# Supp_MaterialCH1

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2024-02-15

## Time series analysis plots

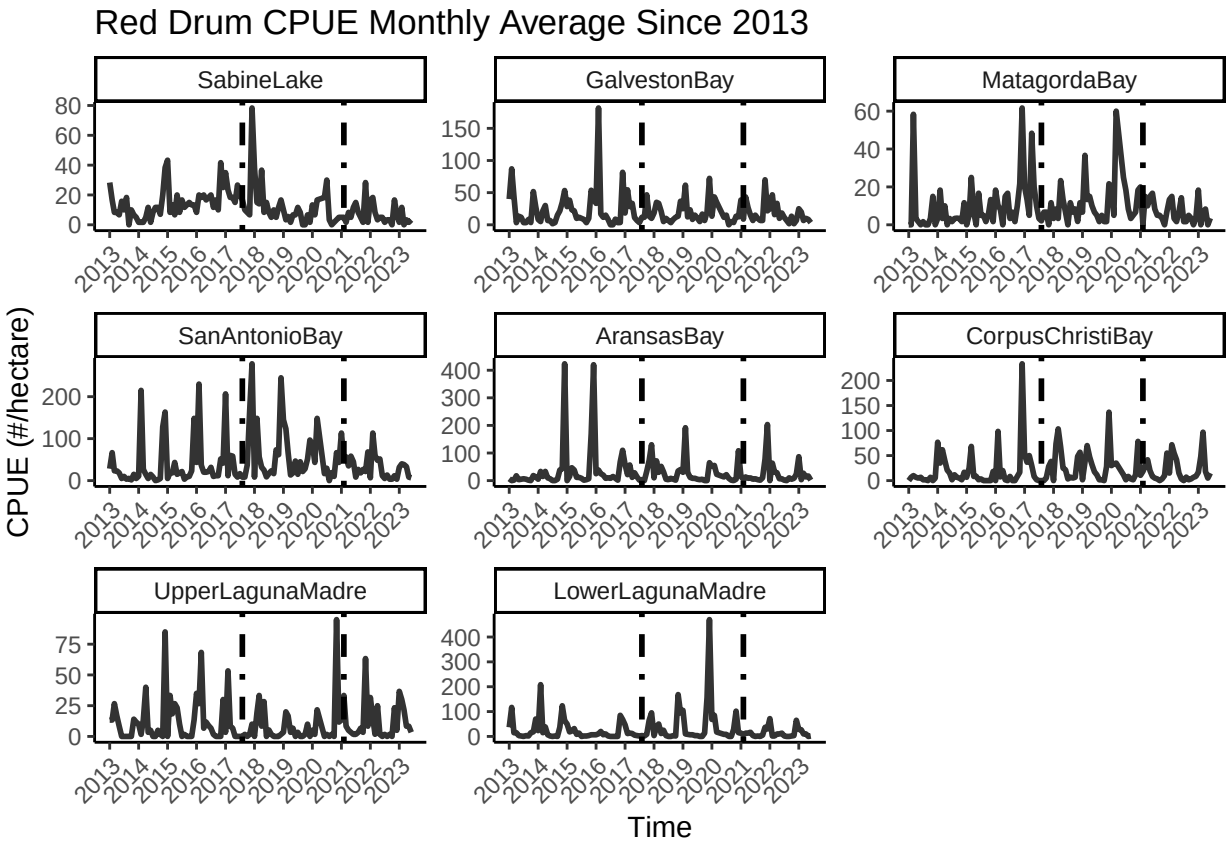


Figure S1: Red Drum montly averaged CPUE over the last ten years parsed out by bay system. Dotted lines signifing two extreme events, Hurricane Harvey and the 2021 Texas Freeze, left to right.

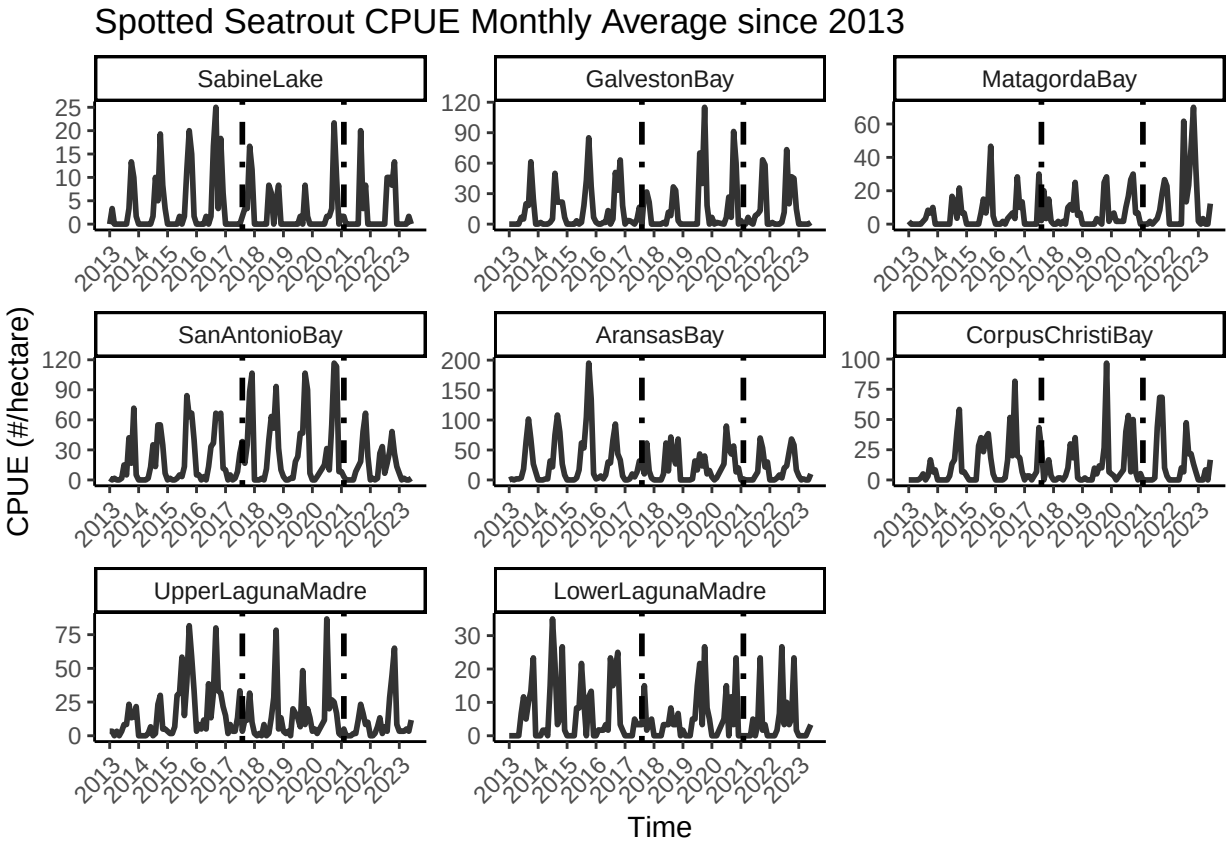


Figure S2: Spotted Seatrout montly averaged CPUE over the last ten years parsed out by bay system. Dotted lines signifing two extreme events, Hurricane Harvey and the 2021 Texas Freeze, left to right.

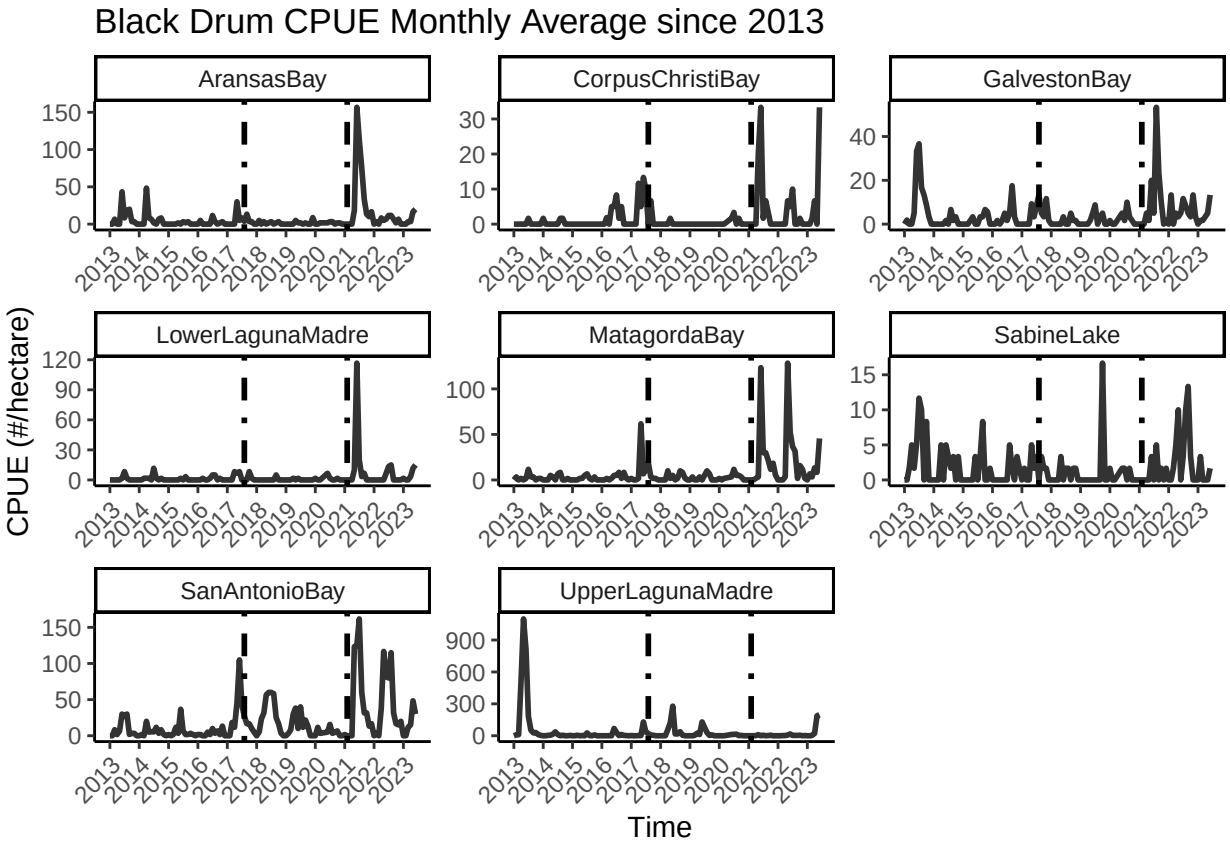


Figure S3: Black Drum montly averaged CPUE over the last ten years parsed out by bay system. Dotted lines signifing two extreme events, Hurricane Harvey and the 2021 Texas Freeze, left to right.

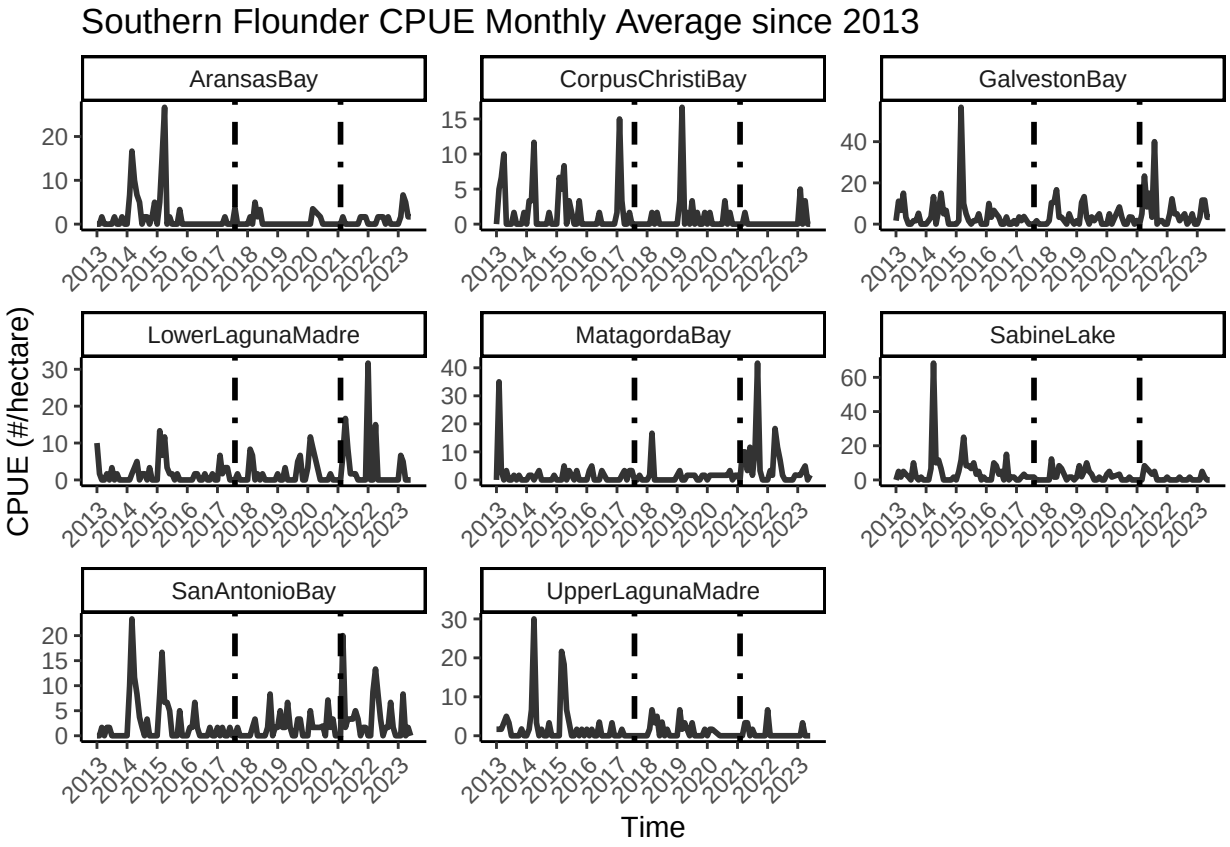


Figure S4: Southern Flounder montly averaged CPUE over the last ten years parsed out by bay system. Dotted lines signifing two extreme events, Hurricane Harvey and the 2021 Texas Freeze, left to right.

## Recruitment Windows

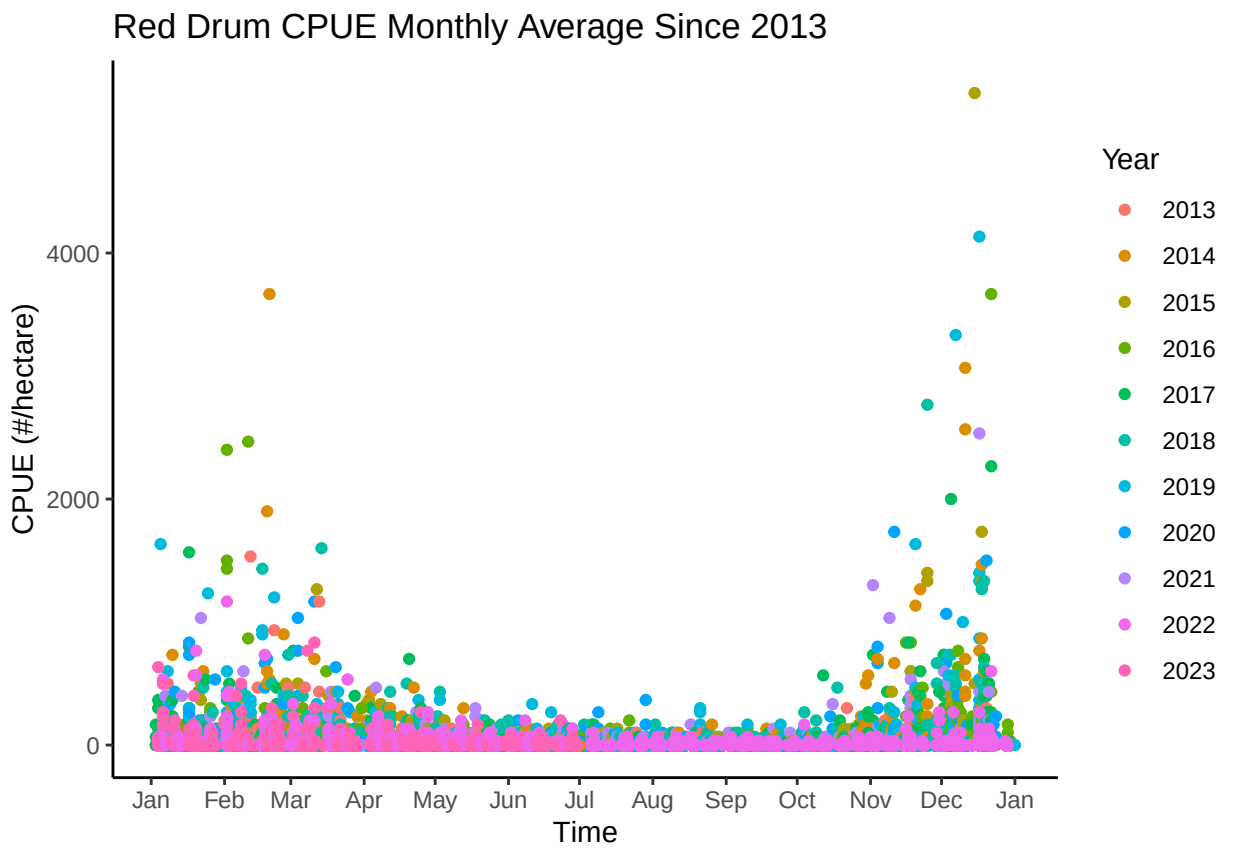


Figure S5: Red Drum CPUE monthly average raw data points plots over julian day establishing the recruitment window for Red Drum.

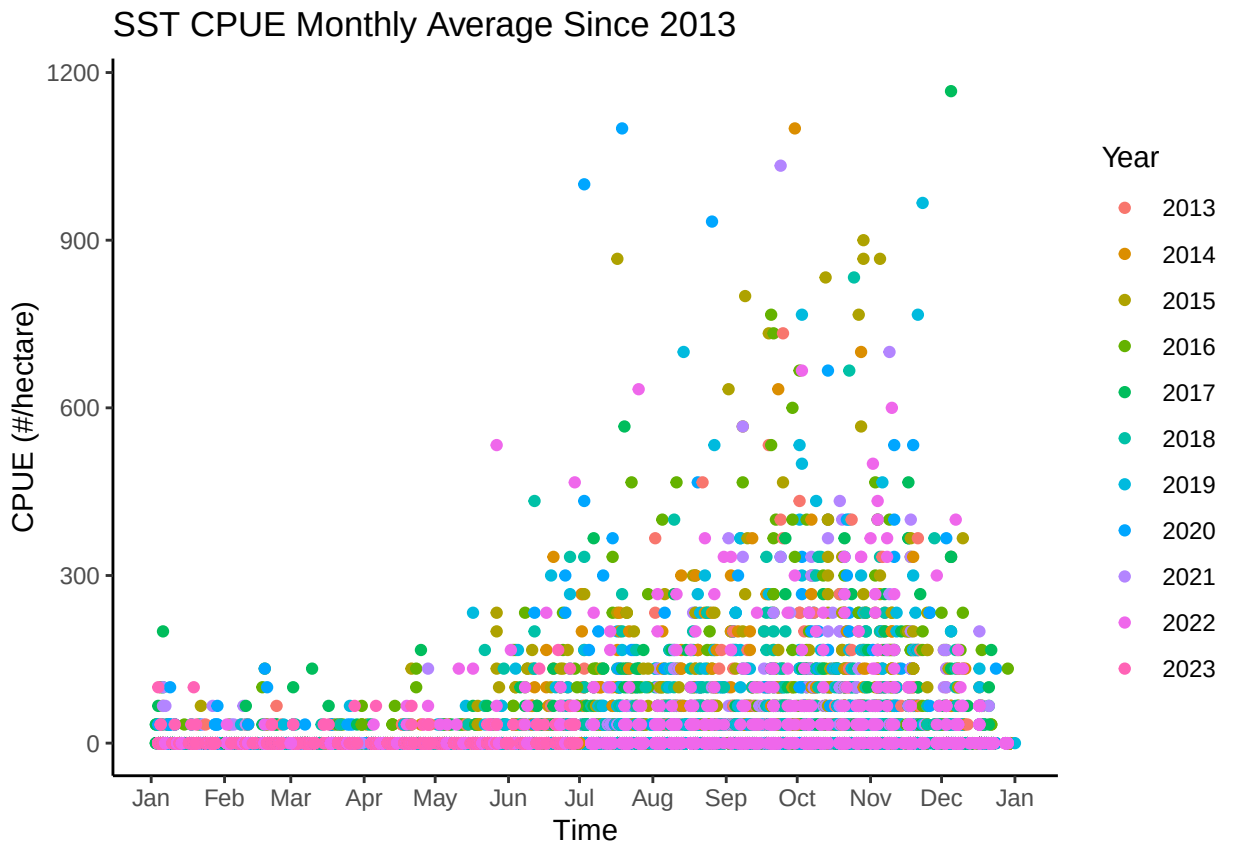


Figure S6: Spotted Seatrout CPUE monthly average raw data points plots over julian day establishing the recruitment window for Spotted Seatrout.

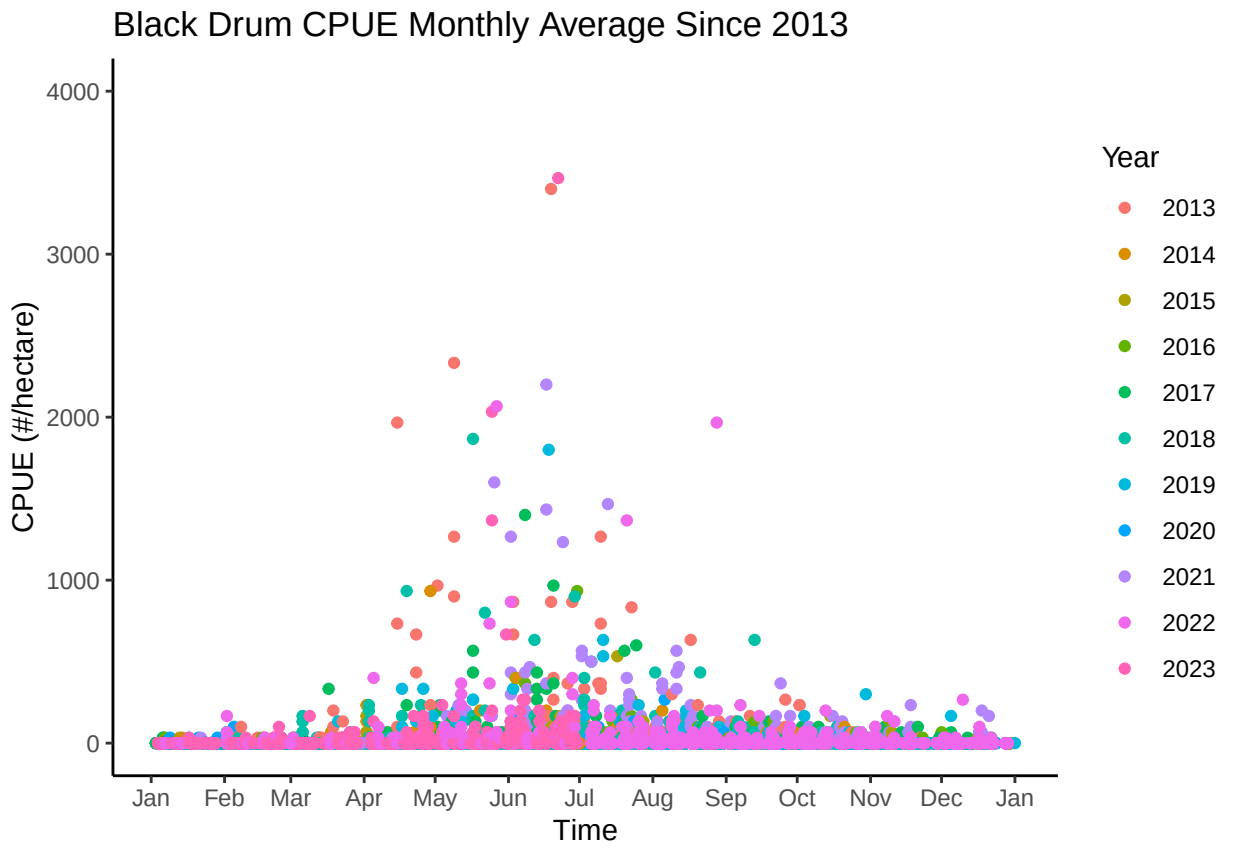


Figure S7: Black Drum CPUE monthly average raw data points plots over julian day establishing the recruitment window for Black Drum.

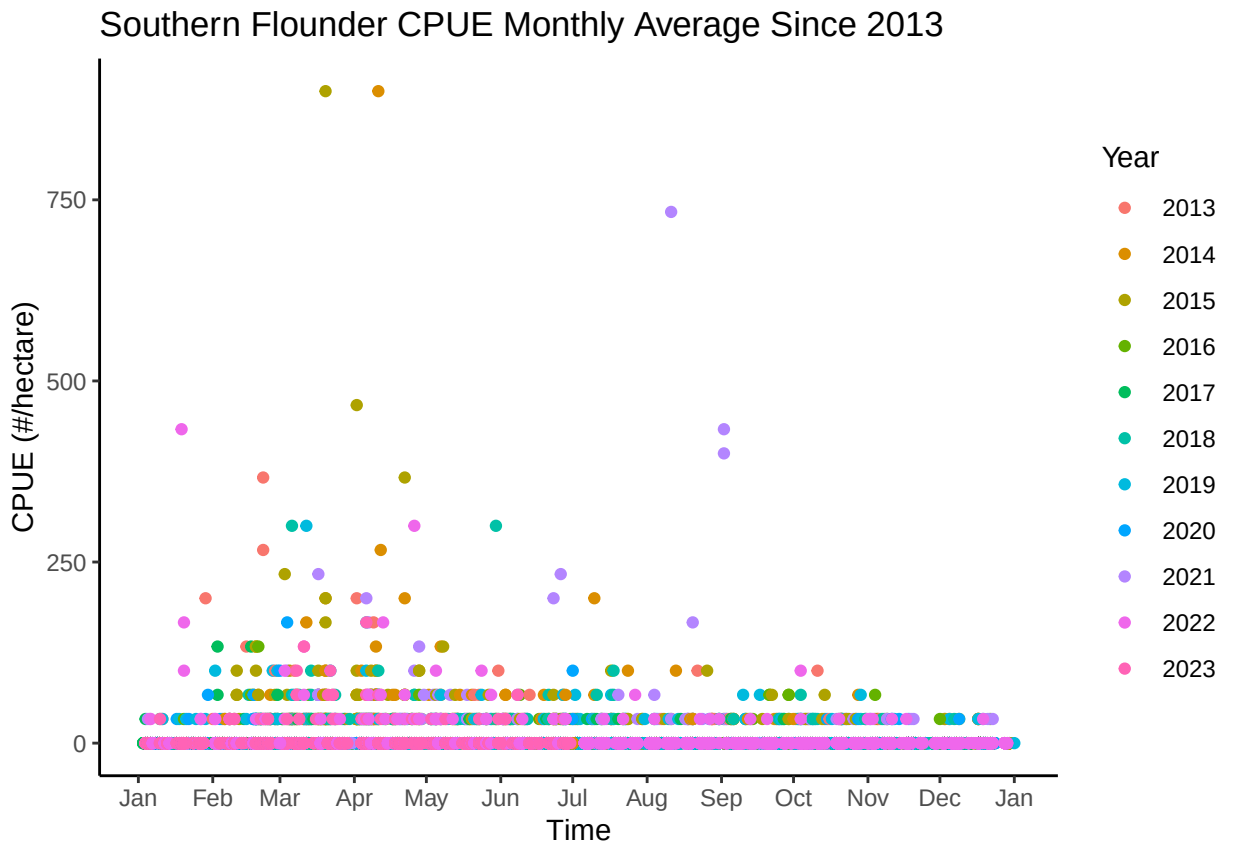


Figure S8: Southern Flounder CPUE monthly average raw data points plots over julian day establishing the recruitment window for Southern Flounder.

## Hurricane Harvey Percent Change Tables

Table S1: Red Drum percent changes after Hurricane Harvey

| MAJOR_AREA_CODE | SPECIES | 10 yrs | 1st year | 2nd year | first_perChange | second_perChange |
|---|---|---|---|---|---|---|
| SabineLake | Red Drum | 18.46 | 25.79 | 7.595 | 39.7 | -58.9 |
| GalvestonBay | Red Drum | 27.26 | 22.58 | 24.109 | -17.2 | -11.5 |
| MatagordaBay | Red Drum | 12.57 | 8.75 | 12.998 | -30.4 | 3.44 |
| SanAntonioBay | Red Drum | 35.42 | 93.75 | 93.333 | 165 | 163 |
| AransasBay | Red Drum | 34.80 | 53.96 | 43.542 | 55 | 25.1 |
| CorpusChristiBay | Red Drum | 28.69 | 43.31 | 37.317 | 51 | 30.1 |
| UpperLagunaMadre | Red Drum | 21.65 | 12.58 | 6.458 | -41.9 | -70.2 |
| LowerLagunaMadre | Red Drum | 35.50 | 37.08 | 50.208 | 4.45 | 41.4 |

Table S2: Spotted Seatrout percent changes after Hurricane Harvey

| MAJOR_AREA_CODE | SPECIES | 10 yrs | 1st year | 2nd year | first_perChange | second_perChange |
|---|---|---|---|---|---|---|
| SabineLake | Spotted Seatrout | 5.926 | 4.048 | 1.667 | -31.7 | -71.9 |
| GalvestonBay | Spotted Seatrout | 22.470 | 13.333 | 35.523 | -40.7 | 58.1 |
| MatagordaBay | Spotted Seatrout | 10.218 | 9.592 | 8.571 | -6.12 | -16.1 |
| SanAntonioBay | Spotted Seatrout | 29.361 | 44.197 | 48.333 | 50.5 | 64.6 |
| AransasBay | Spotted Seatrout | 60.999 | 40.476 | 25.899 | -33.6 | -57.5 |
| CorpusChristiBay | Spotted Seatrout | 21.365 | 13.909 | 24.088 | -34.9 | 12.7 |
| UpperLagunaMadre | Spotted Seatrout | 26.590 | 20.144 | 18.095 | -24.2 | -31.9 |
| LowerLagunaMadre | Spotted Seatrout | 11.350 | 4.048 | 12.143 | -64.3 | 6.99 |

Table S3: Black Drum percent changes after Hurricane Harvey

| MAJOR_AREA_CODE | SPECIES | 10 yrs | 1st year | 2nd year | first_perChange | second_perChange |
|---|---|---|---|---|---|---|
| SabineLake | Black Drum | 4.402 | 1.1905 | 2.3810 | -73 | -45.9 |
| GalvestonBay | Black Drum | 8.214 | 1.4388 | 3.3573 | -82.5 | -59.1 |
| MatagordaBay | Black Drum | 4.608 | 5.2381 | 3.5714 | 13.7 | -22.5 |
| SanAntonioBay | Black Drum | 9.971 | 43.4568 | 23.5714 | 336 | 136 |
| AransasBay | Black Drum | 5.906 | 1.9048 | 1.4286 | -67.8 | -75.8 |
| CorpusChristiBay | Black Drum | 2.269 | 0.2398 | 0.0000 | -89.4 | -100 |
| UpperLagunaMadre | Black Drum | 96.679 | 76.9784 | 41.1905 | -20.4 | -57.4 |
| LowerLagunaMadre | Black Drum | 1.073 | 0.7143 | 0.4762 | -33.4 | -55.6 |

Table S4: Southern Flounder percent changes after Hurricane Harvey

| MAJOR_AREA_CODE | SPECIES | 10 yrs | 1st year | 2nd year | first_perChange | second_perChange |
|---|---|---|---|---|---|---|
| SabineLake | Southern Flounder | 7.673 | 5.0420 | 5.6497 | -34.3 | -26.4 |
| GalvestonBay | Southern Flounder | 8.842 | 7.5362 | 5.0847 | -14.8 | -42.5 |
| MatagordaBay | Southern Flounder | 4.762 | 3.0556 | 1.3889 | -35.8 | -70.8 |
| SanAntonioBay | Southern Flounder | 3.818 | 0.8696 | 2.7778 | -77.2 | -27.3 |
| AransasBay | Southern Flounder | 3.122 | 1.9444 | 0.0000 | -37.7 | -100 |
| CorpusChristiBay | Southern Flounder | 2.846 | 0.5556 | 4.3103 | -80.5 | 51.5 |
| UpperLagunaMadre | Southern Flounder | 3.005 | 3.3898 | 2.7778 | 12.8 | -7.56 |
| LowerLagunaMadre | Southern Flounder | 2.613 | 3.0556 | 0.5556 | 16.9 | -78.7 |

## Texas 2021 Freeze Percent Change Tables

Table S5: Red Drum percent changes after freeze event

| MAJOR_AREA_CODE | SPECIES | 10 yrs | 1st year | 2nd year | first_perChange | second_perChange |
|---|---|---|---|---|---|---|
| SabineLake | Red Drum | 16.40 | 10.417 | 5.208 | -36.46 | -68.23 |
| GalvestonBay | Red Drum | 26.37 | 28.721 | 11.458 | 8.911 | -56.55 |
| MatagordaBay | Red Drum | 11.68 | 6.289 | 5.063 | -46.13 | -56.63 |
| SanAntonioBay | Red Drum | 49.00 | 49.476 | 21.250 | 0.9738 | -56.63 |
| AransasBay | Red Drum | 39.48 | 54.060 | 22.917 | 36.92 | -41.96 |
| CorpusChristiBay | Red Drum | 29.86 | 33.333 | 25.417 | 11.64 | -14.88 |
| UpperLagunaMadre | Red Drum | 17.07 | 18.868 | 16.667 | 10.51 | -2.384 |
| LowerLagunaMadre | Red Drum | 34.67 | 20.833 | 18.125 | -39.91 | -47.72 |

Table S6: Spotted Seatrout percent changes after freeze event

| MAJOR_AREA_CODE | SPECIES | 10 yrs | 1st year | 2nd year | first_perChange | second_perChange |
|---|---|---|---|---|---|---|
| SabineLake | Spotted Seatrout | 5.675 | 4.524 | 5.952 | -20.28 | 4.892 |
| GalvestonBay | Spotted Seatrout | 23.084 | 21.905 | 30.476 | -5.11 | 32.02 |
| MatagordaBay | Spotted Seatrout | 10.279 | 11.511 | 36.869 | 11.99 | 258.7 |
| SanAntonioBay | Spotted Seatrout | 37.269 | 25.476 | 24.762 | -31.64 | -33.56 |
| AransasBay | Spotted Seatrout | 56.129 | 27.857 | 33.809 | -50.37 | -39.76 |
| CorpusChristiBay | Spotted Seatrout | 19.396 | 27.857 | 17.986 | 43.63 | -7.27 |
| UpperLagunaMadre | Spotted Seatrout | 23.861 | 10.476 | 22.619 | -56.09 | -5.204 |
| LowerLagunaMadre | Spotted Seatrout | 10.595 | 5.238 | 10.476 | -50.56 | -1.124 |

Table S7: Black Drum percent changes after freeze event

| MAJOR_AREA_CODE | SPECIES | 10 yrs | 1st year | 2nd year | first_perChange | second_perChange |
|---|---|---|---|---|---|---|
| SabineLake | Black Drum | 2.718 | 1.429 | 6.429 | -47.44 | 136.5 |
| GalvestonBay | Black Drum | 5.631 | 16.905 | 5.952 | 200.2 | 5.699 |
| MatagordaBay | Black Drum | 5.580 | 31.667 | 38.095 | 467.6 | 582.8 |
| SanAntonioBay | Black Drum | 17.831 | 76.191 | 68.571 | 327.3 | 284.6 |
| AransasBay | Black Drum | 5.499 | 58.571 | 7.381 | 965.1 | 34.22 |
| CorpusChristiBay | Black Drum | 1.886 | 9.286 | 3.357 | 392.4 | 78.02 |
| UpperLagunaMadre | Black Drum | 88.841 | 3.333 | 5.714 | -96.25 | -93.57 |
| LowerLagunaMadre | Black Drum | 1.524 | 22.381 | 5.000 | 1369 | 228.1 |

Table S8: Southern Flounder percent changes after freeze event

| MAJOR_AREA_CODE | SPECIES | 10 yrs | 1st year | 2nd year | first_perChange | second_perChange |
|---|---|---|---|---|---|---|
| SabineLake | Southern Flounder | 7.386 | 4.2424 | 0.3236 | -42.56 | -95.62 |
| GalvestonBay | Southern Flounder | 7.911 | 10.5769 | 5.3872 | 33.7 | -31.9 |
| MatagordaBay | Southern Flounder | 2.339 | 7.1197 | 7.9208 | 204.4 | 238.6 |
| SanAntonioBay | Southern Flounder | 3.440 | 6.0897 | 6.6007 | 77.05 | 91.9 |
| AransasBay | Southern Flounder | 2.673 | 0.3333 | 0.9709 | -87.53 | -63.68 |
| CorpusChristiBay | Southern Flounder | 2.597 | 0.3175 | 0.0000 | -87.77 | -100 |
| UpperLagunaMadre | Southern Flounder | 3.175 | 1.6181 | 0.0000 | -49.03 | -100 |
| LowerLagunaMadre | Southern Flounder | 2.446 | 6.4815 | 2.7273 | 164.9 | 11.48 |

# Models

In the order of

- Hurricane and first year percent change
- Hurricane and second year percent change
- Freeze and first year percent change
- Freeze and second year percent change

### Collinerarity, linear relationships among the x-variables themselves, running a pair plot

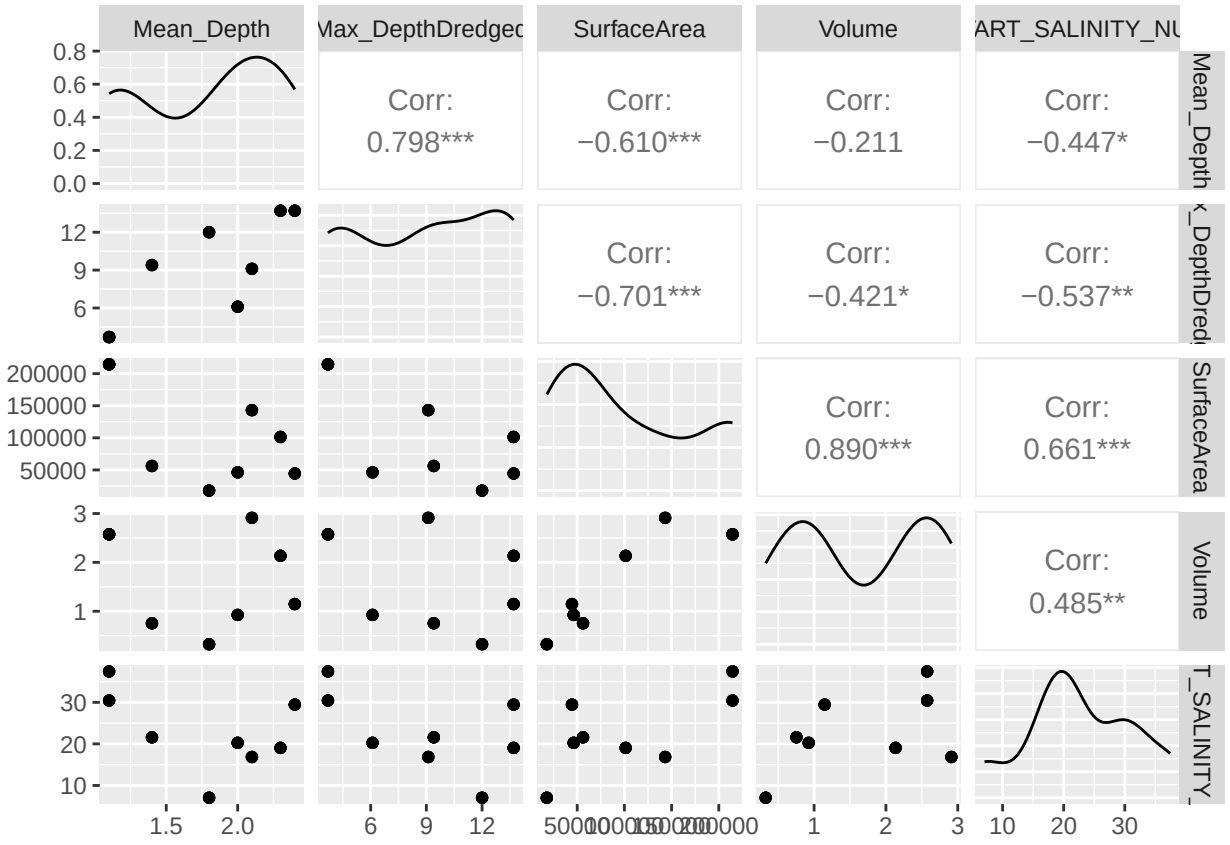


Figure S9: Correlation between the x-varaibles to observe any signicant linear relationships before building the model

### Model Selection

Surface area and mean depth were removed as explanatory variables given the results from the correlation matrix. Max depth dredged was chosen based off the literature (Stevens et al 2016) to test the hypothesis of deeper water as a refuge explaining the variation in percent change. A global model was created for all four models, (First and second percent change during Hurricane Harvey and first and second percent change during the freeze event). From these global models, we ran combinations of the explanatory variables to determined the best fitting model.

**Units of variables:**

- Maximum depth is in meters
- Volume is in cubic kilometers
- Salinity is in parts per thousand

## Global model 1

| model | aicc | weights |
|---|---|---|
| first_perChange ~ 1 | 376 | 0.36 |
| first_perChange ~ 1 + Volume | 377 | 0.229 |
| first_perChange ~ 1 + START_SALINITY_NUM | 378 | 0.106 |
| first_perChange ~ 1 + Max_DepthDredged | 378 | 0.106 |
| first_perChange ~ 1 + Max_DepthDredged + Volume | 379 | 0.0762 |
| first_perChange ~ 1 + Volume + START_SALINITY_NUM | 379 | 0.0737 |
| first_perChange ~ 1 + Max_DepthDredged + START_SALINITY_NUM | 381 | 0.0289 |
| first_perChange ~ 1 + Max_DepthDredged + Volume + START_SALINITY_NUM | 381 | 0.0198 |

## Global model 2

| model | aicc | weights |
|---|---|---|
| second_perChange ~ 1 | 359 | 0.404 |
| second_perChange ~ 1 + Volume | 361 | 0.152 |
| second_perChange ~ 1 + Max_DepthDredged | 361 | 0.15 |
| second_perChange ~ 1 + START_SALINITY_NUM | 361 | 0.124 |
| second_perChange ~ 1 + Max_DepthDredged + START_SALINITY_NUM | 363 | 0.0546 |
| second_perChange ~ 1 + Volume + START_SALINITY_NUM | 363 | 0.053 |
| second_perChange ~ 1 + Max_DepthDredged + Volume | 364 | 0.0447 |
| second_perChange ~ 1 + Max_DepthDredged + Volume + START_SALINITY_NUM | 365 | 0.0179 |

## Global model 3

| model | aicc | weights |
|---|---|---|
| first_perChange ~ 1 | 462 | 0.428 |
| first_perChange ~ 1 + Max_DepthDredged | 464 | 0.158 |
| first_perChange ~ 1 + Volume | 464 | 0.141 |
| first_perChange ~ 1 + START_SALINITY_NUM | 464 | 0.138 |
| first_perChange ~ 1 + Max_DepthDredged + Volume | 467 | 0.0434 |
| first_perChange ~ 1 + Max_DepthDredged + START_SALINITY_NUM | 467 | 0.0426 |
| first_perChange ~ 1 + Volume + START_SALINITY_NUM | 467 | 0.0388 |
| first_perChange ~ 1 + Max_DepthDredged + Volume + START_SALINITY_NUM | 470 | 0.0106 |

## Global model 4

| model | aicc | weights |
|---|---|---|
| second_perChange ~ 1 + Max_DepthDredged | 413 | 0.283 |
| second_perChange ~ 1 | 413 | 0.238 |
| second_perChange ~ 1 + Max_DepthDredged + Volume | 414 | 0.163 |
| second_perChange ~ 1 + START_SALINITY_NUM | 415 | 0.0892 |
| second_perChange ~ 1 + Max_DepthDredged + START_SALINITY_NUM | 415 | 0.0781 |
| second_perChange ~ 1 + Volume | 415 | 0.075 |
| second_perChange ~ 1 + Max_DepthDredged + Volume + START_SALINITY_NUM | 417 | 0.0406 |
| second_perChange ~ 1 + Volume + START_SALINITY_NUM | 417 | 0.0337 |

All models performed similarly within 2 AIC points and gave the best fitting model with only the intercept. Because they all performed similarly, analysis continued with the global model equation (first_perChange ~ Max_DepthDredged + Volume + START_SALINITY_NUM and second_perChange ~ Max_DepthDredged + Volume + START_SALINITY_NUM for both Hurricane Harvey and Texas Freeze).

## Hurricane Harvey and first year percent change plotted against each explanatory variable

**Units of variables:**

- Maximum depth is in meters
- Volume is in cubic kilometers
- Salinity is in parts per thousand

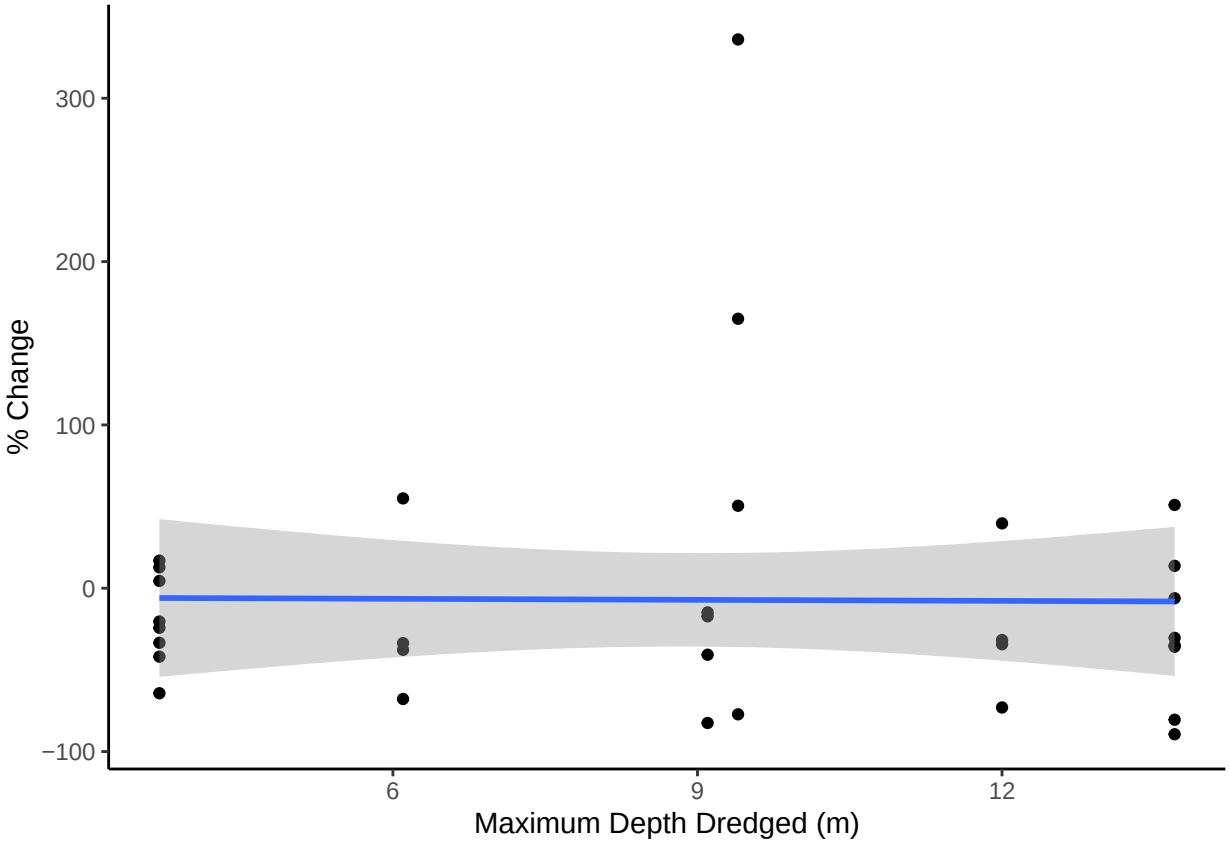


Figure S10: First year percent change during Hurricane Harvey correlated with max depth of bays

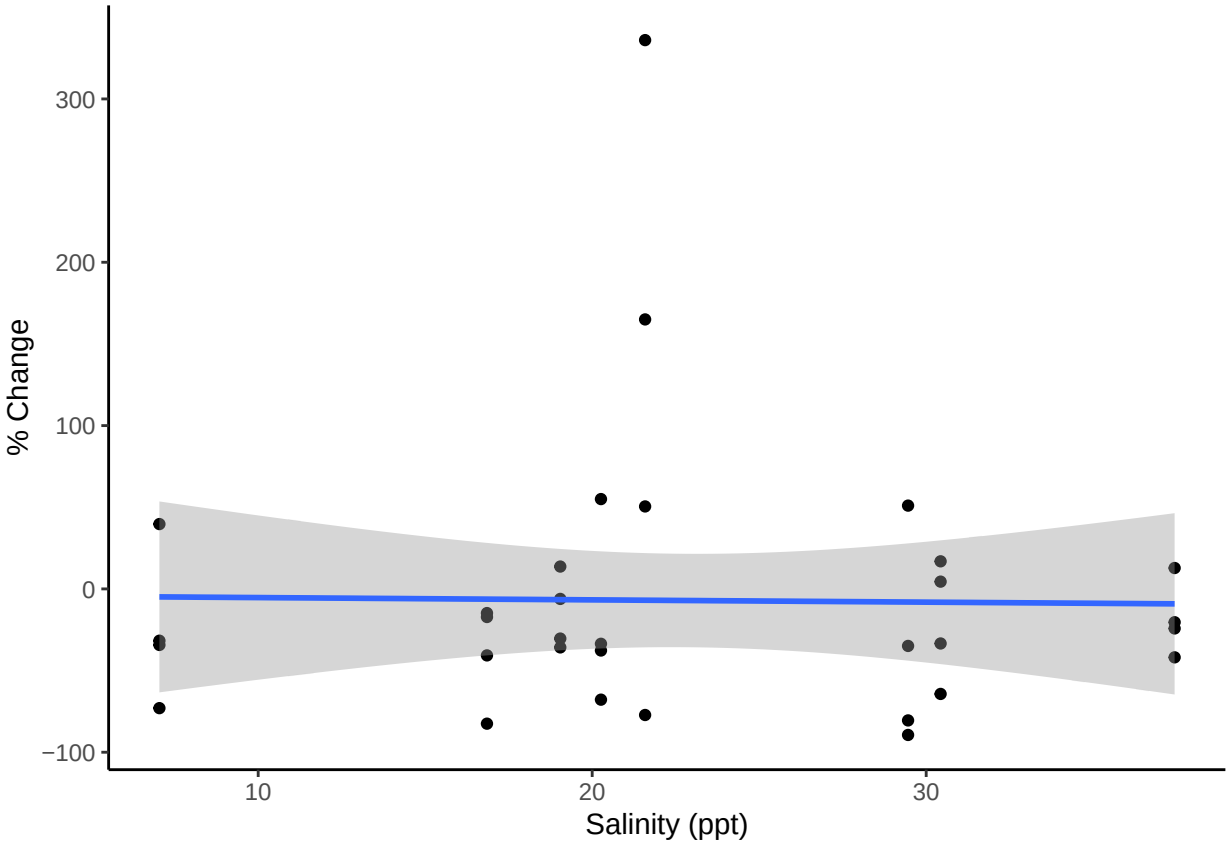


Figure S11: First year percent change during Hurricane Harvey correlated with average salinity

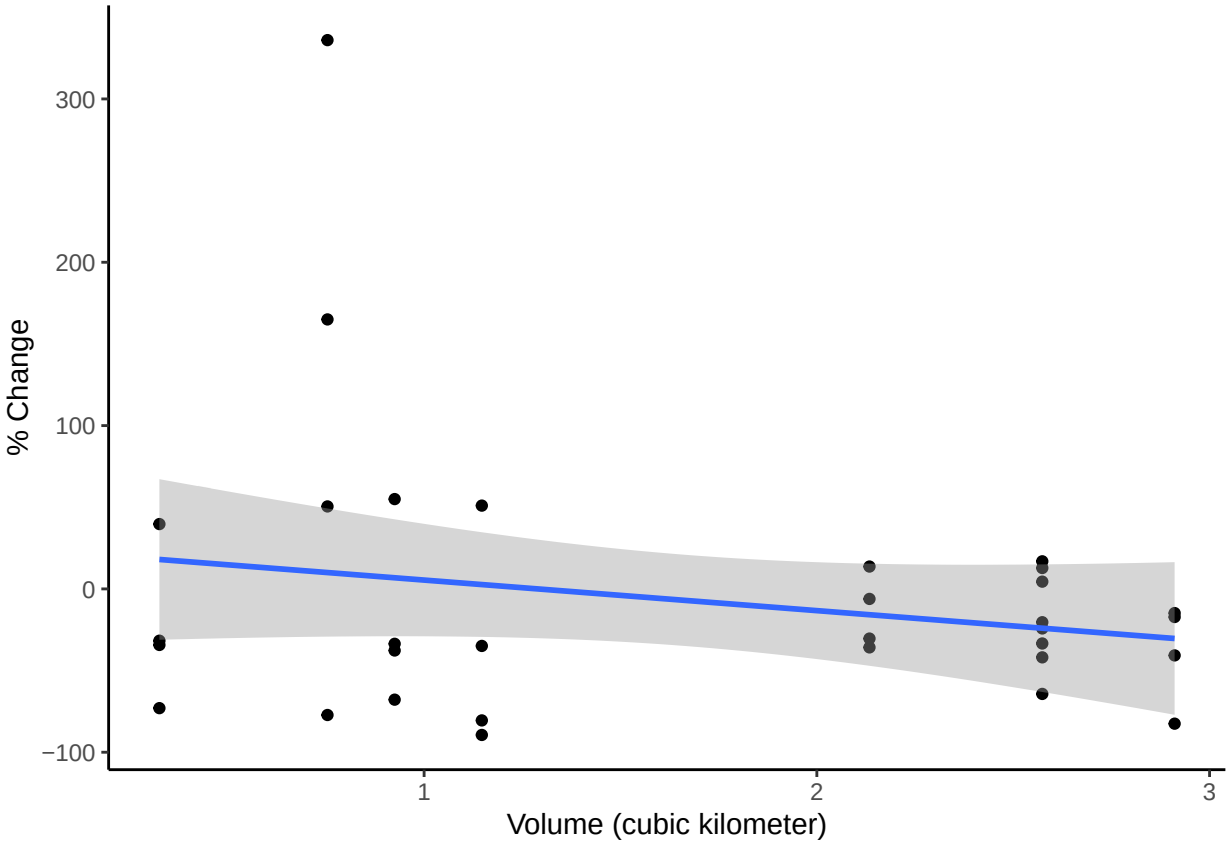


Figure S12: First year percent change during Hurricane Harvey correlated with volume of the bays

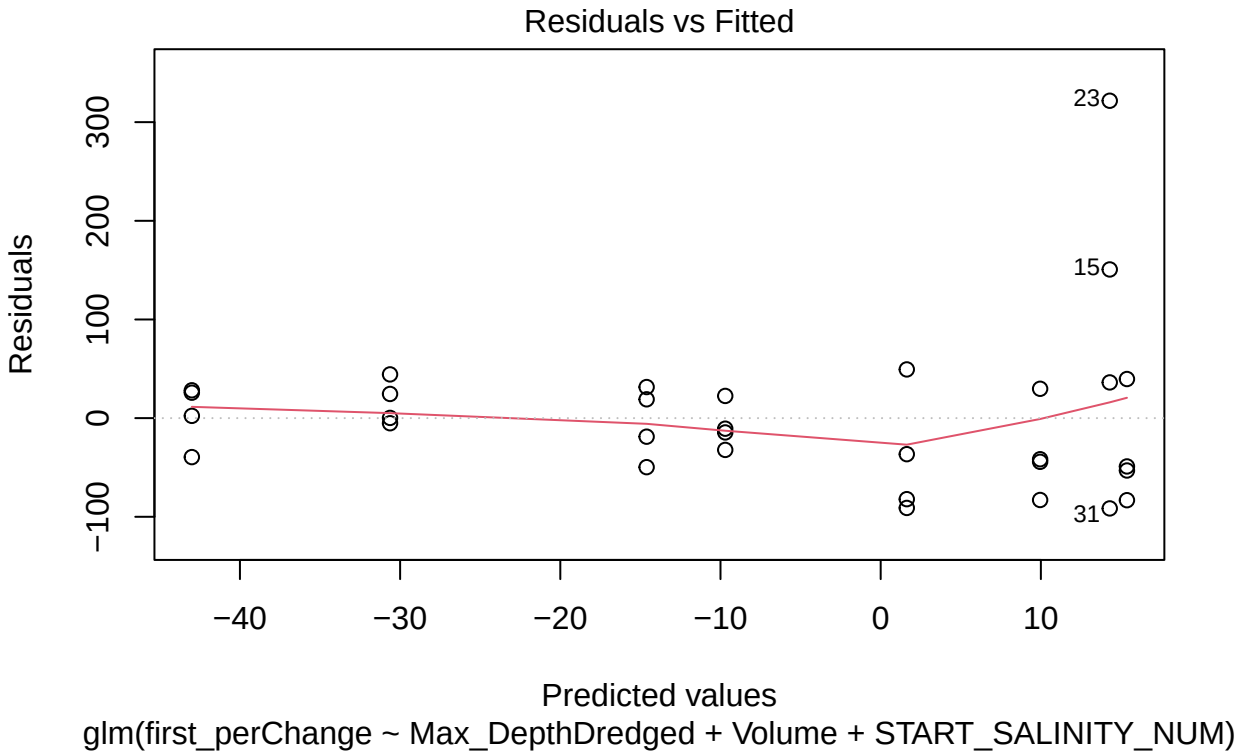


Figure S13: Residual vs fitted for first year percent change during hurricane harvey model

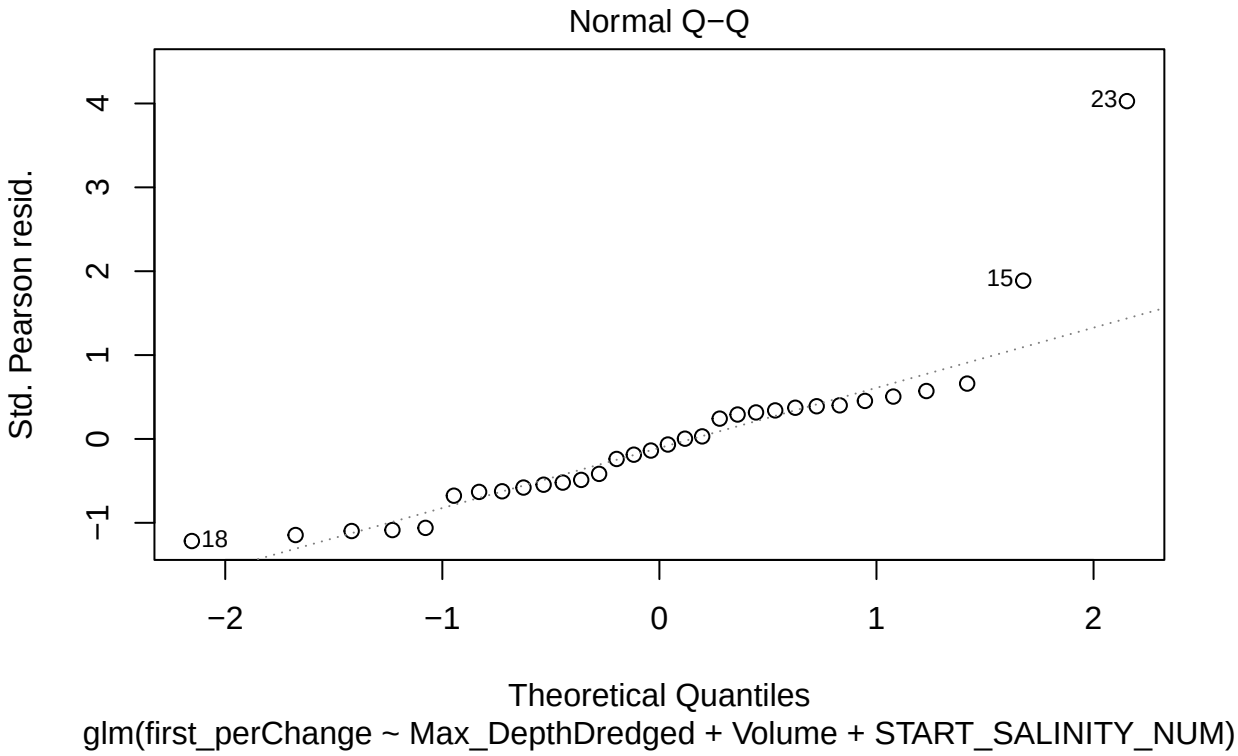


Figure S14: Normal Q-Q plot for first year percent change during hurricane harvey model

## Hurricane Harvey and first year percent change generalized linear regression with a Gaussian error distribution

Model equation: first_perChange ~ Max_DepthDredged + volume + START_SALINITY_NUM

| | |
|---|---|
| Observations | 32 |
| Dependent variable | first_perChange |
| Type | Linear regression |

| | |
|---|---|
| $\chi^2(3)$ | 12943.08 |
| Pseudo-R² (Cragg-Uhler) | 0.06 |
| Pseudo-R² (McFadden) | 0.01 |
| AIC | 379.12 |
| BIC | 386.44 |

| | Est. | S.E. | t val. | p |
|---|---|---|---|---|
| (Intercept) | 36.27 | 79.58 | 0.46 | 0.65 |
| Max_DepthDredged | -1.92 | 4.62 | -0.41 | 0.68 |
| Volume | -25.29 | 18.49 | -1.37 | 0.18 |
| START_SALINITY_NUM | 0.70 | 2.09 | 0.34 | 0.74 |

Standard errors: MLE

**Hurricane Harvey and second year percent change**

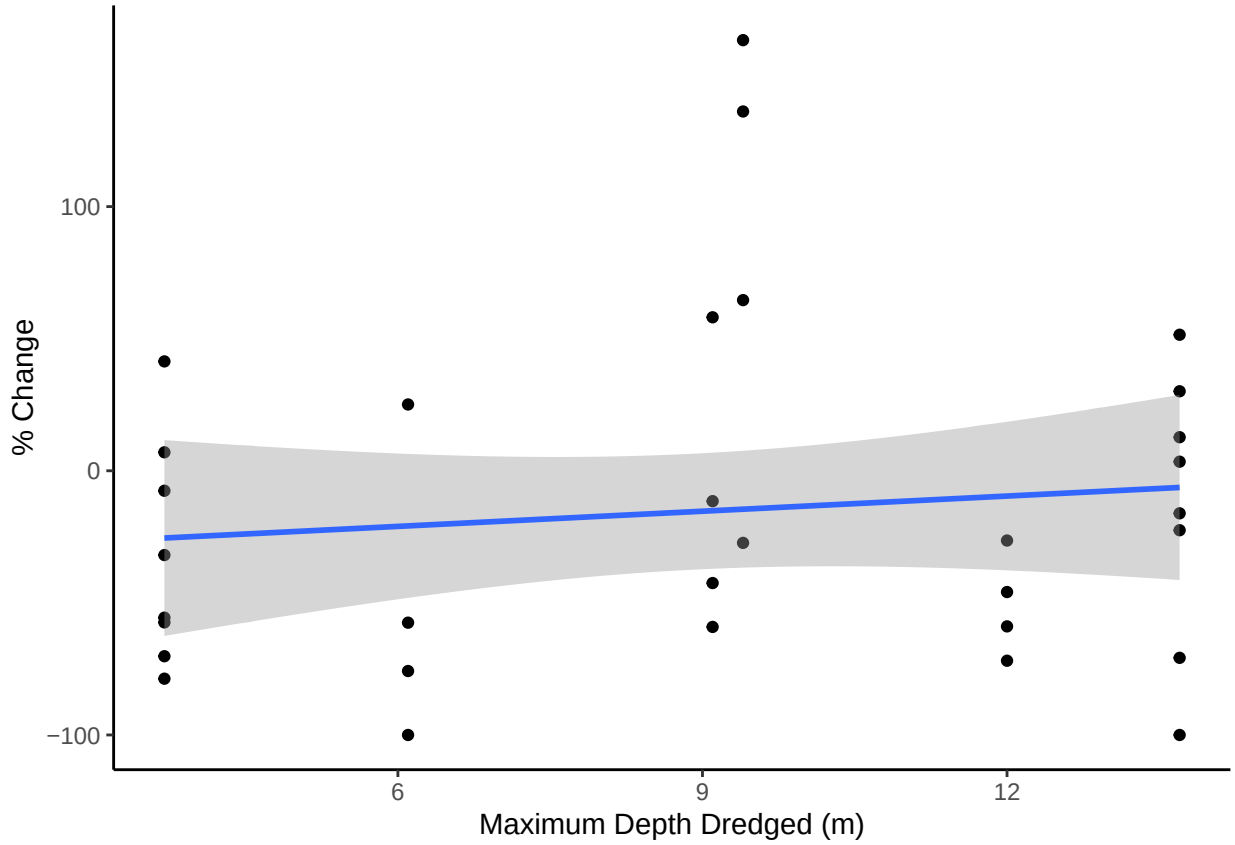


Figure S15: Second year percent change during Hurricane Harvey correlated with max depth of bay

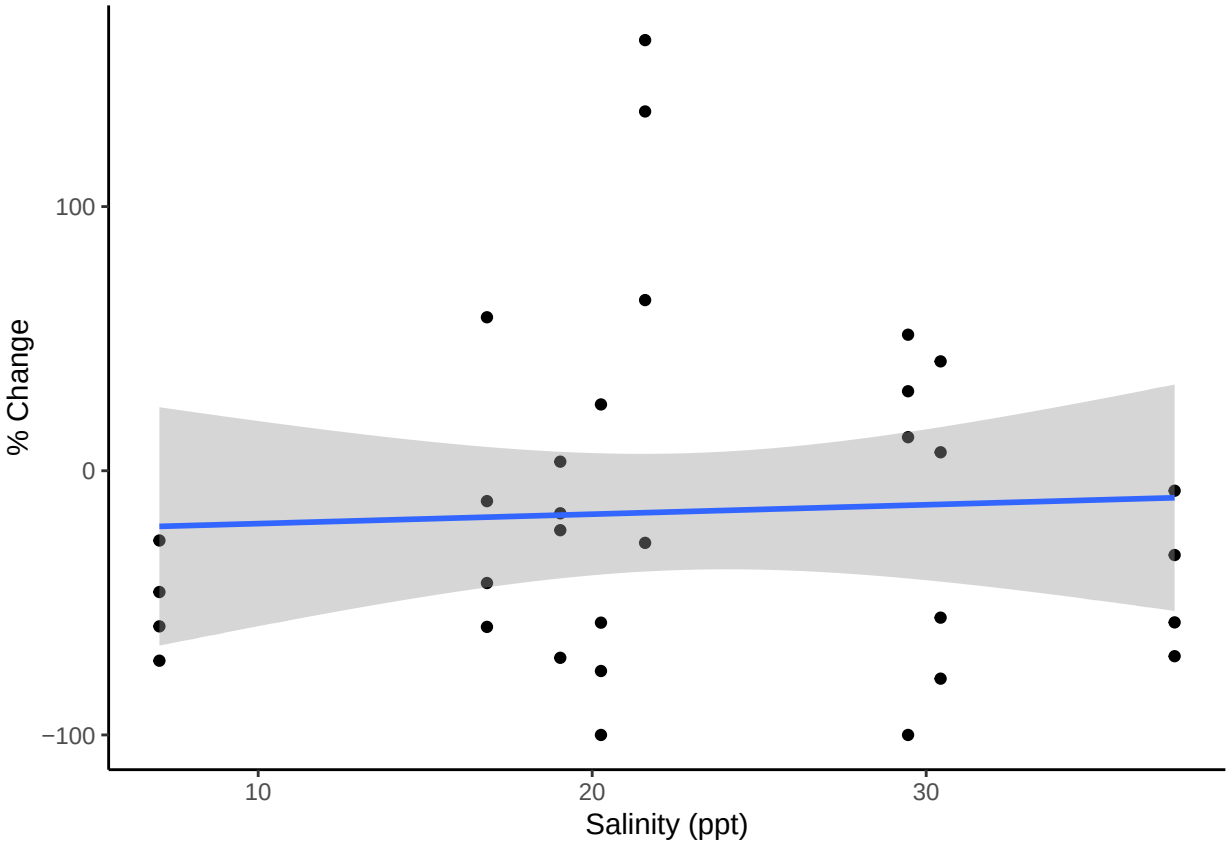


Figure S16: Second year percent change during Hurricane Harvey correlated with average salinity

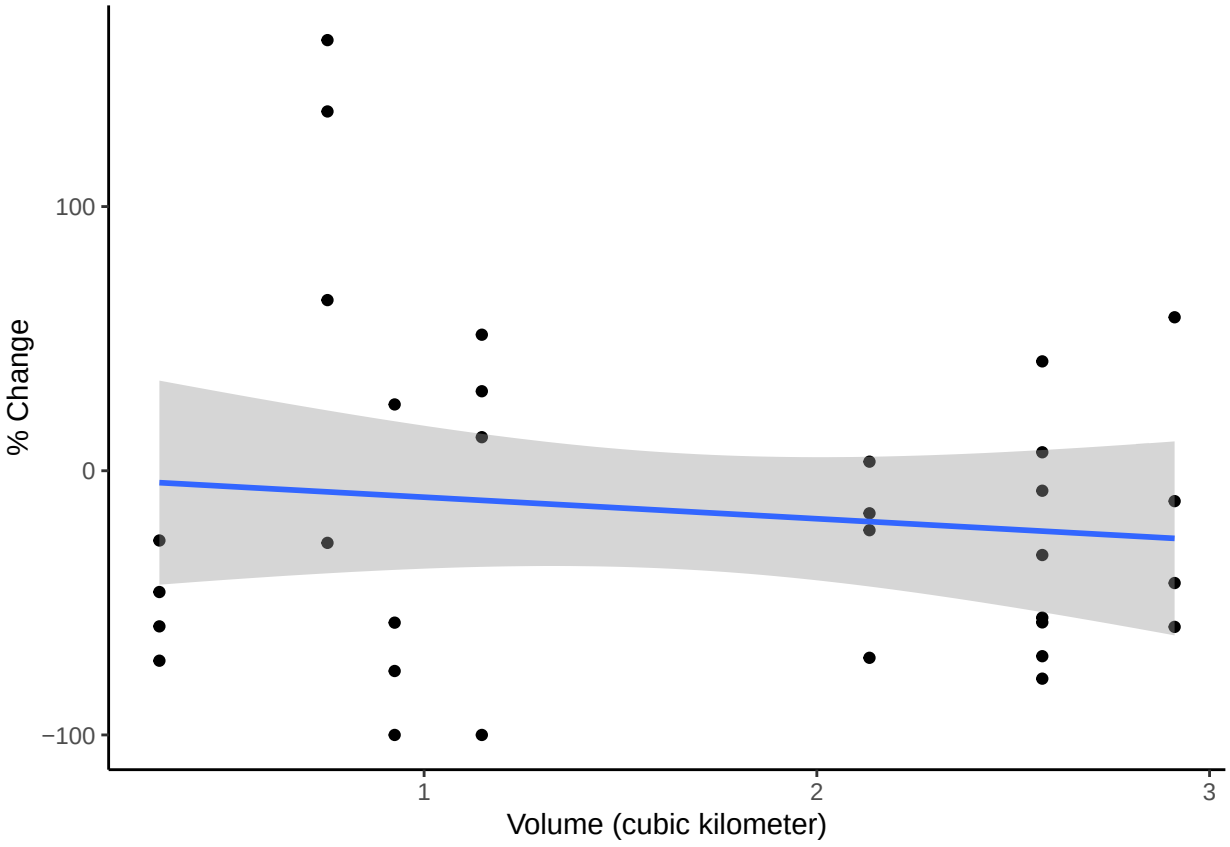


Figure S17: Second year percent change during Hurricane Harvey correlated with volume

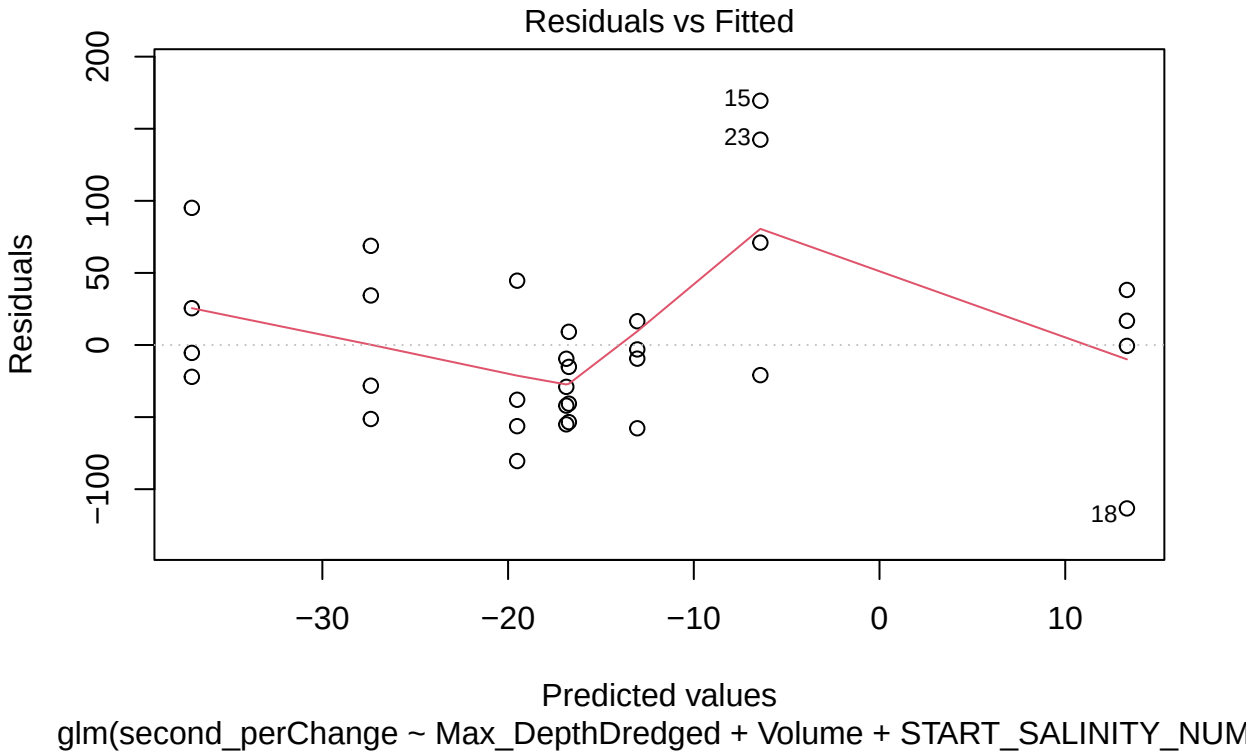


Figure S18: Residual vs fitted for second year percent change during hurricane harvey model

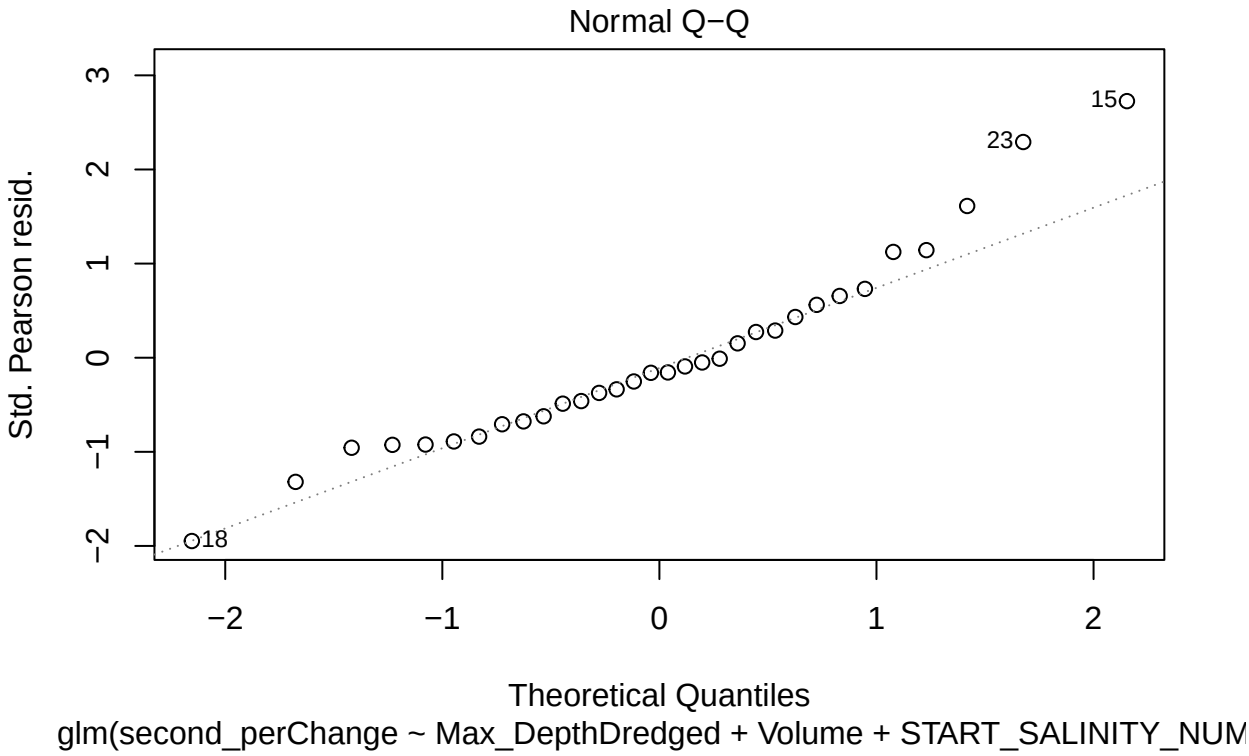


Figure S19: Normal Q-Q plot for second year percent change during hurricane harvey model

## Hurricane Harvey and second year percent change generalized linear regression with a Gaussian error distribution

Model equation: second_perChange ~ Max_DepthDredged + volume + START_SALINITY_NUM

| | |
|---|---|
| Observations | 32 |
| Dependent variable | second_perChange |
| Type | Linear regression |

| | |
|---|---|
| $\chi^2(3)$ | 6174.54 |
| Pseudo-$R^2$ (Cragg-Uhler) | 0.05 |
| Pseudo-$R^2$ (McFadden) | 0.00 |
| AIC | 363.06 |
| BIC | 370.39 |

| | Est. | S.E. | t val. | p |
|---|---|---|---|---|
| (Intercept) | -57.04 | 61.74 | -0.92 | 0.36 |
| Max_DepthDredged | 2.72 | 3.59 | 0.76 | 0.46 |
| Volume | -10.51 | 14.41 | -0.73 | 0.47 |
| START_SALINITY_NUM | 1.54 | 1.63 | 0.94 | 0.35 |

Standard errors: MLE

**Freeze and first year percent change**

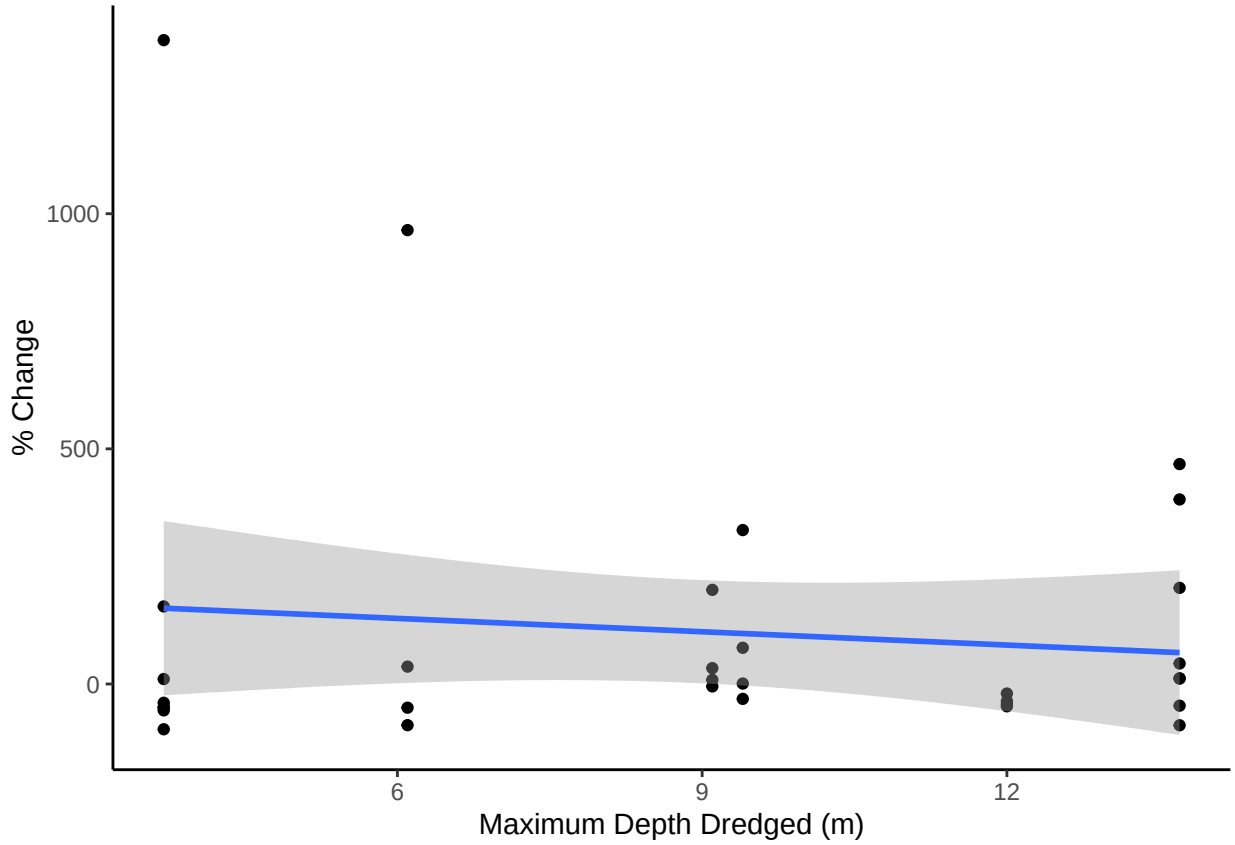


Figure S20: First year percent change during Texas freeze correlated with max depth

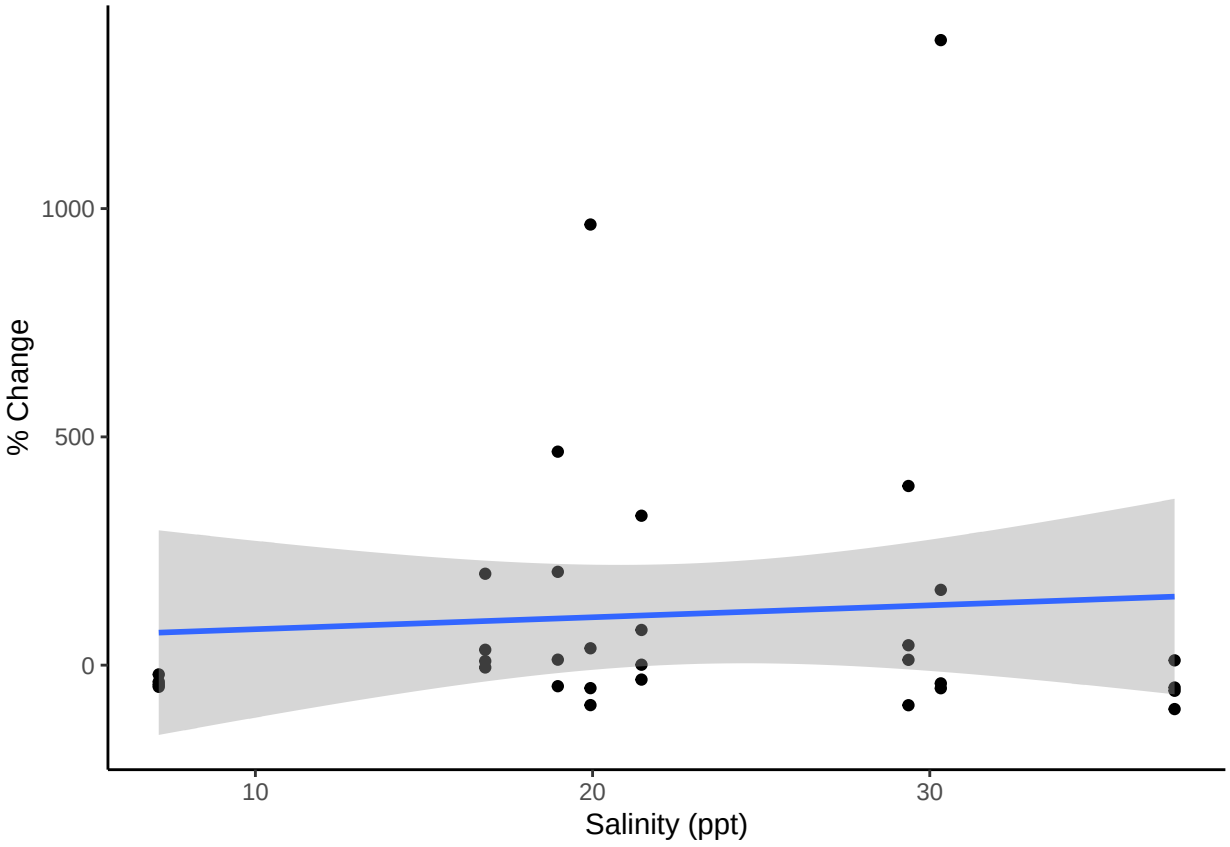


Figure S21: First year percent change during Texas freeze correlated with average salinity

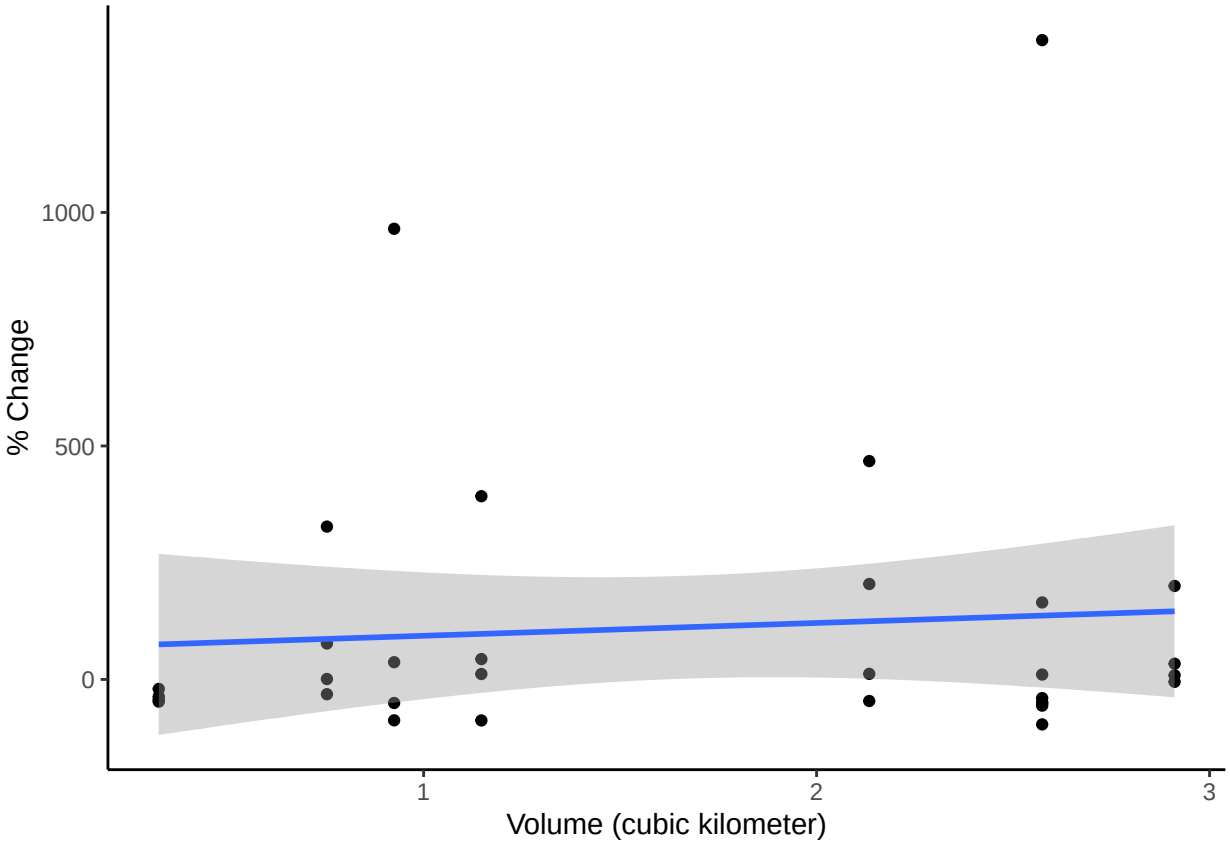


Figure S22: First year percent change during Texas freeze correlated with volume

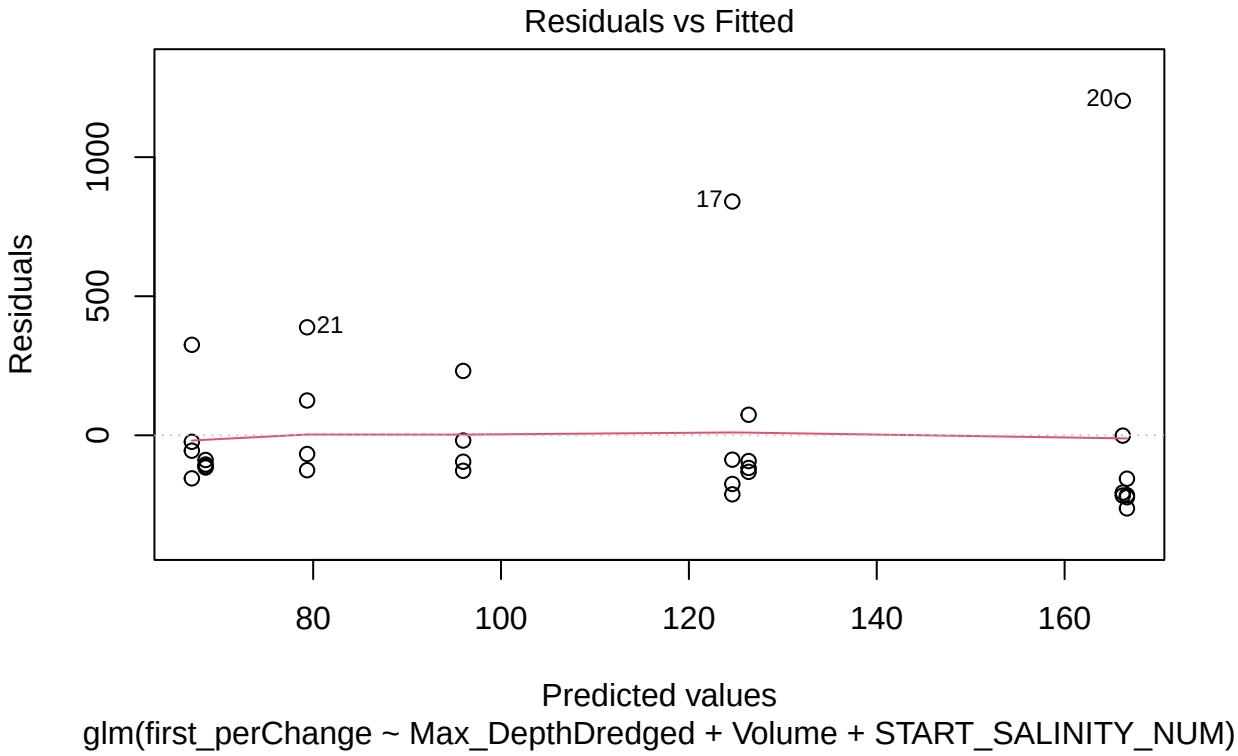


Figure S23: Residual vs fitted for first year percent change during Texas freeze model

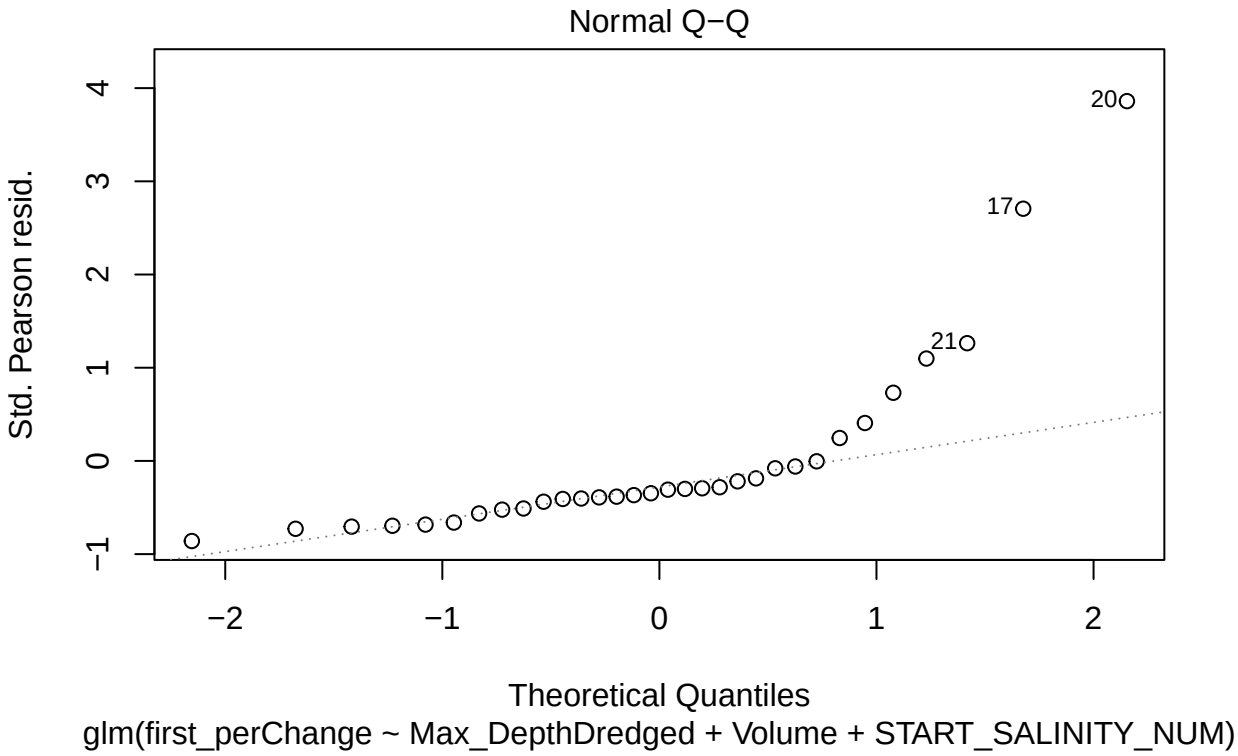


Figure S24: Normal Q-Q plot for first year percent change during Texas freeze model

## Freeze event and first year percent change generalized linear regression with a Gaussian error distribution

Model equation: first_perChange ~ Max_DepthDredged + volume + START_SALINITY_NUM

| | |
|---|---|
| Observations | 32 |
| Dependent variable | first_perChange |
| Type | Linear regression |

| | |
|---|---|
| $\chi^2(3)$ | 46065.88 |
| Pseudo-R² (Cragg-Uhler) | 0.02 |
| Pseudo-R² (McFadden) | 0.00 |
| AIC | 467.21 |
| BIC | 474.54 |

| | Est. | S.E. | t val. | p |
|---|---|---|---|---|
| (Intercept) | 160.23 | 314.28 | 0.51 | 0.61 |
| Max_DepthDredged | -8.03 | 18.27 | -0.44 | 0.66 |
| Volume | 13.11 | 73.36 | 0.18 | 0.86 |
| START_SALINITY_NUM | 0.06 | 8.31 | 0.01 | 0.99 |

Standard errors: MLE

**Freeze and second year percent change**

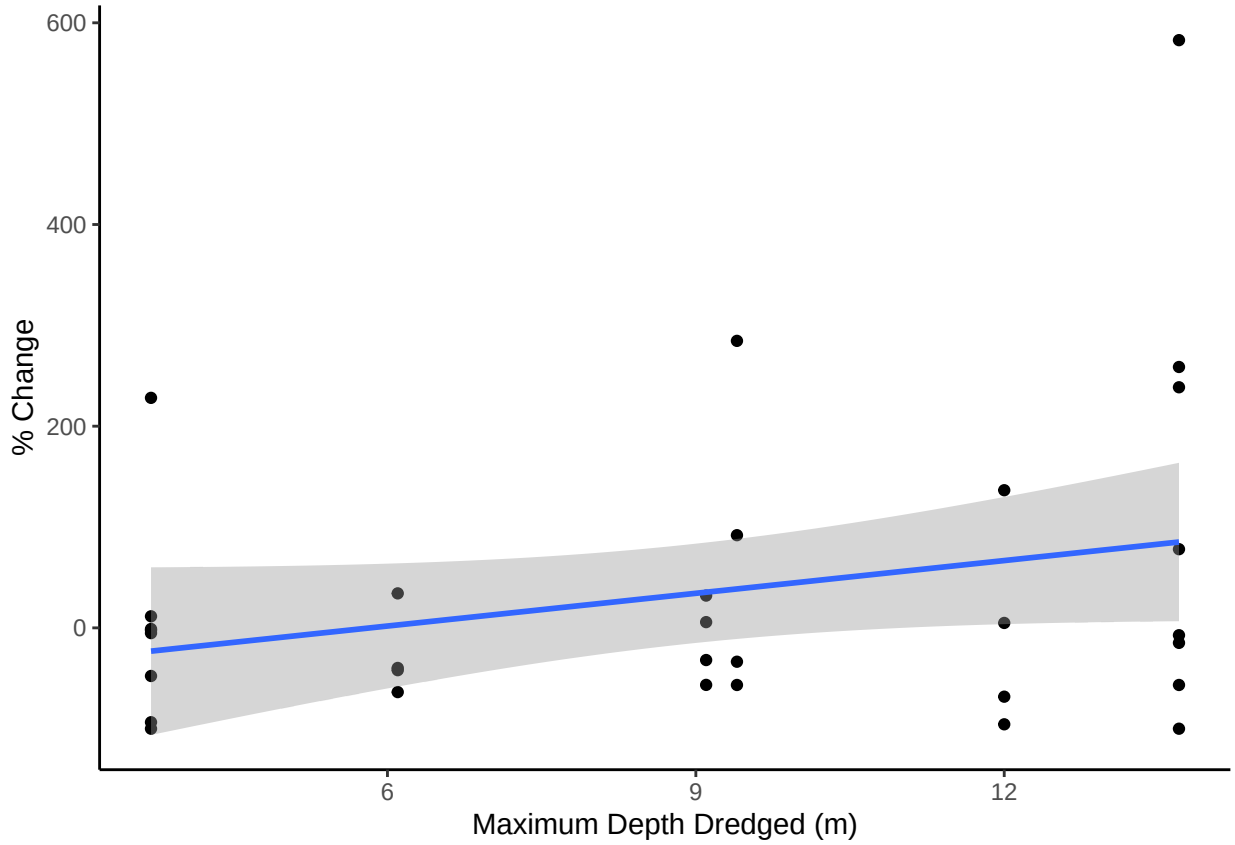


Figure S25: Second year percent change during Texas freeze correlated with max depth

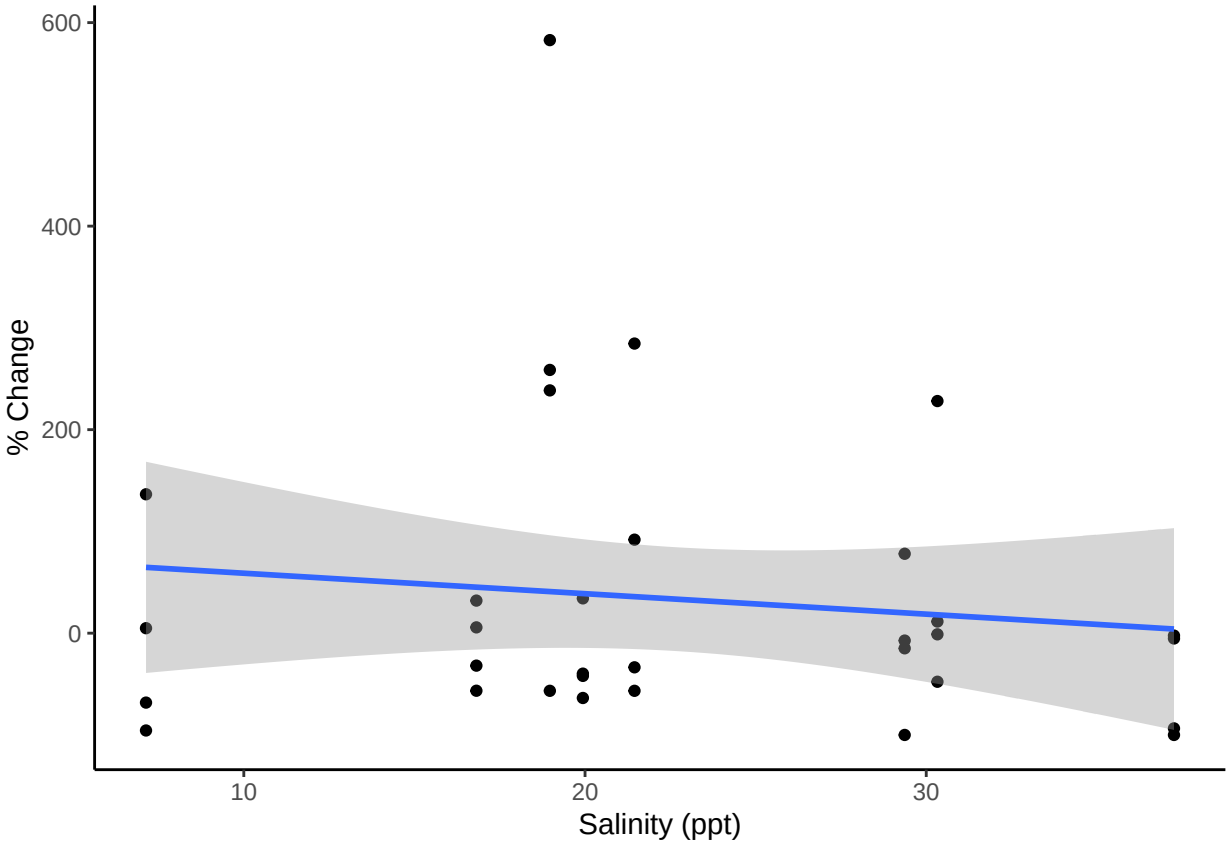


Figure S26: Second year percent change during Texas freeze correlated with average salinity

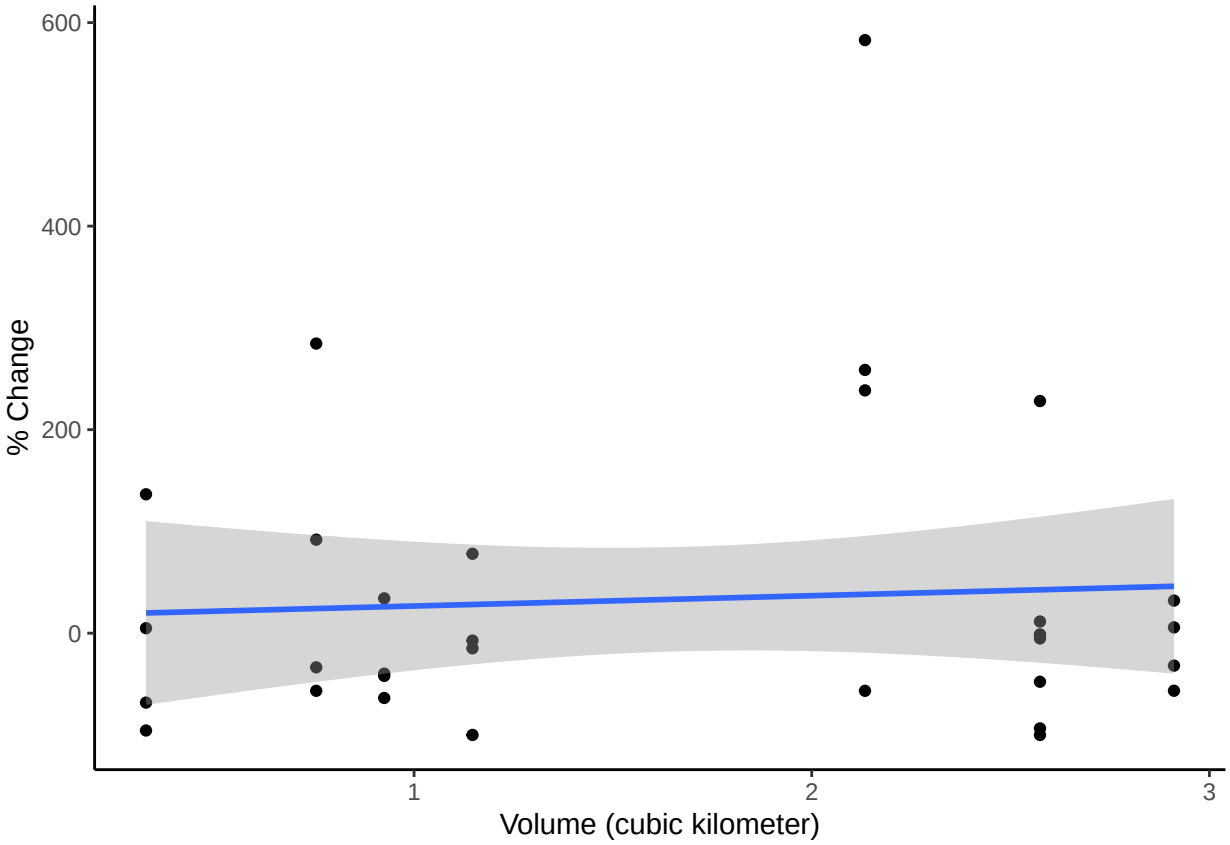


Figure S27: Second year percent change during Texas freeze correlated with volume

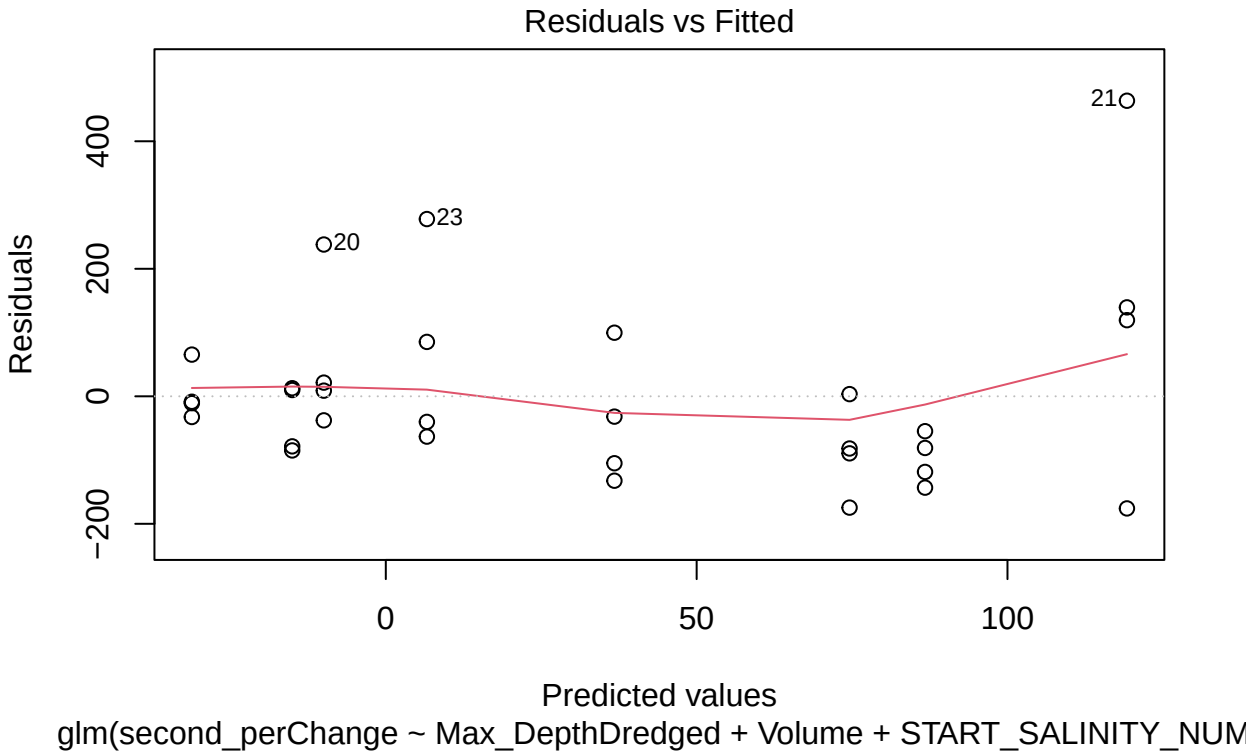


Figure S28: Residual vs fitted for second year percent change during Texas freeze model

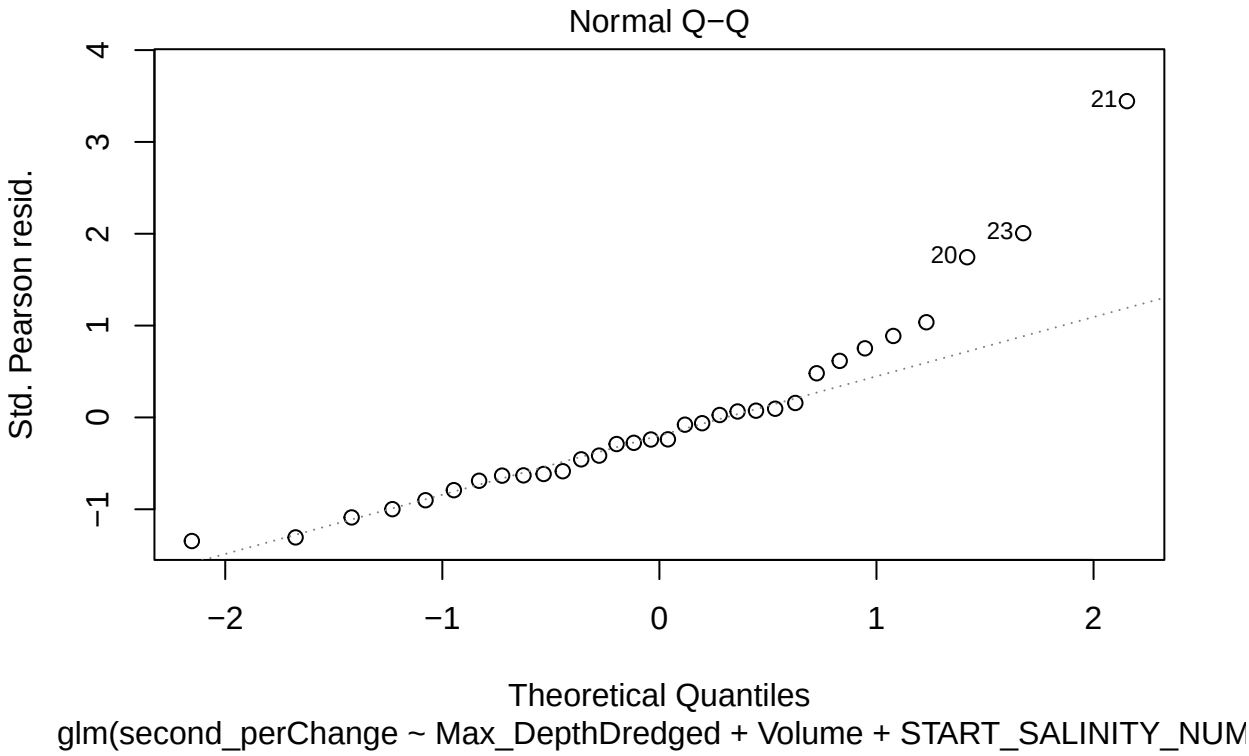


Figure S29: Normal Q-Q plot for second year percent change during Texas freeze model

## Freeze event and second year percent change generalized linear regression with a Gaussian error distribution

Model equation: Second_perChange ~ Max_DepthDredged + volume + START_SALINITY_NUM

| | |
|---|---|
| Observations | 32 |
| Dependent variable | second_perChange |
| Type | Linear regression |

| | |
|---|---|
| $\chi^2(3)$ | 84148.54 |
| Pseudo-R² (Cragg-Uhler) | 0.13 |
| Pseudo-R² (McFadden) | 0.01 |
| AIC | 414.37 |
| BIC | 421.70 |

| | Est. | S.E. | t val. | p |
|---|---|---|---|---|
| (Intercept) | -135.04 | 137.65 | -0.98 | 0.33 |
| Max_DepthDredged | 13.74 | 8.00 | 1.72 | 0.10 |
| Volume | 37.48 | 32.13 | 1.17 | 0.25 |
| START_SALINITY_NUM | -0.73 | 3.64 | -0.20 | 0.84 |

Standard errors: MLE