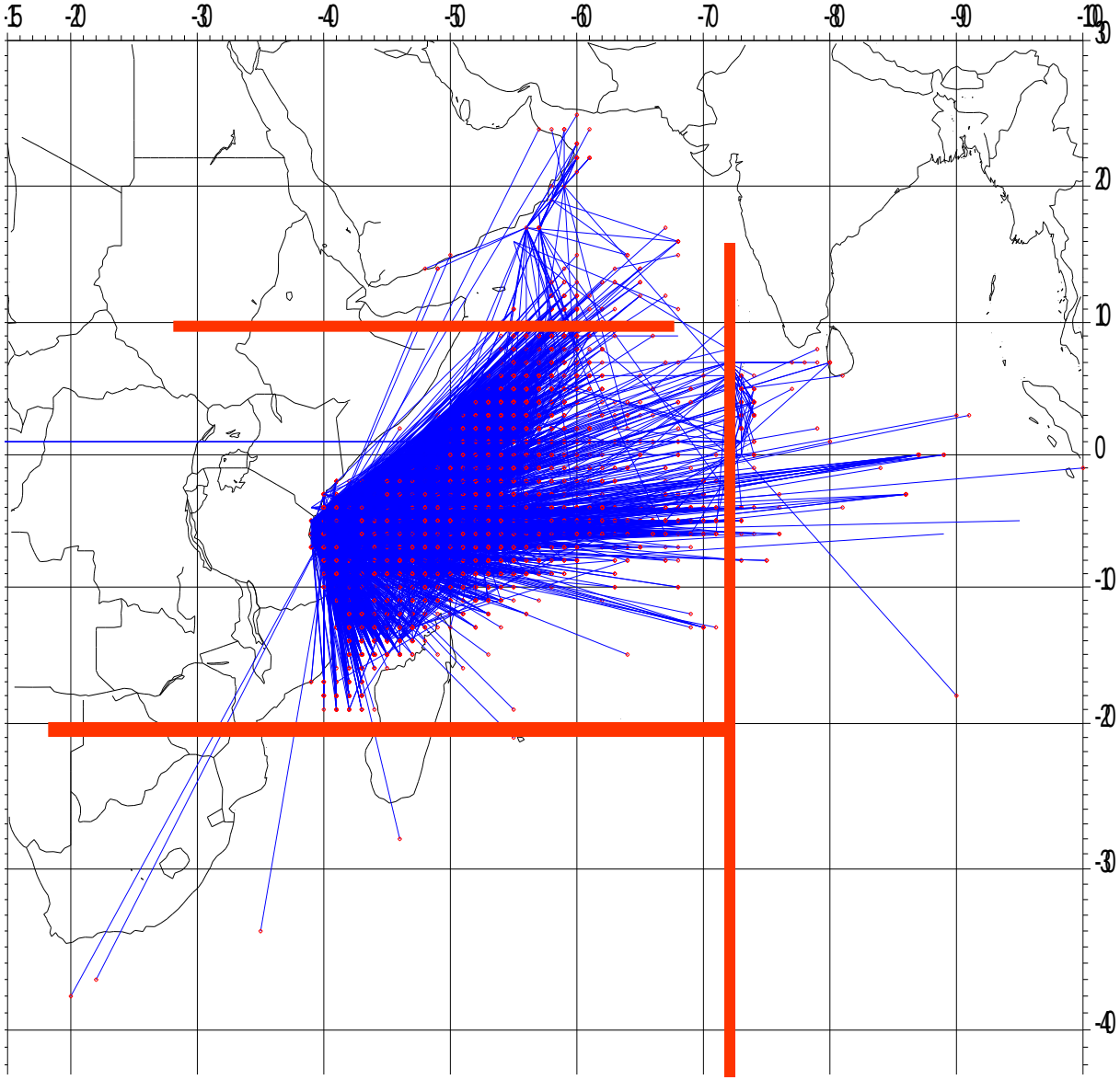


BET YFT
Catches
2007-2010

Year	YFT	BET	total	YFT	BET	total
2006	4	0	4	22 310	13 920	36 230
2007	15	4	19	18 592	18 168	36 760
2008	17	7	24	10 425	13 739	24 164
2009	2	10	12	4 878	8 993	13 871
2010	1	8	9	3 623	4 080	7 703
Total	39	29	68	59 828	58 900	118 728

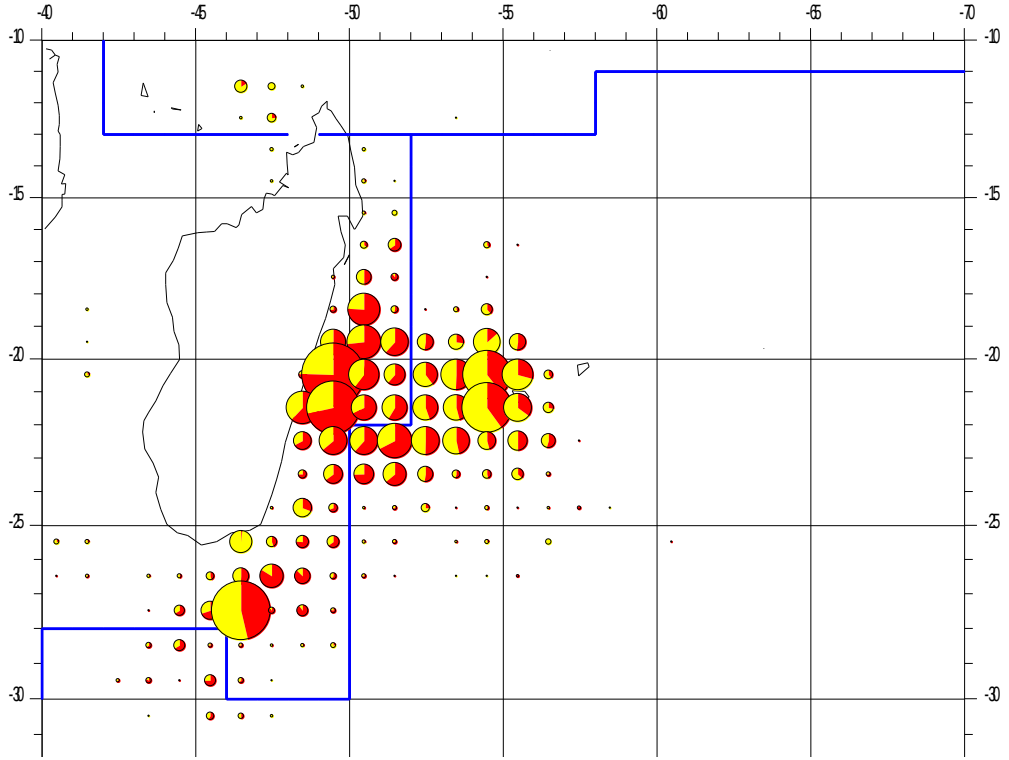
Av. tags /1000 t tunas **0.57**

YFT recoveries



Each line represents a tagging and recapture event where the red cross shows recovery point.

French Longliners



BET YFT

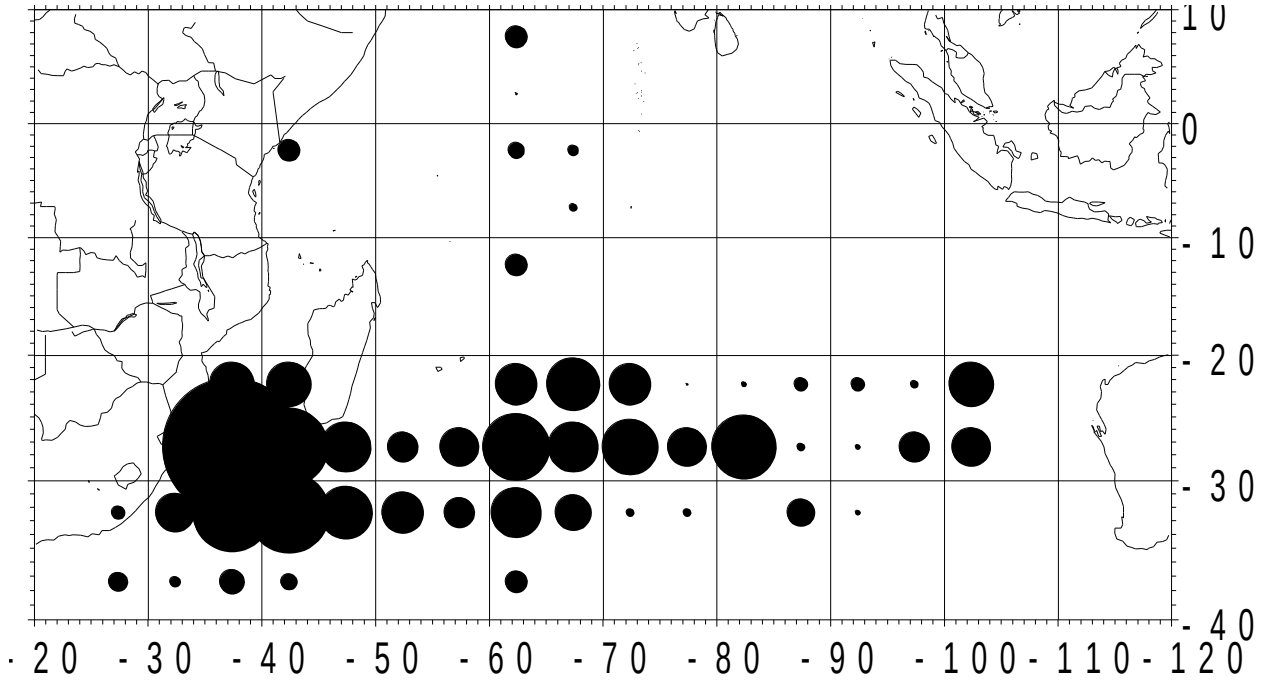
Catches

2007-2010

France	Recoveries Nb			Catches t.		
Year	YFT	BET	total	YFT	BET	total
2006	0	0	0	594	561	1 155
2007	0	1	1	583	712	1 295
2008	0	0	0	334	503	837
2009	1	2	3	283	351	634
2010	1	3	4	264	314	578
Total	2	6	8	2 058	2 441	4 499

Av. tags /1000 t tunas **1.78**

Spanish longliners



SPAIN	Recoveries Nb			Catches t.		
Year	YFT	BET	total	YFT	BET	total
2006	0	0	0	152	272	424
2007	0	0	0	86	102	188
2008	2	2	4	110	137	247
2009	0	1	1	96	69	165
2010	0	2	2	90	65	155
Total	2	5	7	534	645	1 179

Av. tags /1000 t tunas **5.94**

What does the catch and recapture data of the Indian Ocean tell us?

- Relative reporting rates appear to vary widely
- Spatio-temporal heterogeneity in the fishery
- Spatial coincidence in the data gathered from different fleets
- Spatio-temporal heterogeneity in the stock
- Species may have very different mark rates by region
- Size structuring of mark rates

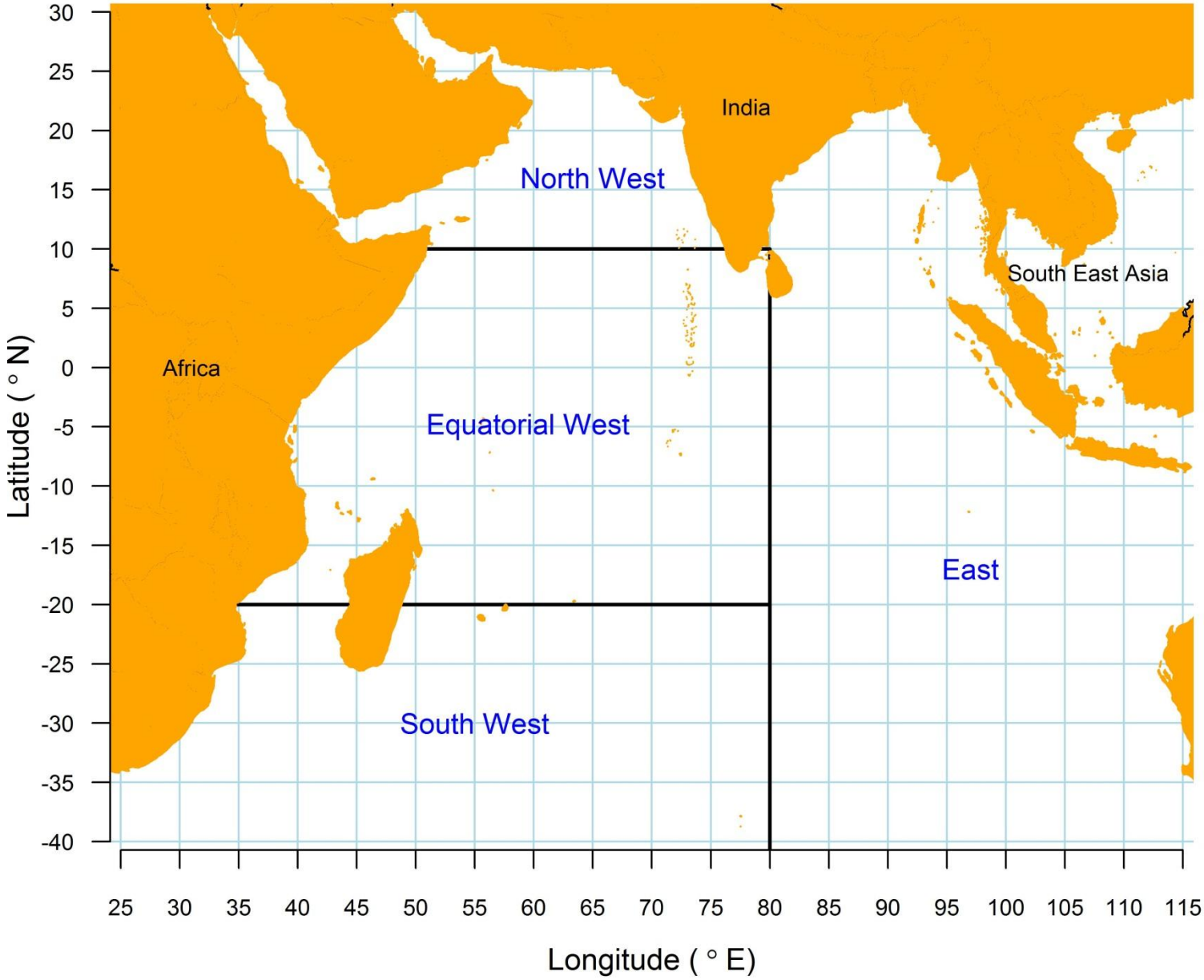
The definition of strata in this analysis

- Mark rates are estimated for each:

  Year (2006, 2007, 2008, 2009, 2010, 2011),
  Quarter (Jan-Mar, Apr-Jun, Jul-Sep, Oct-Dec),
  Area (East, South West, North West, Equatorial West),
  Species (skipjack, yellowfin, bigeye),
  Size (skipjack: < 55cm and > 55cm),
  (yellowfin and bigeye: < 90cm and > 90cm).

- *E.g.* the fraction of small skipjack that have tags in the Eastern Indian Ocean in the first quarter of 2008

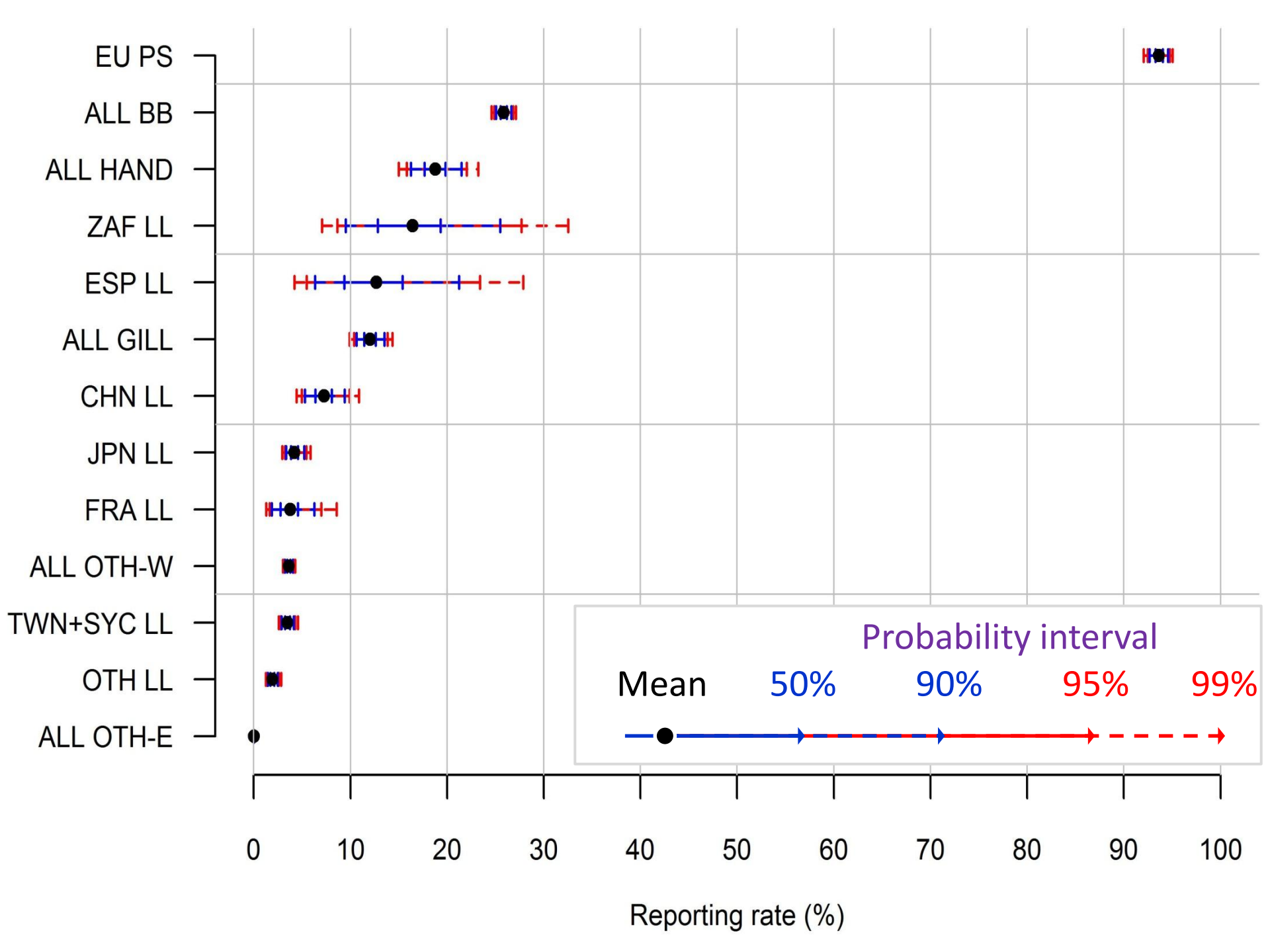
Area definitions



Fleet definitions

	Flag	Gear	Area	Fleet code
1	All countries	Bait boat	W	ALL BB
2	All countries	Gill net	W	ALL GILL
3	All Countries	Handline	W	ALL HAND

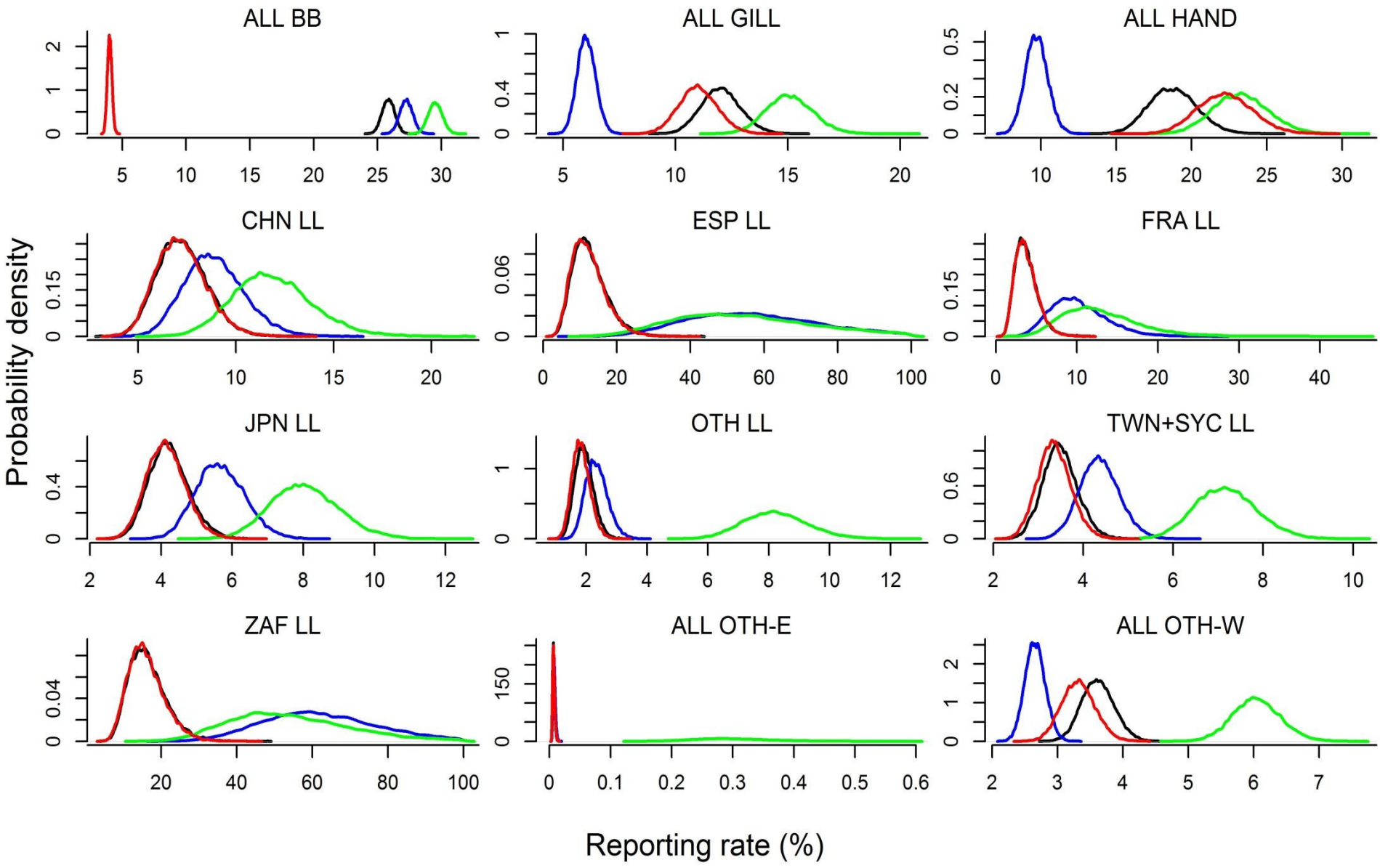
The results


EU PS
ALL BB
ALL HAND
ZAF LL
ESP LL
ALL GILL
CHN LL
JPN LL
FRA LL
ALL OTH-W
TWN+SYC LL
OTH LL
ALL OTH-E
Probability interval
Mean
50%
90%
95%
99%
0
10
20
30
40
50
60
70
80
90
100
Reporting rate (%)

Reporting rate %				Percentiles				
Flag	Gear	Mean	S.Dev	5	10	50	90	95
EU	PS	93.64	0.58	92.65	92.88	93.66	94.37	94.57
ALL	BB	25.85	0.50	25.04	25.21	25.85	26.49	26.66
ALL	HAND	18.78	1.60	16.27	16.77	18.73	20.86	21.48
ZAF	LL	16.43	4.95	9.52	10.63	15.81	23.01	25.48
ESP	LL	12.69	4.60	6.34	7.35	12.05	18.85	21.25
ALL	GILL	12.02	0.88	10.61	10.91	12.00	13.17	13.51
CHN	LL	7.25	1.27	5.30	5.69	7.19	8.92	9.41
JPN	LL	4.22	0.56	3.35	3.53	4.19	4.95	5.21
FRA	LL	3.77	1.38	1.87	2.18	3.59	5.59	6.28
ALL	OTH-W	3.62	0.25	3.22	3.31	3.61	3.95	4.04
TWN+SYC	LL	3.49	0.38	2.88	3.01	3.47	4.00	4.14
OTH	LL	1.94	0.31	1.47	1.56	1.92	2.34	2.47
ALL	OTH-E	0.01	0.00	0.00	0.01	0.01	0.01	0.01

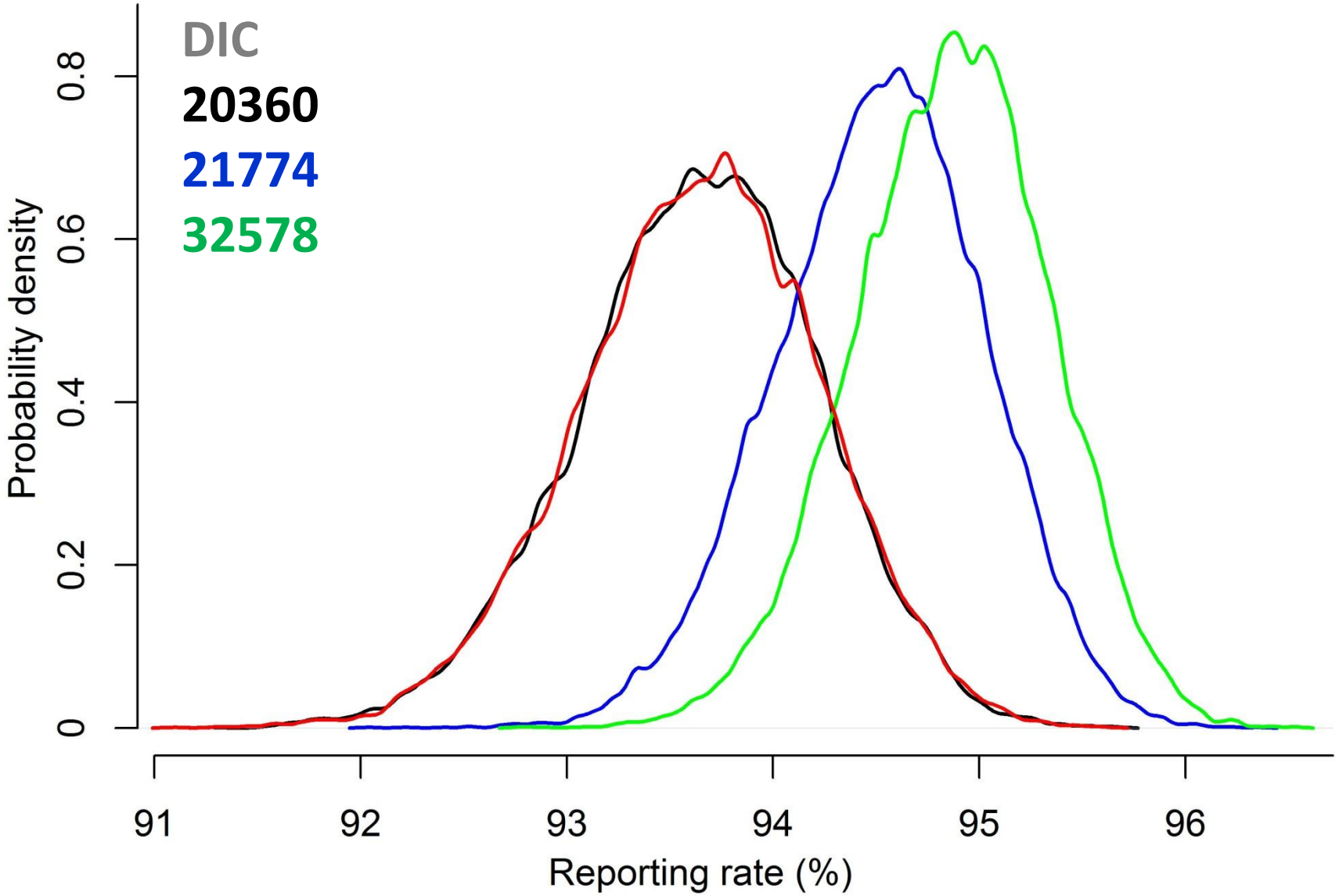
Sensitivity

Base case **2 areas** **No quarter** **DAL > 90**



The EU PS fleet (with tag seeding)

Base case 2 areas No quarter DAL > 90



Assumptions and problems

- Tags are mixed within strata.
- The negative binomial distribution is a suitable observation model (overdispersion problems).
- Reporting rates (detection, reporting and recording combined) of fleets are the same over time / space / species / size.
- That the seeding experiment is representative of the reporting rate of the EU PS fleet in general.

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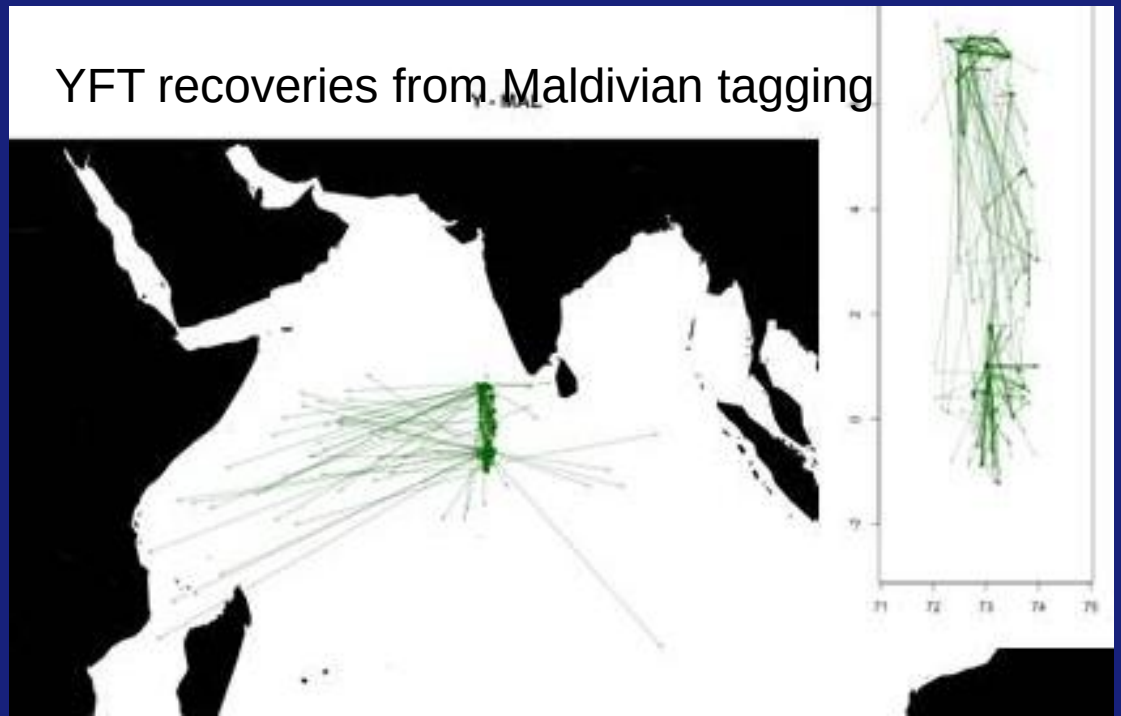
Discussion points

- At what level of disaggregation should mark rates be modelled?
- Use of model selection criteria may not be appropriate.
- Use of other tagging data to understand mixing.
- More size classes may be modelled.
- Less arbitrary definitions of ‘strata’ should be considered.

Baitboat reporting rates at 26 % are clearly underestimated by the model

- Most Maldivian tagged tunas are recovered locally & during very short time intervals, and showing few movements towards the Central Western area used in the model
- Tagged tunas are probably trapped locally due to “Islands & anchored FAD effects”.
- Maldivian reporting rates estimated at 80% by Maldivian scientists



(courtesy Julian Million)

Discussion points

- How is this different from a spatial stock assessment that includes tagging data (*e.g.* CASAL, MULTIFAN-CL, SS3)?

- This method can use data at finer scales to infer reporting rates without confounding with other rates:

Tag shedding rate / Tag-induced mortality rate / Natural mortality rate / Fishing mortality rate.

Discussion points

- Comparison with reporting rate estimates in other oceans (much higher than reporting rate estimates of the Atlantic).
- Other opportunities:

- Temporal reporting rates (*e.g*. Hillary *et al*.)
- Making use of other data (observers etc)
- Fine-scale conditional autogressive modelling

Conclusions

- Reporting rates are likely to vary widely among fleets.
- Based on the tag seeding experiment, the reporting rate of the EU purse seine fleet was estimated to be very high.
- In general reporting rates are high relative to those estimated in the Atlantic.

! The reporting rates are likely to be estimated too precisely - likelihood functions that properly account for over-dispersion are a priority !

Acknowledgments

- We wish to thank all those that have supported this research, in particular:

  - Julien Million

  - Miguel Herrara

  - Vivi Nordstrom

- We wish to acknowledge the contributions of all the people that have been involved in the Indian Ocean Tuna Tagging Programme.

Supporting materials

ALL BB

ALL GILL

ALL HAND

CHN LL

ESP LL

FRA LL

JPN LL

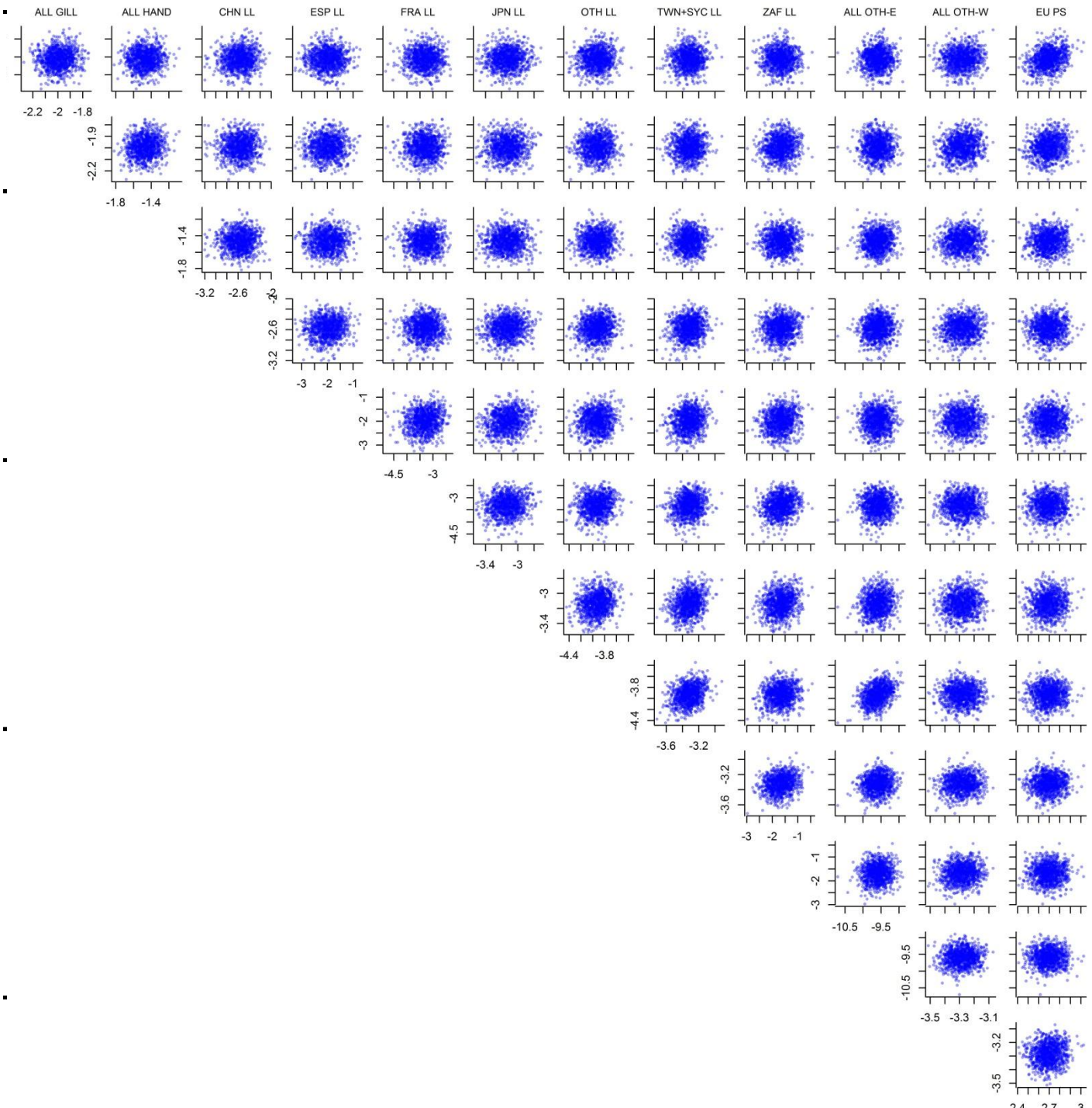
OTH LL

TWN+SYC LL

ZAF LL

ALL OTH-E

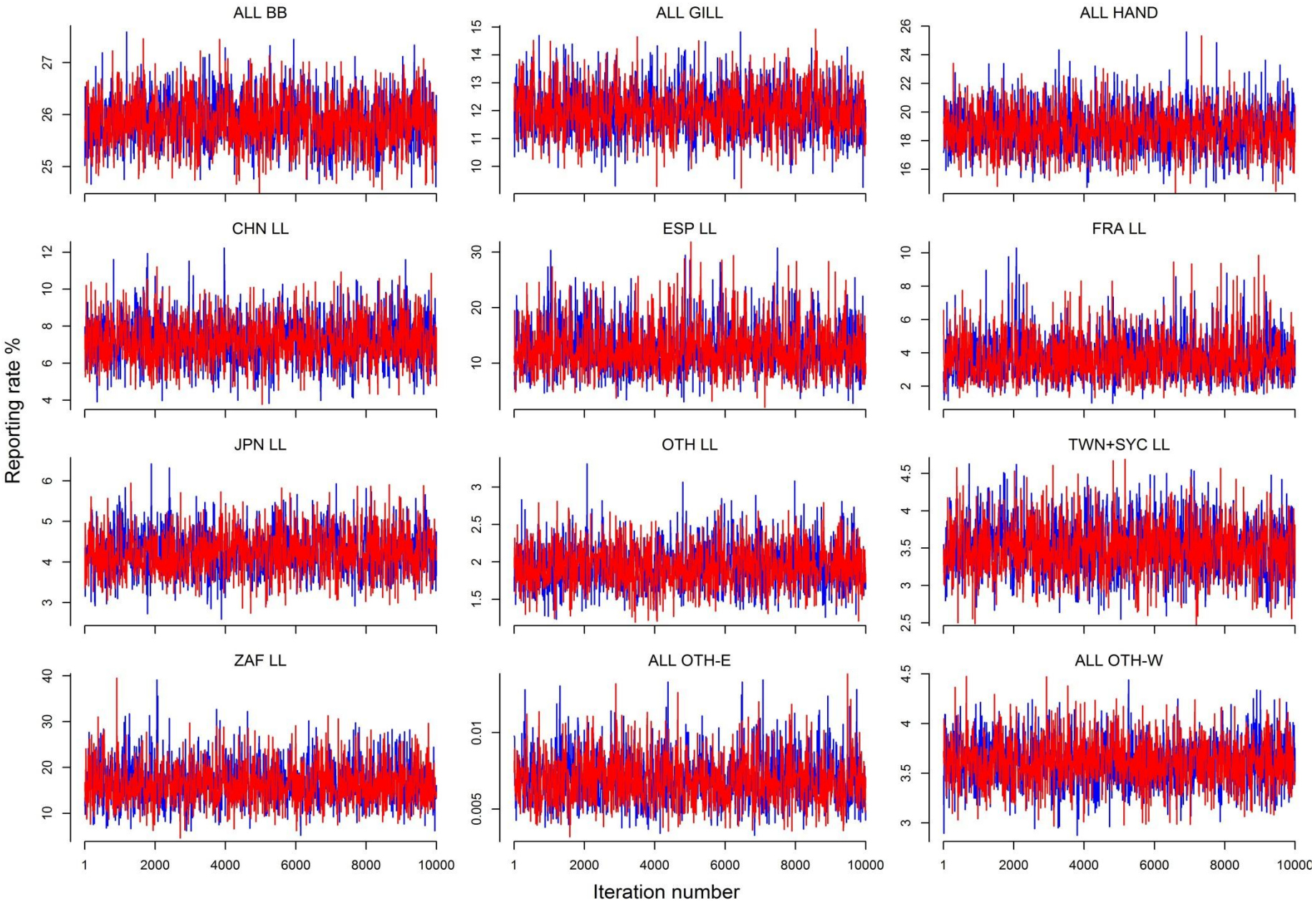
ALL OTH-W



Coincidence of tag and catch observations by fleet

	ALL GILL	ALL HAND	CHN LL	ESP LL	FRA LL	JPN LL	OTH LL	TWN+ SYC LL	ZAF LL	ALL OTH-E	ALL OTH-W	EU PS
ALL BB	88	127	40	60	40	63	64	64	0	0	136	136
ALL GILL		188	39	43	23	66	94	89	0	0	190	138
ALL HAND			64	68	48	90	120	114	0	0	229	177
CHN LL				88	88	144	160	158	40	40	120	102
ESP LL					96	134	136	136	56	0	136	101
FRA LL						94	96	96	48	0	96	71
JPN LL							239	239	60	68	171	149
OTH LL								274	60	72	212	176
TWN+SYC LL									60	72	202	170
ZAF LL										0	60	28
ALL OTH-E											0	76
ALL OTH-W												282

Mixing of MCMC chains (burn-in 2000 iterations, thinned to 1:15)



Flag	Gear	Catch numbers (M)	Number of recaptures	Average recapture rate	Simple rep. rate. estimate
All countries	Bait boat	203.99	3815	18.7	28.4%
All countries	Gill net	104.04	205	2.0	3.0%
All Countries	Handline	7.48	160	21.4	32.4%
China	Longline	0.72	35	48.5	73.6%
Spain	Longline	0.03	7	276.7	419.6%
France	Longline	0.10	8	77.4	117.3%
Japan	Longline	2.60	63	24.2	36.7%
Other flags	Longline	6.46	67	10.4	15.7%
Chinese Taipei and Seychelles	Longline	6.08	125	20.6	31.2%
South Africa	Longline	0.03	9	340.6	516.5%
All countries	Other gears East	219.91	74	0.3	0.5%
All countries	Other gears West	59.92	281	4.7	7.1%
European Union	Purse seine	415.28	26016	62.6	95.0%