Hatchery Effectiveness Review

AN EXPLORATORY ANALYSIS INTO SPATIAL PATTERNS OF CORRELATION RELATIVE TO ENHANCEMENT

APPENDICES

Photo credit: Eiko Jones

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PACIFIC SALMON FOUNDATION

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2023-03-07

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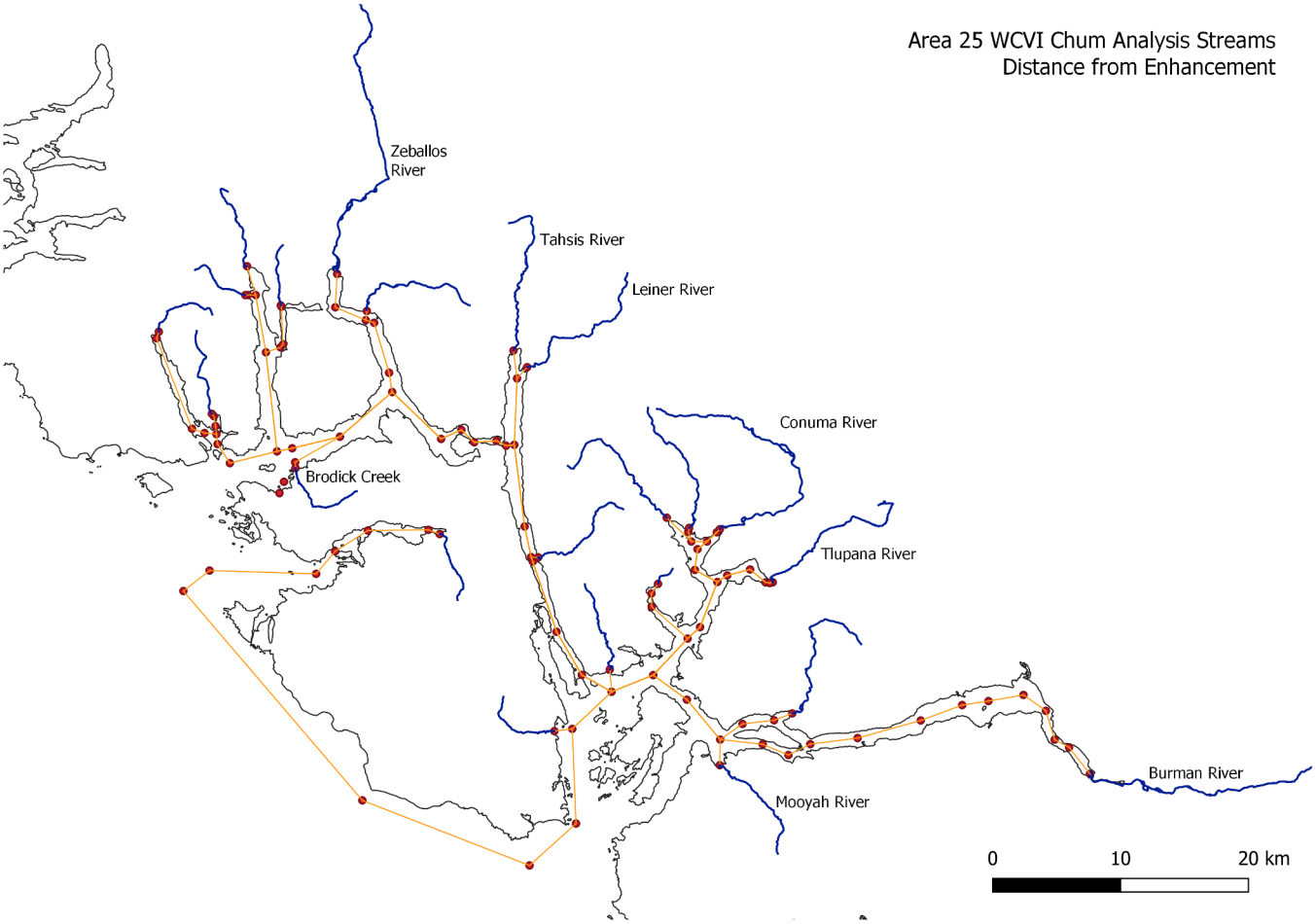
Area 25 Chum streams



Summary statistics

Bubbleplot of escapement by enhancement rank

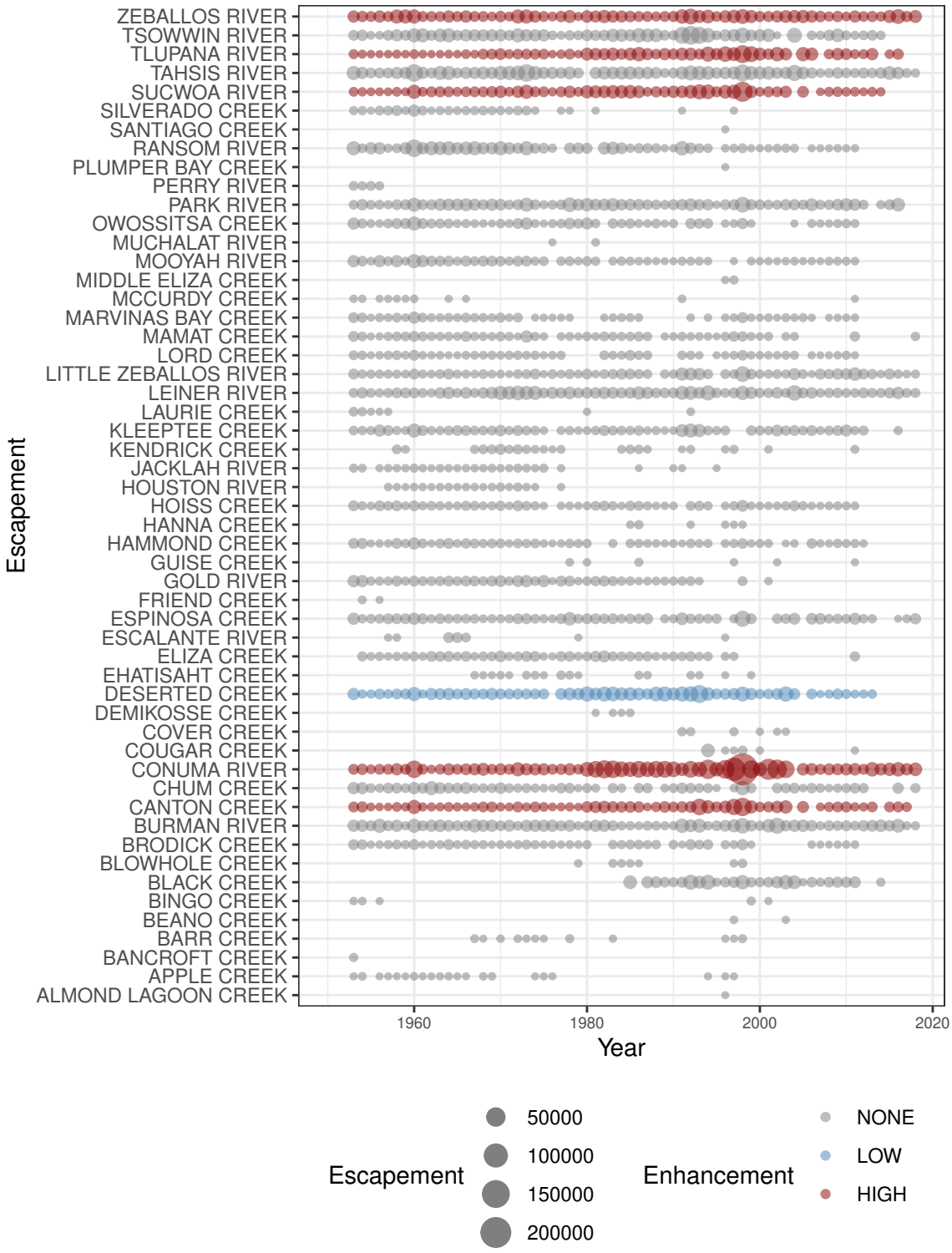


Figure 1: Escapement to all Area 8 chum streams in the PSE database.

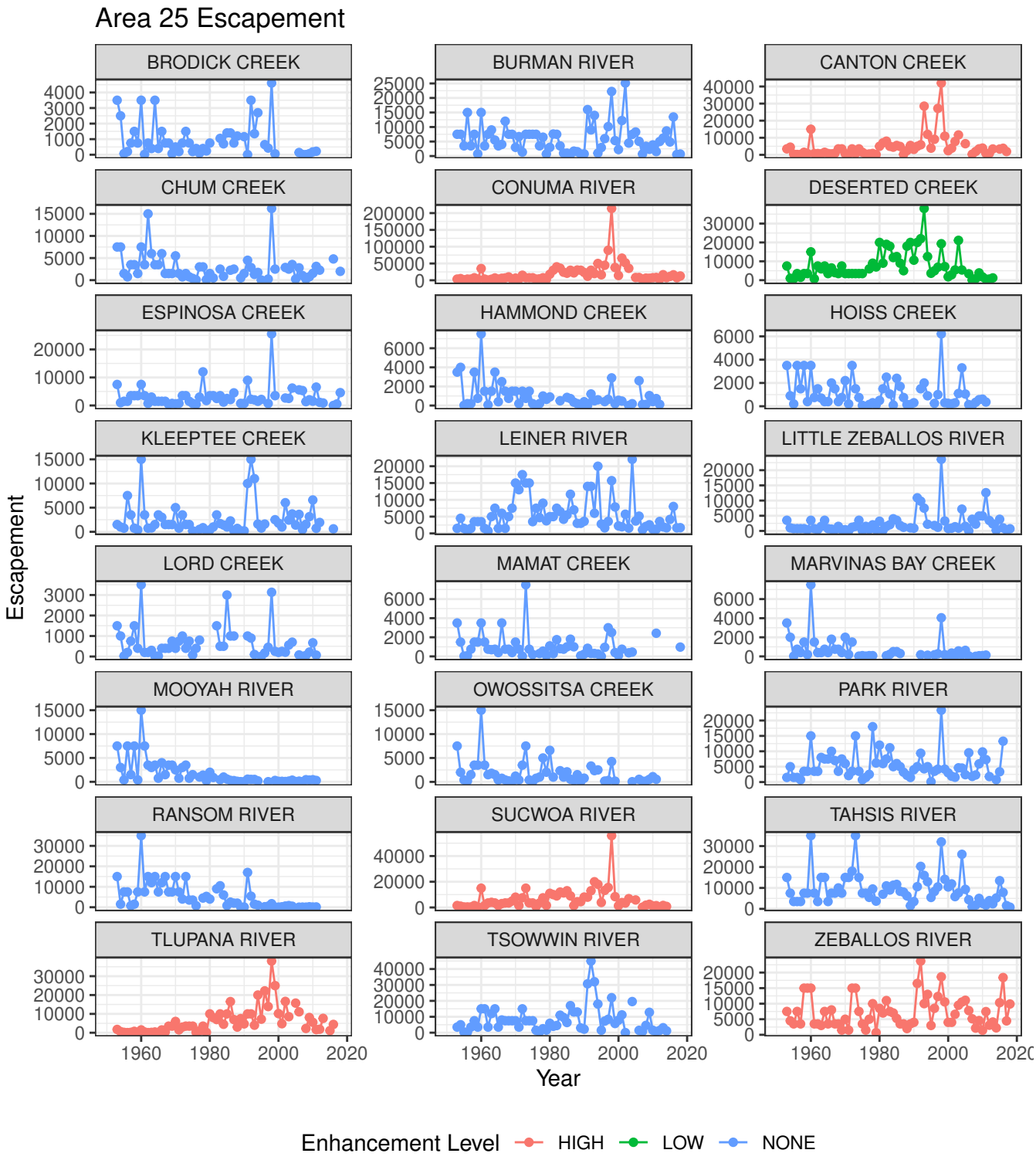


Figure 2: Escapement to all streams for Area 25 chum. Colour shows the stream enhancement level from the PSE database.

Table 1: Distance from Conuma River (major enhancement location for chum systems included in analysis)

Stream	Dist. from enhancement
BRODICK CREEK	61655
BURMAN RIVER	54299
CANTON CREEK	3718
CHUM CREEK	75361
CONUMA RIVER	0
DESERTED CREEK	16768
ESPINOSA CREEK	76904
HAMMOND CREEK	78677
HOISS CREEK	20255
KLEEPTEE CREEK	27400
LEINER RIVER	46500
LITTLE ZEBALLOS RIVER	58802
LORD CREEK	43611
MAMAT CREEK	73524
MARVINAS BAY CREEK	24133
MOOYAH RIVER	23265
OWOSSITSA CREEK	63067
PARK RIVER	70239
RANSOM RIVER	92551
SUCWOA RIVER	5286
TAHSIS RIVER	46465
TLUPANA RIVER	10890
TSOWWIN RIVER	30761
ZEBALLOS RIVER	63279

Hatchery releases to area

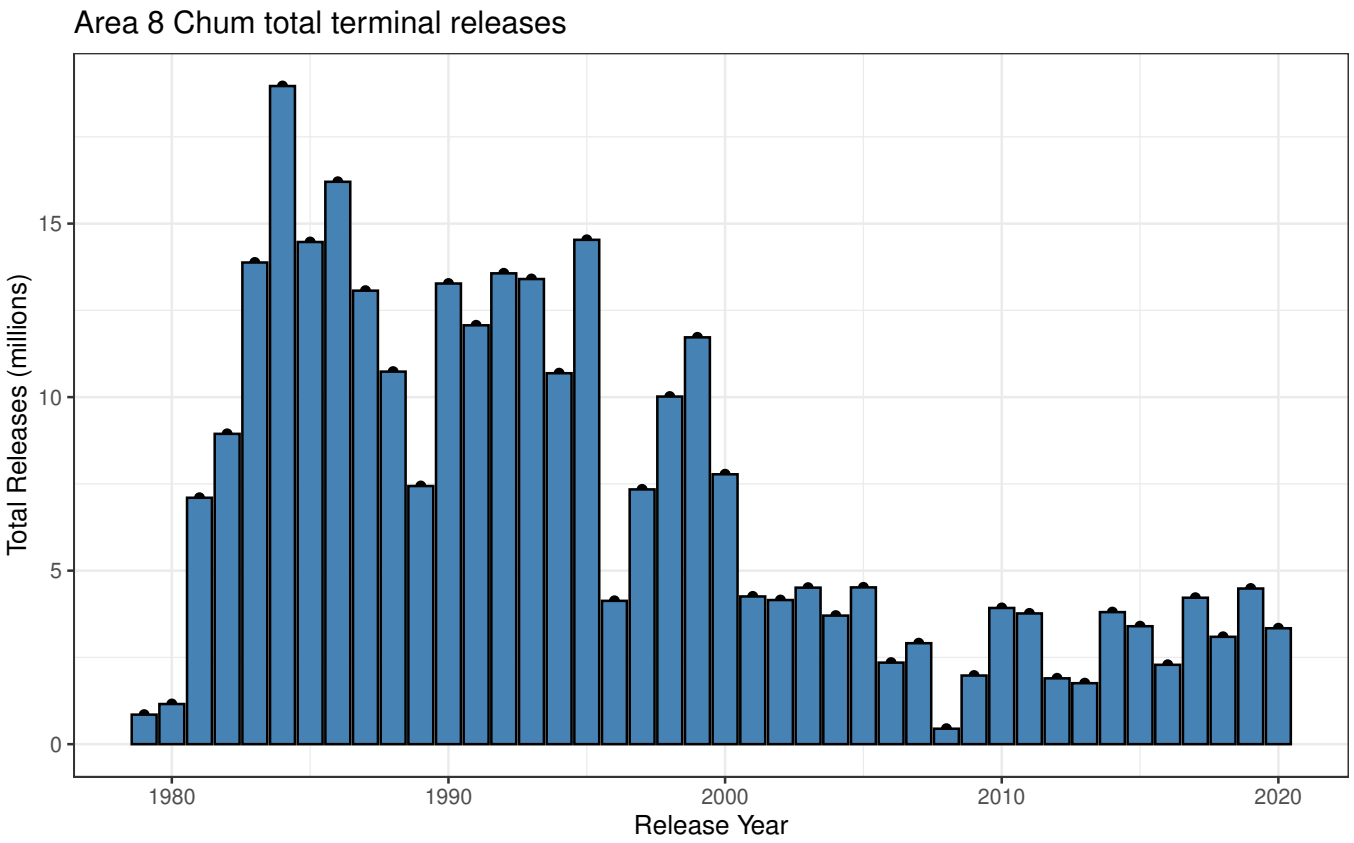


Figure 3: Total hatchery chum salmon releases in Area 25

Releases by system

Figure 4: Chum releases to Area 25 by release site and release stage.

Metrics

Escapement, logged escapement, Z-scores, Pavg, and moving average

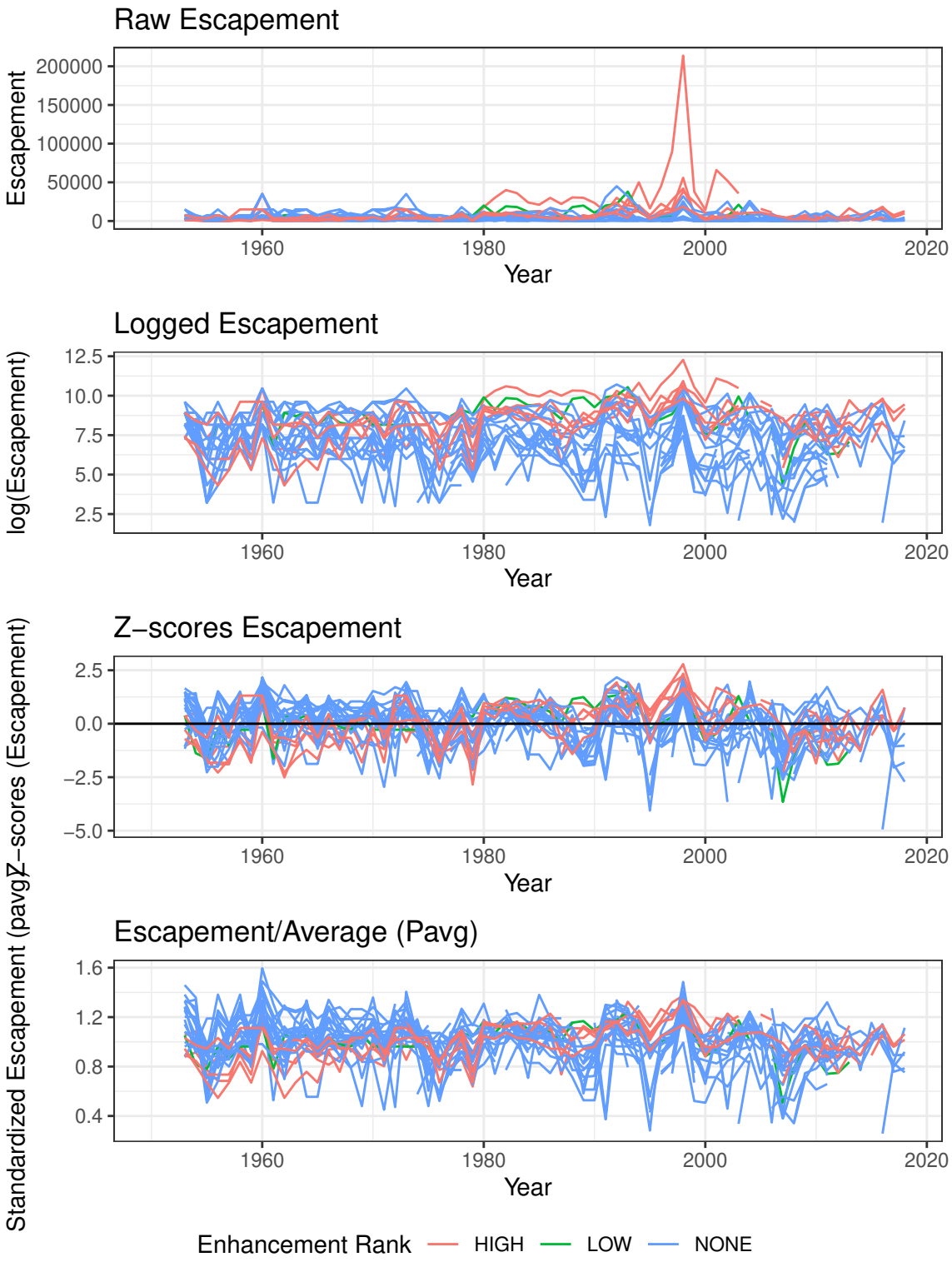


Figure 5: Various plots for escapement and transformations.

Moving average and LOESSS fits

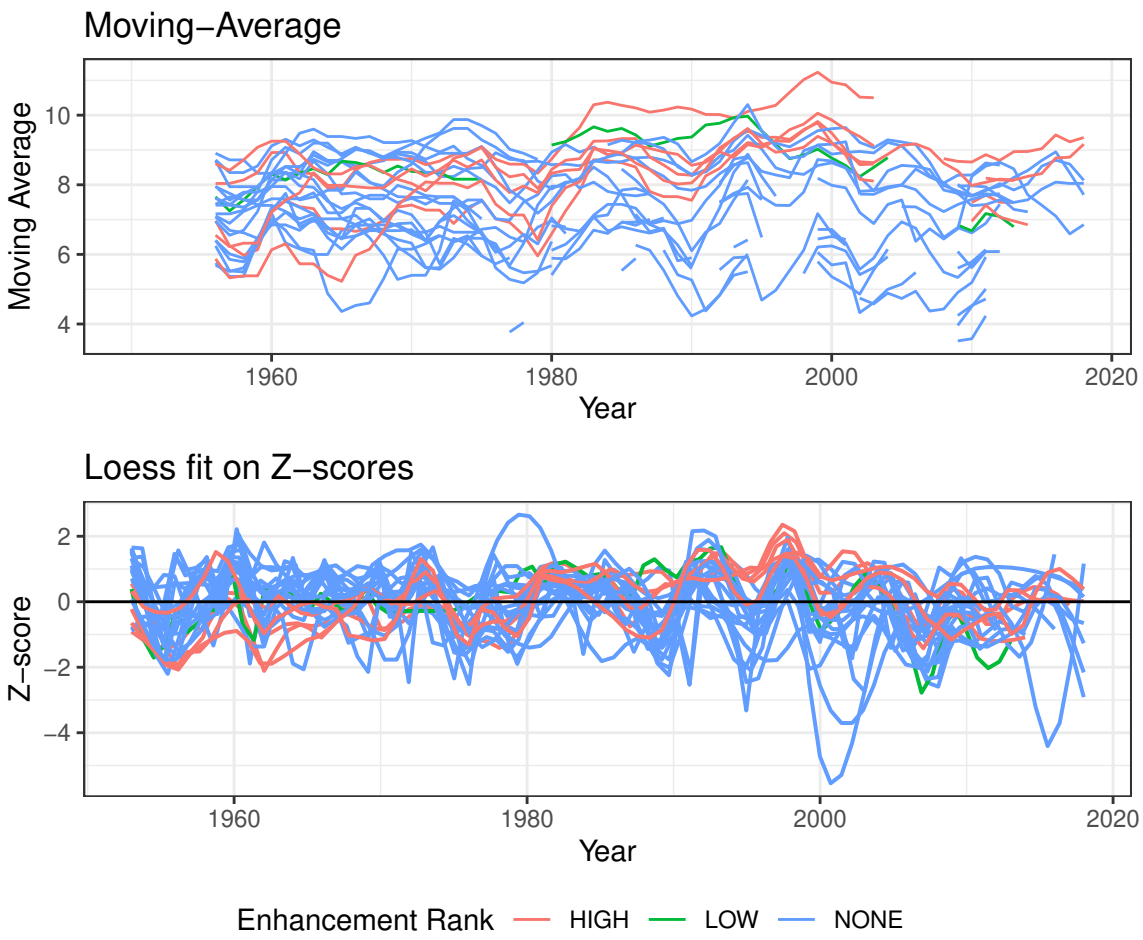


Figure 6: Moving average and LOESS fits on logged escapement by enhancement ranking.

Means trends by enhancement rank

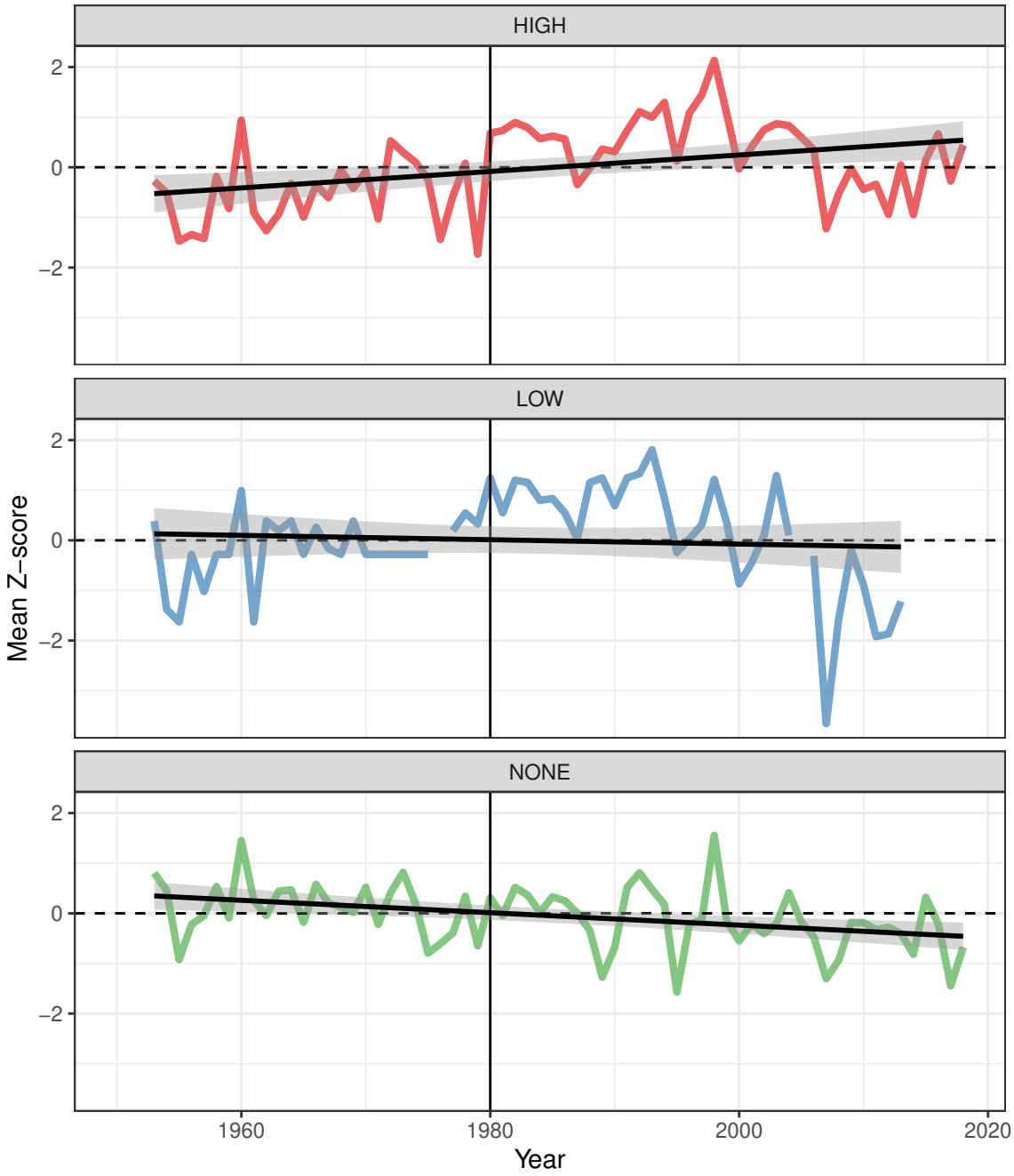


Figure 7: Area 25 chum: Mean Z-score for analysis streams by enhancement rank. Linear regression over all years with SE are shown.

Recruits per spawner by system

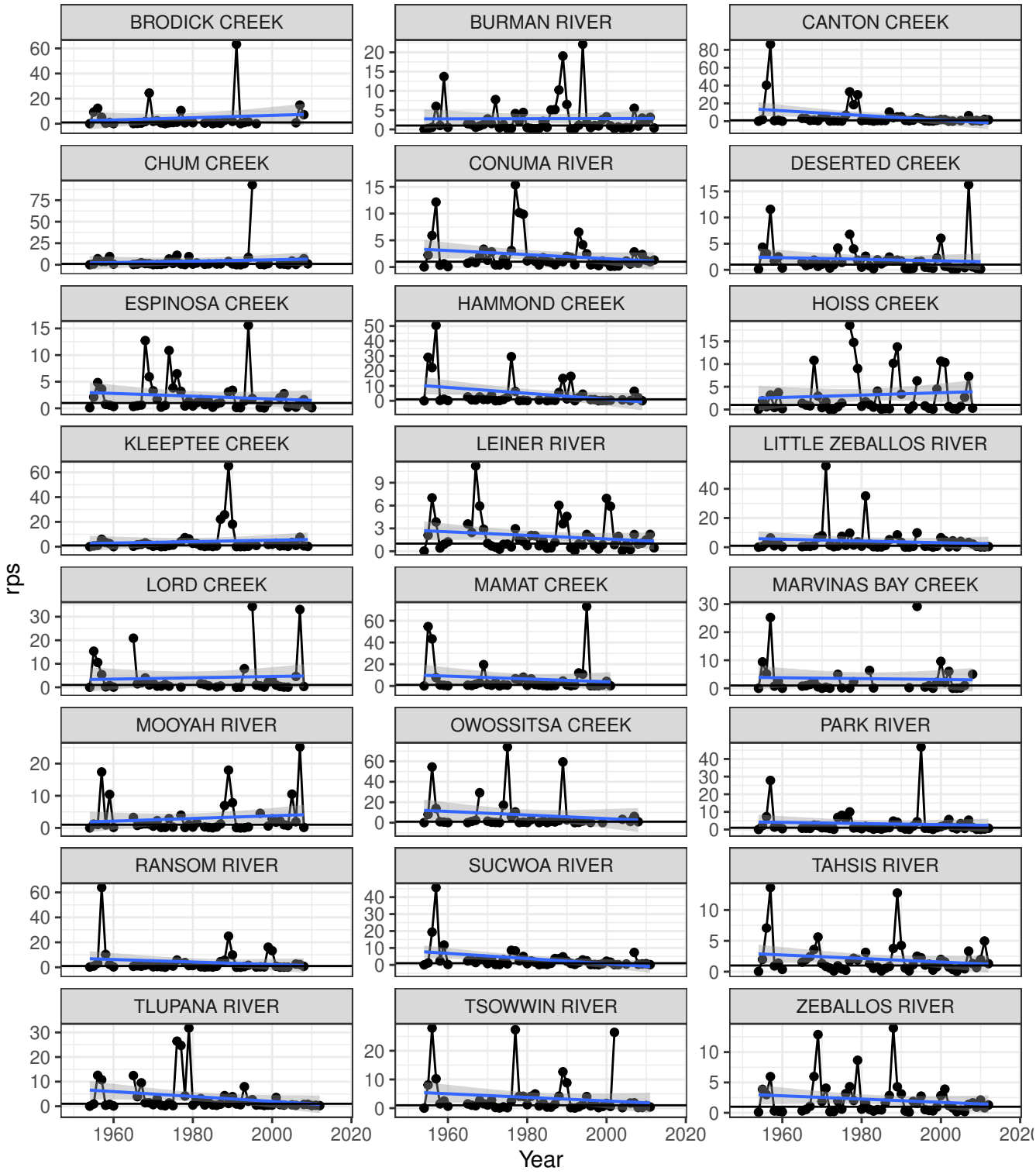


Figure 8: Area 25 chum: recruits per spawner by system.

Log recruits per spawner by system by period

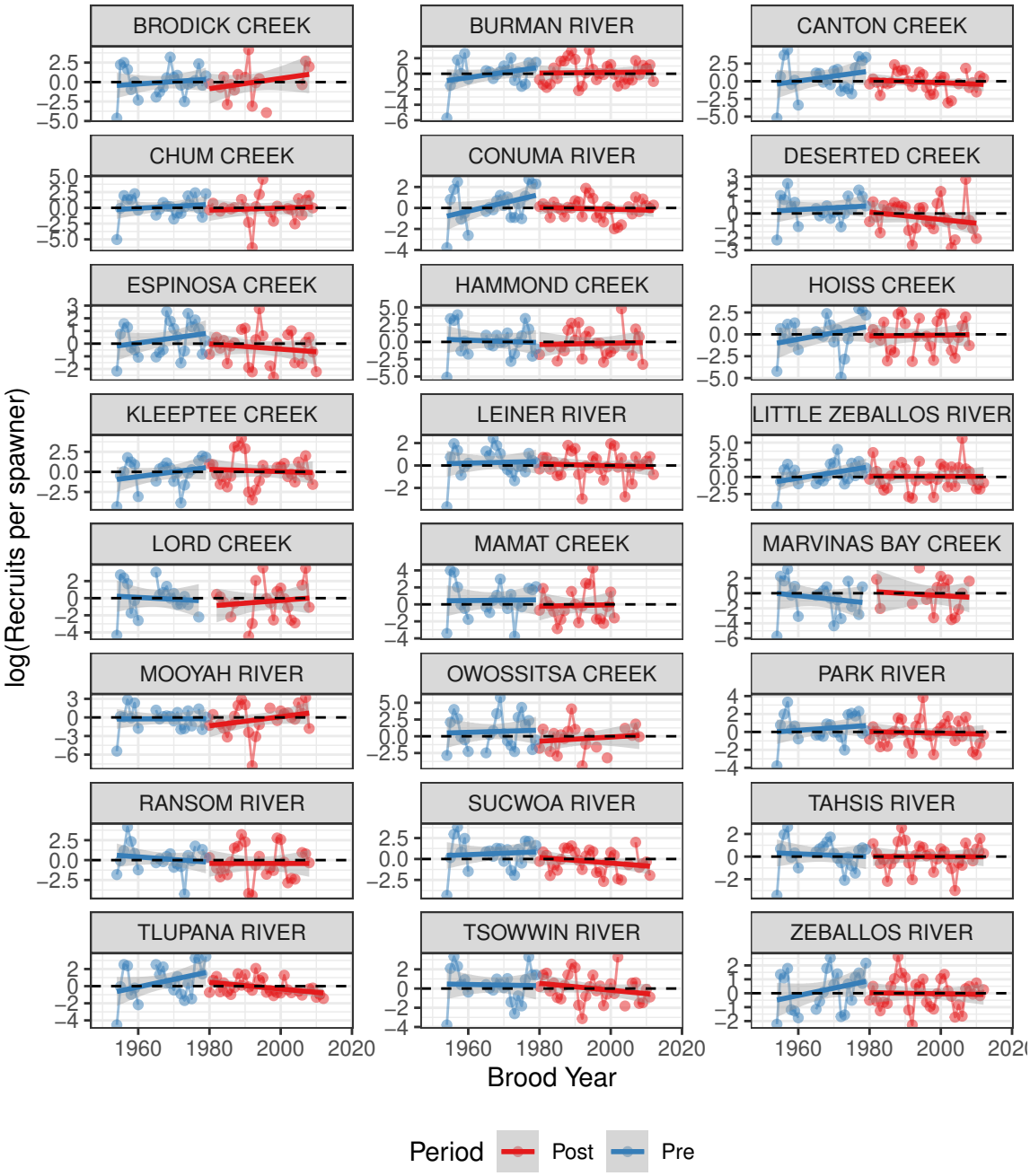


Figure 9: Area 25 chum: log recruits per spawner by system fitted with linear regression for the periods pre- and post-enhancement.

Log RPS comparison before and after enhancement

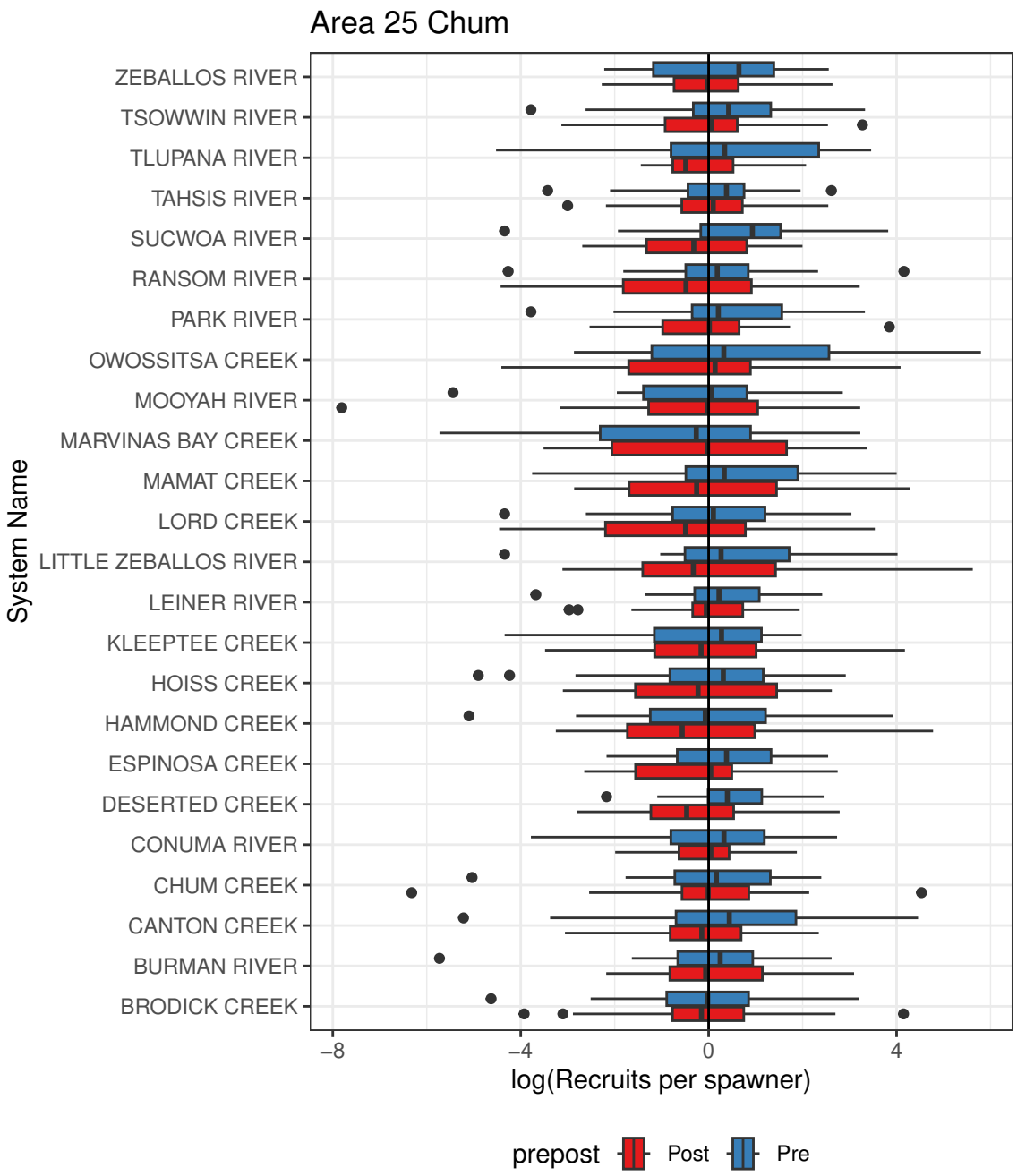


Figure 10: Area 25 chum: Boxplots of log recruits per spawner by system.

Bubbleplots of metric by inlet

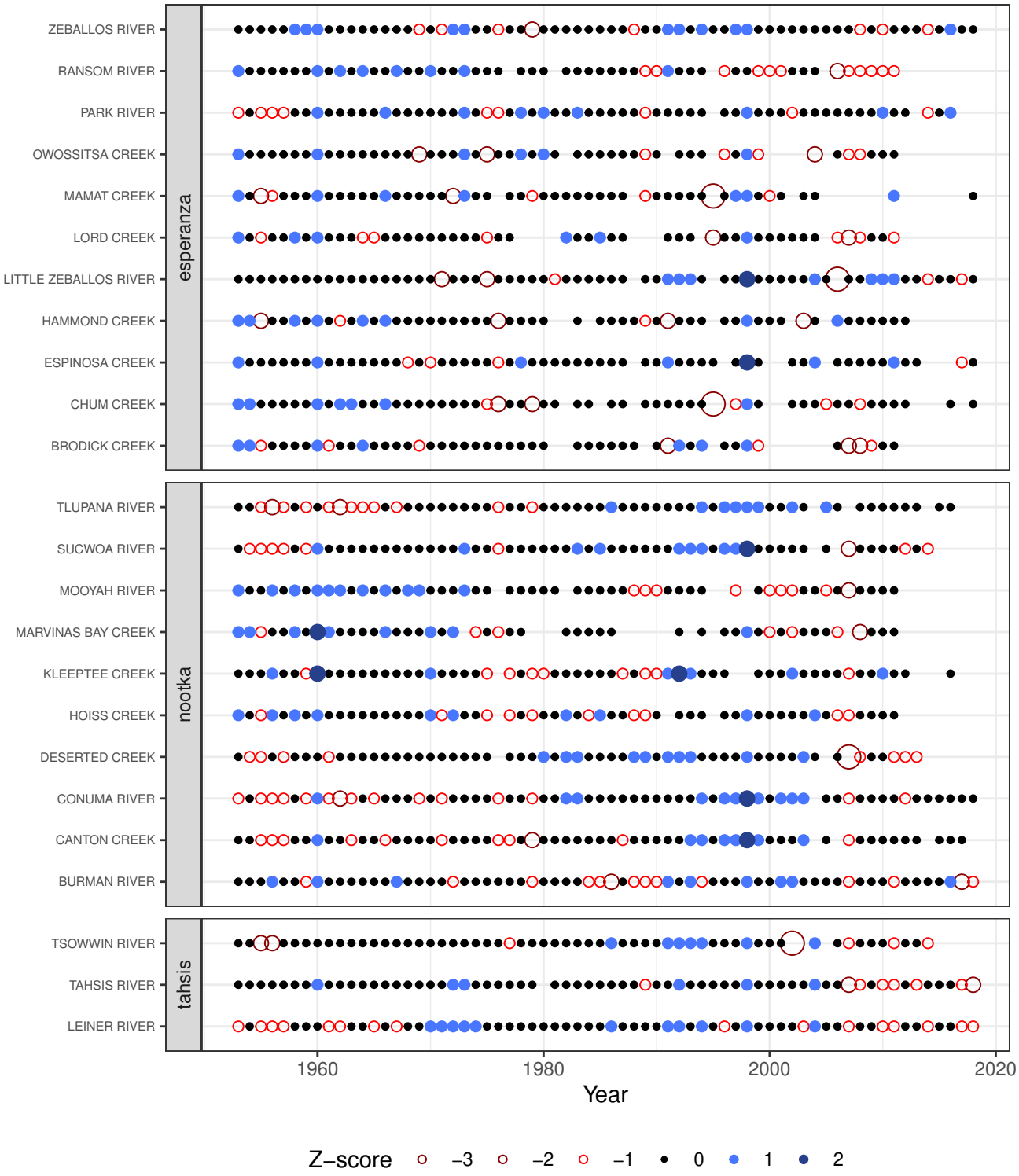


Figure 11: Z-scores of log escapement for each system grouped by inlet. Solid blue points indicate positive values and open red circles indicate negative values. The size of the point indicates the magnitude of the metric.

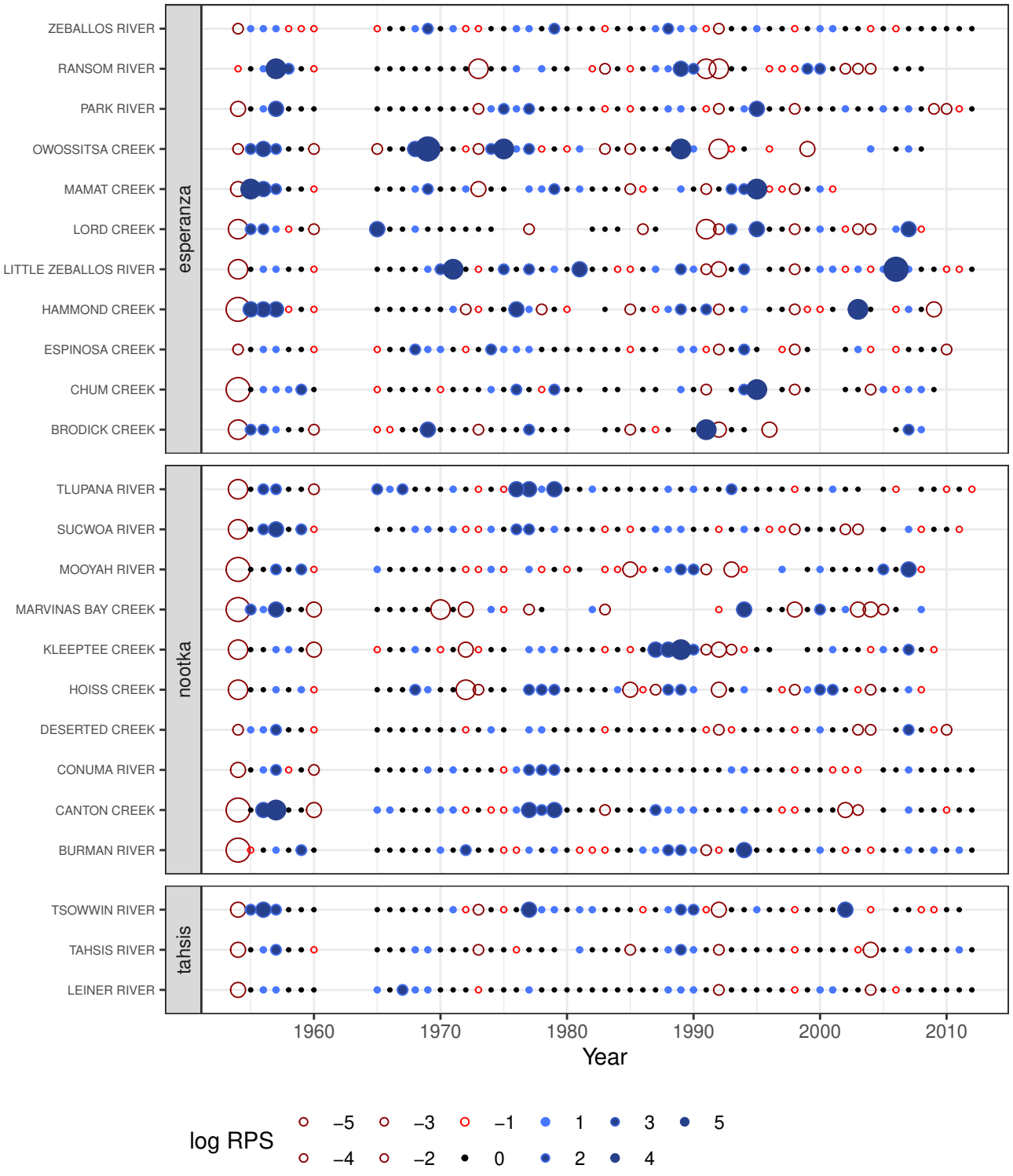


Figure 12: Log(recruits per spawner) for each system grouped by inlet. Solid blue points indicate positive values and open red circles indicate negative values. The size of the point indicates the magnitude of the metric.

Correlation analyses and Dendrograms

Cross correlation plots

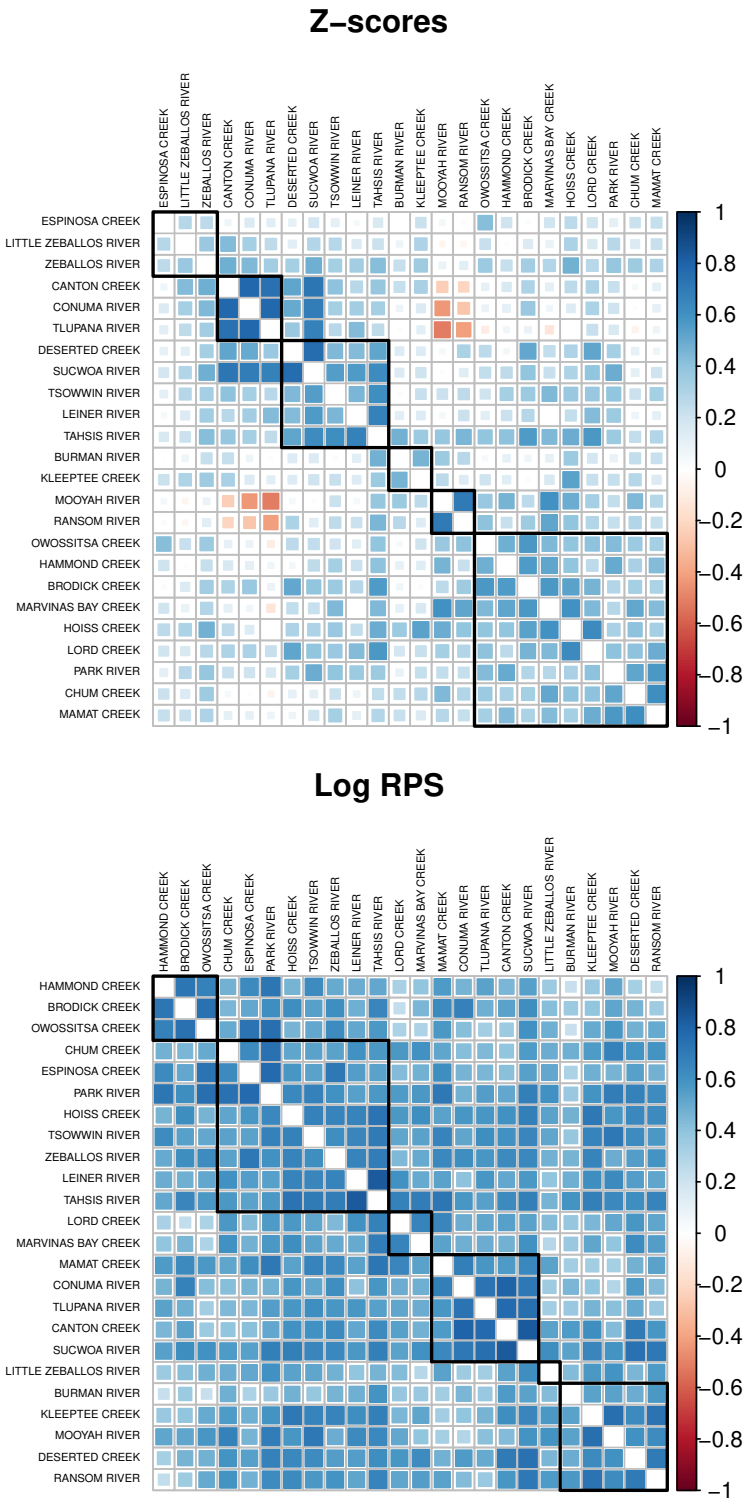


Figure 13: Cross correlation plots to compare metrics.

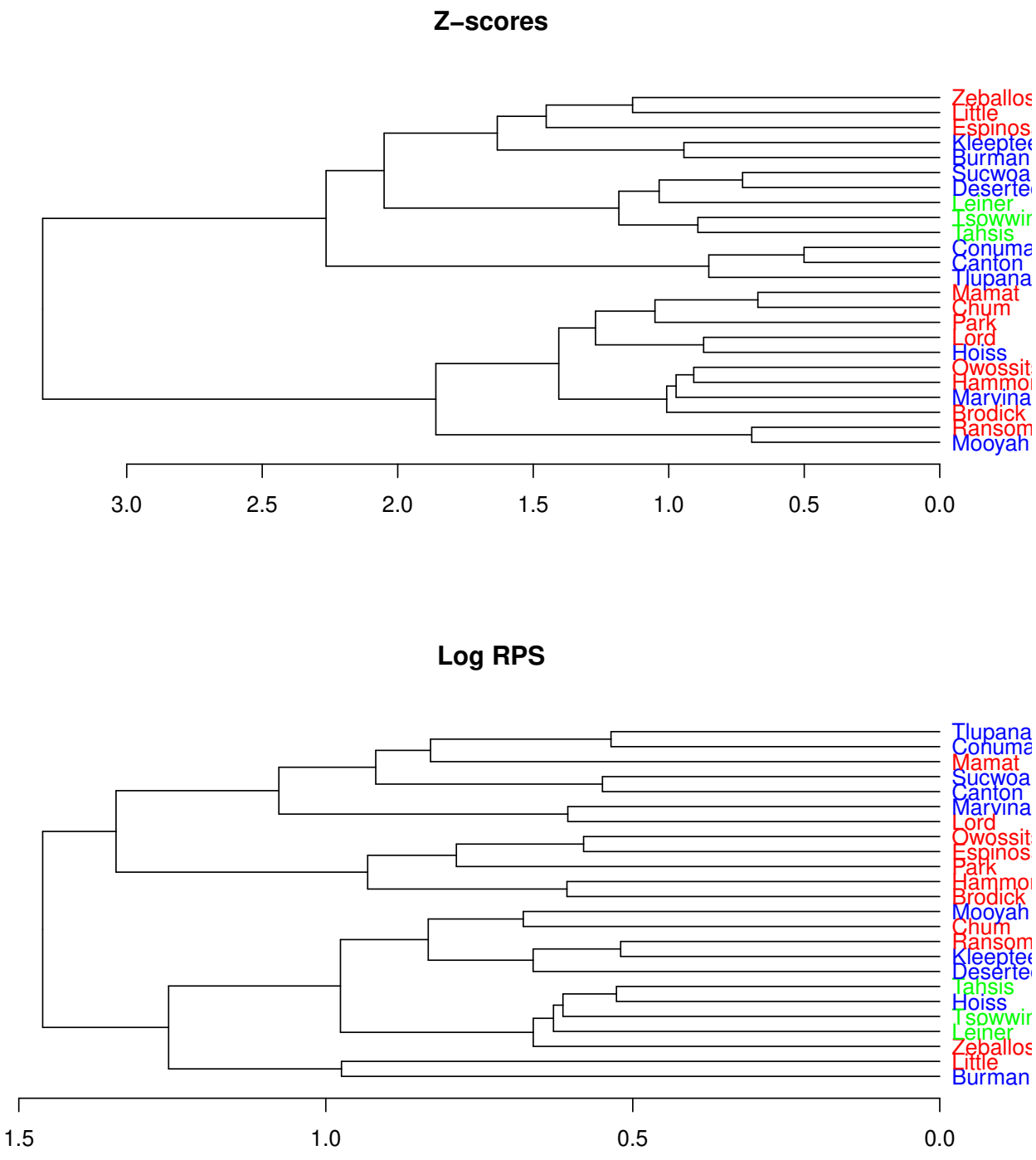


Figure 14: Dendrograms by metric. Red labels are from Esperanza inlet, blue are from Nootka inlet, and green are from Tahsis inlet.

Tanglegrams comparing effect of metric choice on cluster analysis

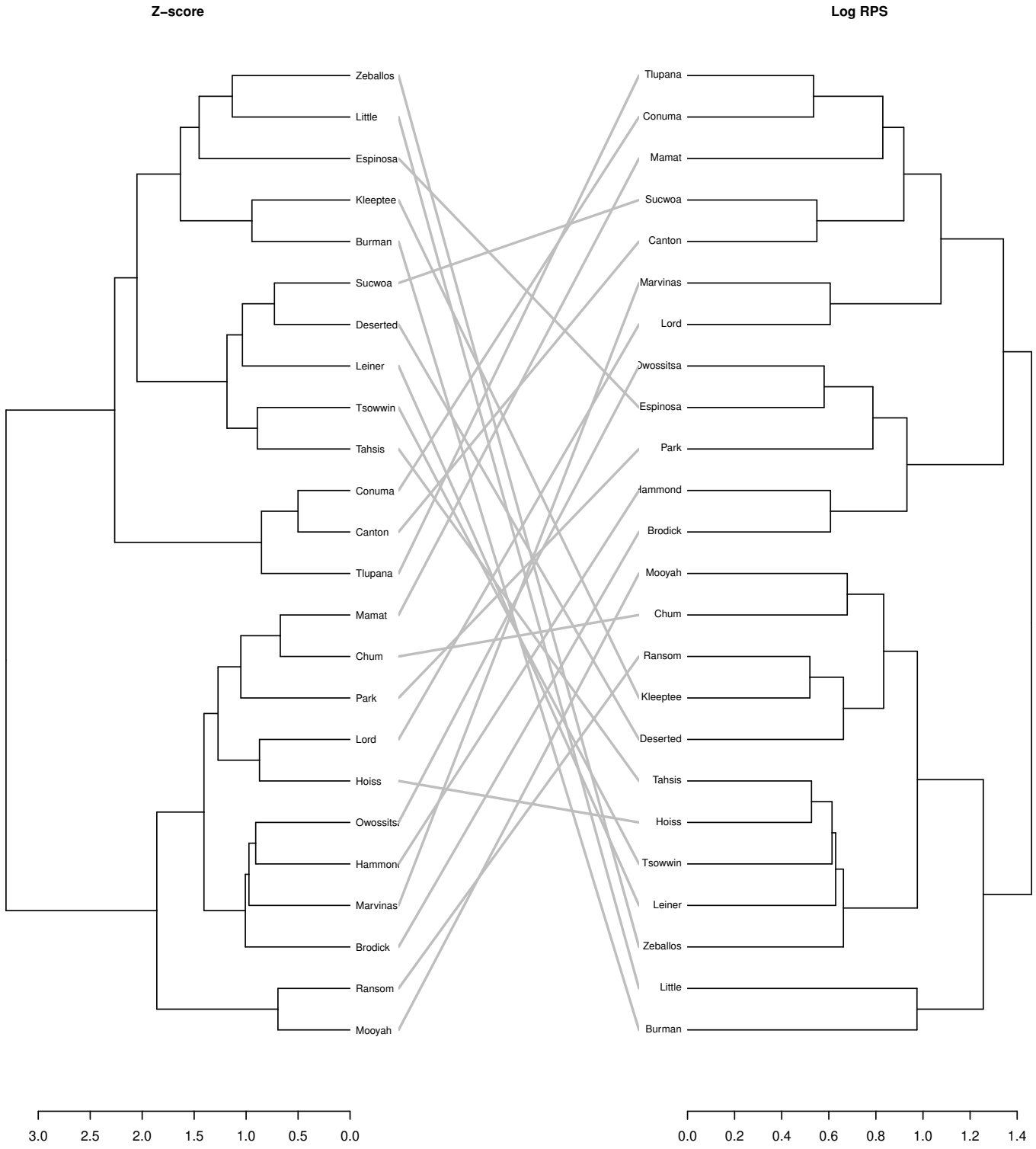


Figure 15: Tanglegram of z-score vs. Log RPS

Pre- and post-enhancement correlation analyses

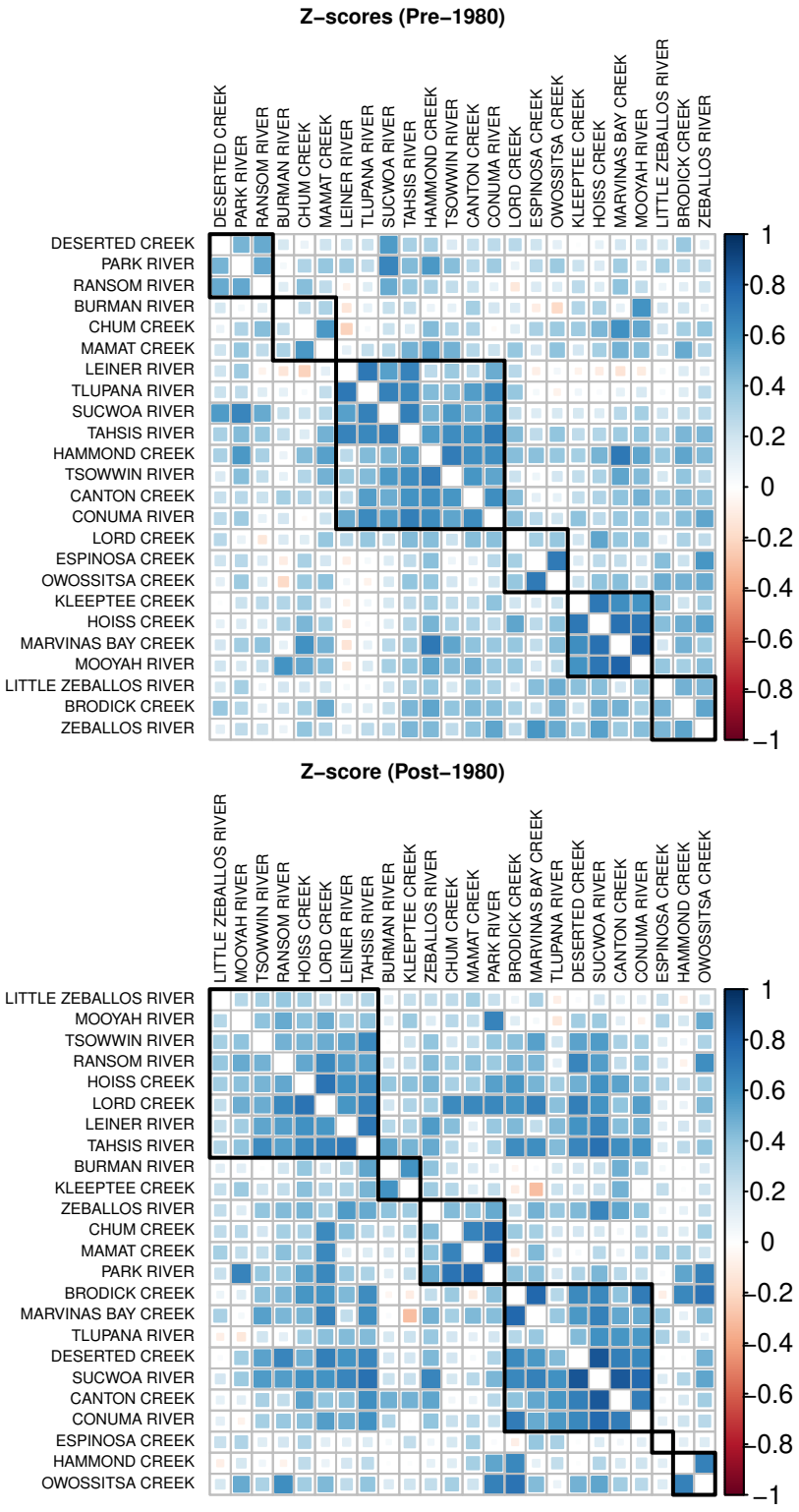


Figure 16: Cross correlation plots of z-scores to compare pre- and post-enhancement.

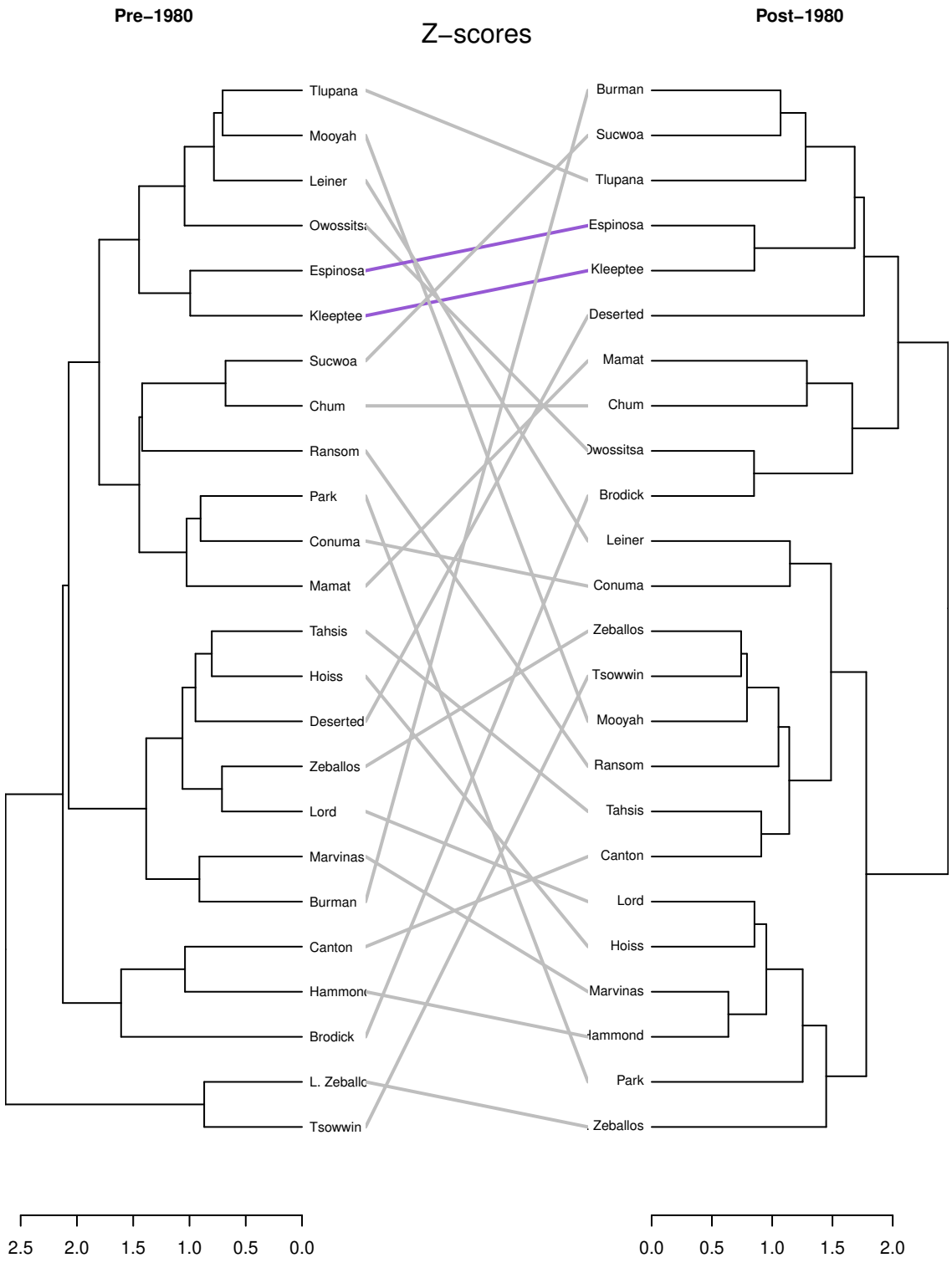


Figure 17: Tanglegram comparing z-scores pre- and post-enhancement (1980)

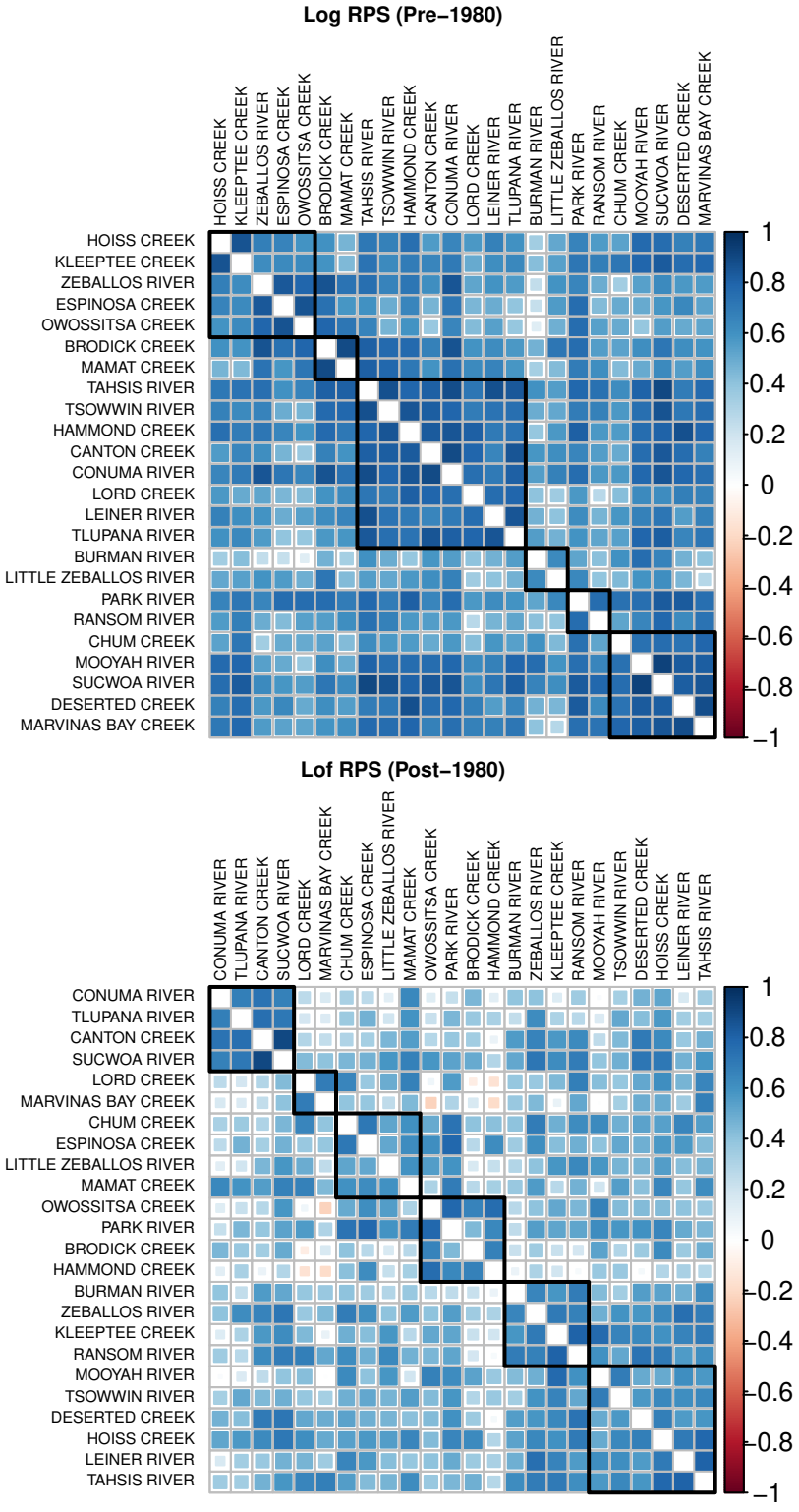


Figure 18: Cross correlation plots of Log RPS to compare pre- and post-enhancement.

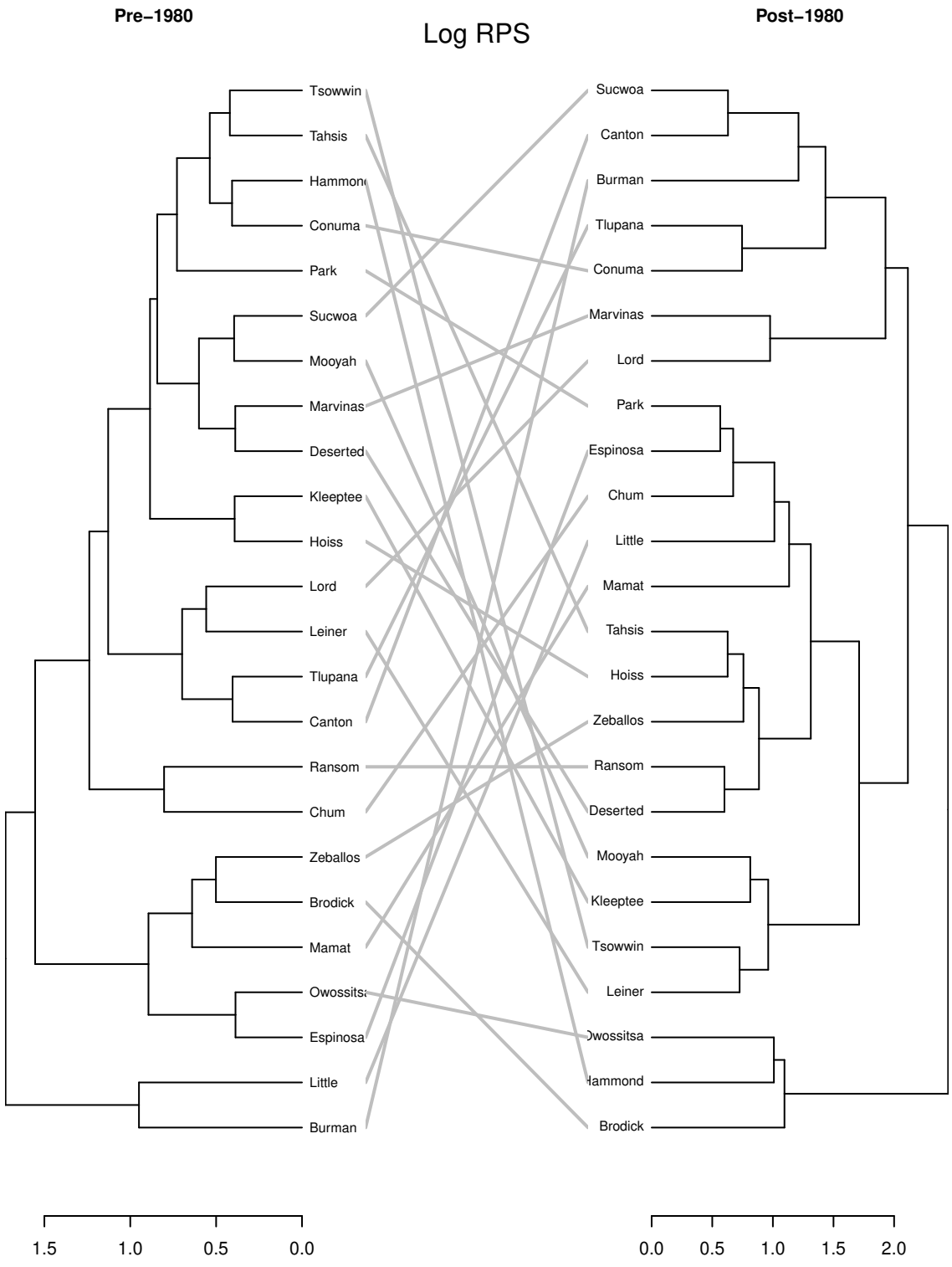


Figure 19: Tanglegram comparing Log RPS pre- and post-enhancement (1980)

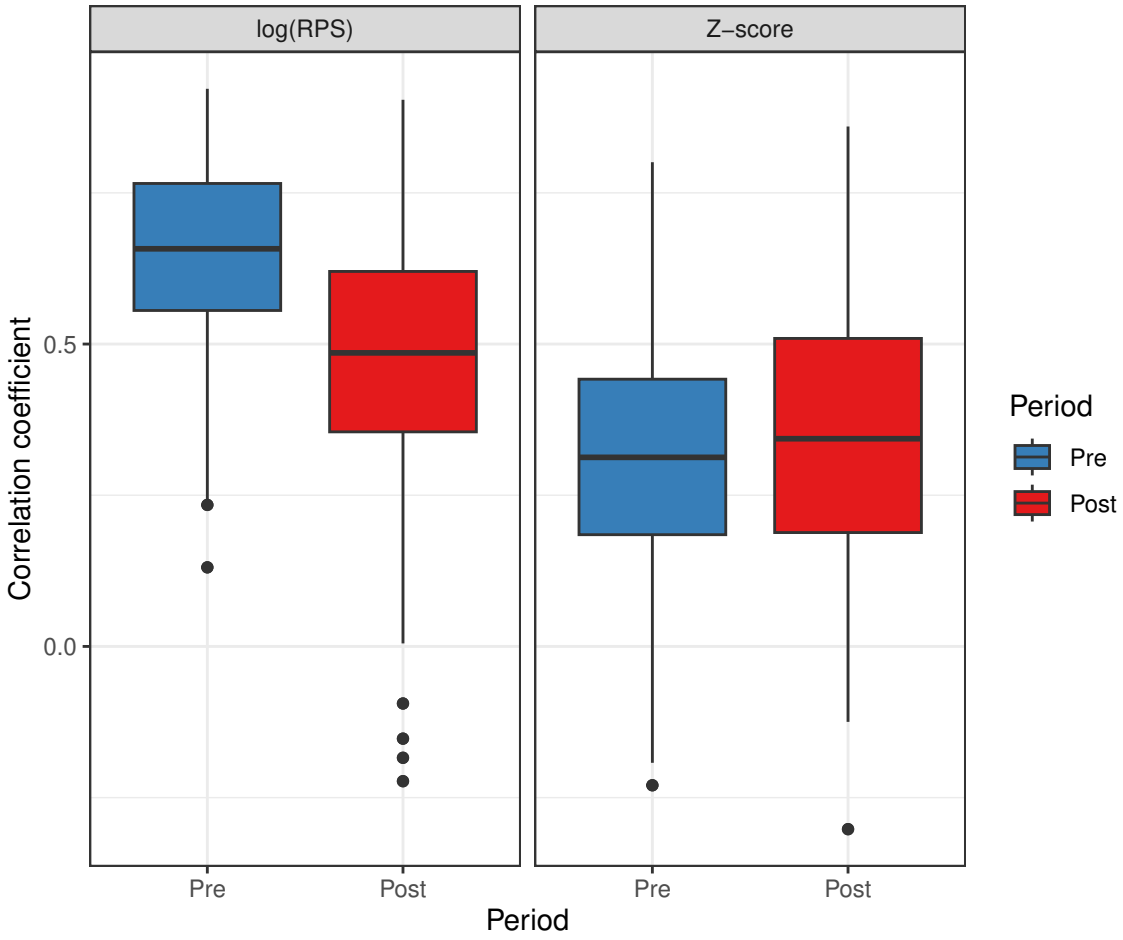


Figure 20: Comparison between correlation coefficients for all pairwise combinations of streams using Z-score and log(RPS) over the pre- and post-1980 periods.

Pairwise stream to stream correlation versus distance

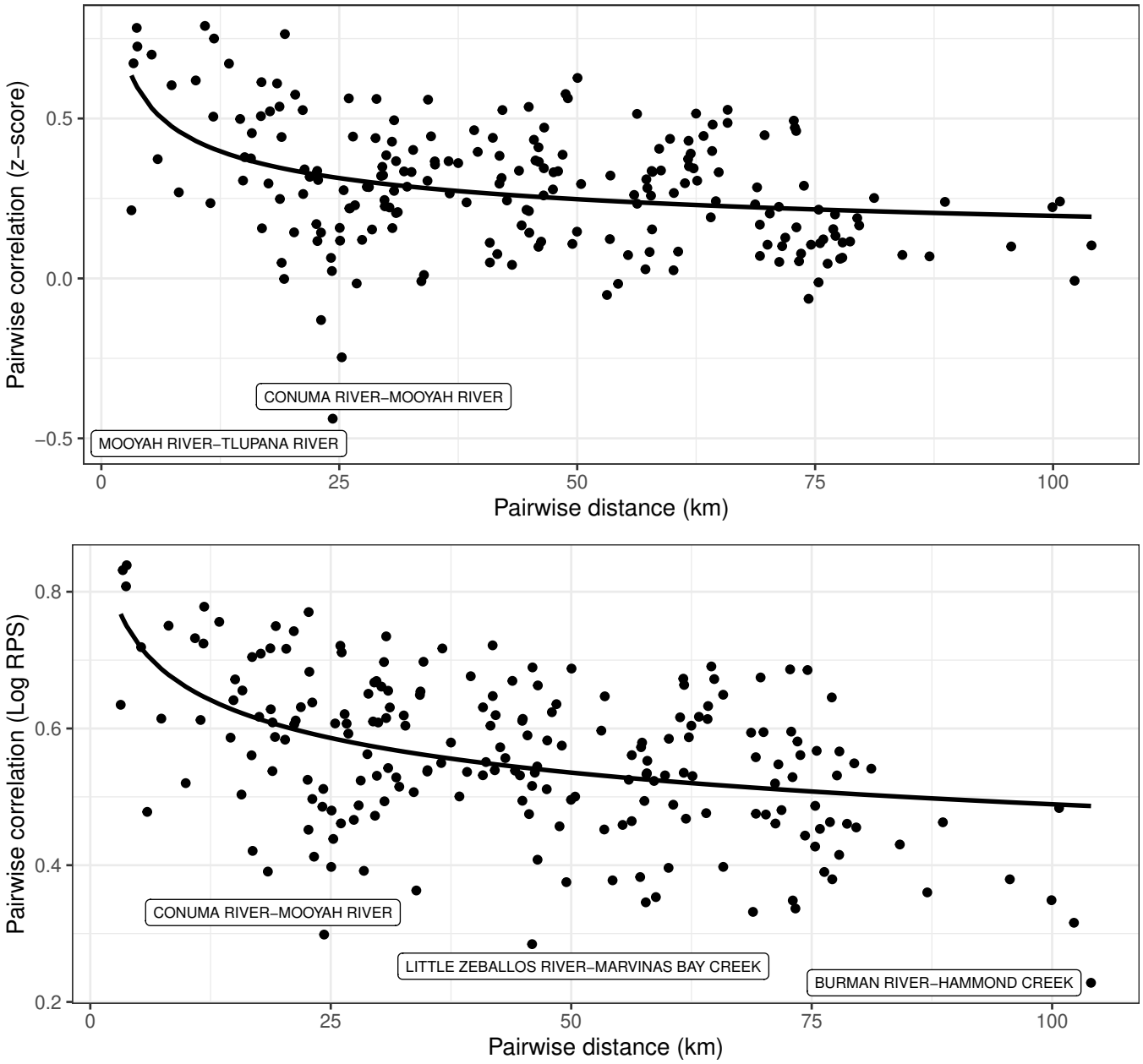


Figure 21: Pairwise stream-stream correlation of Z-score (top) and log(RPS) (bottom) against pairwise distance.

Dendrogram of pairwise distances

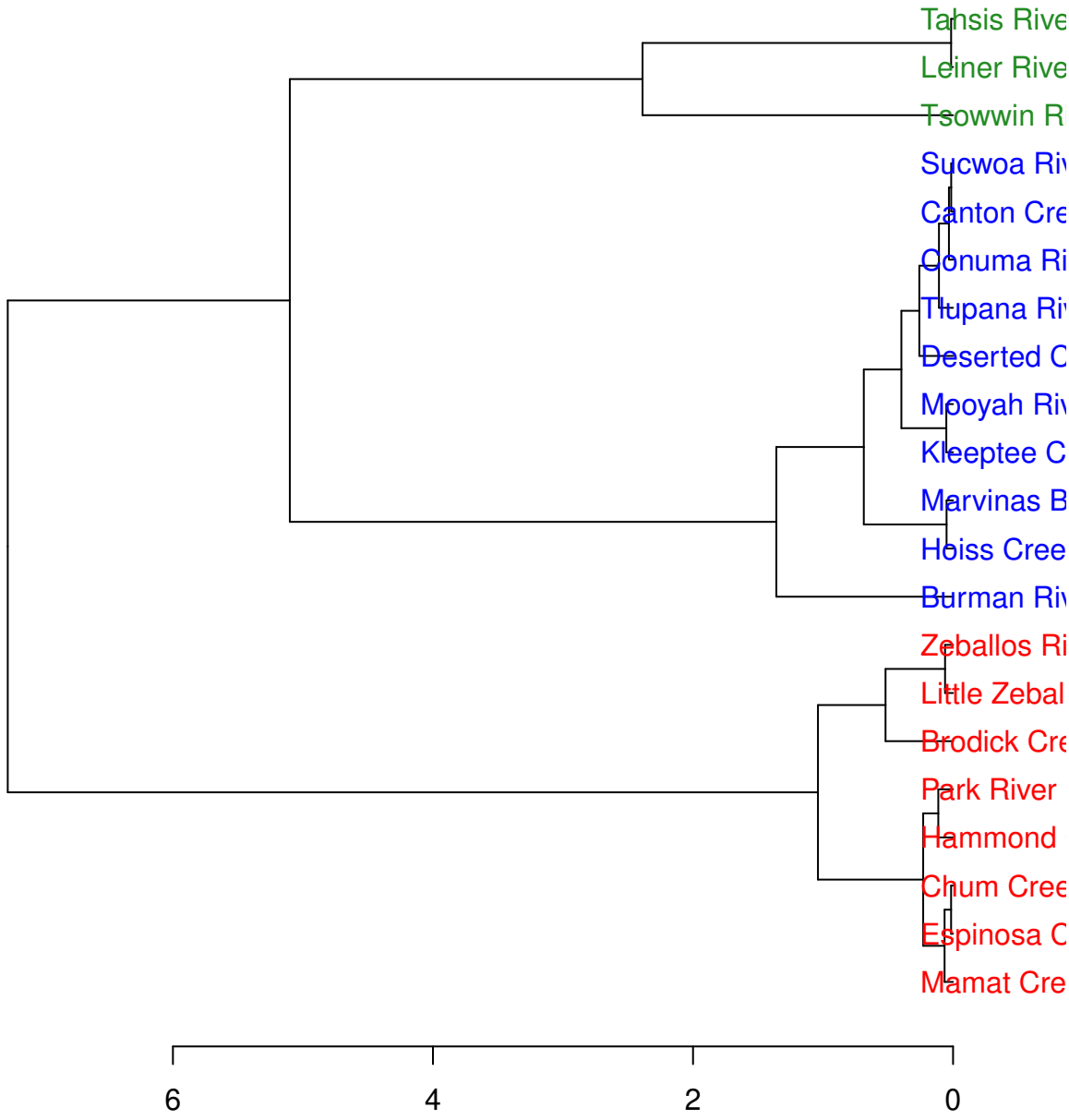


Figure 22: Dendrogram of pairwise distance between stream mouths. Red labels - Esperanza Inlet; Blue - Nootka Inlet; Green - Tahsis Inlet

Correlation metrics against distance, pre- and post-1980

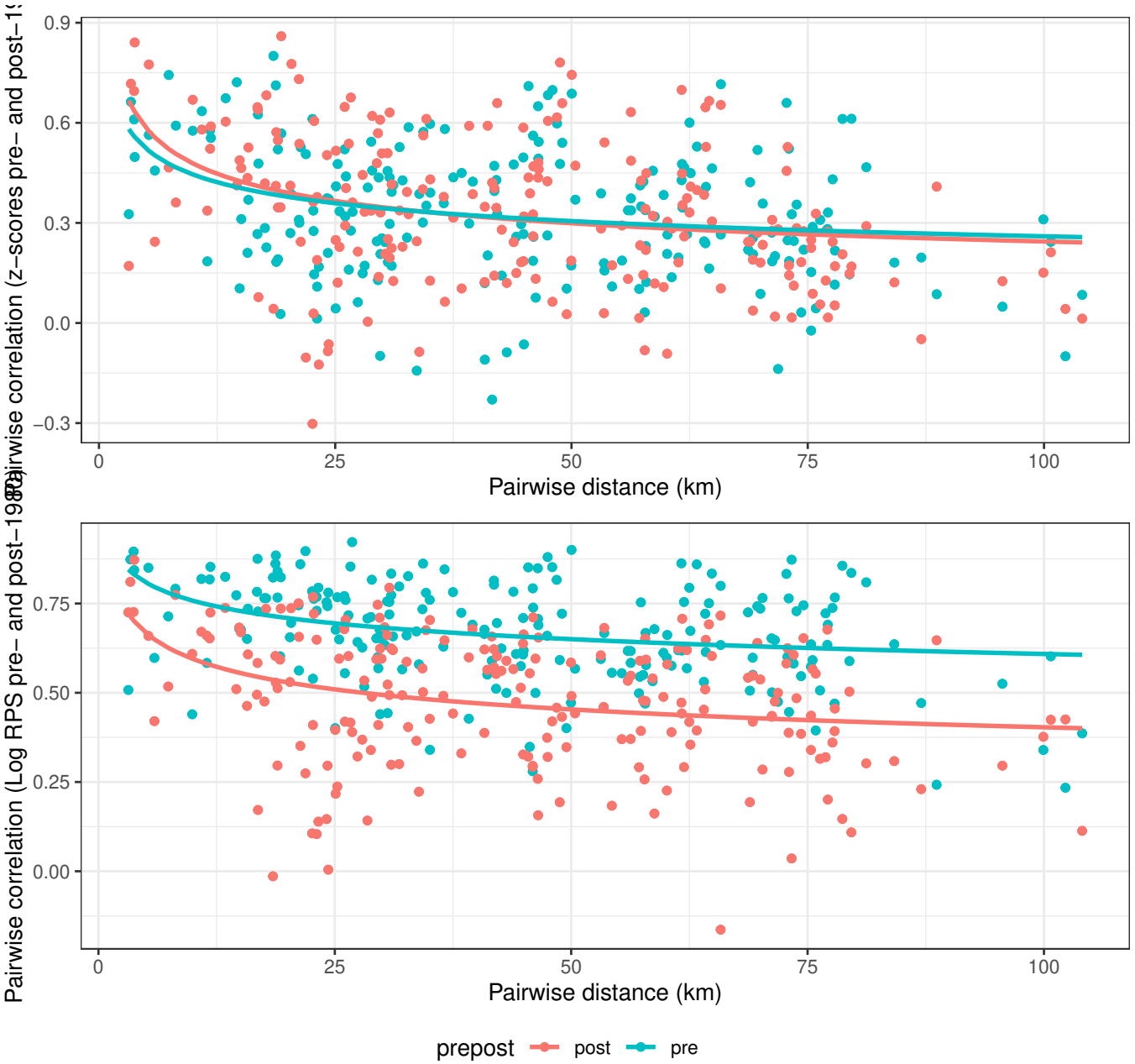


Figure 23: Pairwise stream-stream correlation of Z-score (top) and log(RPS) (bottom) against pairwise distance by period (pre-enhancement and post-enhancement.

Statistical models

Candidate Models with AIC scores for log RPS and log escapement

Table 2: Candidate models for log RPS and distance from enhancement (dist), total releases (totrel), and year, with AIC scores.

Candidate model	Degrees of freedom	AIC
logrps ~ total releases + factor(year)	33	1360.448
logrps ~ total releases + factor(year) + year	33	1360.448
log rps ~ total releases + year	4	1720.592
logrps ~ correlation coefficient + year + total releases	5	1720.627
log rps ~ distance from enhancement + total releases + year	5	1722.590
logrps ~ correlation coefficient + year	4	1722.756
log rps ~ distance from enhancement + year	4	1724.998
logrps ~ total releases + year + subinlet	12	1730.376
logrps ~ total releases + year + system name	27	1756.327
logrps ~ correlation coefficient + year + system name	26	1758.053

Table 3: Candidate models for log escapement and distance from enhancement (dist), total releases (totrel), and year, with AIC scores.

Candidate models	Degrees of freedom	AIC
log escapement ~ correlation coefficient + distance from enhancement + total releases + year	14	2645.411
log escapement ~ correlation coefficient + total releases + subinlet + year	13	2651.303
log escapement ~ correlation coefficient + total releases + inlet + year	7	2896.195
log escapement ~ correlation coefficient + total releases + year	5	2934.982
log escapement ~ distance from enhancement + total releases + year	5	2982.832
log escapement ~ distance from enhancement + year	4	2991.802

Effects plots for top model: log(RPS)

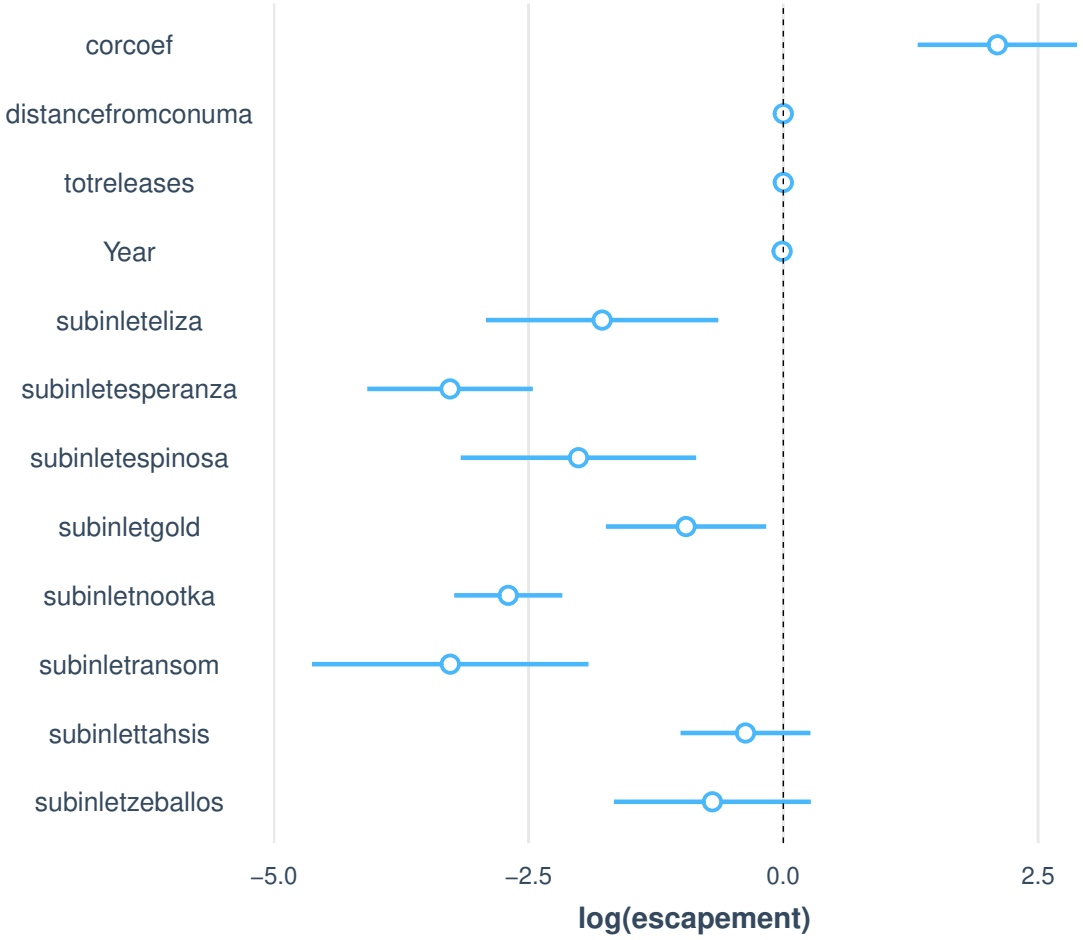


Figure 24: Plot of effects included in most parsimonious model.

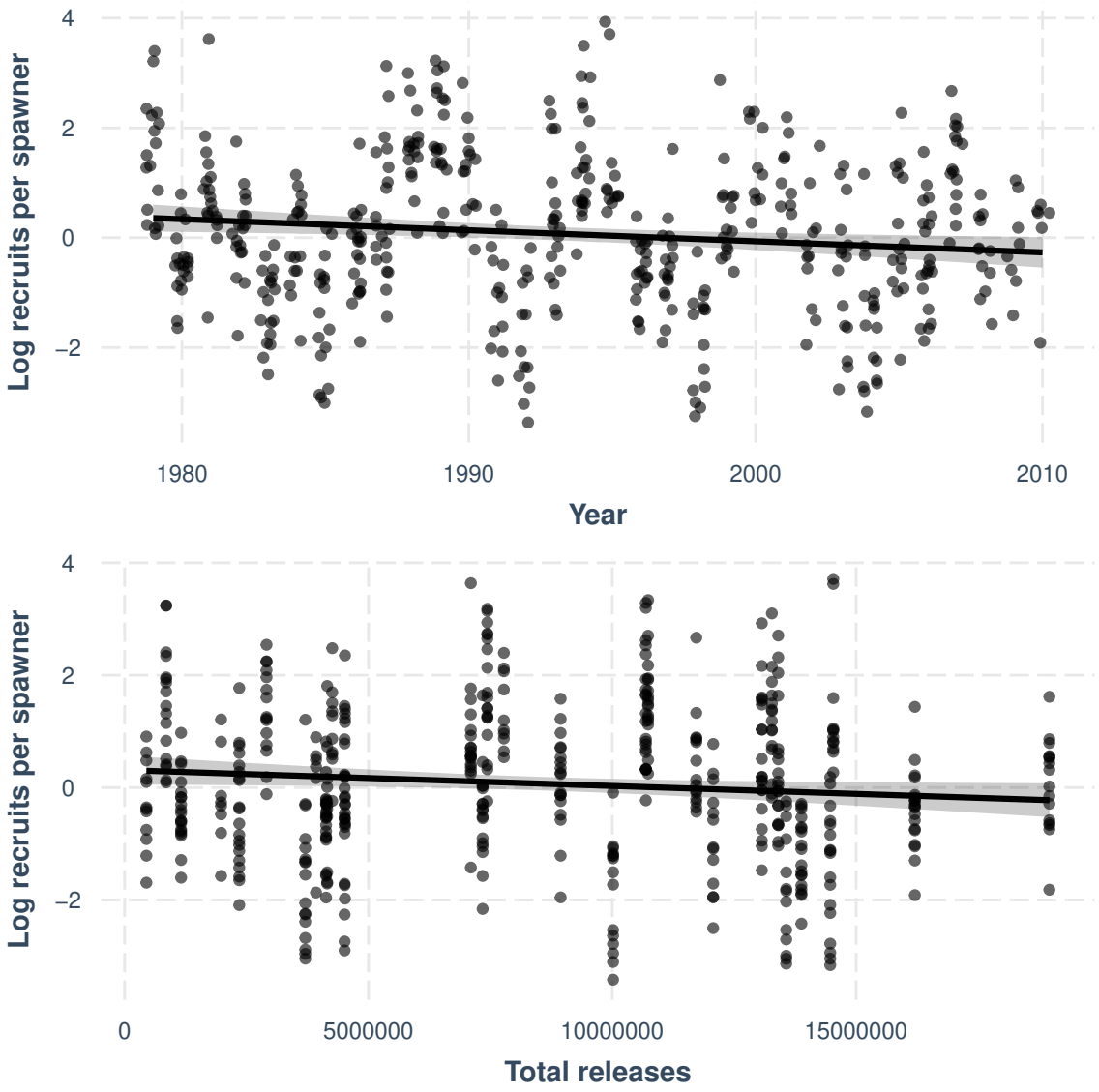


Figure 25: Effects plots of recruits per spawner by year (top) and total releases (bottom).

Effects plots for top model: log(escapement)

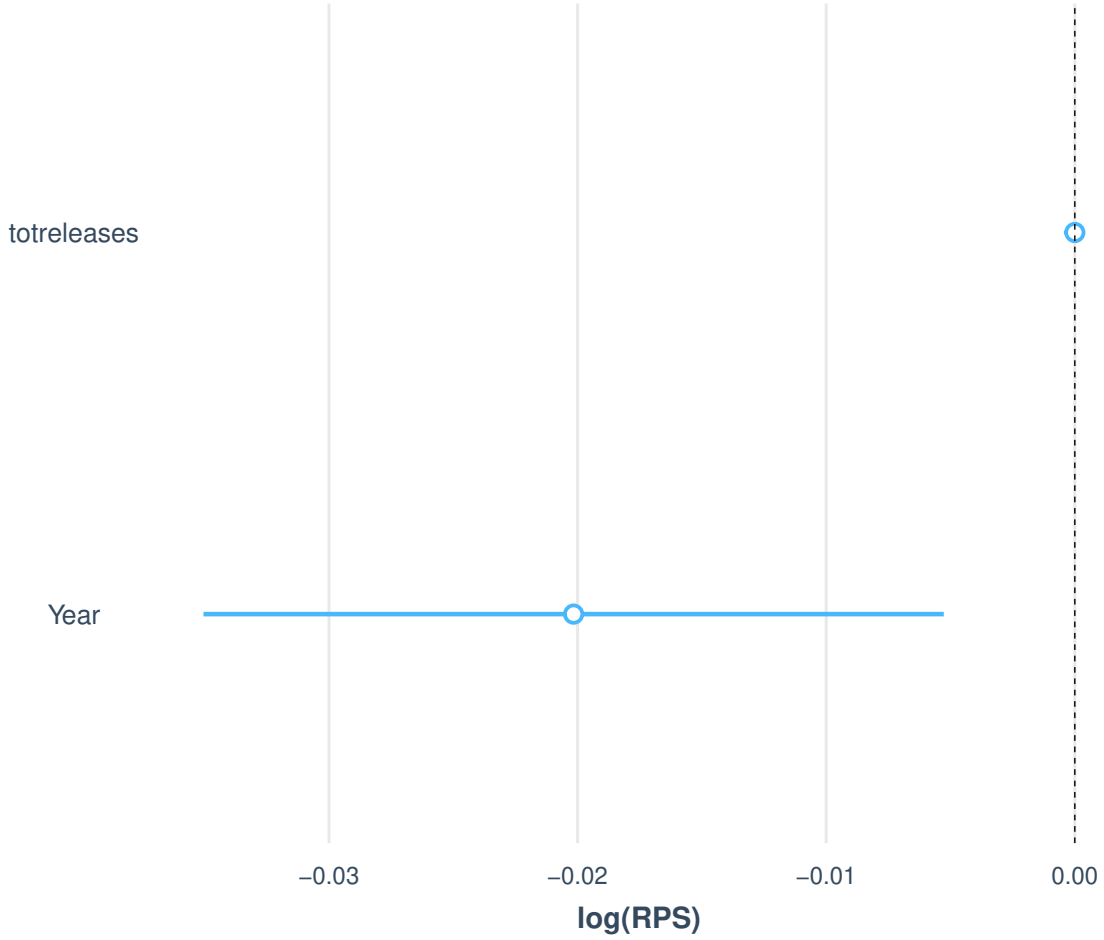


Figure 26: Effects plots of Escapement by correlation coefficient.

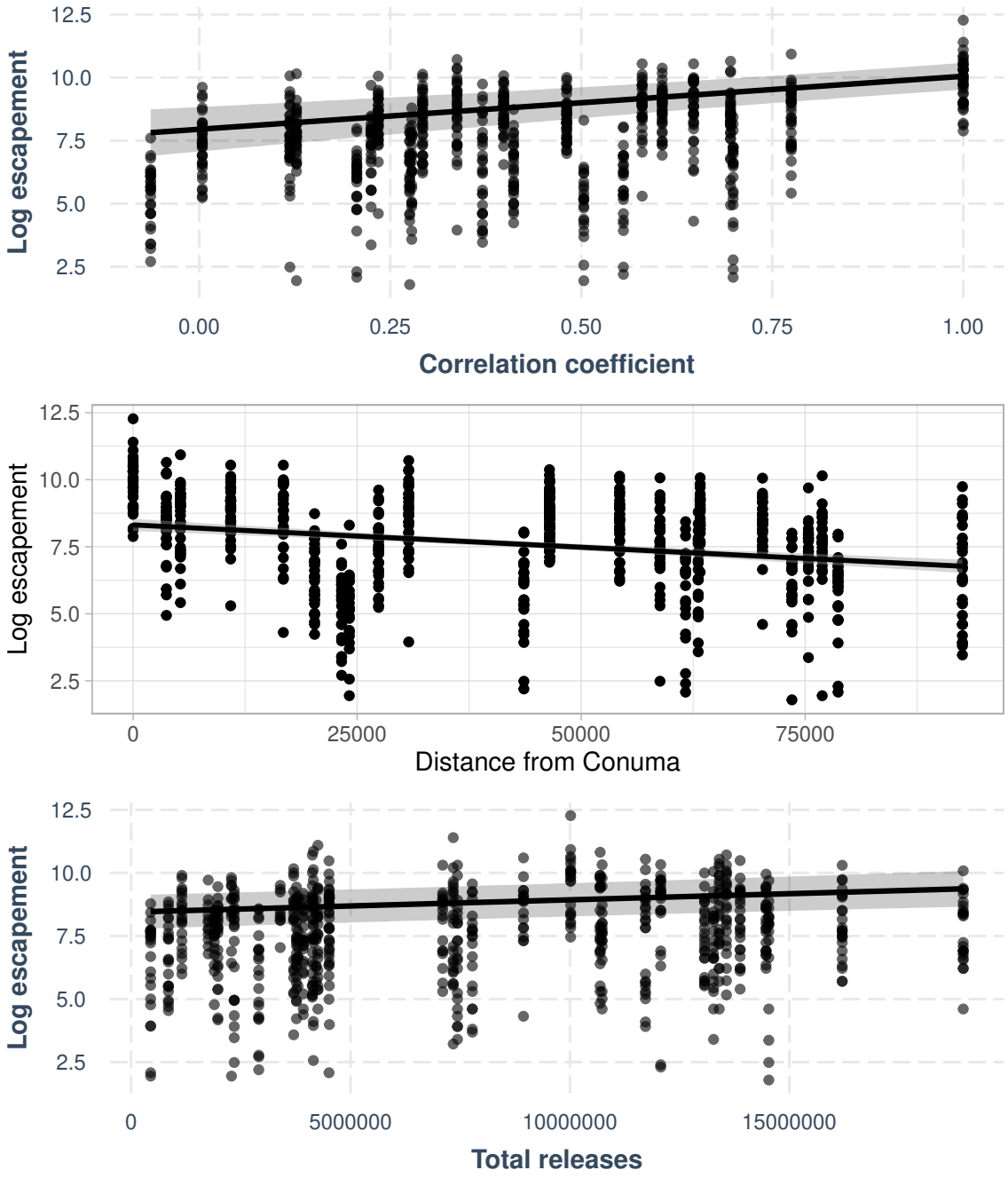


Figure 27: Effects plots of log(escapement) by correlation coefficient (top), distance from enhancement (middle) and total releases (bottom).

Appendix 2

Area 08 Chum Salmon

Coastland

2023-03-07

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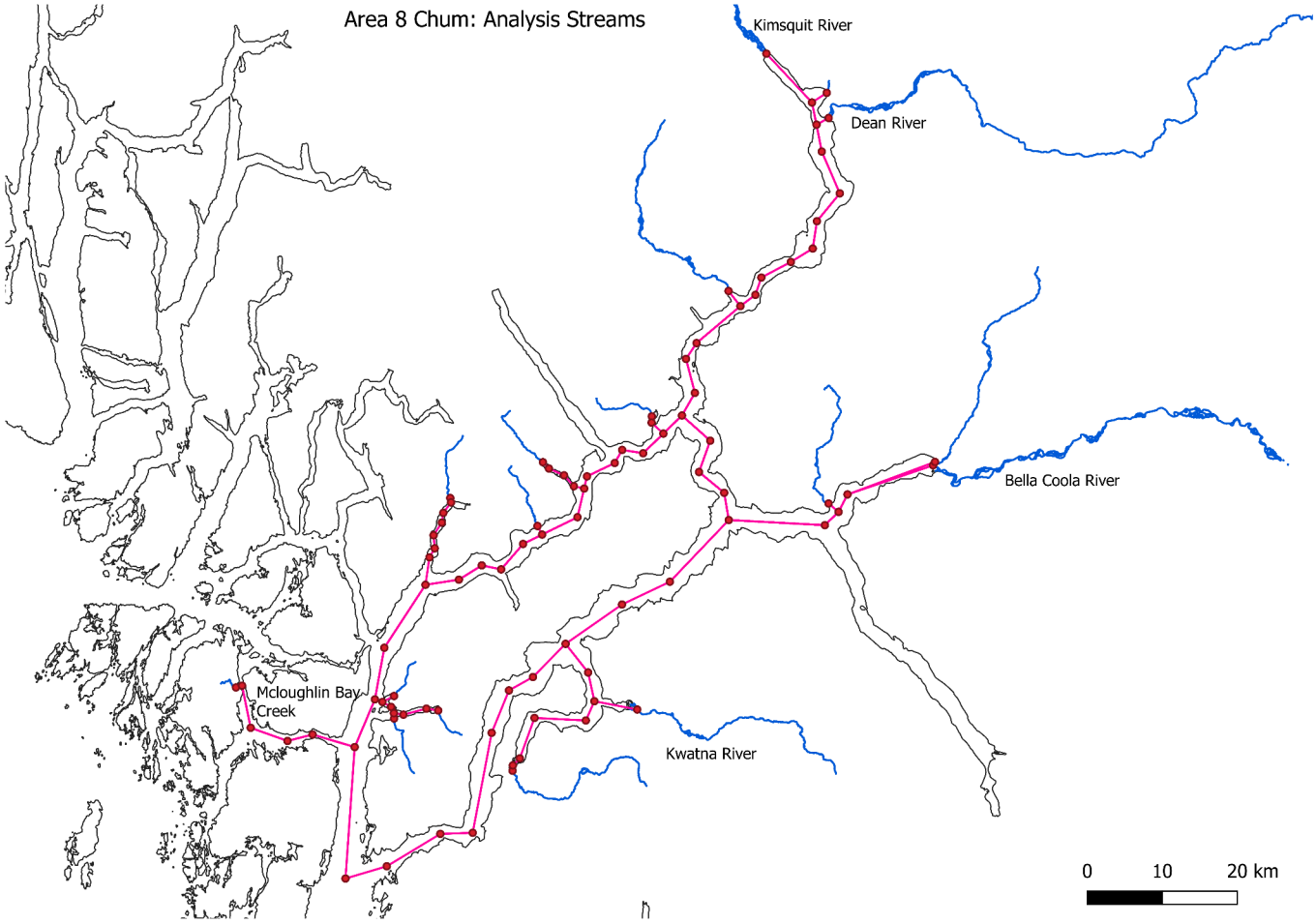
Study area

Area 8



Summary figures

Escapement: Raw and filtered stream list

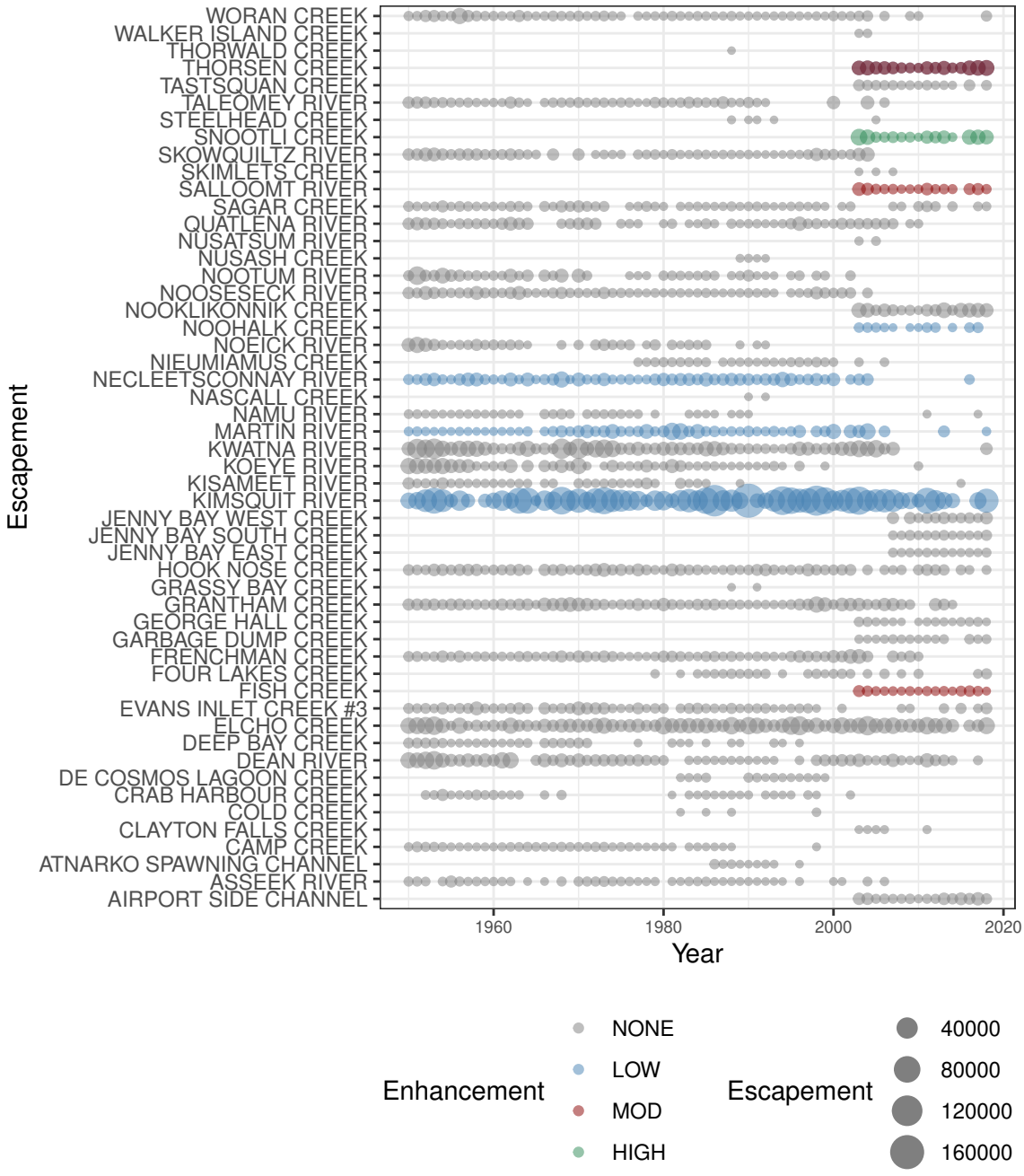


Figure 1: Escapement to area streams by enhancement rank.

Area 8 Escapement (filtered streams)

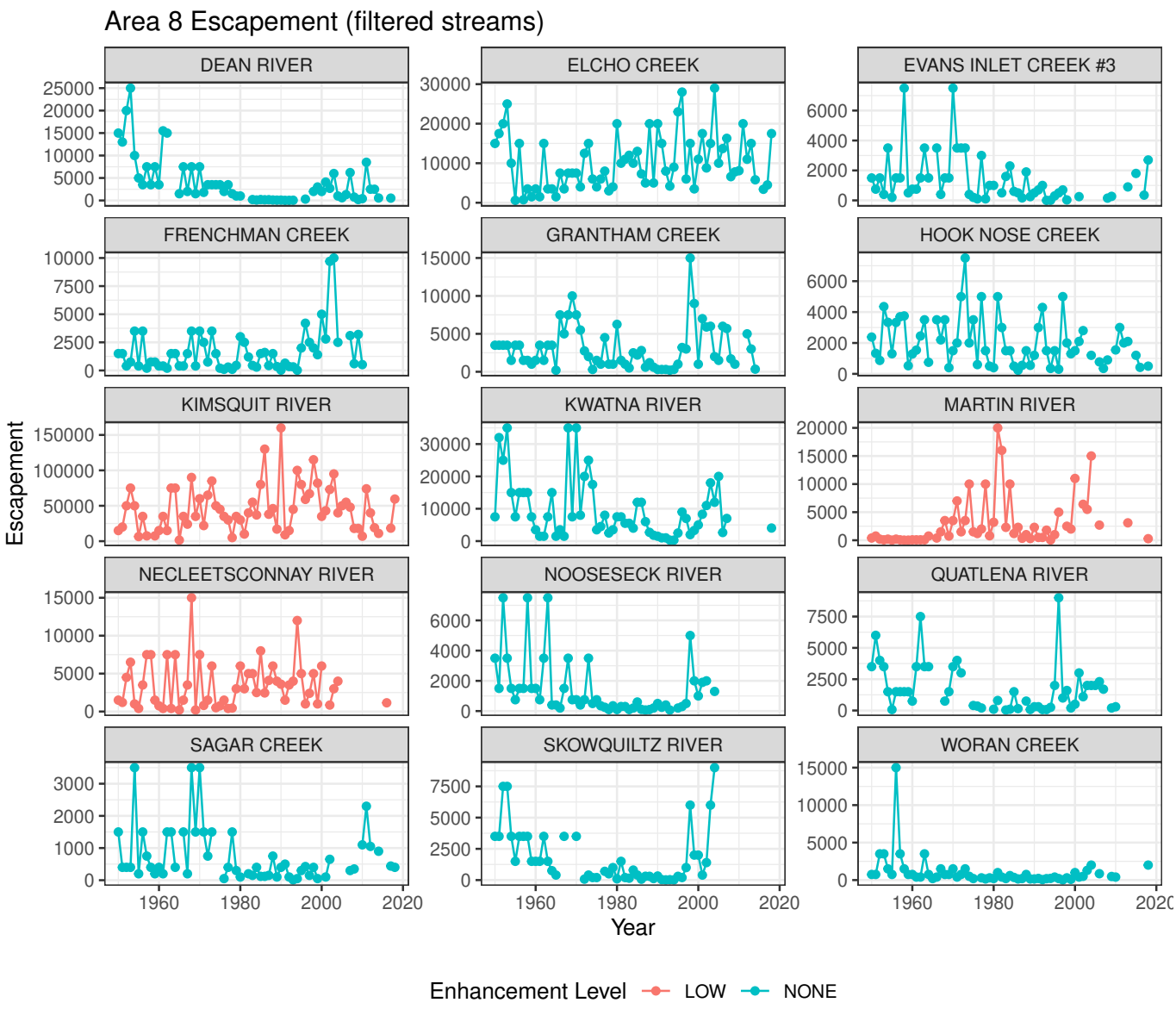


Figure 2: Escapement to filtered streams for Area 8 chum. Colour shows the stream enhancement level from the PSE database.

Table 1: Distance from enhanced systems (Bella Coola and McLaughlin

Stream	Dist. from Bella Coola (km)	Dist. from McLoughlin (km)
NECLEETSCONNAY RIVER	0.330	131.240
NOOSESECK RIVER	24.643	170.440
WORAN CREEK	76.866	120.913
SKOWQUILTZ RIVER	94.720	148.313
ELCHO CREEK	103.148	106.639
KWATNA RIVER	105.902	130.621
FRENCHMAN CREEK	107.102	86.179
QUATLENA RIVER	119.732	144.451
DEAN RIVER	131.461	185.054
GRANTHAM CREEK	137.067	190.660
KIMSQUIT RIVER	145.334	198.927
MARTIN RIVER	146.597	33.405
HOOK NOSE CREEK	156.657	42.239
SAGAR CREEK	157.723	43.305
EVANS INLET CREEK #3	166.711	52.293

Hatchery Releases: Total and by release site

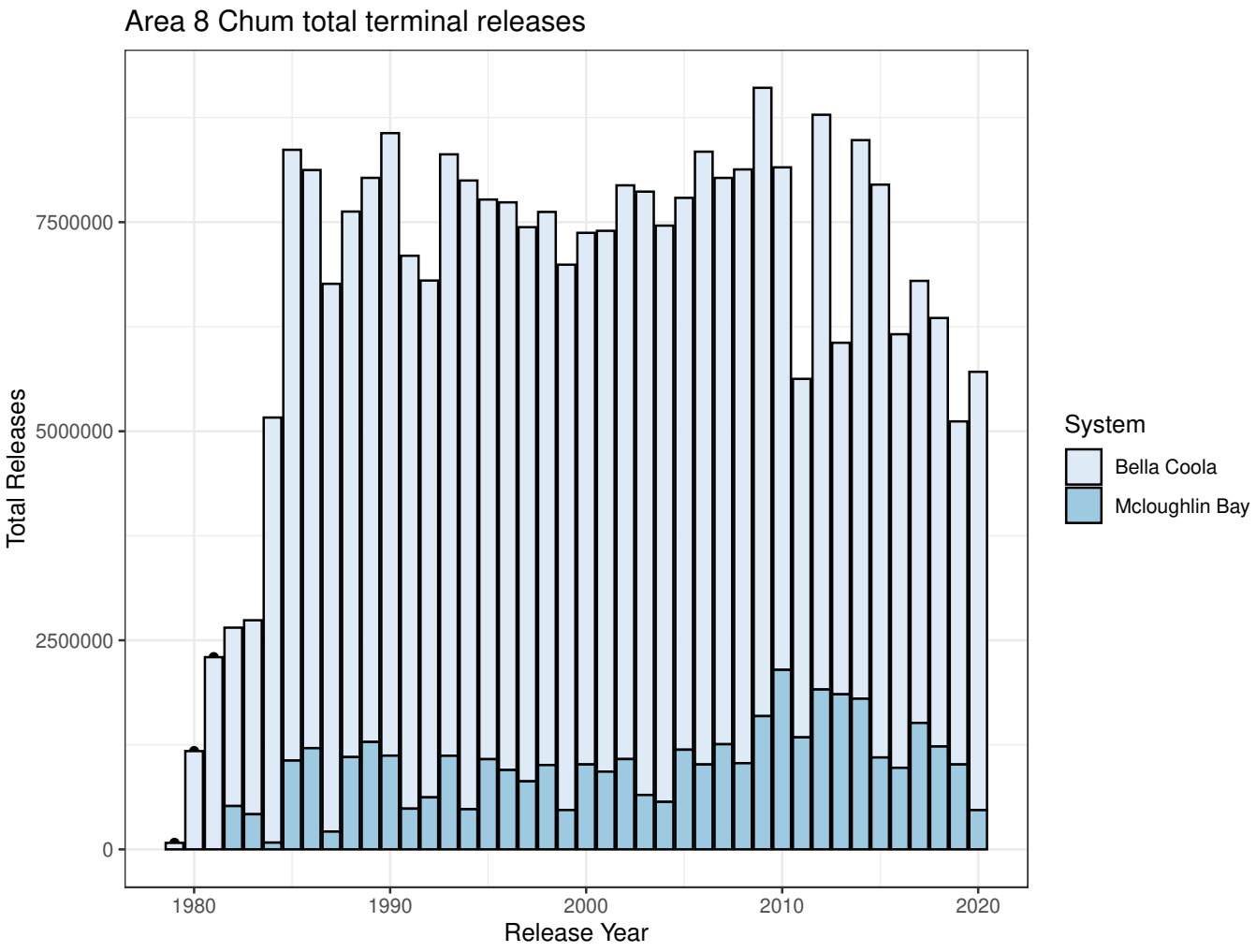


Figure 3: Total releases for Area 8

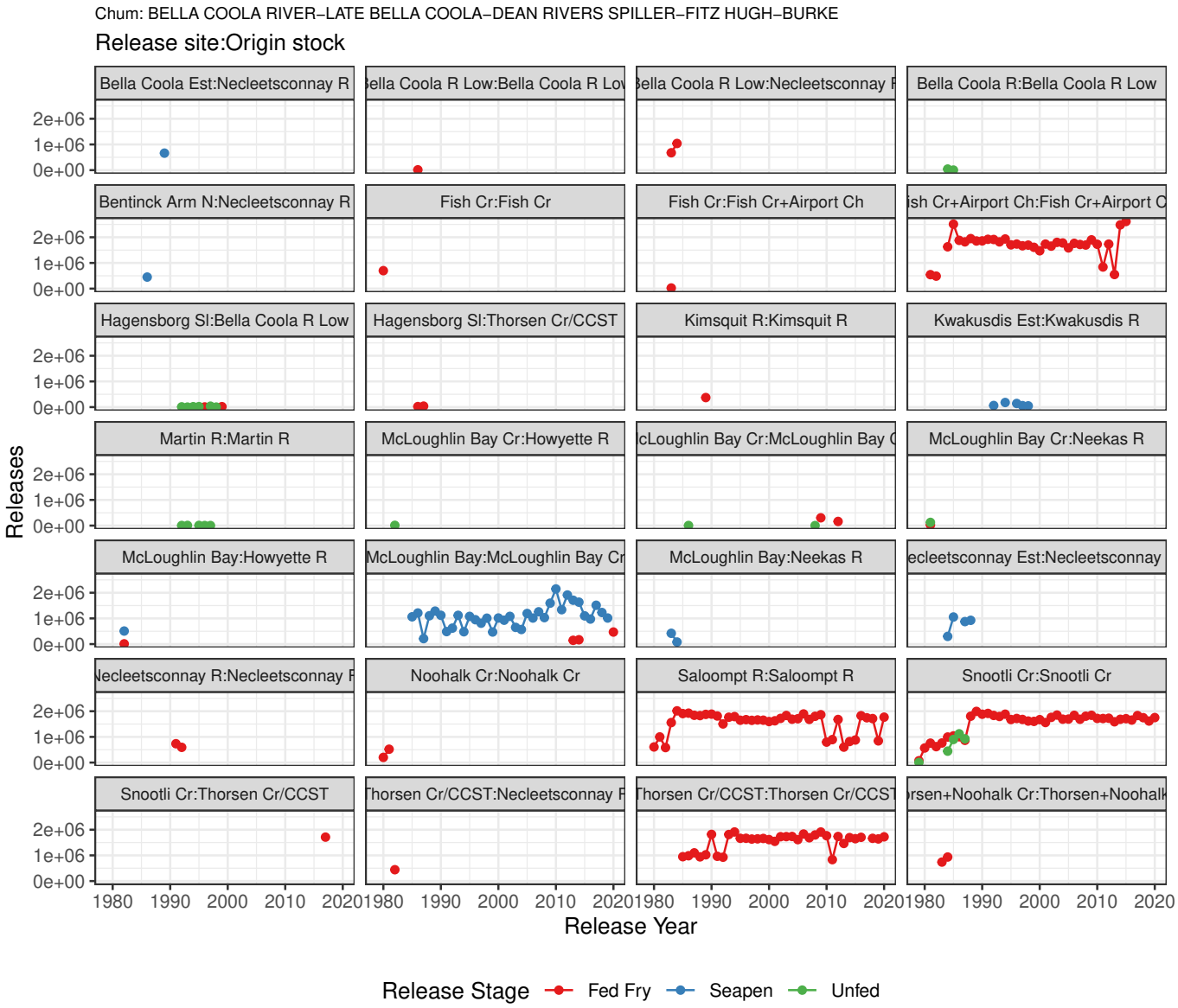
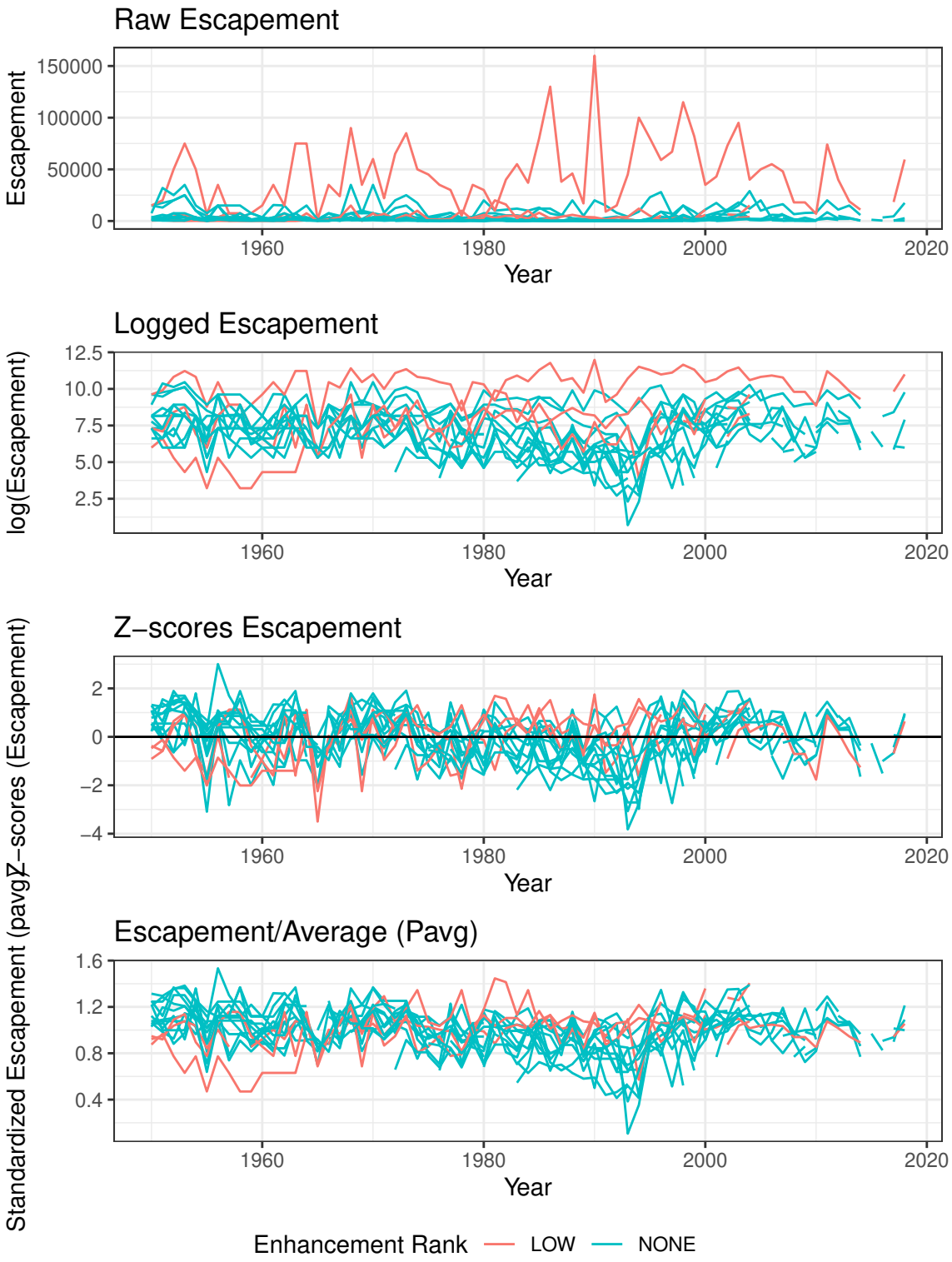


Figure 4: Facet plot of all releases in Area 8

Metrics

Escapement, logged escapement, Z-scores, Pavg, and moving average



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Moving average and LOESSS fit

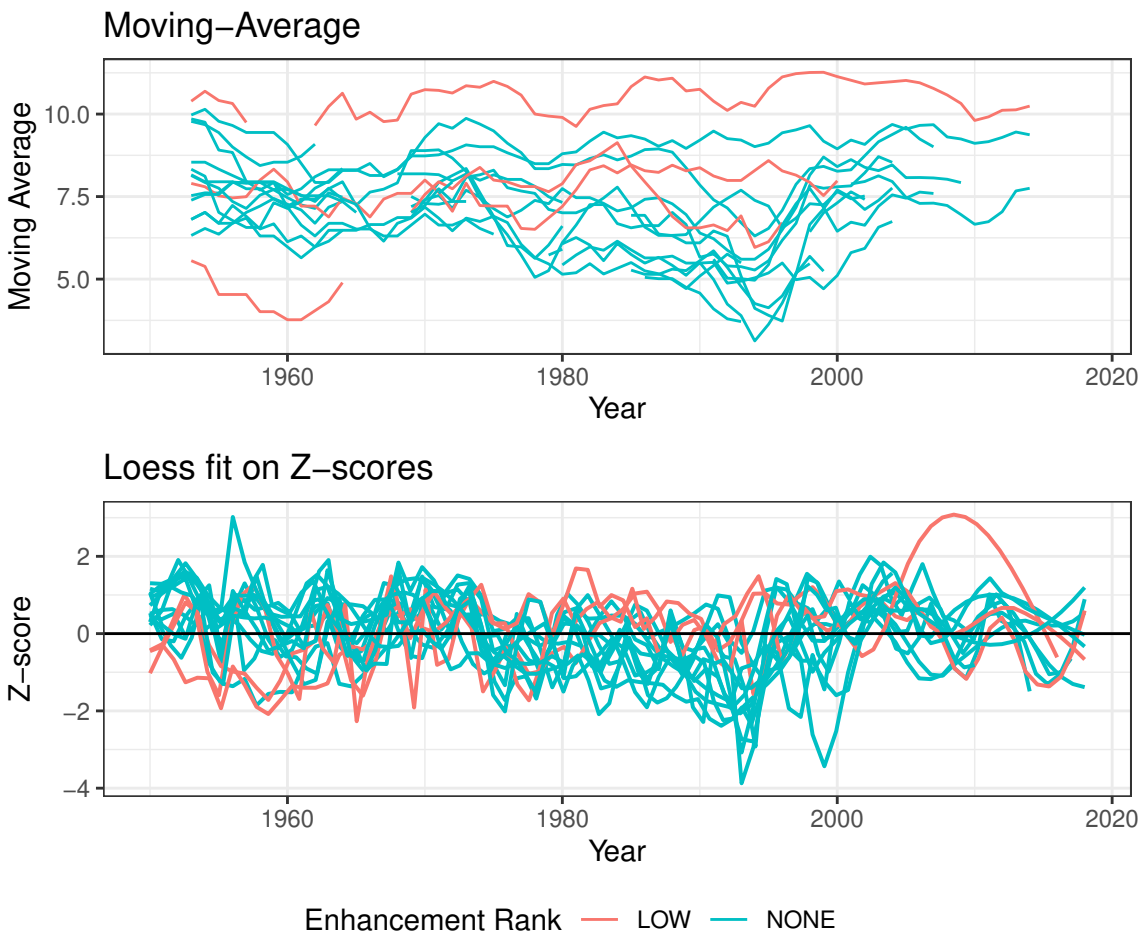


Figure 6: Moving average and LOESS fits on logged escapement by enhancement ranking.

Means trends by enhancement rank

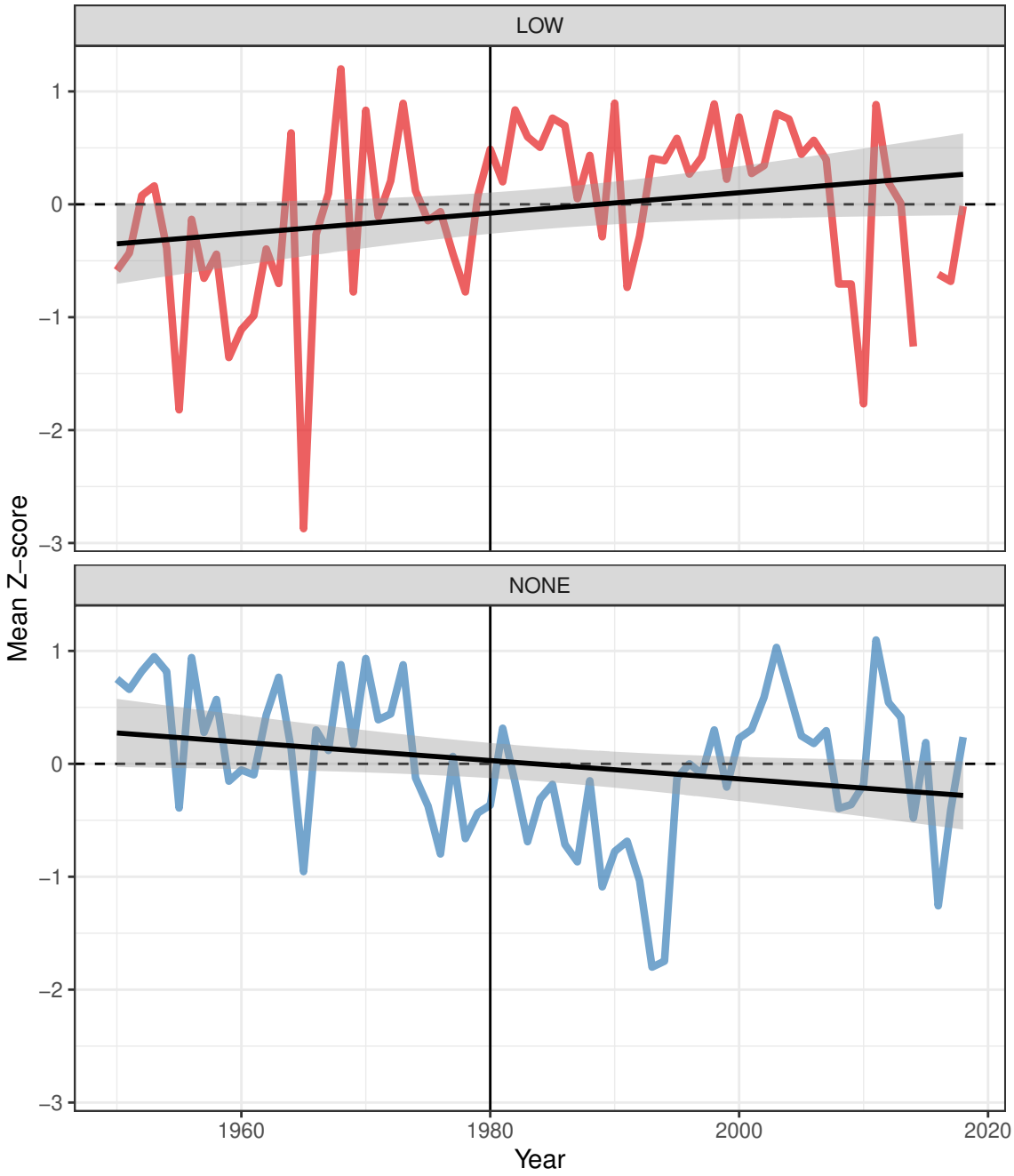


Figure 7: Area 8 chum: Mean Z-score for analysis streams by enhancement rank. Linear regression over all years with SE are shown.

Recruits per spawner

Recruits per spawner by system

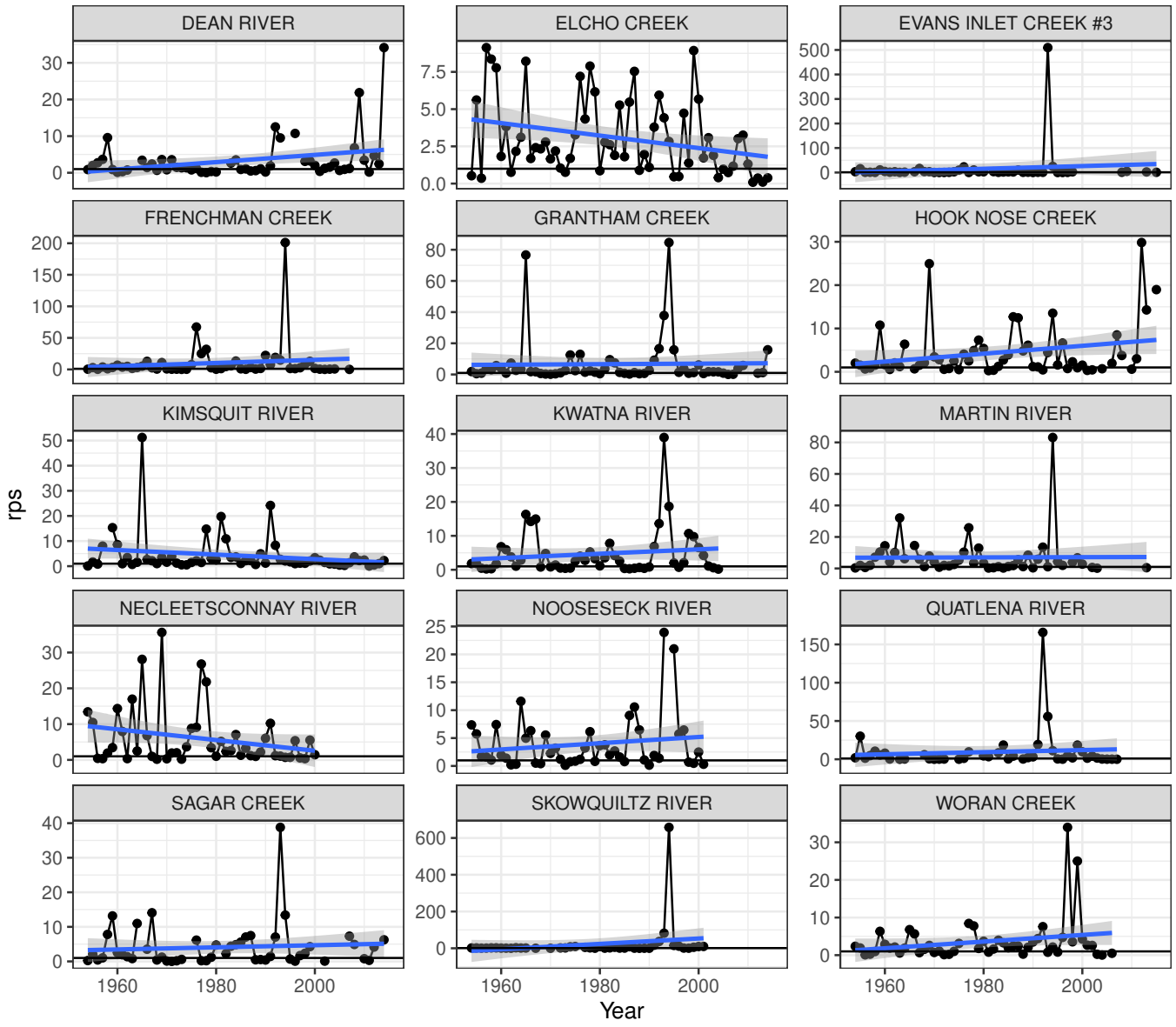


Figure 8: Recruits per spawner by system

Log recruits per spawner by system by period

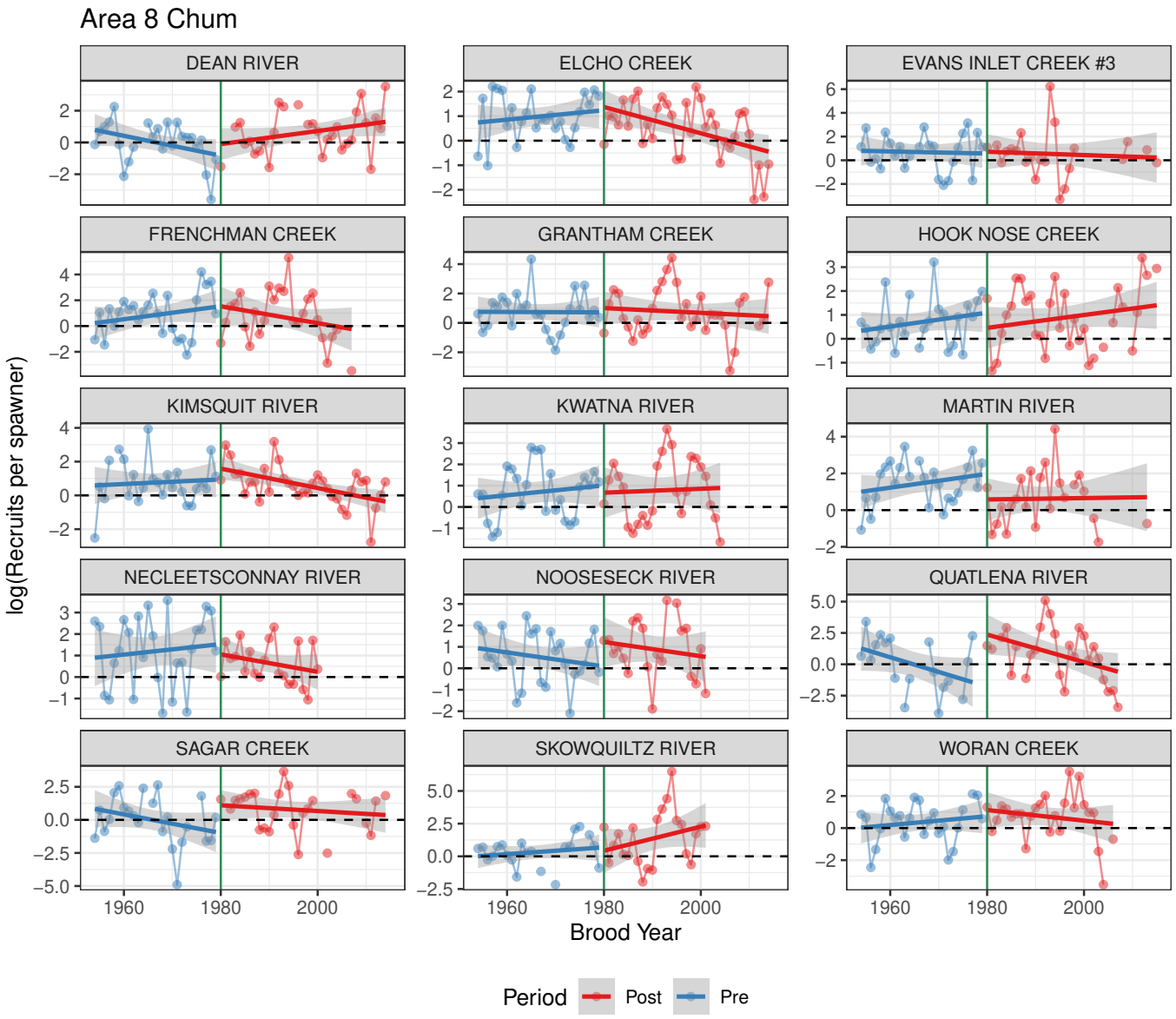


Figure 9: Area 8 chum: log recruits per spawner by system fitted with linear regression for the periods pre- and post-enhancement.

Log RPS comparison before and after enhancement

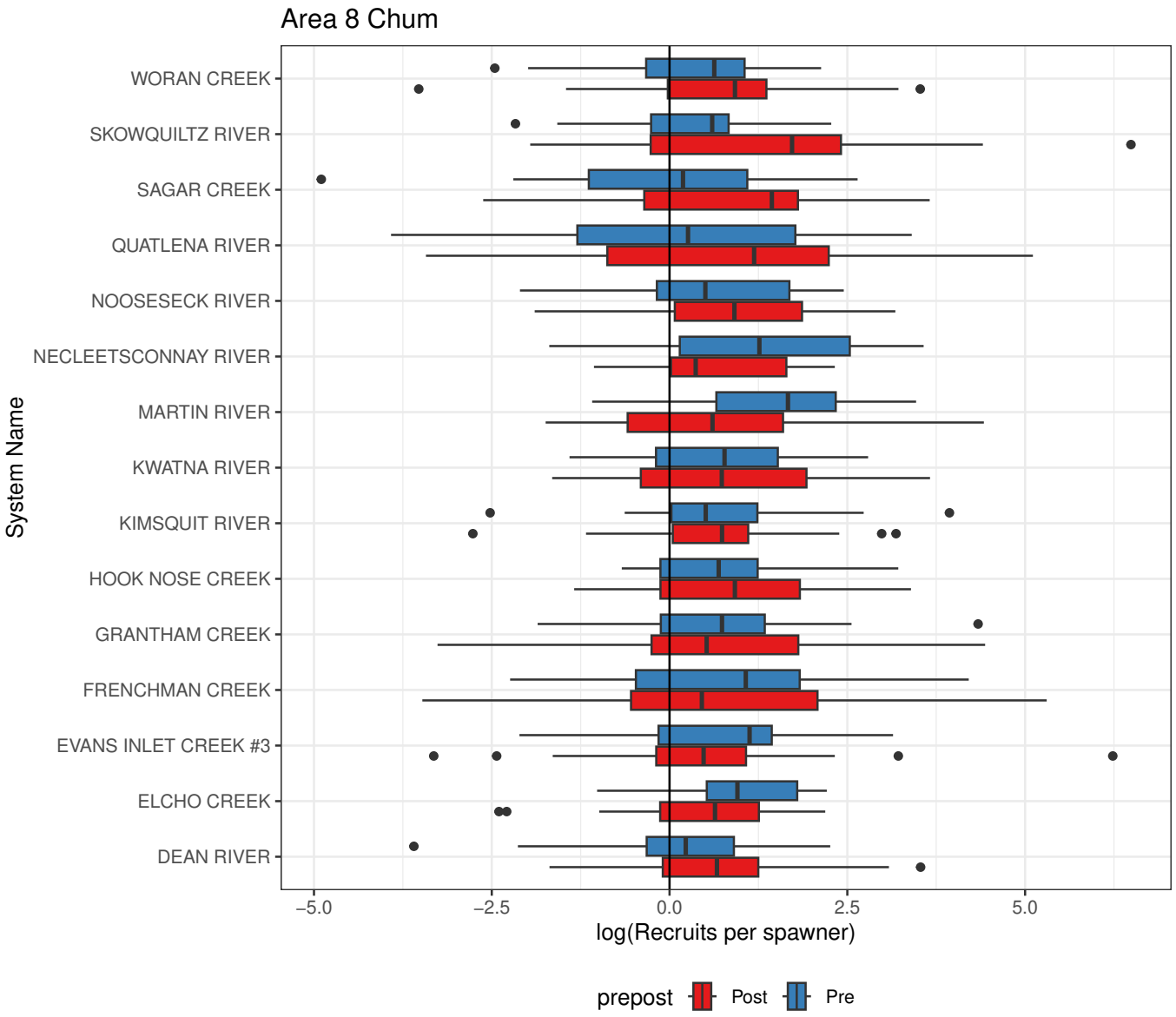
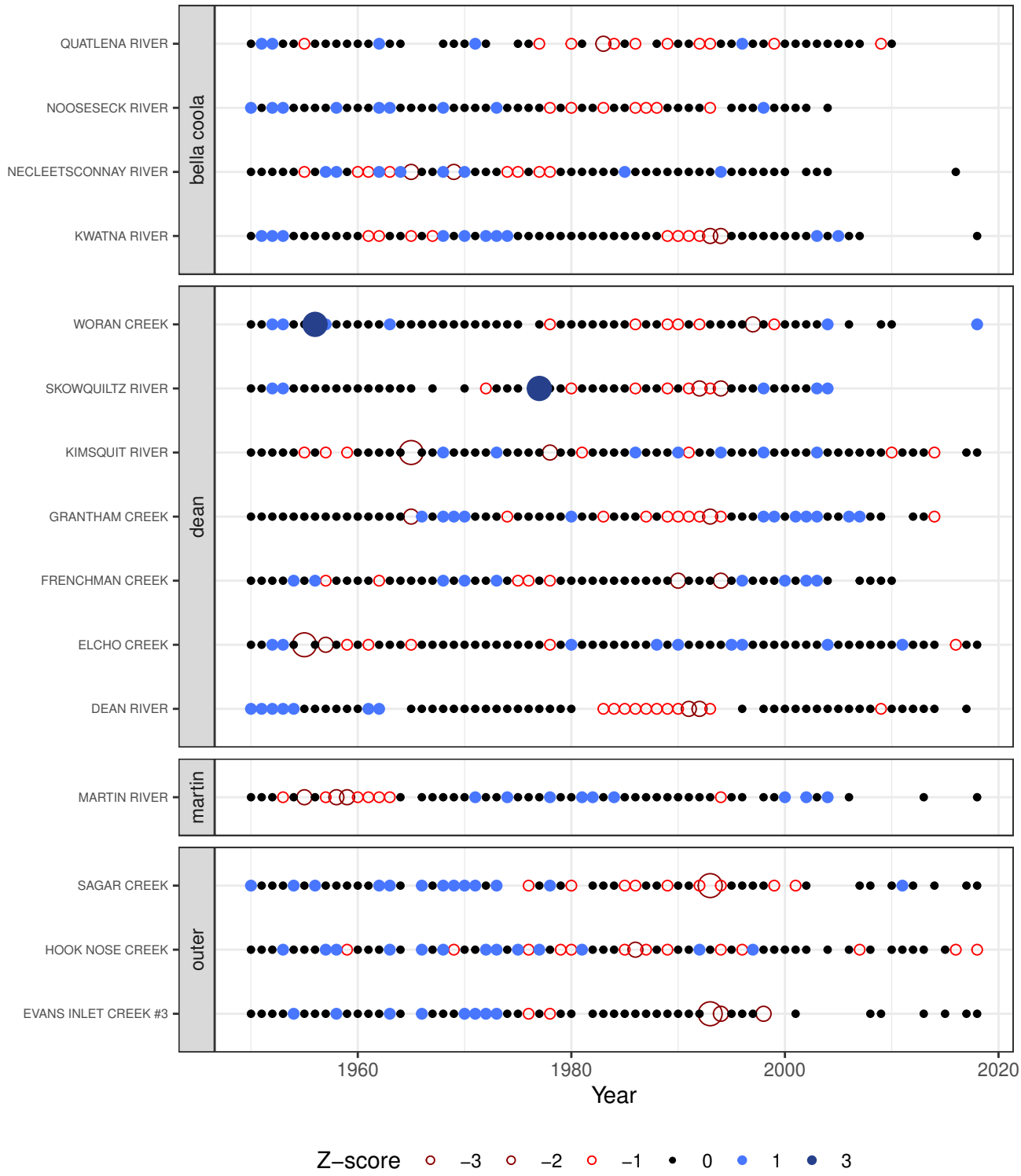


Figure 10: Boxplot of log recruits per spawner by system

Bubbleplots of metric by inlet



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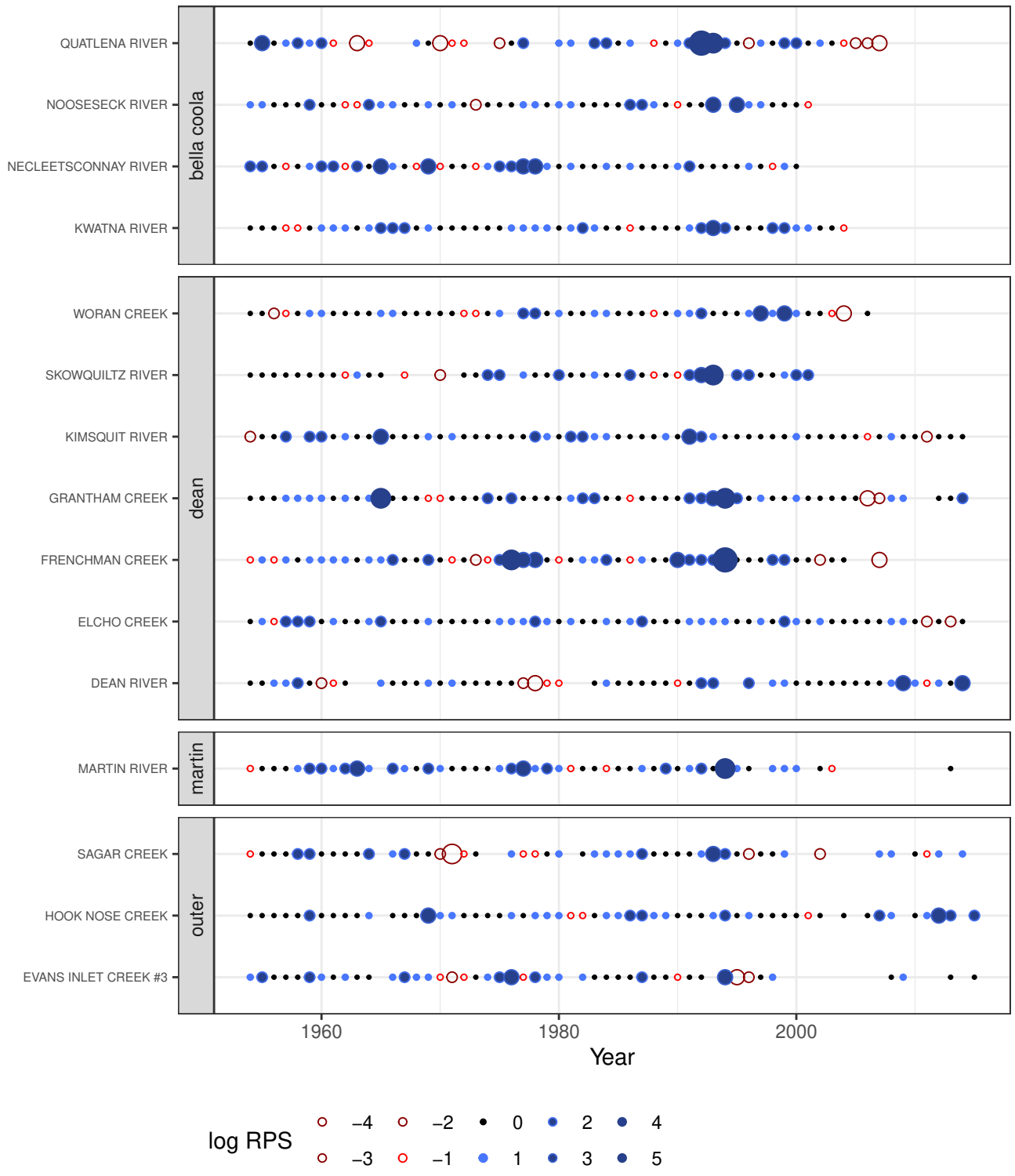


Figure 12: Log(recruits per spawner) for each system grouped by inlet. Solid blue points indicate positive values and open red circles indicate negative values. The size of the point indicates the magnitude of the metric.

Correlation analyses and Dendrograms

Cross correlation plots

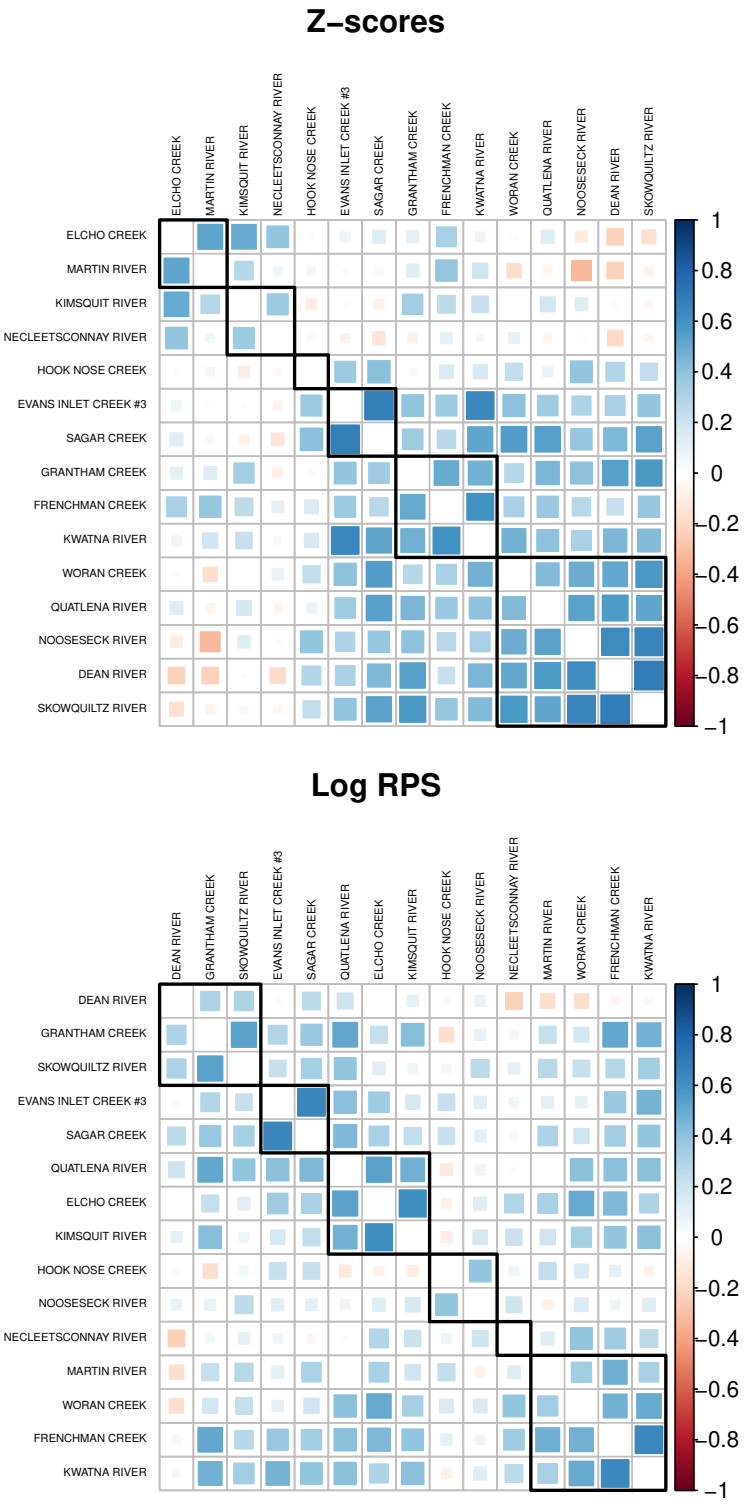


Figure 13: Cross correlation plots to compare metrics.

Dendrogram clusters analysis

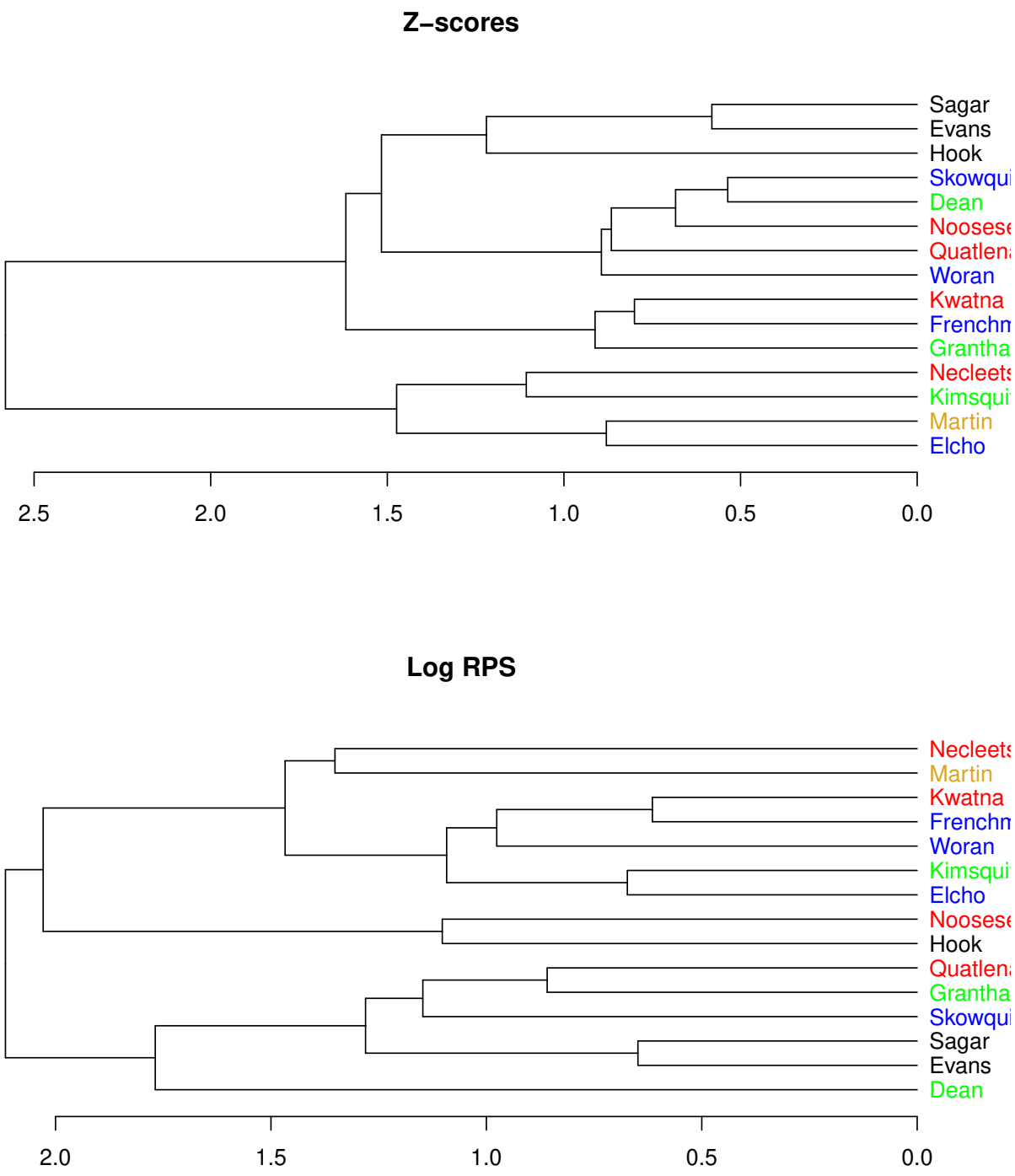


Figure 14: Dendrogram cluster analysis to compare uses of different metrics. Colours represent different subinlets; Bella Coola = red; Dean = blue; Kimsquit = green; Martin = yellow; Sagar = black

Tanglegrams to compare dendrograms

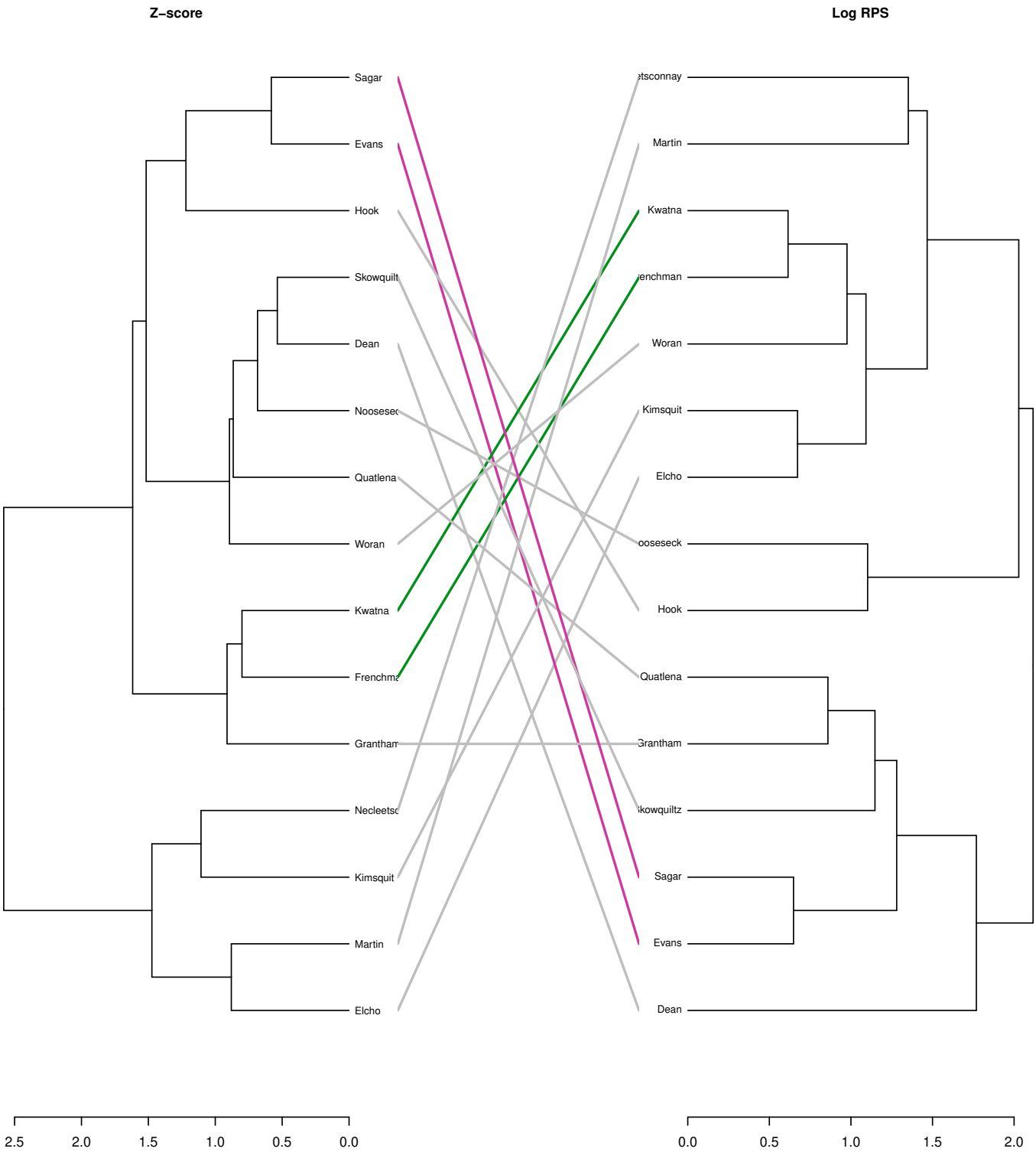


Figure 15: Tanglegram of z-score vs. log RPS

Pre- and post-1980 correlation analyses

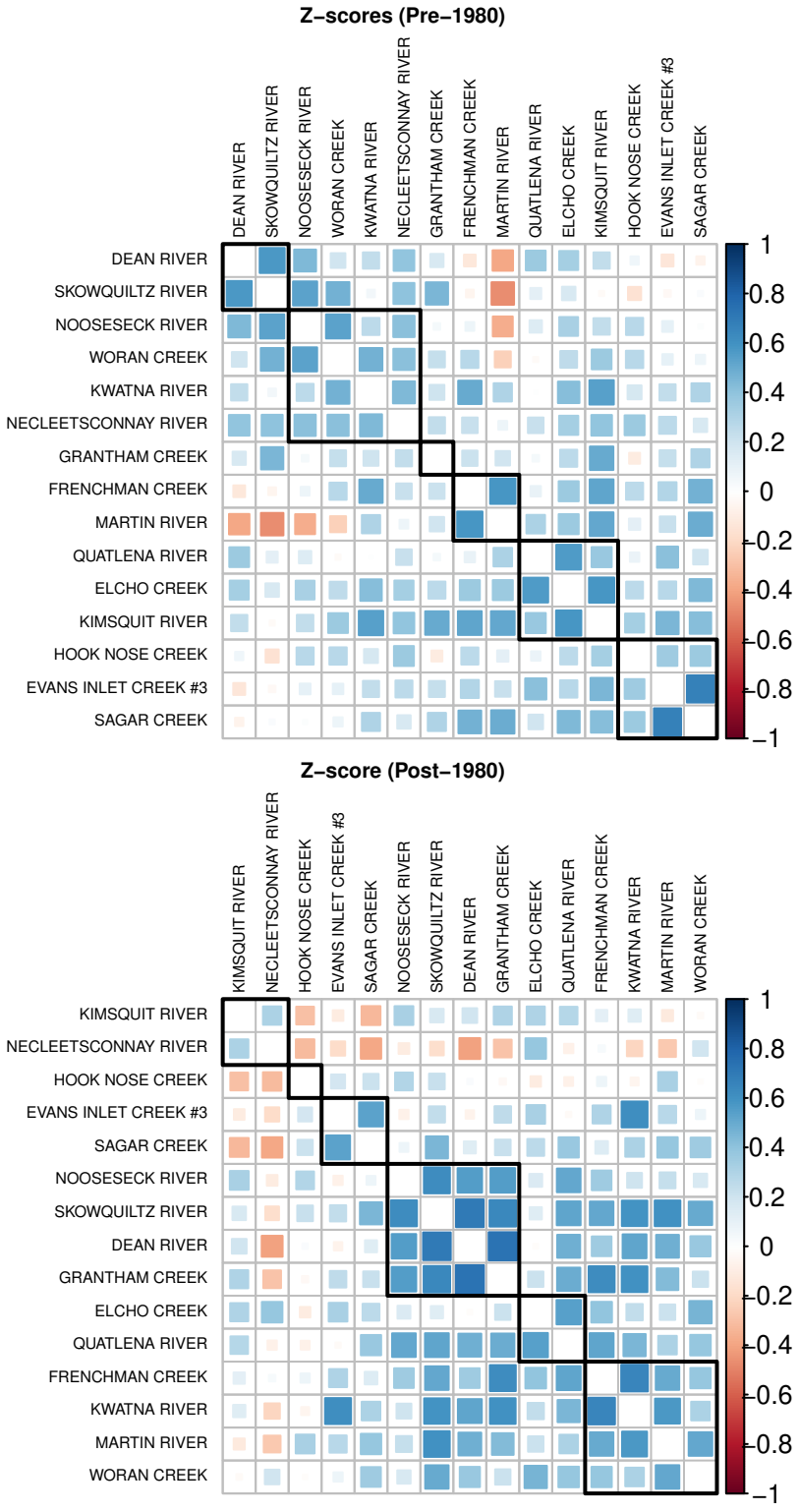


Figure 16: Cross correlation plots of z-scores to compare pre- and post-enhancement.

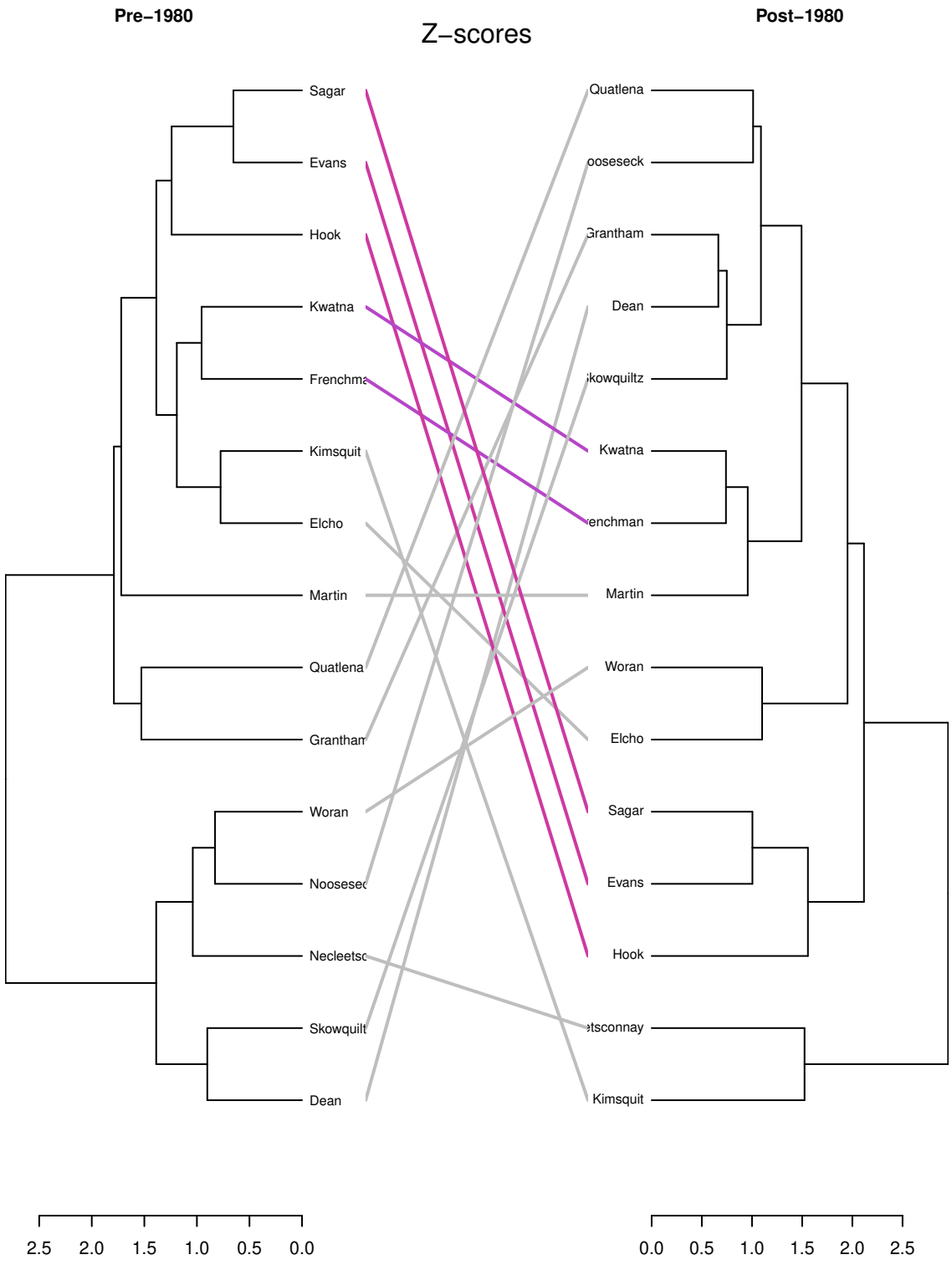


Figure 17: Tanglegram comparing z-scores pre- and post-enhancement (1980)

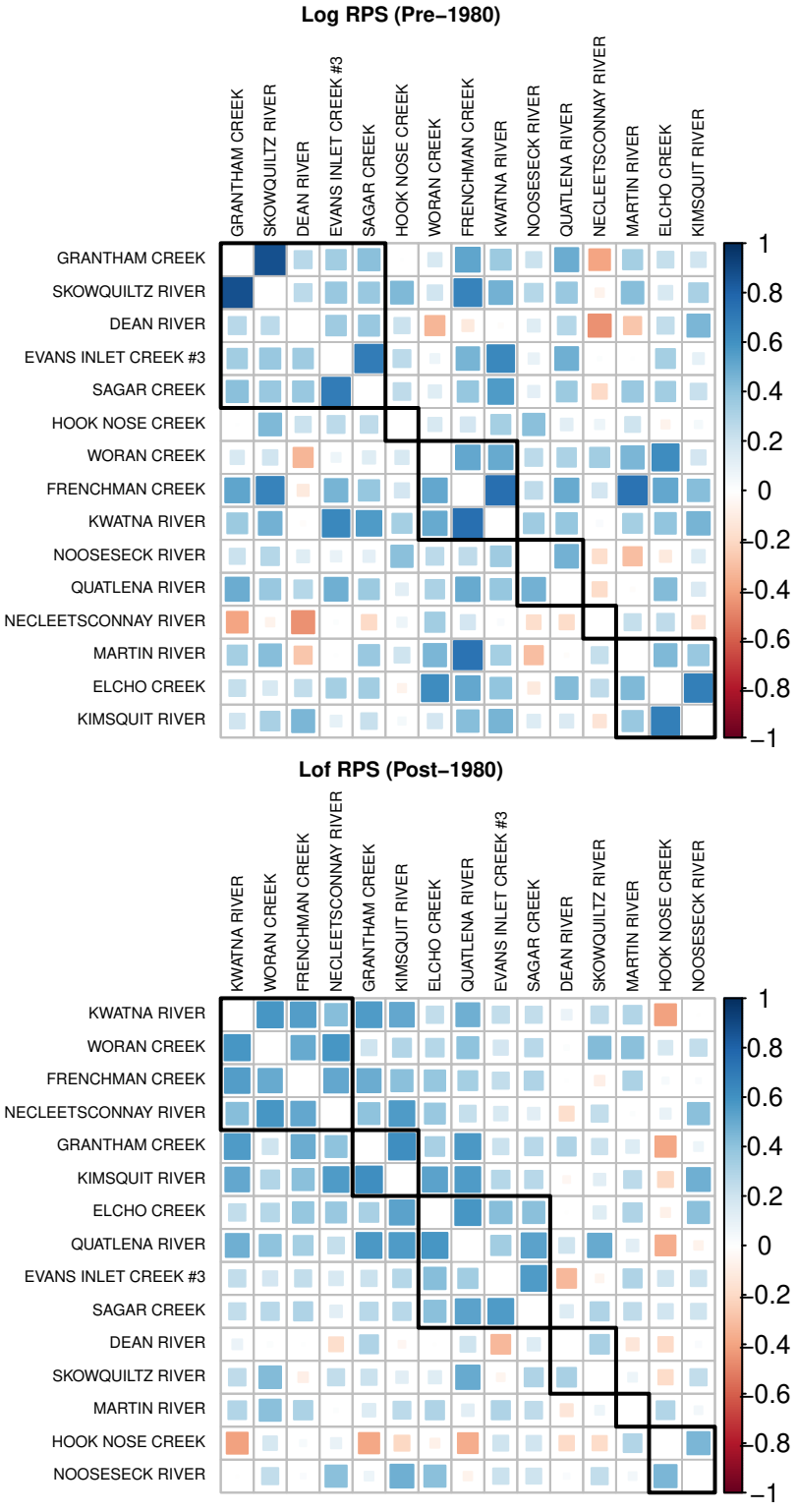


Figure 18: Cross correlation plots of Log RPS to compare pre- and post-enhancement.

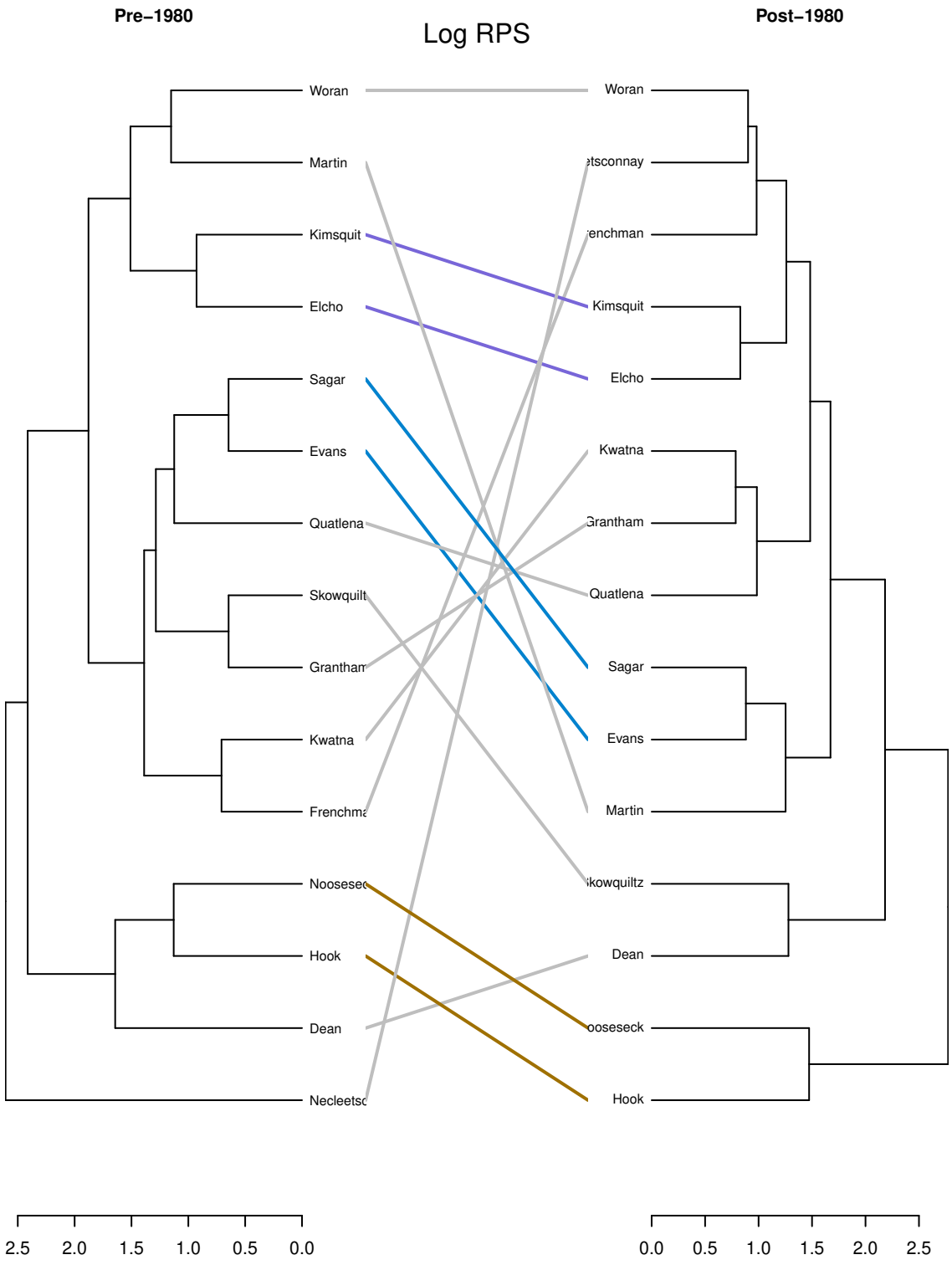


Figure 19: Tanglegram comparing Log RPS pre- and post-enhancement (1980)

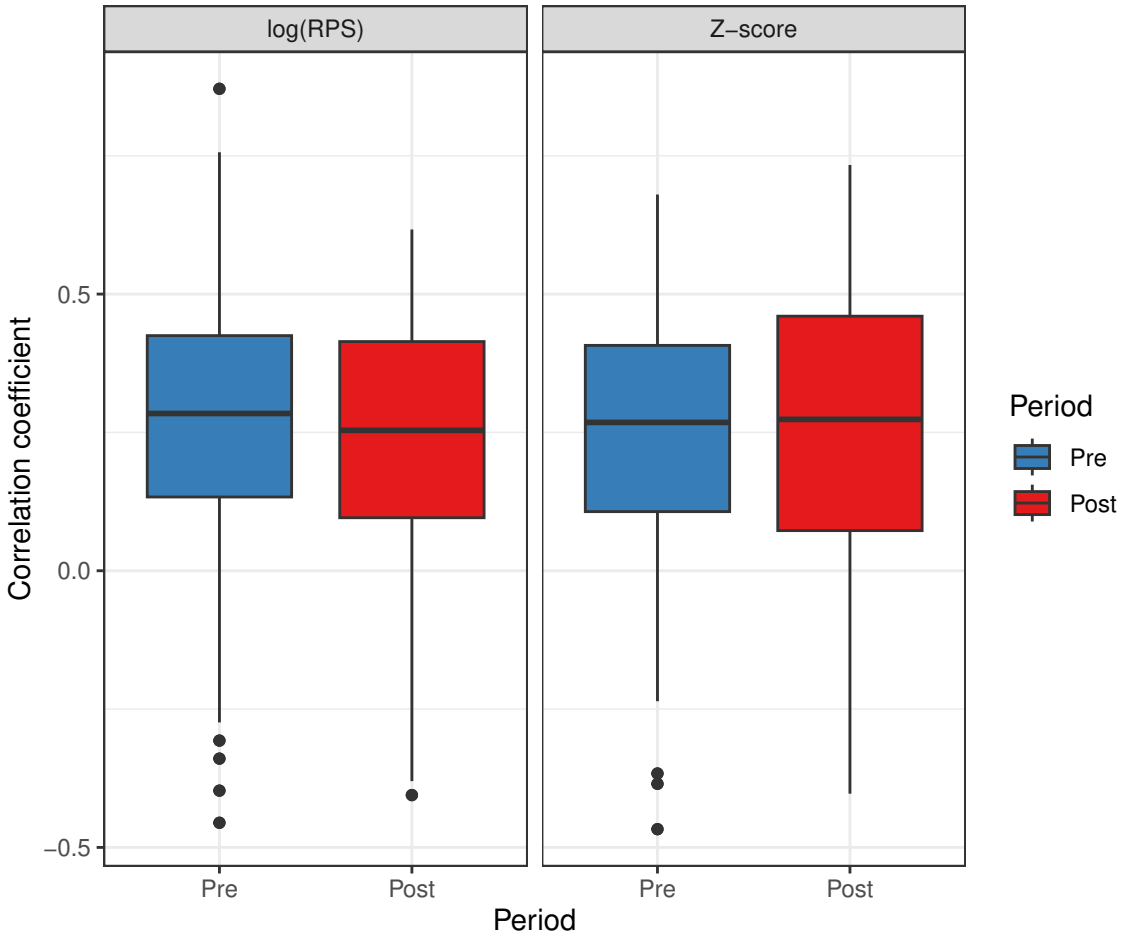


Figure 20: Comparison between correlation coefficients for all pairwise combinations of streams using Z-score and log(RPS) over the pre- and post-1980 periods.

Pairwise stream to stream correlation versus distance

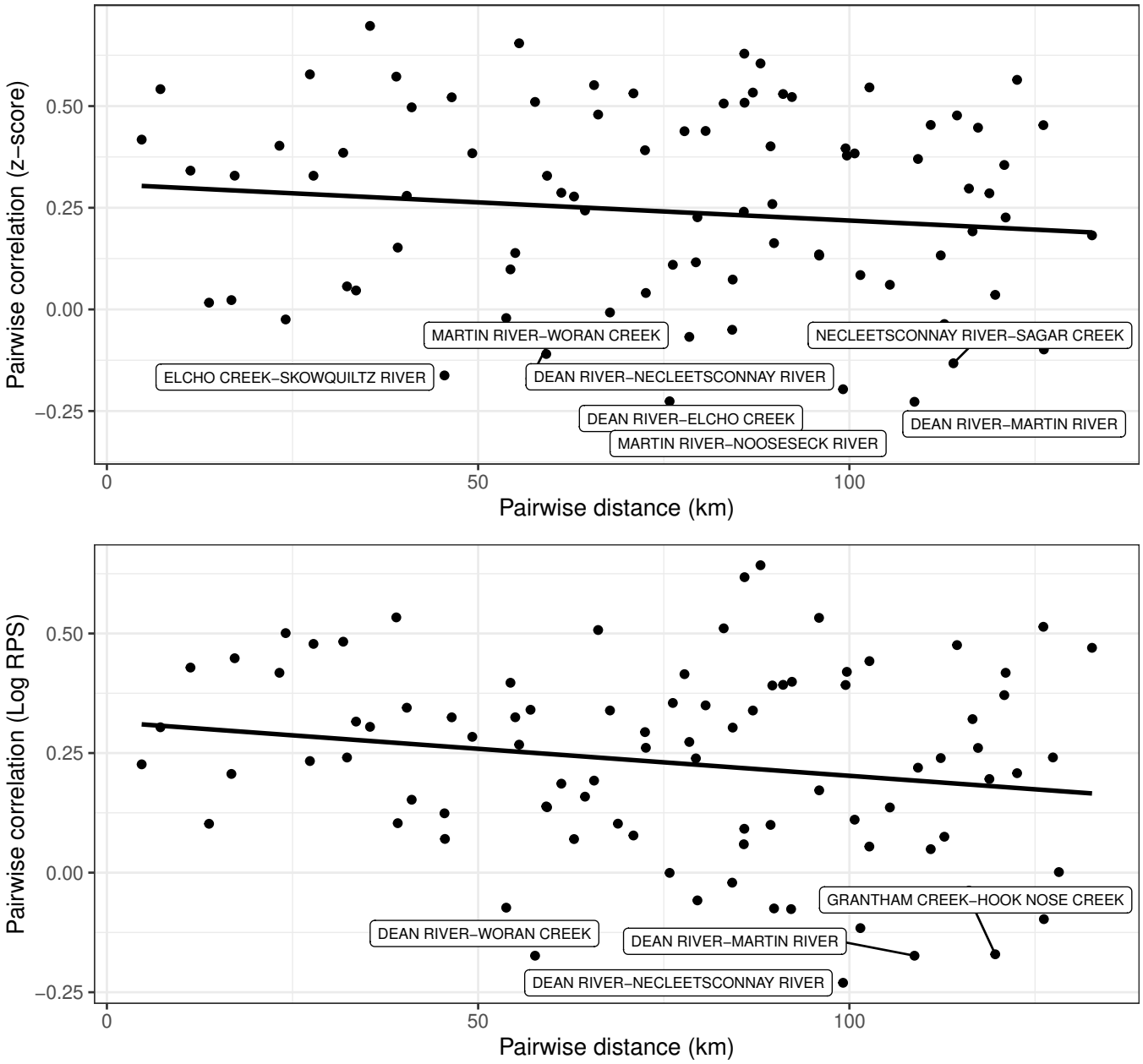


Figure 21: Pairwise stream-stream correlation of Z-score (top) and log(RPS) (bottom) against pairwise distance.

Dendrogram of pairwise distances

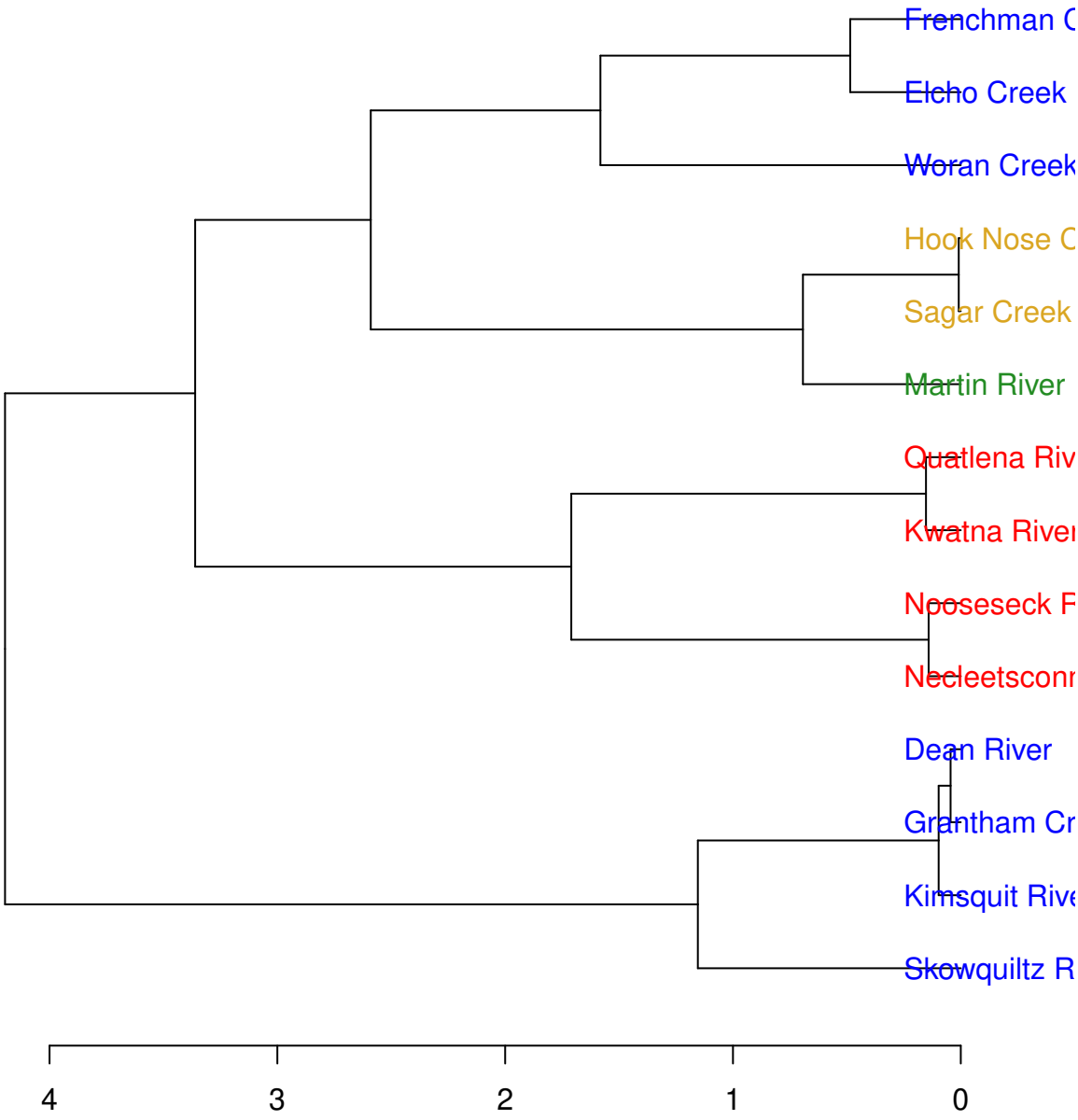


Figure 22: Dendrogram of pairwise distance between river mouths. Red labels - Bella Coola Inlet; Blue - Dean Inlet; Green - Martin Inlet; Yellow - Outer Inlet

Correlation metrics against distance, pre- and post-1980

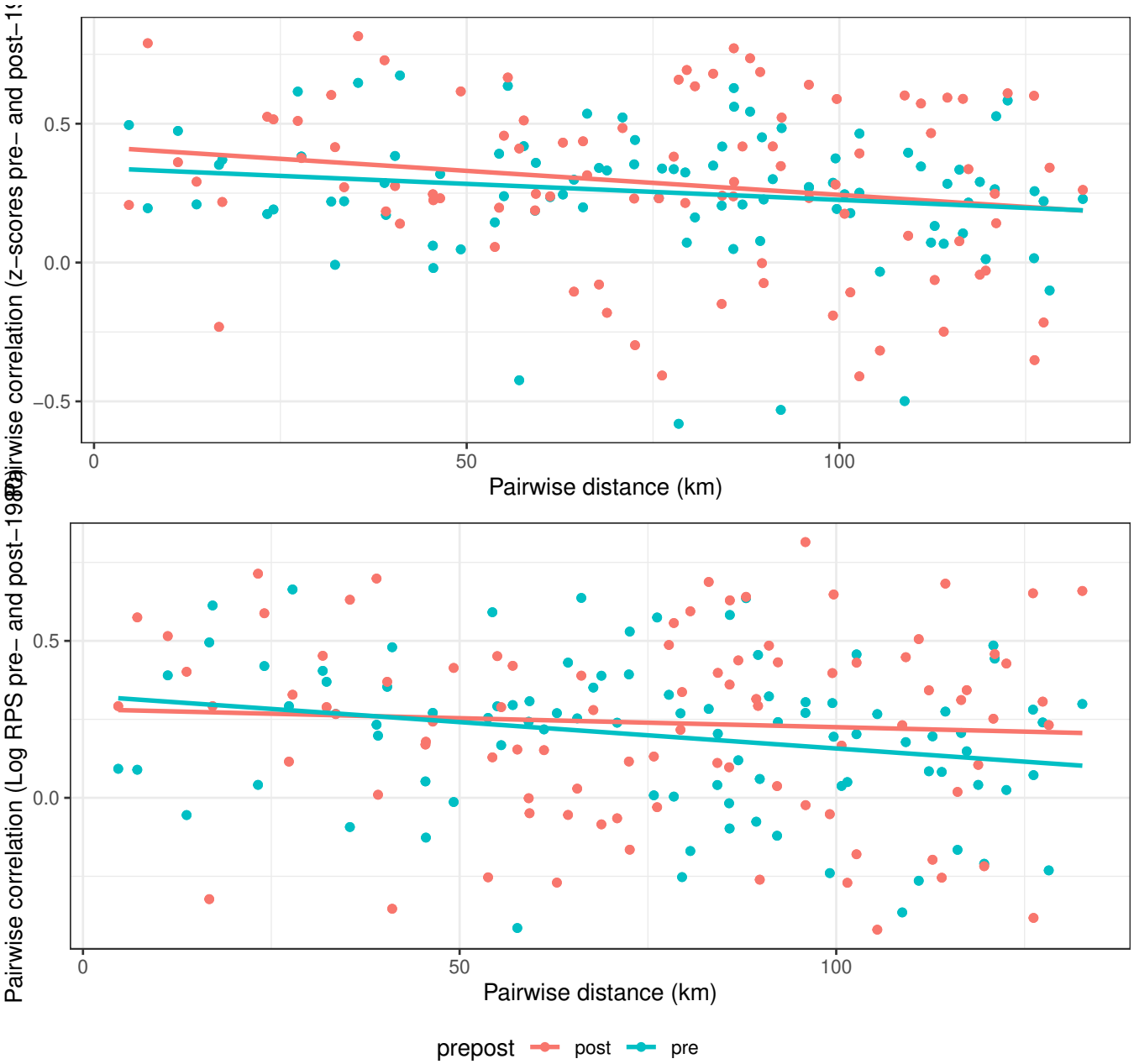


Figure 23: Pairwise stream-stream correlation of Z-score (top) and log(RPS) (bottom) against pairwise distance by period (pre-enhancement and post-enhancement.

Statistical models

Candidate Models with AIC scores for log RPS and log escapement

Table 2: Candidate models for log RPS and distance from enhancement (dist), total releases (totrel), and year, with AIC scores.

Candidate model	df	AIC
Log RPS ~ Wt. dist. Bella Coola + Wt. dist. McLoughlin + Rel.McLoughin + Rel.Bella Coola + Year	7	2776.004
Log RPS ~ dist from Bella Coola + dist from McLoughlin	4	2783.424
Log RPS ~ Wt. dist. from Bella Coola + Wt. dist. from McLoughlin	4	2783.424
Log RPS ~ dist from Bella Coola + dist from McLoughlin + Year	5	2785.416
Log RPS ~ Wt. dist. from Bella Coola + Wt. dist. from McLoughlin + Year	5	2785.416
Log RPS ~ dist from Bella Coola + dist from McLoughlin + Year + Subinlet	9	2790.437
Log RPS ~ Wt. dist. from Bella Coola + Wt. dist. from McLoughlin + Year + Subinlet	9	2790.437

Table 3: Candidate models for log escapement and distance from enhancement (dist), total releases (totrel), and year, with AIC scores.

Candidate model	df	AIC
Log escapement ~ dist from Bella Coola + dist from McLoughlin + Year + Subinlet	9	3019.123
Log escapement ~ Wt. dist. from Bella Coola + Wt. dist. from McLoughlin + Year + Subinlet	9	3019.123
Log escapement ~ Wt.dist.BellaCoola + Wt.dist.McLoughlin + Rel.Bella Coola + Rel.McLoughlin + Year	7	3045.062
Log escapement ~ Wt. dist. from Bella Coola + Wt. dist. from McLoughlin	4	3059.479
Log escapement ~ dist from Bella Coola + dist from McLoughlin	4	3059.479
Log escapement ~ dist from Bella Coola + dist from McLoughlin + Year	5	3060.954
Log escapement ~ Wt. dist. from Bella Coola + Wt. dist. from McLoughlin + Year	5	3060.954

Effects plots for top model: log(RPS)

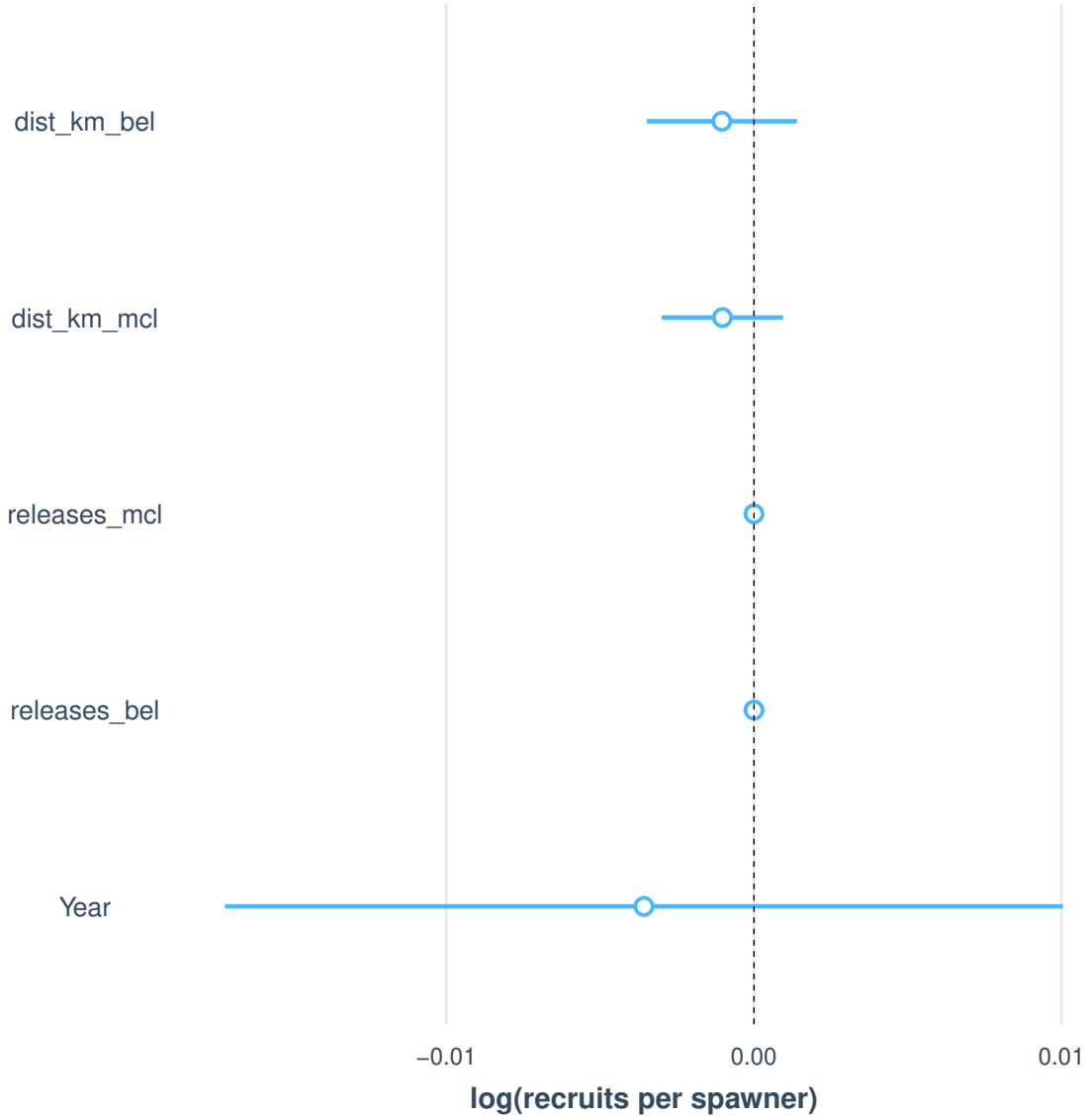


Figure 24: Plot of effects included in the most parsimonious model for log(RPS).

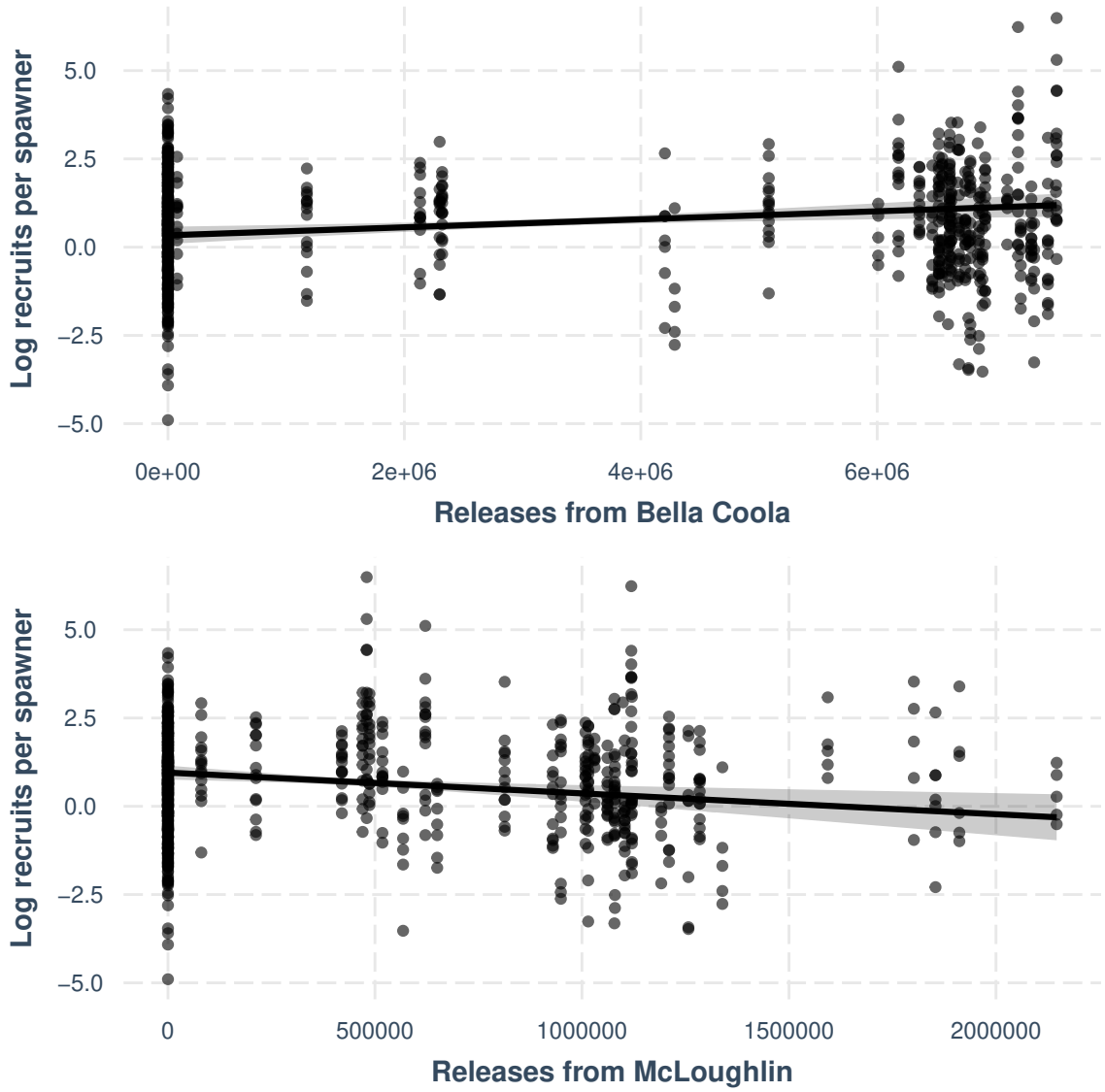


Figure 25: Effects plots of recruits per spawner by releases from Bella Coola (top) and releases from Mclouhglin Creek (bottom).

Effects plots for top model: log(escapement)

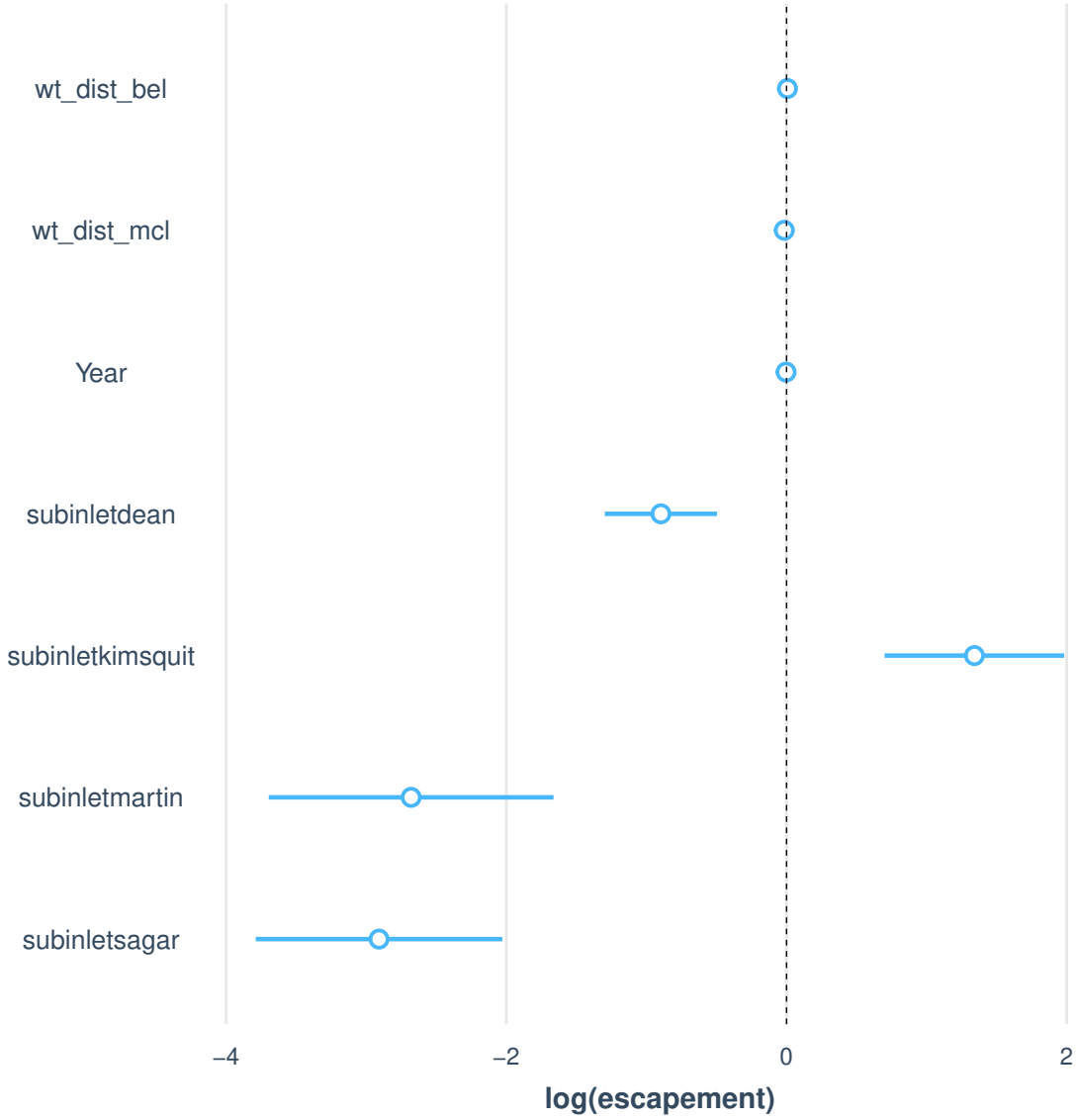
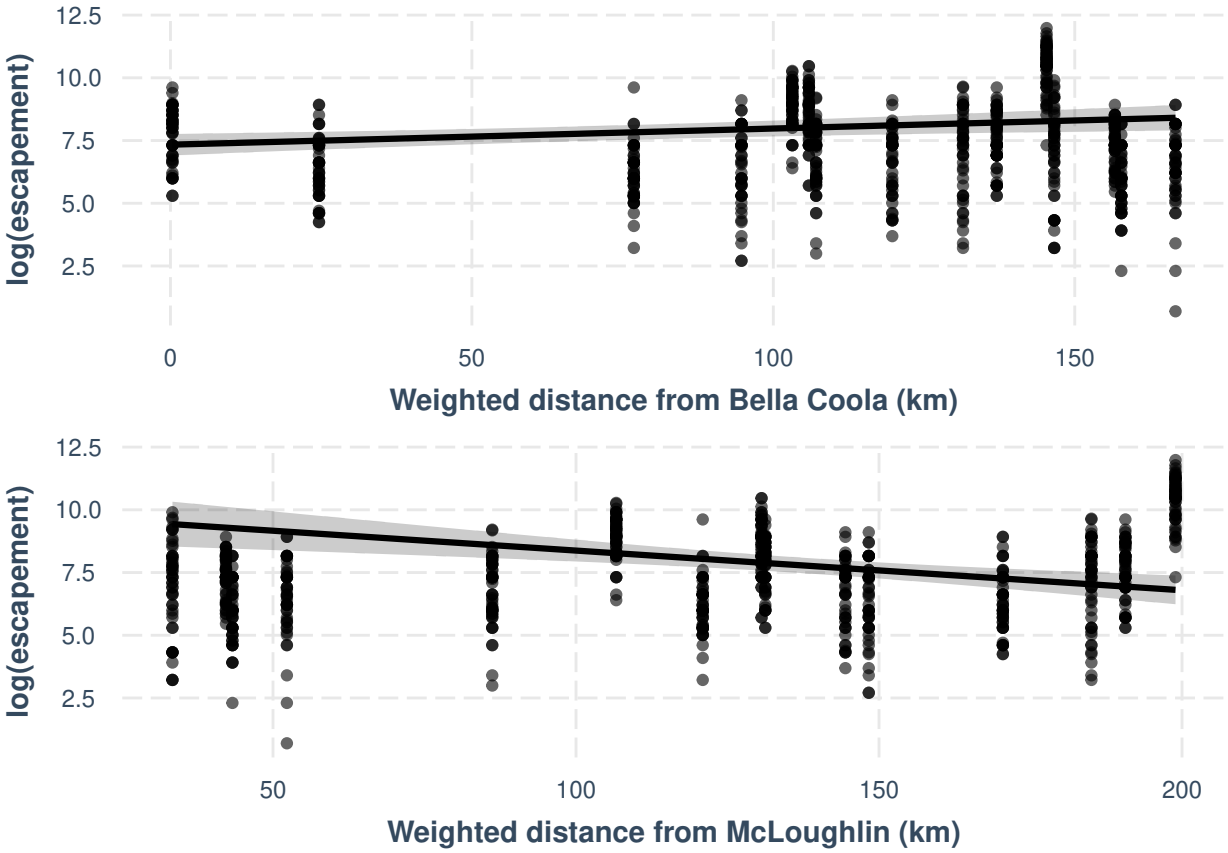


Figure 26: Plot of effects included in the most parsimonious model for log(escapement).


log(escapement)
12.5
10.0
7.5
5.0
2.5
0
50
100
150
Weighted distance from Bella Coola (km)
log(escapement)
12.5
10.0
7.5
5.0
2.5
50
100
150
200
Weighted distance from McLoughlin (km)

Appendix 3

Area 06 - Douglas Gardner CU Chum Salmon

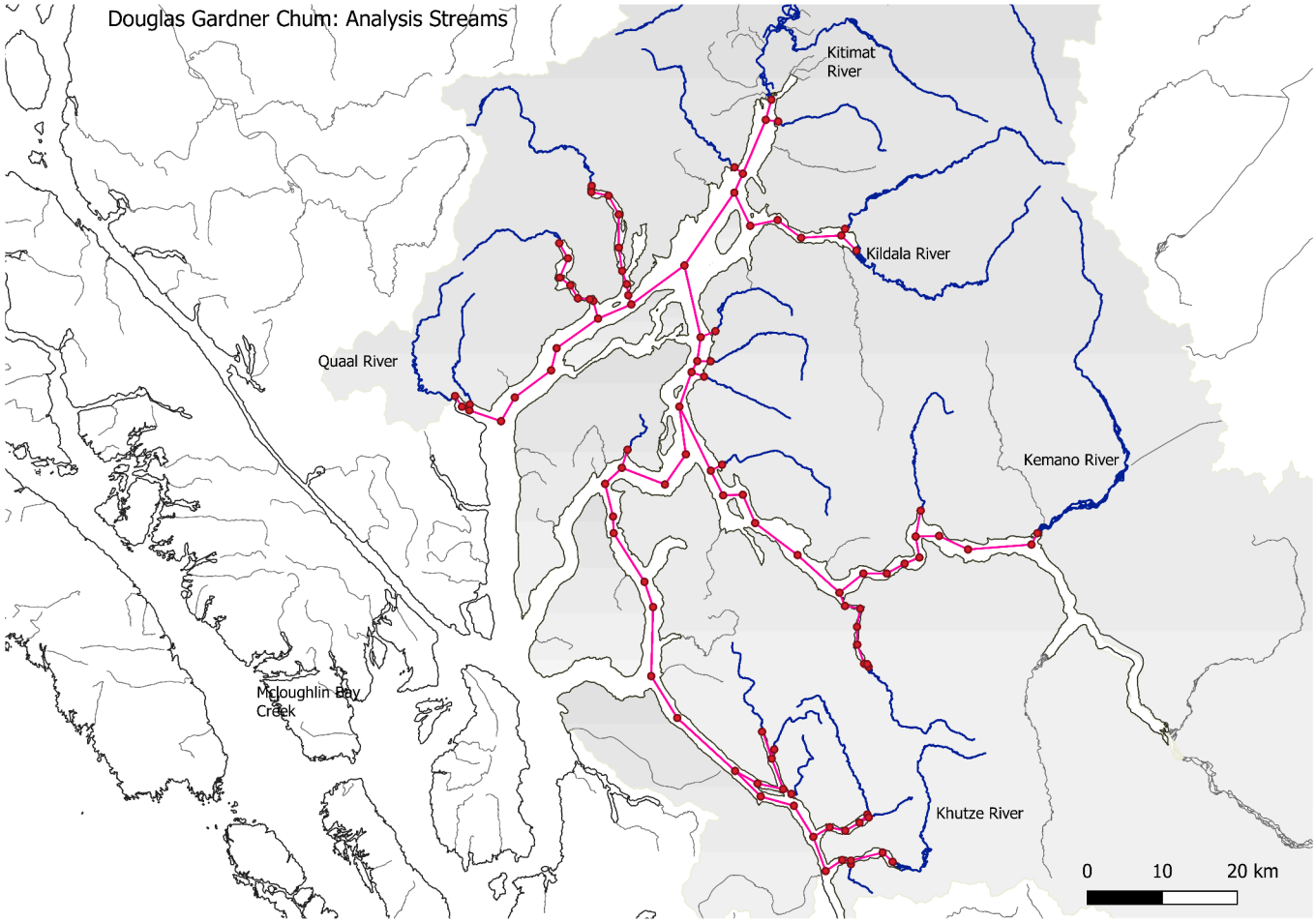
Coastland

2023-03-08

Contents

Study area

Douglas Gardner CU



Summary figures

Escapement: Raw and filtered stream list

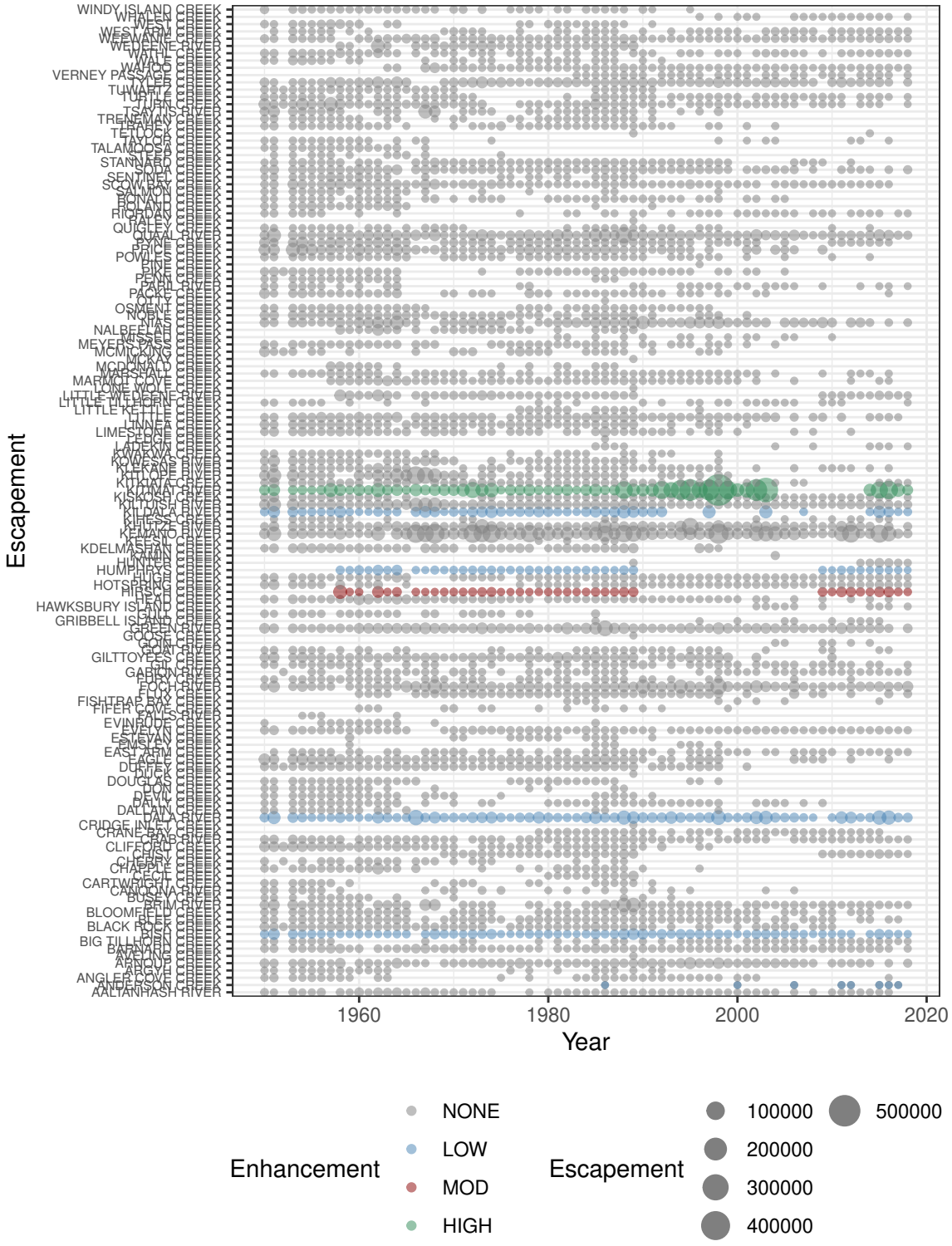


Figure 1: Escapement to all Douglas-Gardner chum streams in the PSE database, by enhancement rank.

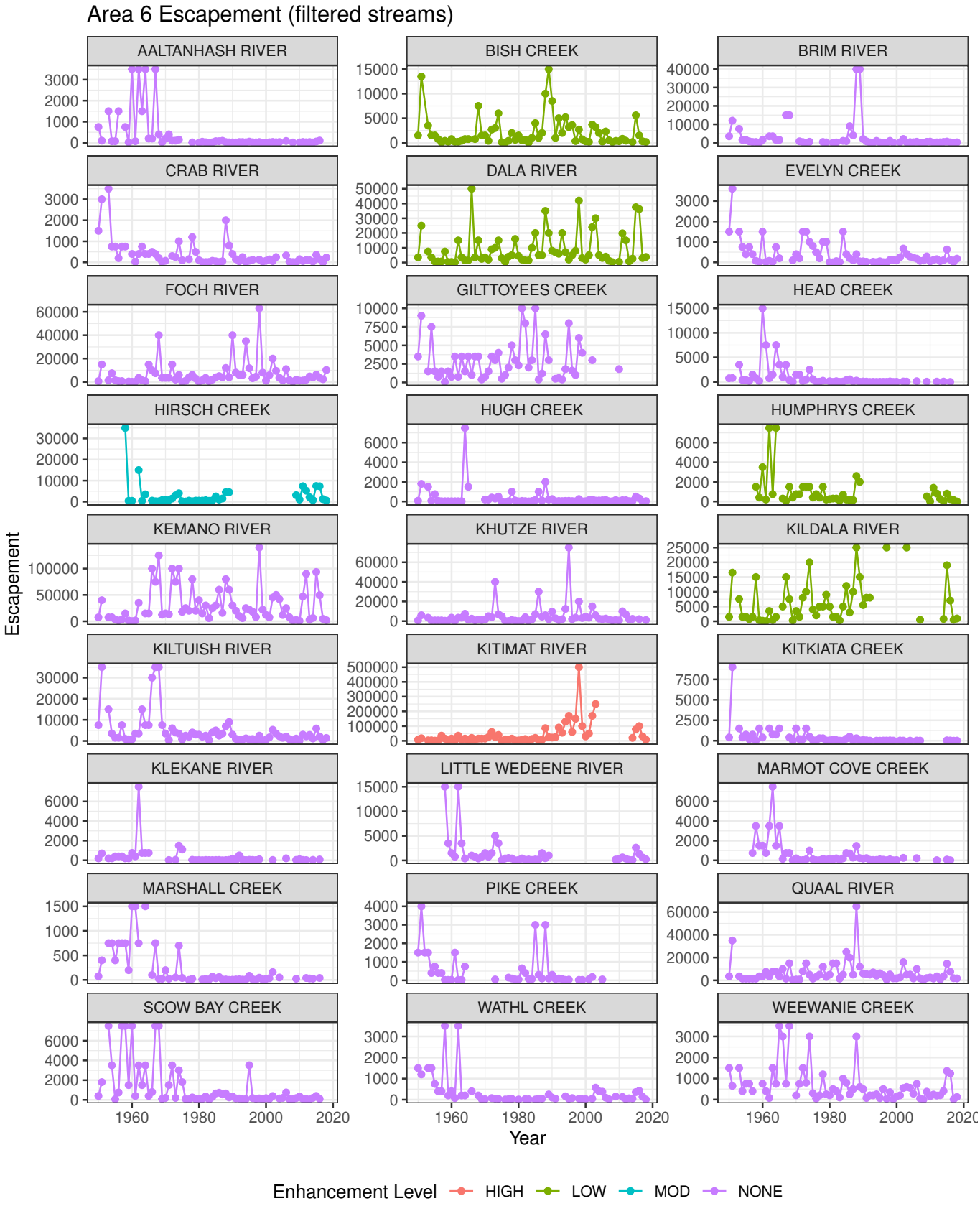


Figure 2: Escapement to filtered streams for Douglas-Gardner chum. Colour shows the stream enhancement level from the PSE database.

Table 1: Distance from Kitimat River (major enhancement location for chum systems included in analysis.

Stream	Dist. from enhancement
WATHL CREEK	4.470
BISH CREEK	11.998
DALA RIVER	32.303
KILDALA RIVER	34.146
HUGH CREEK	37.112
WEEWANIE CREEK	39.982
PIKE CREEK	41.635
FOCH RIVER	52.191
GILTTOYEES CREEK	52.216
CRAB RIVER	55.985
KITKIATA CREEK	63.528
EVELYN CREEK	64.768
QUAAL RIVER	65.544
KILTUISH RIVER	91.658
BRIM RIVER	97.710
KEMANO RIVER	111.829
MARMOT COVE CREEK	117.746
SCOW BAY CREEK	122.091
KLEKANE RIVER	124.855
HEAD CREEK	132.104
AALTANHASH RIVER	132.200
MARSHALL CREEK	133.004
KHUTZE RIVER	138.697

Hatchery Releases: Total and by release site

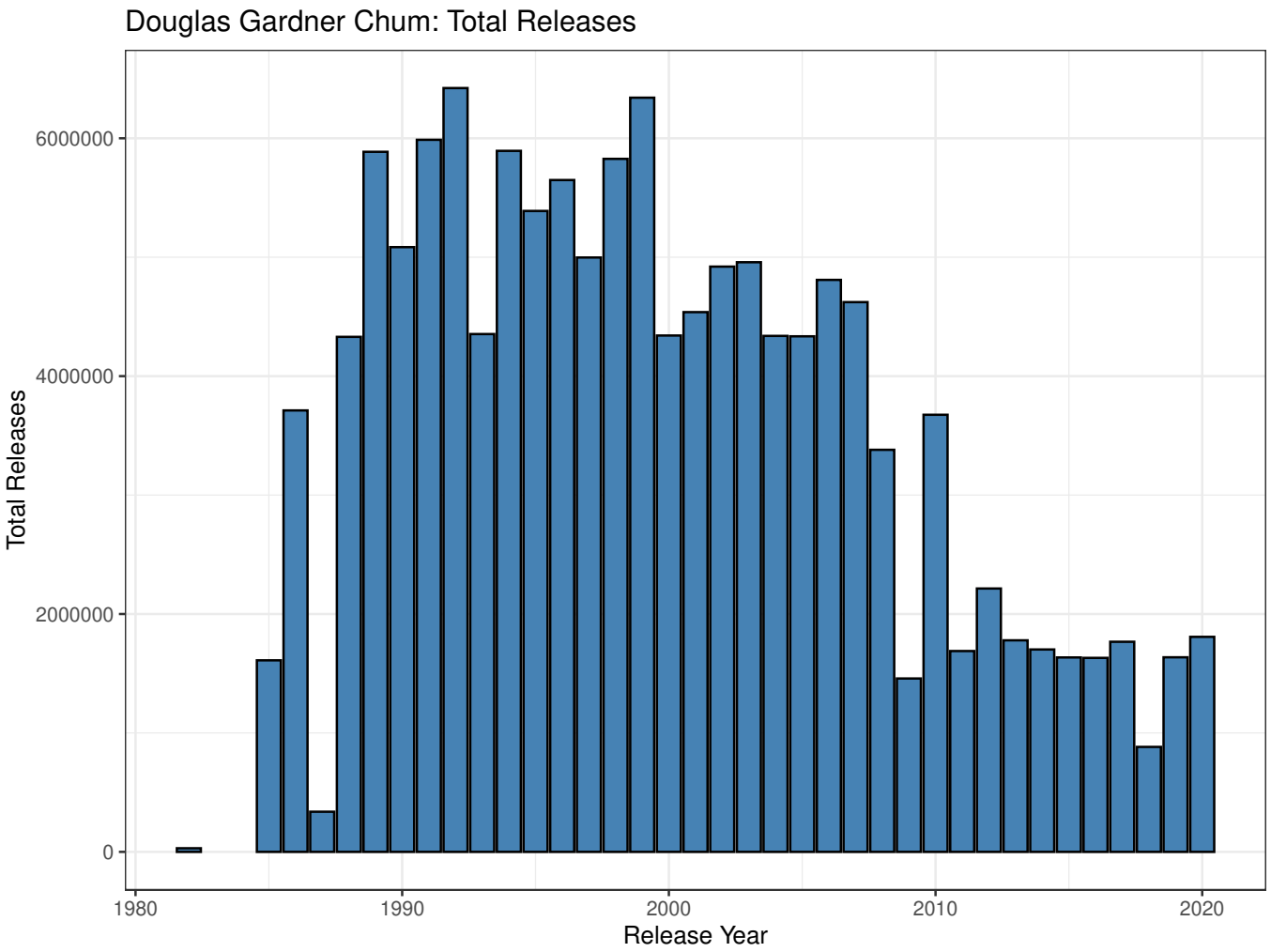


Figure 3: Total releases in the Douglas Gardner CU.

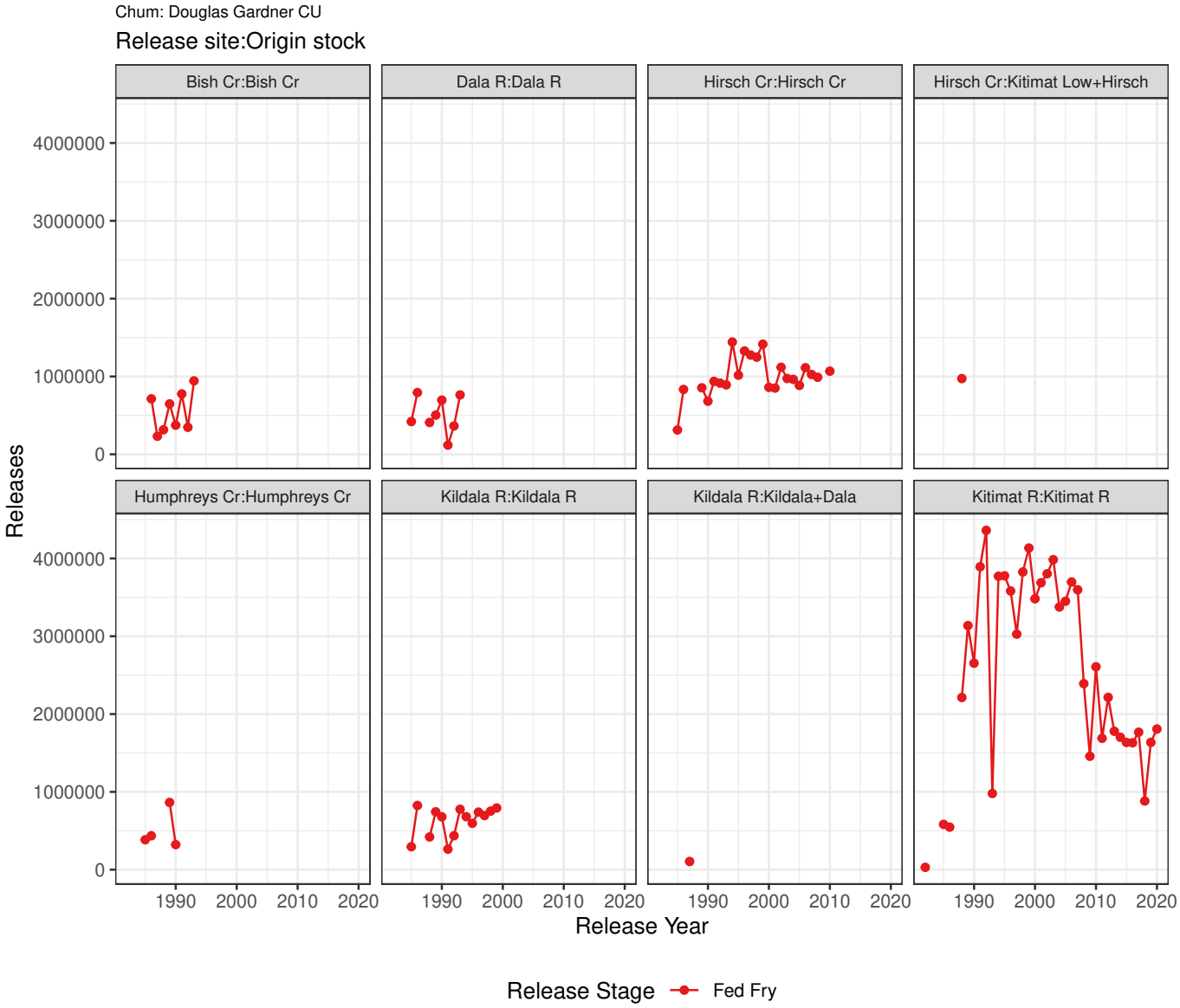


Figure 4: Releases by release site:origin stock for chum in the Douglas Gardner CU.

Metrics

Escapement, logged escapement, Z-scores, Pavg, and moving average

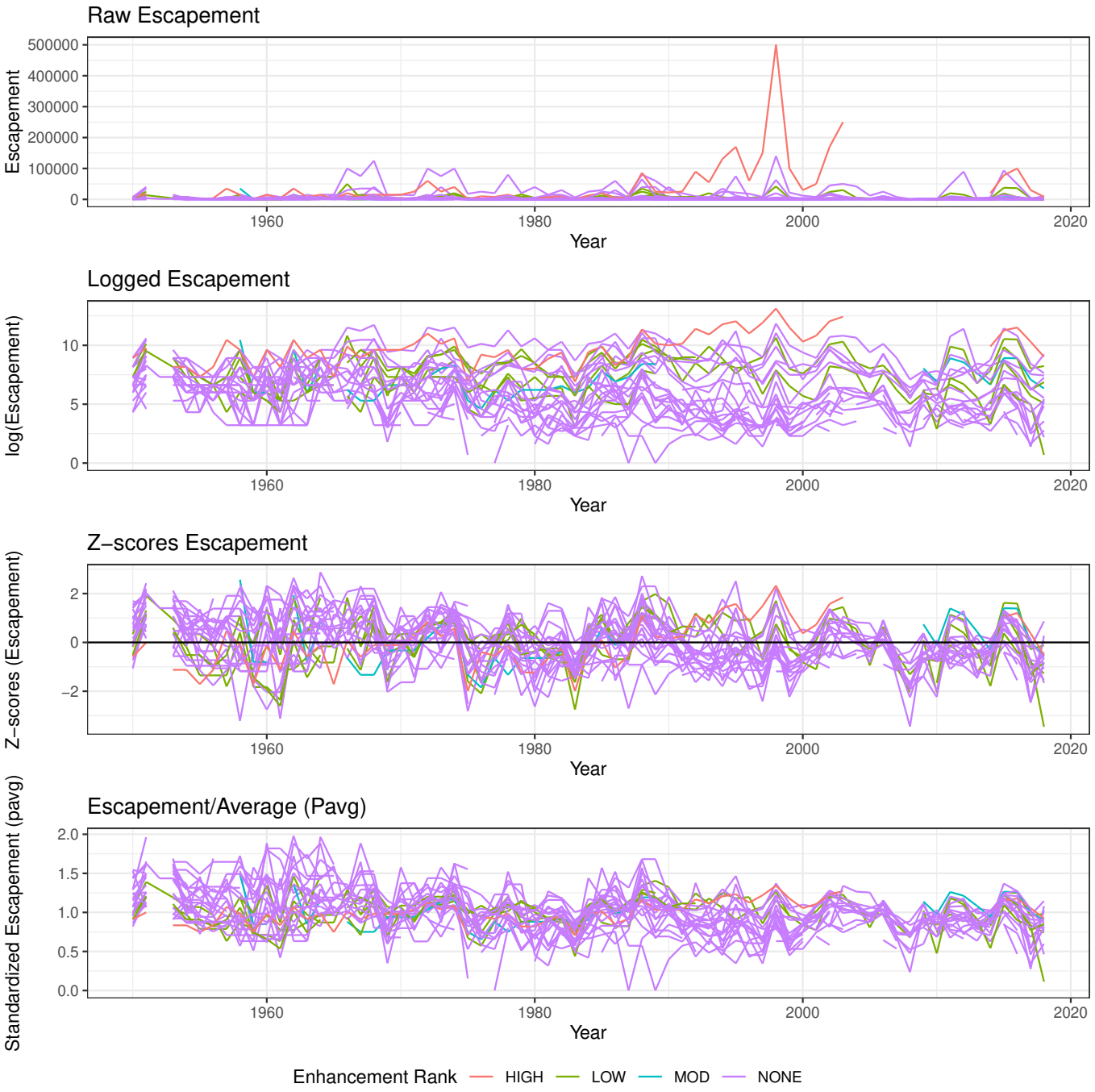


Figure 5: Various plots for escapement and transformations.

Moving average and LOESS fits

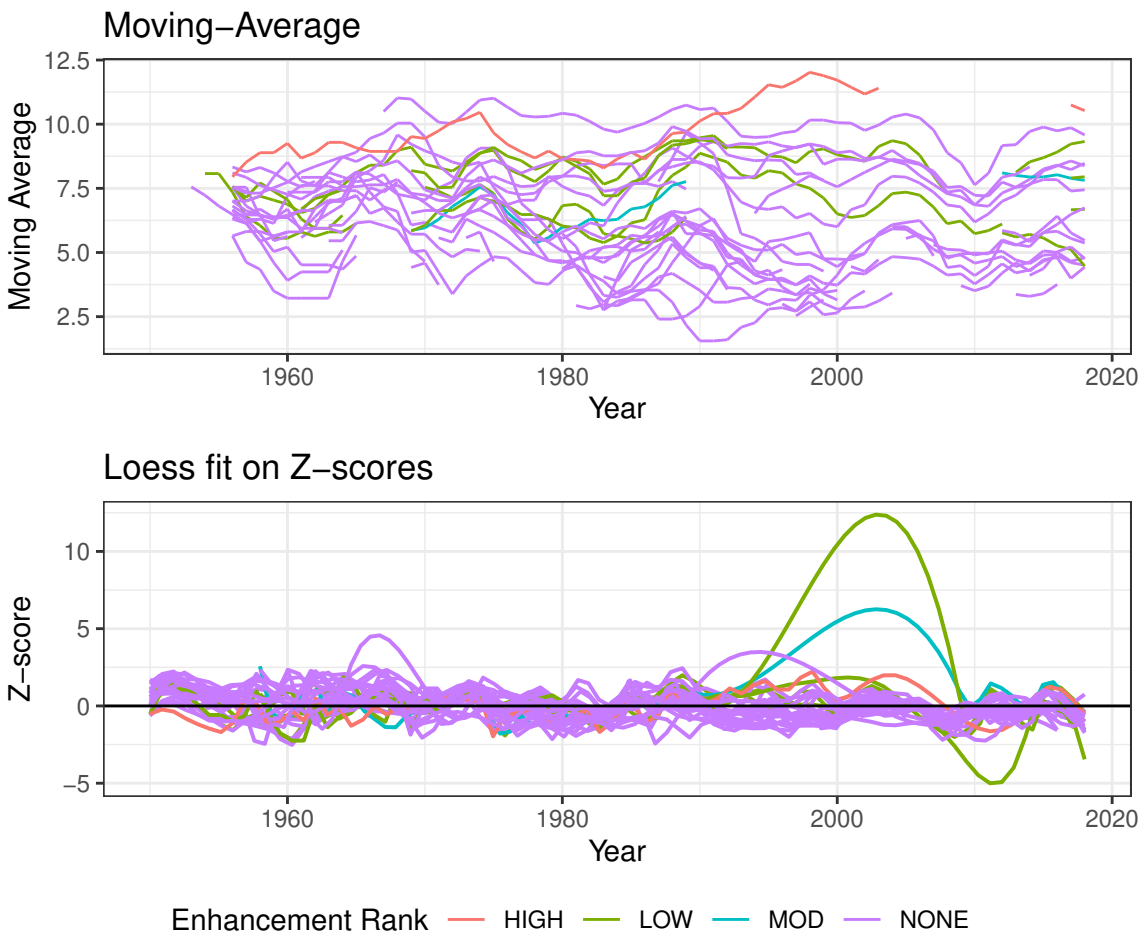


Figure 6: Moving average and LOESS fits on logged escapement by enhancement ranking.

Means trends by enhancement rank

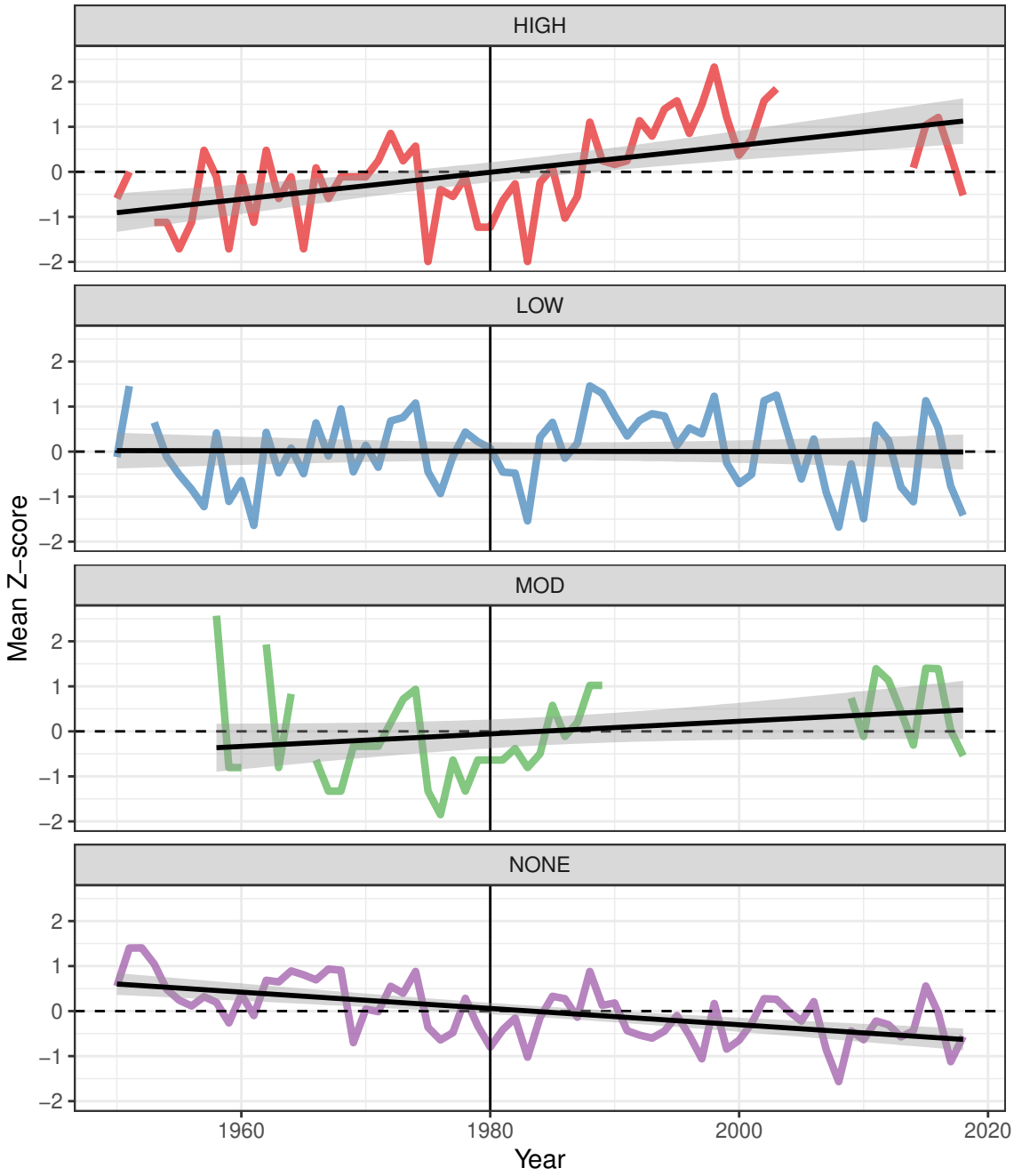


Figure 7: Douglas-Gardner chum: Mean Z-score for analysis streams by enhancement rank. Linear regression over all years with SE are shown.

Recruits per spawners

Recruits per spawner by system

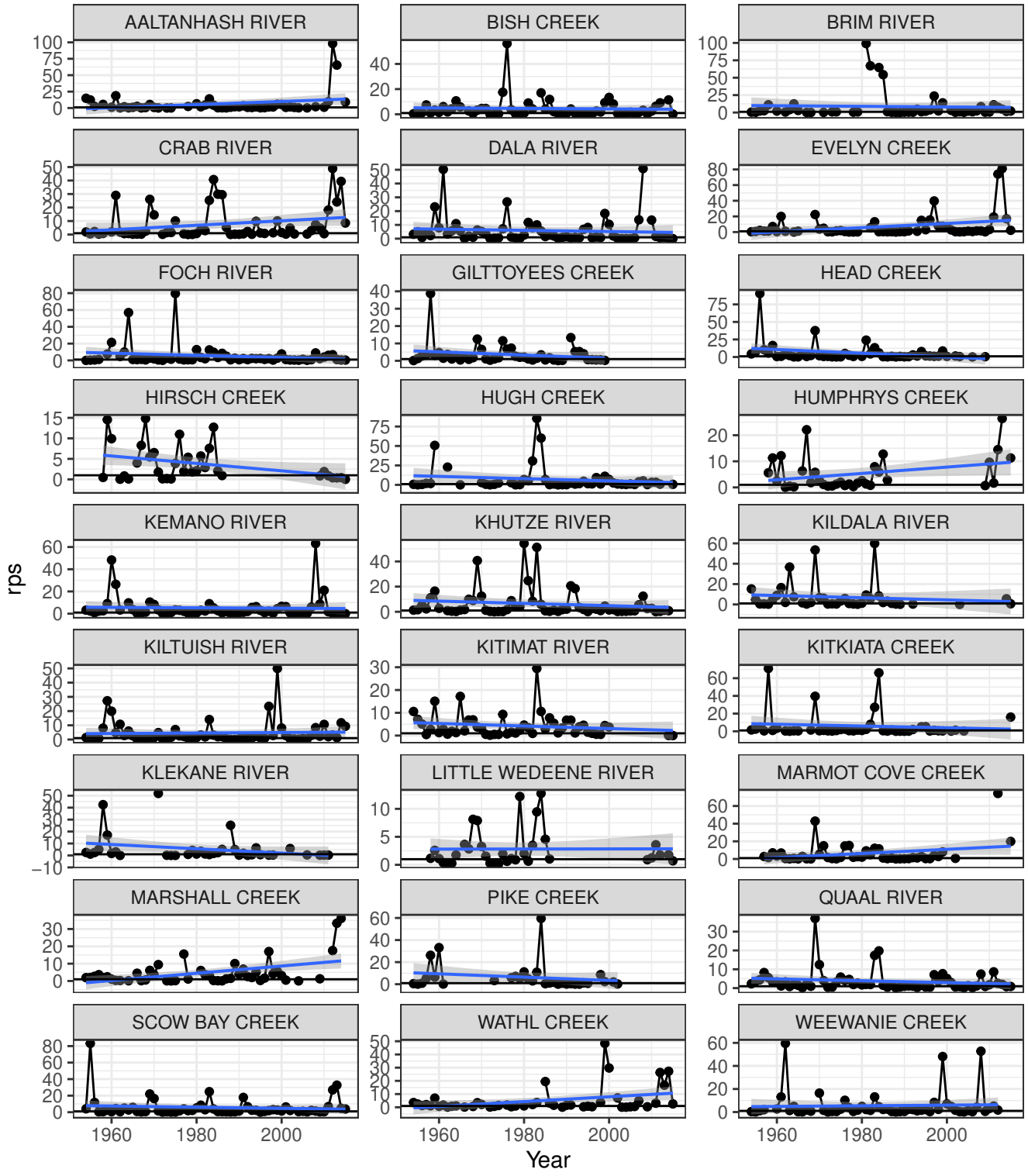


Figure 8: Douglas-Gardner chum: recruits per spawner by system.

Log recruits per spawner by system by period

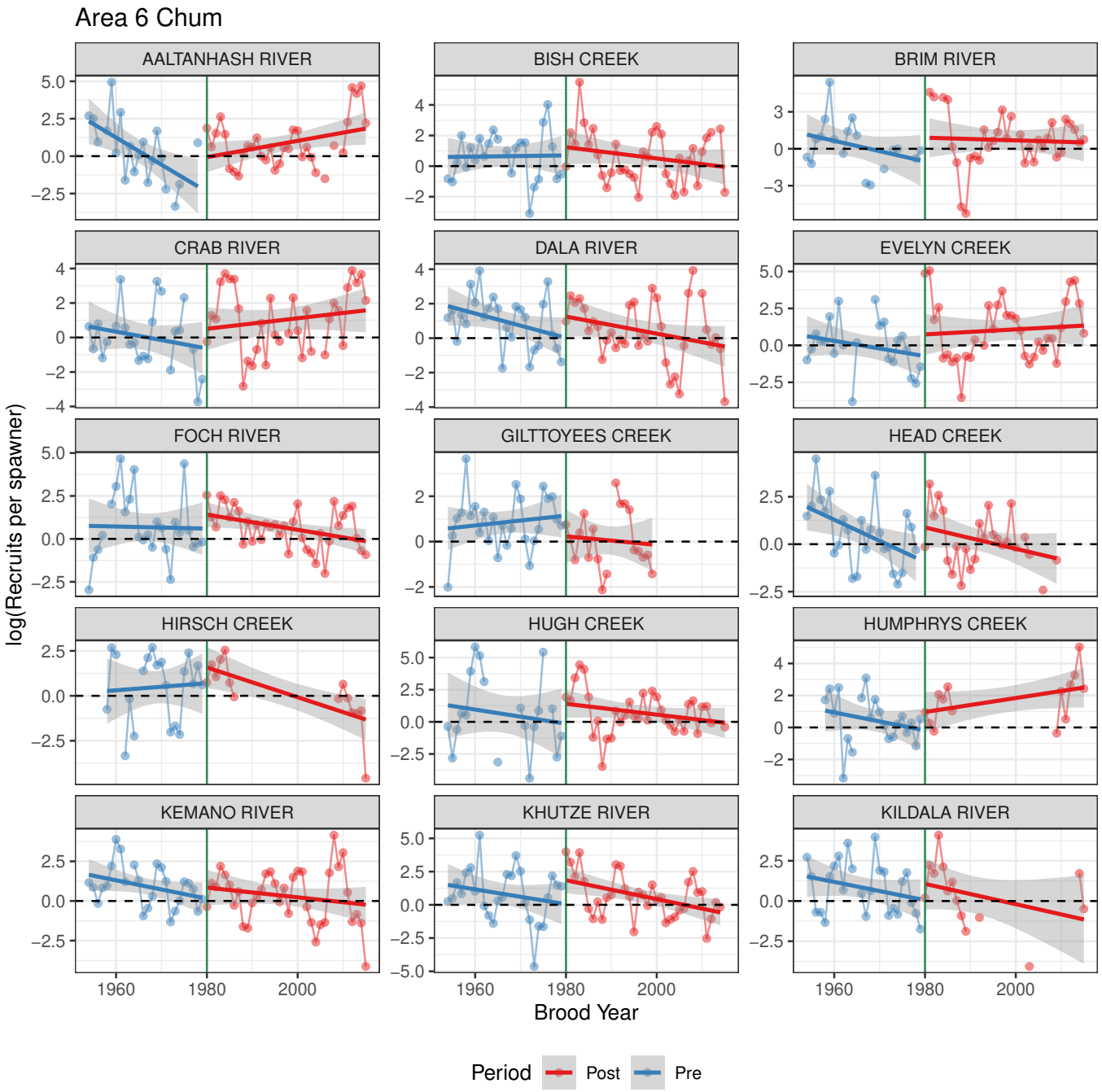


Figure 9: Douglas-Gardner chum: log recruits per spawner by system fitted with linear regression for the periods pre- and post-enhancement (Aaltanhash to Kildala).

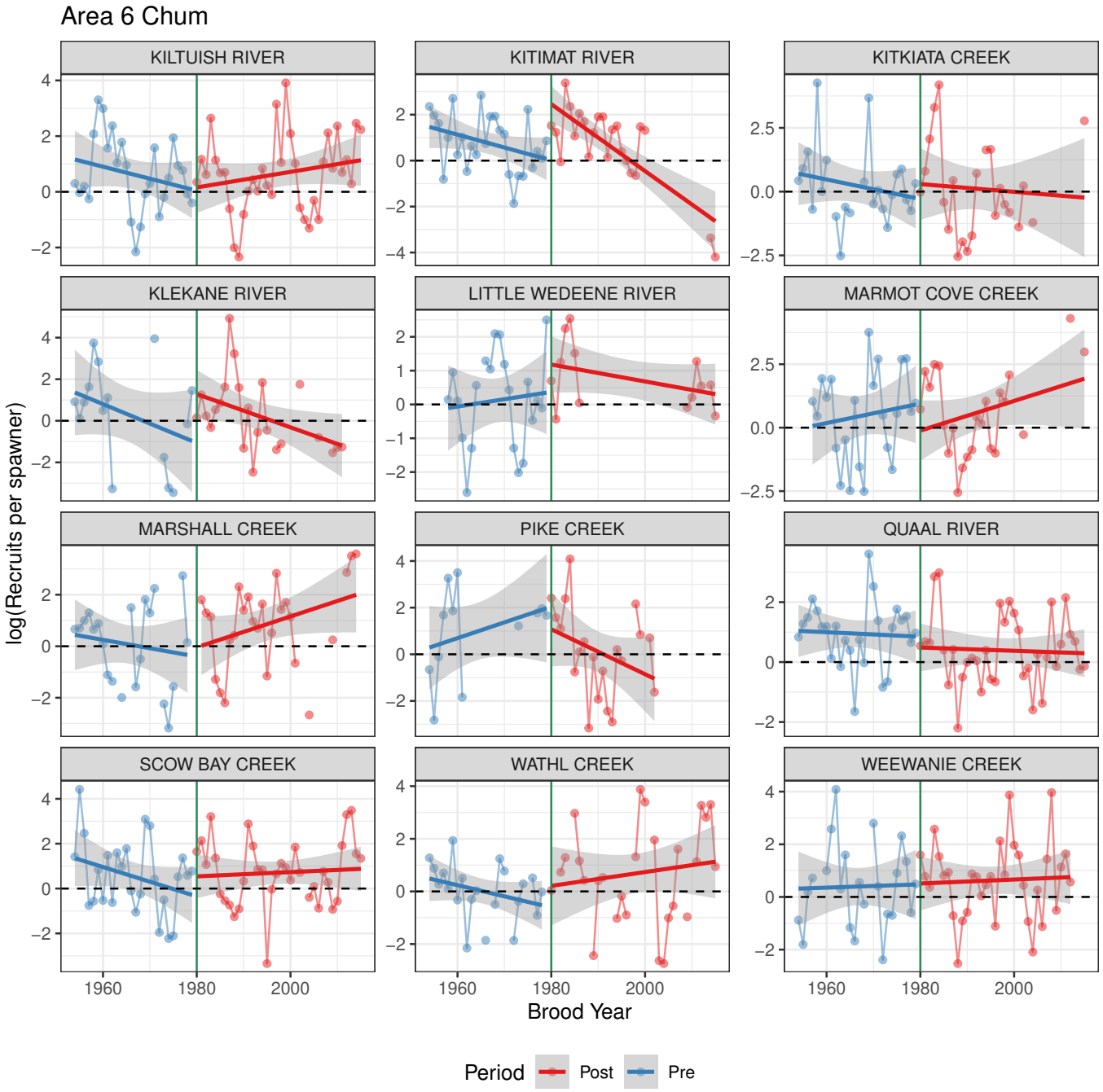


Figure 10: Douglas-Gardner chum: log recruits per spawner by system fitted with linear regression for the periods pre- and post-enhancement (Kiltuish to Weewanie).

Log RPS comparison before and after enhancement

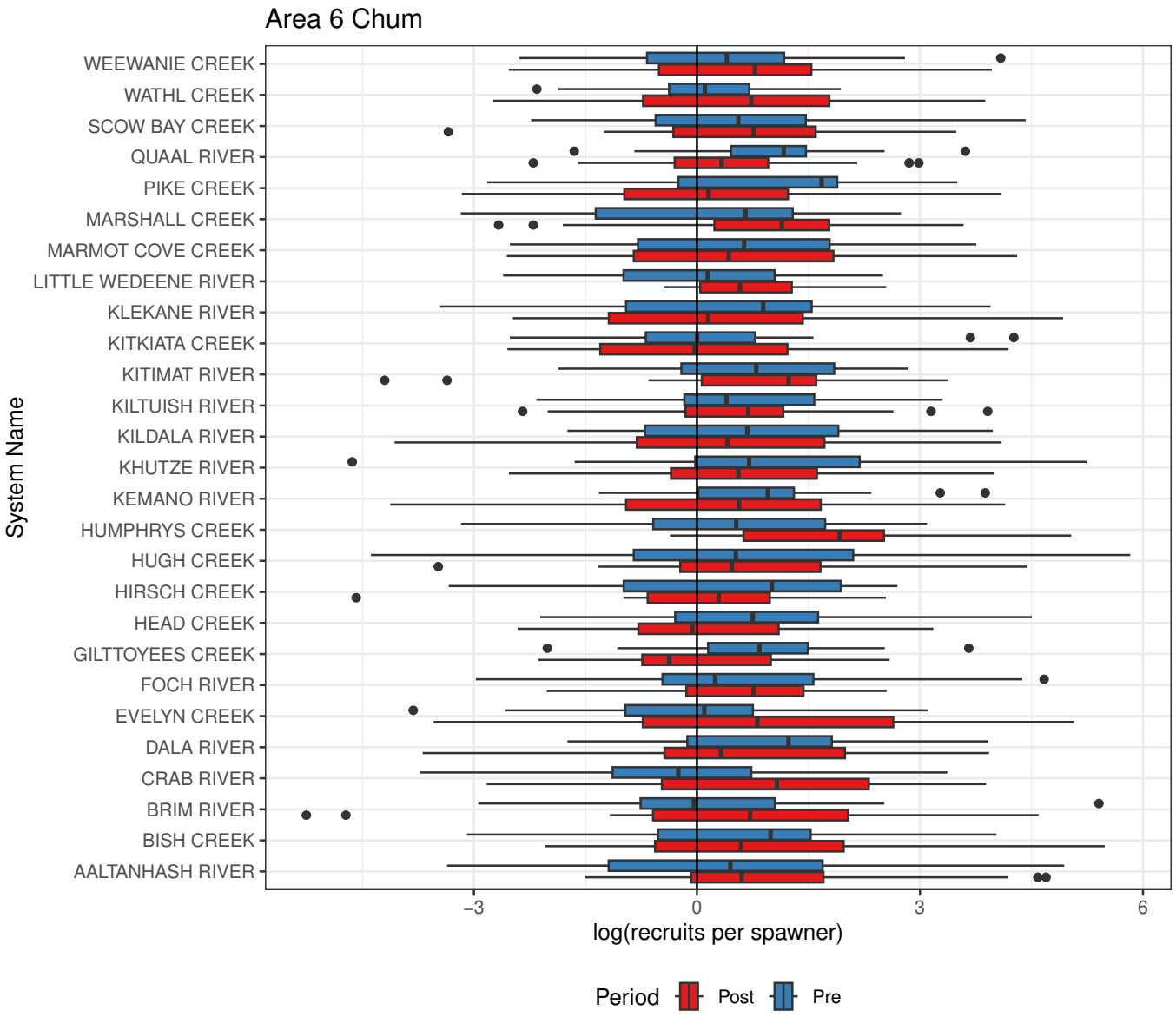


Figure 11: Douglas-Gardner chum: boxplot of log recruits per spawner by system.

Bubbleplots of metric by inlet

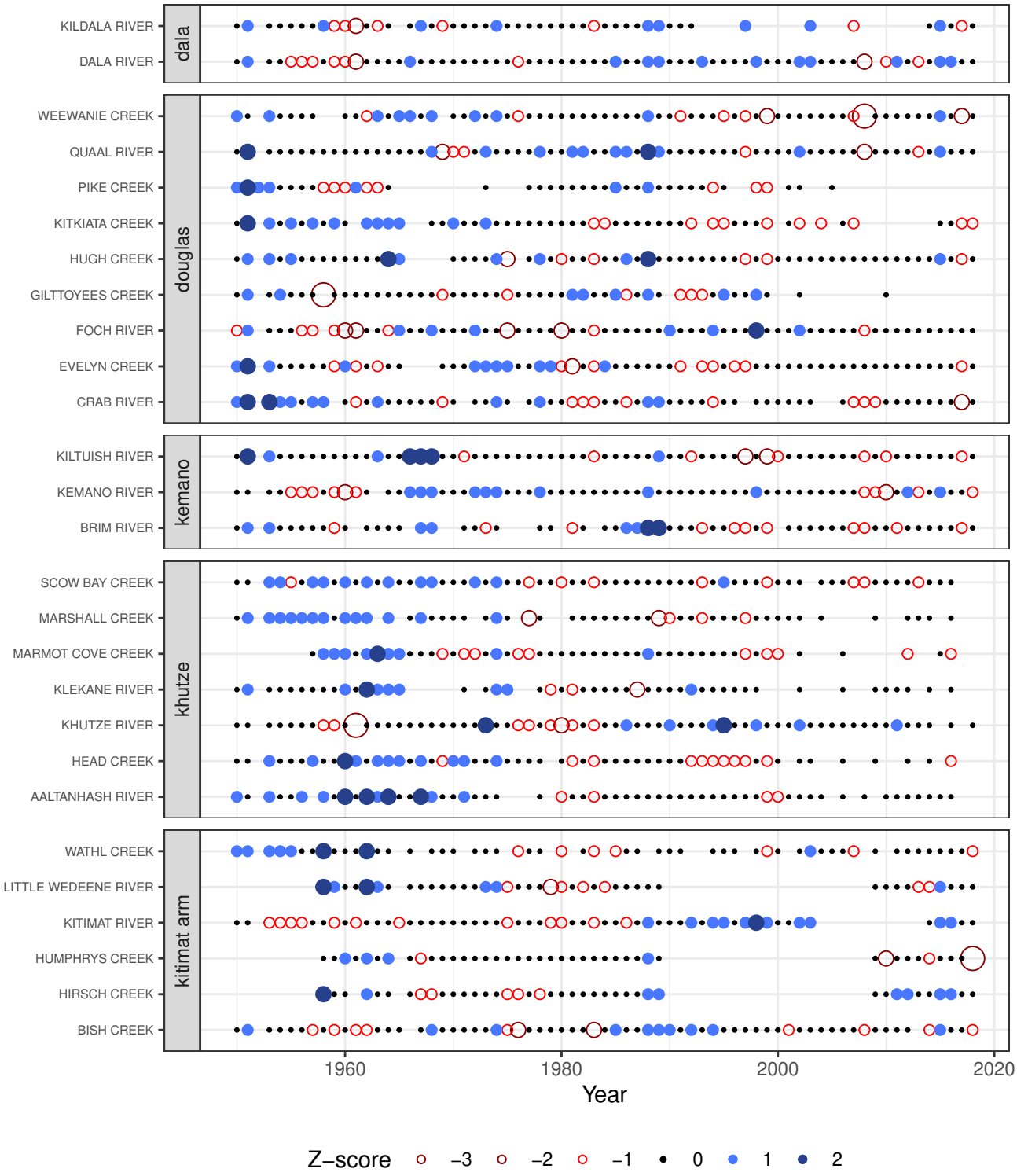


Figure 12: Z-scores of escapement for each system grouped by inlet. Solid blue points indicate positive values and open red circles indicate negative values. The size of the point indicates the magnitude of the metric.

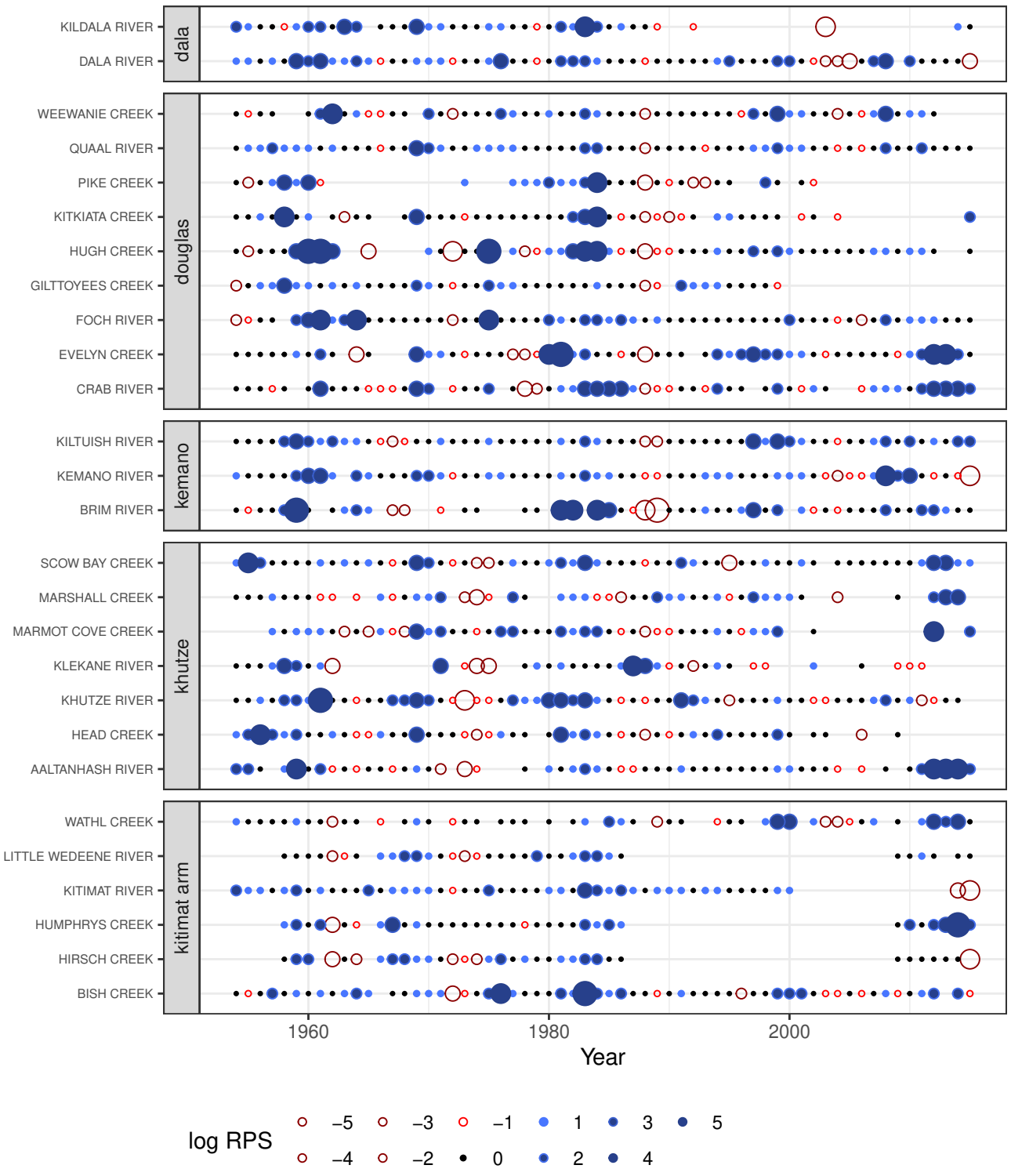


Figure 13: Log(recruits per spawner) for each system grouped by inlet. Solid blue points indicate positive values and open red circles indicate negative values. The size of the point indicates the magnitude of the metric.

Correlation analyses and Dendrograms

Cross correlation plots

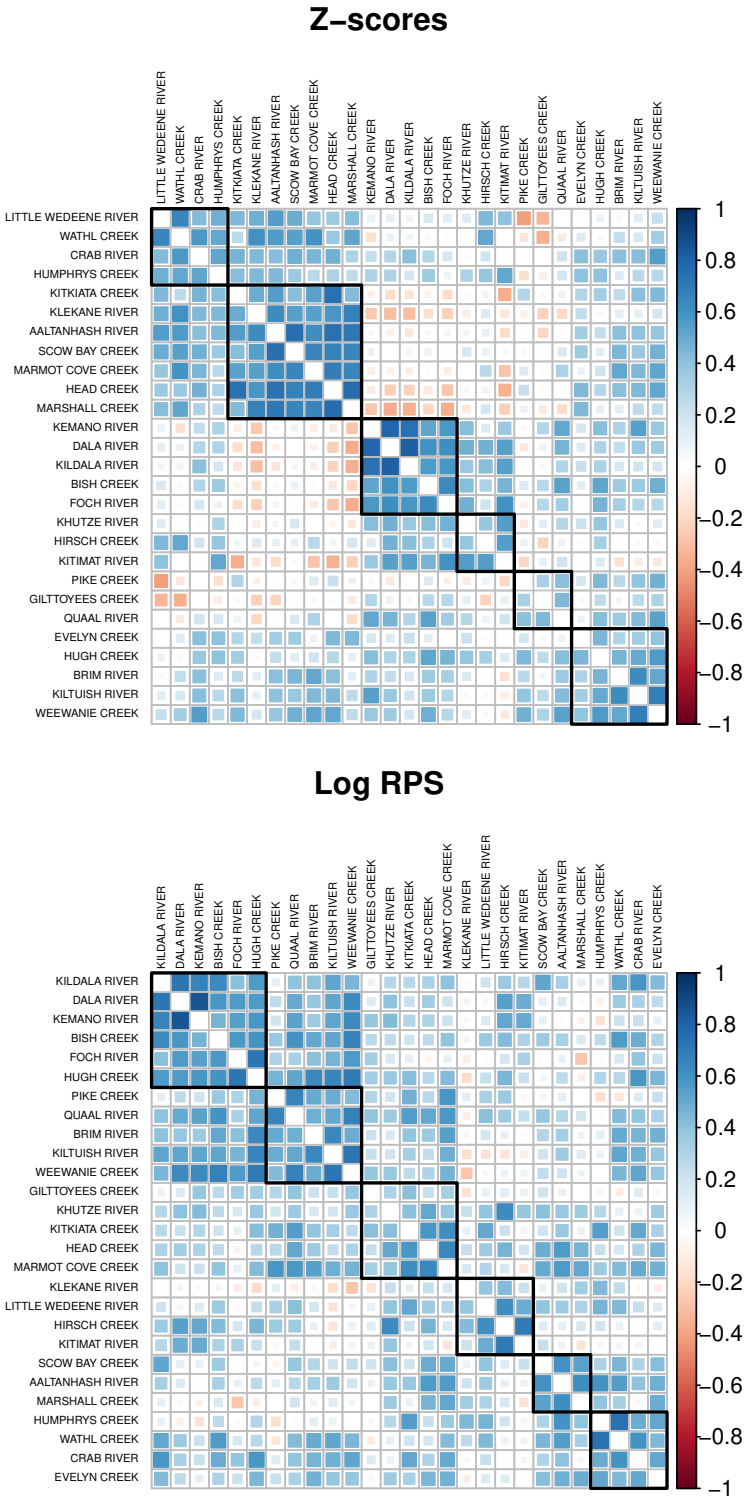


Figure 14: Cross correlation plots to compare metrics.

Dendrogram cluster analysis

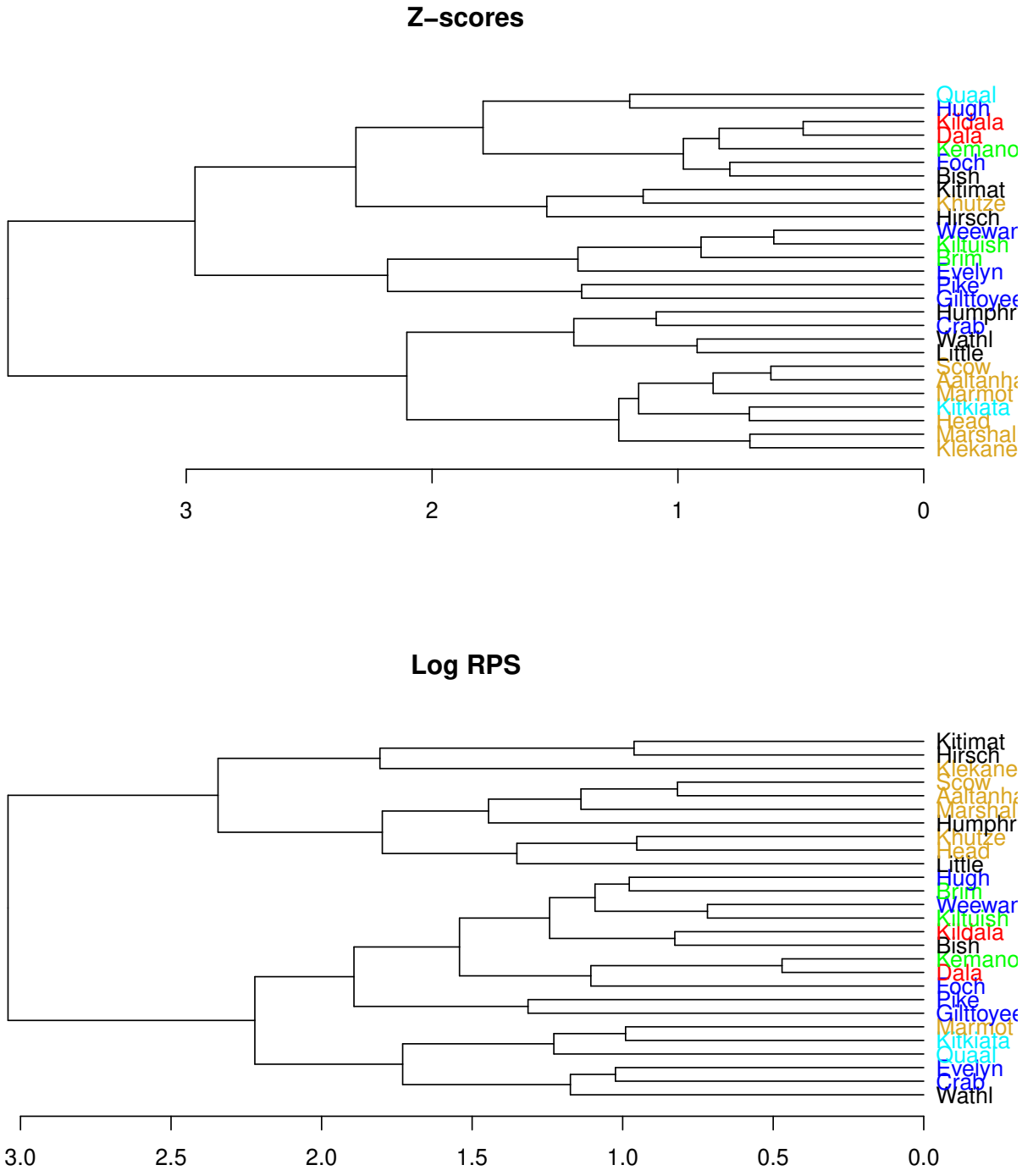


Figure 15: Dendrogram cluster analysis to compare uses of different metrics. Colours plotted by subinlet; Dala = red; Douglas = blue; Kemano = green; Khutze = yellow; Kitimat arm = black; Quaal = turquoise

Tanglegrams to compare dendrograms

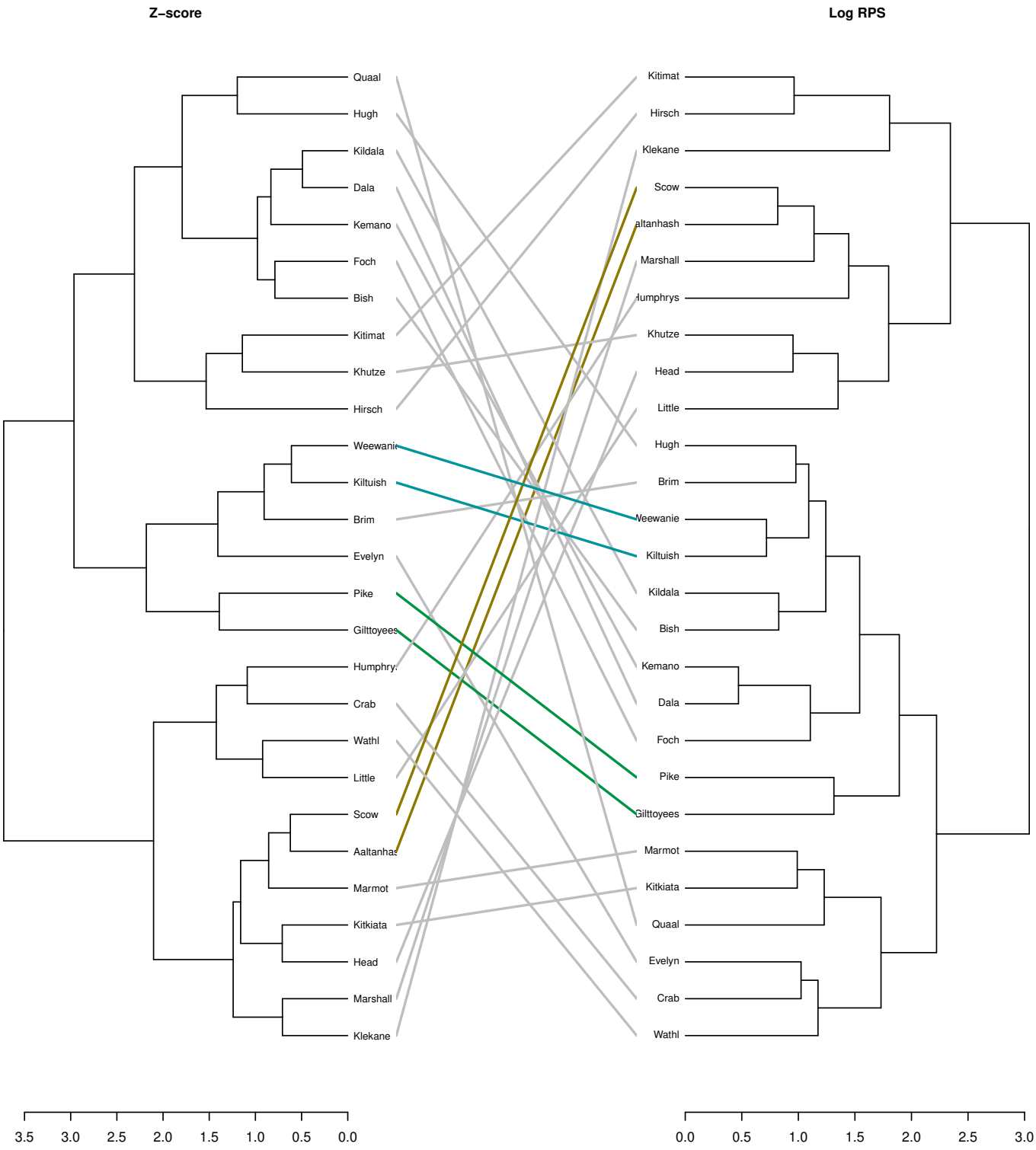


Figure 16: Tanglegram of z-score vs. Log RPS

Pre- and post-enhancement correlation analyses

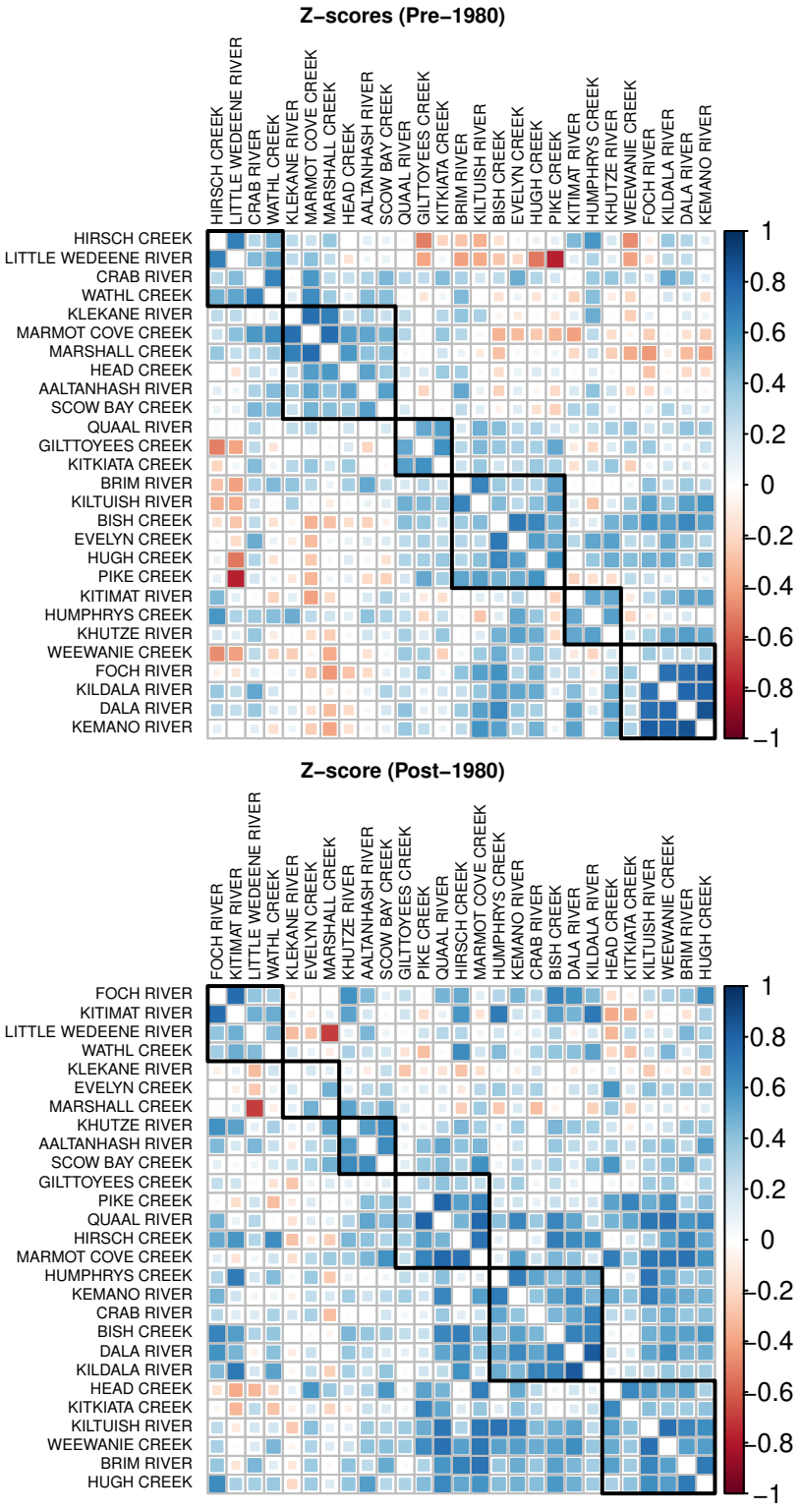


Figure 17: Cross correlation plots of z-scores to compare pre- and post-enhancement.

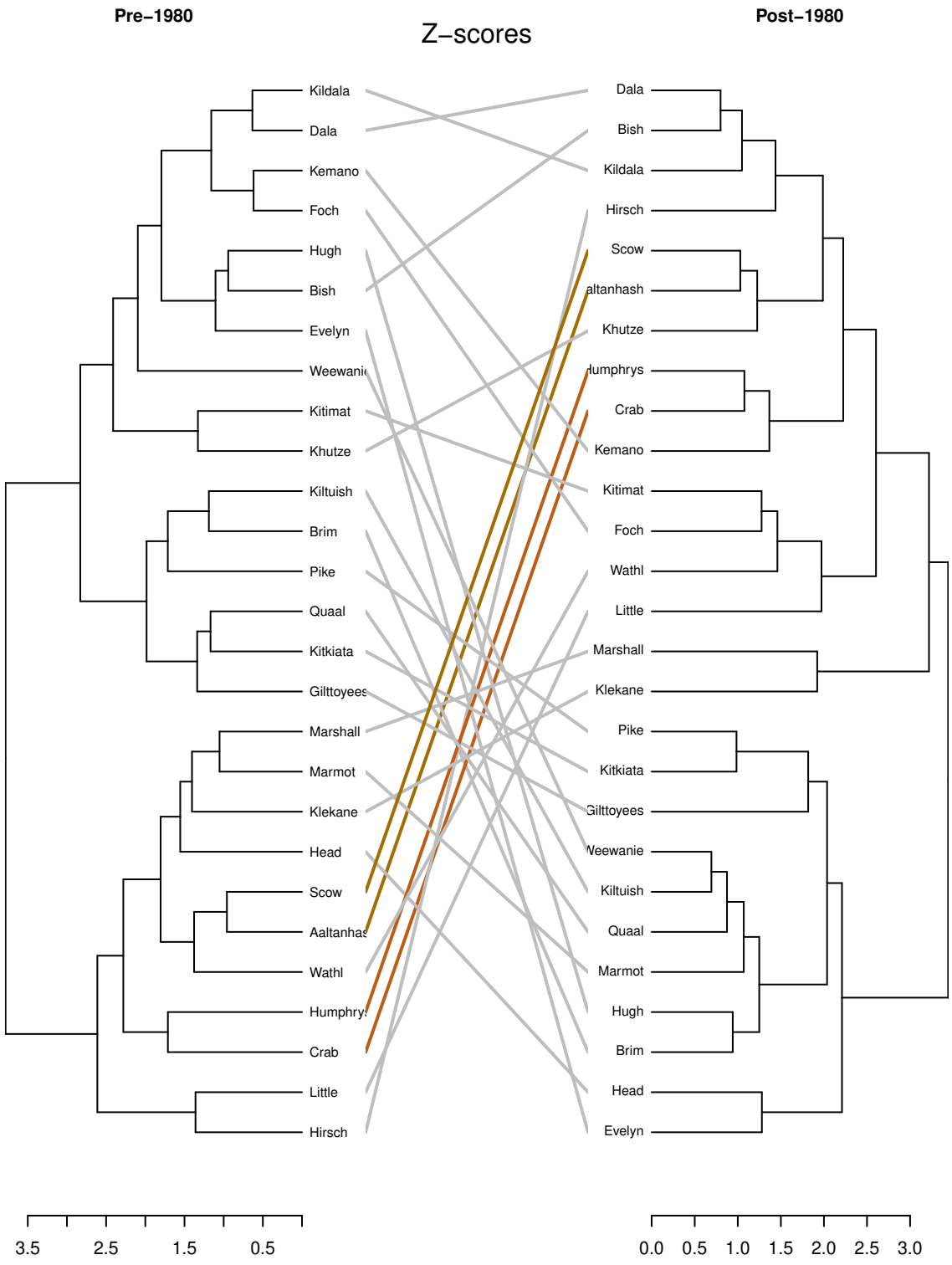


Figure 18: Tanglegram comparing z-scores pre- and post-enhancement (1980)

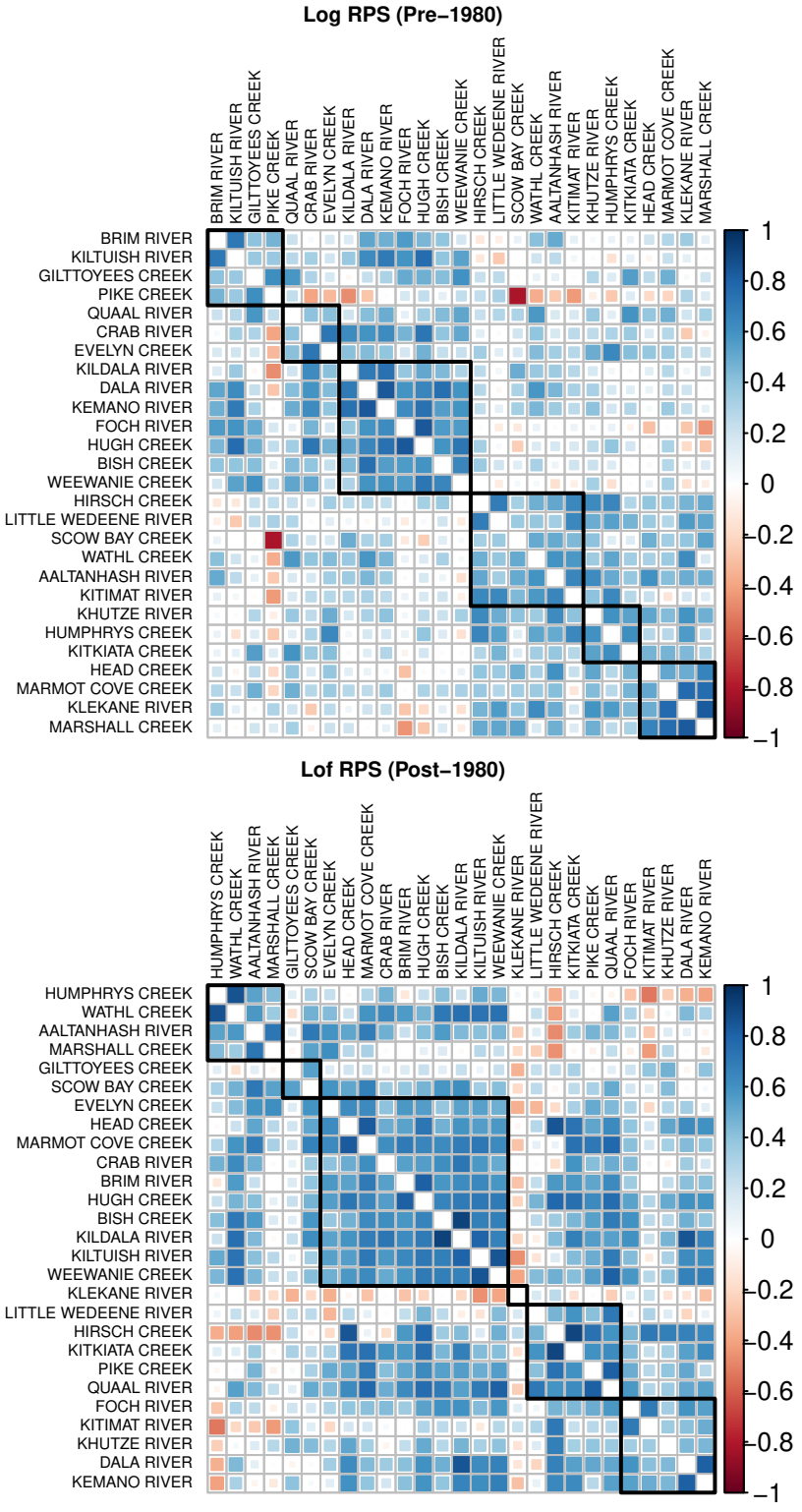


Figure 19: Cross correlation plots of Log RPS to compare pre- and post-enhancement.

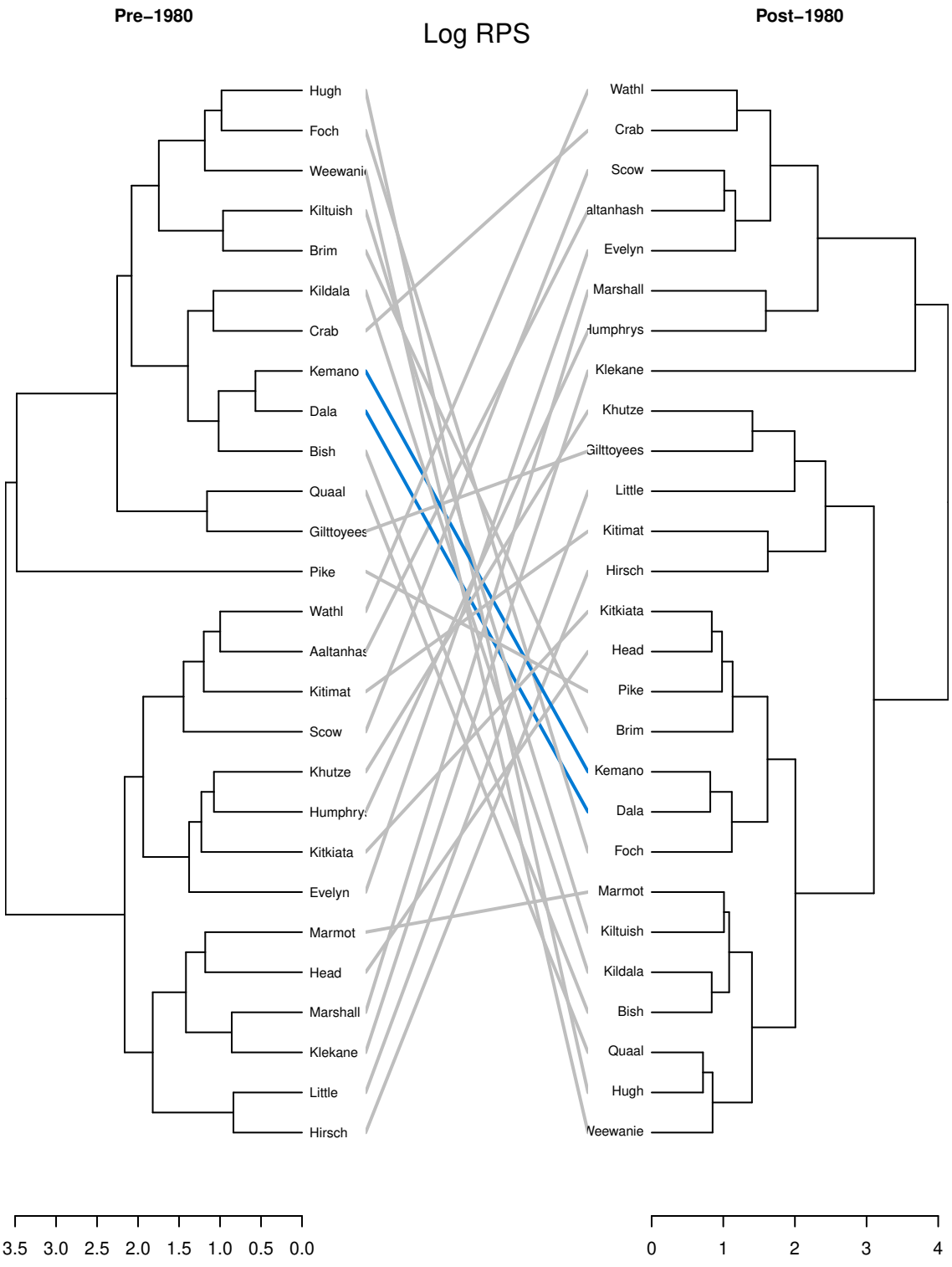


Figure 20: Tanglegram comparing Log RPS pre- and post-enhancement (1980)

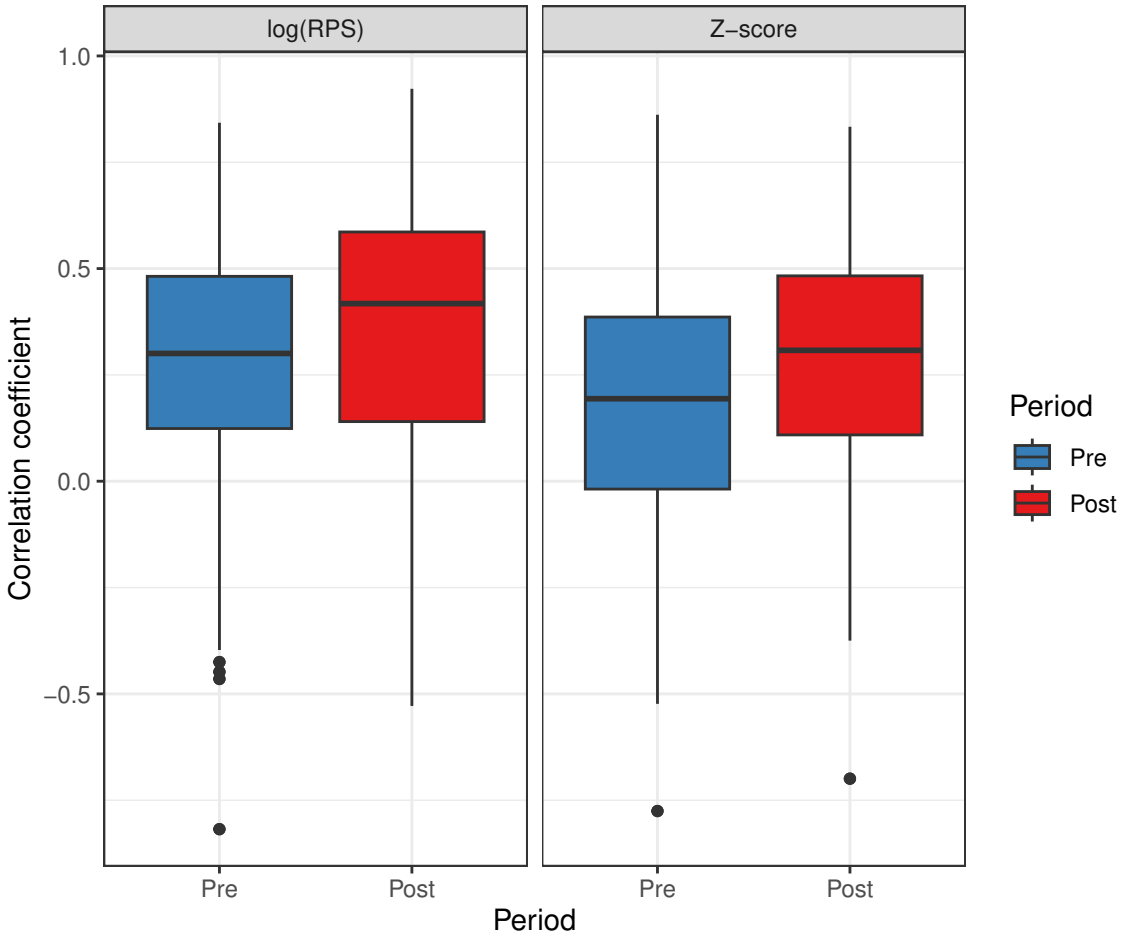


Figure 21: Comparison between correlation coefficients for all pairwise combinations of streams using Z-score and log(RPS) over the pre- and post-1980 periods.

Pairwise stream to stream correlation versus distance

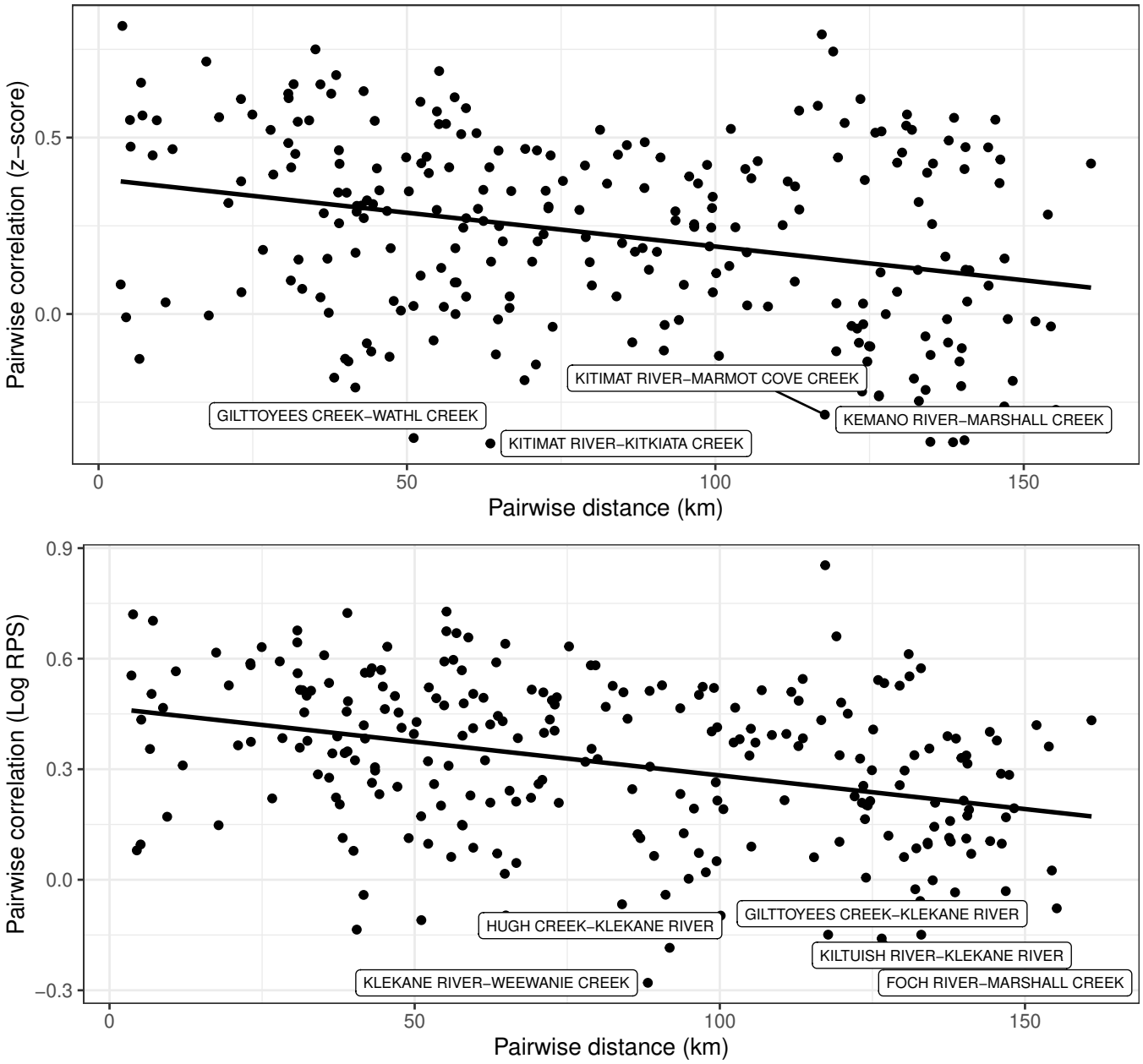


Figure 22: Pairwise stream-stream correlation of Z-score (top) and log(RPS) (bottom) against pairwise distance.

Dendrogram of pairwise distances

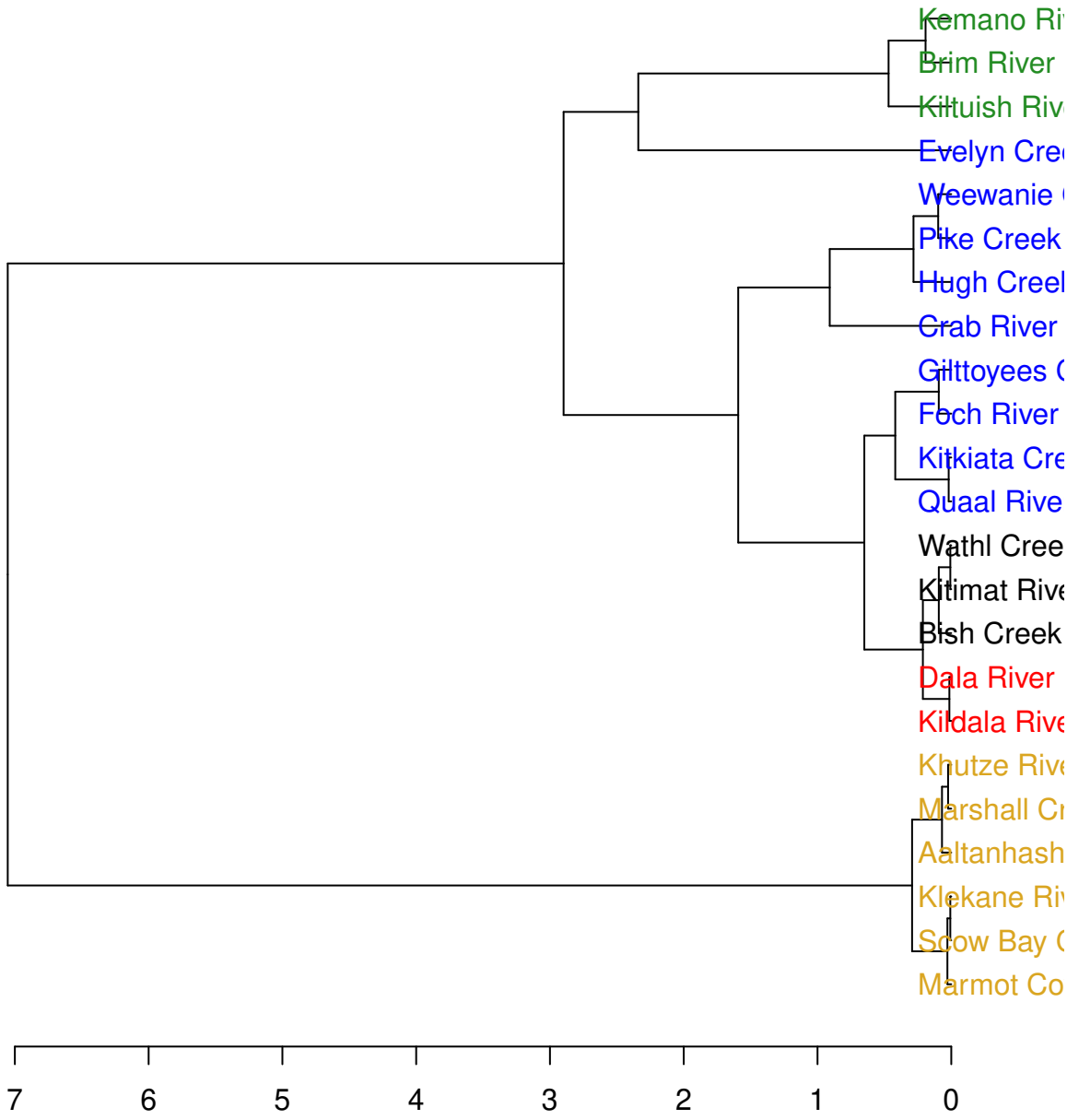


Figure 23: Dendrogram of pairwise distance between river mouths. Red labels - Dala Inlet; Blue - Douglas; Green - Kemano; Yellow - Khutze; Black - Kitimat Arm.

Correlation metrics against distance, pre- and post-1980

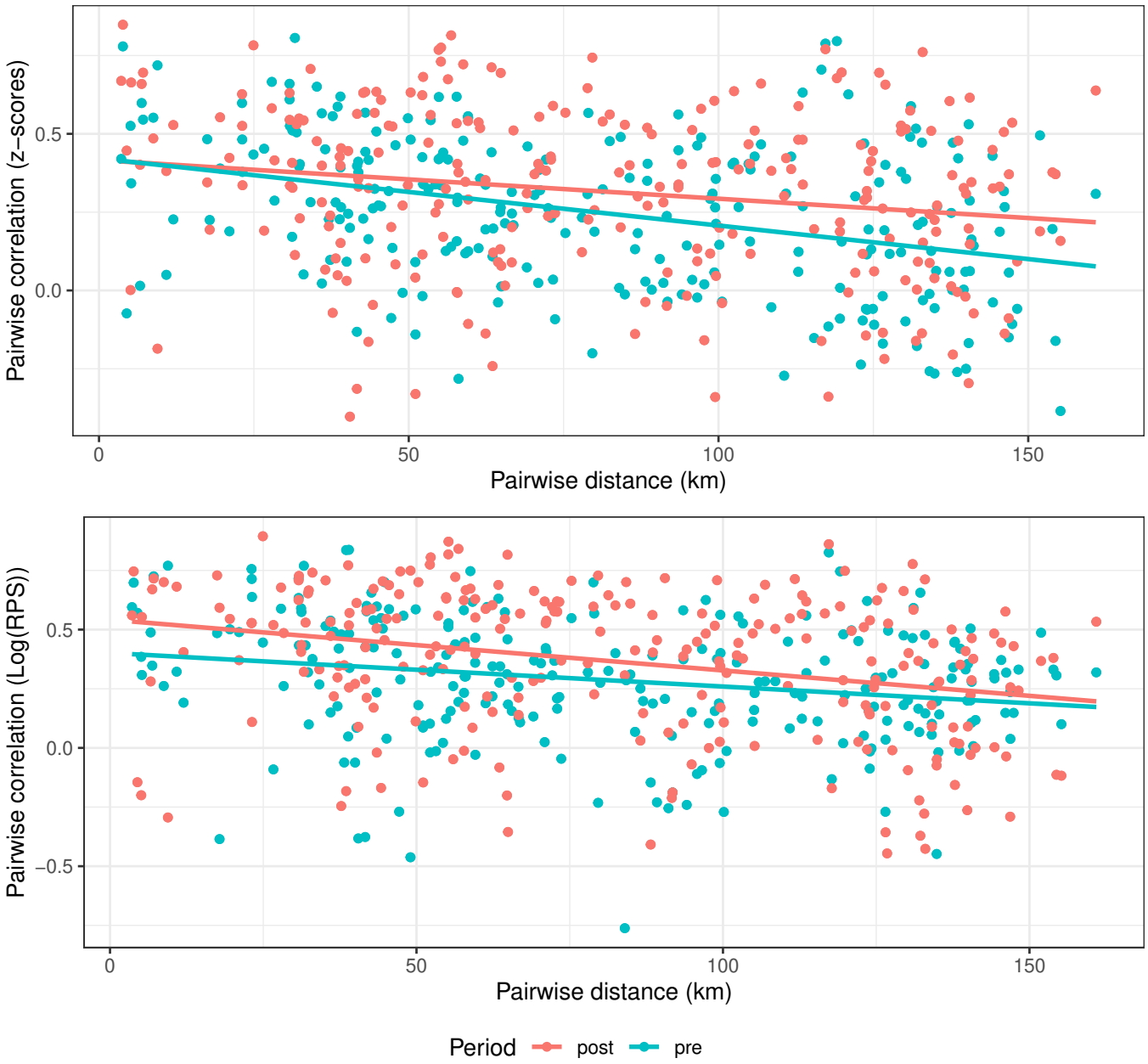


Figure 24: Pairwise stream-stream correlation of Z-score (top) and log(RPS) (bottom) against pairwise distance by period (pre-enhancement and post-enhancement.

Statistical Models

Candidate Models with AIC scores for log RPS and log escapement

Table 2: Candidate models for log RPS and distance from enhancement (dist), total releases (totrel), and year, with AIC scores.

Response	Candidate model	df	AIC
log RPS	Log RPS ~ dist + totrel + year	5	4640.250
log RPS	Log RPS ~ dist + totrel	4	4649.087
log RPS	Log RPS ~ dist	3	4674.840
log RPS	Log RPS ~ dist + year	4	4675.224
log RPS	Log RPS ~ totrel + year	4	5207.678
log RPS	Log RPS ~ releases	3	5213.524
log RPS	Log RPS ~ year	3	5237.491

Table 3: Candidate models for log escapement and distance from enhancement (dist), total releases (totrel), and year, with AIC scores.

Response	Candidate model	df	AIC
log escapement	Log esc ~ dist + year	4	5455.093
log escapement	Log esc ~ dist + totrel + year	5	5457.085
log escapement	Log esc ~ dist + totrel	4	5468.276
log escapement	Log esc ~ dist	3	5478.798
log escapement	Log esc ~ year	3	6220.673
log escapement	Log esc ~ totrel + year	4	6222.325
log escapement	Log esc ~ releases	3	6236.895

Effects plots for top model: log(RPS)

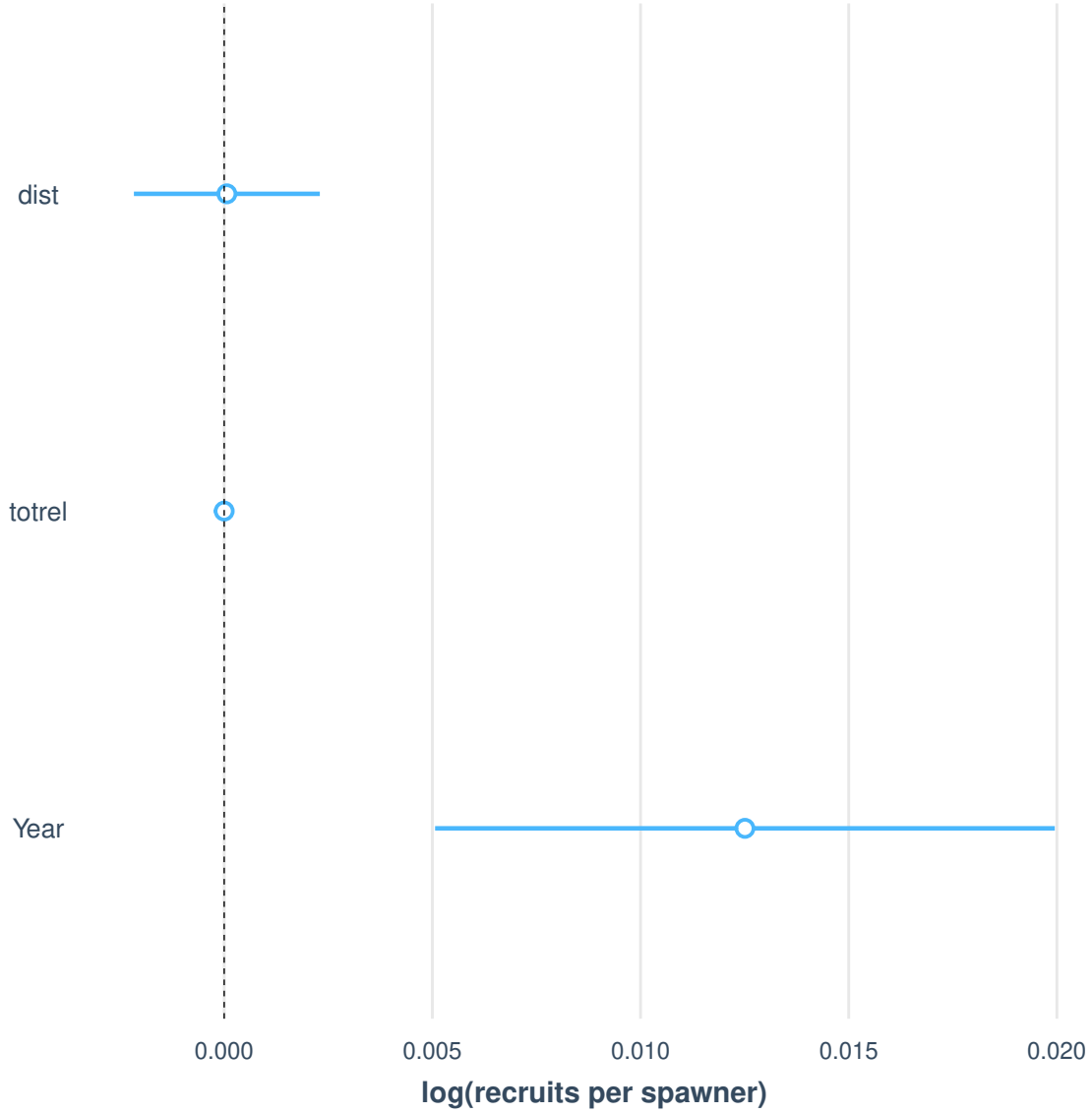


Figure 25: Plot of effects included in the most parsimonious model for log(RPS).

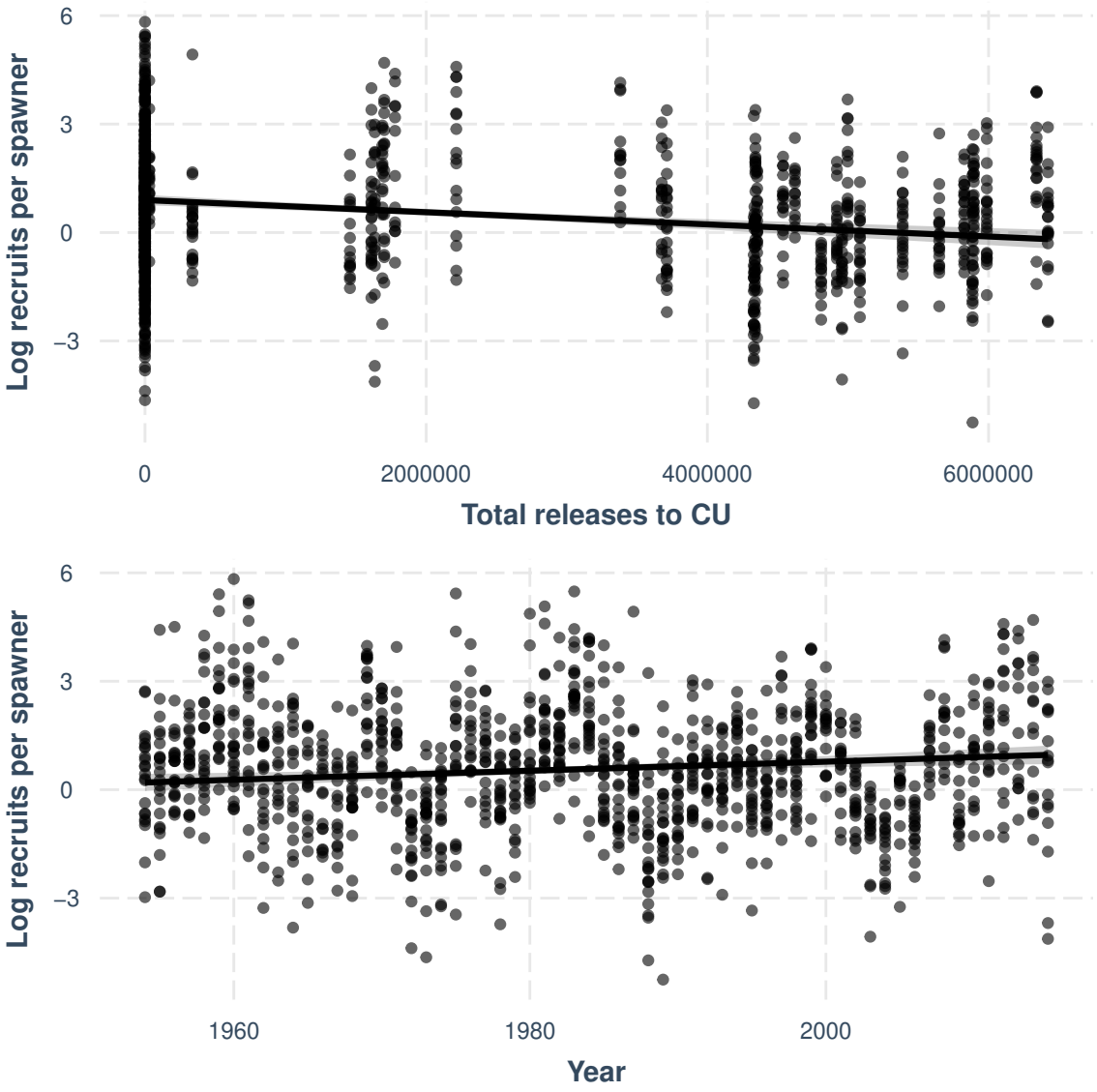


Figure 26: Effects plots of log(RPS) by releases from Kitimat (top) and year (bottom).

Effects plots for top model: log(escapement)

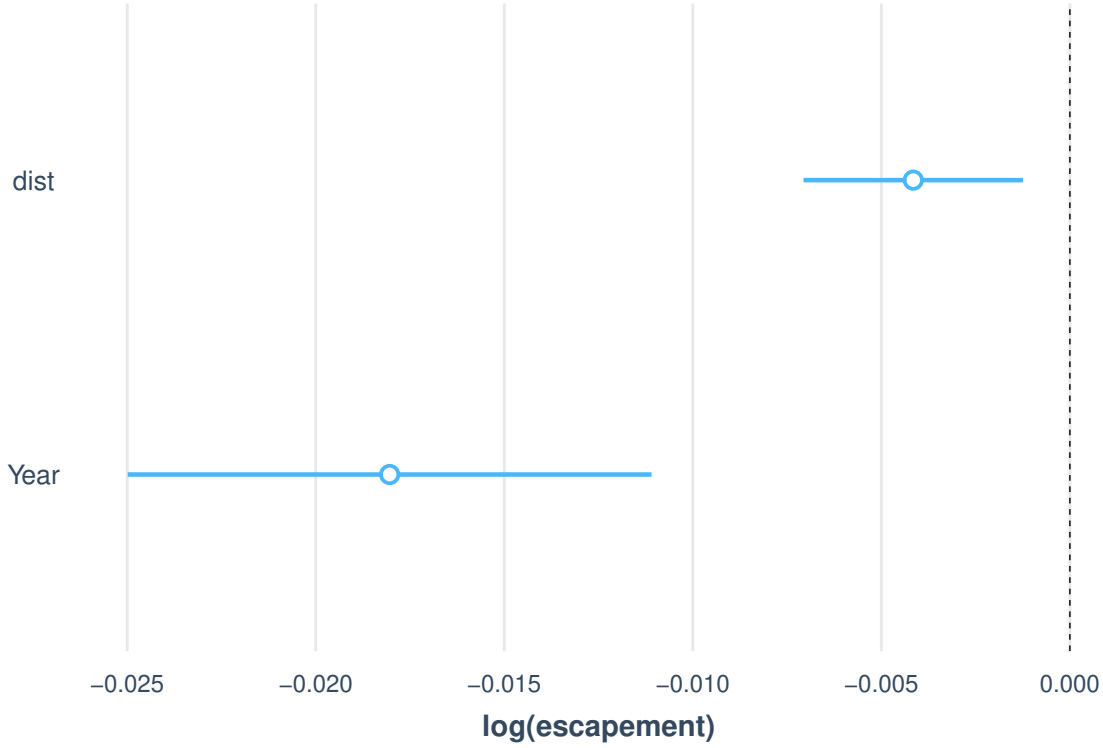
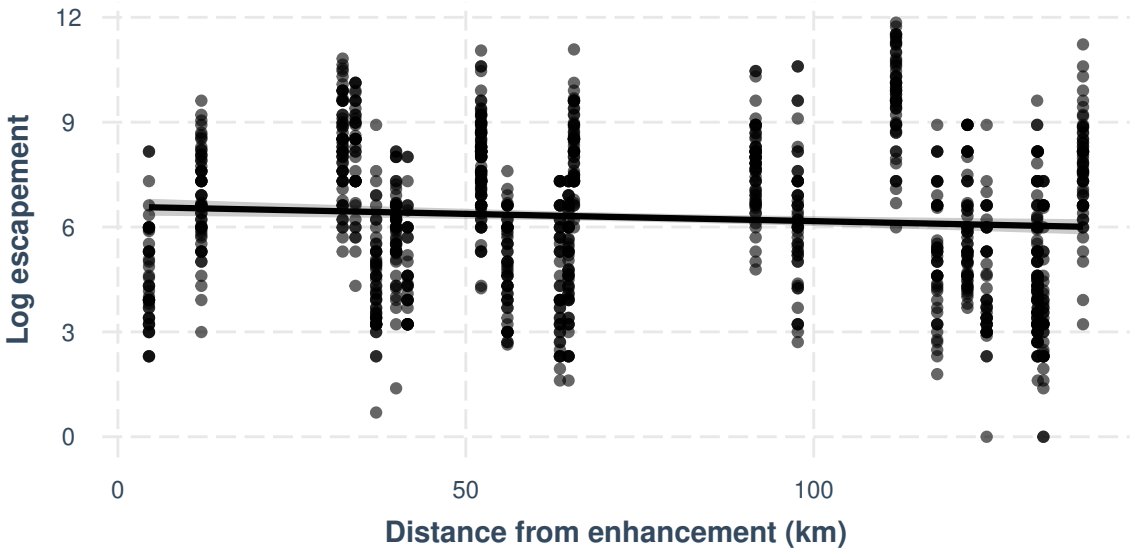
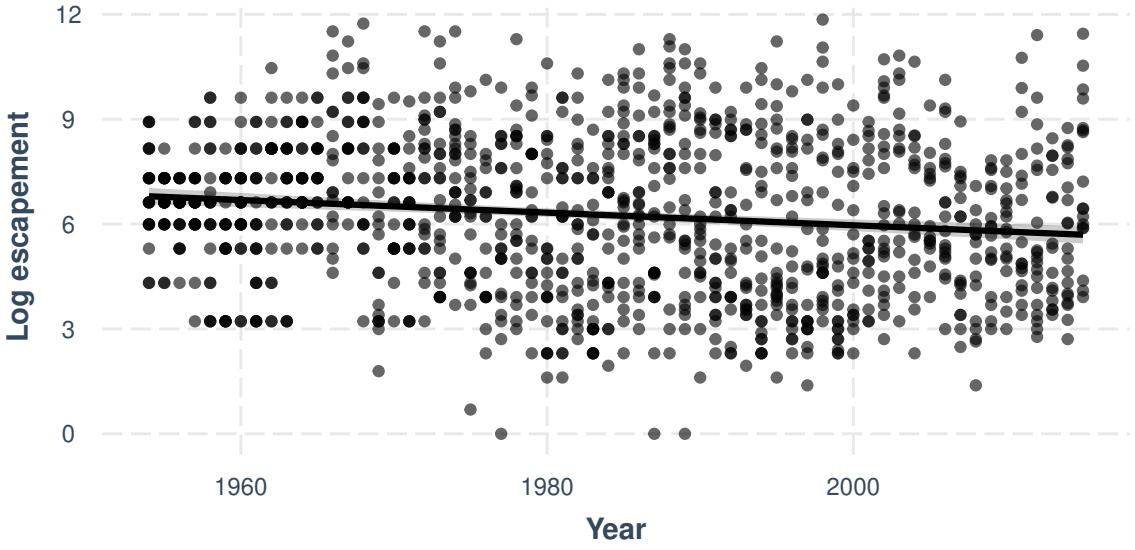


Figure 27: Plot of effects included in the most parsimonious model for log(escapement).


Log escapement
12
9
6
3
0
0
50
100
Distance from enhancement (km)


Log escapement
12
9
6
3
0
1960
1980
2000
Year