Tracking San Francisco Bay water quality using generalized additive models in an R Shiny framework

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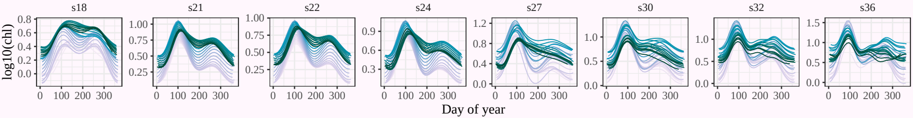
Nov. 4, 2019



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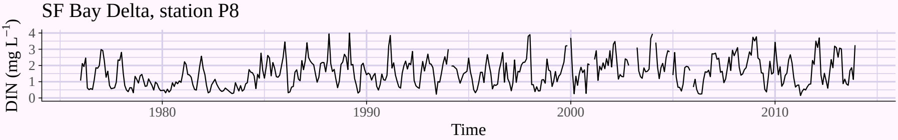
- Provide information on natural variation of water quality parameters - identify 1st order principles to understand a system
- Document historical changes in response to management actions - did investments make a difference?
- Anticipate future changes with proposed restoration or management - understand the past to predict the future

Trends vary in space and time

Observed data represent effects from many processes



Climate

precipitation
temperature
wind events
ENSO effects

Local

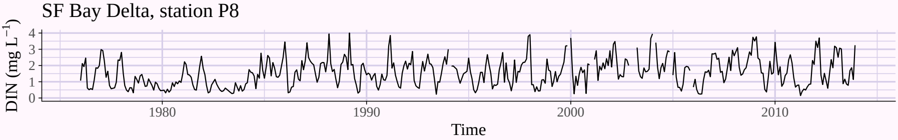
light/turbidity
residence time
invasive species
trophic effects

Regional/historical

watershed inputs
point sources
management actions
flow changes

Must translate data into information

Observed data represents effects of many processes



Models should describe components to evaluate effects

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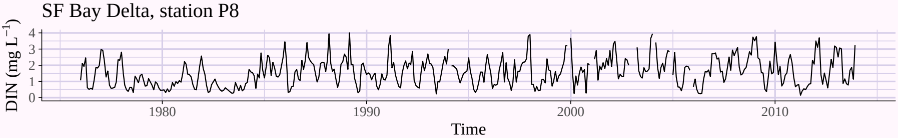

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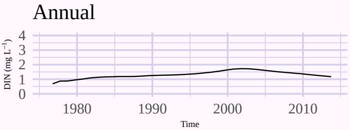

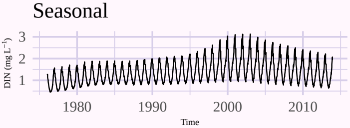

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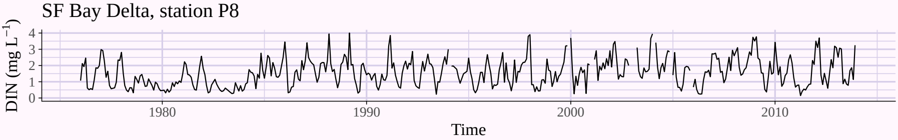

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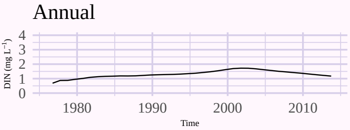

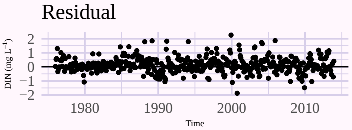

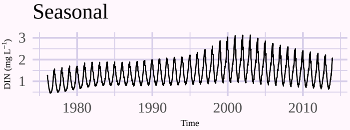

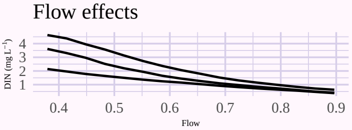

South San Francisco Bay

- A high-nutrient, high-turbidity, low-productivity system

  [Cole and Cloern, 1984,

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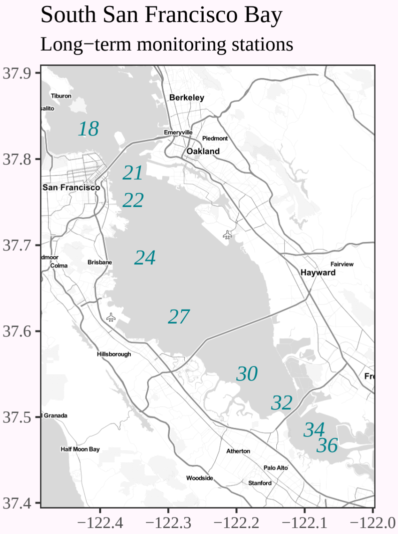

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- Recent increases observed in summer/fall chl-a

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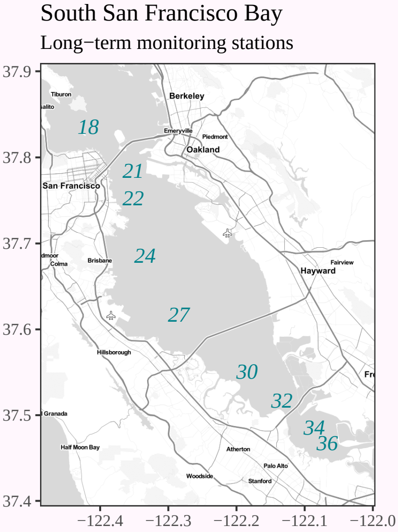

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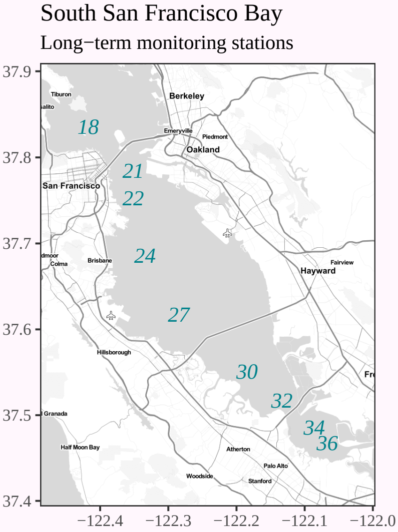
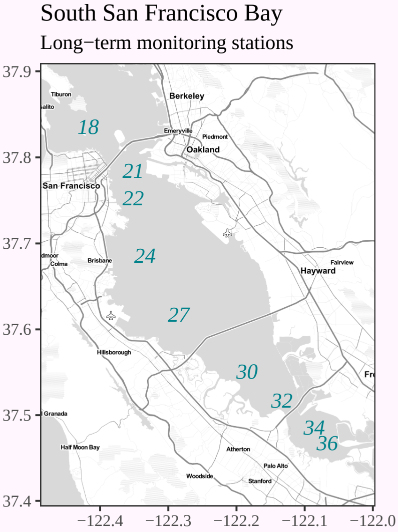
- Recent increases observed in summer/fall chl-a [Cloern et al., 2007, Cloern and Jassby, 2012]
- Nutrient Management Strategy (NMS) to characterize status/trends and management needs



South San Francisco Bay

Questions of concern:



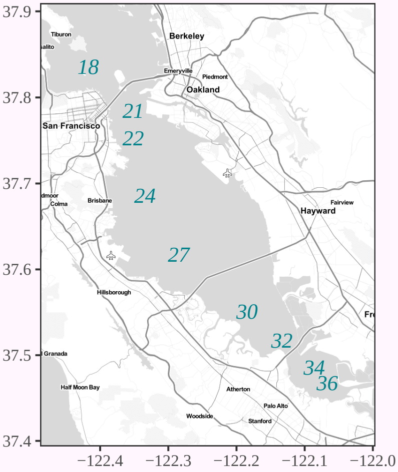
South San Francisco Bay

Questions of concern:

- Since changes are visually apparent, which are significant?

South San Francisco Bay

Long−term monitoring stations



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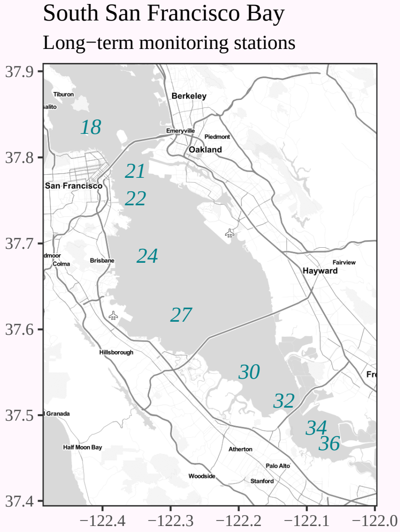
- What has been the estimated rate and direction of any linear or non-monotonic change?



South San Francisco Bay

Questions of concern:

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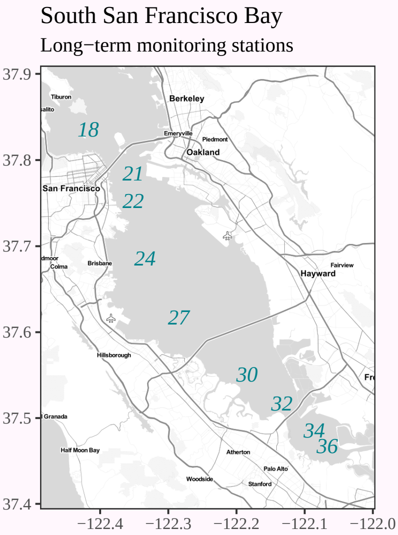
- What has been the estimated rate and direction of any linear or non-monotonic change?
- Do any of these changes coincide with changes in other water quality parameters?



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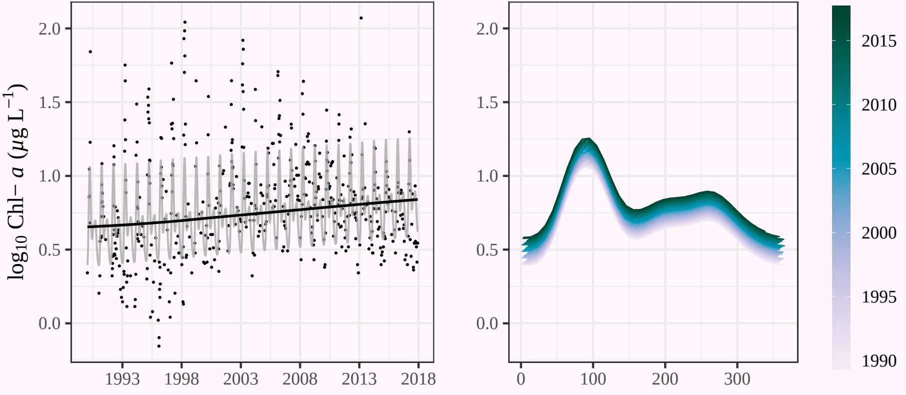
  - `gam6`: chl $\sim$ year + s(doy) + s(year, k = large)

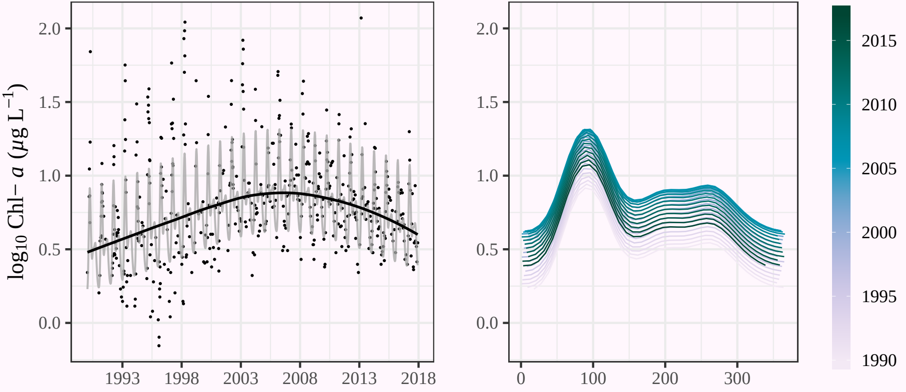
Application of additive models

`gam0`: chl $\sim$ year + s(doy)

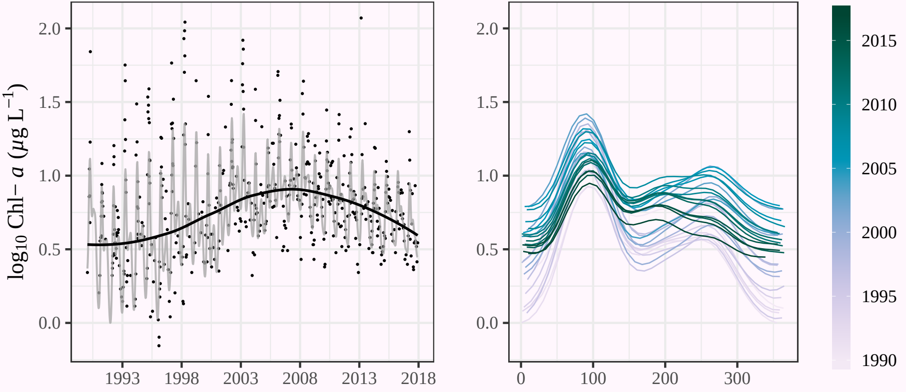


Application of additive models

`gam1`: chl ~ year + s(doy) + s(year)

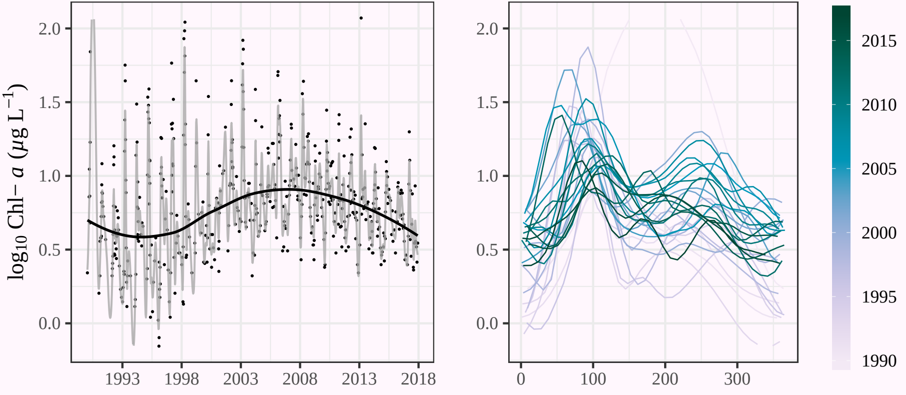


`gam2`: chl $\sim$ year + s(doy) + s(year) + ti(doy, year)



Application of additive models

`gam6`: chl ∼ year + s(doy) + s(year, k = large)



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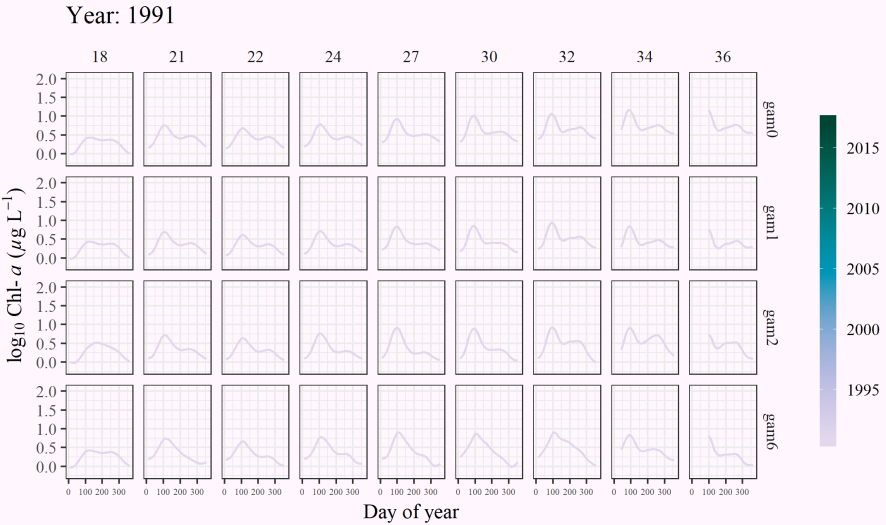
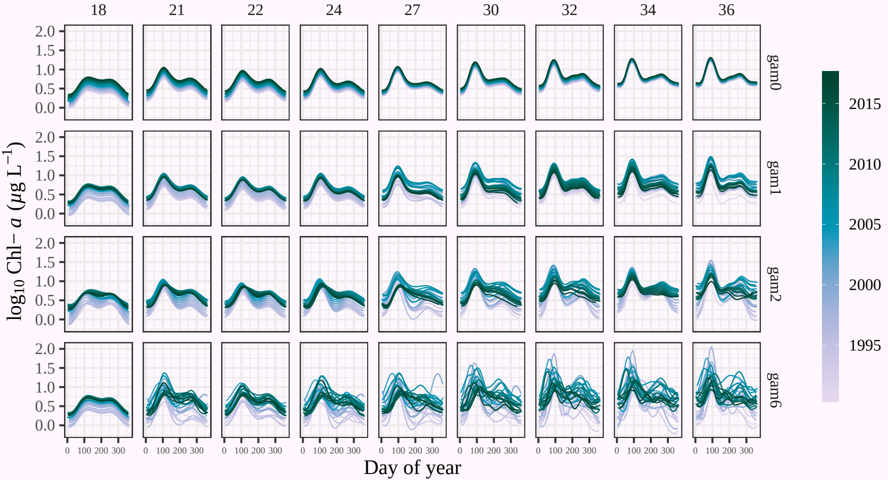


Application of additive models

All years



Application of additive models

Table: GCV summary statistics by station and model

	Stations (north to south)								
Model	18	21	22	24	27	30	32	34	36
gam0	-117.5	-30.6	-20.6	38.9	174.4	205.5	232.9	256.6	238.7
gam1	-138.8	-89.3	-70.3	-18.7	104.1	111.5	162.6	196	182
gam2	**-141.8**	-147.3	**-116.4**	-98.5	4	49.6	108.1	189.9	147.2
gam6	-139.5	**-235.2**	-116.3	**-176.8**	**-92.1**	**-115.9**	**-149**	**-3.3**	**-65.5**

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Table: R-squared summary statistics by station and model

	Stations (north to south)								
Model	18	21	22	24	27	30	32	34	36
gam0	0.47	0.41	0.37	0.37	0.33	0.36	0.32	0.31	0.32
gam1	0.51	0.48	0.43	0.44	0.43	0.48	0.41	0.41	0.43
gam2	**0.53**	0.54	0.48	0.53	0.54	0.54	0.49	0.41	0.48
gam6	0.51	**0.68**	**0.54**	**0.66**	**0.68**	**0.72**	**0.75**	**0.69**	**0.75**

Conclusions from additive models

- More complex models provided more “parsimonious” fit
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How can this information support decision-making??

Shiny interactive web platform

https://sccwrp.shinyapps.io/sfbaytrends

GAM evaluation - SF South Bay

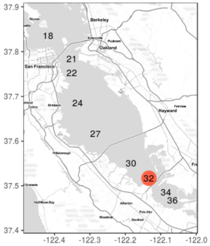
Exploratory plots

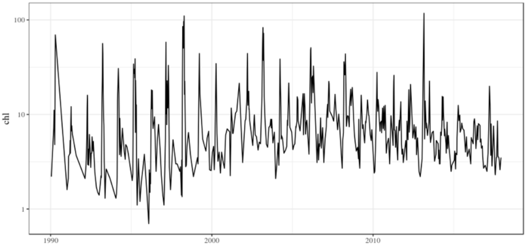
The following plots show the raw data for all monitoring stations and parameters in South Bay, 1990 - 2017. Select the parameter, plot type (total time series, by year, or by month), and variable transformation. The year and month plots are aggregated boxplots of all observations at a station for each selected time period. The variable transformation can be used to show the observations in arithmetic or logarithmic space.

Choose station: 32

Choose plot type: tot

Log-space: TRUE

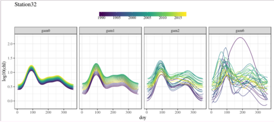




Explore results for each station, by model

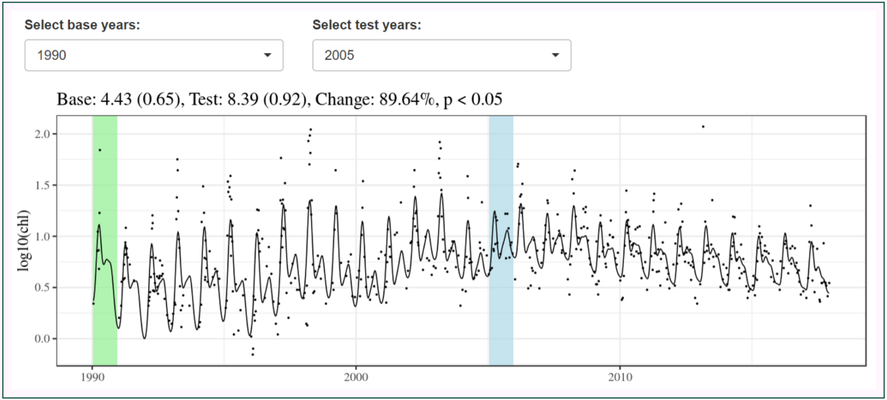
model	smoother	edf	Ref.df	F	p.value
gam0	s(doy)	7.10	8.00	31.64	0.00
gam1	s(dec_time)	2.45	27.00	2.74	0.00
gam1	s(doy)	7.17	8.00	37.97	0.00
gam2	s(dec_time)	21.40	27.00	5.05	0.00
gam2	s(doy)	7.11	8.00	42.39	0.00
gam2	ti(dec_time,doy)	8.98	12.00	3.98	0.00
gam6	s(dec_time)	218.84	334.00	3.06	0.00
gam6	s(doy)	5.07	8.00	2.24	0.00

model	k	AIC	GCV	R2
gam0	NA	232.88	0.09	0.32
gam1	28	162.57	0.08	0.41
gam2	28	108.06	0.07	0.49
gam6	336	-148.96	0.06	0.75



Shiny interactive web platform

Perform trend tests with selected years



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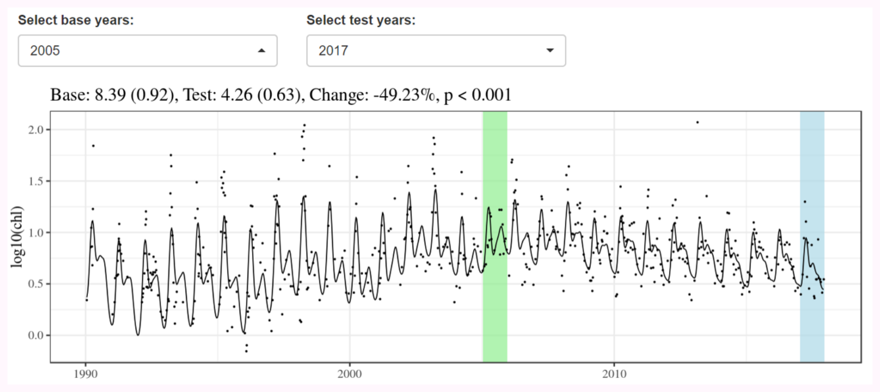
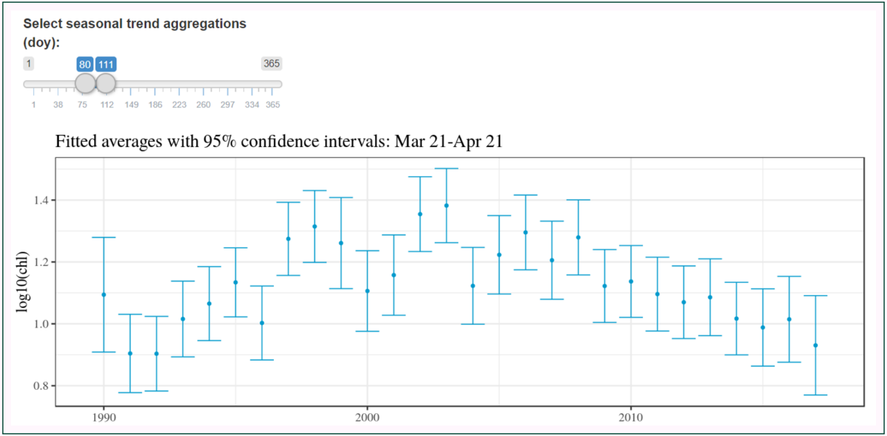


Evaluate trends between years, by season



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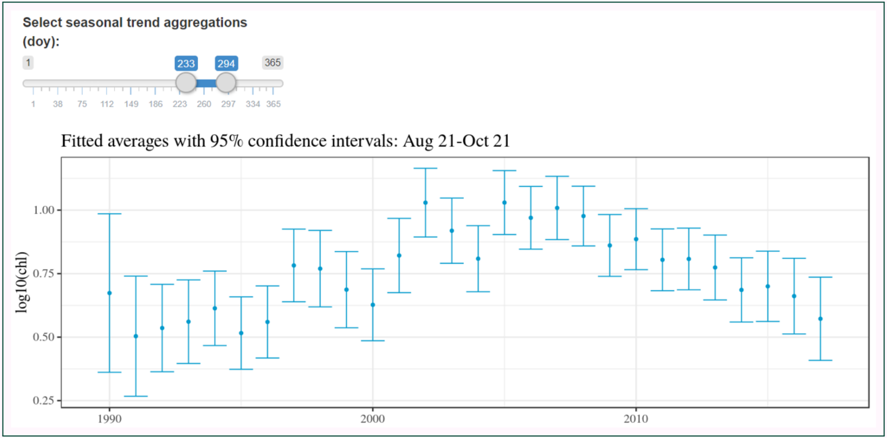

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- Shiny platform helps communicate results to stakeholder
  - Which station, model, and time period do I care about?
  - How can I understand limitations of the different models?
- Follow-up work:
  - Extend to other locations in the Bay
  - Explore trend analysis of aggregated stations
  - Incorporate additional variables - as response or as explanatory

Acknowledgments

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