**Model Assumption: Variables were made stationary through differencing and NaN values were dropped.**

**Forecast pH Results**

ARIMA results:

```
Best model:  ARIMA(0,1,1)(0,0,0)[0] intercept
Total fit time: 3.449 seconds
    ▼              ARIMA              ❶
  ARIMA(0,1,1)(0,0,0)[0] intercept
```

```
                              SARIMAX Results
==============================================================================
Dep. Variable:              Hawaii pH   No. Observations:                  19
Model:               SARIMAX(0, 1, 1)   Log Likelihood                  71.016
Date:                Sun, 23 Mar 2025   AIC                           -130.032
Time:                        22:30:00   BIC                           -125.397
Sample:                    01-01-2004   HQIC                          -129.795
                         - 01-01-2022
Covariance Type:                  opg
================================================================================================
                                   coef    std err          z      P>|z|      [0.025      0.975]
------------------------------------------------------------------------------------------------
Hawaii pCO2                     -0.0014      0.000     -5.743      0.000      -0.002      -0.001
Ocean Surface Temperature (C)   -0.0014      0.000     -5.743      0.000      -0.002      -0.001
Global Temperature Anomaly (C)  -0.0010      0.000     -2.283      0.022      -0.002      -0.000
Eruptions                        0.0001      0.001      0.176      0.860      -0.001       0.001
ma.L1                            0.2882      0.363      0.793      0.428      -0.424       1.000
sigma2                        8.159e-06   4.77e-06      1.709      0.087    -1.2e-06    1.75e-05
===================================================================================
Ljung-Box (L1) (Q):                   0.56   Jarque-Bera (JB):               1.18
Prob(Q):                              0.45   Prob(JB):                       0.56
Heteroskedasticity (H):               1.03   Skew:                           0.66
Prob(H) (two-sided):                  0.97   Kurtosis:                       3.01
===================================================================================
```
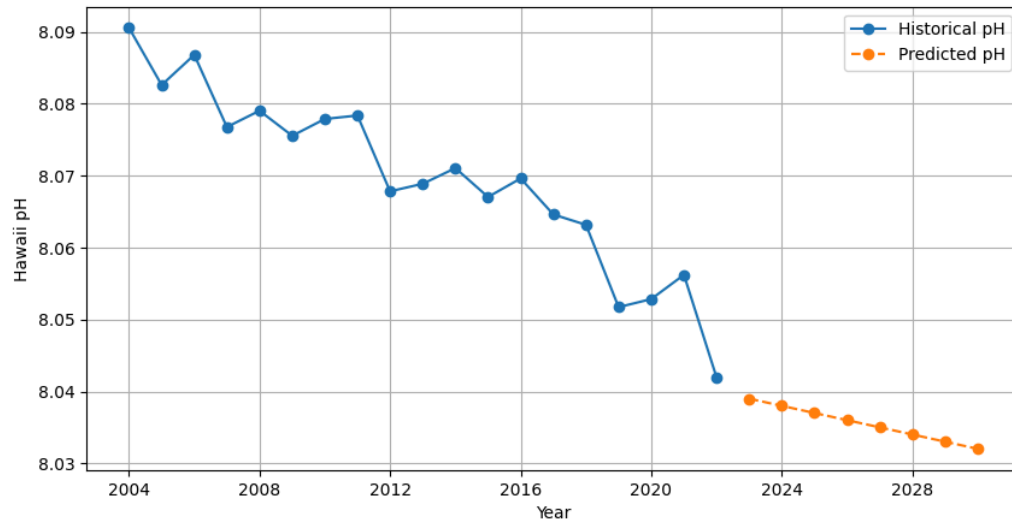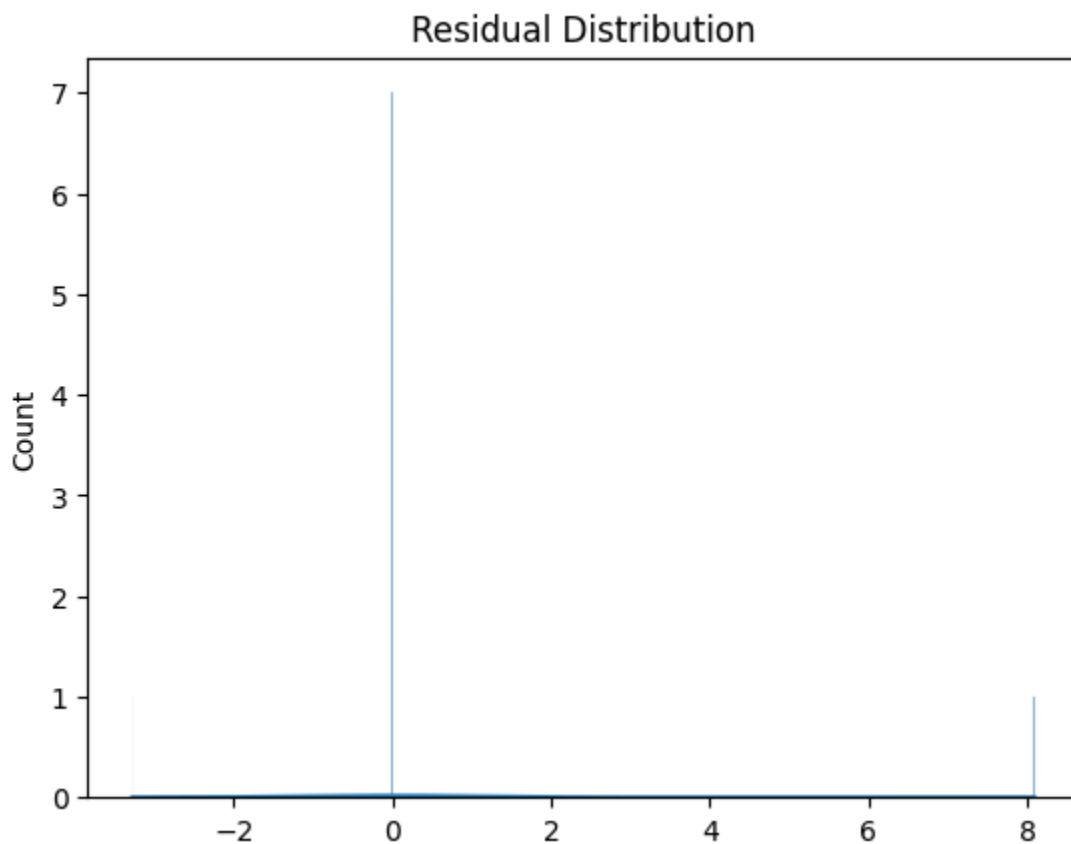
Hawaii pH Forecasting:



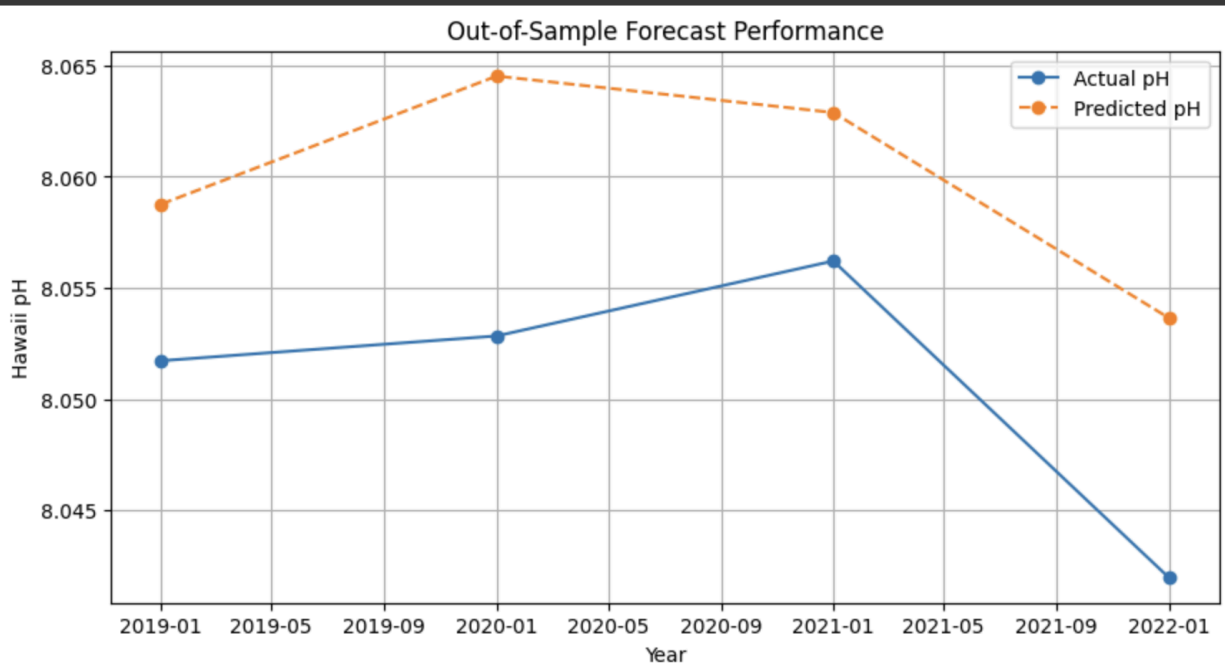pH Forecasting Statistical Analysis:



Shapiro–Wilk Test: Statistic=0.39925639232119103, p-value=7.219432236644757e-08
Residuals deviate from normality.

```
      lb_stat   lb_pvalue
10  2.622528    0.988967
Residuals are uncorrelated (Good).
```
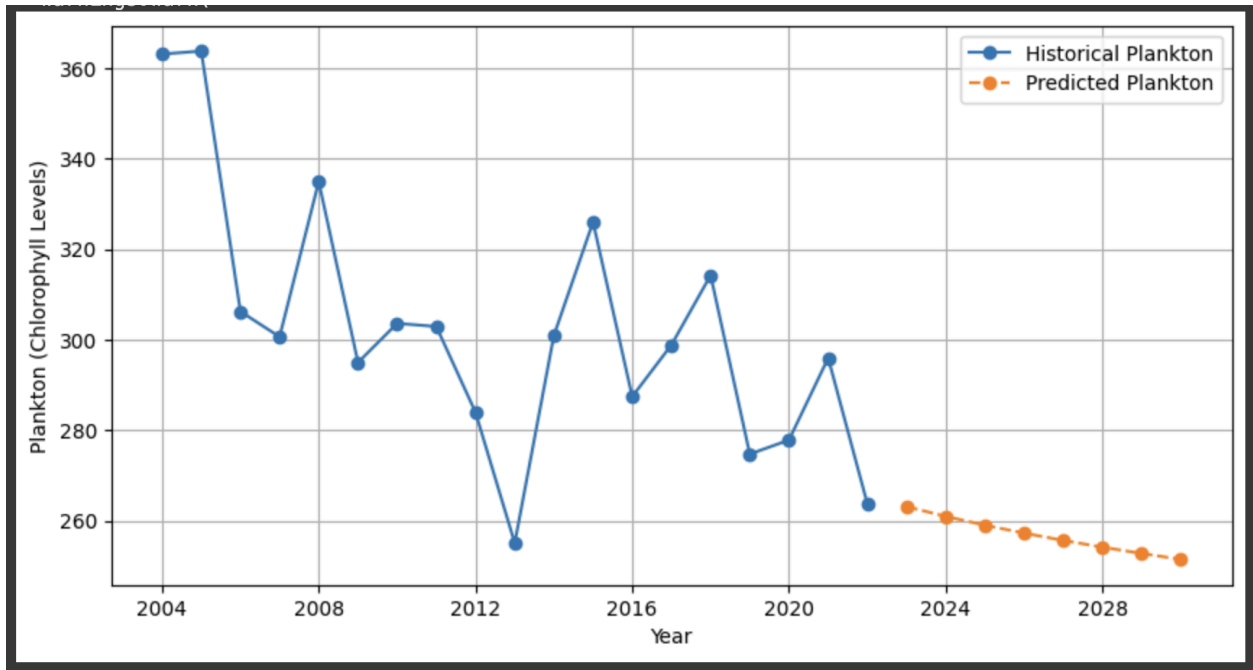
```
Mean Absolute Error (MAE): 0.6001
Mean Squared Error (MSE): 4.0088
Root Mean Squared Error (RMSE): 2.0022
R² Score: -26751.7749
```
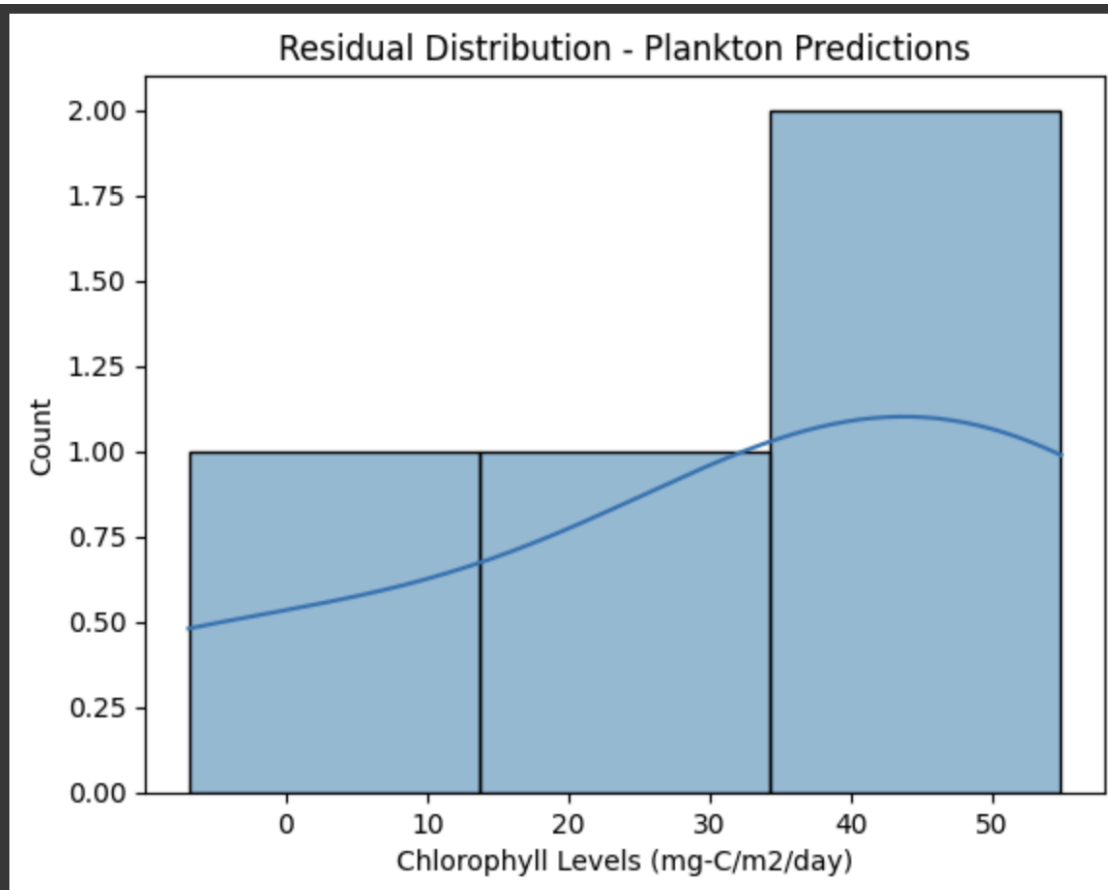
```
Test MAE: 0.0093
Test RMSE: 0.0096
Test R²: -2.2705
```

Out-of-Sample Forecast Performance

Plankton Forecasting:

MAE: 35.1534, RMSE: 39.5570

Plankton Forecast Statistical Testing:



**Residual Distribution - Plankton Predictions**

Shapiro–Wilk Test: Statistic=0.8926604626153445, p–value=0.3955246343131717
Residuals appear to be normally distributed (Good).

Mean Absolute Error (MAE): 35.1534
Mean Squared Error (MSE): 1564.7550
Root Mean Squared Error (RMSE): 39.5570
R² Score: −0.9055

Train MAE: 10.5874, Train RMSE: 15.5332
Test MAE: 35.1534, Test RMSE: 39.5570
Model may be overfitting. Consider regularization or adding more data.

AIC: 128.85756658617487
BIC: 130.2736669883793