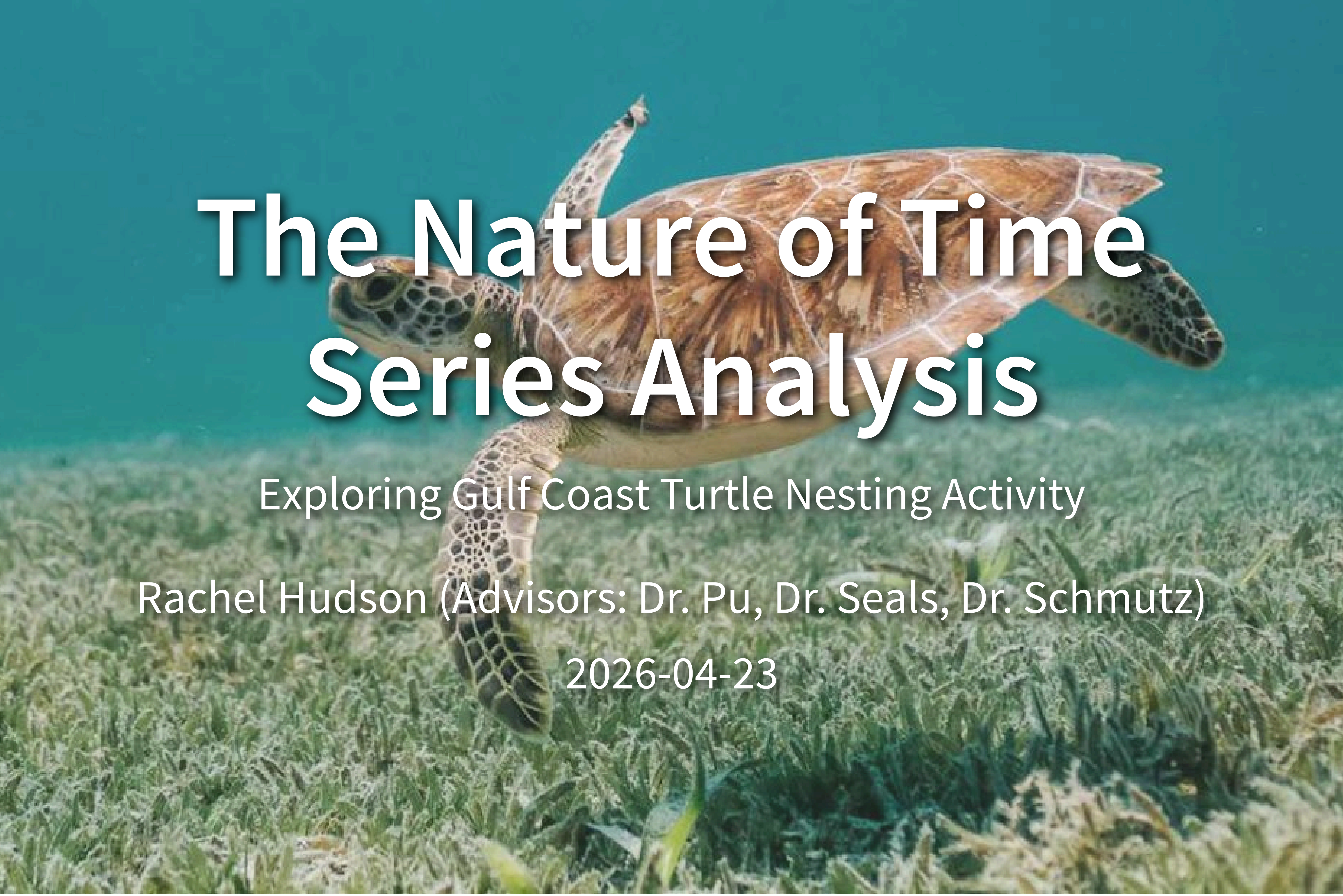

The Nature of Time Series Analysis

Exploring Gulf Coast Turtle Nesting Activity

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Introduction

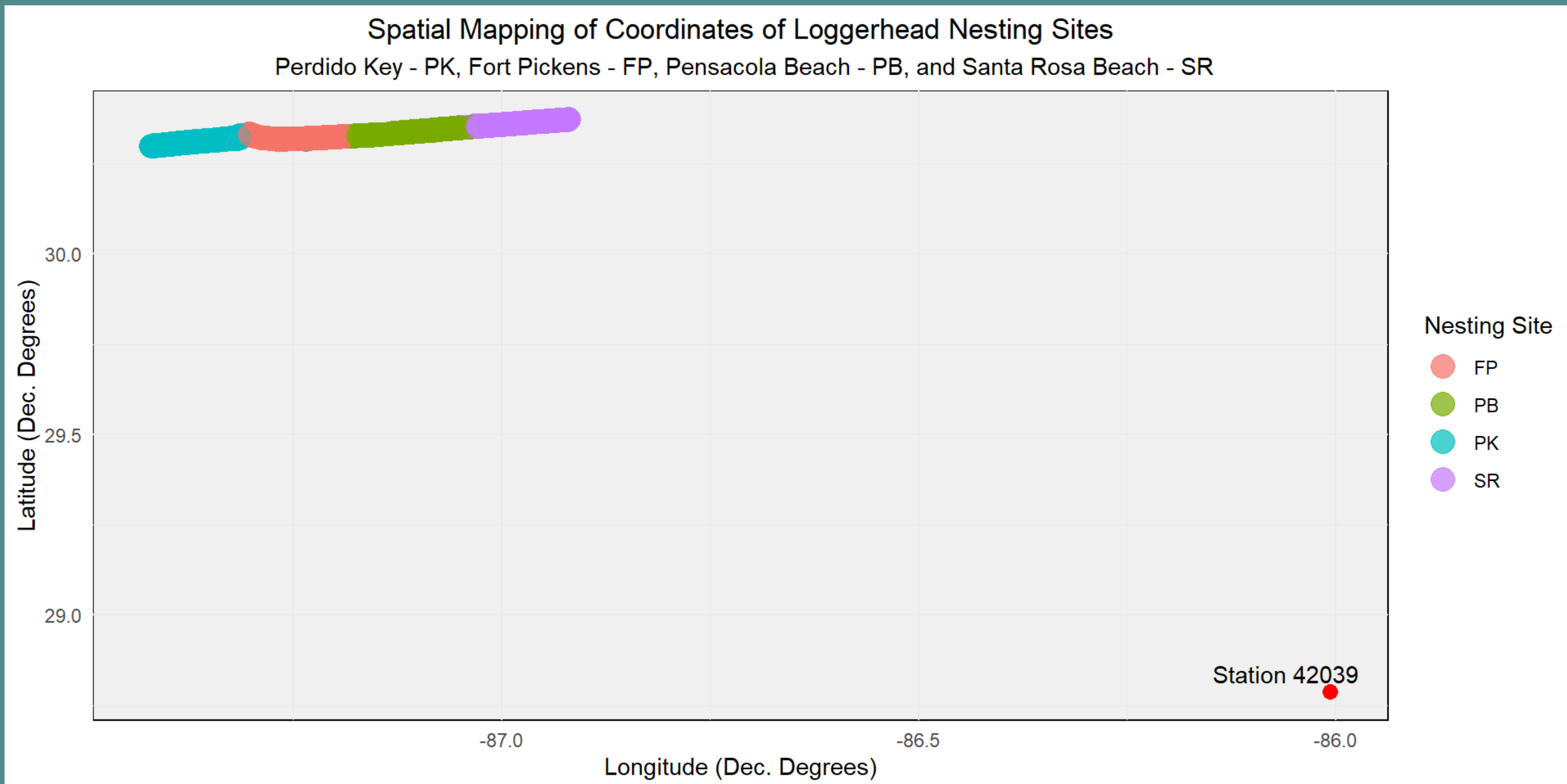
- Evaluate Loggerhead Turtle Nesting Habits
- How **predictable** are the nesting counts?
- How much **influence** do environmental factors have on outcomes?
- Why **Time Series Analysis** as our chosen solution?
- Helps support **local conservation** activities

Delving Into The Data

- Data Range, **1998-2020** - 2017 highest number of nesting sites
- **Date, Loggerhead Turtles, Temperature**
- **Grouped nests** per season month (most in July)
- **Not every day had a nest; not every day had a temperature**

Delving Into The Data

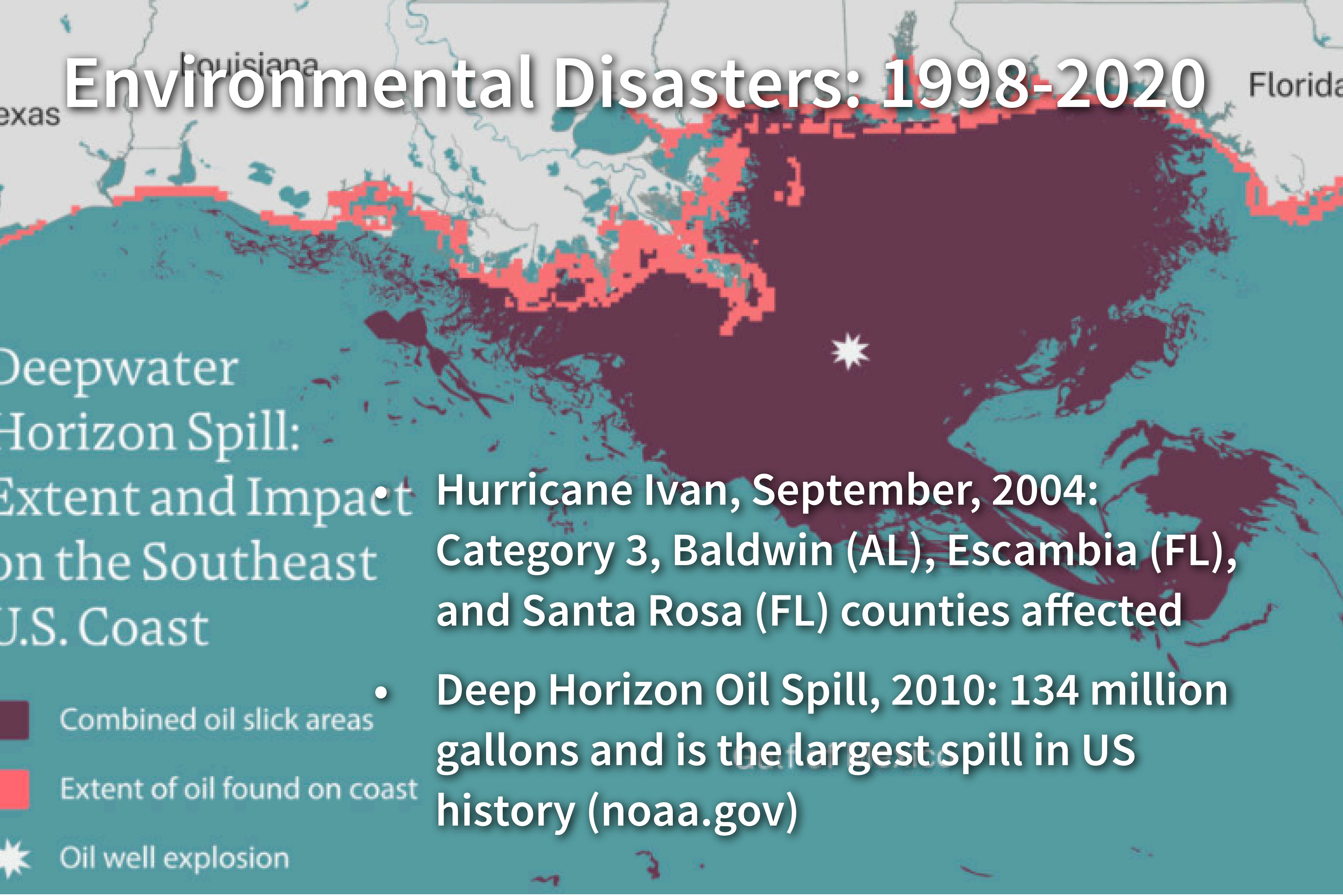
Gulf Coast Buoy Water Temperature Data added



Natural Behavior

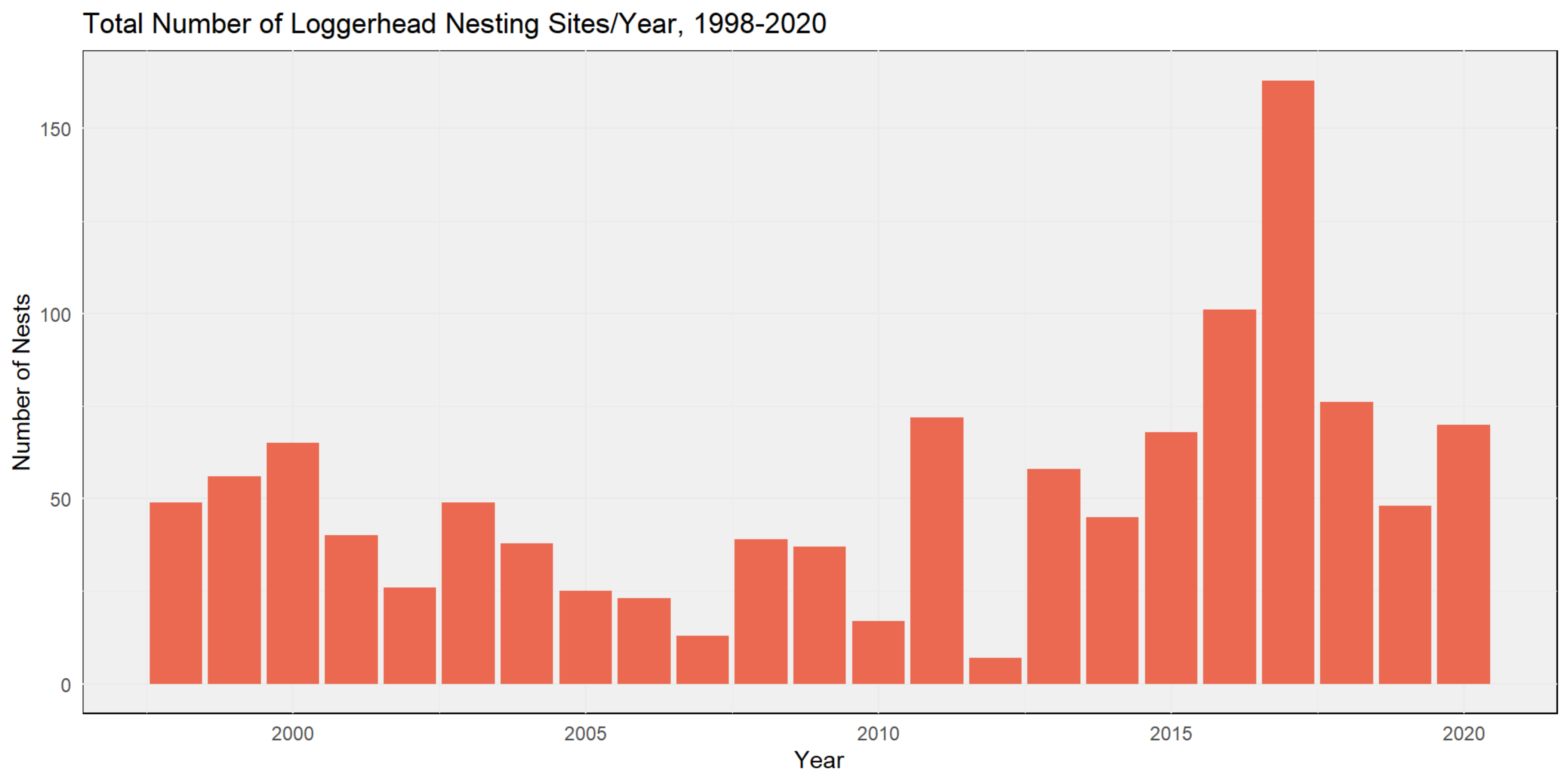
- **Nesting season** is generally May through September
- Florida is host to around **100,000 nests**
- Females return to nesting site **every 2 (or more) years**
- **Re-migration** of females
- Florida is the breeding ground for **90% of Loggerhead population** worldwide!

Environmental Disasters: 1998-2020



- Hurricane Ivan, September, 2004: Category 3, Baldwin (AL), Escambia (FL), and Santa Rosa (FL) counties affected
- Deep Horizon Oil Spill, 2010: 134 million gallons and is the largest spill in US history (noaa.gov)

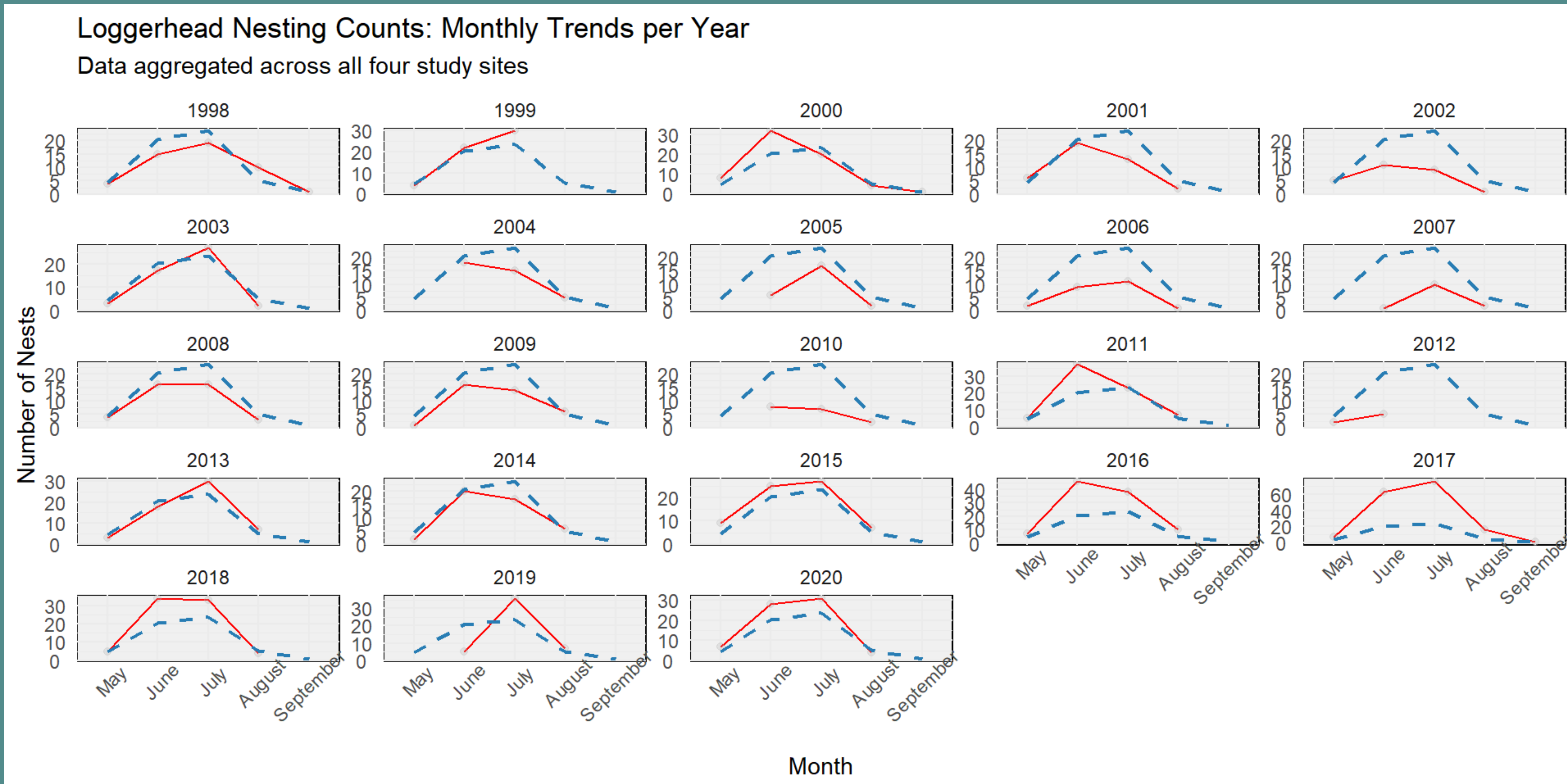
Impacts: 1998-2020



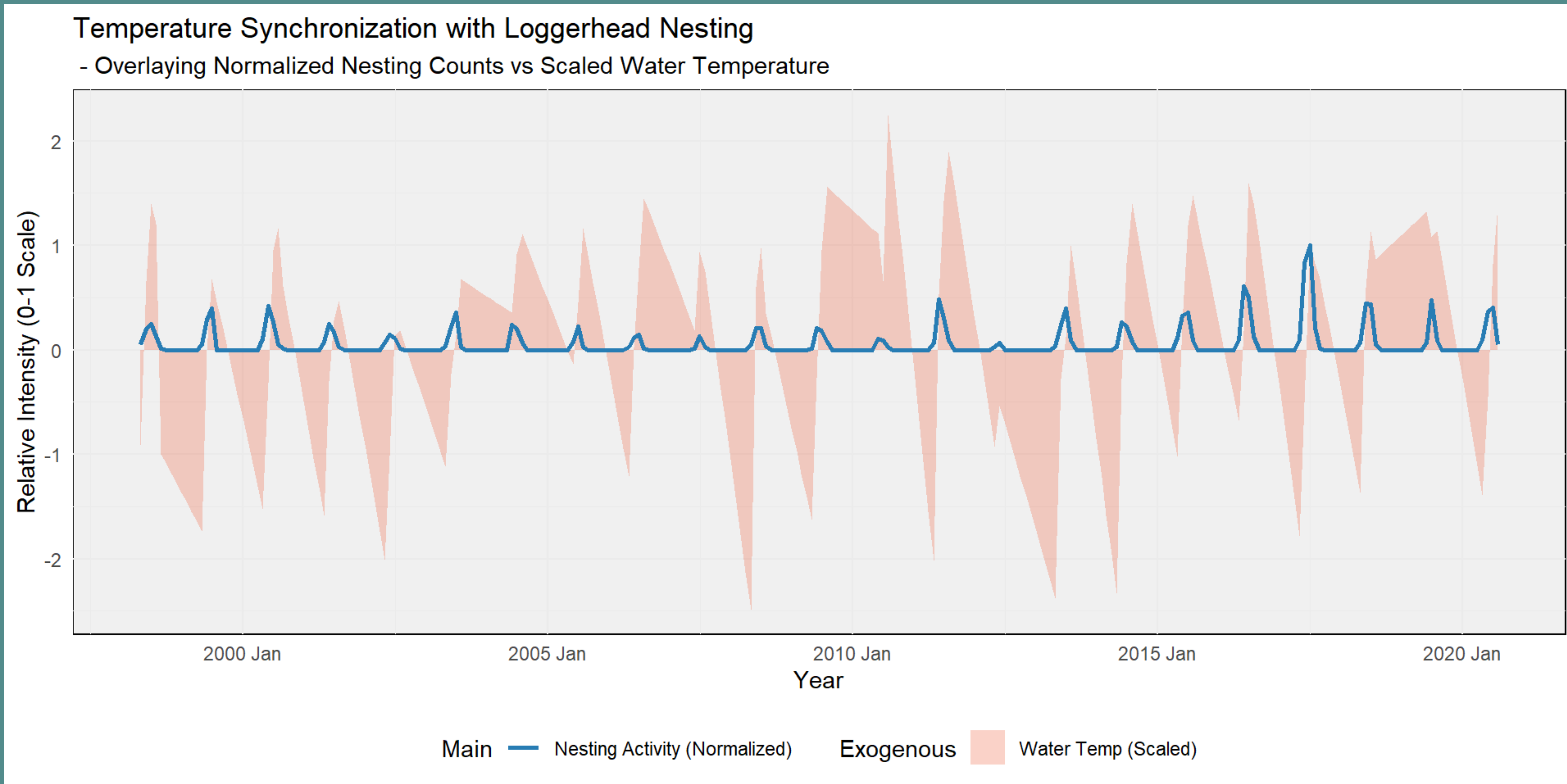
TSA Process Overview

- **Exploring** relationships in the data
- Examining the **Stationarity** of data
- Determining the **Decomposition** method
- Selecting a **Model** to capture pattern(s)
- **Training and validation** of the model
- Assessing the resulting **Metrics**
- **Forecasting** outcomes and testing consequential **Residuals**

Exploratory Data Visializations



Exploratory Data Visualizations



TSA SARIMAX Components

S (Seasonal) Component - represents the **regular intervals** at which a relationship can be identified; it is to be expected using biological data, i.e., finding the natural rhythm of the model.

AR (Autoregressive) Component, p - involves the model using the relationship of the variable with its own **previous values** (or lagged observations).

I (Integrated) Component, d - helps to **stabilize the mean** and remove trends from the time series analysis; makes the model stationary by **differencing**.

MA (Moving Average) Component, q - represents the effect of **previous error** terms on the present value of the time series.

X (eXogenous) Component - the **external variable** that can help fill in the gaps of past behaviour of the data to soften fluctuations and strengthen future predictions. For this analysis, our exogenous variable is the Gulf of Mexico Surface Water Temperature.

Box-Jenkins: Identification

Box-Jenkins: Identification

Box-Jenkins: Estimation

Box-Jenkins: Estimation

- **Modelling**
- p, d, q, P, D, Q to be estimated/confirmed
- Annual model, monthly data used
- Use z-statistic ~ p-value
- fable package used for ARIMA() and model() functions
- D = 1 added to stabilize the mean
- New model… **ARIMA(0,0,2)(0,1,1)[12]**
- Will be tested as a “neighbor” model in Validation

```
auto_SARIMA_fit <- SARIMAX_table %>%
  model(ARIMA(total_per_month))
report(auto_ARIMA_fit)
```

SARIMA Automatic Modelling Coefficients

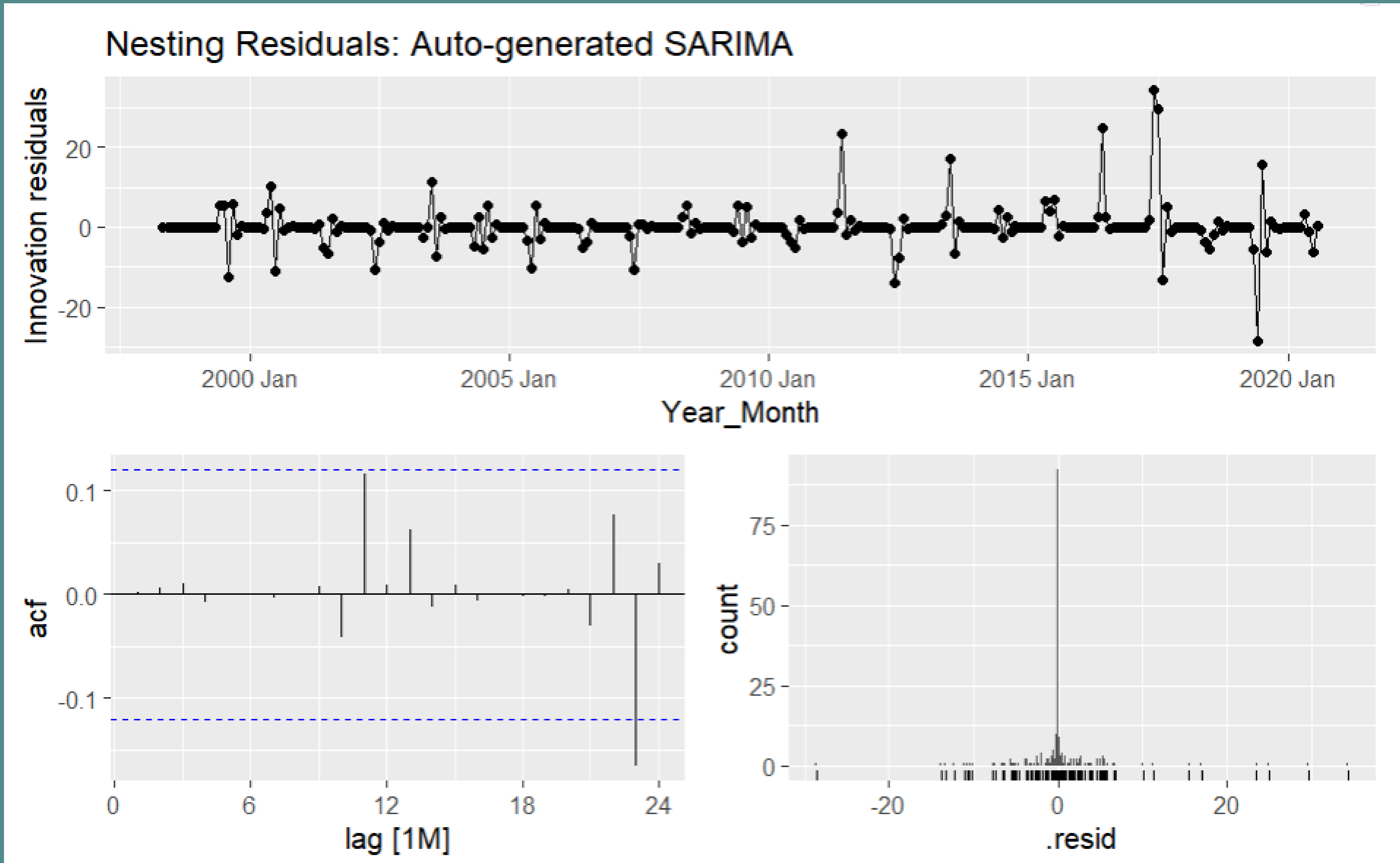
- ARIMA(0,0,2)(0,0,1)[12] for Nesting Activity

Parameter	Coefficient	Std. Error	z-value
ma1	0.6001480	0.06212687	9.660039
ma2	0.1378960	0.06141272	2.245397
sma1	-0.6977397	0.05465797	-12.765562

$$(1 - B^{12})y_t = (1 + \theta_1 B + \theta_2 B^2)(1 + \Theta_1 B^{12})\epsilon_t$$

$$= (1 + 0.6B + 0.14B^2)(1 - 0.7B^{12})\epsilon_t$$

Box-Jenkins: Diagnostic Checks



Training and Validation

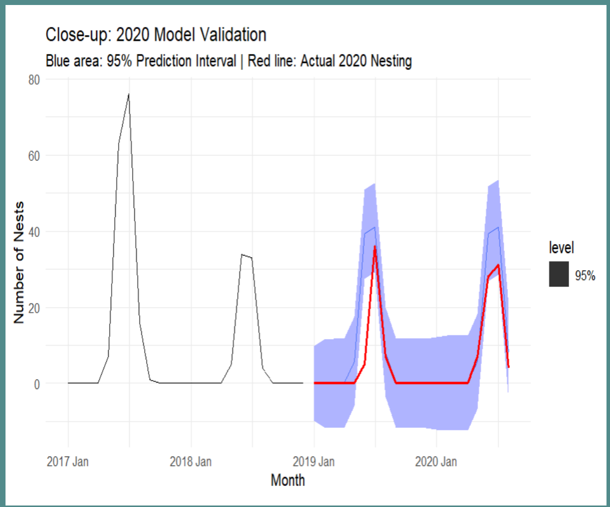
- Models trained on data from 1998-2018
- n_sarimax_002_011 = ARIMA(total_per_month ~ pdq(0,0,2) + PDQ(0,1,1))
- temp_sarimax_002_011 = ARIMA(total_per_month ~ avg_water_temp + pdq(0,0,2) + PDQ(0,1,1))
- sarimax_002_001 = ARIMA(total_per_month ~ pdq(0,0,2) + PDQ(0,0,1))
- fourier_sarimax_5 = ARIMA(total_per_month ~ fourier(K = 5) + pdq(0,0,2))

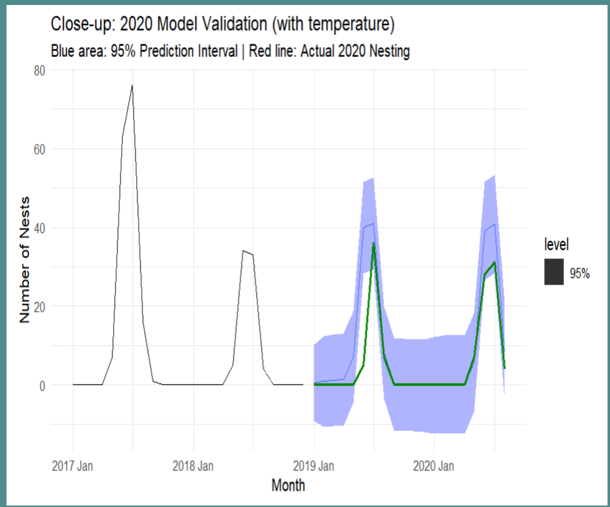
Models AICc Scores (Ranked Lowest to Highest)

- Partial Dataset, 1998-2019

Model	AIC	AICc	BIC	Log Likelihood	Sigma Squ.
n_sarimax_002_011	1437.11	1437.28	1450.96	-714.55	24.62
temp_sarimax_002_011	1438.26	1438.52	1455.58	-714.13	24.63
auto_sarimax	1438.75	1439.25	1463.00	-712.38	24.49
temp_sarimax	1440.17	1440.80	1467.88	-712.08	24.53
fourier_sarimax_5	1500.54	1502.90	1556.76	-734.27	23.02
fourier_sarimax_6	1502.54	1505.20	1562.27	-734.27	23.12
fourier_sarimax_4	1504.21	1506.01	1553.40	-738.11	23.51
fourier_sarimax_3	1518.99	1520.32	1561.15	-747.50	25.05
fourier_sarimax_2	1539.44	1540.37	1574.57	-759.72	27.28
temp_sarimax_002_001	1625.56	1625.91	1646.64	-806.78	39.55
sarimax_002_001	1631.76	1632.01	1649.33	-810.88	40.69
gam_fourier_4	1636.81	1637.73	1671.94	-808.40	41.20
ets_model	2262.00	2264.07	2314.71	-1116.00	34.63
base_snaive	NA	NA	NA	NA	49.45

Forecasting and Metrics





Ljung-Box Residual Test Results - n_sarimax_002_011

Model	Q-Statistic	p-value
n_sarimax_002_011	10.63584	0.9694178

Ljung-Box Residual Test Results - temp_sarimax_002_011

Model	Q-Statistic	p-value
temp_sarimax_002_011	9.936386	0.979726

Root Mean Squared Error & Mean Average Error - n_sarimax_002_011

Model	RMSE	MAE
n_sarimax_002_011	8.578671	3.636515

Root Mean Squared Error & Mean Average Error - temp_sarimax_002_011

Model	RMSE	MAE
temp_sarimax_002_011	8.775639	3.959554

Conclusion

- $\pm(4-9)$ nests per month using water temperature to guide through the nesting patterns while also handling extraneous negative influences (natural and man-made).
- The model showed excellent forecasting where it can attain 95% confidence level and so can be considered a practical surveillance tool.
- Turtles still have individualistic circumstances but as a whole, they form a predictable population that can be monitored statistically without too much interference.

Future Work

- Looking at the beginning and end dates
- Observing how the peak of the nesting season changes over time.
- Individual areas to concentrate conservation activities

References

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Questions?