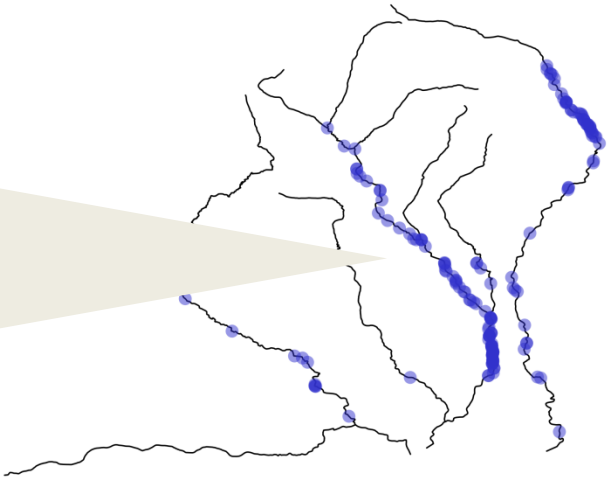

Evaluation of spatial sampling designs for redd surveys

Martin Liermann[1], Dan Rawding[2] , George Pess[1], Bryce Glaser[2]

[1] Northwest Fisheries Science Center,

[2] Washington Department of Fish and Wildlife.

Acknowledgements

- Survey teams
- GIS and data support: Steve VanderPloeg
- Funding:

  Pacific Coast Salmon Recovery Fund, Pacific Salmon Commission's Letter of Agreement (Chinook Technical Committee) and Southern Boundary Fund, NOAA-Fisheries Mitchell Act, the Washington State General Fund, and the Bonneville Power Administration through the Pacific Northwest Aquatic Partnership.

- Prior theoretical and applied salmon sample design research.

Question

What is the best way to choose a sub sample of reaches?

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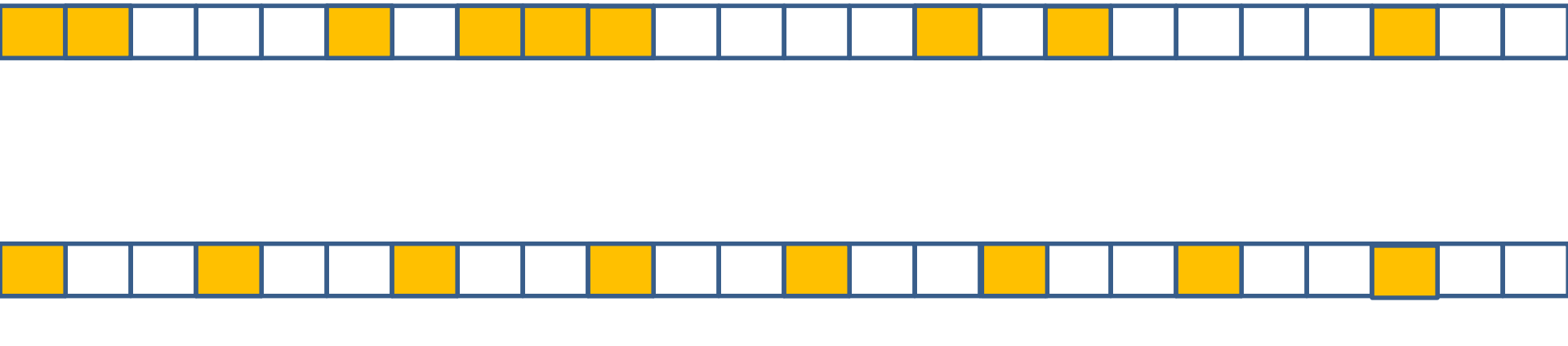

Main points

- Redd locations are geographically clumpy
- This produces much more variable estimates (from sample to sample).
- There are effective strategies for reducing this variability.
  - Spatially balanced designs
  - Stratified designs
  - Regression estimators

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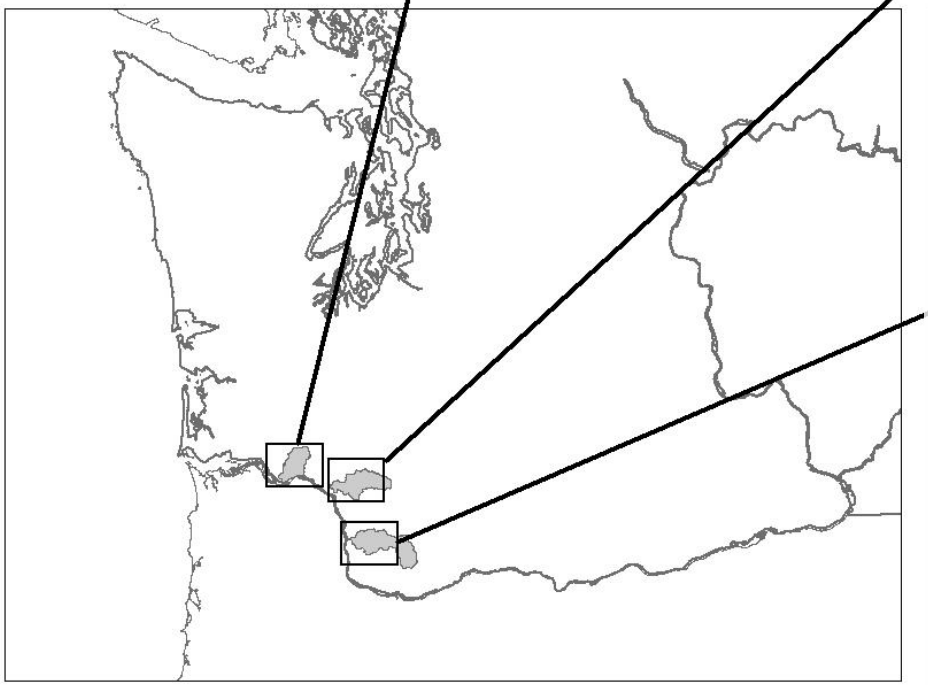
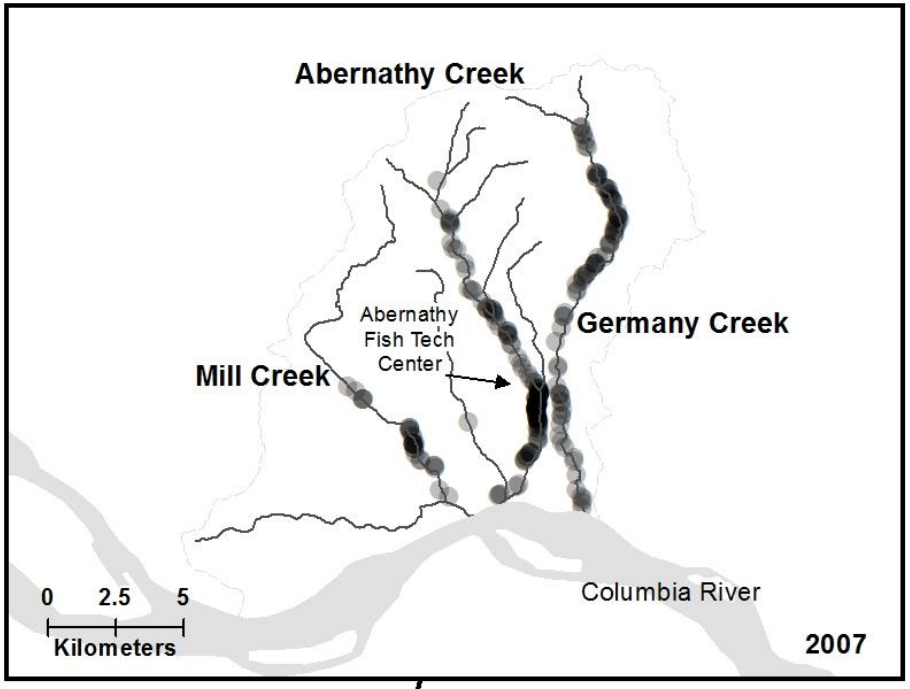
Abernathy Creek
Abernathy Fish Tech Center
Germany Creek
Mill Creek
Columbia River
0 2.5 5
Kilometers
2007

Cowlitz River
Mulholland Creek
Coweeman River
Baird Creek
Washboard Falls
Brown Cr Falls
Goble Creek
0 2.5 5
Kilometers
2008



North Fork Lewis River
Lower Rock Creek
Lucia Falls
East Fork Lewis River
0 2.5 5
Kilometers
2007


Abernathy Creek
Abernathy Fish Tech Center
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Mill Creek
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0 2.5 5
Kilometers
2007

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0 2.5 5
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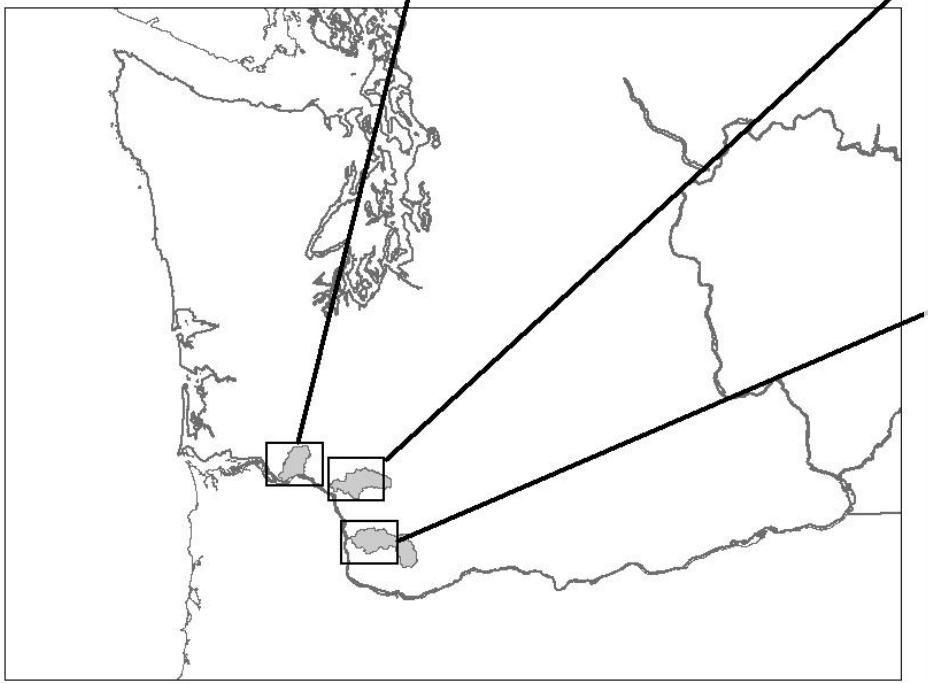
2008



North Fork Lewis River
Lower Rock Creek
Lucia Falls
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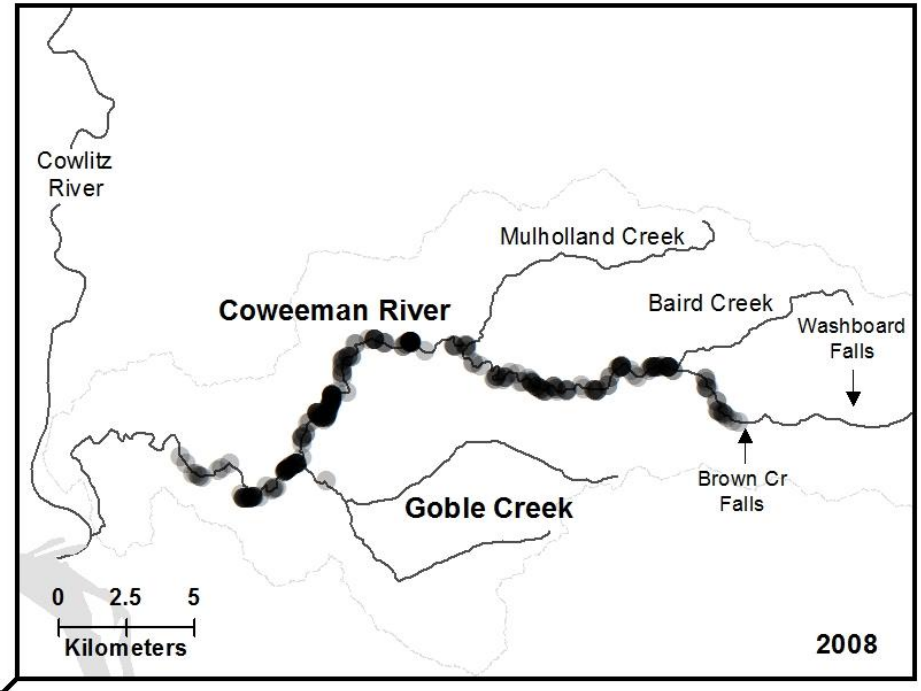
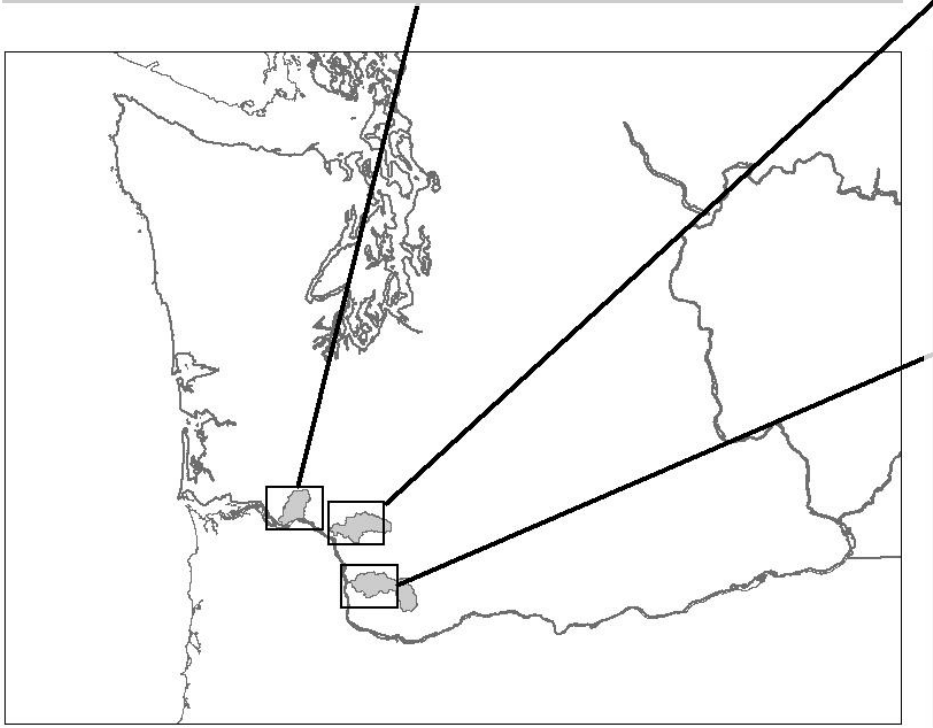
0 2.5 5
Kilometers
2007

Abernathy Creek
Abernathy
Fish Tech
Center
Germany Creek
Mill Creek
Columbia River
0 2.5 5
Kilometers
2007


Cowlitz
River
Mulholland Creek
Coweeman River
Baird Creek
Washboard
Falls
Brown Cr
Falls
Goble Creek
0 2.5 5
Kilometers
2008



North Fork
Lewis River
Lower
Rock Creek
Lucia
Falls
East Fork Lewis River
0 2.5 5
Kilometers
2007

Abernathy Creek
Abernathy Fish Tech Center
Germany Creek
Mill Creek
Columbia River
0 2.5 5
Kilometers
2007

Cowlitz River
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Coweeman River
Baird Creek
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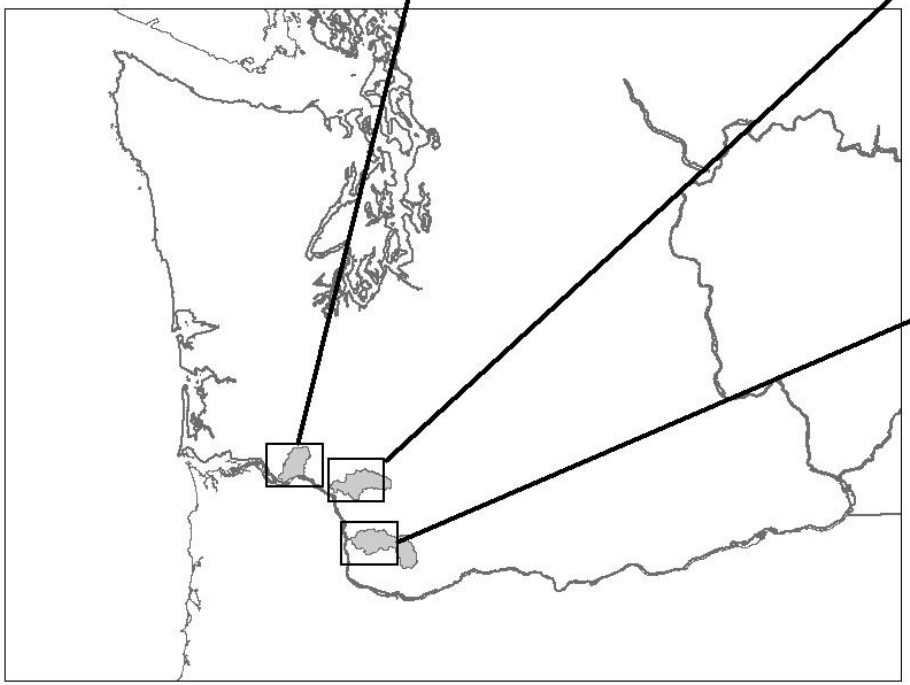
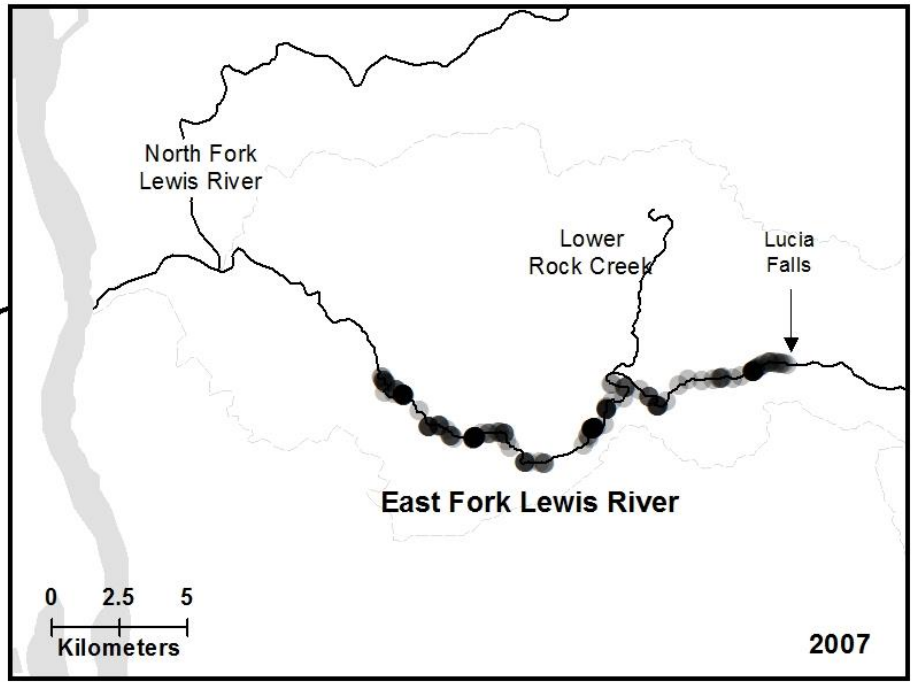
Goble Creek
0 2.5 5
Kilometers
2008

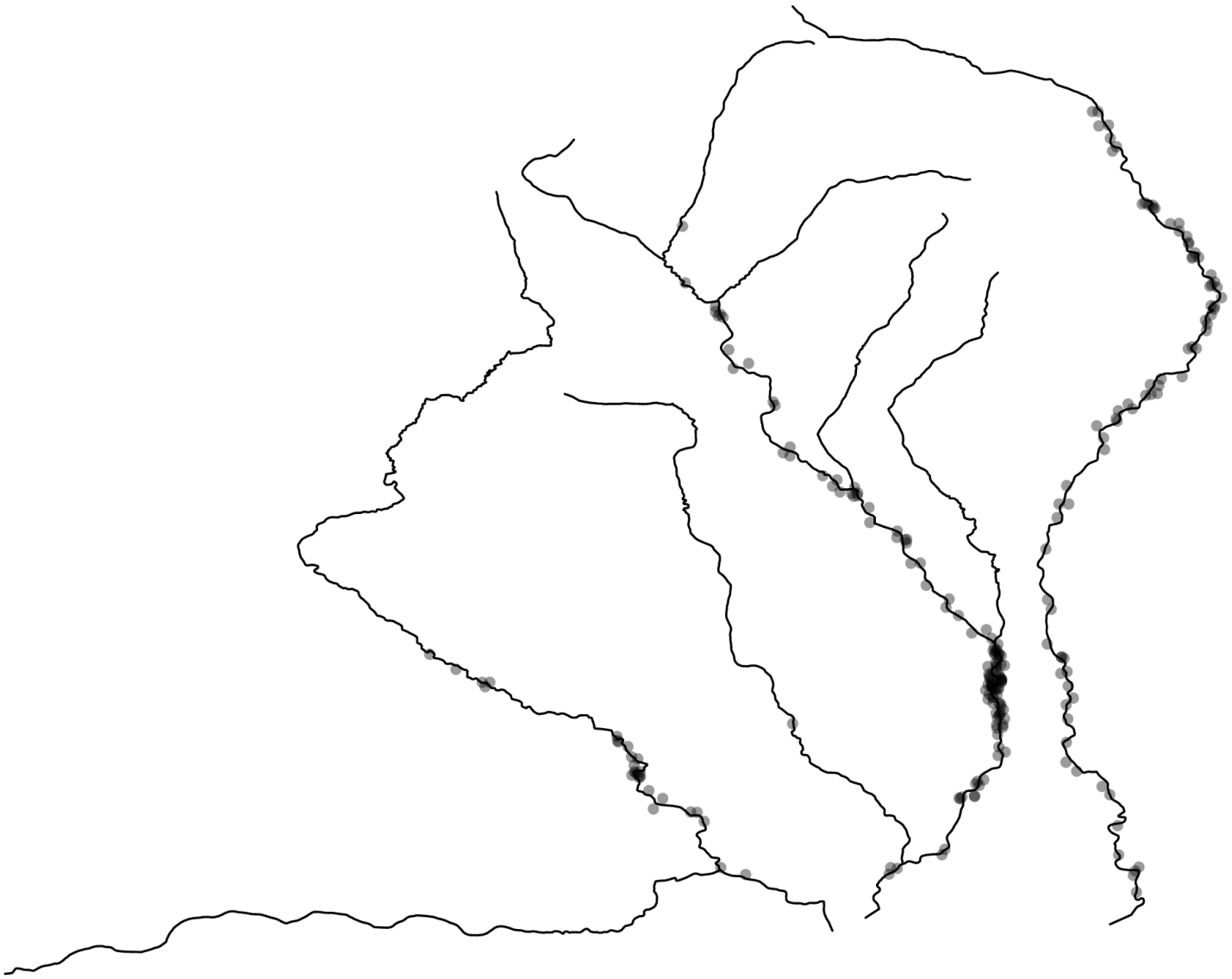


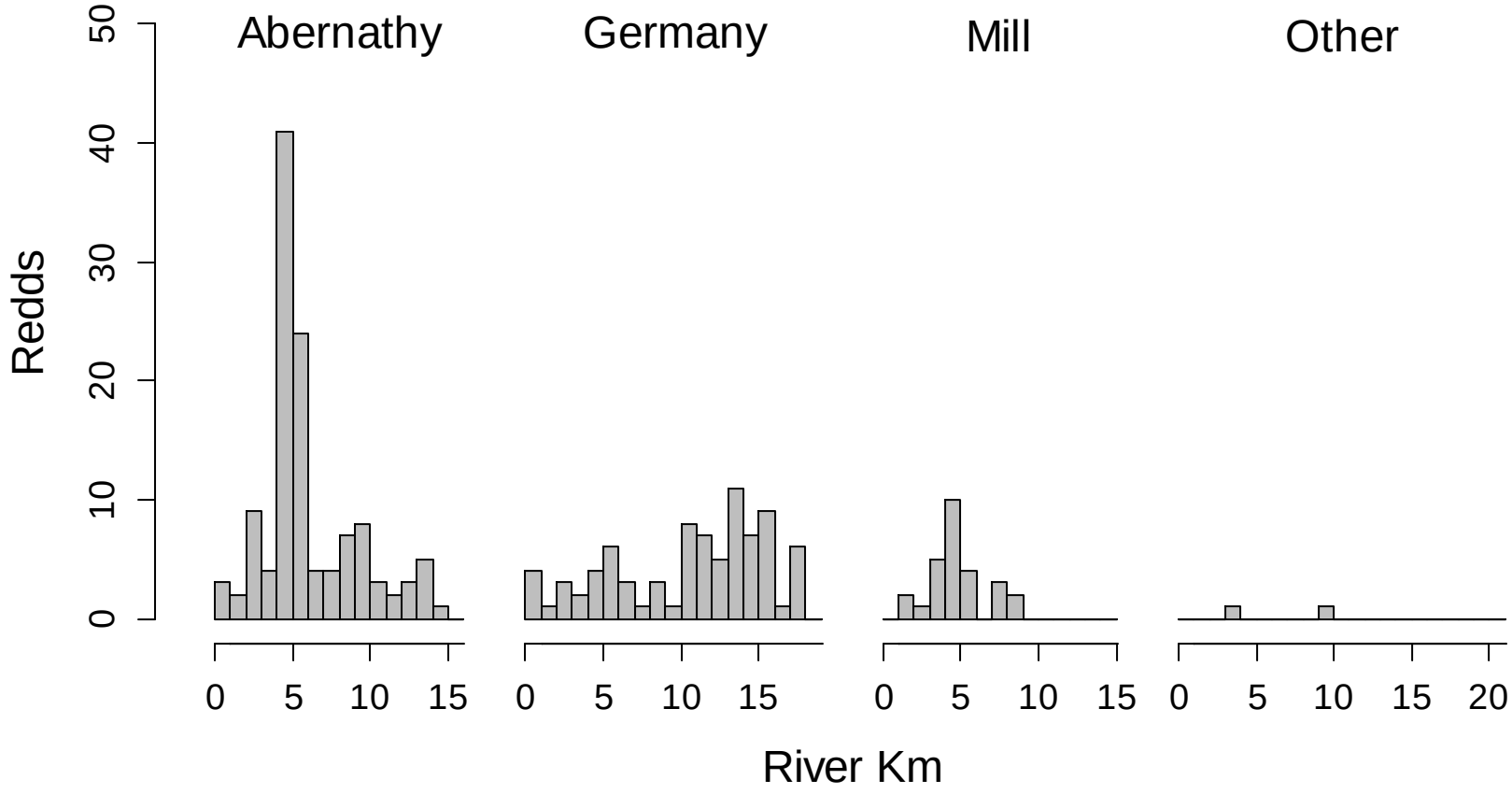

North Fork Lewis River
Lower Rock Creek
Lucia Falls
East Fork Lewis River
0 2.5 5
Kilometers
2007

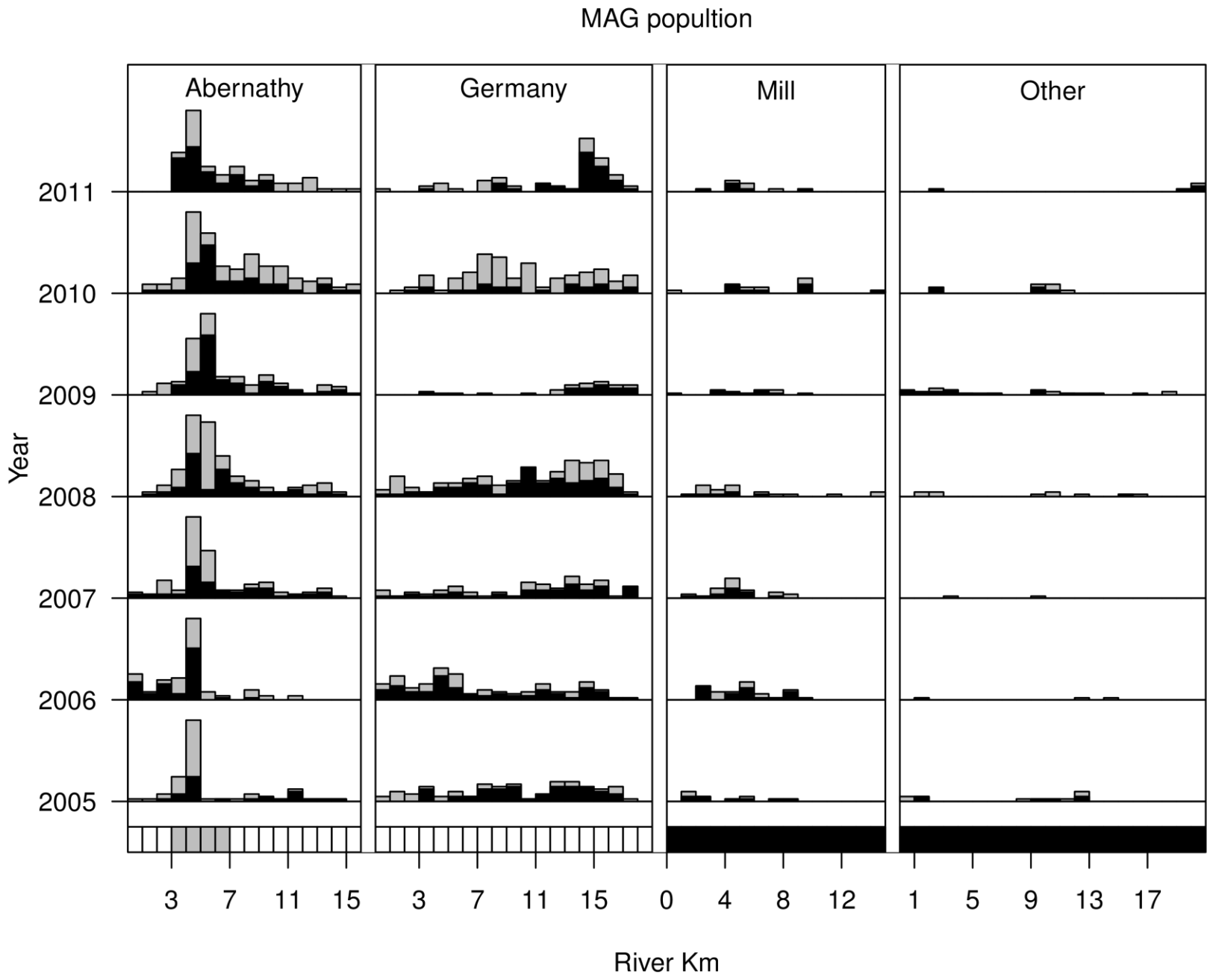
Approach

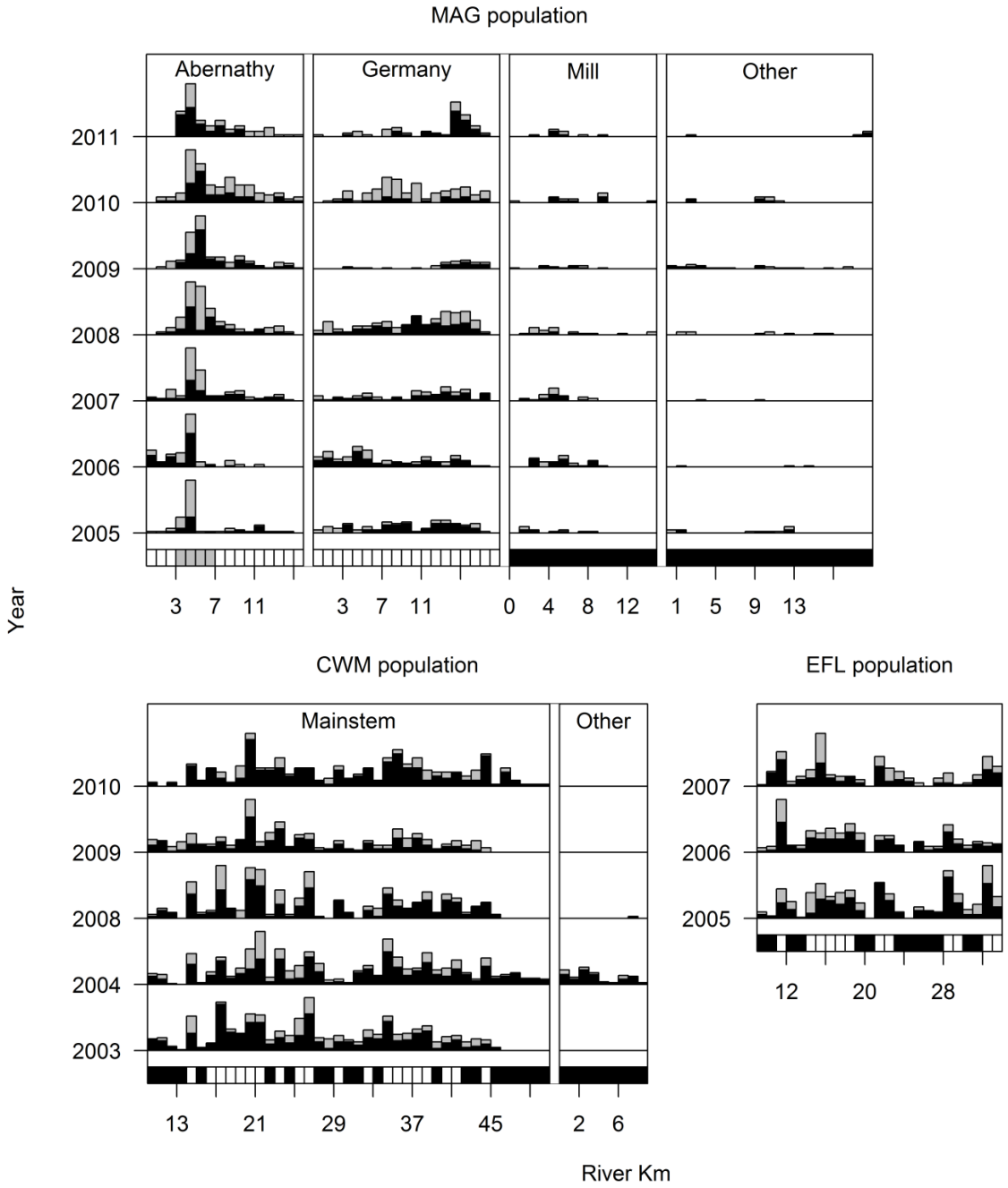
- Bin redds into 1km reaches.
- Select a sample from the reaches based on a design (SRS, GRTS, stratified).
- Repeat many times for each sampling design.
- Summarize results.

Germany, Abernathy, and Mill, Steelhead 2007




Abernathy
Germany
Mill
Other
Redds
0
10
20
30
40
50
0
5
10
15
20
River Km


MAG popultion
Abernathy
Germany
Mill
Other
2011
2010
2009
2008
2007
2006
2005
Year
3
7
11
15
3
7
11
15
0
4
8
12
1
5
9
13
17
River Km


MAG population
Abernathy
Germany
Mill
Other
2011
2010
2009
2008
2007
2006
2005
3 7 11
3 7 11
0 4 8 12
1 5 9 13
Year
CWM population
Mainstem
Other
2010
2009
2008
2004
2003
13 21 29 37 45
2 6
EFL population
2007
2006
2005
12 20 28
River Km

Approach

- Bin redds into 1km reaches.
- Select a random sample from the reaches.
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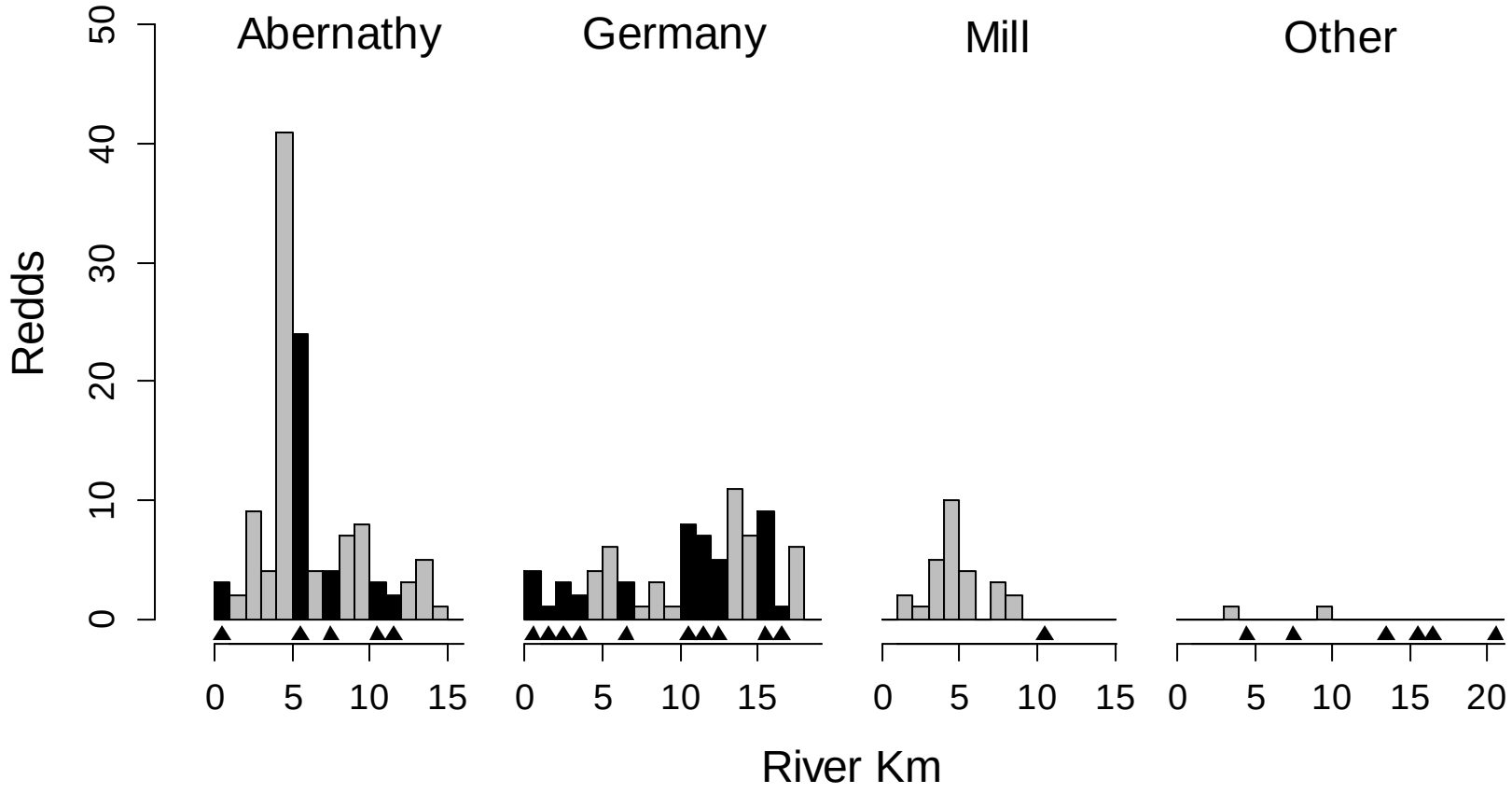
Abernathy
Germany
Mill
Other
Redds
0
10
20
30
40
50
0
5
10
15
0
5
10
15
0
5
10
15
0
5
10
15
20
River Km

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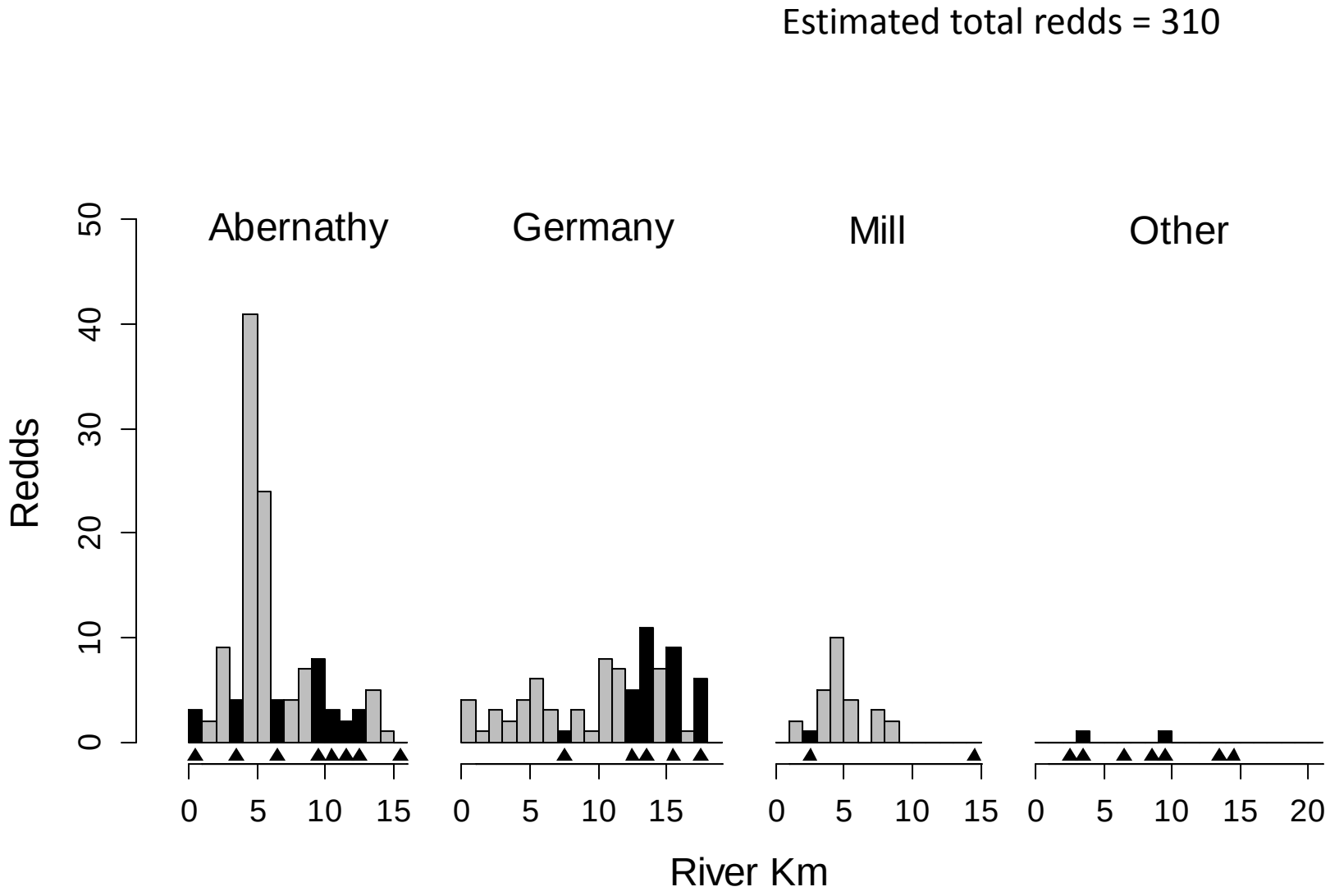
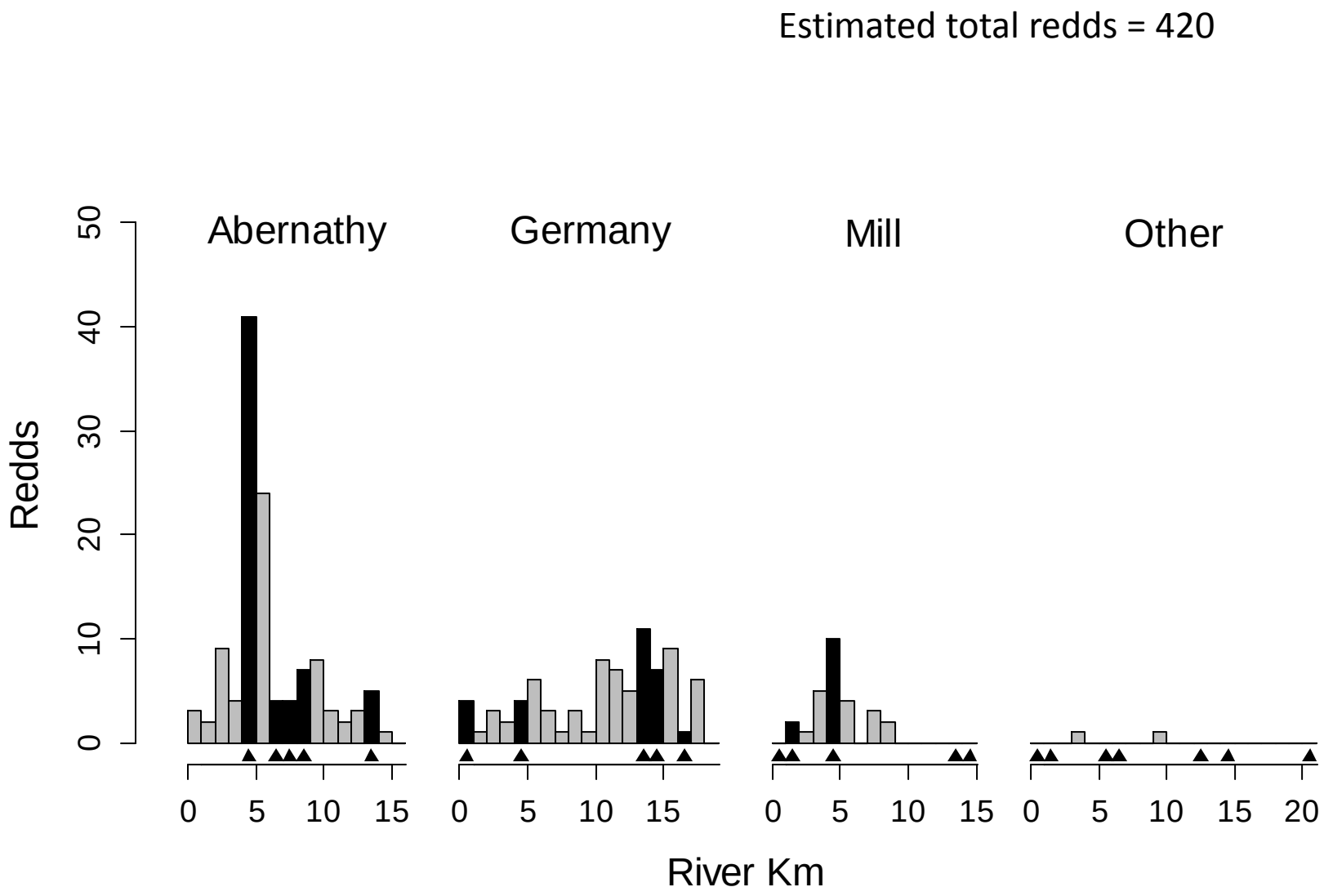
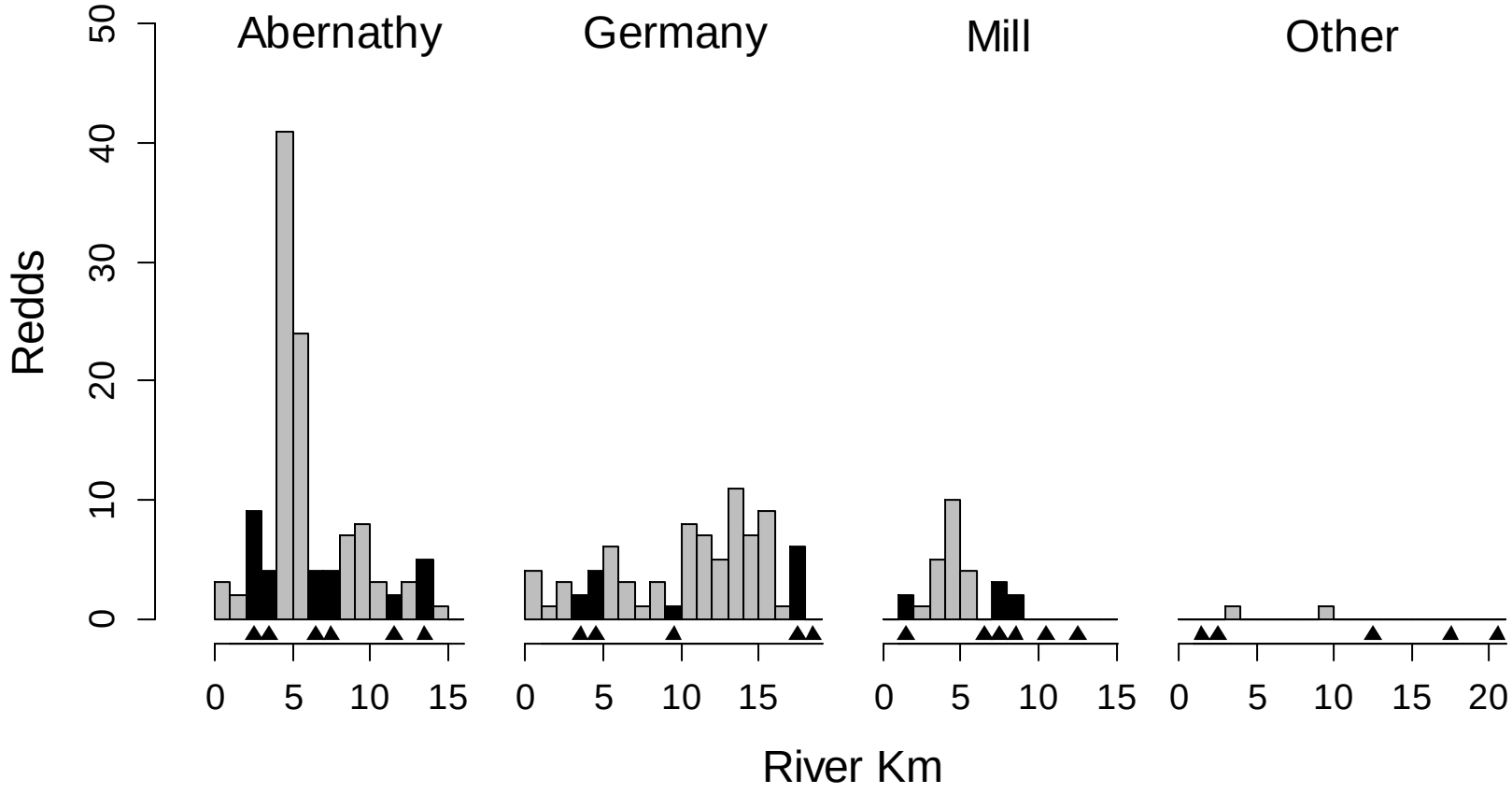

Estimated total redds = 310
Abernathy
Germany
Mill
Other
Redds
0
10
20
30
40
50
0
5
10
15
0
5
10
15
0
5
10
15
0
5
10
15
20
River Km

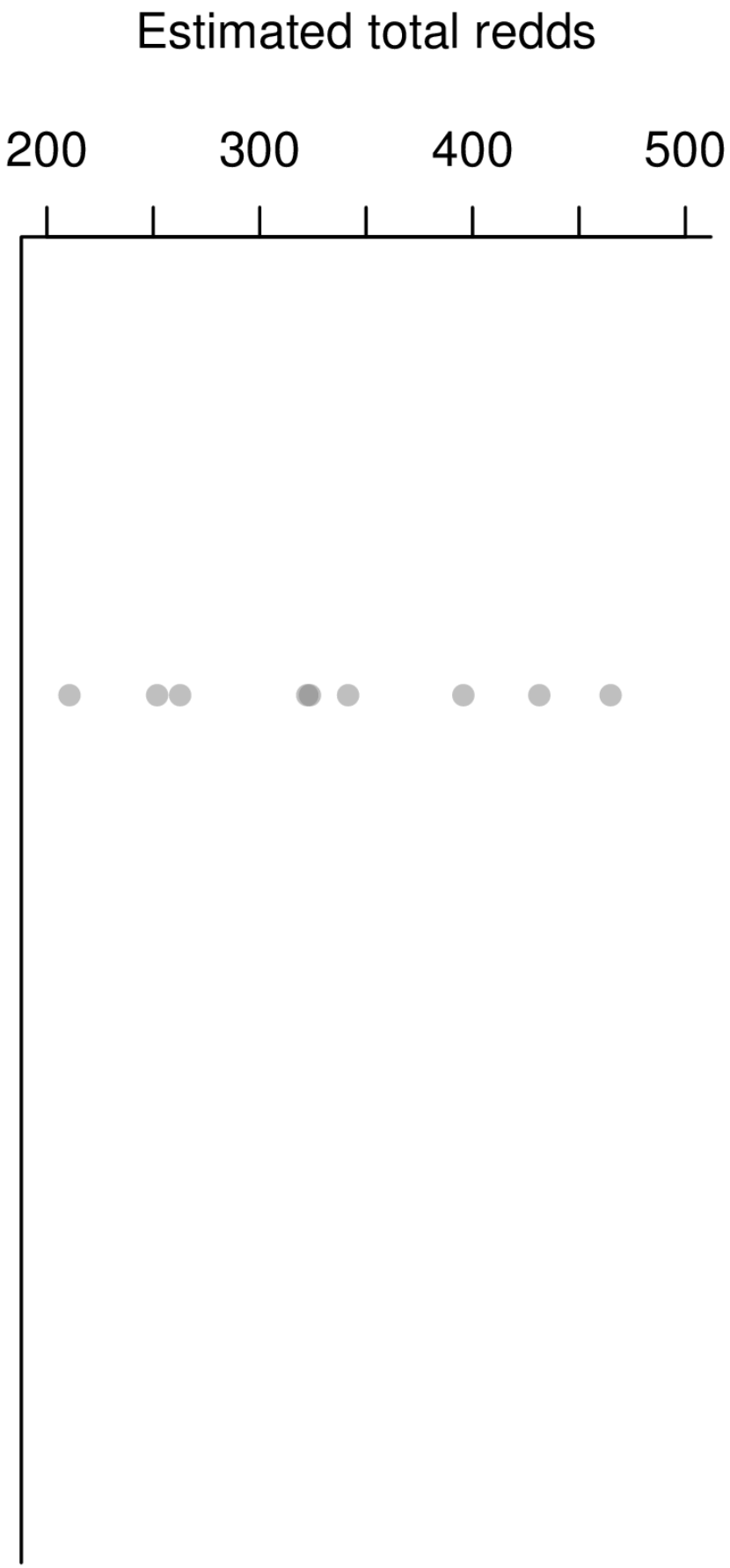

Estimated total redds = 420
Abernathy
Germany
Mill
Other
Redds
0
10
20
30
40
50
0
5
10
15
0
5
10
15
0
5
10
15
0
5
10
15
20
River Km

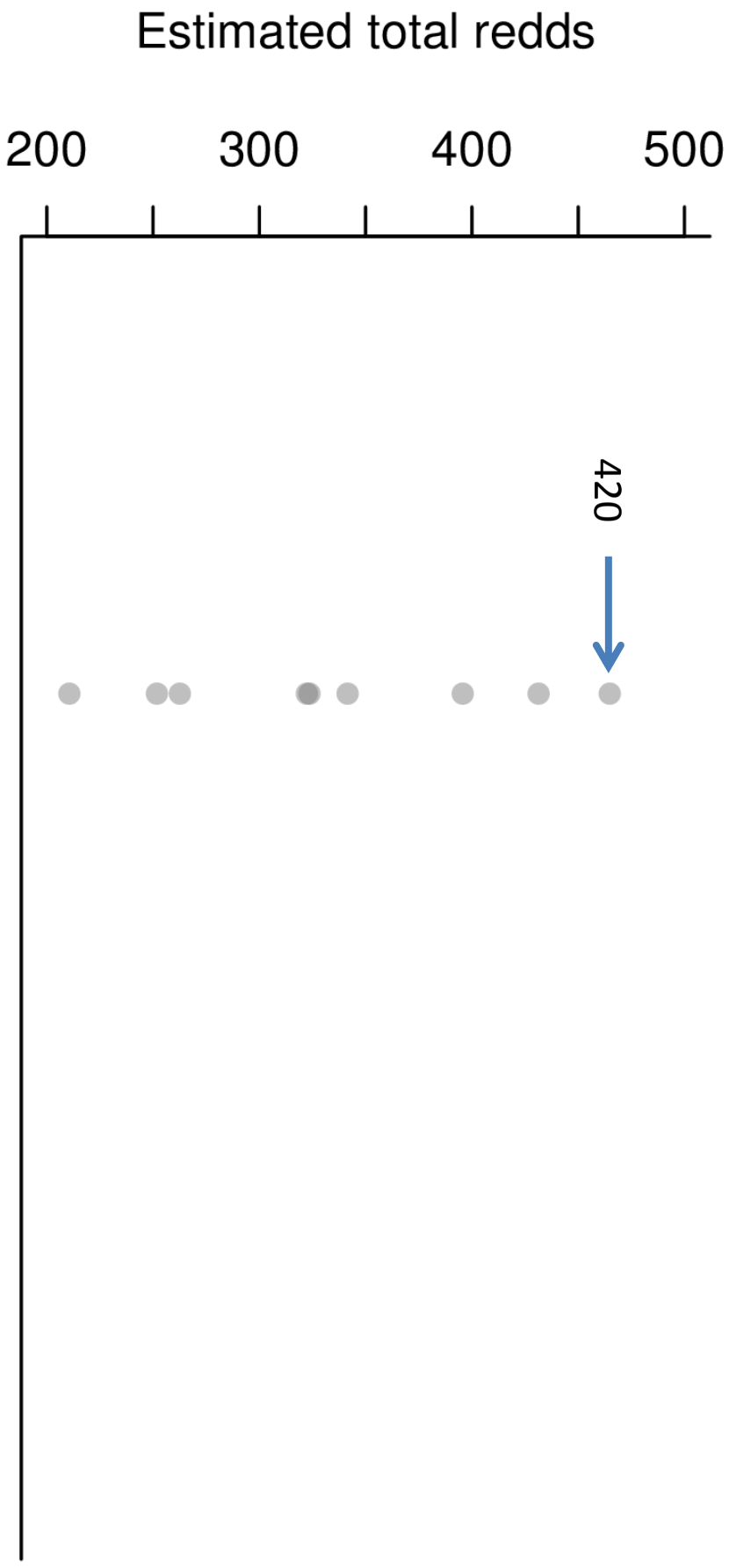
Estimated total redds = 240

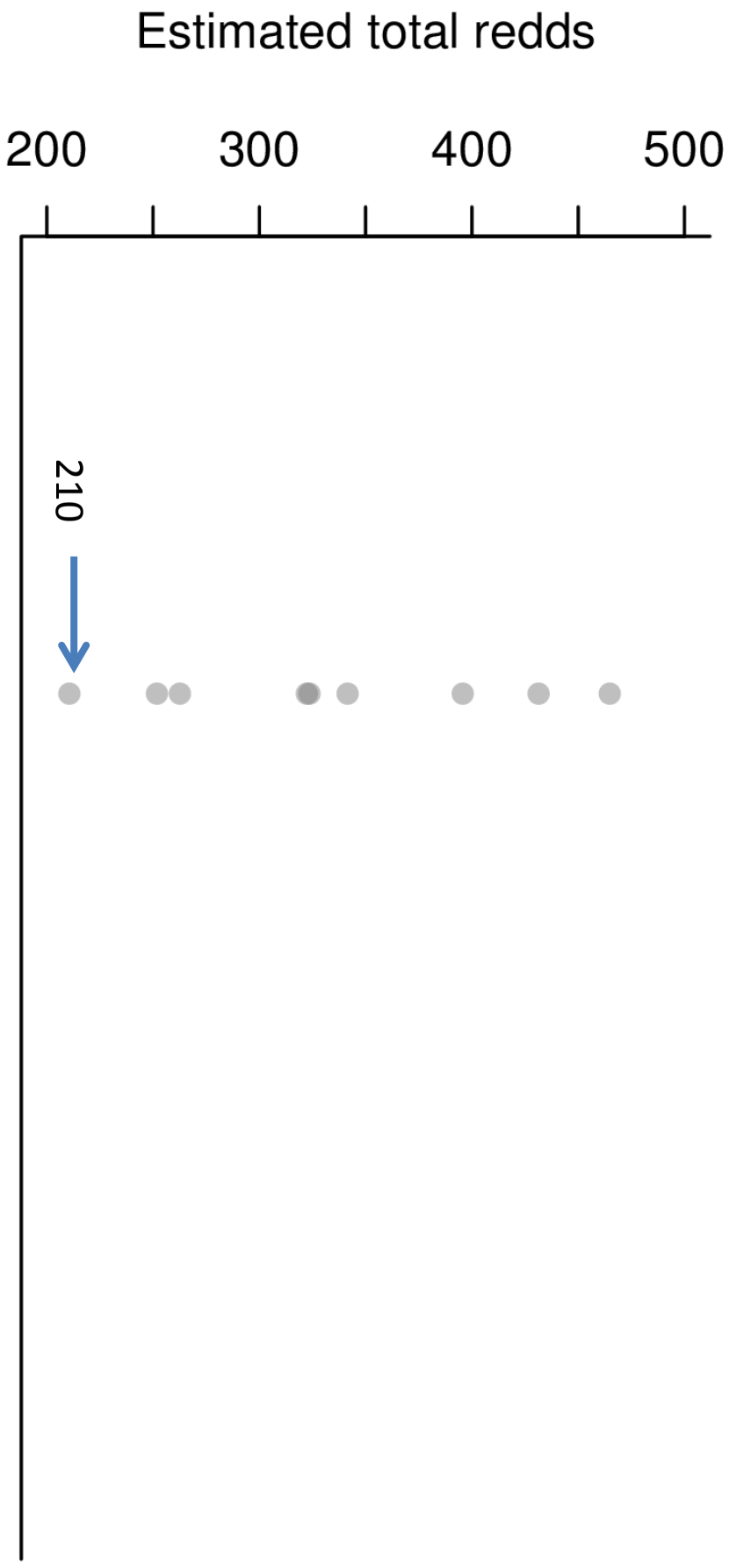


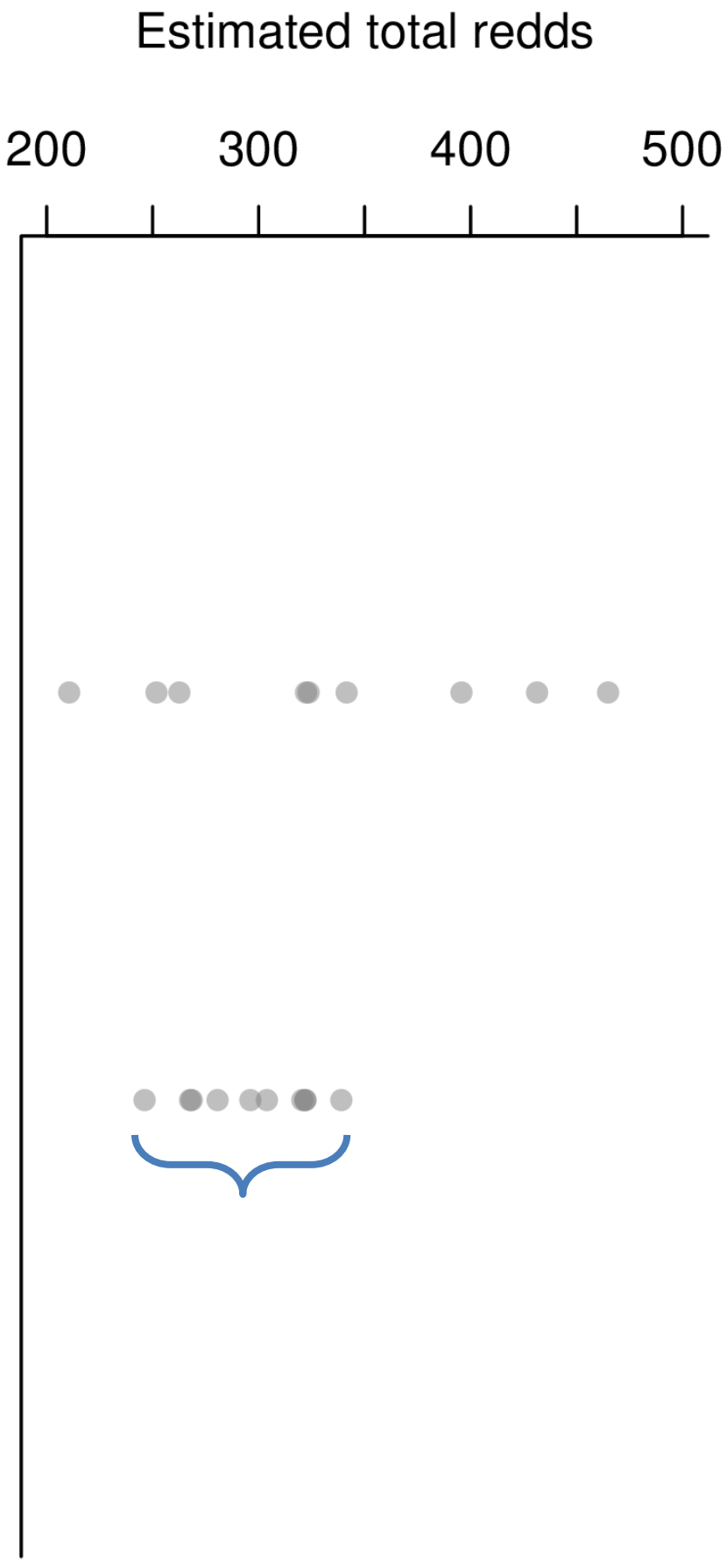
Approach

- Bin redds into 1km reaches.
- Select a random sample from the reaches.
- Repeat many times for each sampling design.
- Summarize results.


Estimated total redds
200
300
400
500


Estimated total redds
200
300
400
500
420


Estimated total redds
200
300
400
500
210

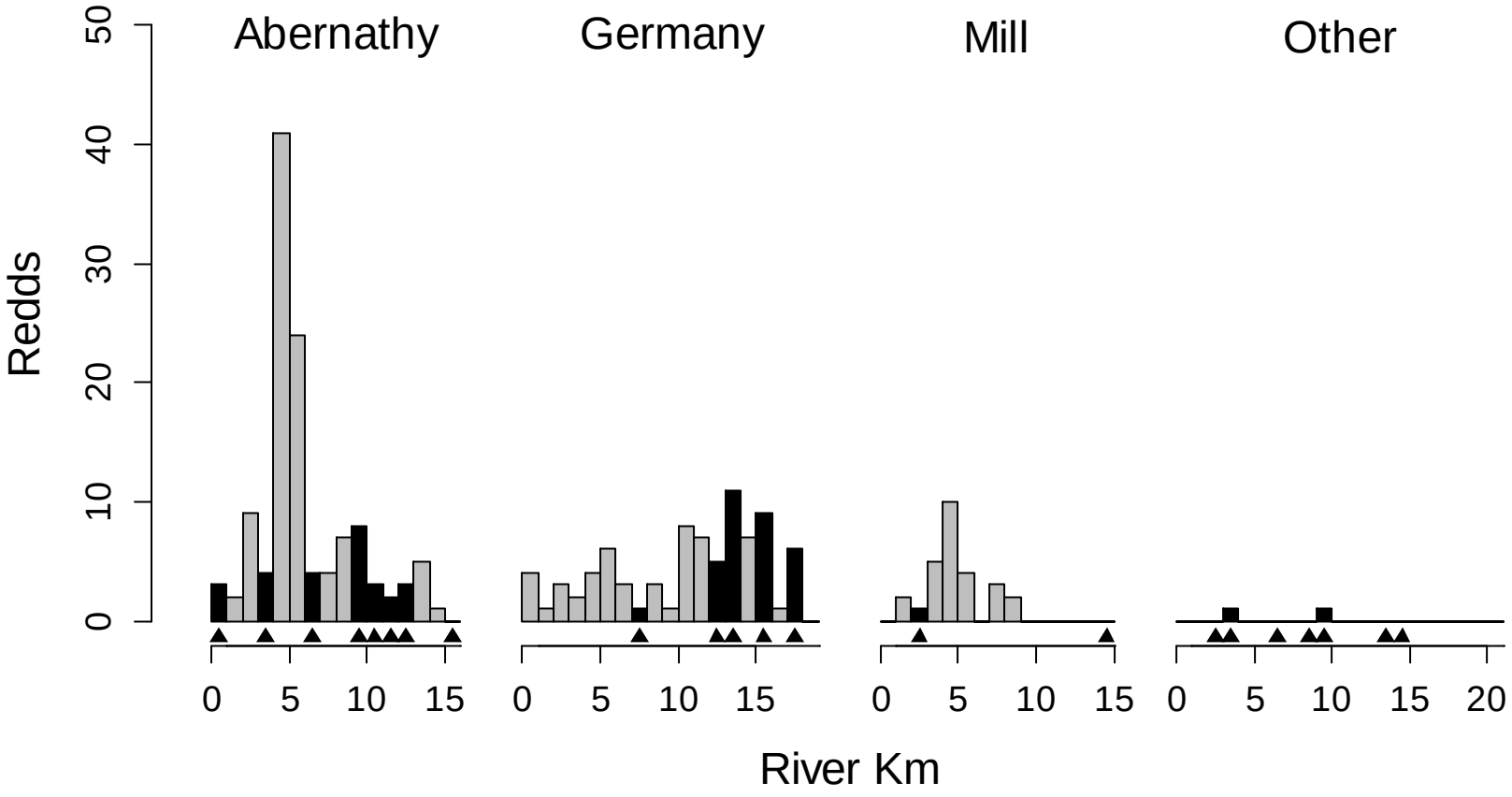

Estimated total redds
200
300
400
500

Sampling approaches

- Simple random sampling (SRS)
- Generalized Random Tesselation Stratified (GRTS)
- Stratified GRTS
- Peak count census + regression estimator

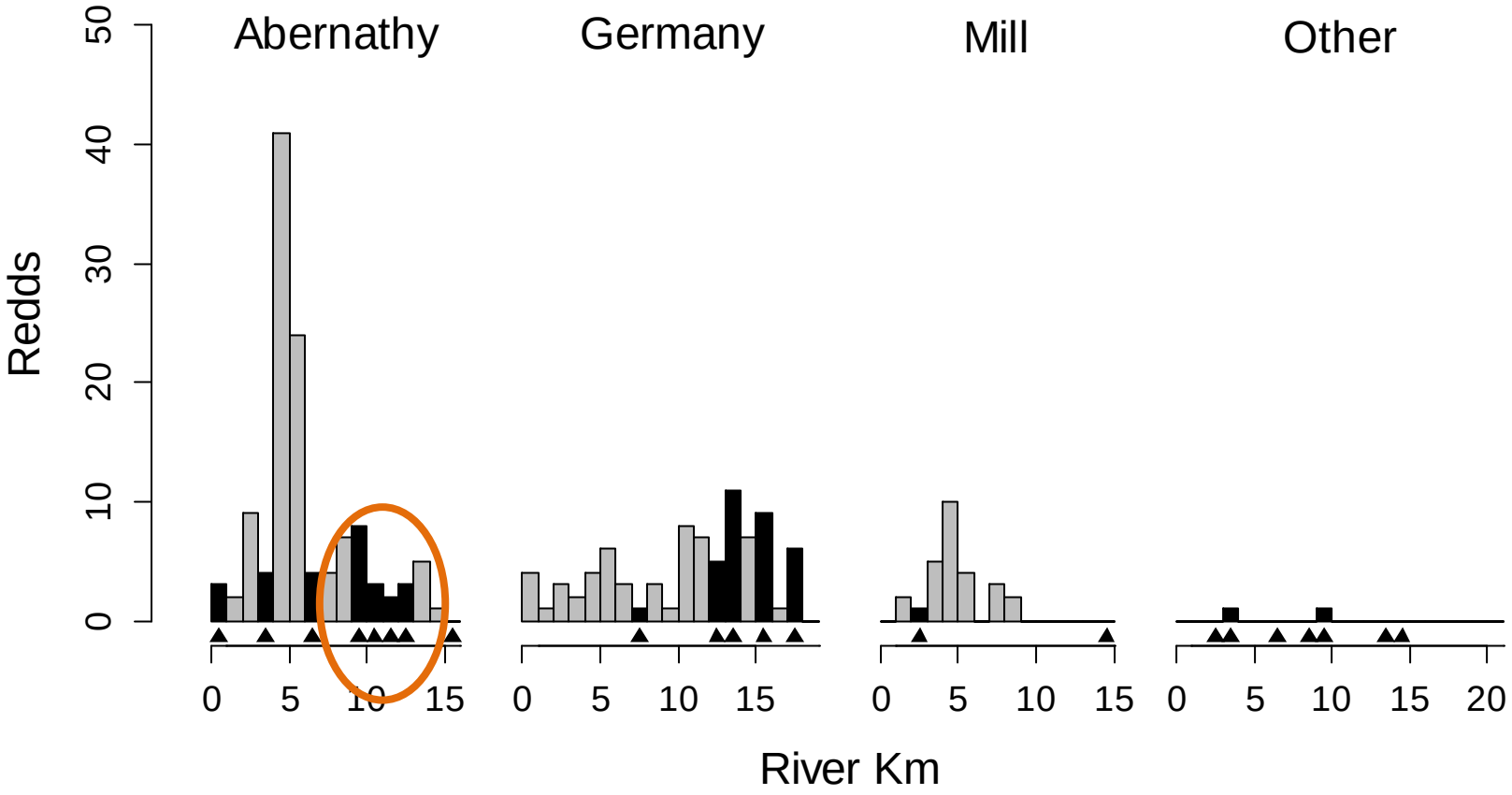
Sampling approaches

- SRS



Sampling approaches

- SRS

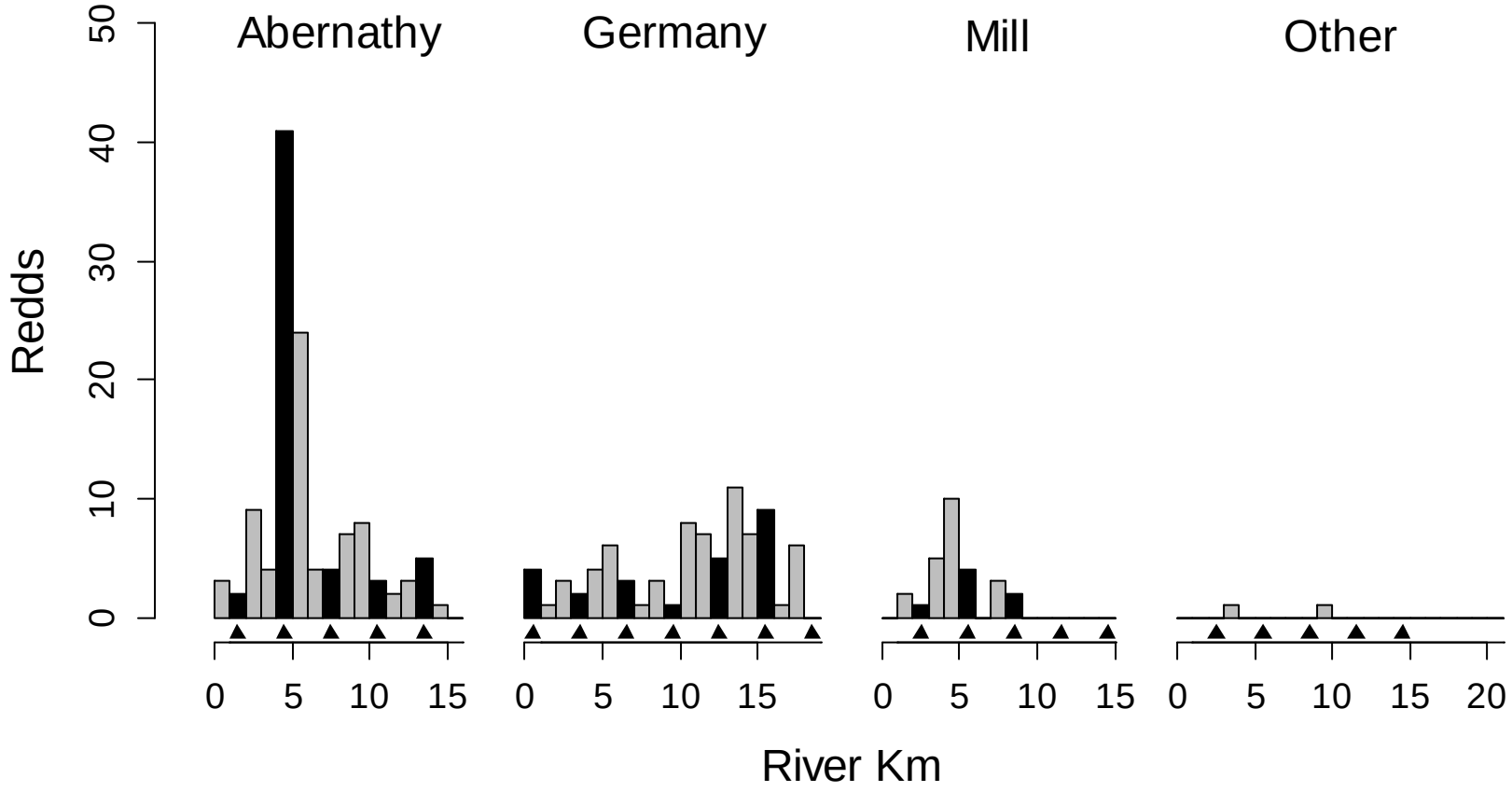


Sampling approaches

- SRS
- GRTS (Generalized Random Tesselation Stratified)
- Stratified GRTS
- Peak count census + regression estimator

Sampling approaches

- SRS
- GRTS (Generalized Random Tesselation Stratified)



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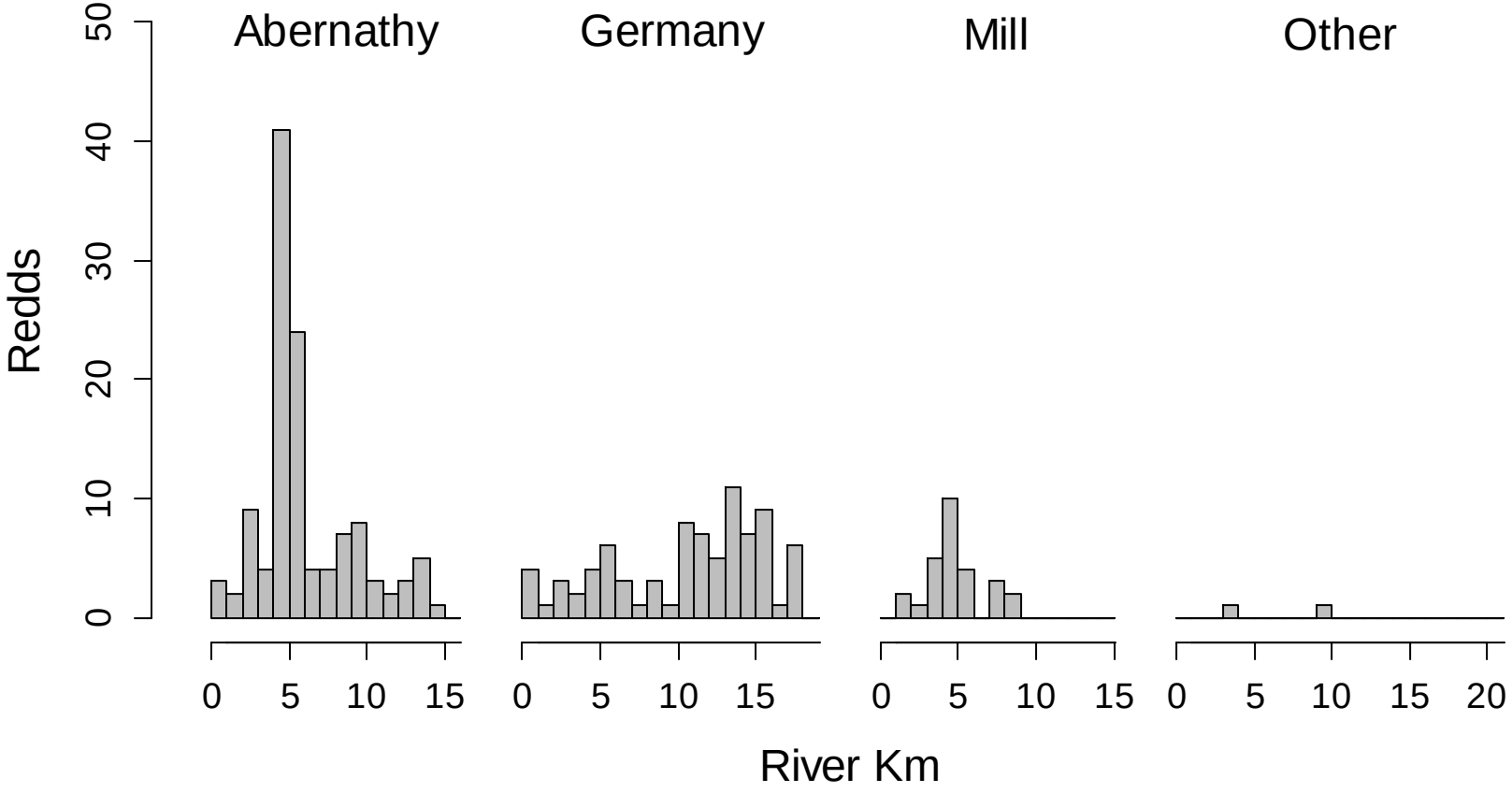
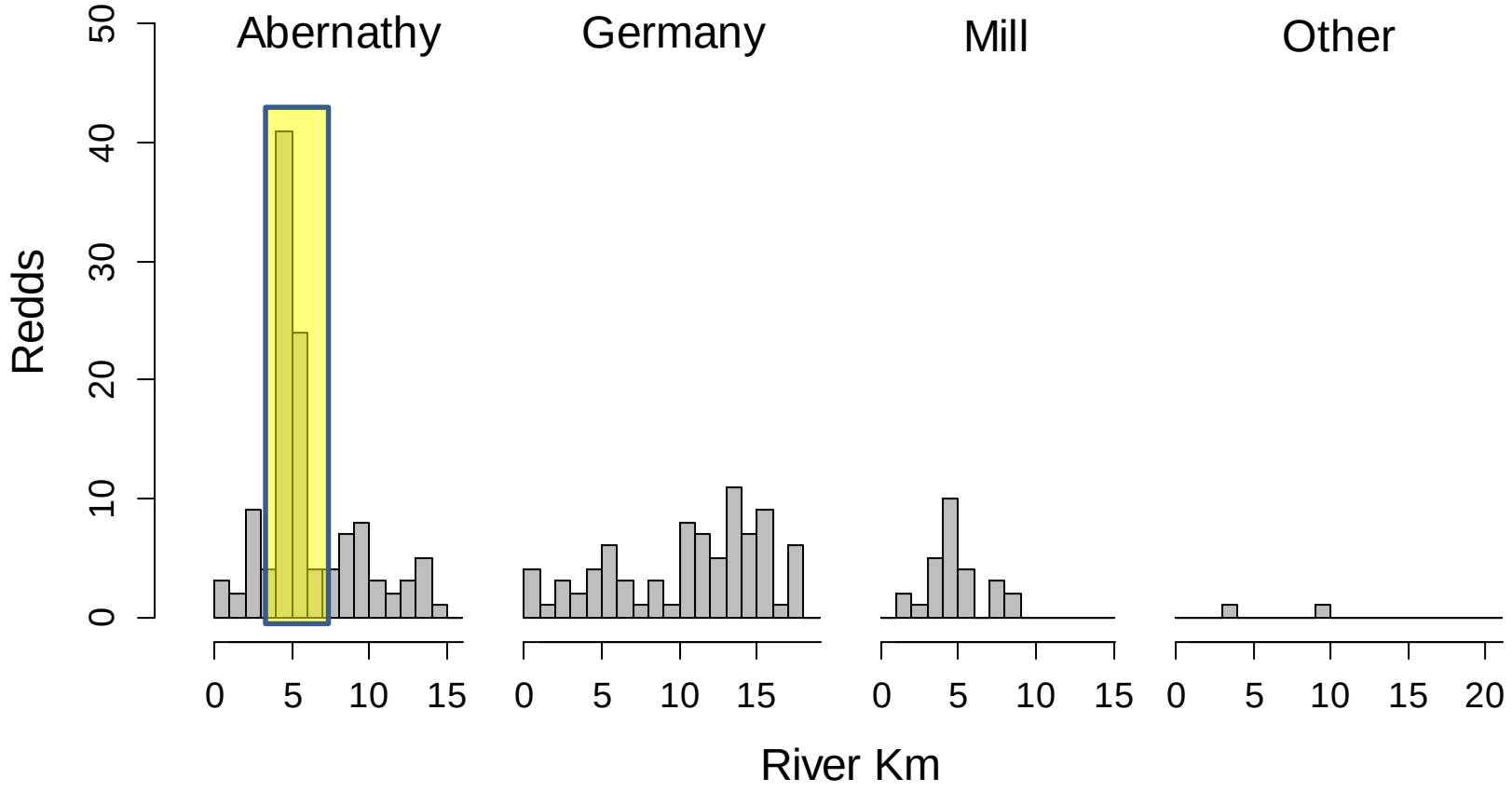
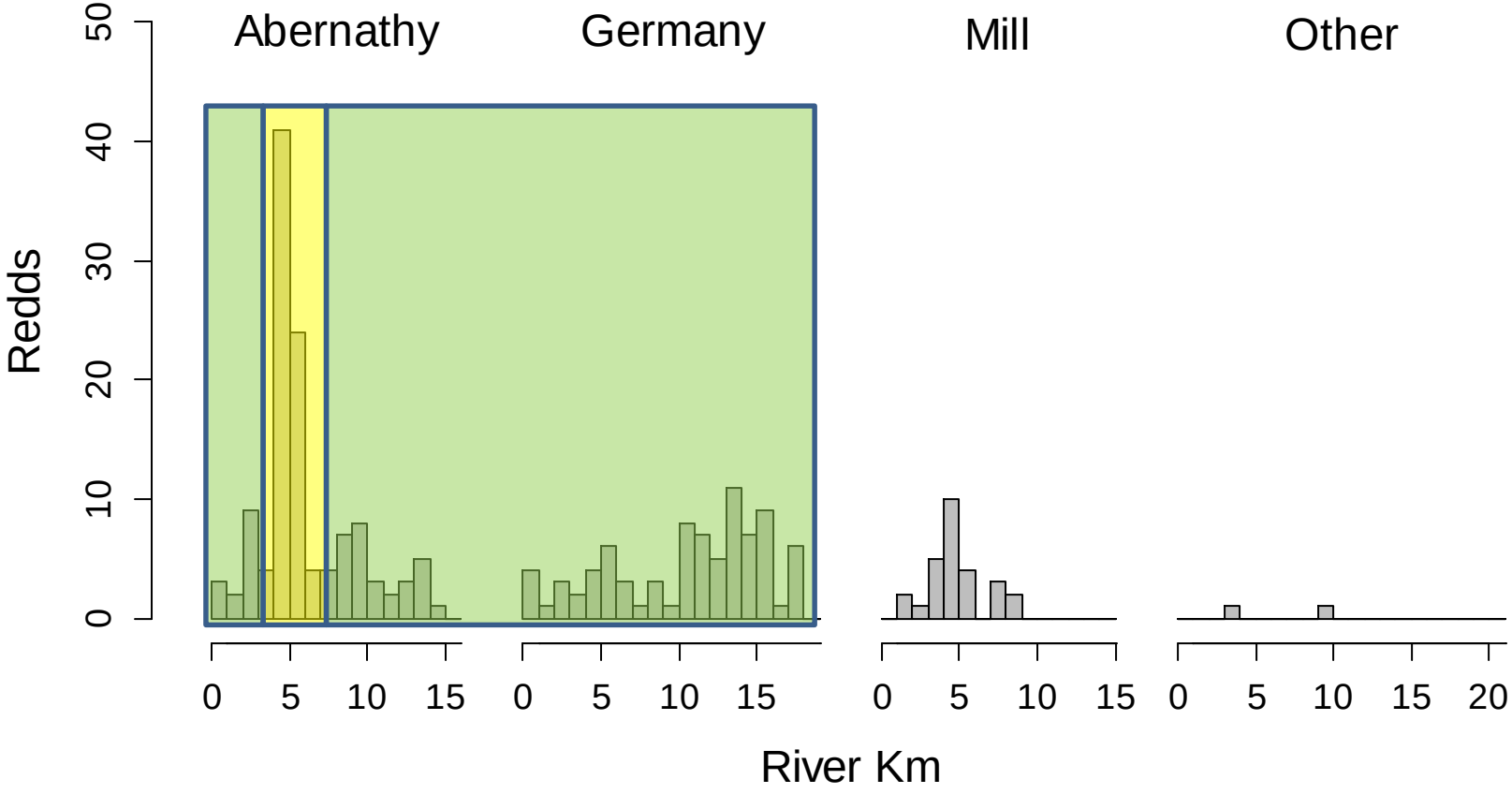
Stratified GRTS



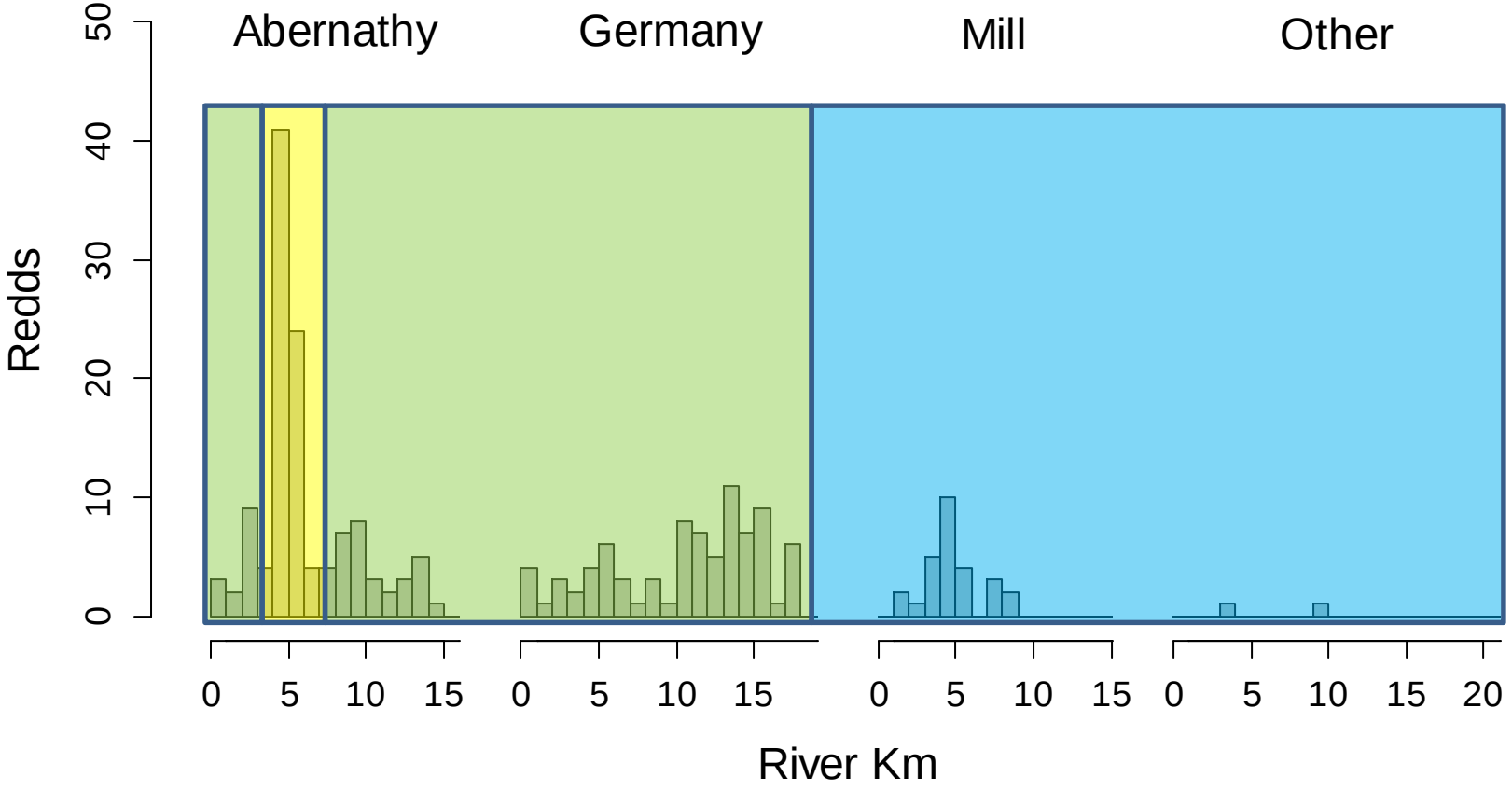
Stratified GRTS



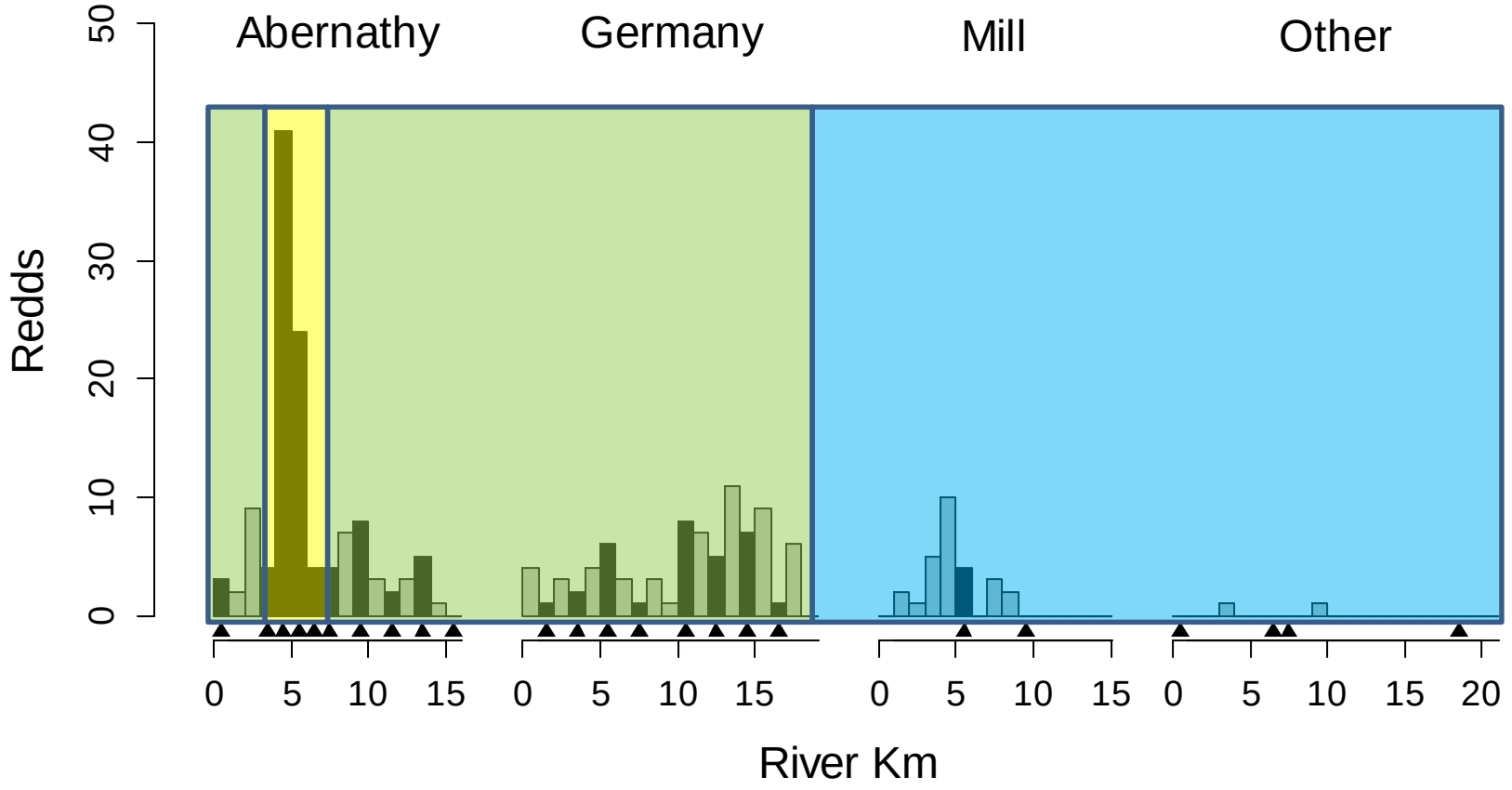
Stratified GRTS



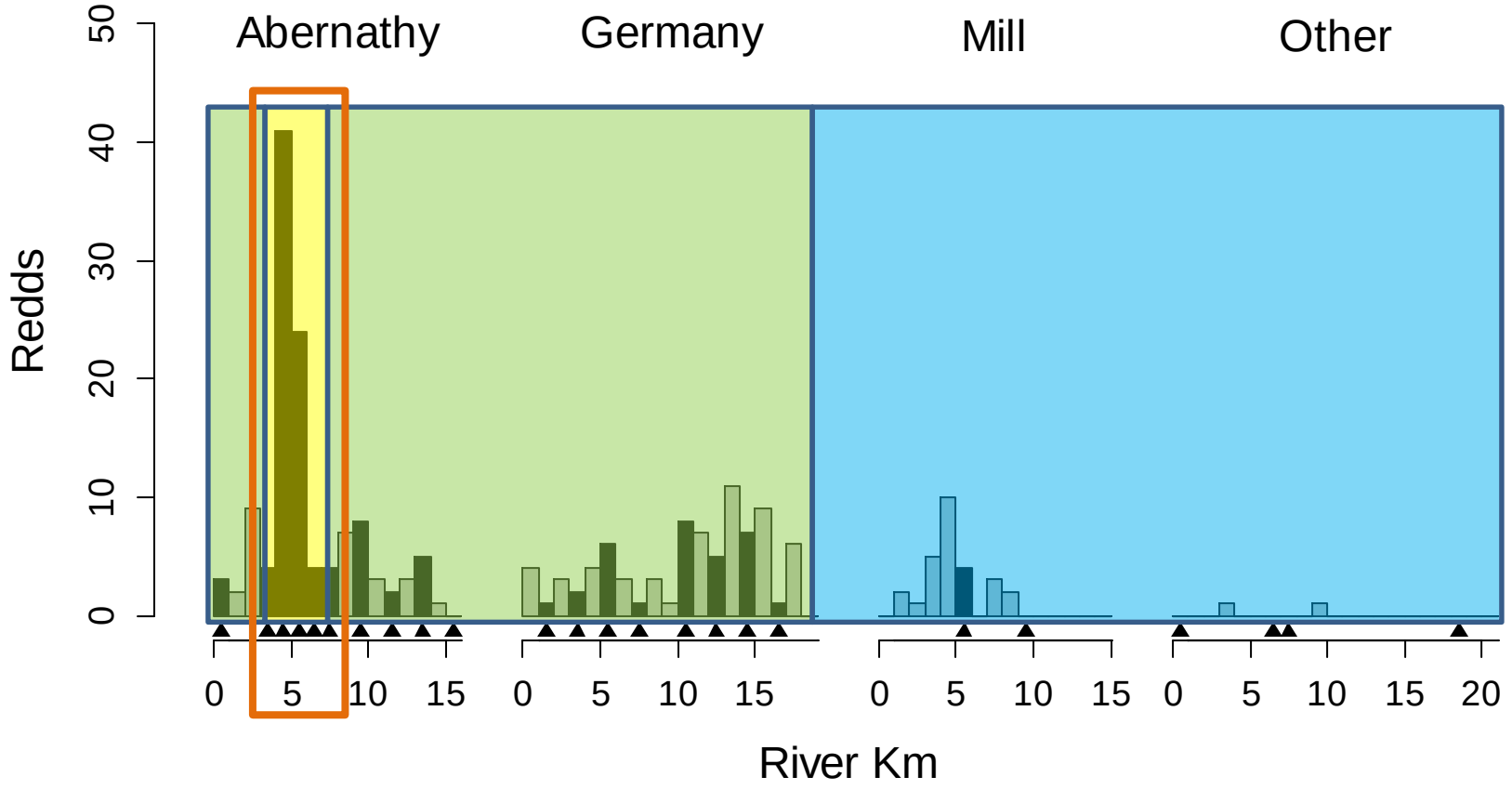
Stratified GRTS



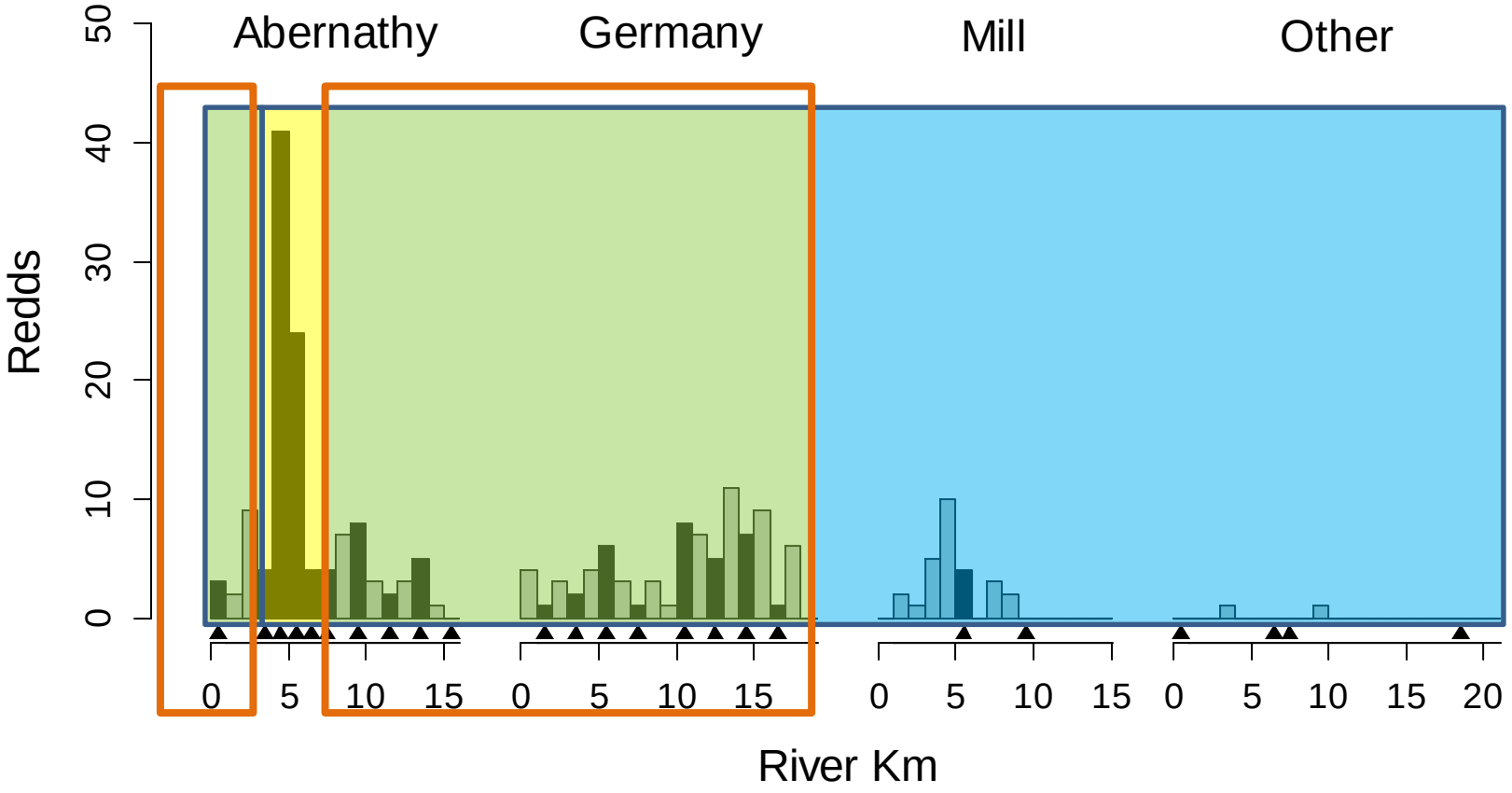
Stratified GRTS



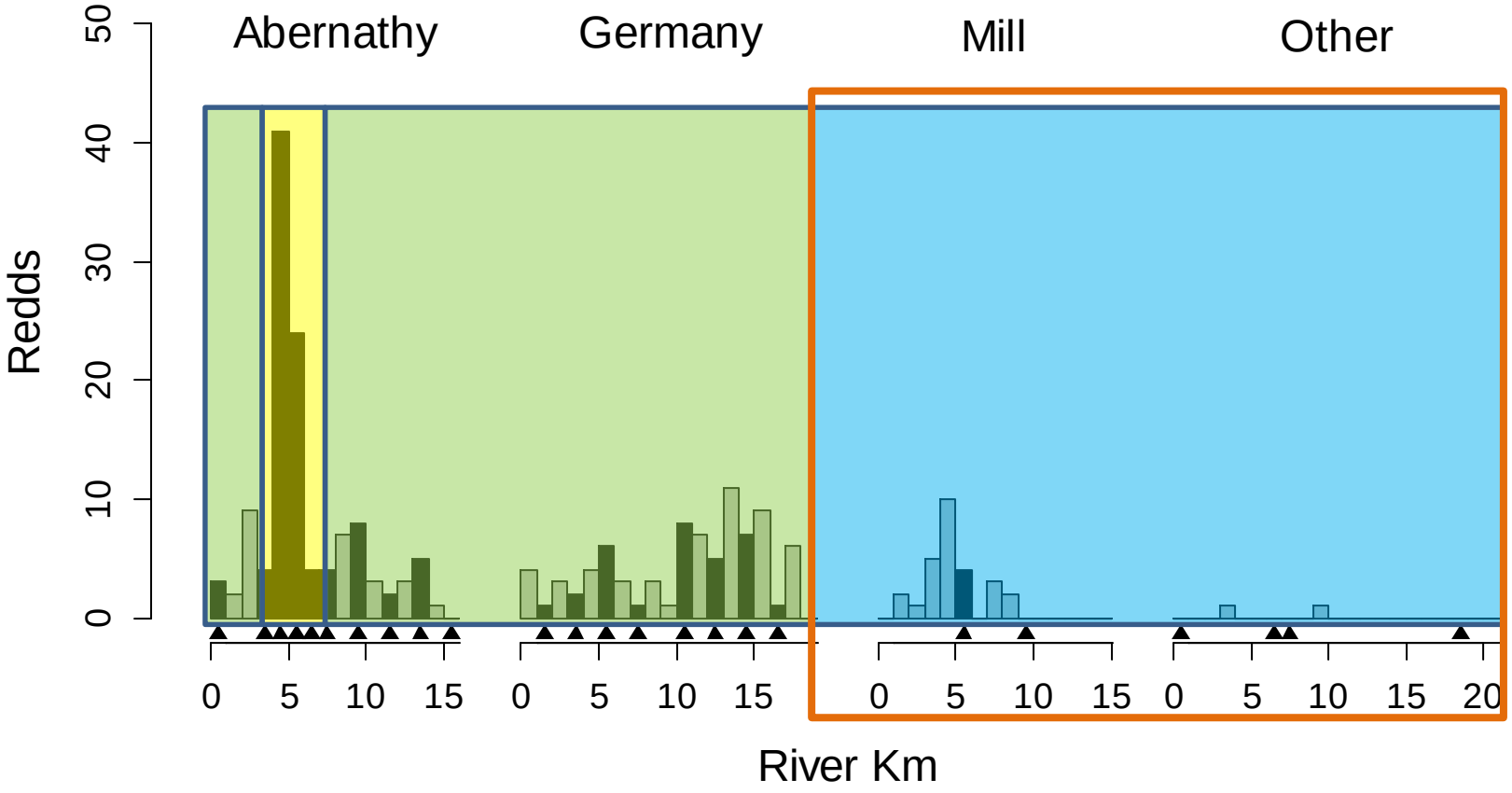
Stratified GRTS



Stratified GRTS



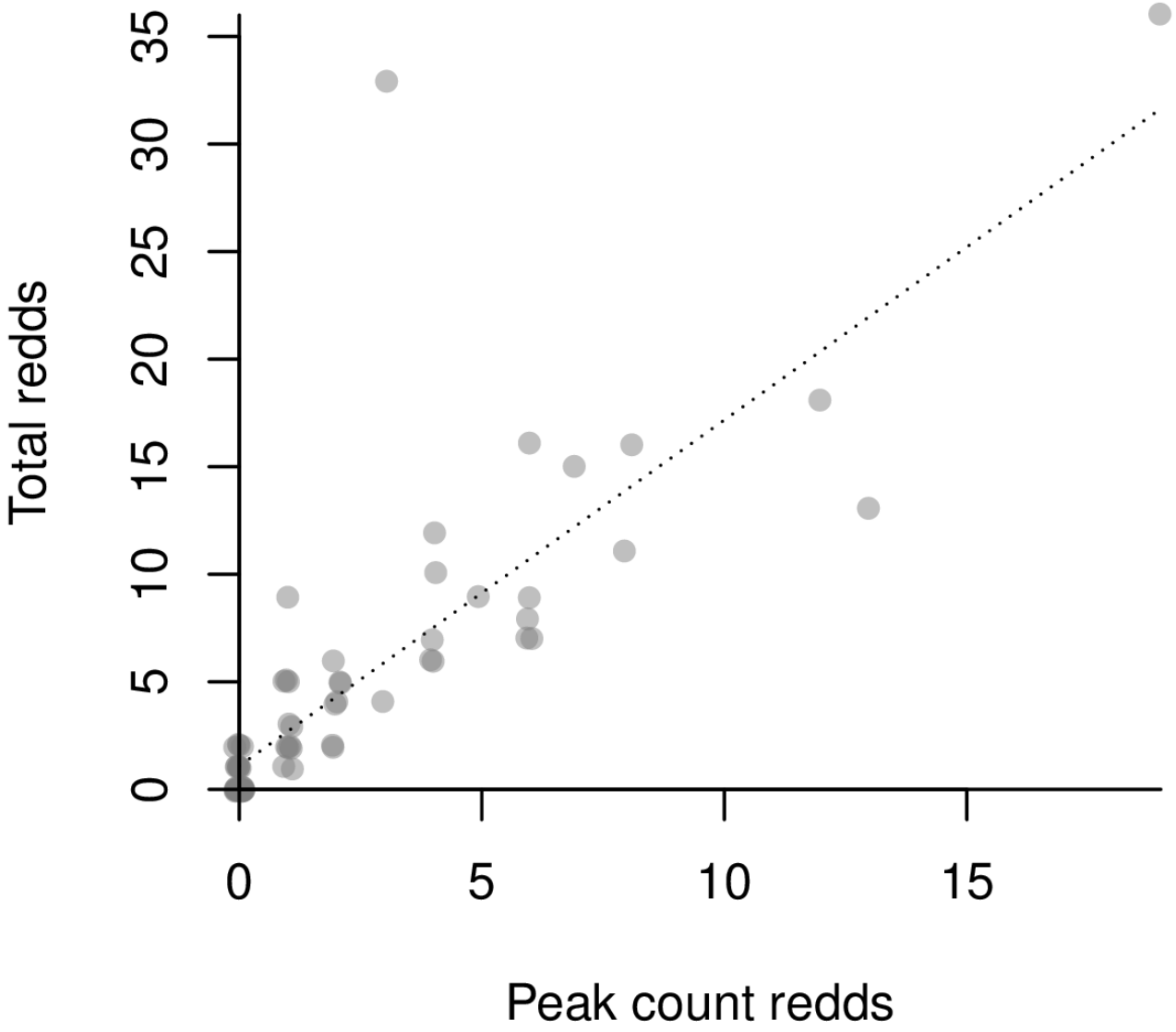
Stratified GRTS



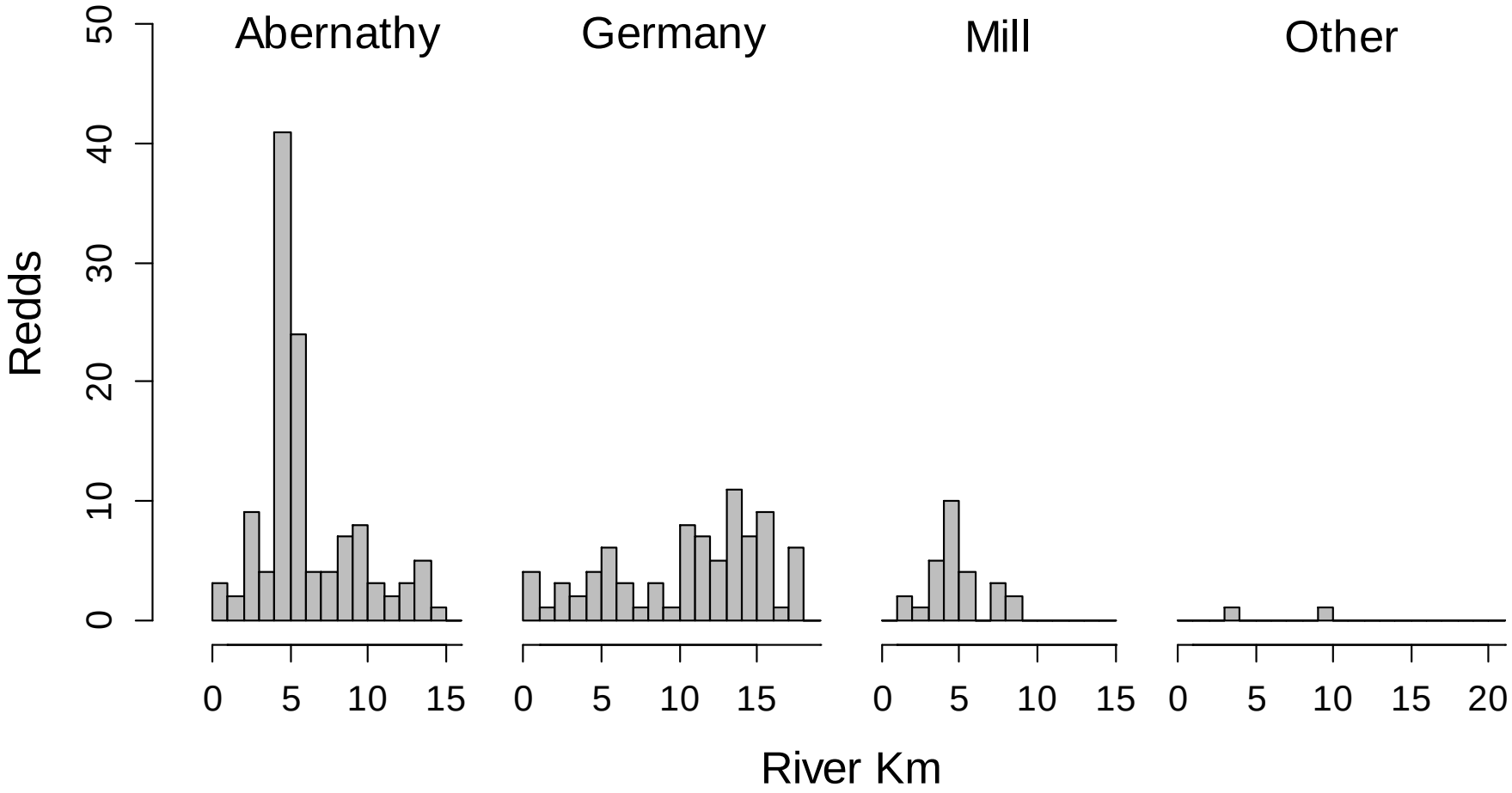
Sampling approaches

- SRS
- GRTS (Generalized Random Tesselation Stratified)
- Stratified GRTS
- Peak count census + regression estimator

Peak count census + regression estimator



Results


Abernathy
Germany
Mill
Other
Redds
0
10
20
30
40
50
0
5
10
15
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5
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15
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5
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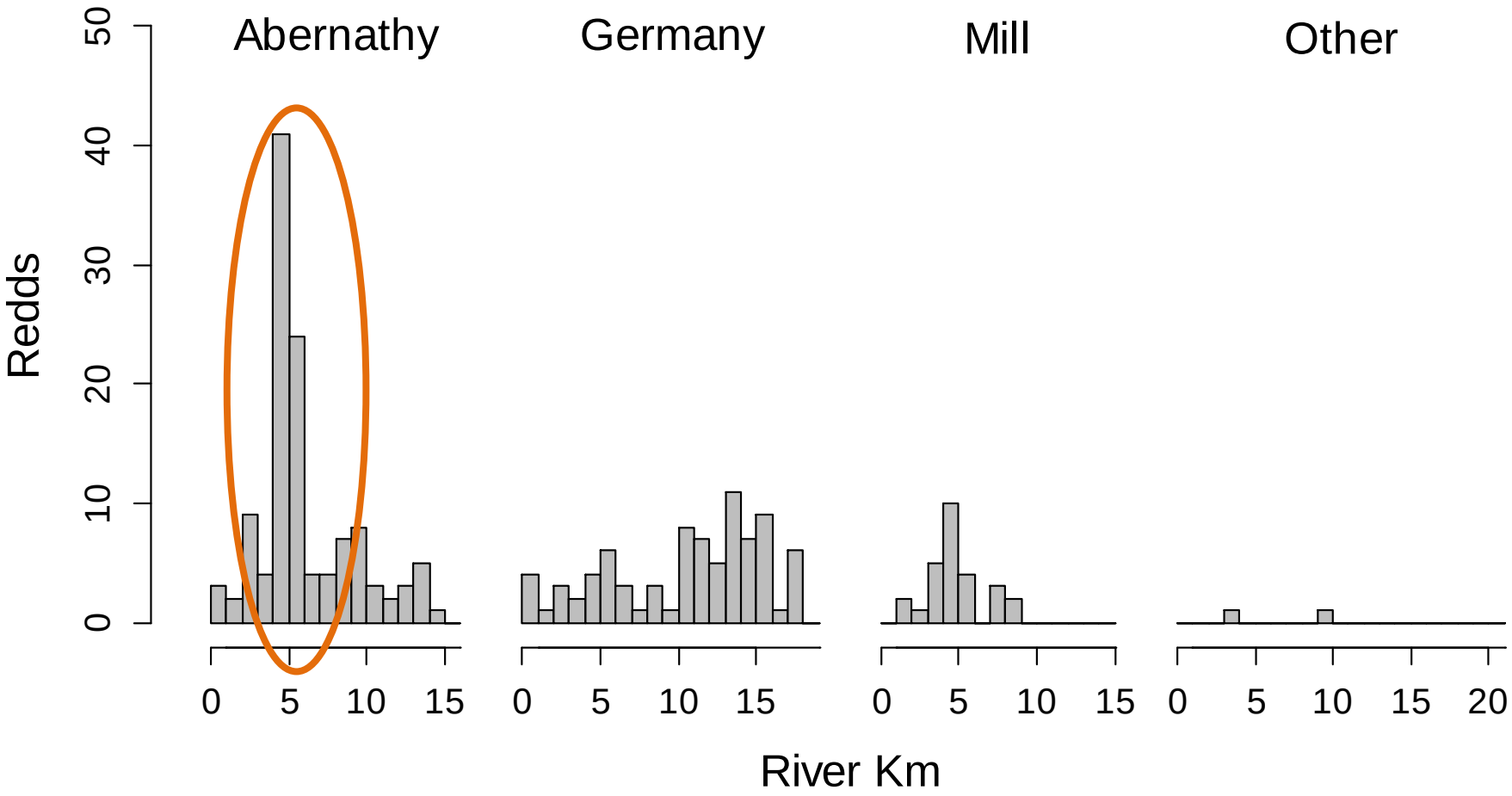
15
0
5
10
15
20
River Km


Abernathy
Germany
Mill
Other
Redds
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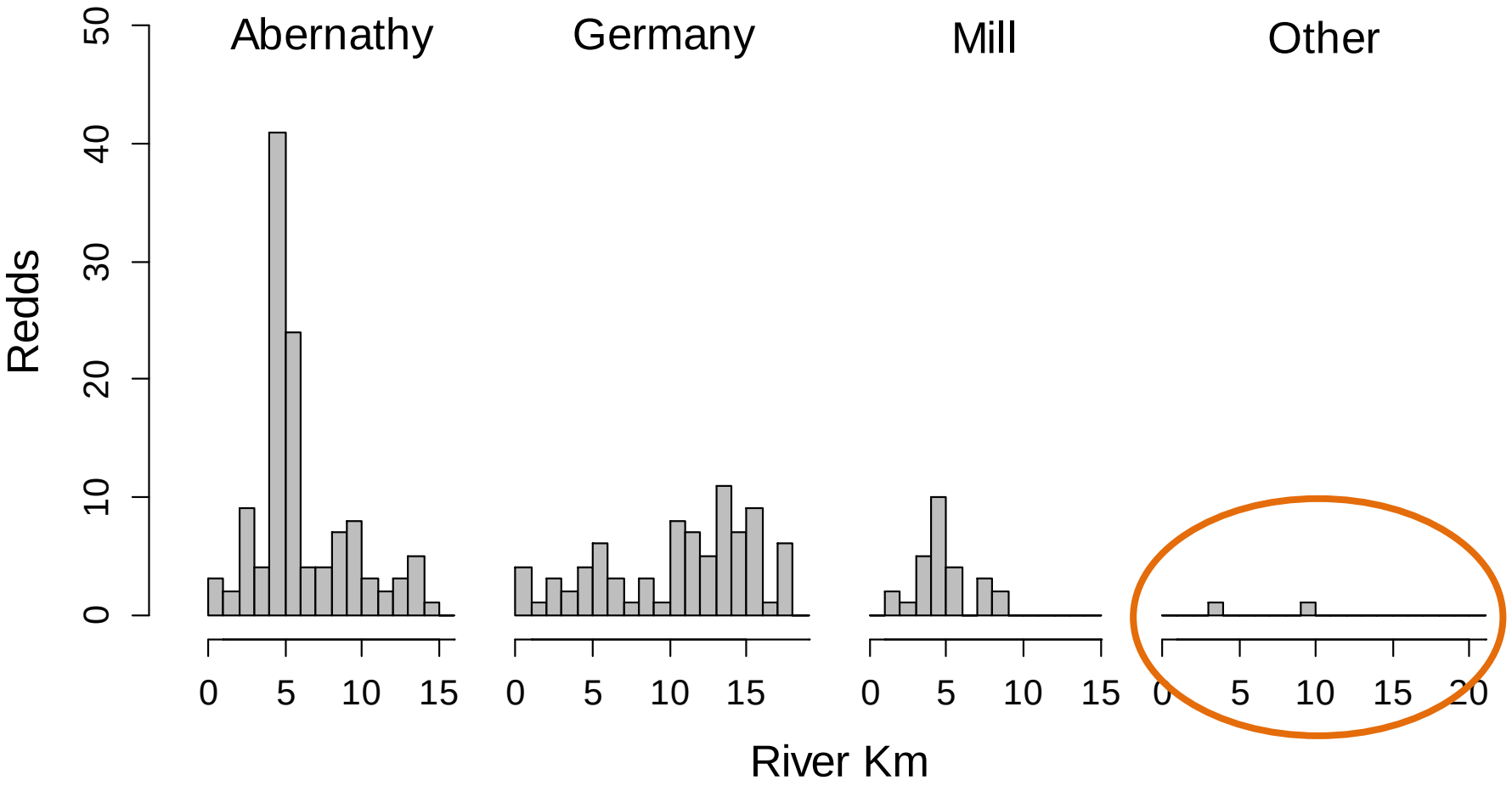
20
River Km


Abernathy
Germany
Mill
Other
Redds
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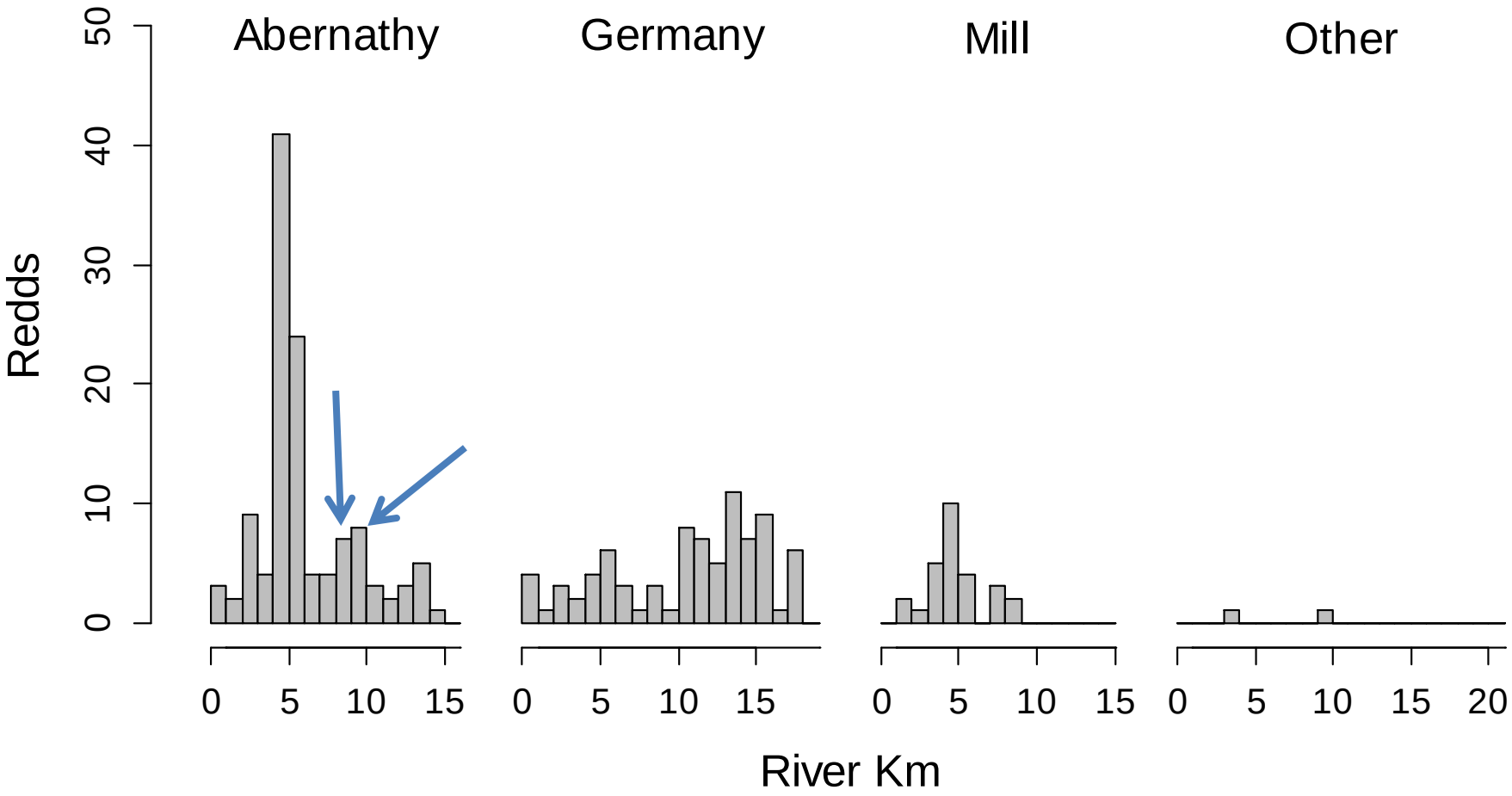
20
River Km


Abernathy
Germany
Mill
Other
Redds
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10
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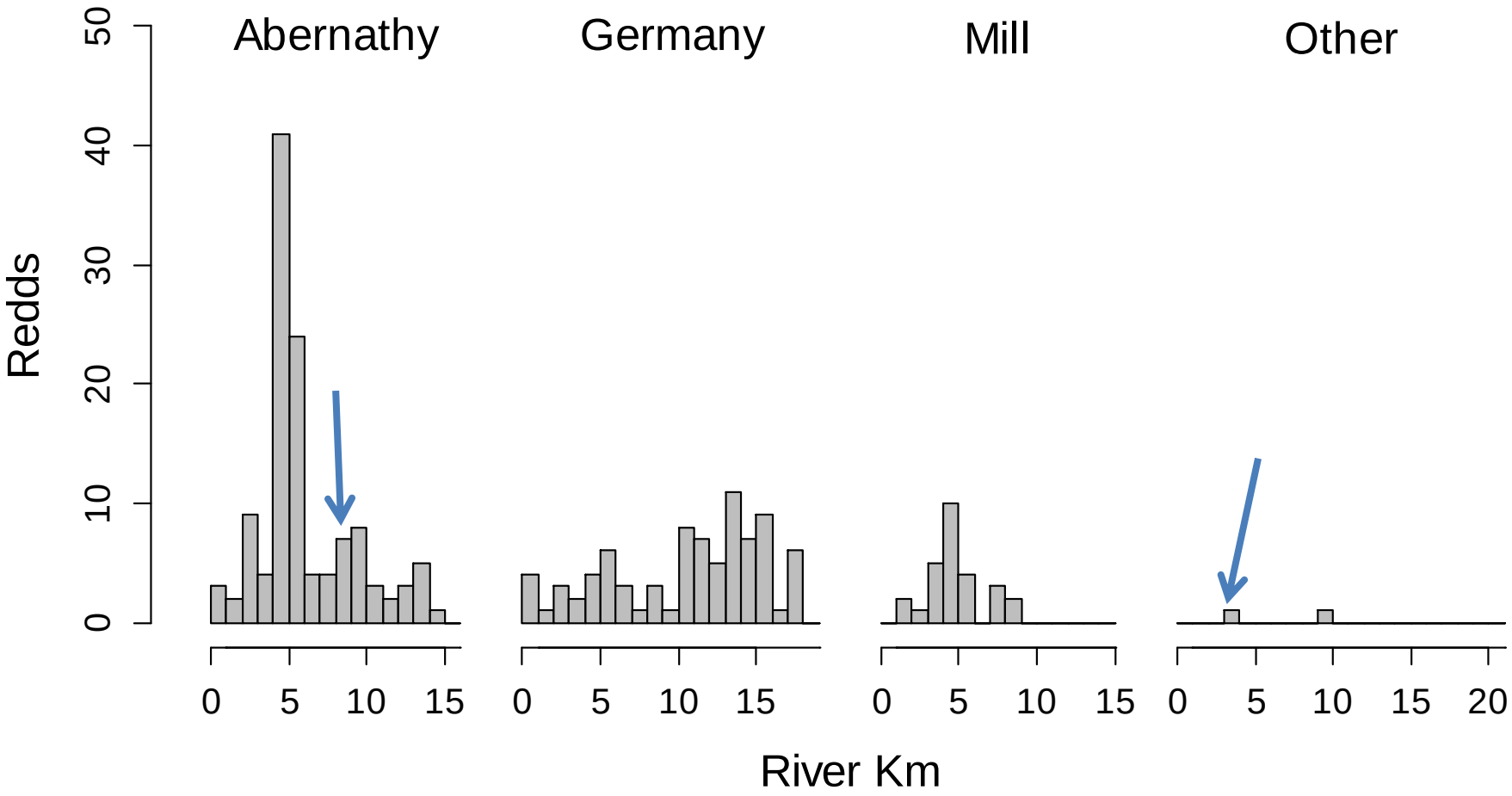
20
River Km


Abernathy
Germany
Mill
Other
Redds
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10
20
30
40
50
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10
15
0
5
10
15
0
5
10
15
0
5
10
15
20
River Km

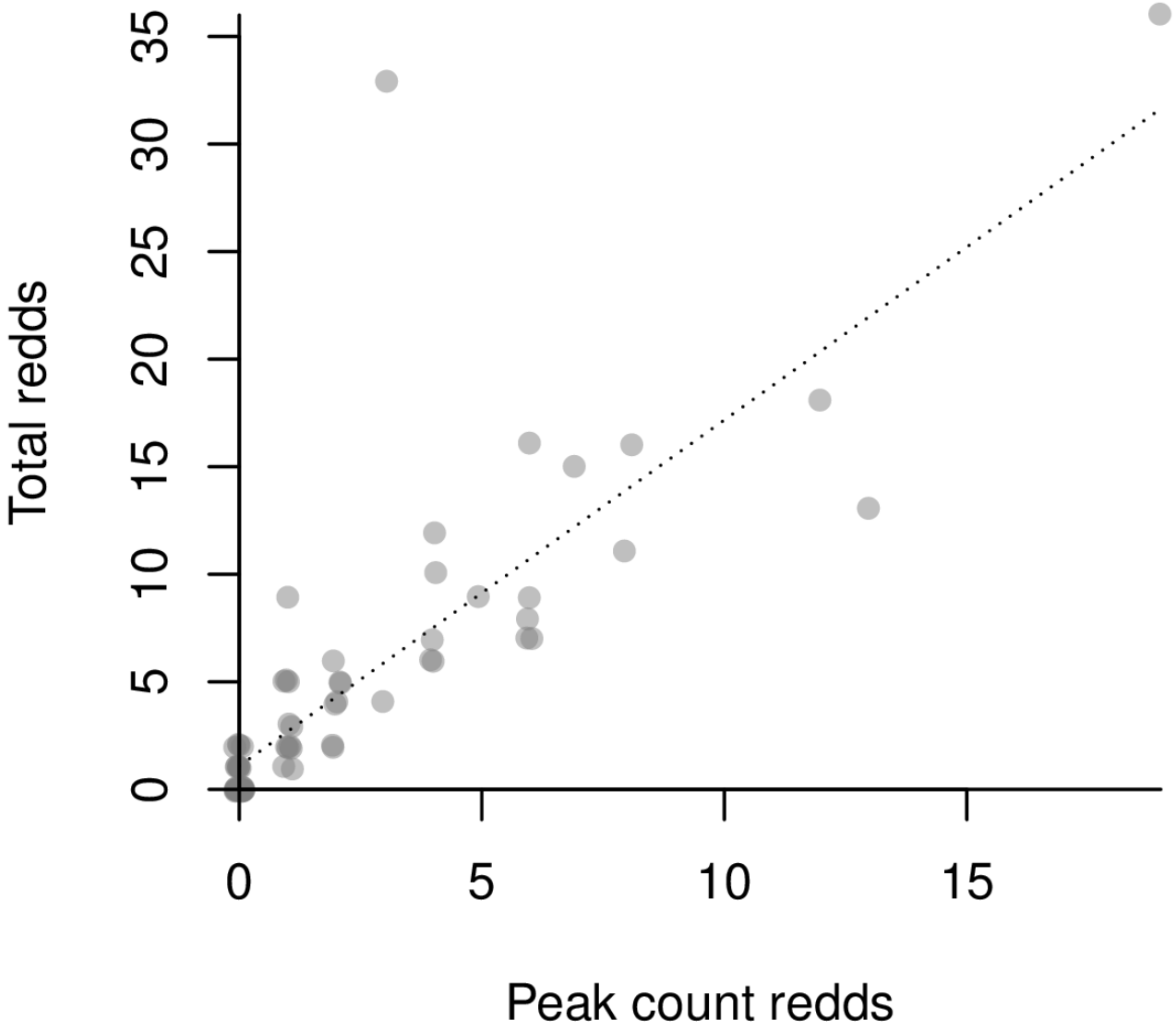
Redd distribution

	Mill, Abernathy & Germany Cr	Coweeman River	East Fork Lewis River
Variance / mean	10.23	9.30	7.70

Redd distribution

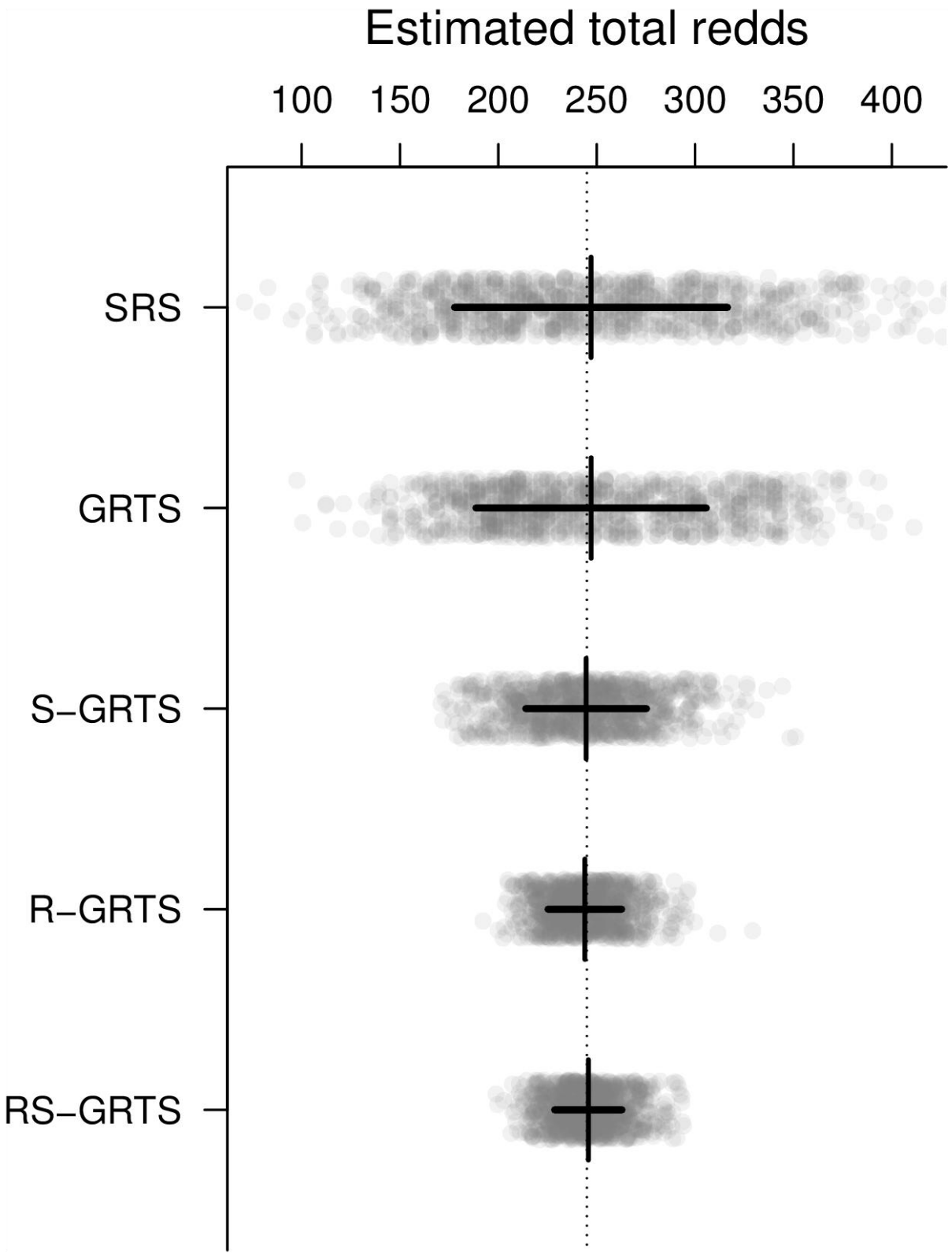
	Mill, Abernathy & Germany Cr	Coweeman River	East Fork Lewis River
Variance / mean	10.23	9.30	7.70
AutoCorr	0.55	0.32	0.03

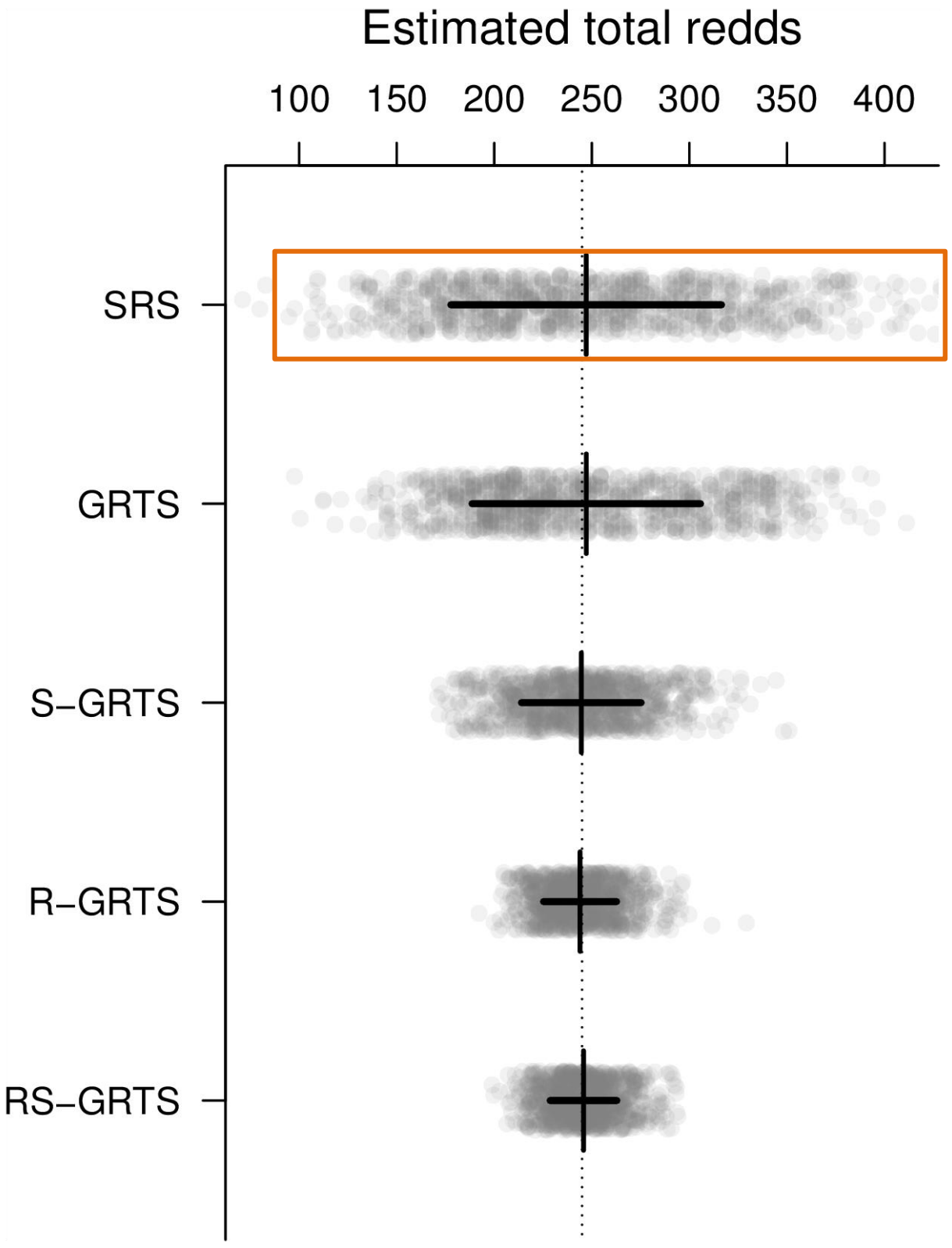
Peak count census + regression estimator

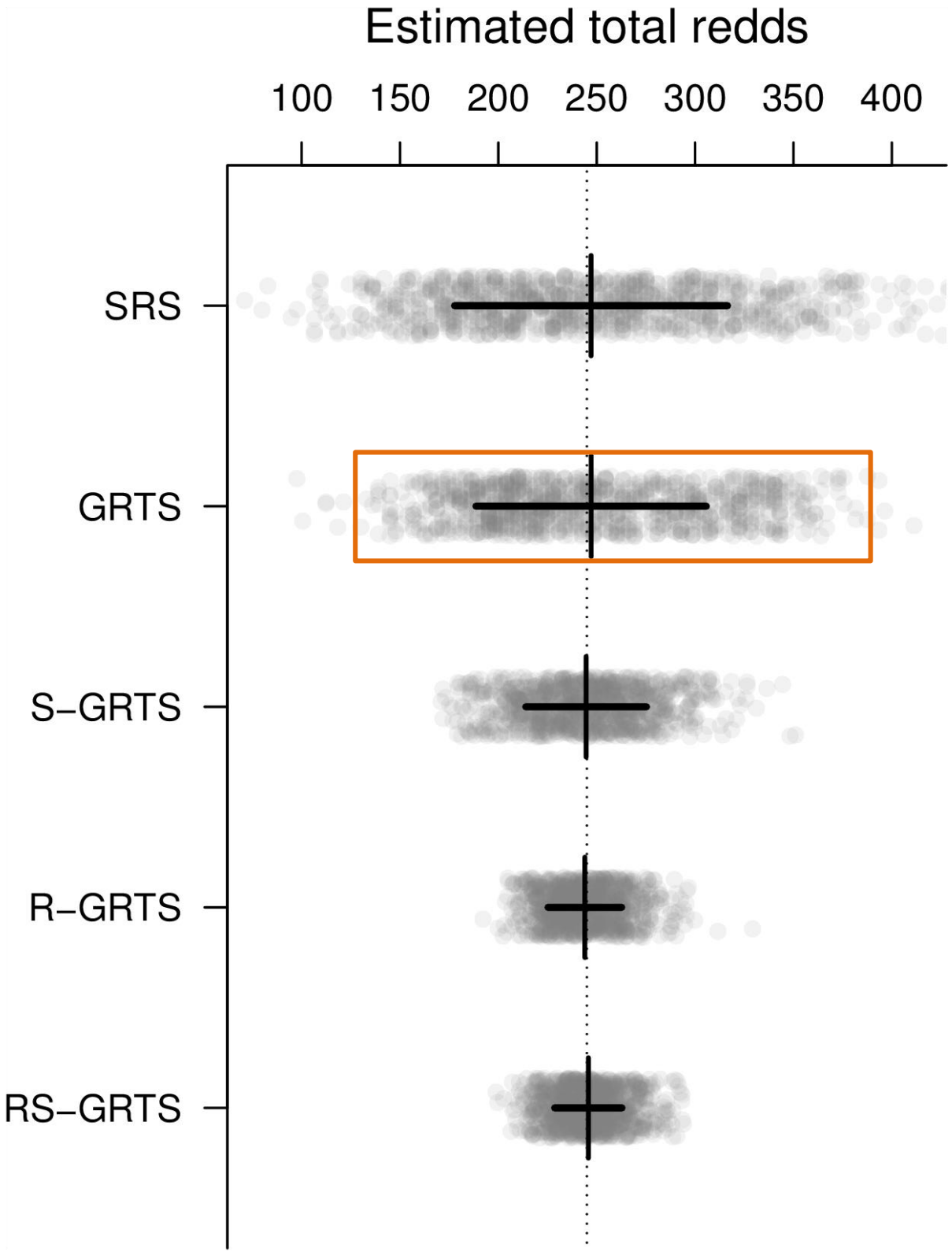


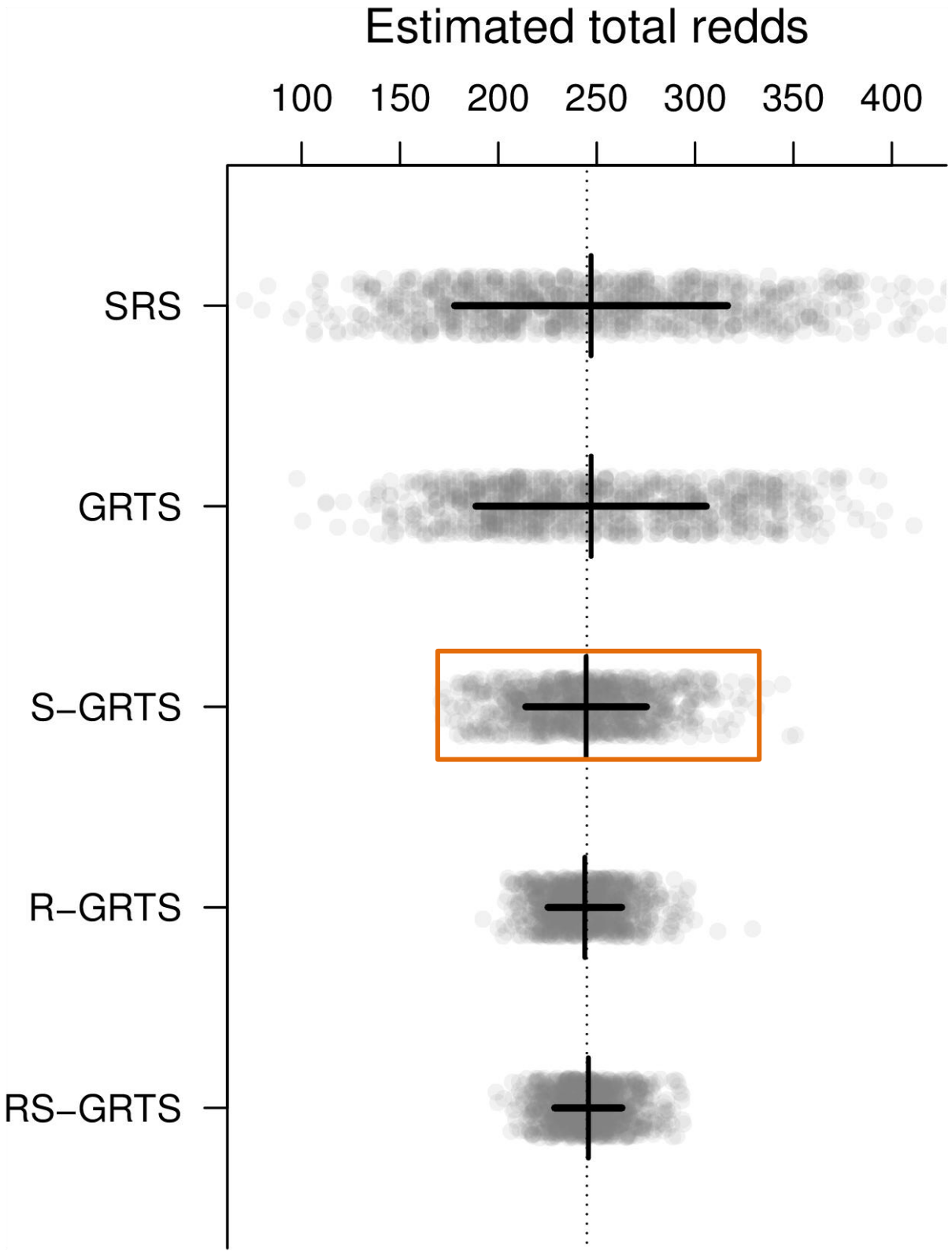
Redd distribution

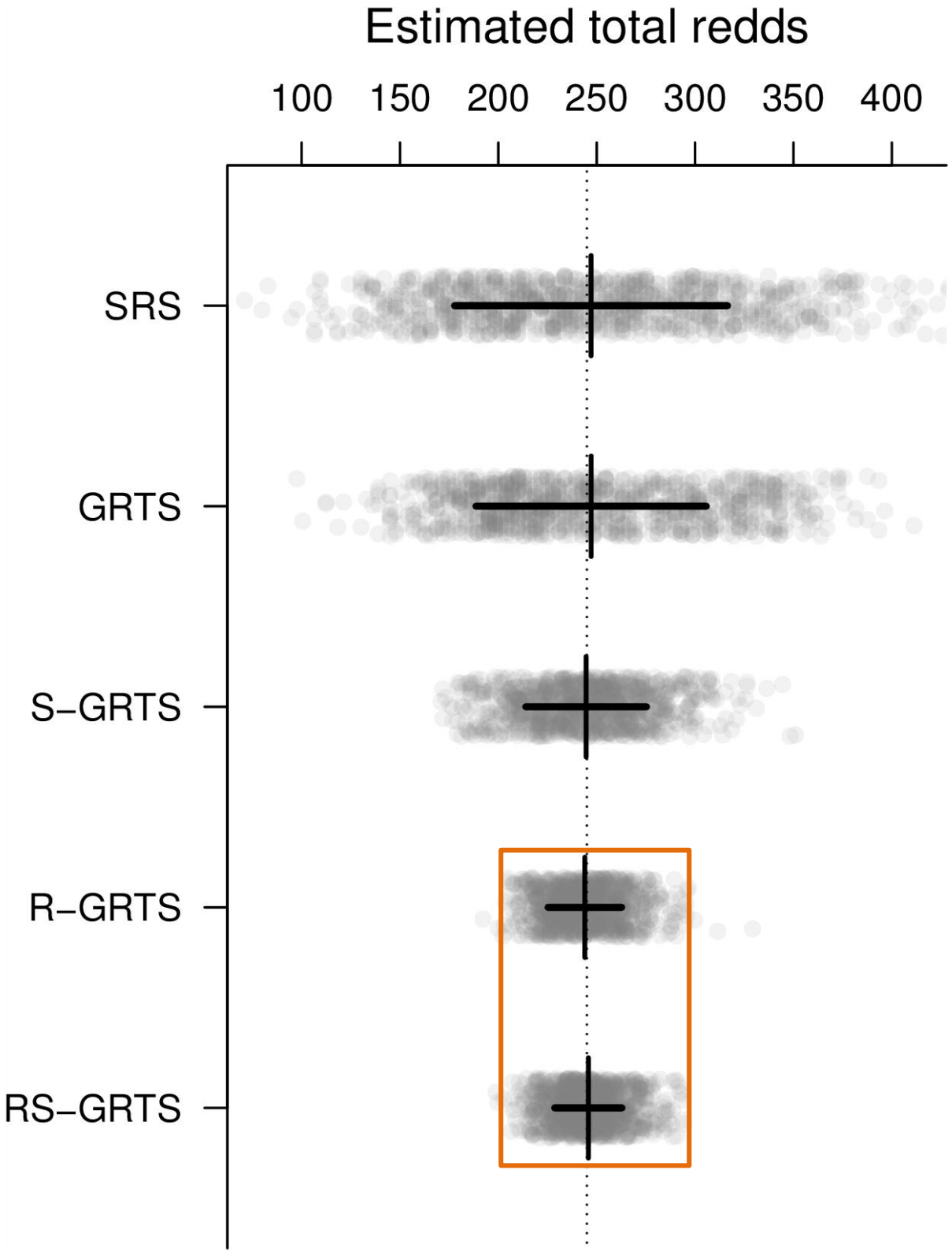
	Mill, Abernathy & Germany Cr	Coweeman River	East Fork Lewis River
Variance / mean	10.23	9.30	7.70
AutoCorr	0.55	0.32	0.03
r	0.90	0.96	0.94
$\sqrt{1-r^2}$	0.40	0.29	0.35

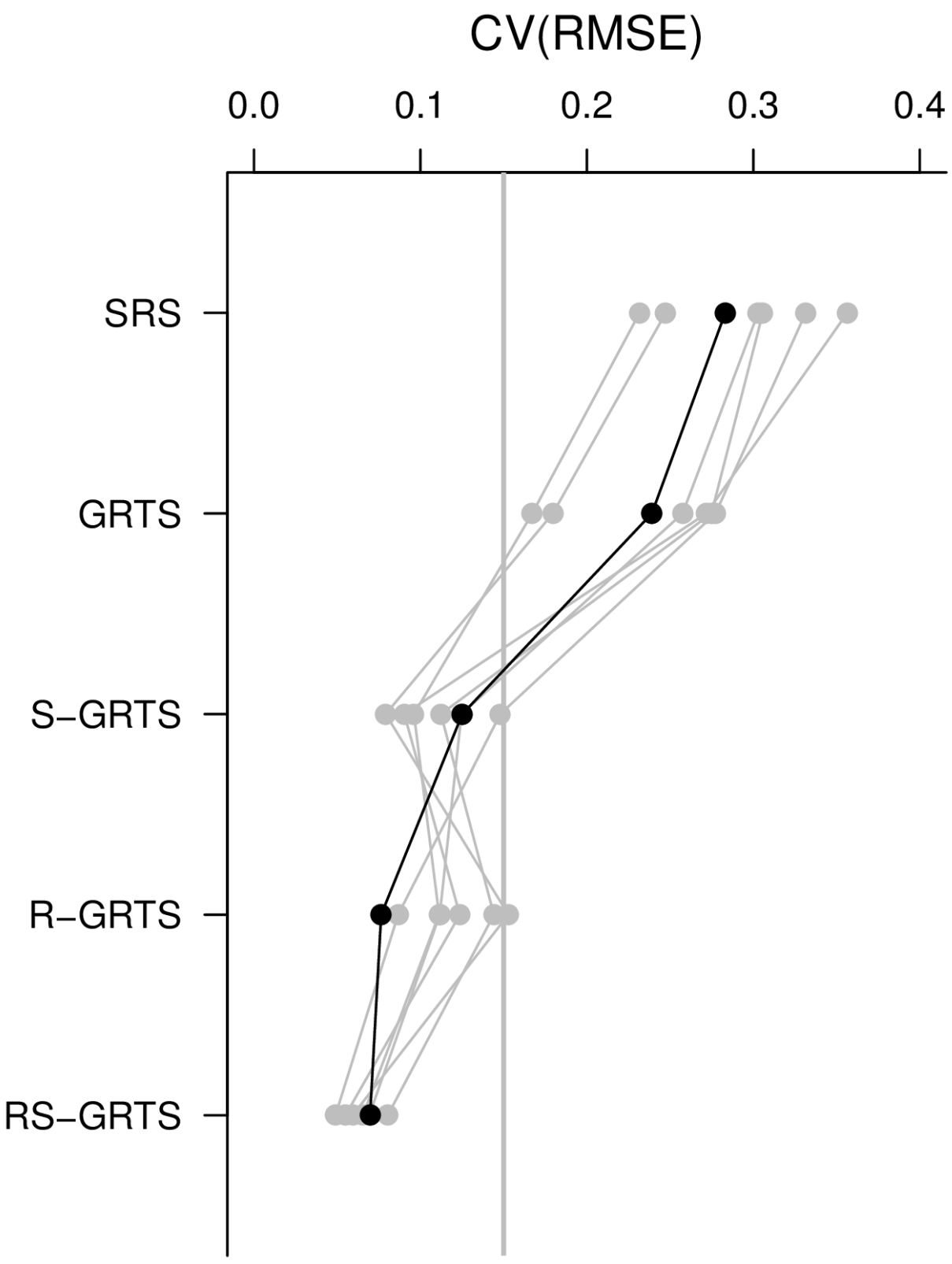

Estimated total redds
100
150
200
250
300
350
400
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS

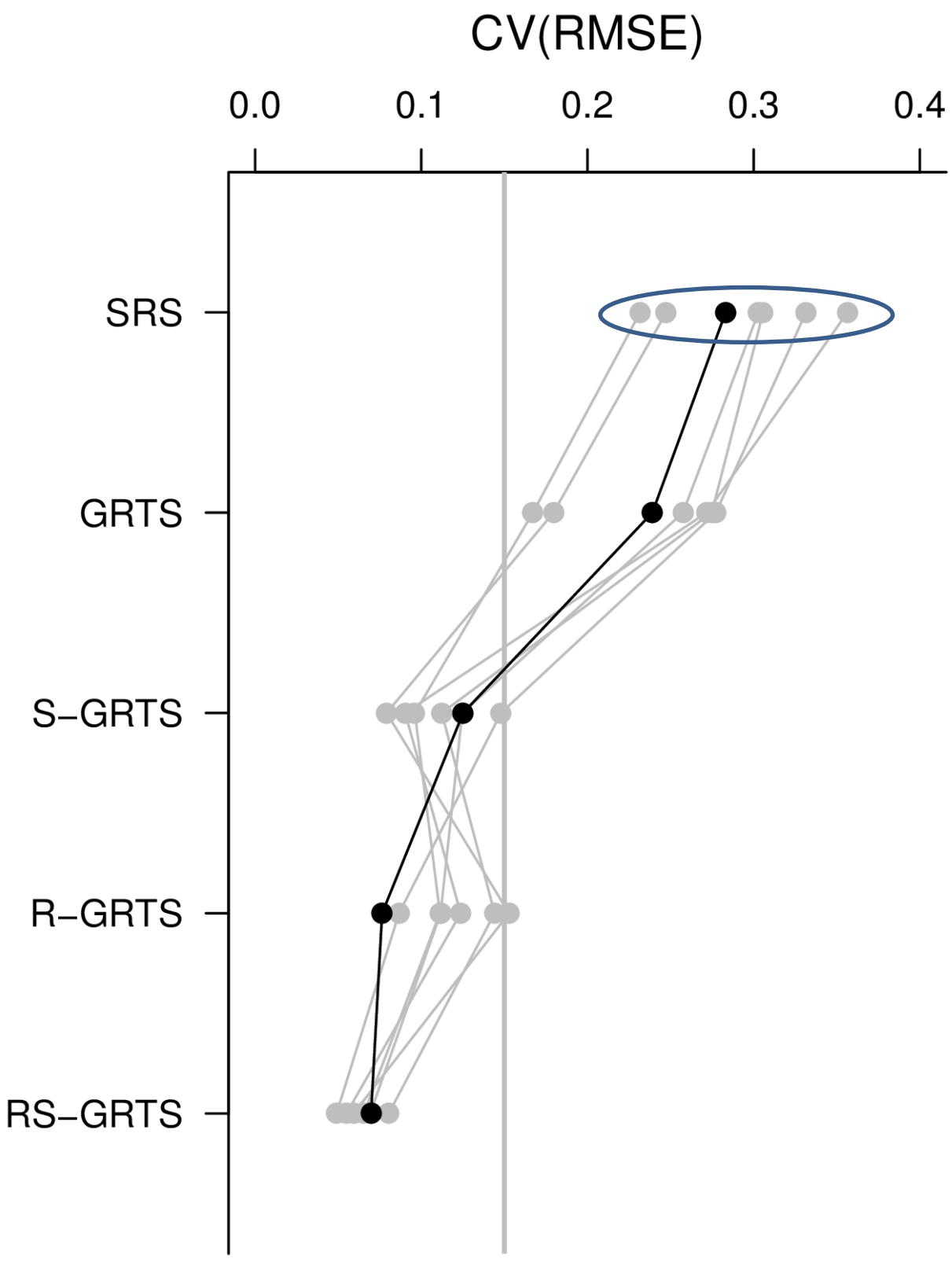

Estimated total redds
100
150
200
250
300
350
400
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS

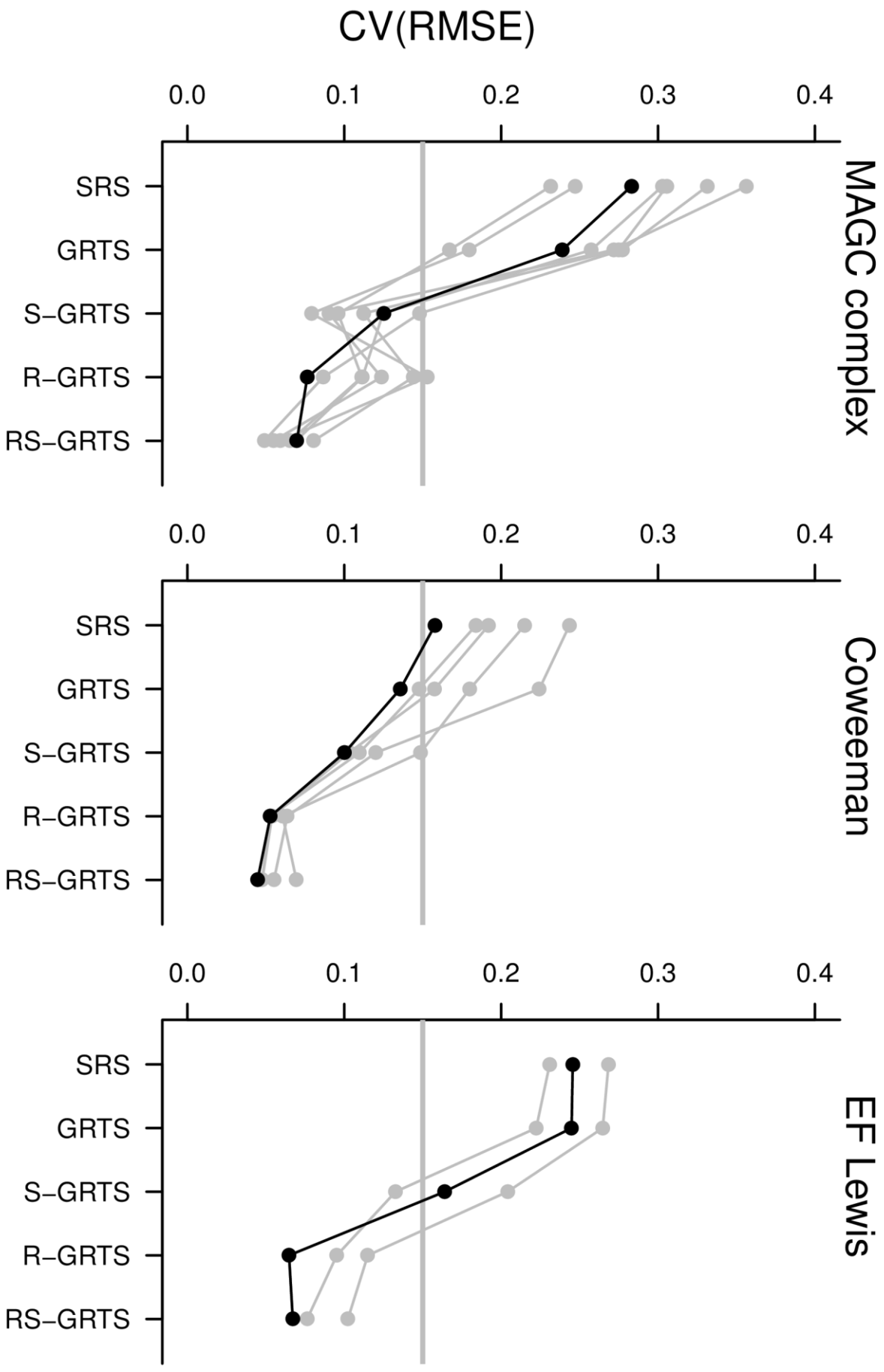

Estimated total redds
100
150
200
250
300
350
400
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS

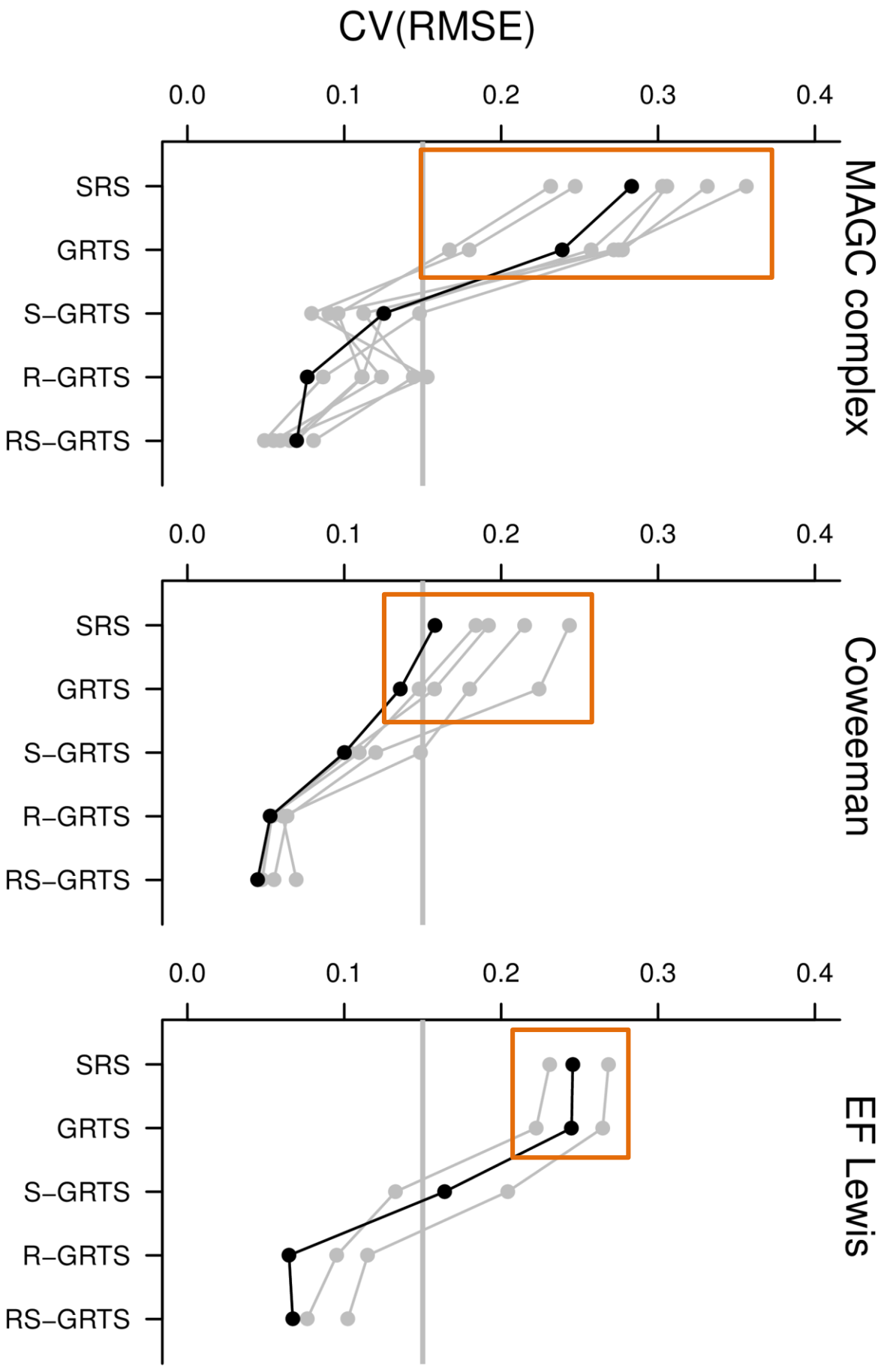

Estimated total redds
100
150
200
250
300
350
400
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS

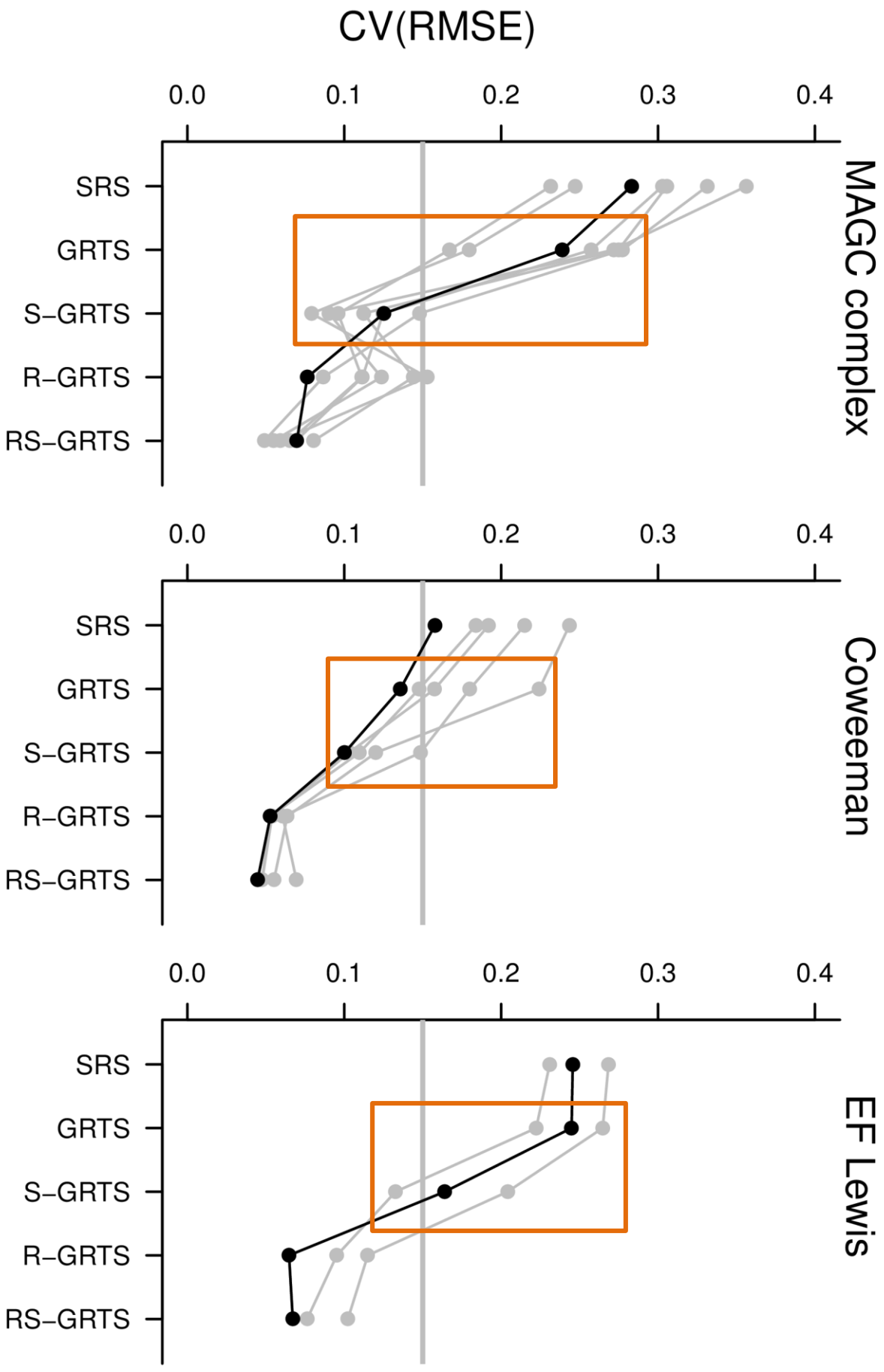

Estimated total redds
100
150
200
250
300
350
400
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS

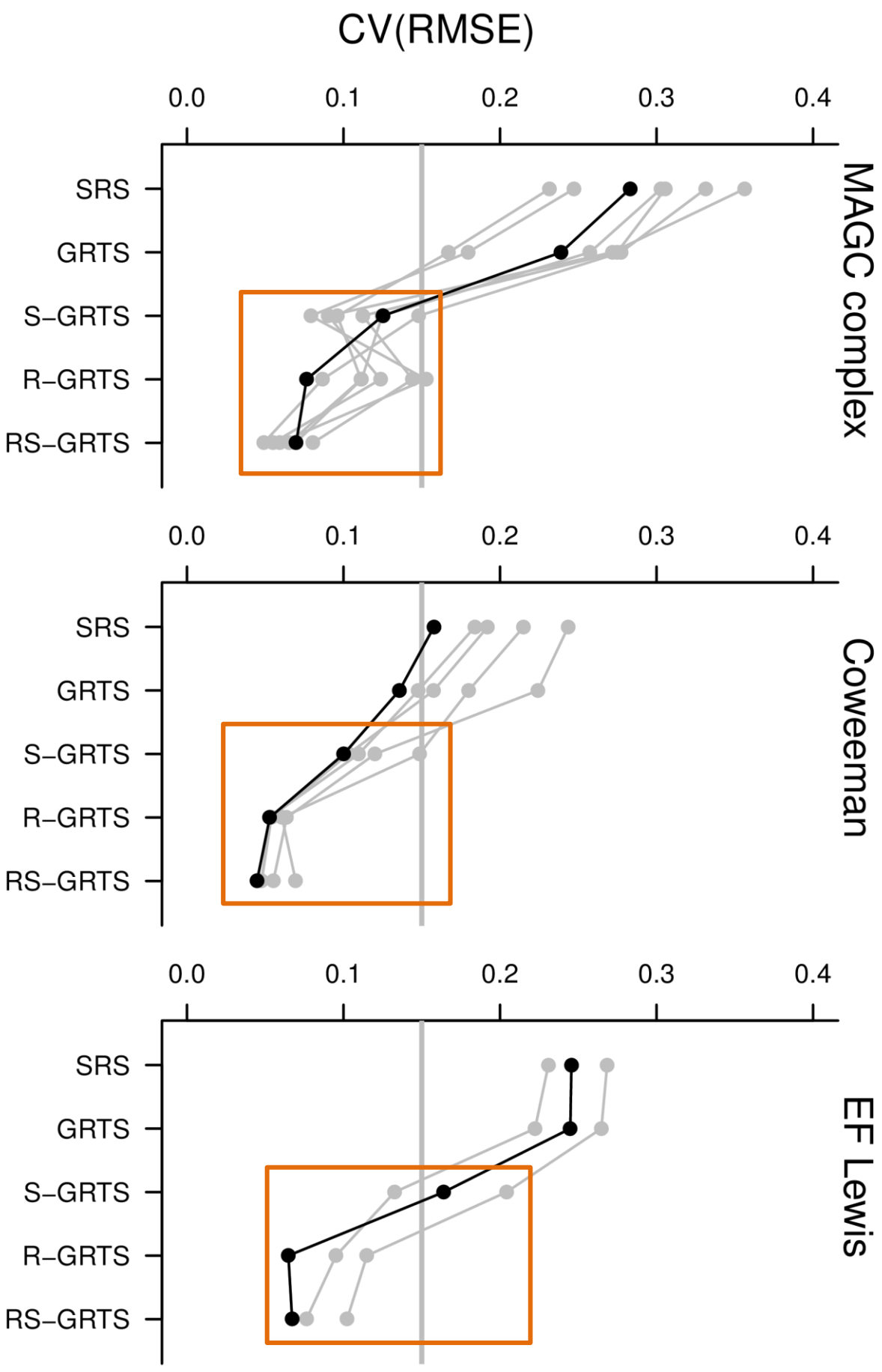

CV(RMSE)
0.0
0.1
0.2
0.3
0.4
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS


CV(RMSE)
0.0
0.1
0.2
0.3
0.4
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS


CV(RMSE)
0.0
0.1
0.2
0.3
0.4
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS
MAGC complex
Coweeman
EF Lewis


CV(RMSE)
0.0
0.1
0.2
0.3
0.4
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS
MAGC complex
Coweeman
EF Lewis


CV(RMSE)
0.0
0.1
0.2
0.3
0.4
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS
MAGC complex
Coweeman
EF Lewis


CV(RMSE)
0.0
0.1
0.2
0.3
0.4
SRS
GRTS
S–GRTS
R–GRTS
RS–GRTS
MAGC complex
Coweeman
EF Lewis

Conclusions

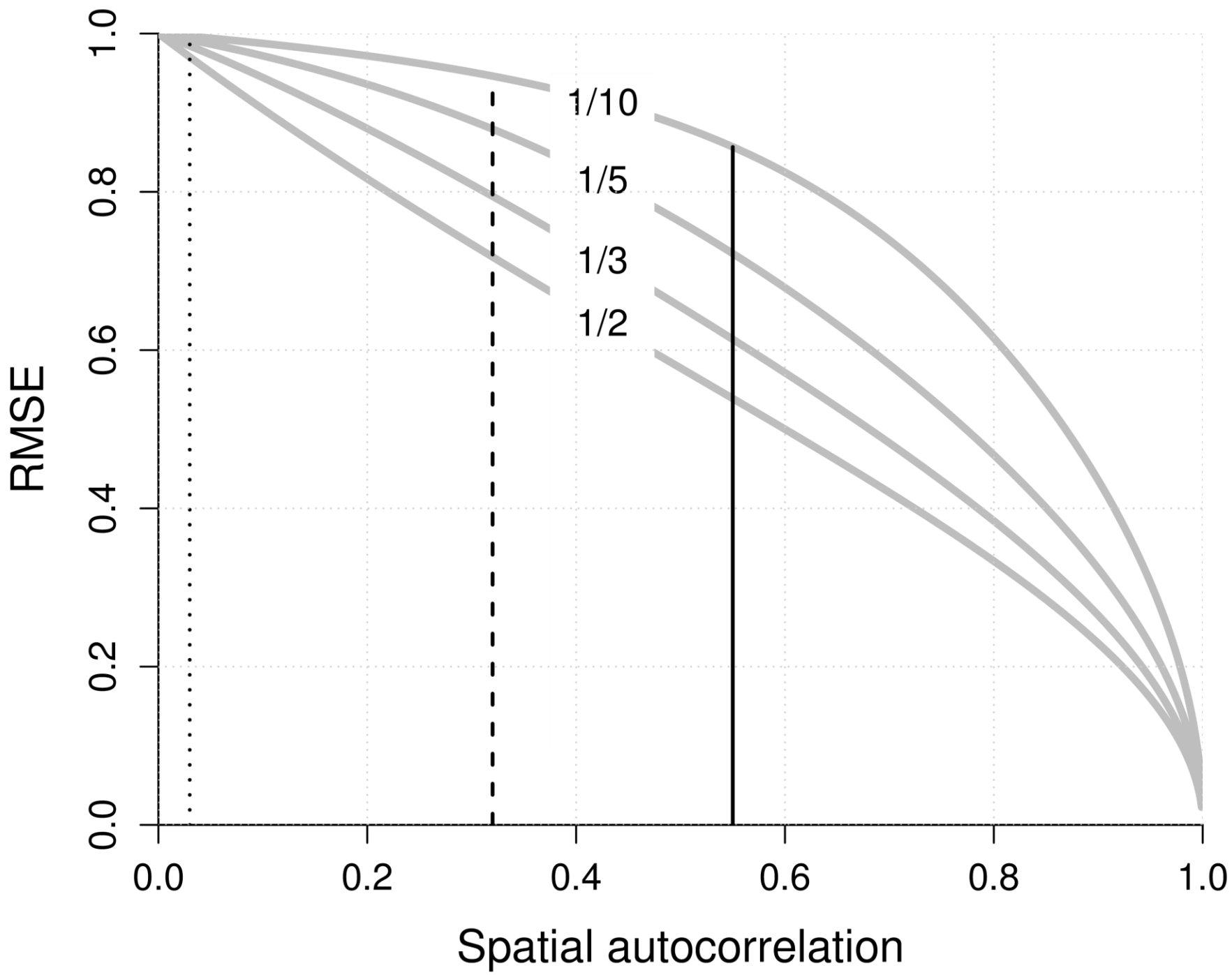
- Redd locations are geographically clumpy
- This produces much more variable estimates (from sample to sample).
- There are effective strategies for reducing this variability (GRTS, stratified, regression).

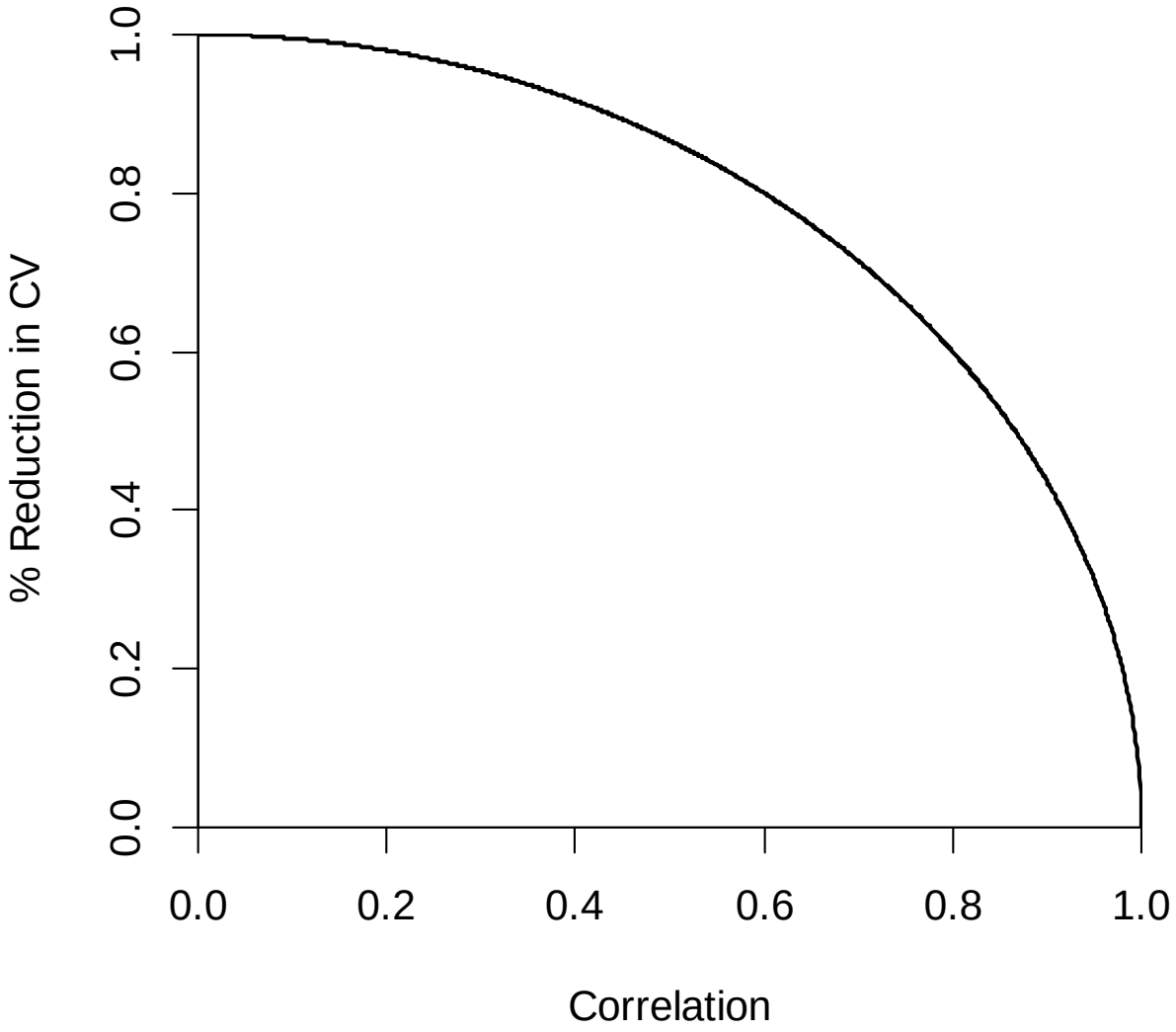
Implications

- Great data set that is likely representative of many other systems.
- Spatially balanced GRTS is a no-brainer.
- Stratified design effectiveness depends on the strata.
- Regression estimator depends on the auxiliary variable. Peak count census works well.

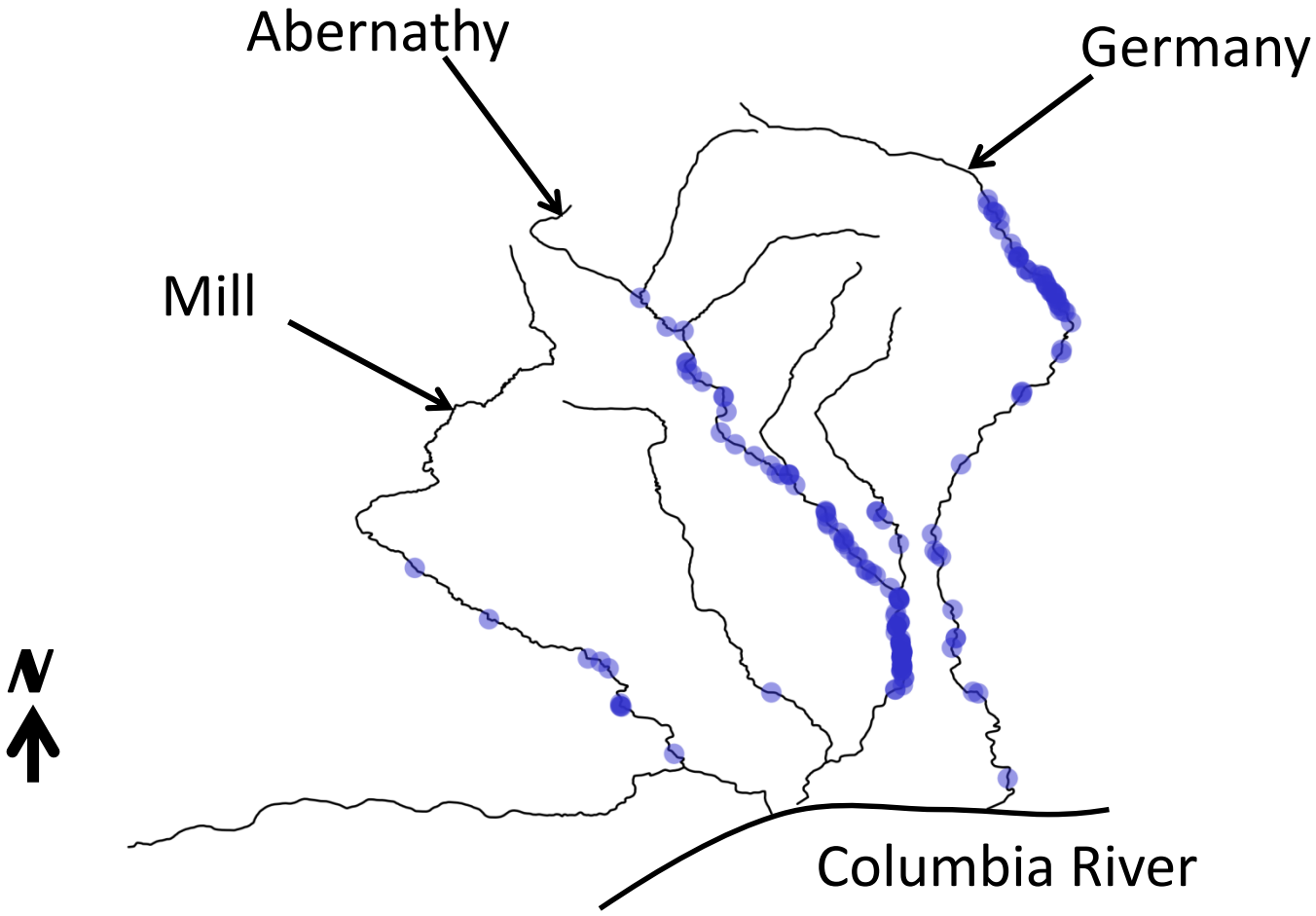
Further work

- Panel designs, etc…
- Other aux. vars. for regression estimators
- Redds to spawners expansion.


RMSE
0.0
0.2
0.4
0.6
0.8
1.0
Spatial autocorrelation
1/10
1/5
1/3
1/2

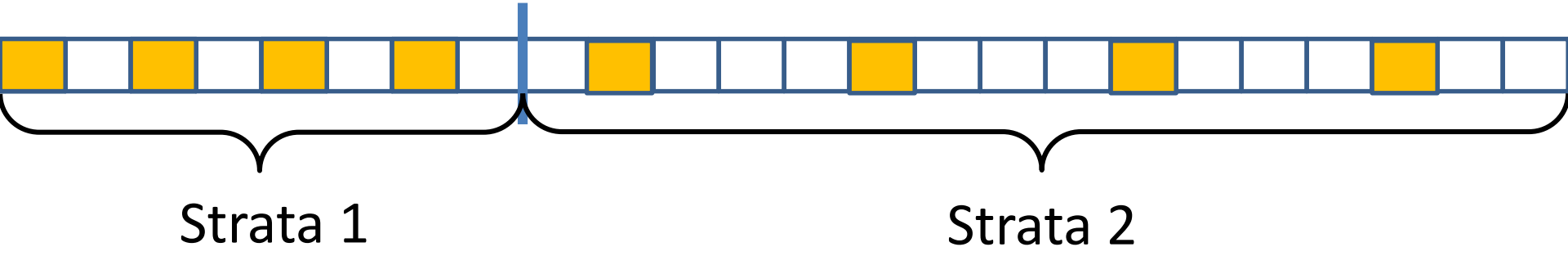

% Reduction in CV
0.0
0.2
0.4
0.6
0.8
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Correlation

Steelhead redd distribution (IMW complex)



Sampling approaches

- SRS
- GRTS (Generalized Random Tesselation Stratified)
- Stratified GRTS



Sampling approaches

- SRS
- GRTS (Generalized Random Tesselation Stratified)
- Stratified GRTS
- Peak count census + regression estimator

Describe spatial distribution