A Retrospective Analysis of Mussel Monitoring in the Puget Sound

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Introduction

The purpose of this report is to provide a retrospective analysis of data generated by previous mussel monitoring surveys coordinated under Washington Department of Fish and Wildlife's (WDFW) Toxics Biological Obsevation System (TBiOS). We determine how existing historical bay mussel (*Mytilus trossulus*) contaminant data can be used for in a Toxics in the Nearshore Vital Sign indicator. In addition, we assess the predictive ability of existing sampling rate to predict expected contaminant trends.

Toxics data was obtained by transplanting relatively uncontaminated mussels from a local aquaculture source to locations along the Puget Sound shoreline, covering a broad range of upland land-use types from rural to highly urban. Mussels were then recovered, and concentrations of several major contaminant classes were measured. Four mussels surveys were performed, with mussels being retrieved in 2013, 2016, 2018, and 2020. Our analysis focuses on polycyclic aromatic hydrocarbons (PAHs), polybrominated diphenyl ethers (PBDEs), and polychlorinated biphenyls(PCBs) due to their significance in both ecosystem and human health.

All materials used to prepare this report can be found in the following GitHub repository: https://github.com/cwangen/mussel_toxics/.

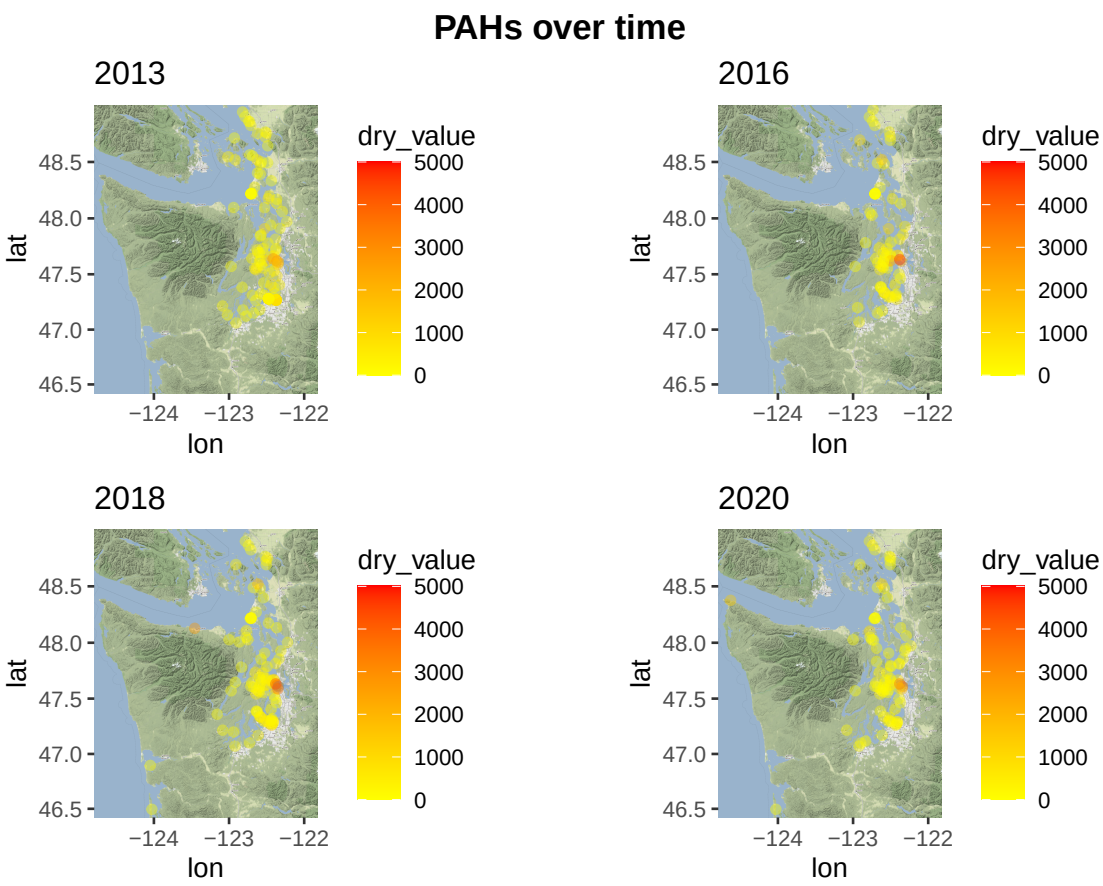
Methods

Data Analysis

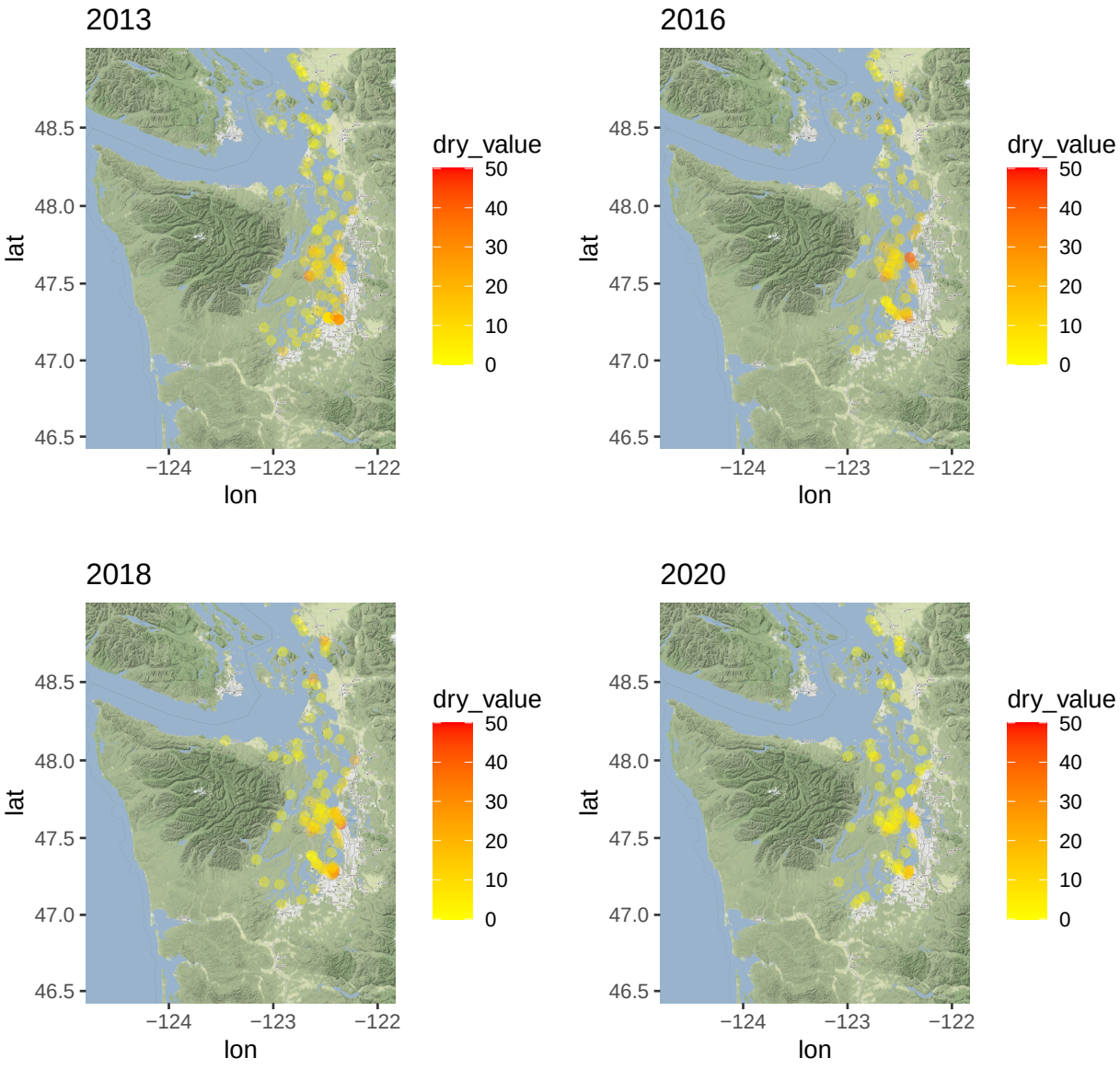
The data used in this analysis originated in the form of an Microsoft Excel file, titled "2013-20MusselCagesPOPsPAHs_Cnty_WRIA_LIO_Coverages.xlsx." The data included more fields than used in our analysis, and can be found in its entirety in "~mussel_toxics/data/raw/." The data was cleaned in order to correct minor inconsistencies and errors, resulting in "~mussel_toxics/data/clean/totals_all.cvs."

Dry weights of toxics found in each sample were used for analysis. Though samples did record the concentration of lipids, as well as wet weight, dry weight is the standard for reporting toxicology data. Summary tables were created for dry weights and categorical variables. Dry weight concentrations were also plotted on maps. Raincloud plots were for subcategories of WRIA and year. Raincloud plots consist of a box plot, an approximate probability density, and individual data points.

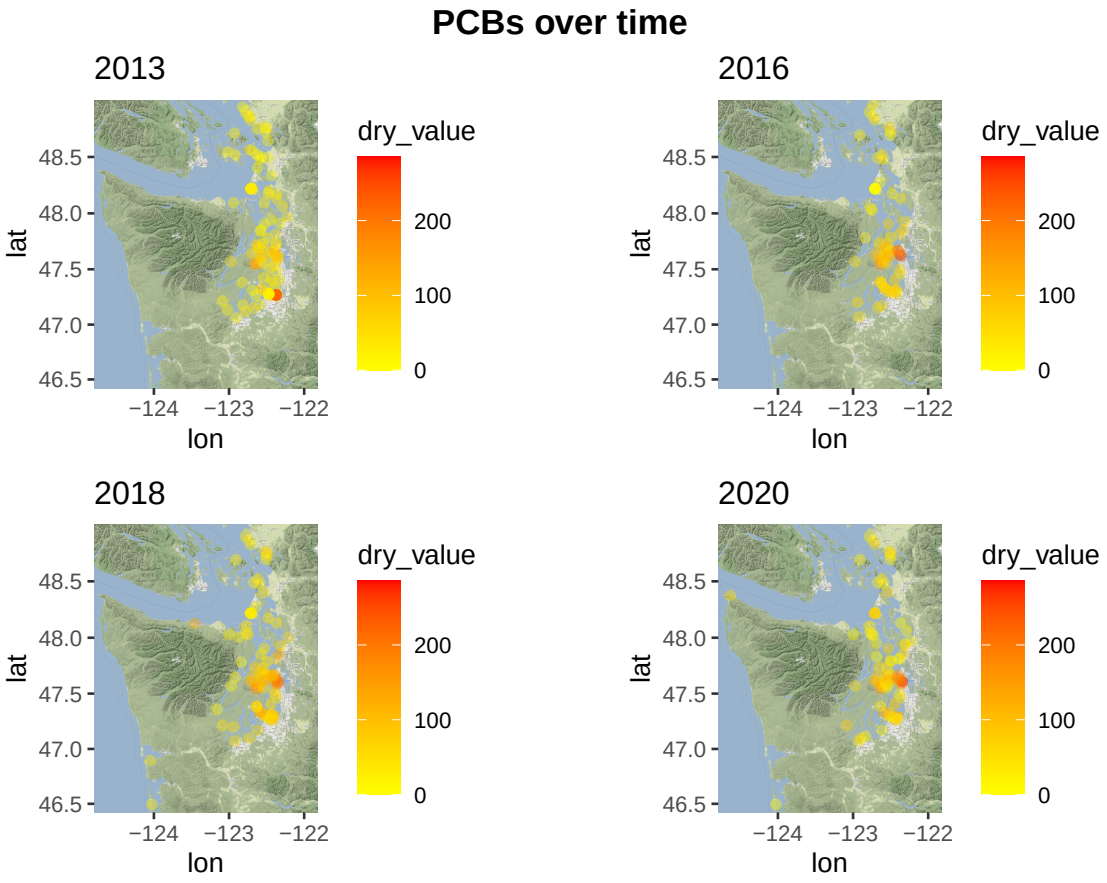
Samples from the original aquaculture source used as reference were removed except for the creation of maps. Samples outside of Puget Sound (latitude less than -123.5) were also removed from sampling, but remain in map figures. Figures **??**, **??**, and **??** display the concentrations of PAHs, PBDEs, and PCBs over time in mussel samples. They also shed light on how sampling is inconsistent both spatially and temporally.


PAHs over time
2013
2016
2018
2020
dry_value
5000
4000
3000
2000
1000
0
lat
48.5
48.0
47.5
47.0
46.5
lon
−124
−123
−122

PBDEs over time



46



Modeling

We modeled the dry weight of the analytes found in mussels using a linear mixed model (LMM). These models consist of fixed effects, which remain constant, and random effects that follow a normal distribution and can correspondingly vary by individual. Our goals were to evaluate 1) The effect of year on dry weight of the relevant toxic analyte 2) If any other factors significantly affected dry weight, and 3) the effect of WRIA by year.

Variables considered in analysis included time (of mussels spent in water), latitude, longitude, year, county, LIO, WRIA, and mean percent AU. Other extraneous variables (IE, funding source) were not used as there is no possible relationship between these and analyte content, though this information could be helpful when we begin to focus on future sampling plans in future reports. Exploratory analysis of the data allowed us to remove extraneous factors, while including those we wished to investigate. Models were created for each of the independent analytes as their nature and distribution should not be assumed to be the same.

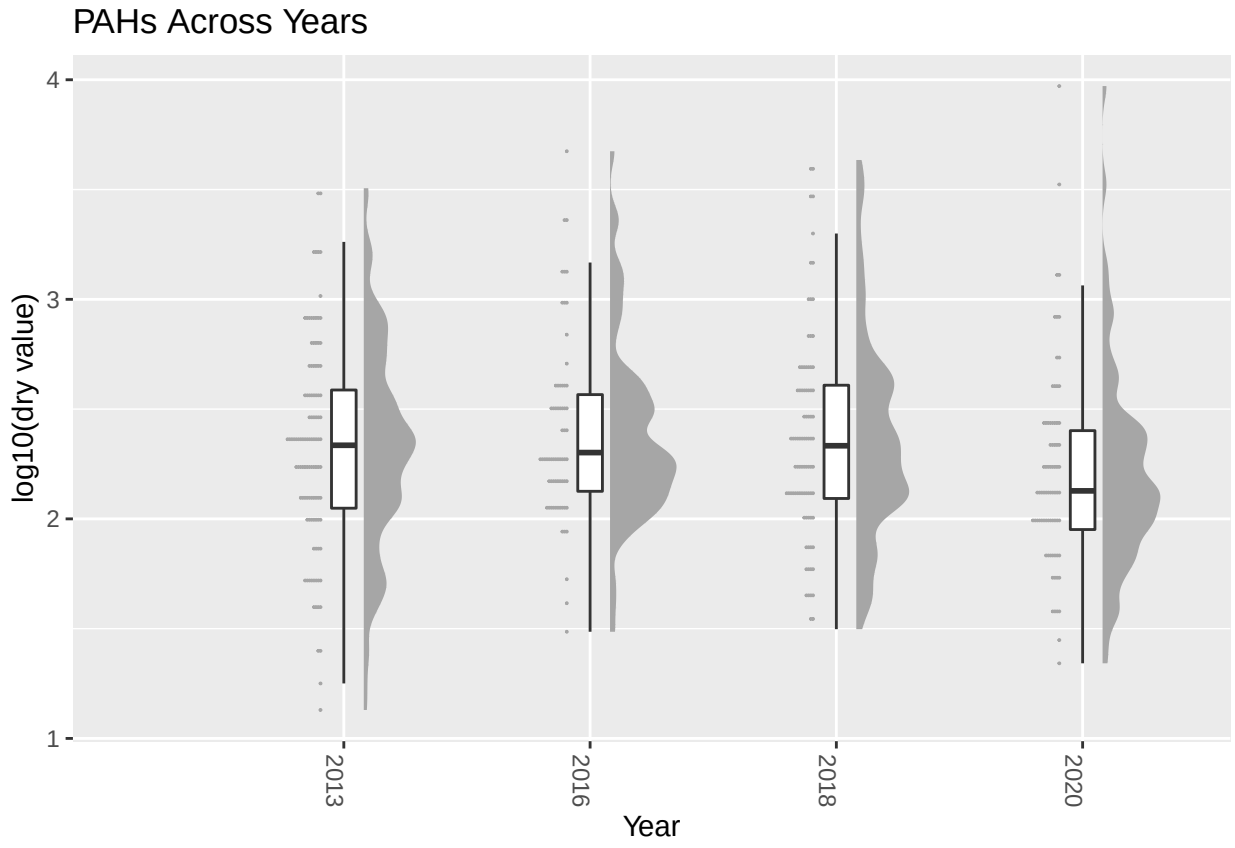
Initial model selection occurred by comparing Akaike information criterion (AIC) of all feasible possible models. Models that were unsuitable due to singular fits (overfitting) or violations or model assumptions such as non-normality were removed. The final model was

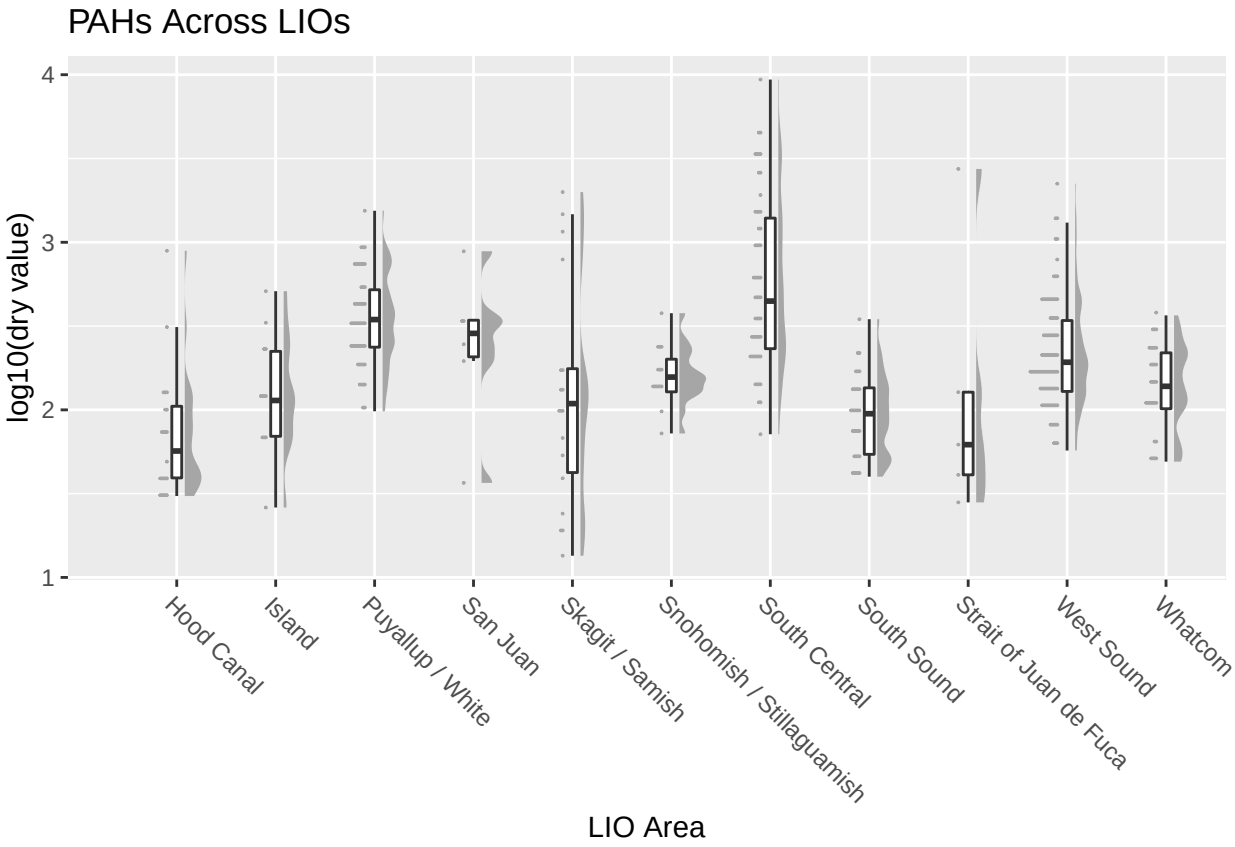
chosen by taking into account AIC, noninfringement of model assumptions, and variables critical to project goals.

Results and Discussion

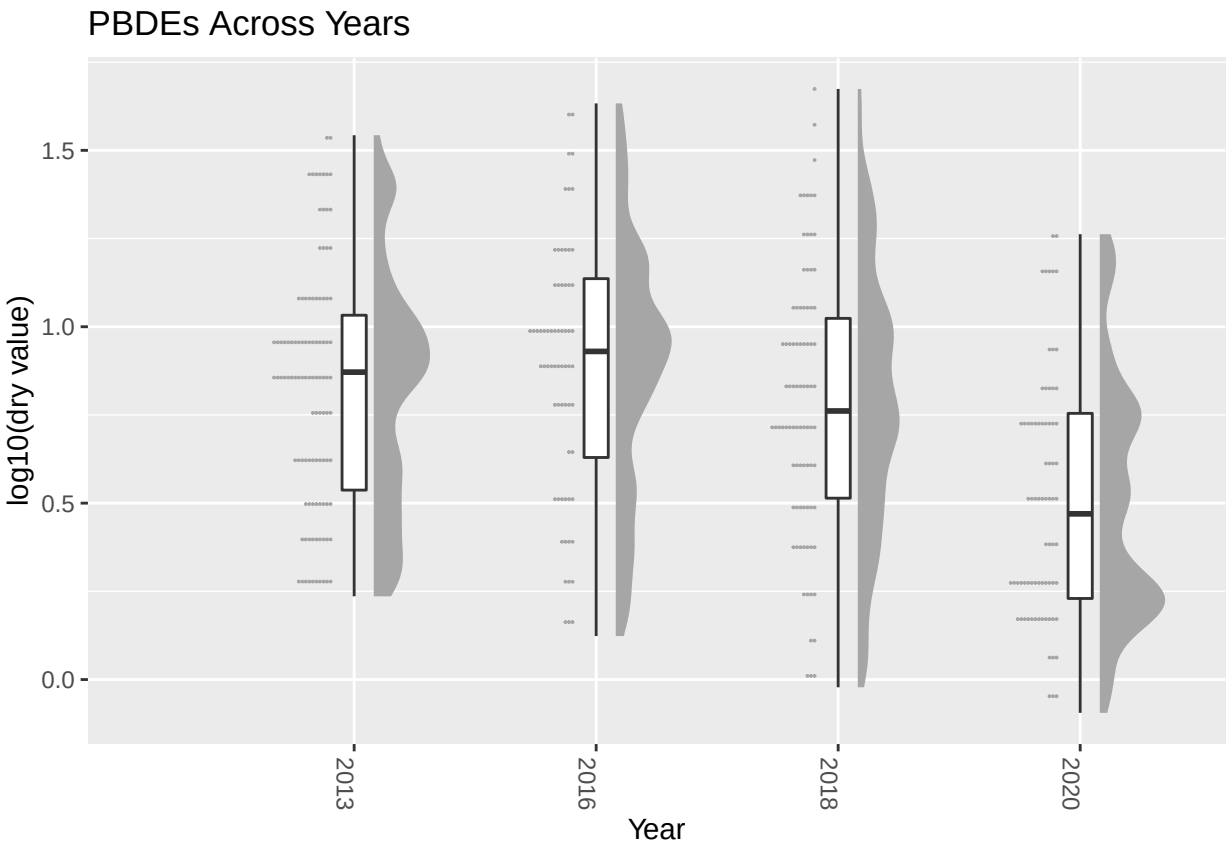
Data Analysis

Here's the code that makes these

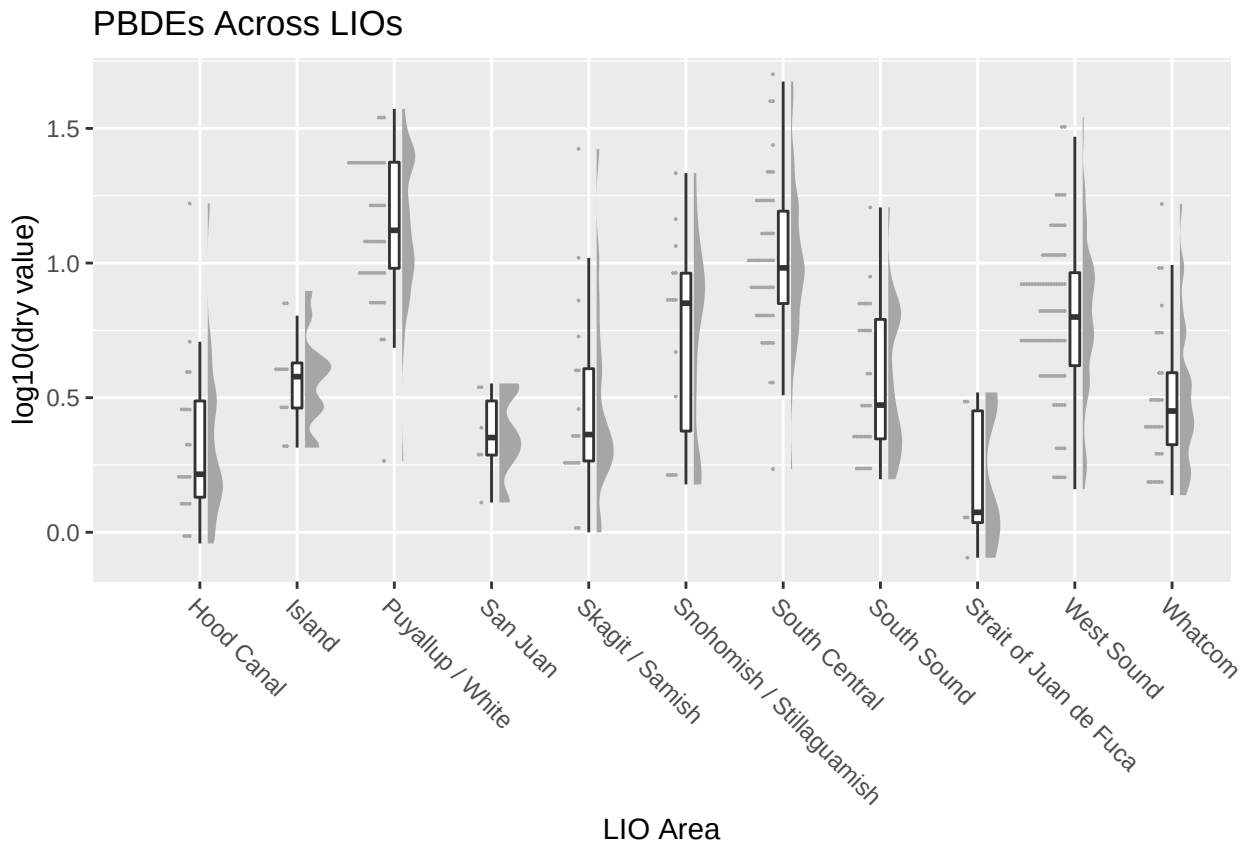



PAHs Across LIOs
log10(dry value)
4
3
2
1
Hood Canal
Island
Puyallup / White
San Juan
Skagit / Samish
Snohomish / Stillaguamish
South Central
South Sound
Strait of Juan de Fuca
West Sound
Whatcom
LIO Area

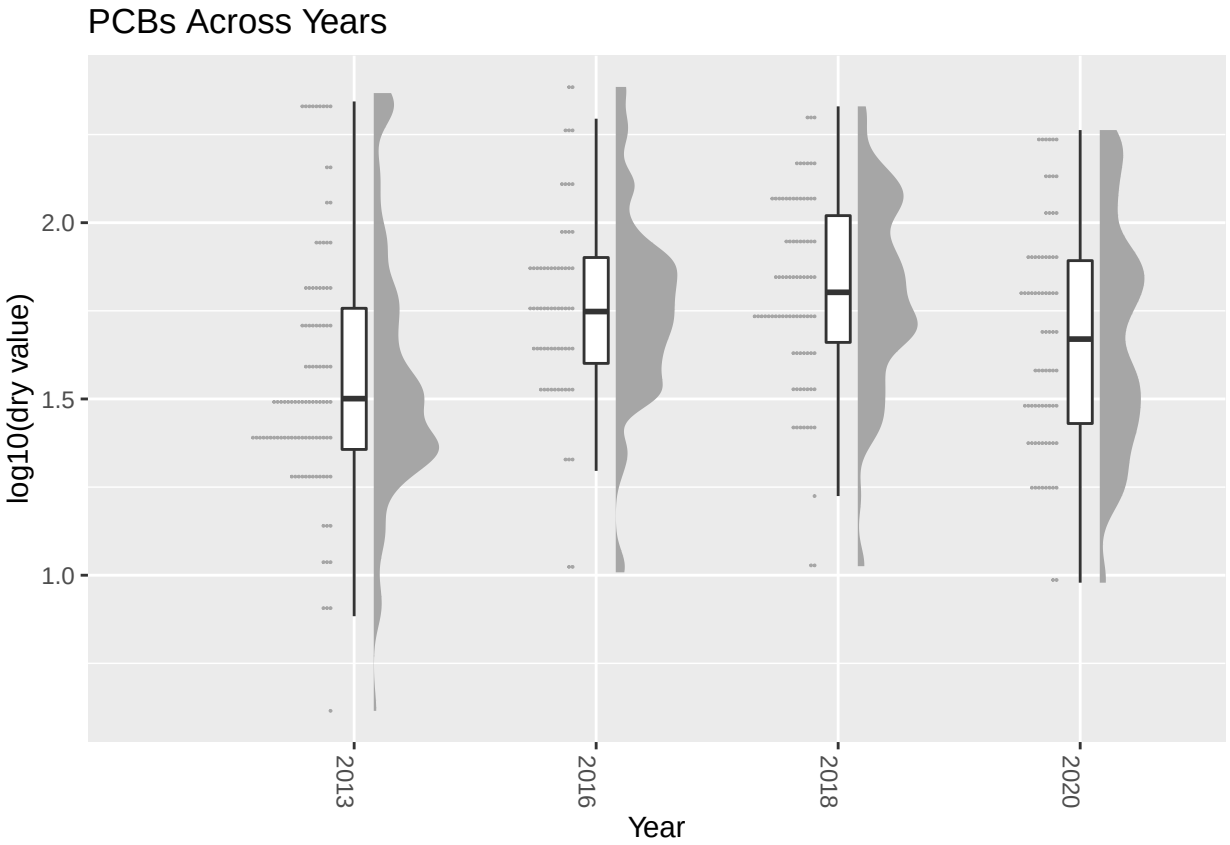
70


PBDEs Across Years
log10(dry value)
1.5
1.0
0.5
0.0
2013
2016
2018
2020
Year

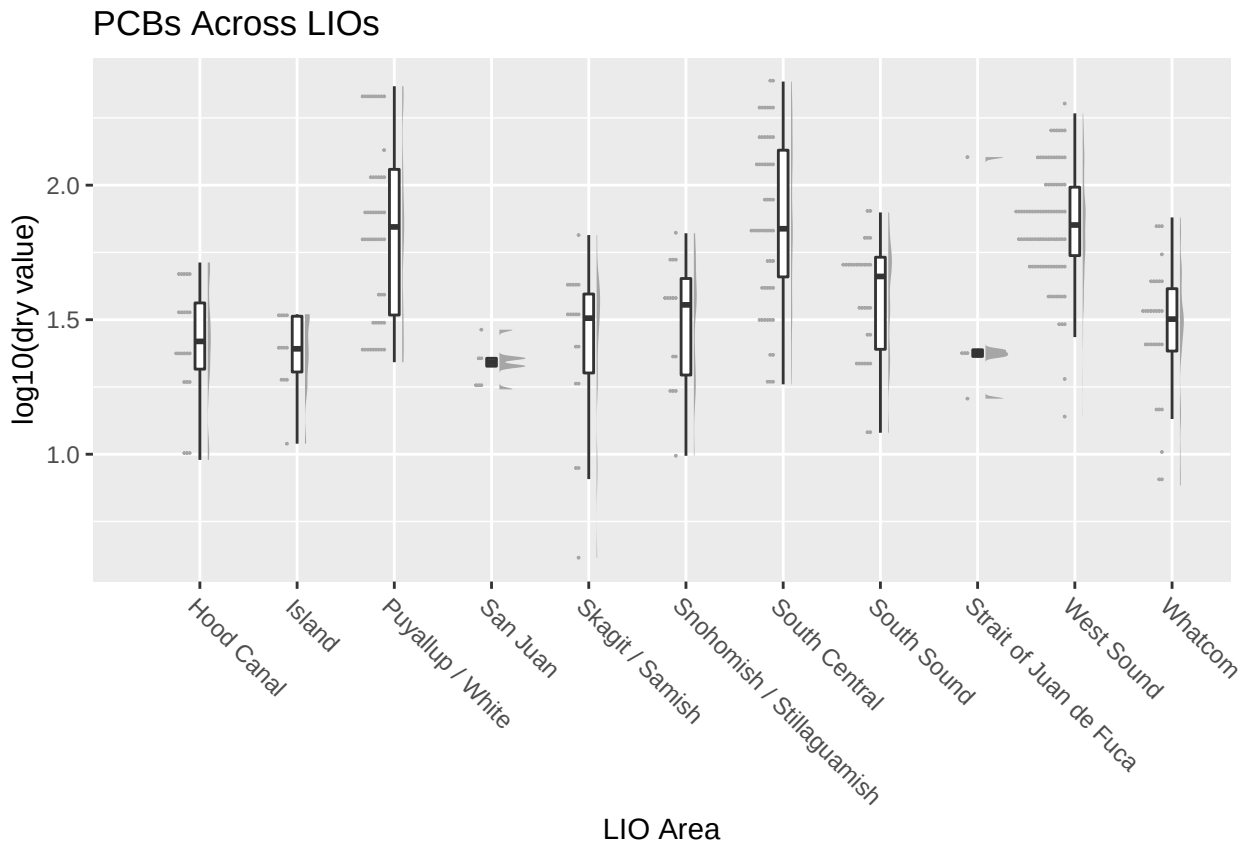
71


PBDEs Across LIOs
log10(dry value)
1.5
1.0
0.5
0.0
Hood Canal
Island
Puyallup / White
San Juan
Skagit / Samish
Snohomish / Stillaguamish
South Central
South Sound
Strait of Juan de Fuca
West Sound
Whatcom
LIO Area

72


PCBs Across Years
log10(dry value)
2.0
1.5
1.0
2013
2016
2018
2020
Year

73

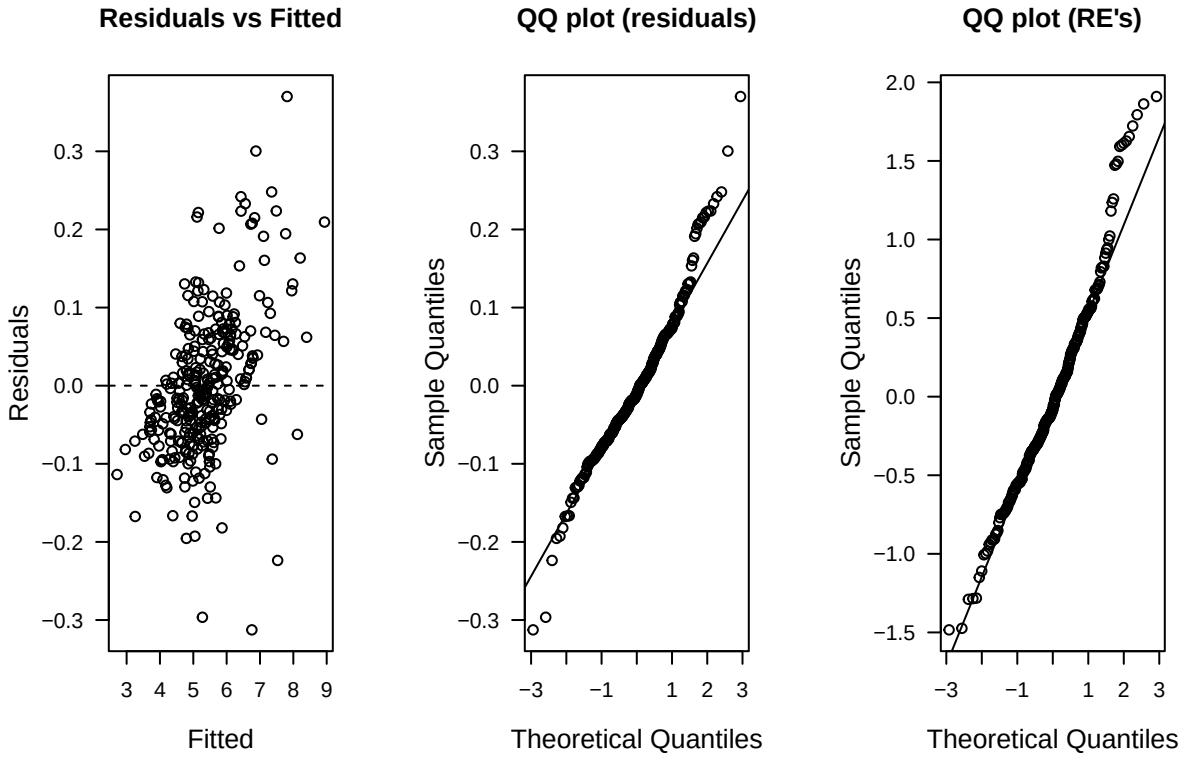


Modelling

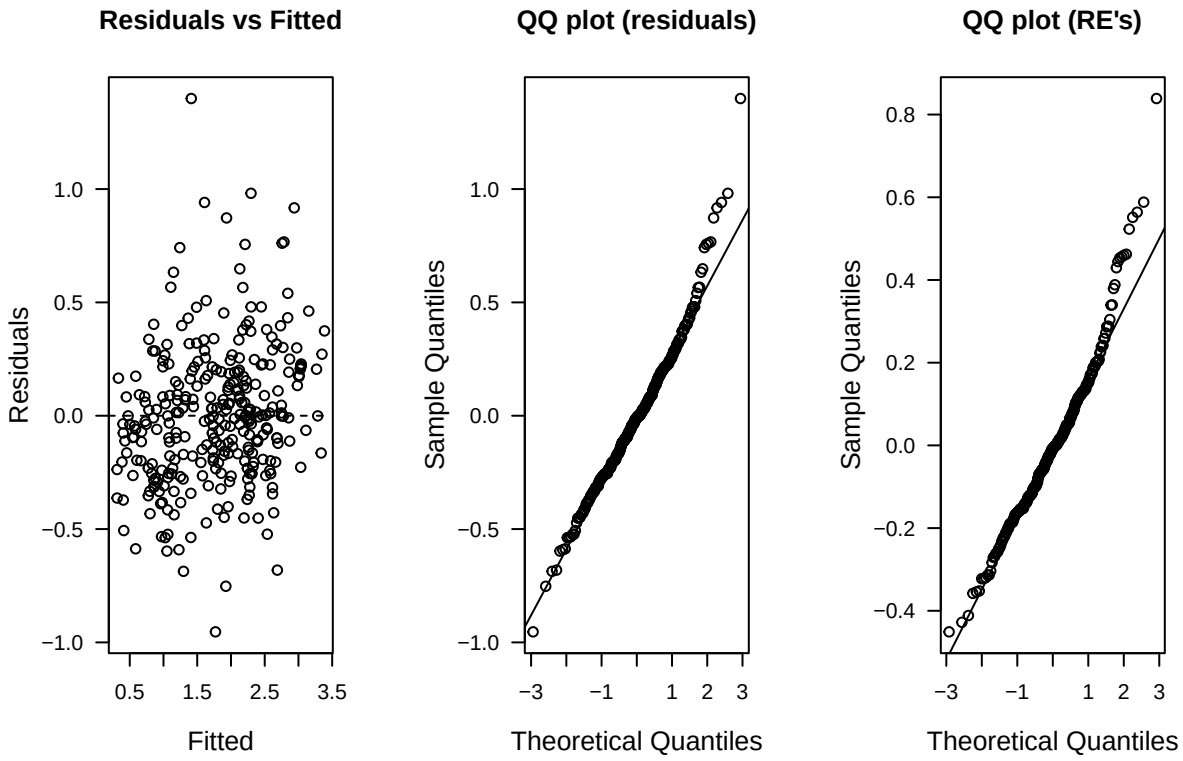
The final model takes the form,

$$D_i = \beta_{1,year} + \beta_{2,year \times LIO} + \beta_3 \text{surface}_i + \beta_4 \text{time}_i + \mu_{i,j} + \epsilon_i \quad (1)$$

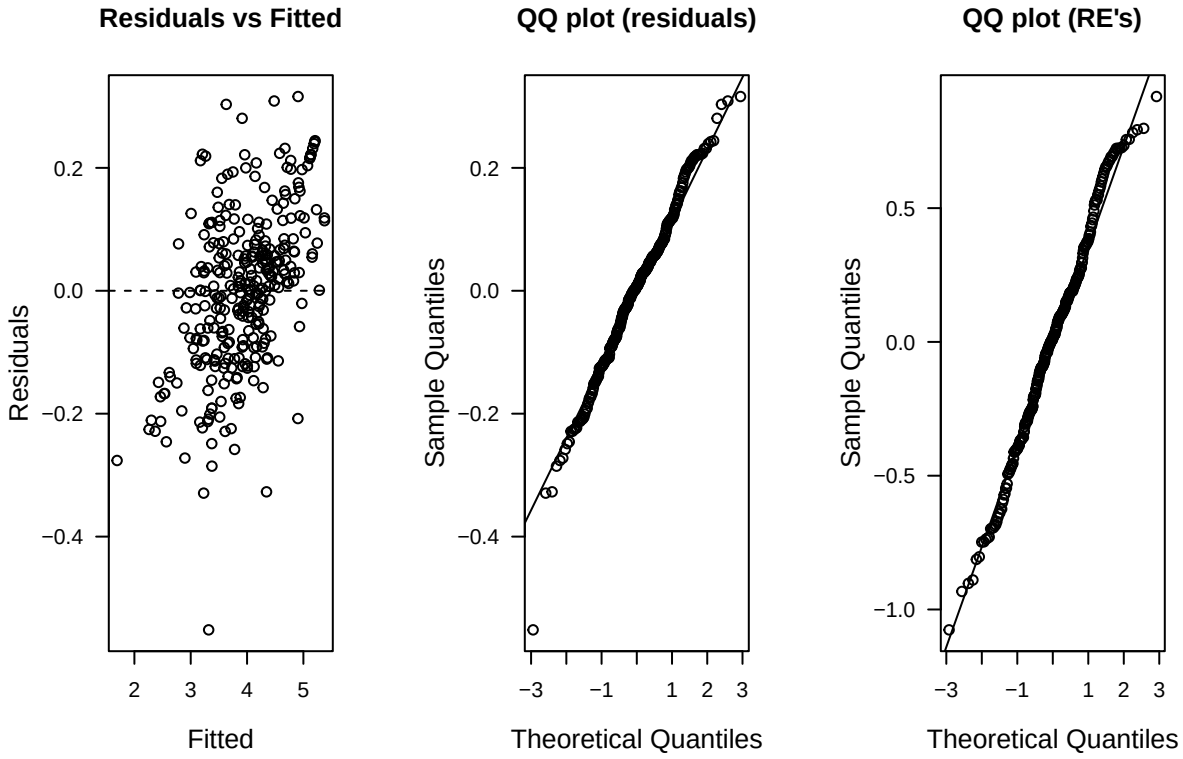
Where D_i is the natural logarithm of the dry weight of the analyze from a sample site, β_1 is the categorical effect of year, β_2 is the interaction effect of year and LIO, β_3 is the coefficient for mean percent AU of the nearest watershed region, β_4 is the coefficient for the time the mussels remained in the water (which varied by sampling year), μ is the random effect of longitude nested in LIO $\mu_i \sim \text{N}(0, \sigma_\mu^2)$, and ϵ is the error distributed $\epsilon_i \sim \text{N}(0, \sigma_\epsilon^2)$.


Residuals vs Fitted
Residuals
Fitted
QQ plot (residuals)
Sample Quantiles
Theoretical Quantiles
QQ plot (RE's)
Sample Quantiles
Theoretical Quantiles

82


Residuals vs Fitted
Residuals
Fitted
QQ plot (residuals)
Sample Quantiles
Theoretical Quantiles
QQ plot (RE's)
Sample Quantiles
Theoretical Quantiles

83




```
## Warning in aictab.AIClmerMod(cand.set = models, modnames = model.names, :
## Model selection for fixed effects is only appropriate with ML estimation:
## REML (default) should only be used to select random effects for a constant set of fix
```

	Random Effect of Model	AIC	Delta AIC
5	(1|longitude)	731.4414	0.000000
2	(1|LIO/longitude)	733.4414	2.000000
4	(1|latitude)	739.3850	7.943634
1	(1|LIO/latitude)	741.3850	9.943634
3	(1|LIO)	763.8950	32.453640

	npar	Sum Sq	Mean Sq	F value
time	1	0.0228454	0.0228454	0.3815897
year	3	2.1121122	0.7040374	11.7596479
mean_is_au	1	11.7407703	11.7407703	196.1079397
year:lio_areas	28	6.3306777	0.2260956	3.7765111

```
## Warning in aictab.AIClmerMod(cand.set = models, modnames = model.names, :
## Model selection for fixed effects is only appropriate with ML estimation:
## REML (default) should only be used to select random effects for a constant set of fix
```

	Random Effect of Model	AIC	Delta AIC
5	1|longitude)	566.8031	0.0000000
4	1|latitude)	567.7357	0.9326201
2	1|LIO/longitude)	568.8031	2.0000000
1	1|LIO/latitude)	569.7357	2.9326201
3	1|LIO)	569.8586	3.0555193

	npar	Sum Sq	Mean Sq	F value
time	1	0.1609362	0.1609362	0.9750445
year	3	23.7643340	7.9214447	47.9926976
mean_is_au	1	39.6328810	39.6328810	240.1189370
year:lio_areas	28	34.5947127	1.2355255	7.4855285

	npar	AIC	BIC	logLik	deviance	Chisq	Df	Pr(>Chisq)
PB_notime	35	497.4085	627.9620	-213.7042	427.4085	NA	NA	NA
PB_LMM	36	496.2293	630.5128	-212.1146	424.2293	3.179225	1	0.0745801

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :
## unable to evaluate scaled gradient
```

```
## Warning in checkConv(attr(opt, "derivs"), opt$par, ctrl = control$checkConv, :
## Model failed to converge: degenerate Hessian with 1 negative eigenvalues
```

```
## Warning in aictab.AIClmerMod(cand.set = models, modnames = model.names, :
## Model selection for fixed effects is only appropriate with ML estimation:
## REML (default) should only be used to select random effects for a constant set of fix
```

	Random Effect of Model	AIC	Delta AIC
5	(1|longitude)	578.6010	0.000000
2	(1|LIO/longitude)	580.6010	2.000000
4	(1|latitude)	584.1236	5.522596

	Random Effect of Model	AIC	Delta AIC
1	(1|LIO/latitude)	586.1236	7.522596
3	(1|LIO)	592.6684	14.067482

	npar	Sum Sq	Mean Sq	F value
time	1	2.311266	2.3112656	34.232954
year	3	1.678516	0.5595055	8.287029
mean_is_au	1	6.632512	6.6325123	98.236431
year:lio_areas	28	9.999718	0.3571328	5.289617

While we decided to fit the same model for each analyte, the parameter estimates are different in each case (REF TABLE HERE). Most notably, in each case the variable with the highest t-value is mean percent AU, indicating that it is the strongest and most significant effect on dry weight.

-model parameters (this might require a table)

-what we can and can't say

Toxics in the Nearshore Recommendation

Acknowledgments

References

Appendix

Parameter Summary Tables

effect	group	term	estimate	std.error	statistic
fixed	NA	(Intercept)	6.2765624	0.9487517	6.6156006
fixed	NA	time	-0.0333872	0.0150282	-2.2216399
fixed	NA	year2016	1.1438858	0.8861281	1.2908809
fixed	NA	year2018	0.6525321	0.6528914	0.9994497
fixed	NA	year2020	0.6519114	0.6671822	0.9771115
fixed	NA	mean_is_au	0.0176958	0.0022143	7.9916168
fixed	NA	year2013:lio_areasPuyallup / White	0.6350302	0.4605221	1.3789355
fixed	NA	year2016:lio_areasPuyallup / White	0.8226249	0.4608683	1.7849457
fixed	NA	year2018:lio_areasPuyallup / White	0.9387117	0.3287235	2.8556272
fixed	NA	year2020:lio_areasPuyallup / White	0.3918281	0.3613502	1.0843446
fixed	NA	year2013:lio_areasSkagit / Samish	-0.6166944	0.4993974	-1.2348770
fixed	NA	year2016:lio_areasSkagit / Samish	1.1390929	0.5549795	2.0524955
fixed	NA	year2018:lio_areasSkagit / Samish	0.7056200	0.4445397	1.5873047
fixed	NA	year2020:lio_areasSkagit / Samish	0.3159018	0.4544027	0.6952025
fixed	NA	year2013:lio_areasSnohomish / Stillaguamish	0.2129240	0.5309136	0.4010522
fixed	NA	year2016:lio_areasSnohomish / Stillaguamish	0.6179667	0.5038938	1.2263828
fixed	NA	year2018:lio_areasSnohomish / Stillaguamish	0.3392289	0.4148951	0.8176255
fixed	NA	year2020:lio_areasSnohomish / Stillaguamish	0.2575482	0.3967836	0.6490898
fixed	NA	year2013:lio_areasSouth Central	1.0081942	0.4506951	2.2369761
fixed	NA	year2016:lio_areasSouth Central	1.7884073	0.4058285	4.4068052
fixed	NA	year2018:lio_areasSouth Central	1.7074824	0.3099487	5.5089189
fixed	NA	year2020:lio_areasSouth Central	1.1627493	0.3245431	3.5827266
fixed	NA	year2013:lio_areasSouth Sound	-0.4336633	0.4765611	-0.9099847

effect	group	term	estimate	std.error	statistic
fixed	NA	year2016:lio_areasSouth Sound	0.5687781	0.4541705	1.2523448
fixed	NA	year2018:lio_areasSouth Sound	0.2316511	0.3613974	0.6409871
fixed	NA	year2020:lio_areasSouth Sound	0.1074163	0.4019557	0.2672341
fixed	NA	year2013:lio_areasWest Sound	0.6192862	0.4463476	1.3874527
fixed	NA	year2016:lio_areasWest Sound	1.1437725	0.3836862	2.9810104
fixed	NA	year2018:lio_areasWest Sound	0.9120430	0.2813508	3.2416574
fixed	NA	year2020:lio_areasWest Sound	0.5893960	0.3026935	1.9471711
fixed	NA	year2013:lio_areasWhatcom	0.0458001	0.4625833	0.0990094
fixed	NA	year2016:lio_areasWhatcom	0.7457055	0.4175714	1.7858153
fixed	NA	year2018:lio_areasWhatcom	0.5302650	0.3590290	1.4769418
fixed	NA	year2020:lio_areasWhatcom	0.2506166	0.3538604	0.7082357
ran_pars	longitude	sd__(Intercept)	0.6789580	NA	NA
ran_pars	Residual	sd__Observation	0.2446813	NA	NA

effect	group	term	estimate	std.error	statistic
fixed	NA	(Intercept)	0.3496092	0.6847147	0.5105911
fixed	NA	time	0.0183058	0.0108812	1.6823311
fixed	NA	year2016	-1.6640937	0.6374253	-2.6106487
fixed	NA	year2018	-1.4257793	0.4682145	-3.0451417
fixed	NA	year2020	-1.3802527	0.4784976	-2.8845549
fixed	NA	mean_is_au	0.0110729	0.0015511	7.1388899
fixed	NA	year2013:lio_areasPuyallup / White	0.6090696	0.3274634	1.8599627
fixed	NA	year2016:lio_areasPuyallup / White	1.6521041	0.3279461	5.0377309
fixed	NA	year2018:lio_areasPuyallup / White	1.7843219	0.2402129	7.4280858
fixed	NA	year2020:lio_areasPuyallup / White	1.0128938	0.2709207	3.7387100
fixed	NA	year2013:lio_areasSkagit / Samish	-0.7160361	0.3555111	-2.0141030
fixed	NA	year2016:lio_areasSkagit / Samish	0.6040931	0.3950230	1.5292605
fixed	NA	year2018:lio_areasSkagit / Samish	0.7085928	0.3164560	2.2391512
fixed	NA	year2020:lio_areasSkagit / Samish	-0.1749629	0.3234838	-0.5408708
fixed	NA	year2013:lio_areasSnohomish / Stillaguamish	0.3697962	0.3779179	0.9785095
fixed	NA	year2016:lio_areasSnohomish / Stillaguamish	1.5495702	0.4332002	3.5770302

effect	group	term	estimate	std.error	statistic
fixed	NA	year2018:lio_areasSnohomish / Stillaguamish	1.4640905	0.3437459	4.2592230
fixed	NA	year2020:lio_areasSnohomish / Stillaguamish	-0.2747226	0.3007902	-0.9133366
fixed	NA	year2013:lio_areasSouth Central	0.3711061	0.3274746	1.1332362
fixed	NA	year2016:lio_areasSouth Central	1.8077996	0.3122823	5.7889909
fixed	NA	year2018:lio_areasSouth Central	1.4610804	0.2323144	6.2892369
fixed	NA	year2020:lio_areasSouth Central	0.7270140	0.2453562	2.9630961
fixed	NA	year2013:lio_areasSouth Sound	-0.2228129	0.3392384	-0.6568035
fixed	NA	year2016:lio_areasSouth Sound	0.7579557	0.3233312	2.3442085
fixed	NA	year2018:lio_areasSouth Sound	0.5119190	0.2572732	1.9897874
fixed	NA	year2020:lio_areasSouth Sound	0.0974607	0.2861554	0.3405865
fixed	NA	year2013:lio_areasWest Sound	0.6006529	0.3219181	1.8658561
fixed	NA	year2016:lio_areasWest Sound	1.2598560	0.2788534	4.5179864
fixed	NA	year2018:lio_areasWest Sound	1.1107103	0.2095135	5.3013769
fixed	NA	year2020:lio_areasWest Sound	0.3615617	0.2220291	1.6284427
fixed	NA	year2013:lio_areasWhatcom	-0.5319712	0.3382538	-1.5726986
fixed	NA	year2016:lio_areasWhatcom	0.7440840	0.3204689	2.3218605
fixed	NA	year2018:lio_areasWhatcom	0.6274997	0.2777402	2.2593043
fixed	NA	year2020:lio_areasWhatcom	-0.0891794	0.2742560	-0.3251686
ran_pars	longitude	sd__(Intercept)	0.3145257	NA	NA
ran_pars	Residual	sd__Observation	0.4062699	NA	NA

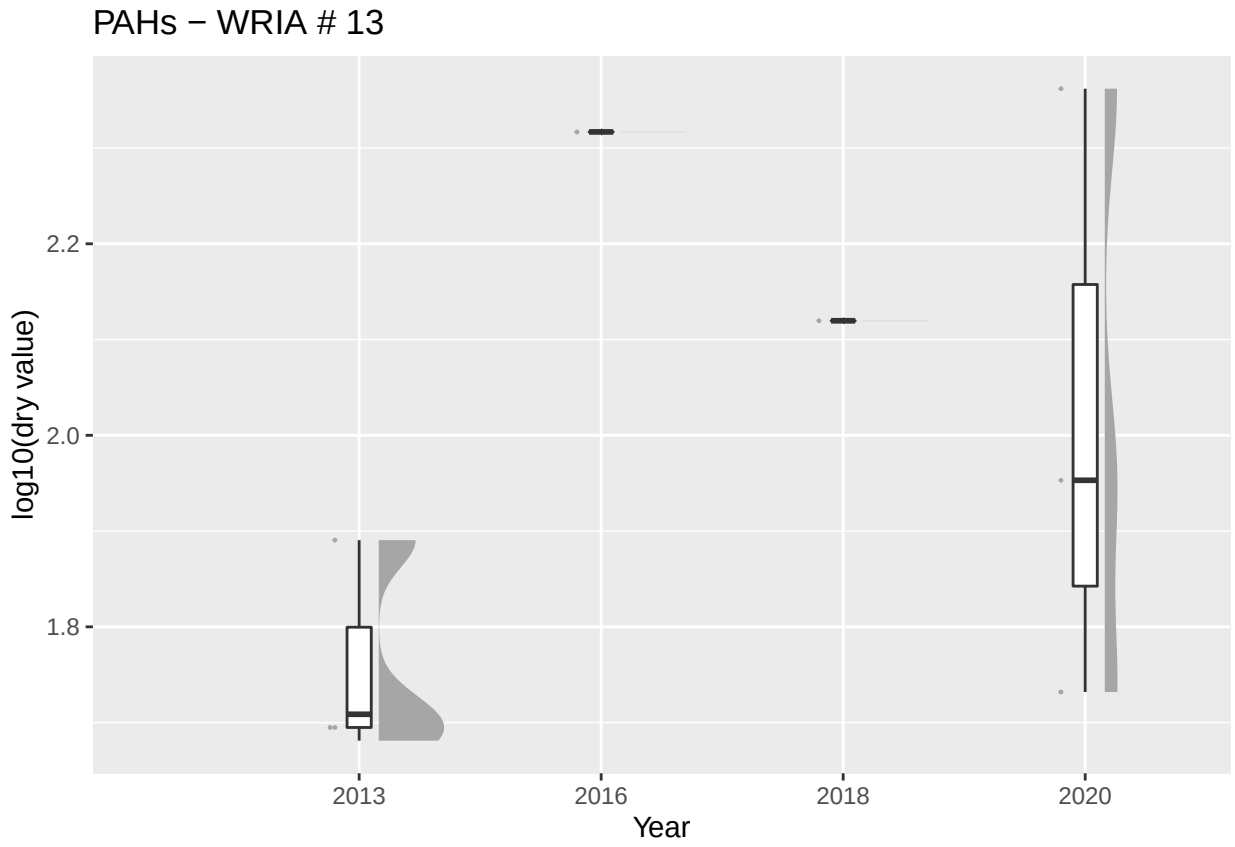
effect	group	term	estimate	std.error	statistic
fixed	NA	(Intercept)	3.5134807	0.7116380	4.9371740
fixed	NA	time	-0.0032171	0.0112948	-0.2848276
fixed	NA	year2016	0.2027042	0.6633304	0.3055856
fixed	NA	year2018	-0.1659919	0.4878430	-0.3402567
fixed	NA	year2020	-0.1270023	0.4985390	-0.2547491
fixed	NA	mean_is_au	0.0098035	0.0016433	5.9655876
fixed	NA	year2013:lio_areasPuyallup / White	0.2613301	0.3424850	0.7630409
fixed	NA	year2016:lio_areasPuyallup / White	0.2645550	0.3427918	0.7717658

effect	group	term	estimate	std.error	statistic
fixed	NA	year2018:lio_areasPuyallup / White	0.8427605	0.2479702	3.3986363
fixed	NA	year2020:lio_areasPuyallup / White	0.5381814	0.2763396	1.9475360
fixed	NA	year2013:lio_areasSkagit / Samish	-0.8328908	0.3714599	-2.2422091
fixed	NA	year2016:lio_areasSkagit / Samish	-0.0482016	0.4127899	-0.1167703
fixed	NA	year2018:lio_areasSkagit / Samish	0.2964648	0.3306639	0.8965742
fixed	NA	year2020:lio_areasSkagit / Samish	0.1489861	0.3379946	0.4407944
fixed	NA	year2013:lio_areasSnohomish / Stillaguamish	-0.1928837	0.3948991	-0.4884379
fixed	NA	year2016:lio_areasSnohomish / Stillaguamish	0.4012922	0.4037738	0.9938540
fixed	NA	year2018:lio_areasSnohomish / Stillaguamish	0.5818442	0.3295202	1.7657313
fixed	NA	year2020:lio_areasSnohomish / Stillaguamish	-0.4992896	0.3031069	-1.6472396
fixed	NA	year2013:lio_areasSouth Central	0.0841193	0.3385743	0.2484514
fixed	NA	year2016:lio_areasSouth Central	0.7404221	0.3113267	2.3782804
fixed	NA	year2018:lio_areasSouth Central	1.0454146	0.2366393	4.4177562
fixed	NA	year2020:lio_areasSouth Central	0.7845679	0.2484273	3.1581381
fixed	NA	year2013:lio_areasSouth Sound	-0.3823504	0.3544673	-1.0786621
fixed	NA	year2016:lio_areasSouth Sound	0.3472277	0.3378299	1.0278181
fixed	NA	year2018:lio_areasSouth Sound	0.7140612	0.2688102	2.6563766
fixed	NA	year2020:lio_areasSouth Sound	0.3279004	0.2989813	1.0967255
fixed	NA	year2013:lio_areasWest Sound	0.3936854	0.3344735	1.1770302
fixed	NA	year2016:lio_areasWest Sound	0.6954890	0.2883086	2.4123074
fixed	NA	year2018:lio_areasWest Sound	1.1397819	0.2136310	5.3352819
fixed	NA	year2020:lio_areasWest Sound	0.9059338	0.2286909	3.9613893
fixed	NA	year2013:lio_areasWhatcom	-0.3977492	0.3488255	-1.1402528
fixed	NA	year2016:lio_areasWhatcom	-0.0802677	0.3212329	-0.2498737
fixed	NA	year2018:lio_areasWhatcom	0.3493509	0.2791823	1.2513361
fixed	NA	year2020:lio_areasWhatcom	-0.1266581	0.2748077	-0.4608971
ran_pars	longitude	sd___(Intercept)	0.4697339	NA	NA
ran_pars	Residual	sd___Observation	0.2598380	NA	NA

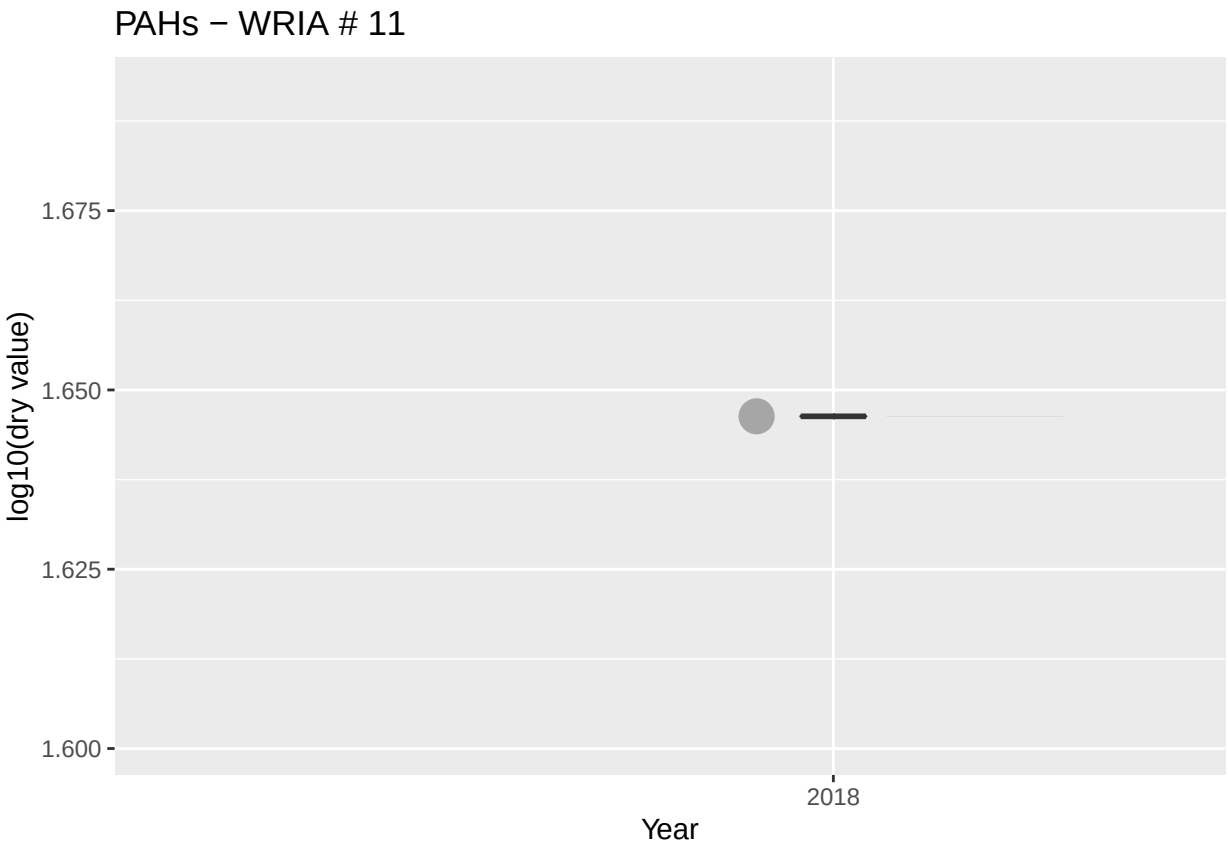
Raincloud plots

These also exist as PDFs or could probably exist as individual files/plots etc.

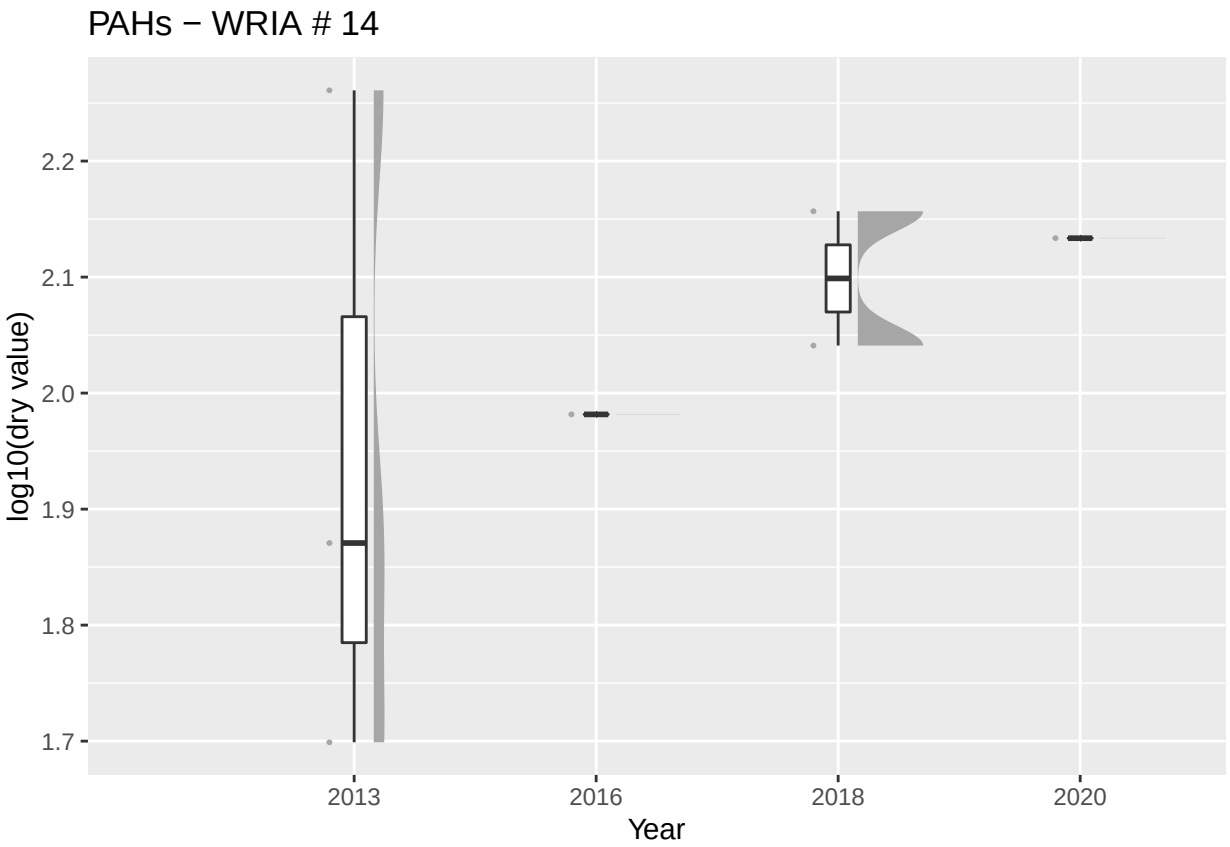
```
## $`13`
```



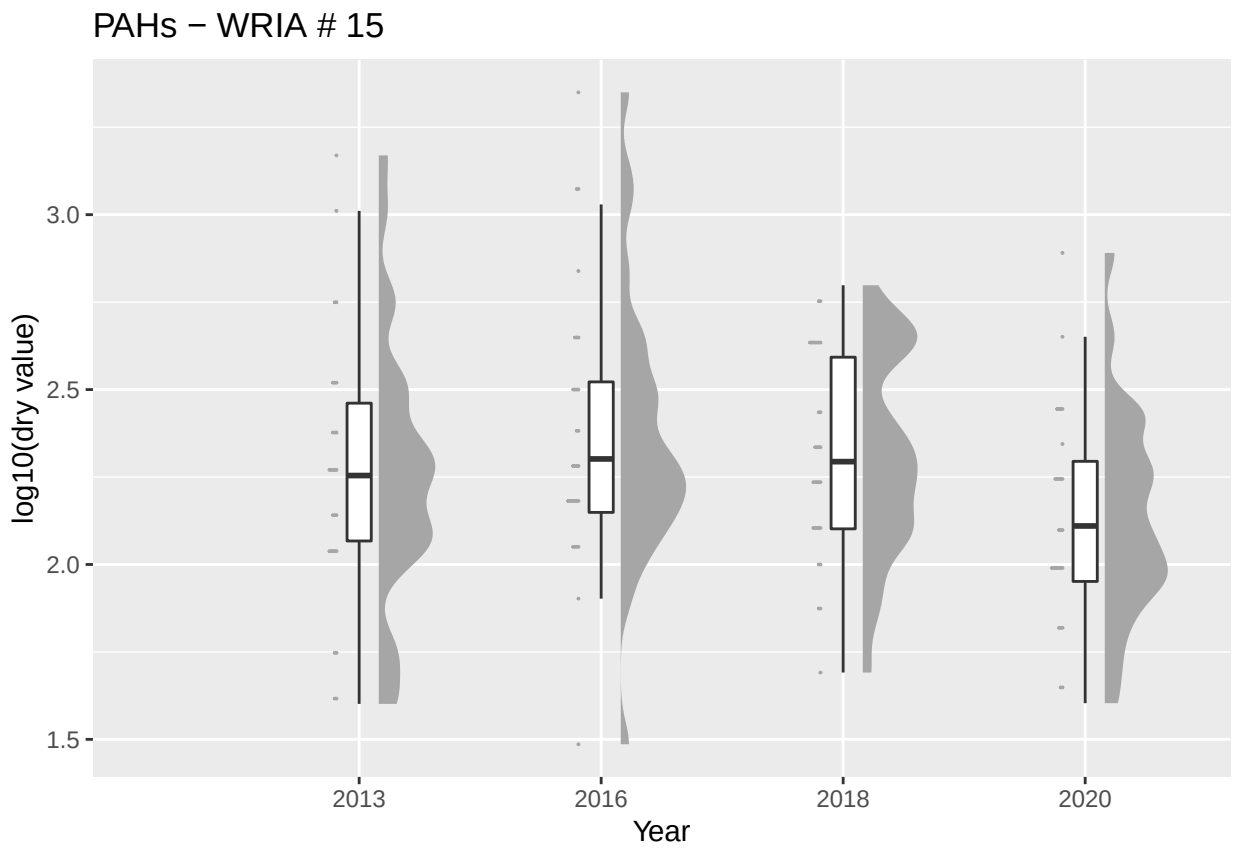

```
##
## $`11`
```



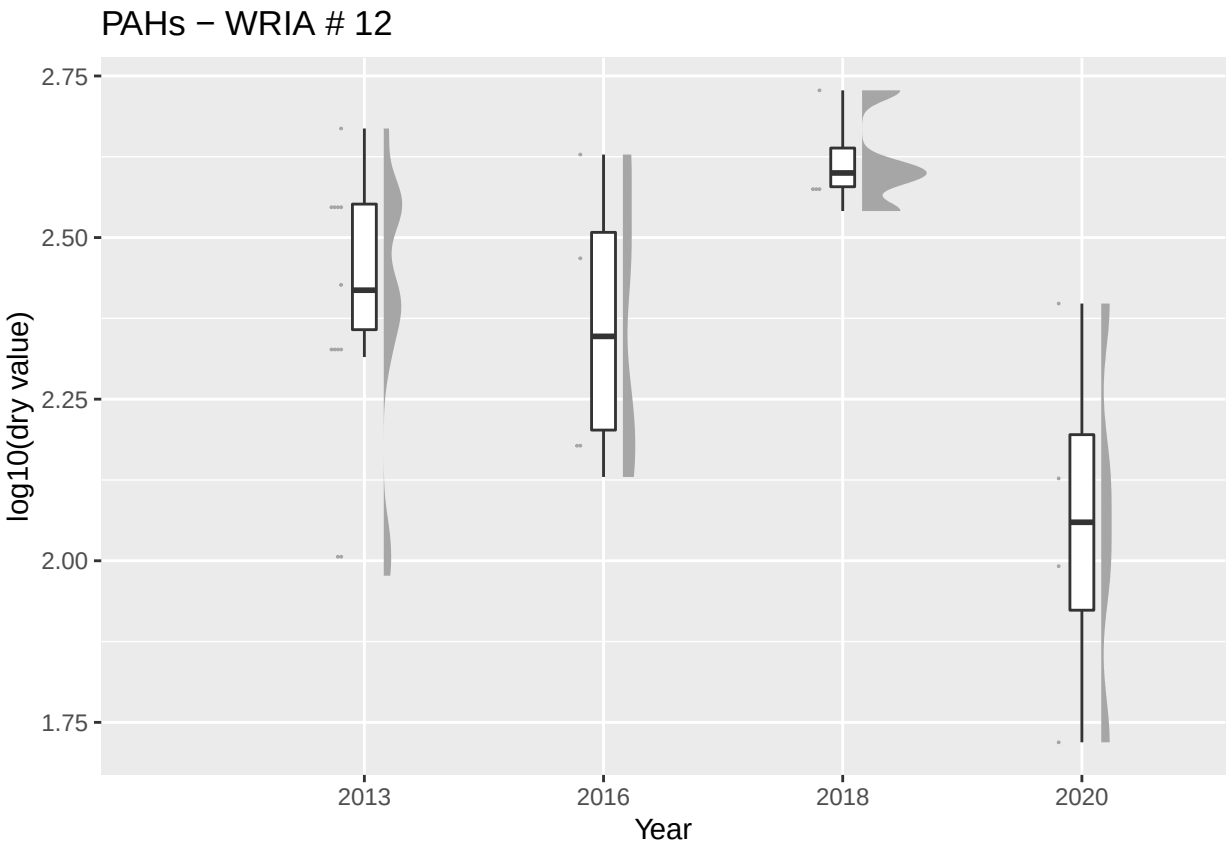

```
##
## $`14`
```


PAHs − WRIA # 14
log10(dry value)
2.2
2.1
2.0
1.9
1.8
1.7
2013
2016
2018
2020
Year

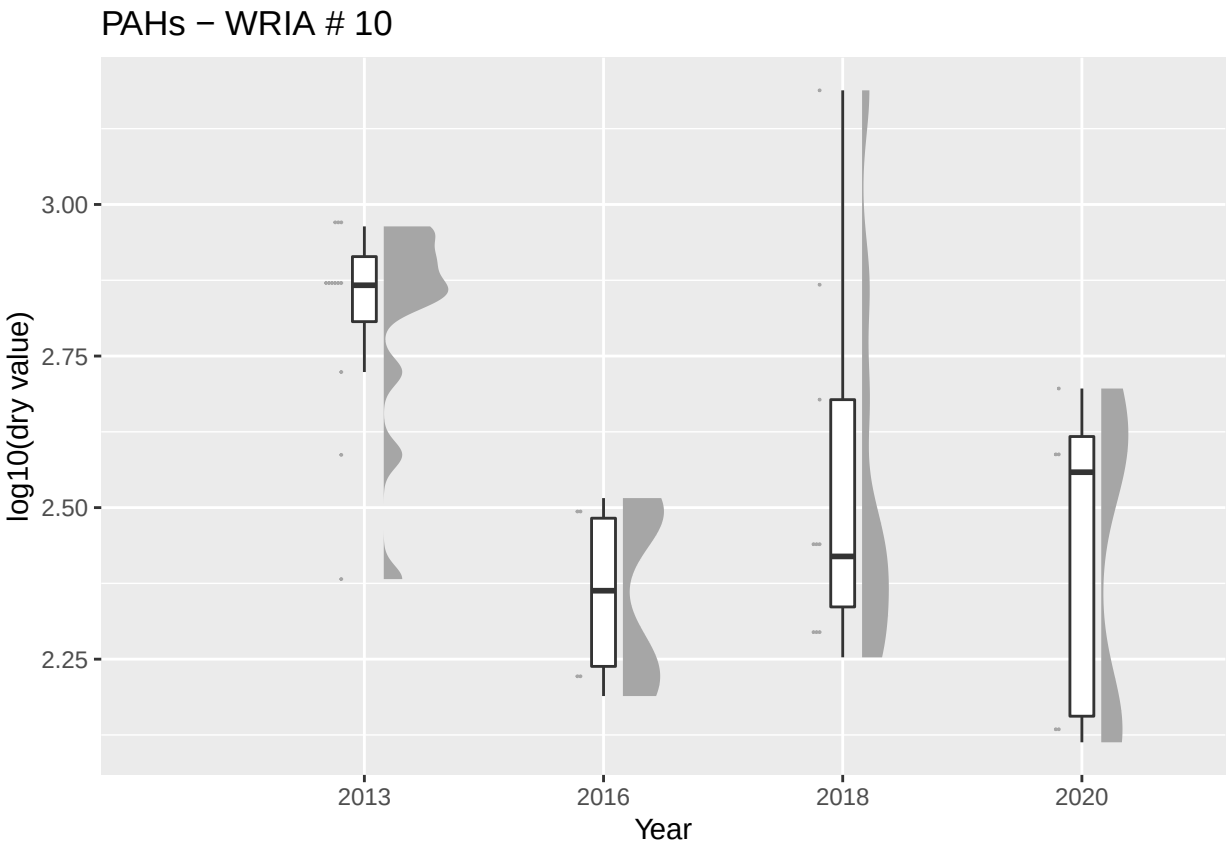
```
##
## $`15`
```


PAHs − WRIA # 15
log10(dry value)
3.0
2.5
2.0
1.5
2013
2016
2018
2020
Year

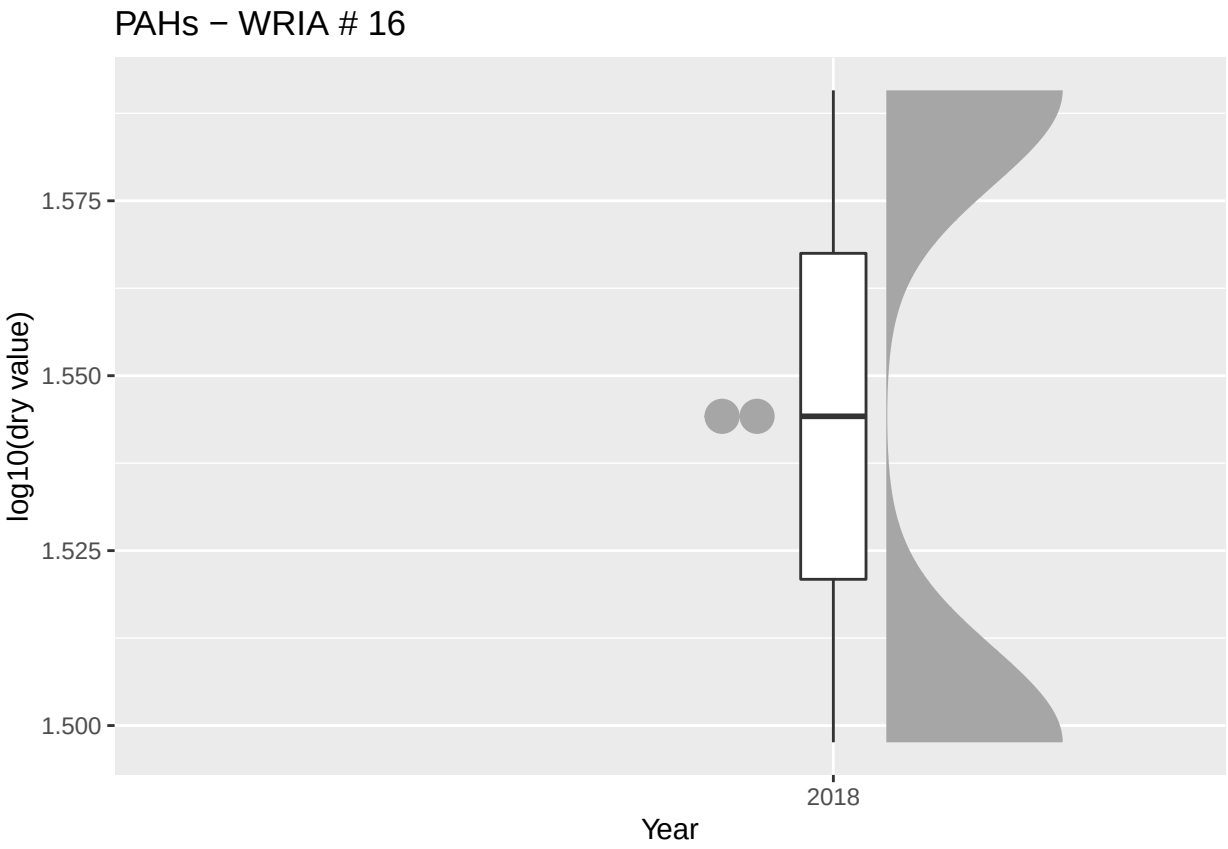
```
##
## $`12`
```


PAHs − WRIA # 12
log10(dry value)
2.75
2.50
2.25
2.00
1.75
2013
2016
2018
2020
Year

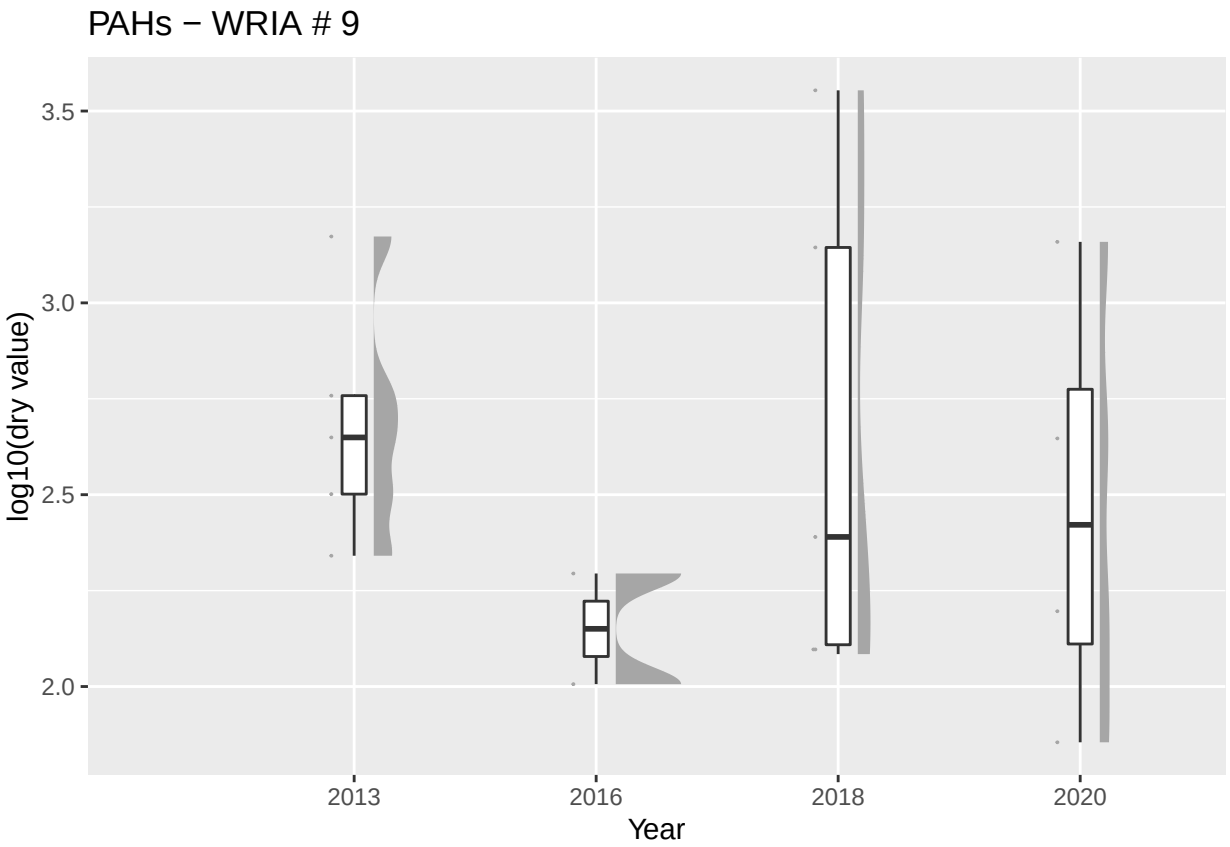
```
##
## $`10`
```


PAHs − WRIA # 10
log10(dry value)
3.00
2.75
2.50
2.25
2013
2016
2018
2020
Year

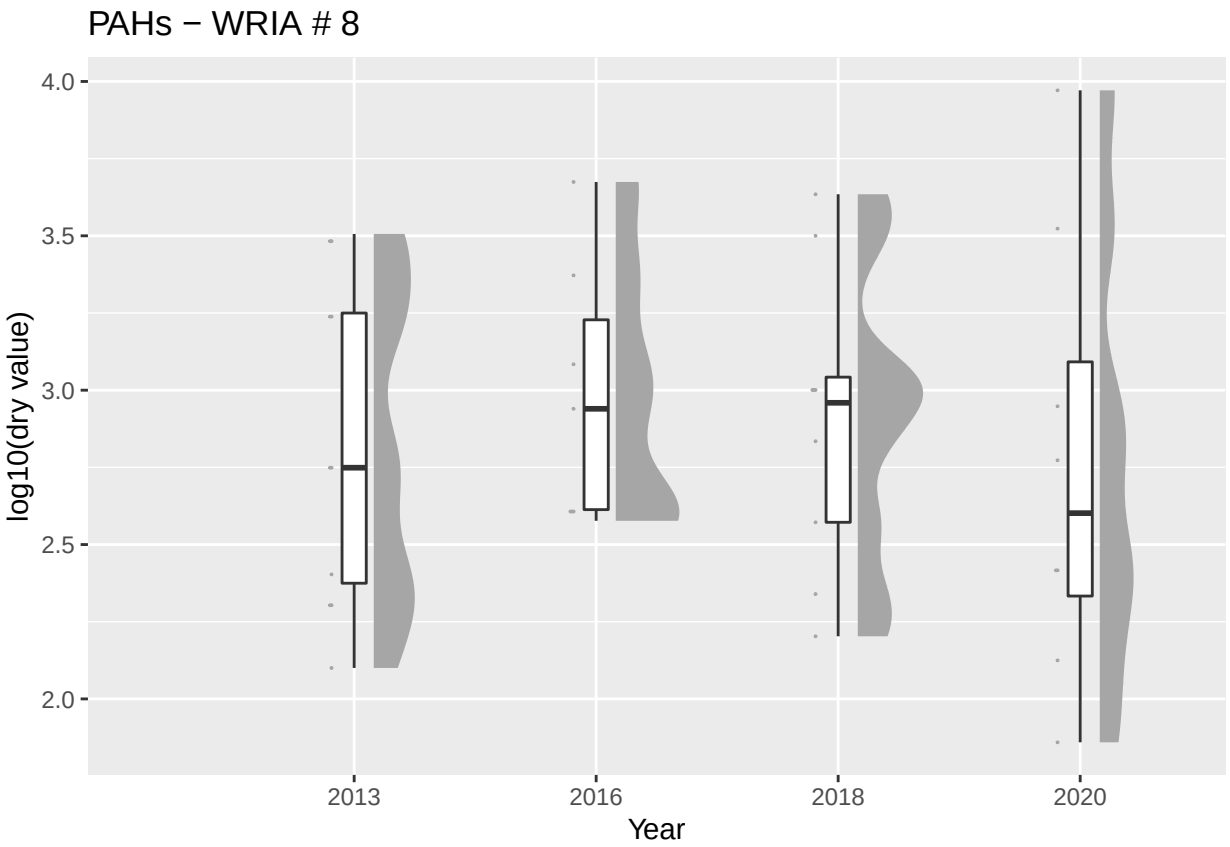
```
##
## $`16`
```




```
##
## $‘9‘
```


PAHs − WRIA # 9
log10(dry value)
3.5
3.0
2.5
2.0
2013
2016
2018
2020
Year

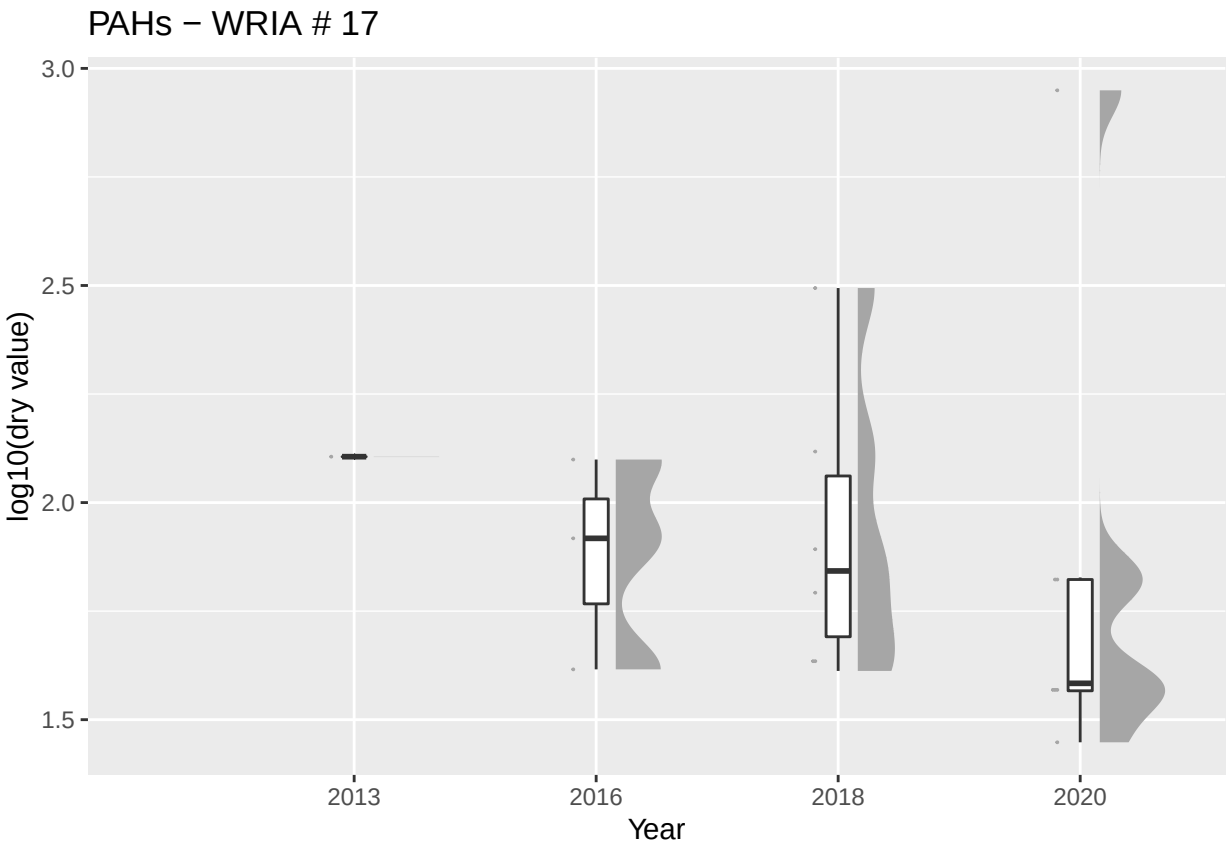
```
##
## $‘8‘
```



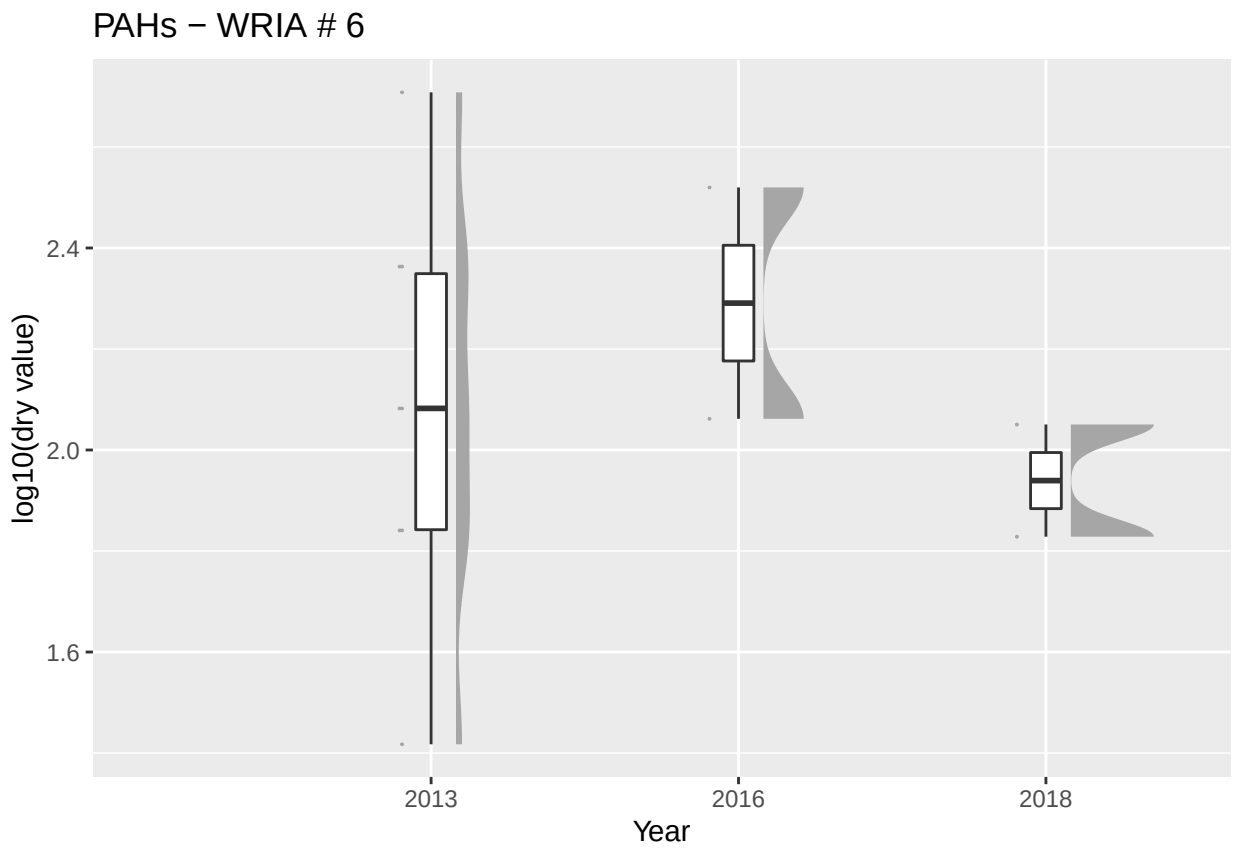
136

137 ##

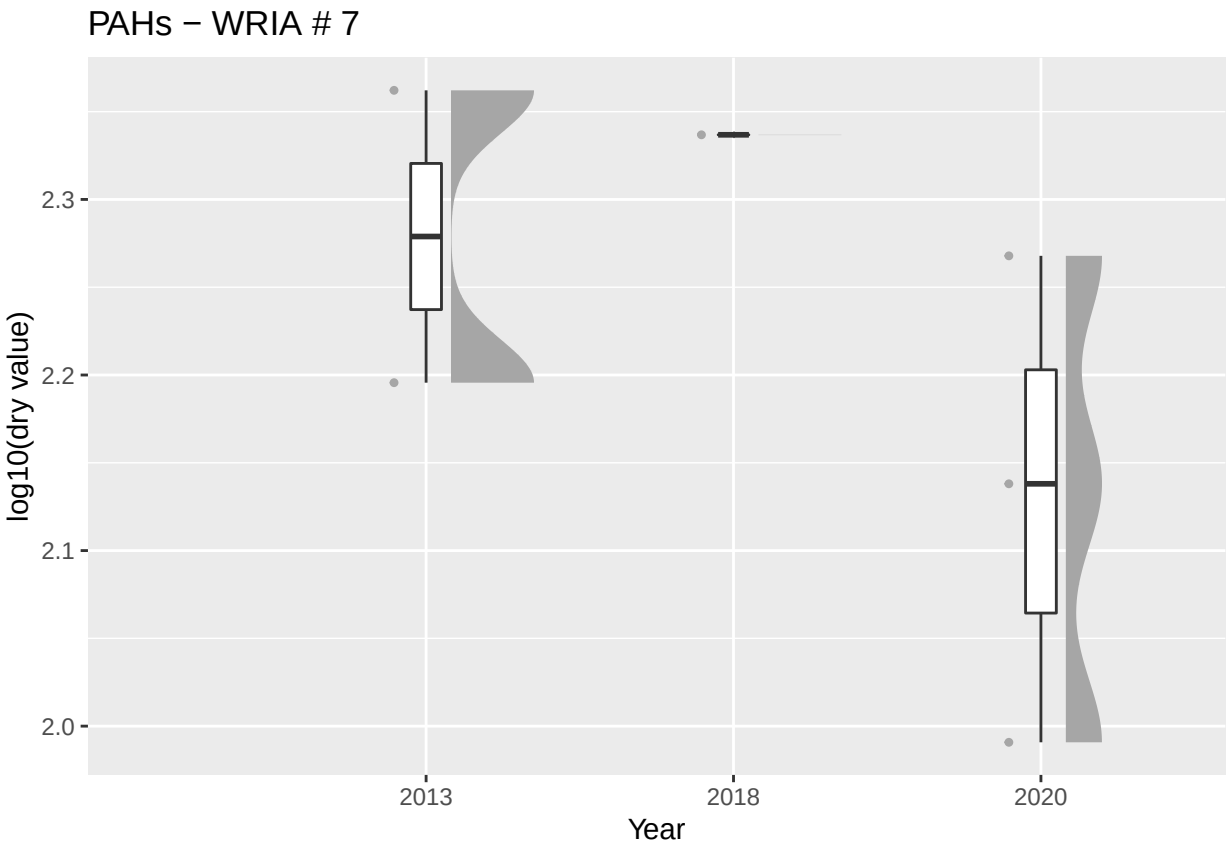
138 ## $‘17‘


PAHs − WRIA # 17
3.0
2.5
2.0
1.5
log10(dry value)
2013
2016
2018
2020
Year

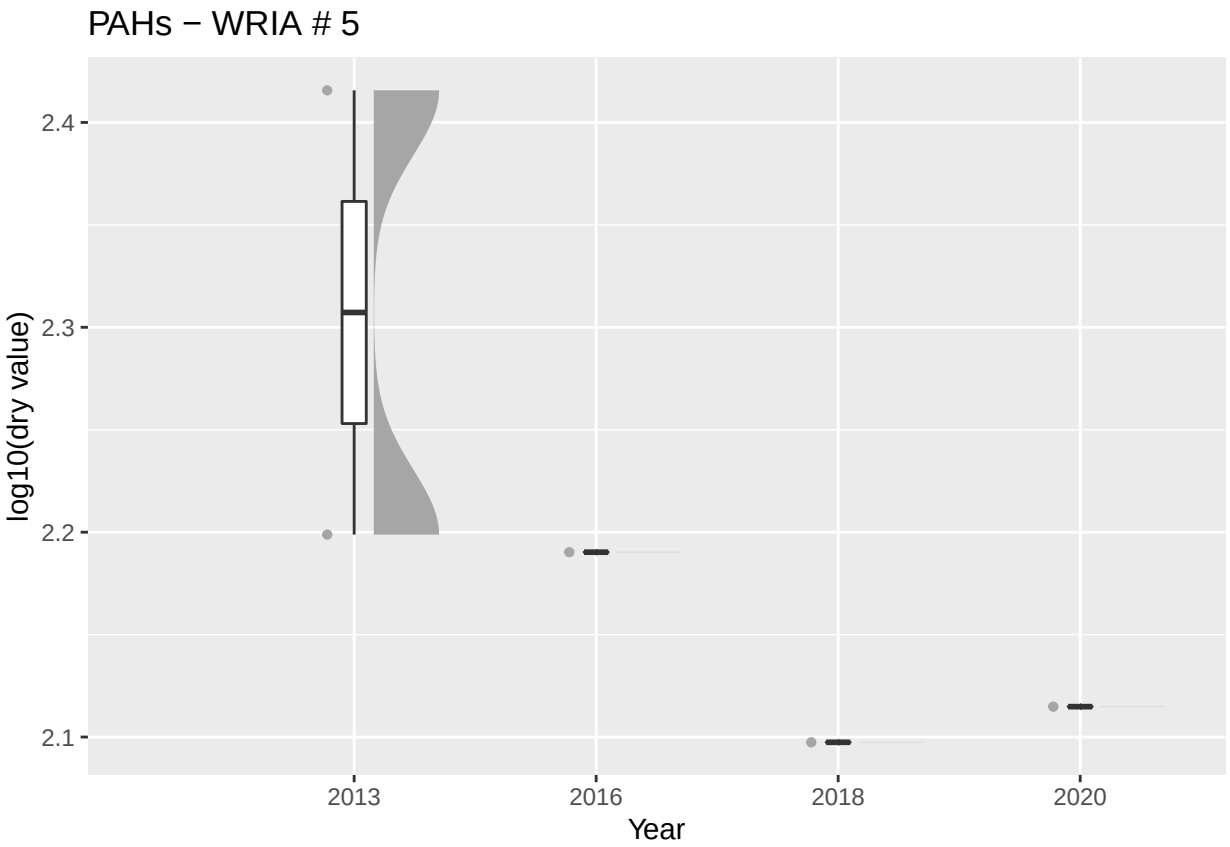
```
##
## $‘6‘
```



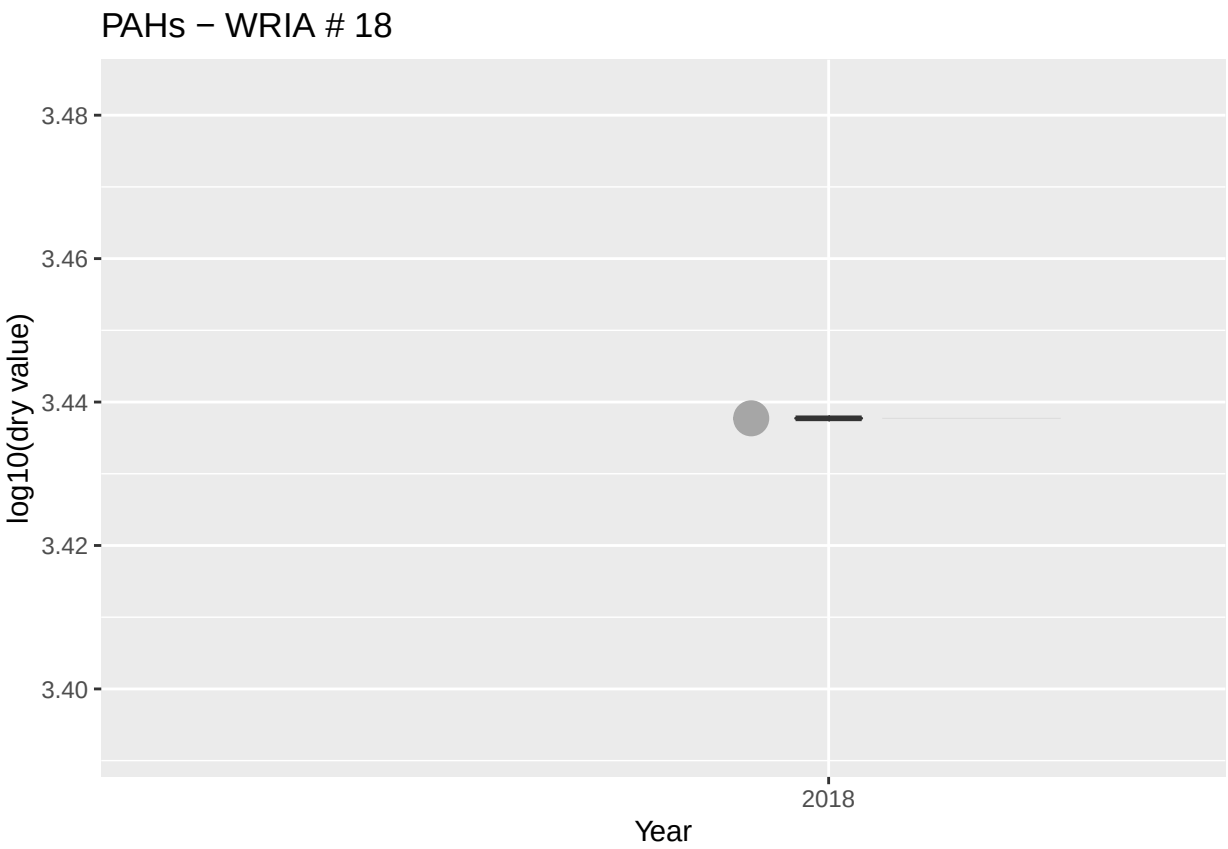

```
##
## $‘7‘
```



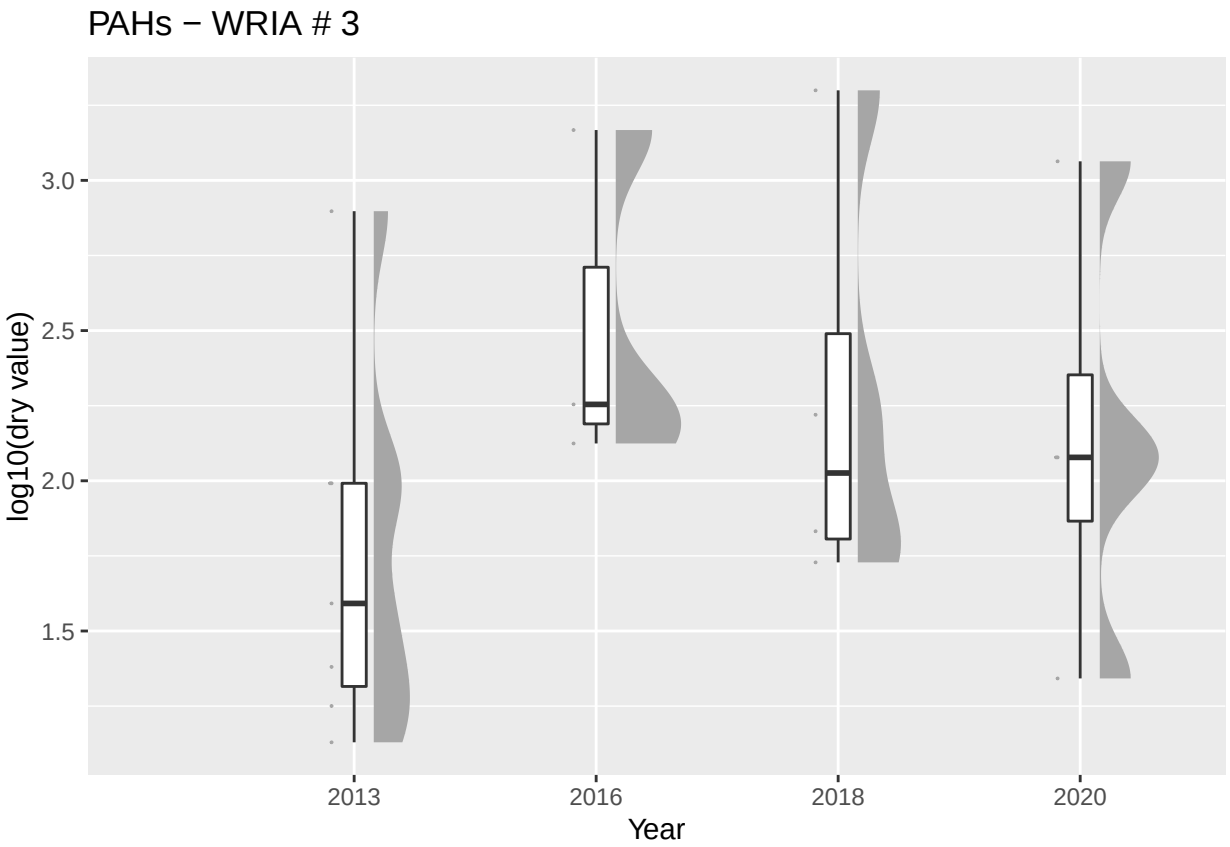

```
##
## $`5`
```


PAHs − WRIA # 5
log10(dry value)
2.4
2.3
2.2
2.1
2013
2016
2018
2020
Year

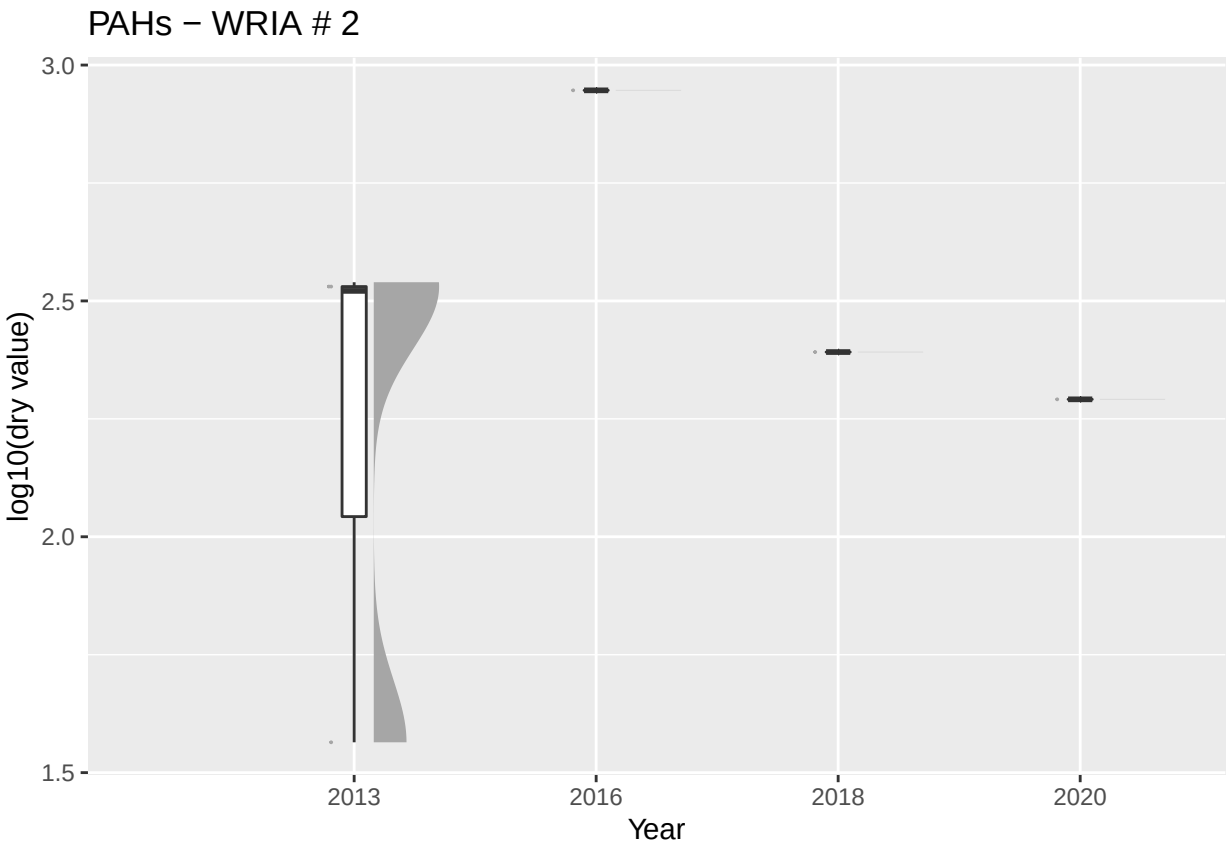
```
##
## $`18`
```



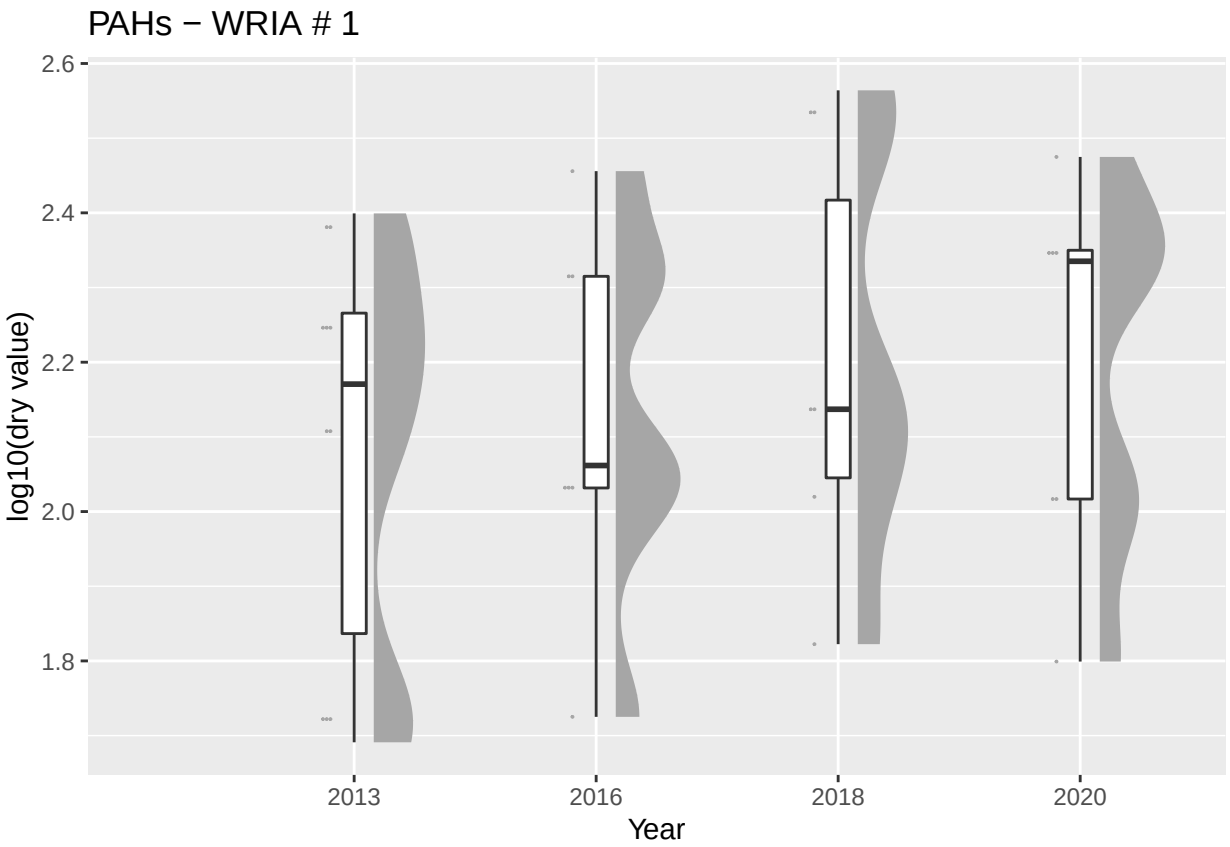

```
##
## $`3`
```


PAHs − WRIA # 3
log10(dry value)
3.0
2.5
2.0
1.5
2013
2016
2018
2020
Year

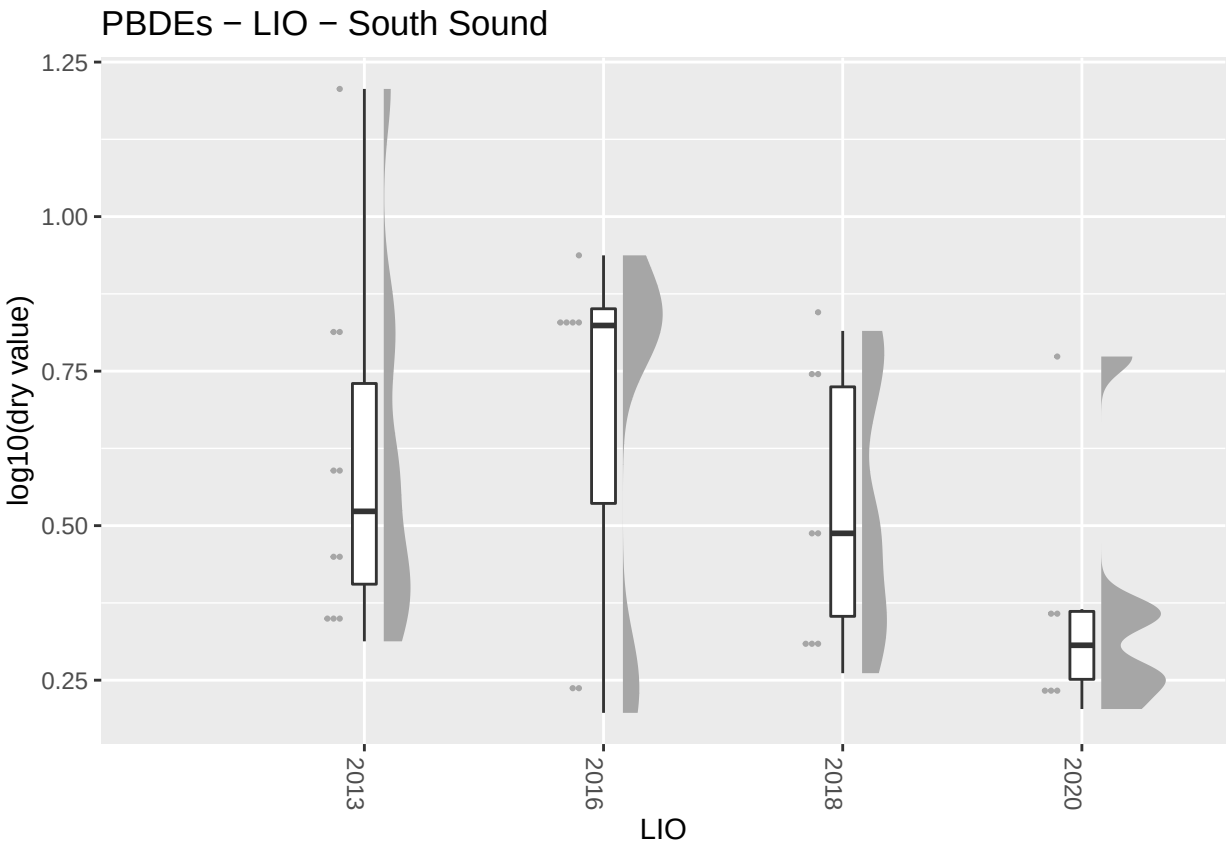
```
##
## $`2`
```


PAHs − WRIA # 2
3.0
2.5
2.0
1.5
log10(dry value)
2013
2016
2018
2020
Year

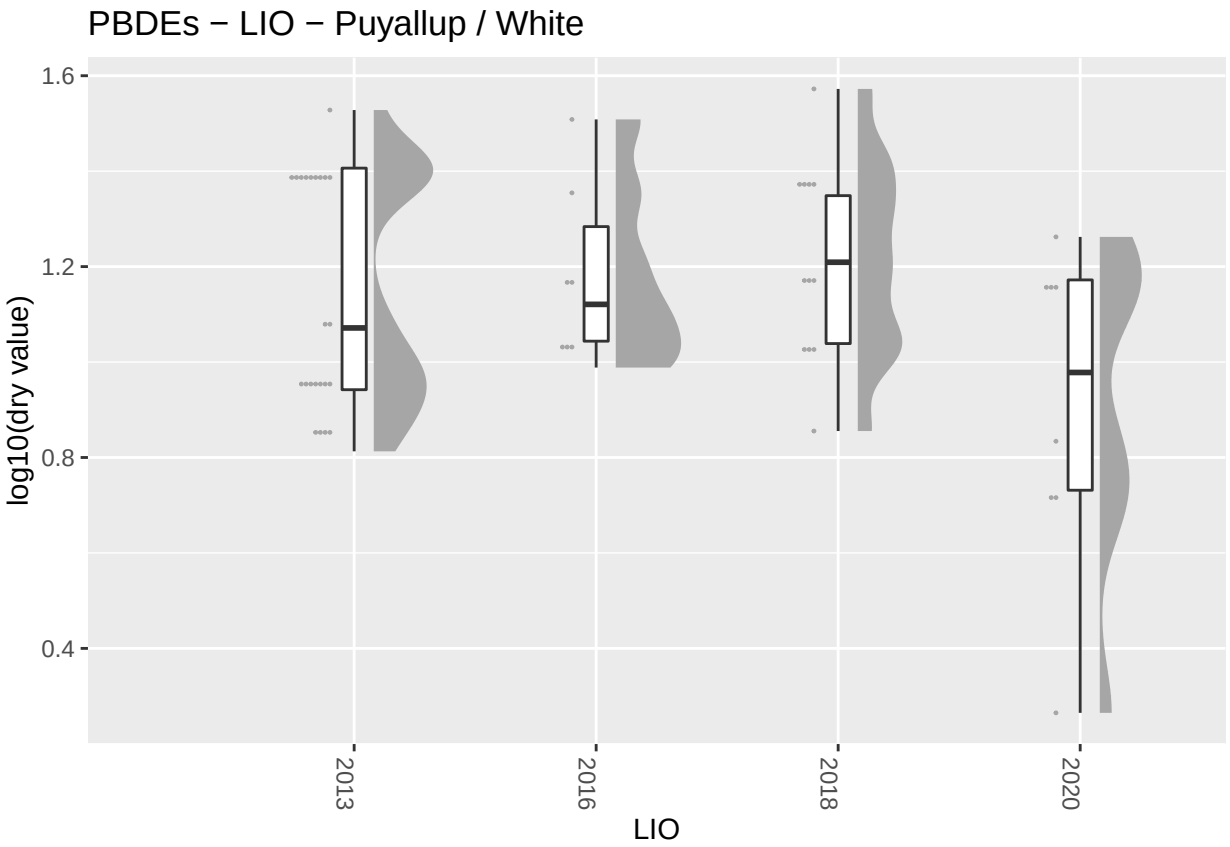
```
##
## $`1`
```


PAHs − WRIA # 1
log10(dry value)
2.6
2.4
2.2
2.0
1.8
2013
2016
2018
2020
Year

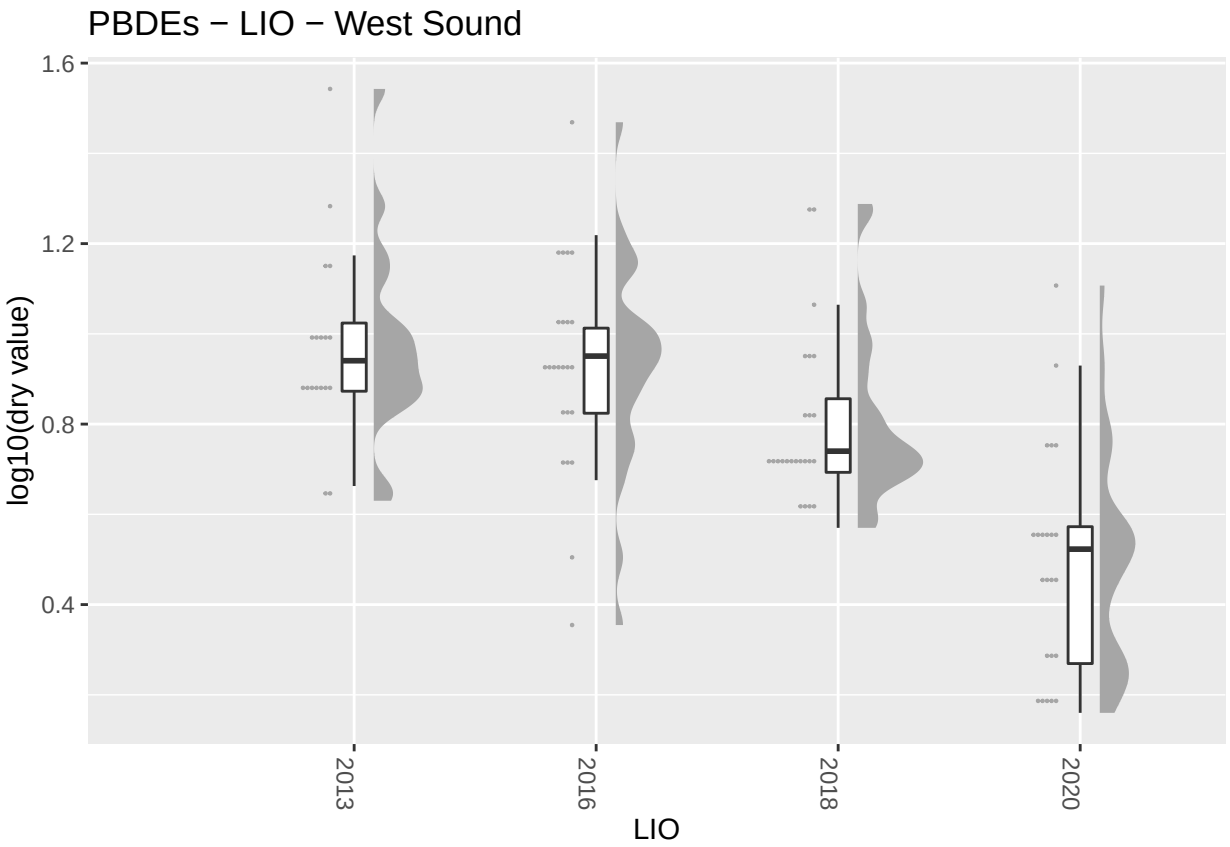
```
## $`South Sound`
```



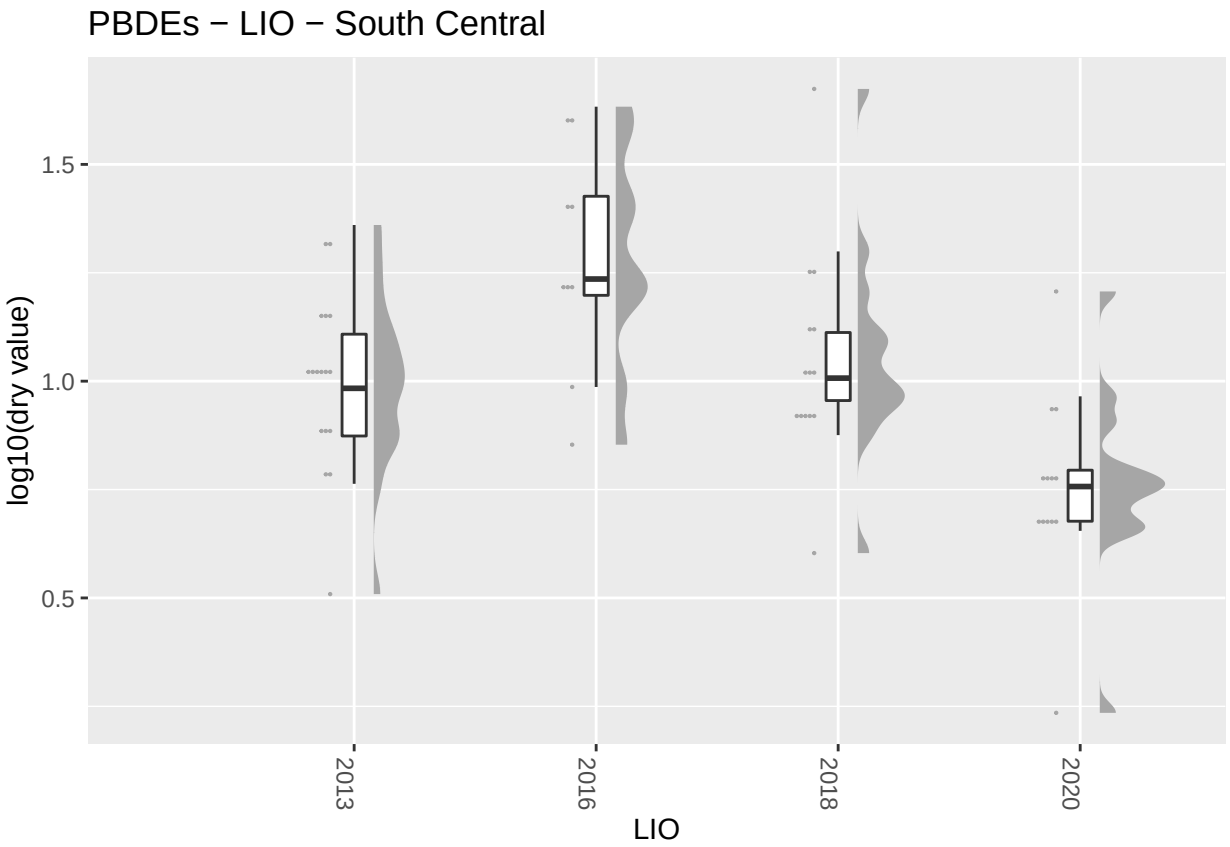

```
##
## $`Puyallup / White`
```


PBDEs − LIO − Puyallup / White
log10(dry value)
1.6
1.2
0.8
0.4
2013
2016
2018
2020
LIO

```
##
## $`West Sound`
```



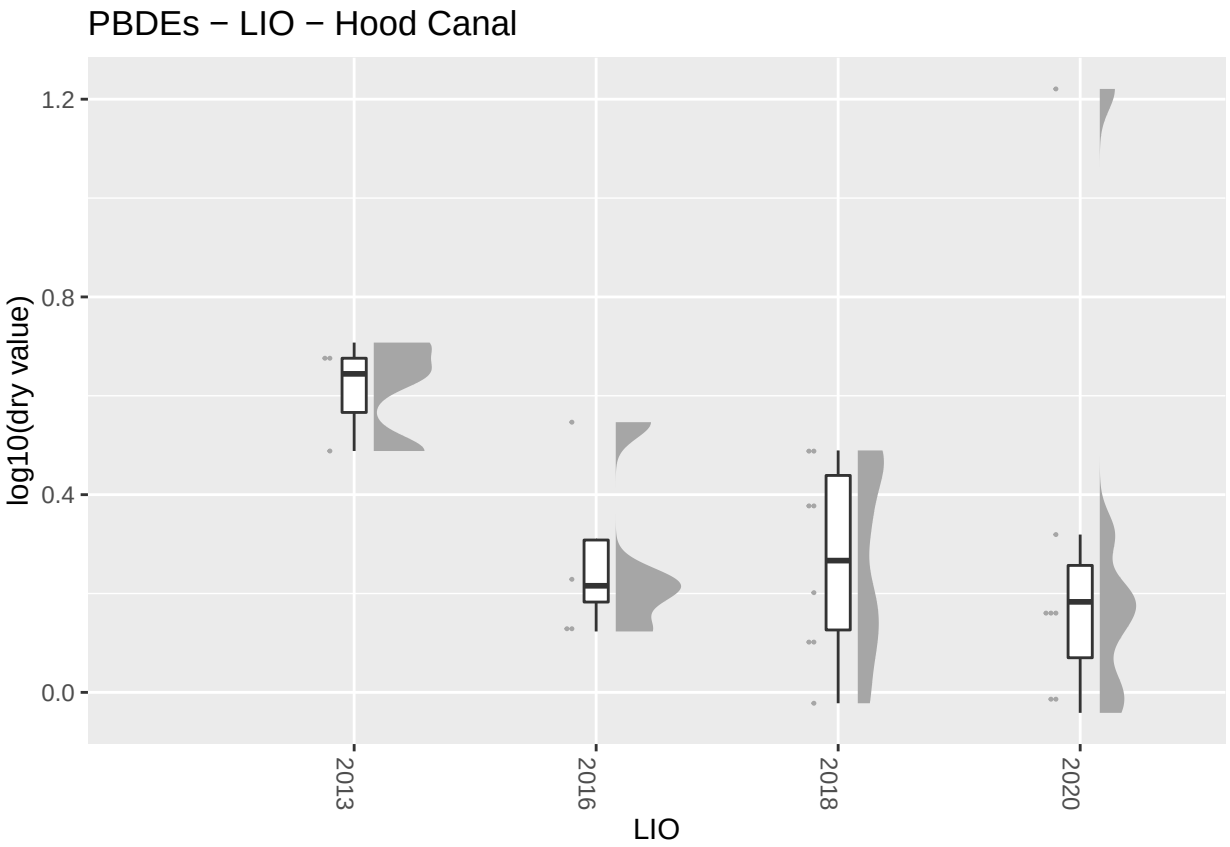

```
##
## $`South Central`
```



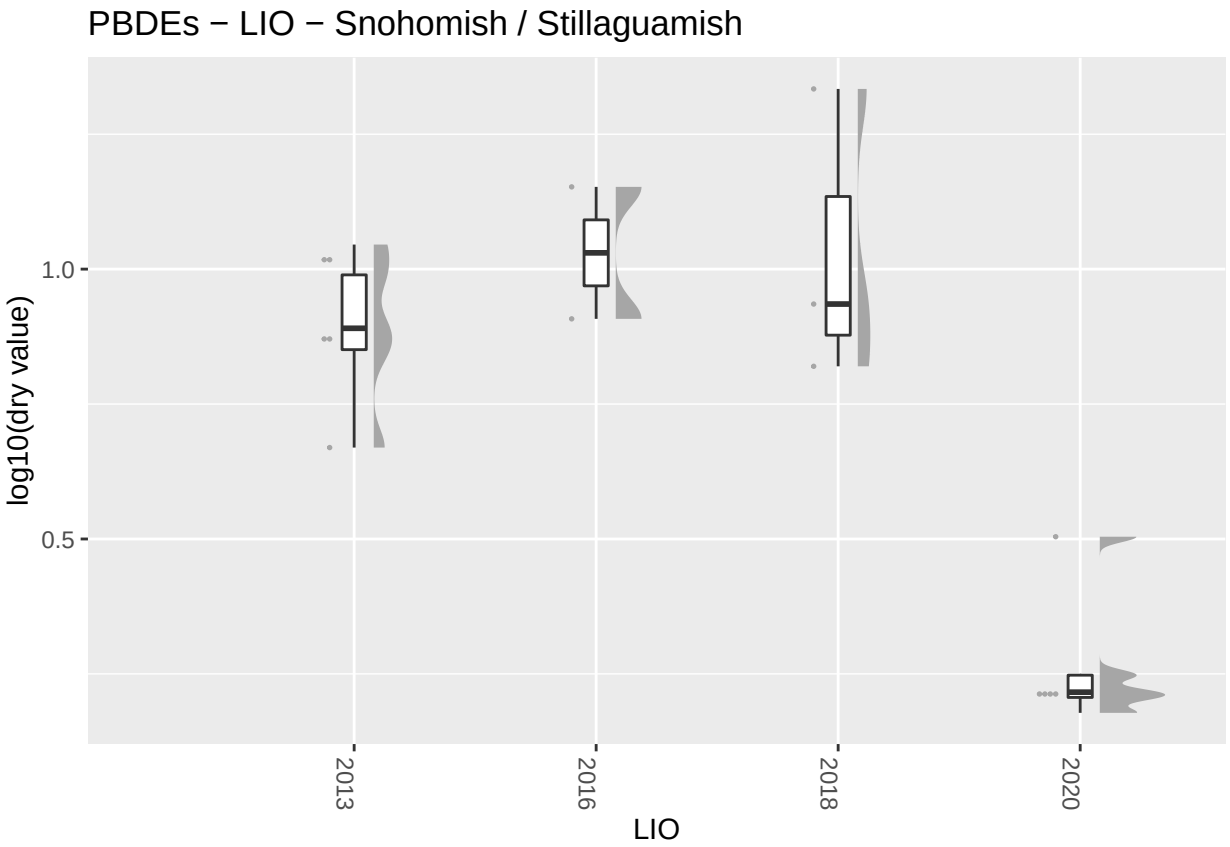
171

172 ##

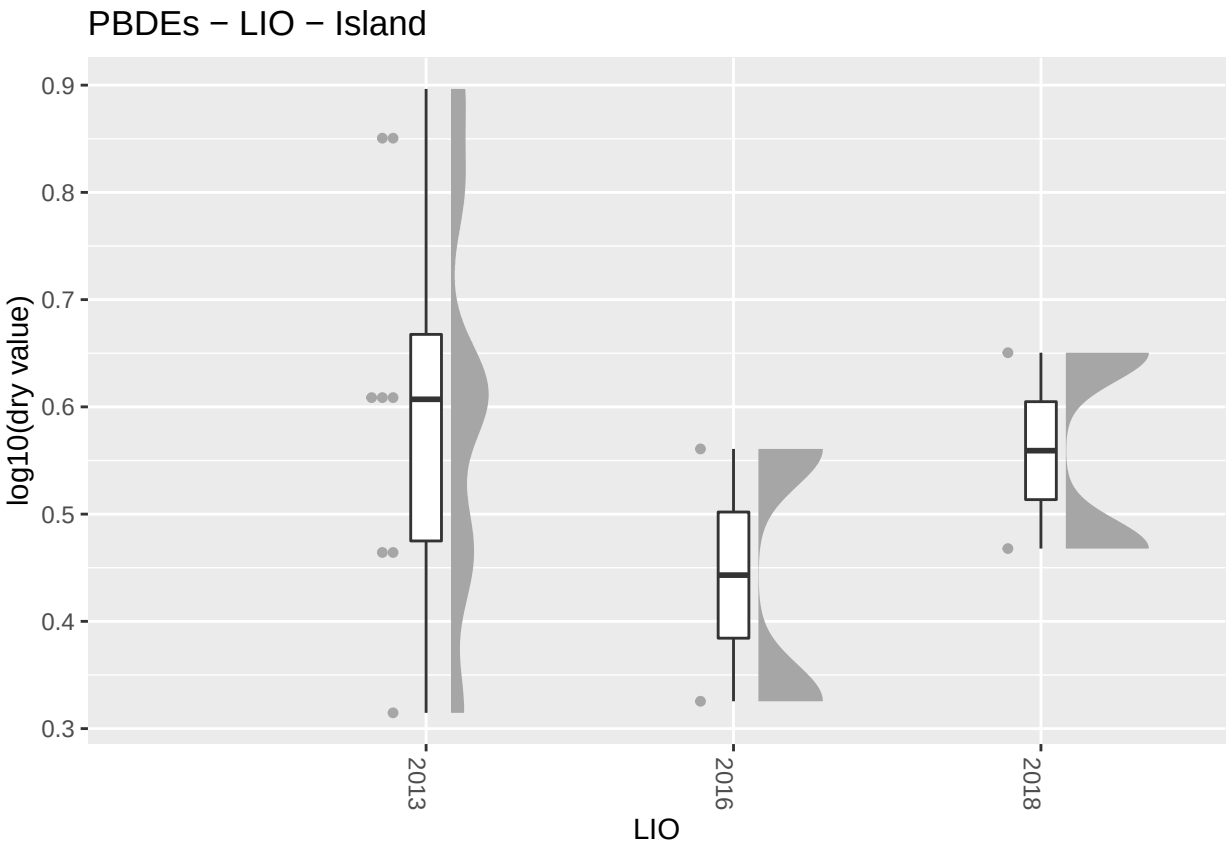
173 ## $‘Hood Canal‘



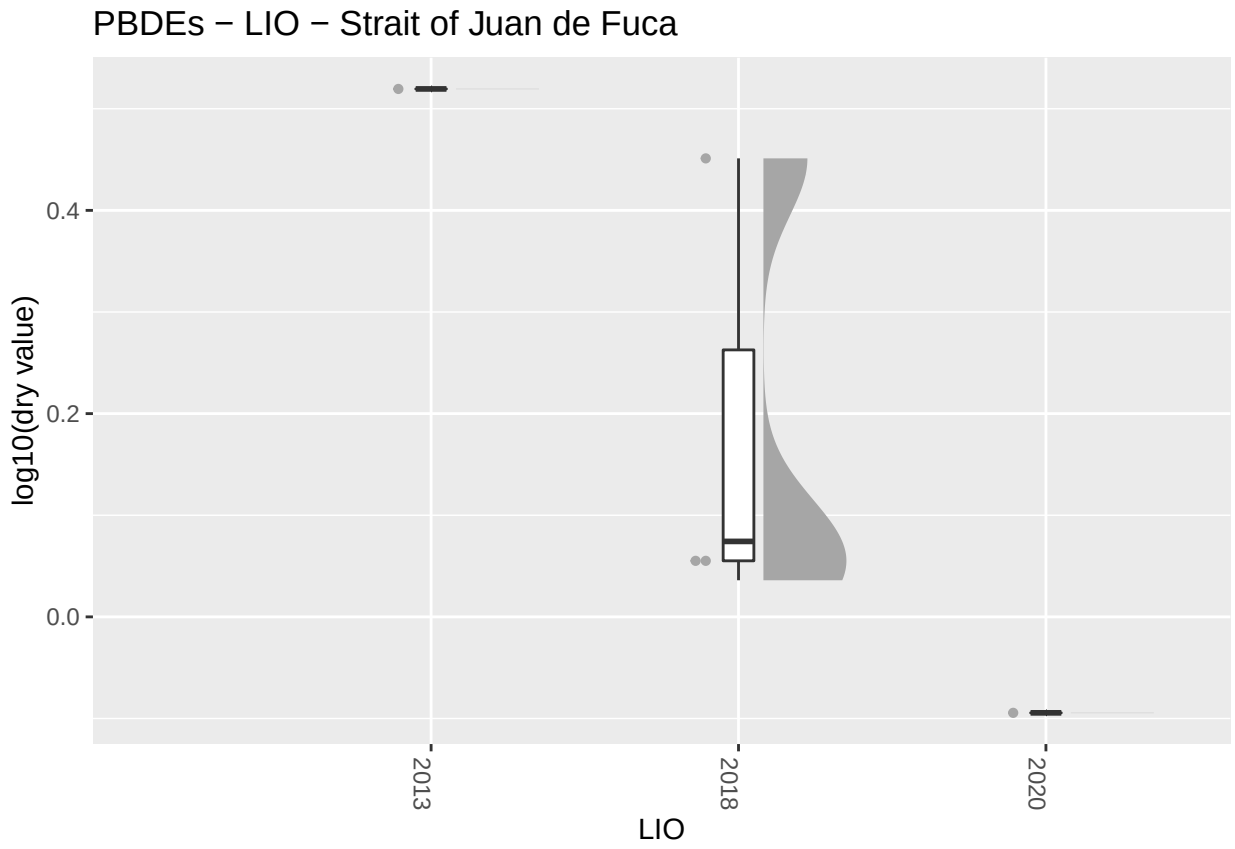

```
##
## $`Snohomish / Stillaguamish`
```


PBDEs − LIO − Snohomish / Stillaguamish
log10(dry value)
1.0
0.5
2013
2016
2018
2020
LIO

```
##
## $Island
```




```
##
## $`Strait of Juan de Fuca`
```

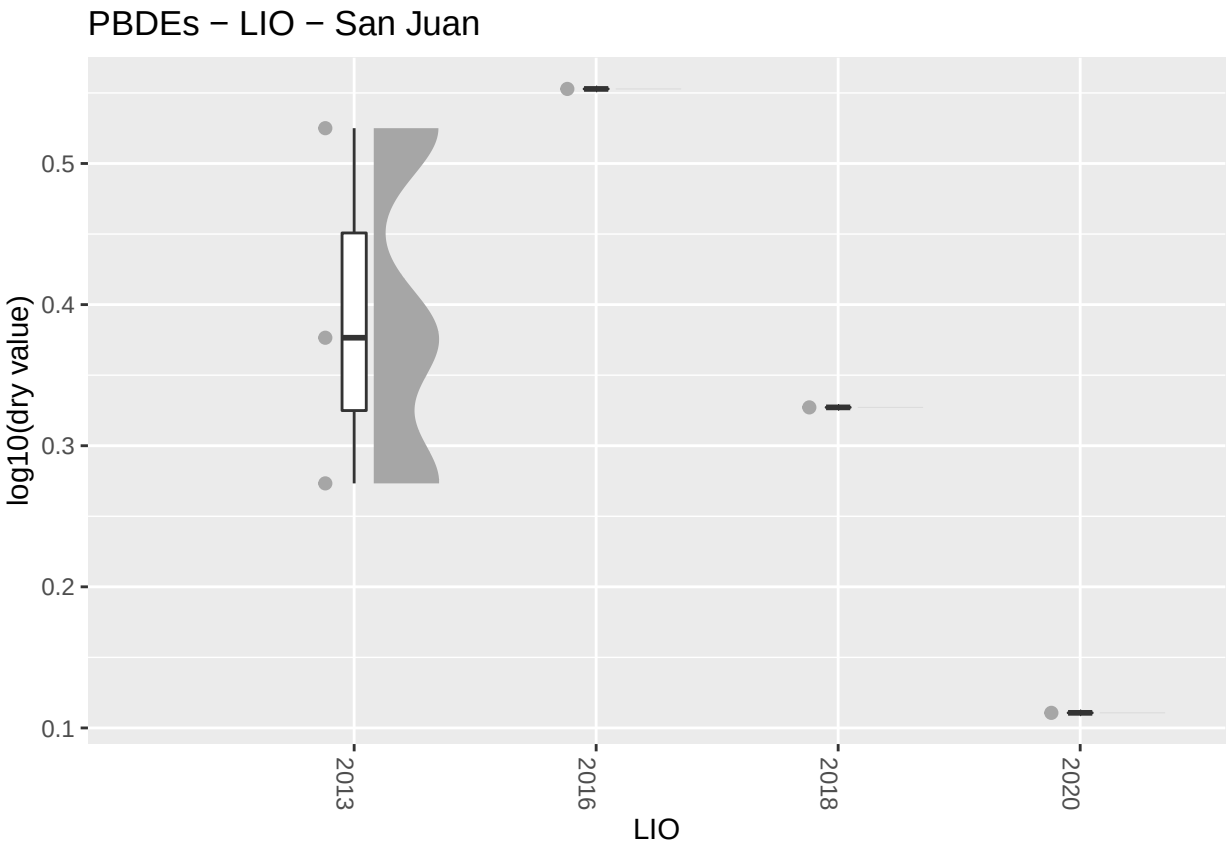



```
##
## $`Skagit / Samish`
```

186

187 ##

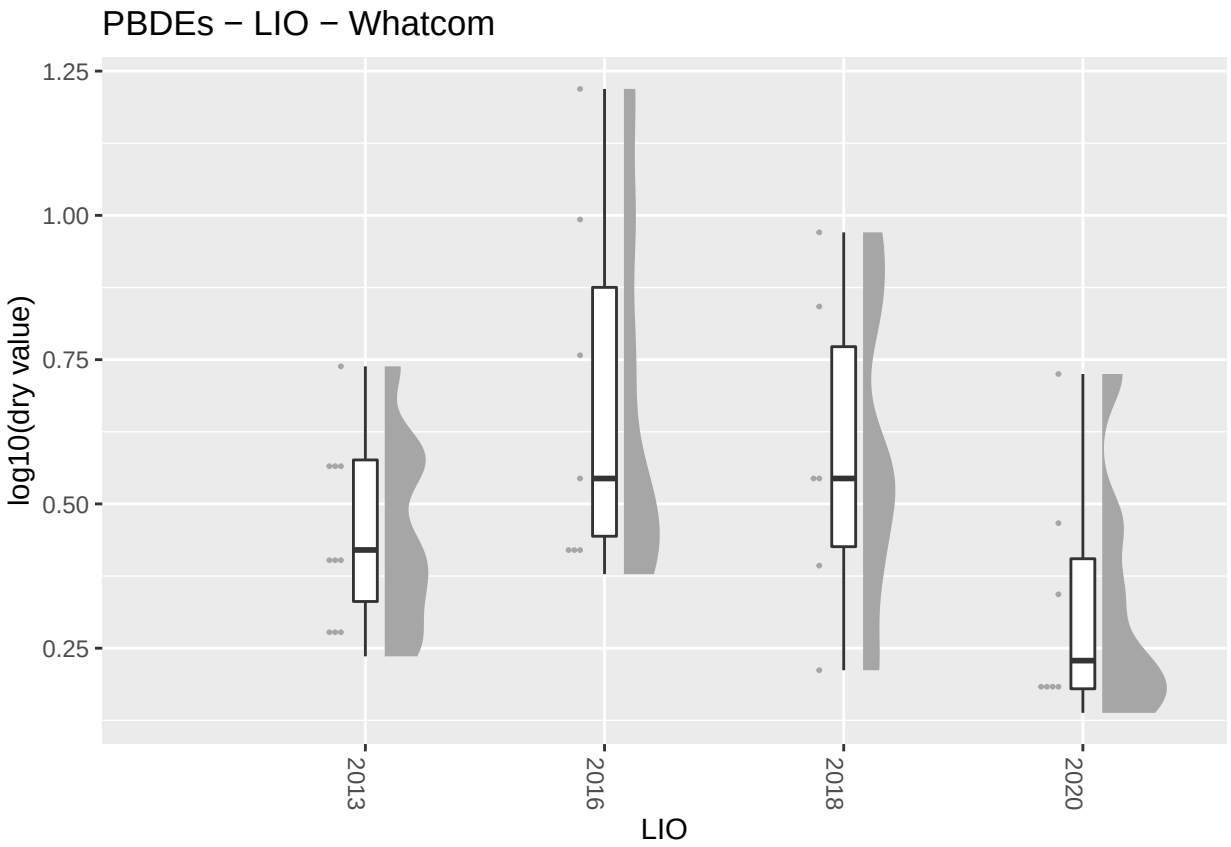
188 ## $‘San Juan‘



189

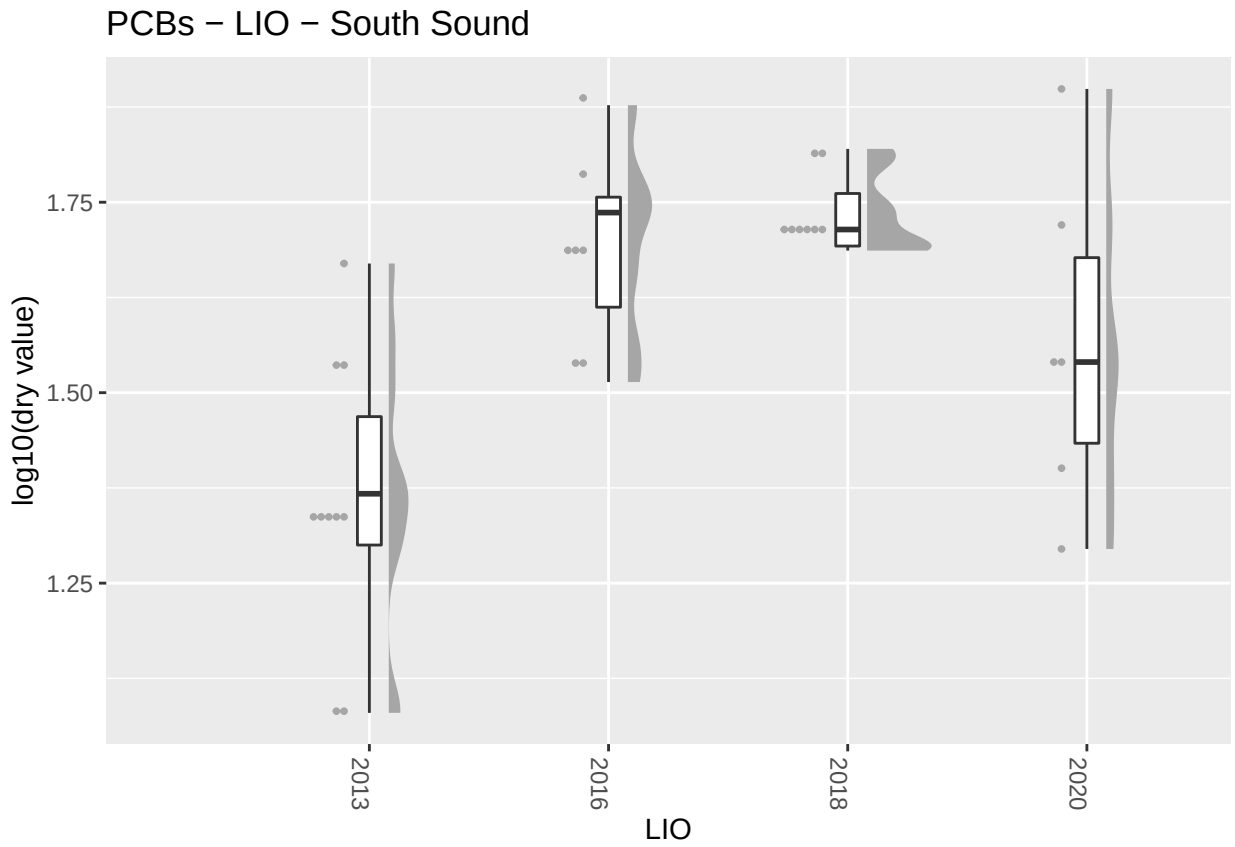
190 ##

191 ## $Whatcom



192

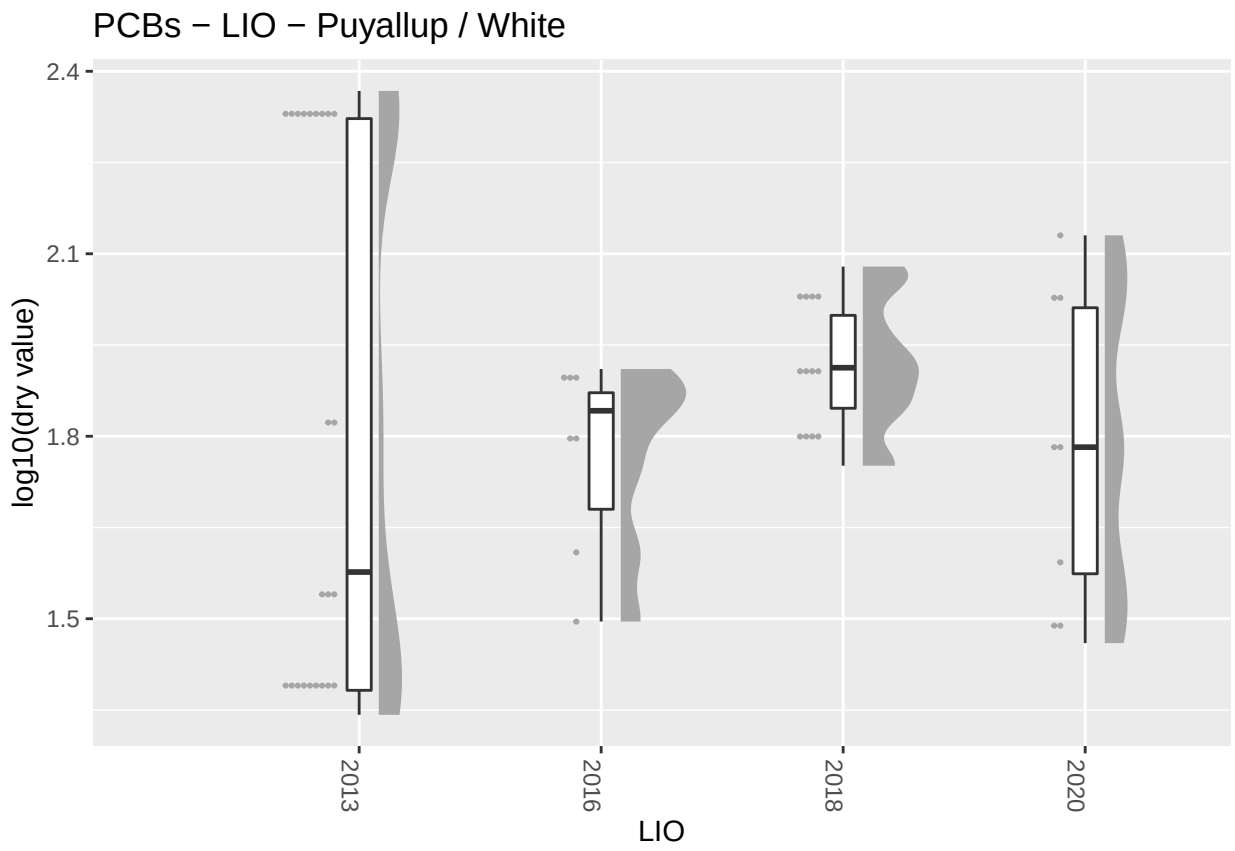
193 ## $‘South Sound‘



194

195 ##

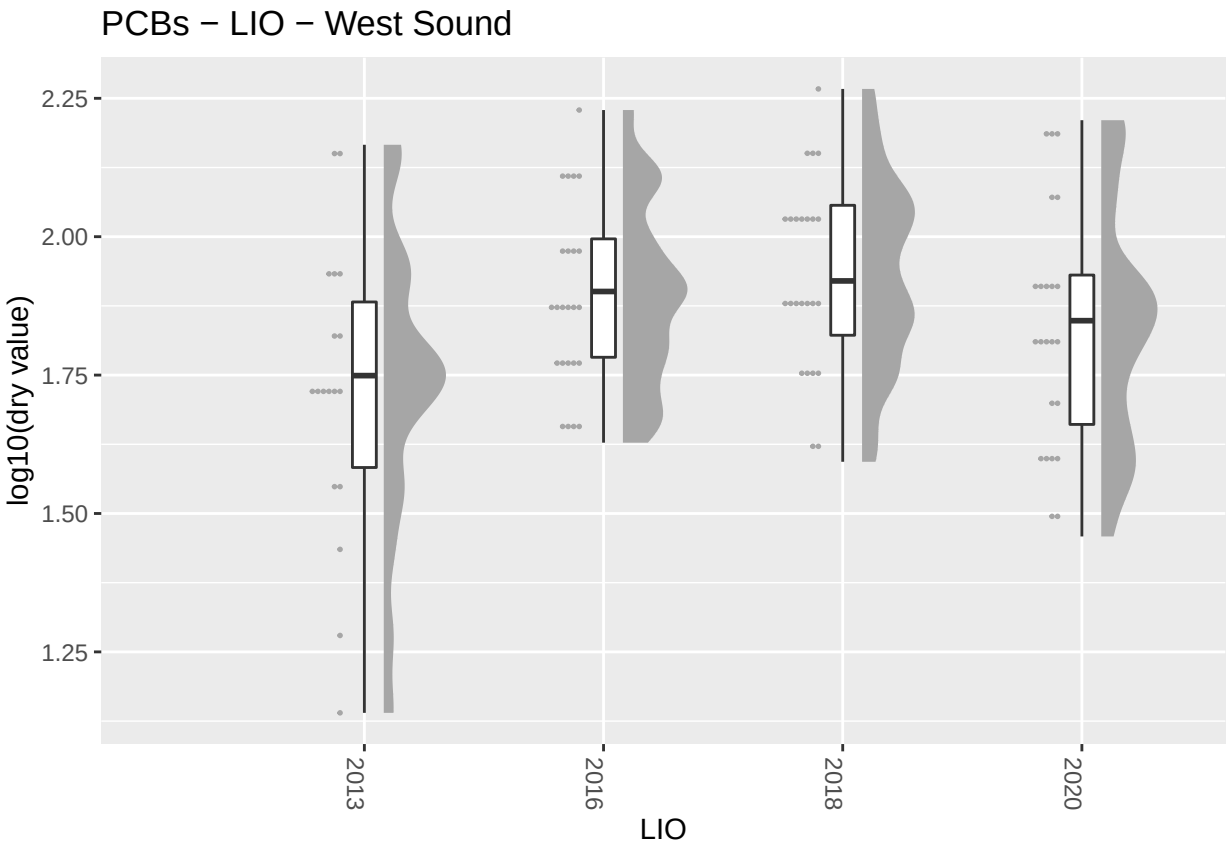
196 ## $‘Puyallup / White‘



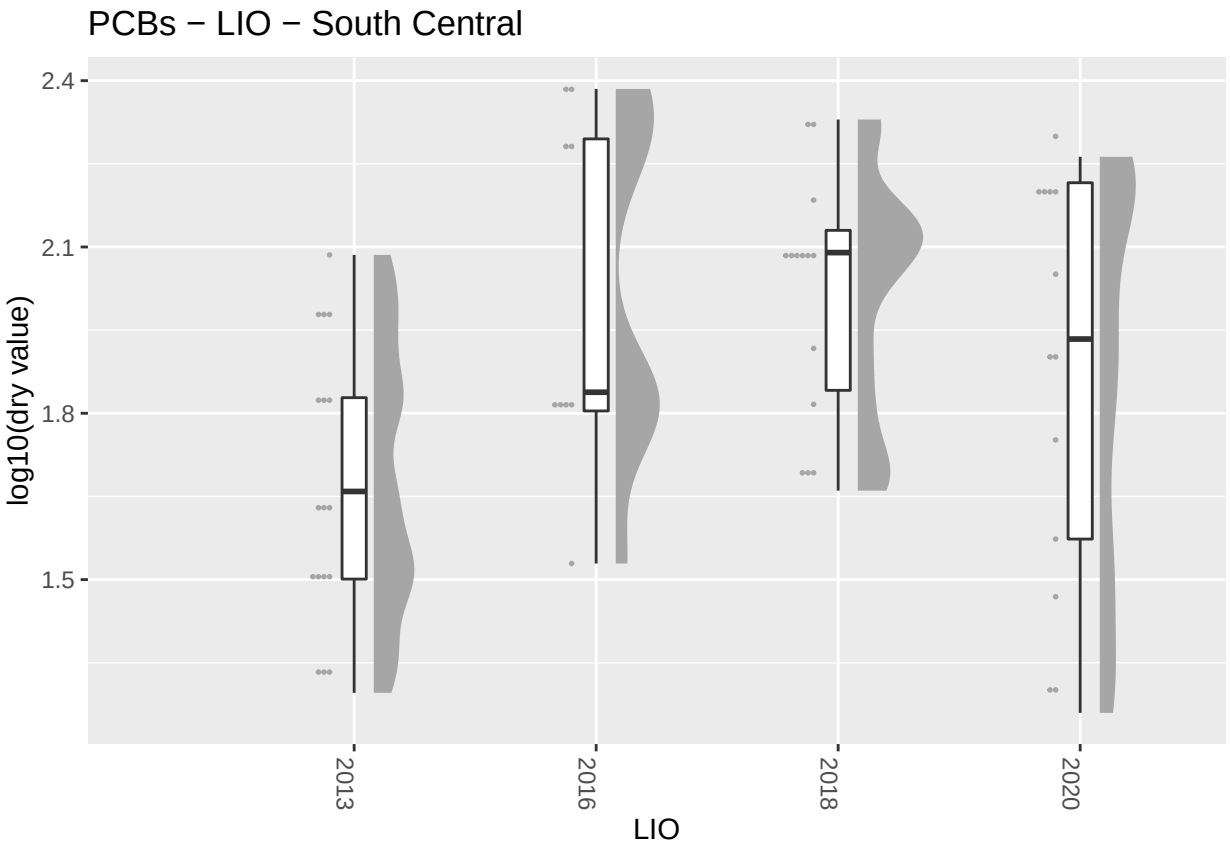
197

198 ##

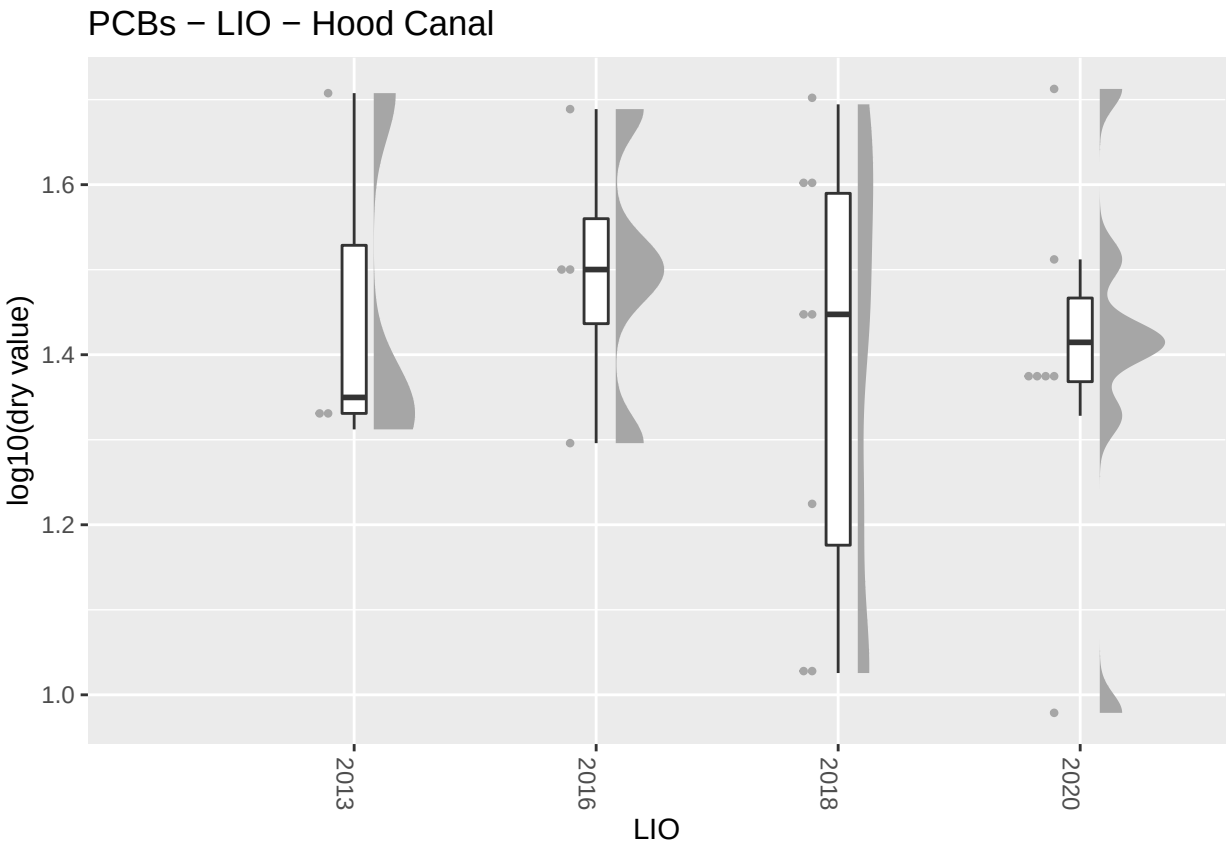
199 ## $‘West Sound‘




```
##
## $`South Central`
```


PCBs − LIO − South Central
log10(dry value)
2.4
2.1
1.8
1.5
2013
2016
2018
2020
LIO

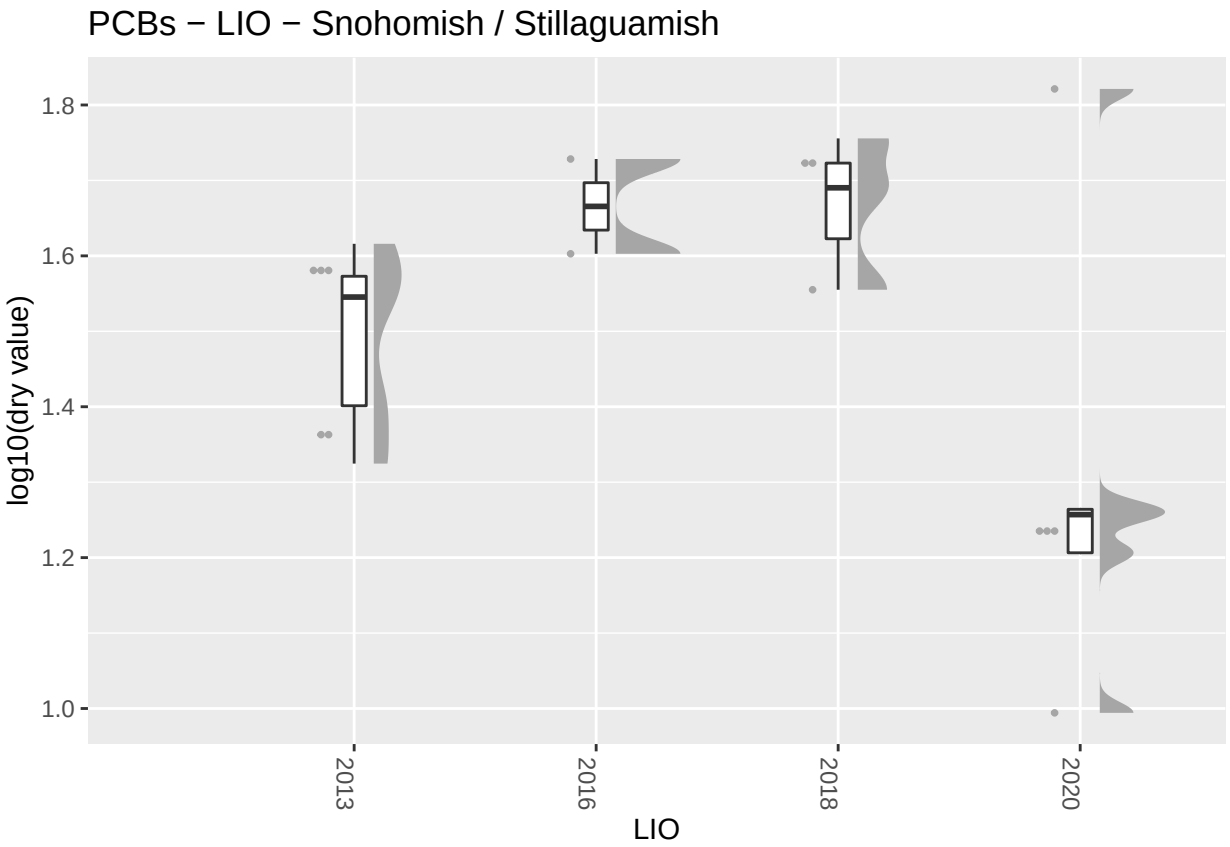
```
##
## $`Hood Canal`
```



206

207 ##

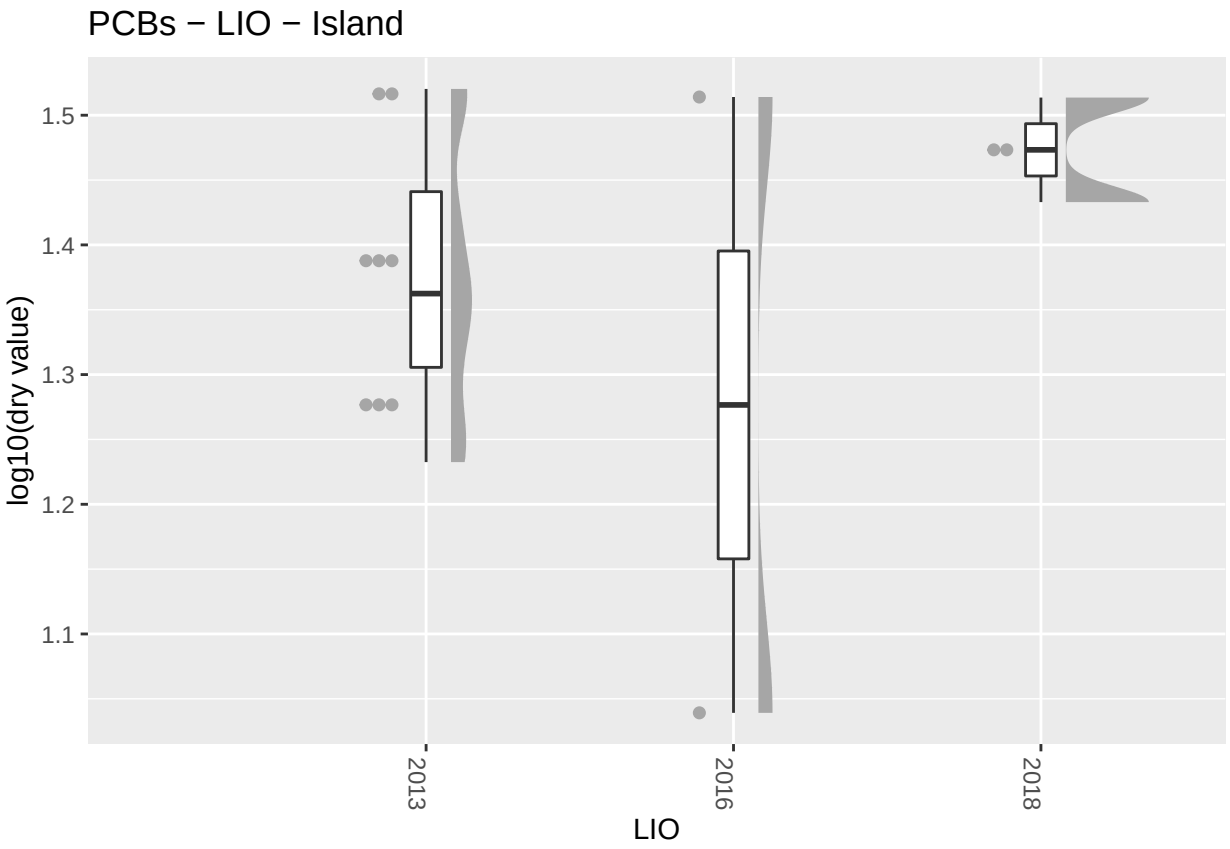
208 ## $‘Snohomish / Stillaguamish‘



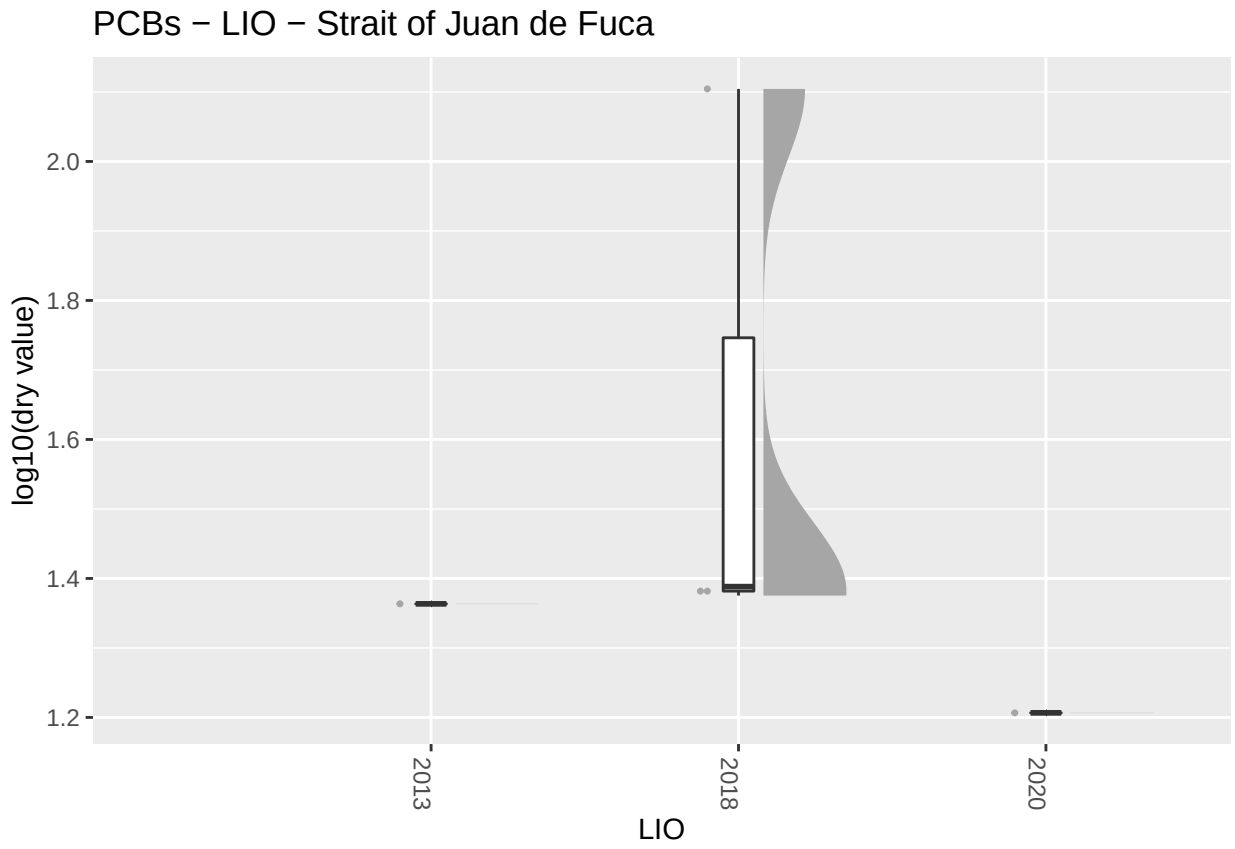
209

210 ##

211 ## $Island



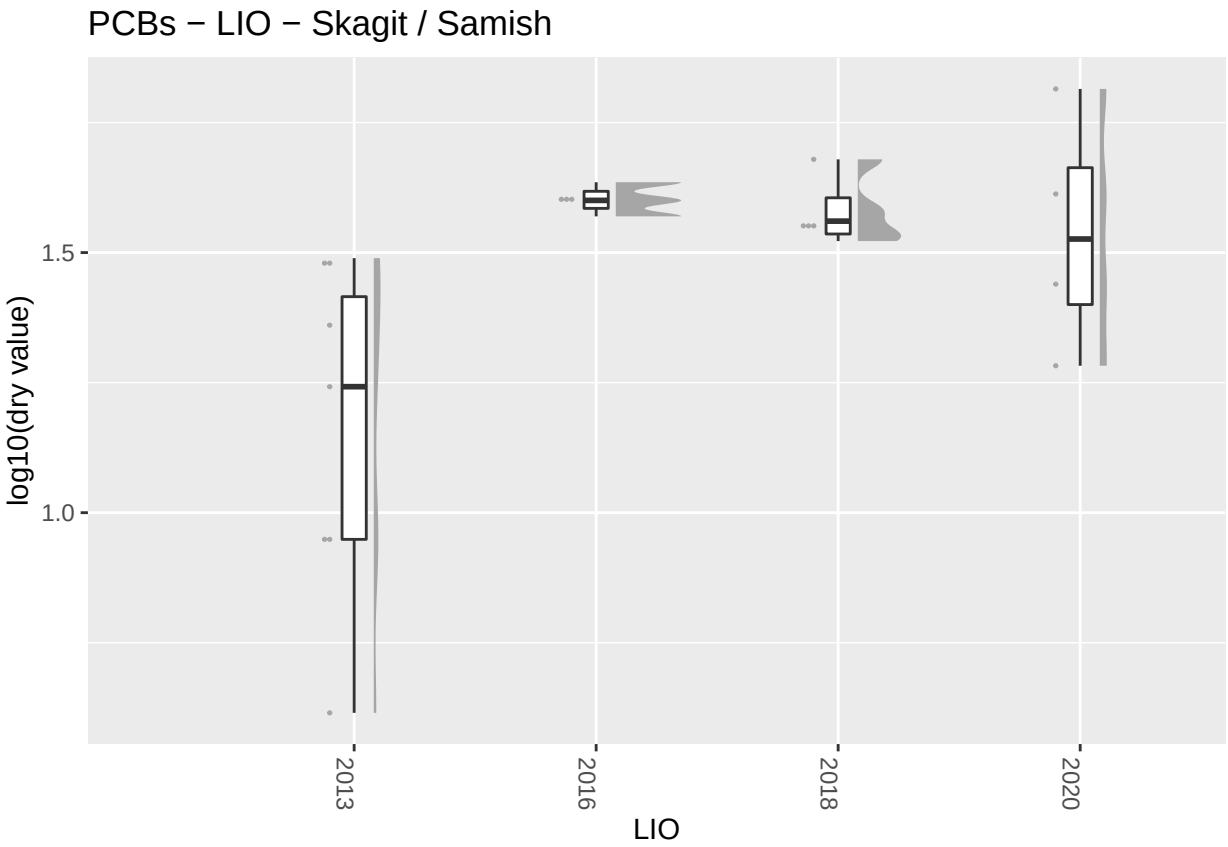

```
##
## $‘Strait of Juan de Fuca‘
```



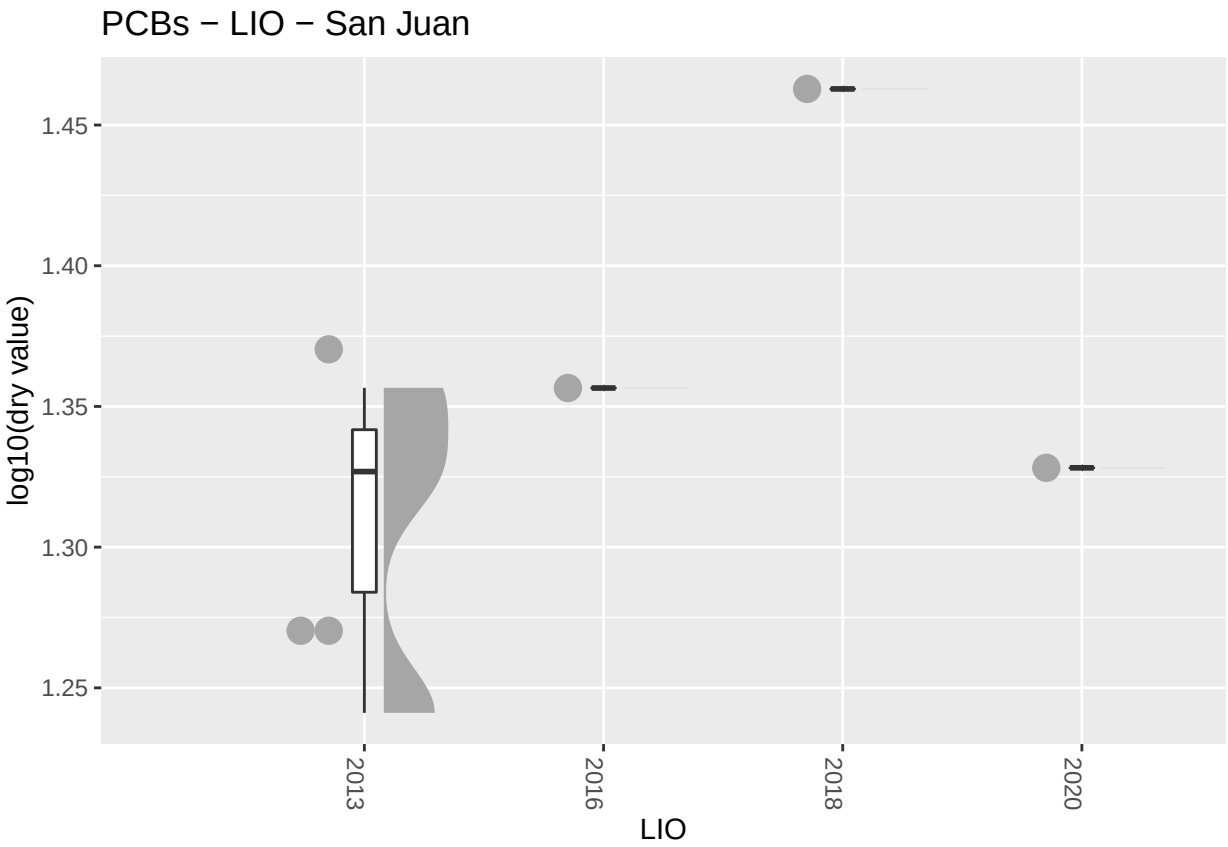
215

216 ##

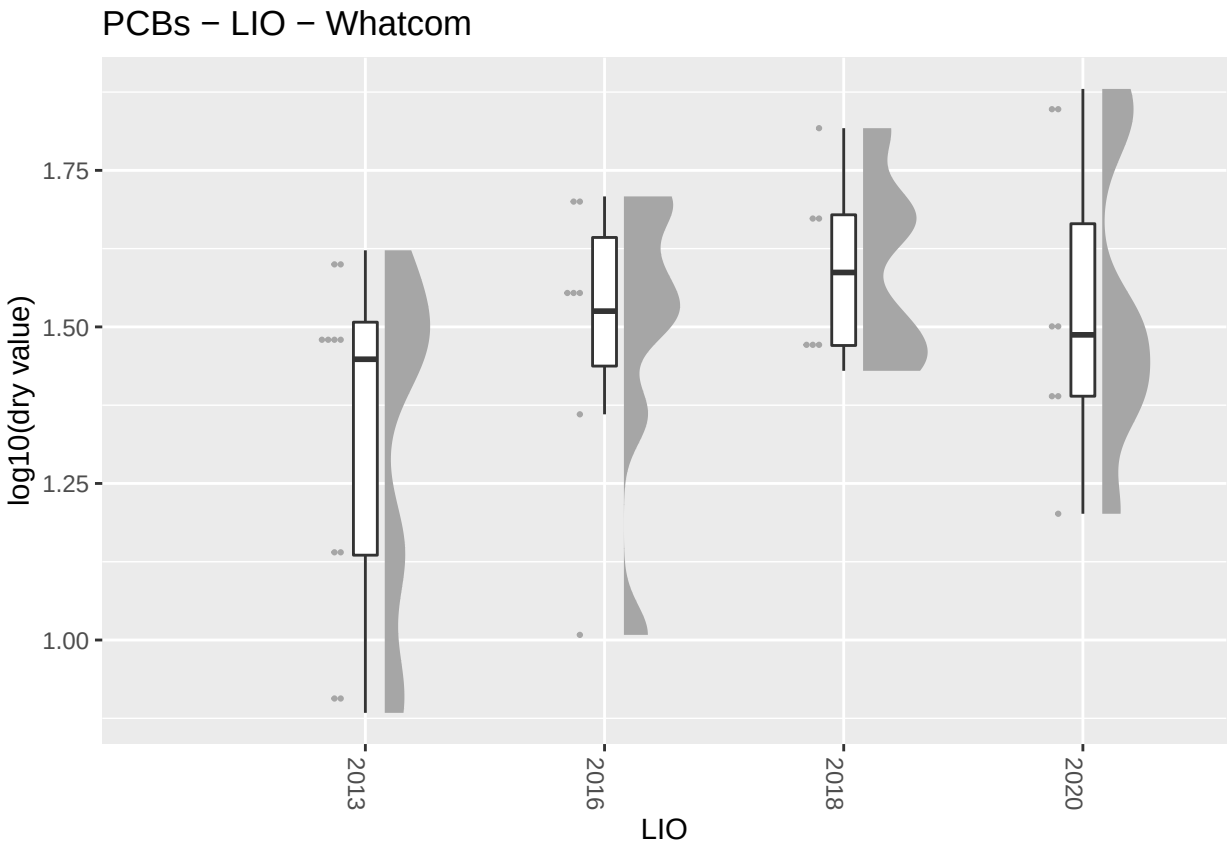
217 ## $‘Skagit / Samish‘


PCBs − LIO − Skagit / Samish
log10(dry value)
1.5
1.0
2013
2016
2018
2020
LIO

```
##
## $‘San Juan‘
```


PCBs − LIO − San Juan
log10(dry value)
1.45
1.40
1.35
1.30
1.25
2013
2016
2018
2020
LIO

```
##
## $Whatcom
```


PCBs − LIO − Whatcom
log10(dry value)
1.75
1.50
1.25
1.00
2013
2016
2018
2020
LIO

224