January 18, 2022

I have been re-examining the “NFWF 1” clutching project from Apalachicola to try and learn how cultch material (lime rock, fossil shell, etc.), cultch density (amount of material per m2), and fishing (open/closed) affect oyster population dynamics on restored reefs in Apalachicola Bay.

Ryan Gandy with FWC provided a file “NFWF\_RAW\_UF\_COPY.xlsx” and I have been working with that file to analyze these data.

I read the data into program R working only with the tab of the datasheet that has the count data and then examined the names

> d1 <- read\_excel("NFWF\_RAW\_UF\_copy.xlsx", sheet=3)

I converted the -999 to NA throughout.

Because stations are sampled in different months, I converted the months to seasons following the same pattern I use for Lone Cabbage in Suwannee Sound. April through September is the “summer” period and October through March is the “winter” period. Because these data are from 2015-2019 the bay is open to fishing.

Here is a summary table of the data

Table 1: Summary of quadrat data from each year, month, station, and the sum of the number of quadrats in data file NFWF\_RAW\_UF\_copy.xlsx sheet 3

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| "Period" | "Year" | "Month" | "Station Name" | "Number Quadrats" |
| 2 | 2015 | 10 | "NFWF Bulkhead" | 75 |
| 2 | 2015 | 10 | "NFWF Dry Bar" | 74 |
| 2 | 2015 | 10 | "NFWF Hotel Bar" | 74 |
| 2 | 2016 | 1 | "NFWF Bulkhead" | 75 |
| 2 | 2016 | 2 | "NFWF Dry Bar" | 75 |
| 2 | 2016 | 2 | "NFWF Hotel Bar" | 75 |
| 3 | 2016 | 4 | "NFWF Bulkhead" | 75 |
| 3 | 2016 | 5 | "NFWF Dry Bar" | 75 |
| 3 | 2016 | 5 | "NFWF Hotel Bar" | 75 |
| 3 | 2016 | 7 | "NFWF Bulkhead" | 75 |
| 3 | 2016 | 7 | "NFWF Dry Bar" | 75 |
| 3 | 2016 | 8 | "NFWF Hotel Bar" | 75 |
| 4 | 2016 | 10 | "NFWF Bulkhead" | 75 |
| 4 | 2016 | 10 | "NFWF Dry Bar" | 75 |
| 4 | 2016 | 10 | "NFWF Hotel Bar" | 75 |
| 4 | 2017 | 1 | "NFWF Bulkhead" | 74 |
| 4 | 2017 | 1 | "NFWF Dry Bar" | 75 |
| 4 | 2017 | 1 | "NFWF Hotel Bar" | 74 |
| 4 | 2017 | 2 | "NFWF Bulkhead" | 1 |
| 4 | 2017 | 2 | "NFWF Hotel Bar" | 1 |
| 5 | 2017 | 4 | "NFWF Bulkhead" | 75 |
| 5 | 2017 | 4 | "NFWF Dry Bar" | 75 |
| 5 | 2017 | 4 | "NFWF Hotel Bar" | 75 |
| 5 | 2017 | 7 | "NFWF Bulkhead" | 75 |
| 5 | 2017 | 7 | "NFWF Hotel Bar" | 75 |
| 5 | 2017 | 8 | "NFWF Dry Bar" | 75 |
| 6 | 2017 | 10 | "NFWF Bulkhead" | 75 |
| 6 | 2017 | 10 | "NFWF Hotel Bar" | 75 |
| 6 | 2017 | 11 | "NFWF Dry Bar" | 75 |
| 6 | 2018 | 1 | "NFWF Bulkhead" | 75 |
| 6 | 2018 | 2 | "NFWF Dry Bar" | 75 |
| 6 | 2018 | 2 | "NFWF Hotel Bar" | 75 |
| 7 | 2018 | 4 | "NFWF Dry Bar" | 75 |
| 7 | 2018 | 4 | "NFWF Hotel Bar" | 75 |
| 7 | 2018 | 5 | "NFWF Bulkhead" | 75 |
| 7 | 2018 | 7 | "NFWF Bulkhead" | 75 |
| 7 | 2018 | 7 | "NFWF Hotel Bar" | 75 |
| 7 | 2018 | 8 | "NFWF Dry Bar" | 75 |
| 8 | 2018 | 11 | "NFWF Dry Bar" | 75 |
| 8 | 2018 | 11 | "NFWF Hotel Bar" | 75 |
| 8 | 2018 | 12 | "NFWF Bulkhead" | 75 |
| 8 | 2019 | 1 | "NFWF Bulkhead" | 75 |
| 8 | 2019 | 1 | "NFWF Dry Bar" | 75 |
| 8 | 2019 | 1 | "NFWF Hotel Bar" | 75 |
| 9 | 2019 | 4 | "NFWF Dry Bar" | 75 |
| 9 | 2019 | 4 | "NFWF Hotel Bar" | 75 |
| 9 | 2019 | 5 | "NFWF Bulkhead" | 75 |
| 9 | 2019 | 8 | "NFWF Hotel Bar" | 75 |
| 9 | 2019 | 9 | "NFWF Bulkhead" | 75 |
| 9 | 2019 | 9 | "NFWF Dry Bar" | 75 |

I then made summary plots of the data. First, I plotted cultch on the x axis and live spat on the y axis. I used different colors for Station Names

Chart, scatter chart

Description automatically generated

*Figure 1. Fossil shell cultch (x axis) treatments and live oyster spat (y axis) at each Station (colored dots) in Apalachicola Bay for all years combined. The gold dot represents the mean live oyster for each cultch density.*

This plot suggests that as the amount of cultch increases the number of live oysters increases and this pattern seems to hold for all the Stations. Let’s see if this pattern holds over years.

Chart

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*Figure 2. Fossil shell cultch (x axis) treatments and live oyster spat (y axis) at each Station (colored dots) in Apalachicola Bay with each year plotted as a different panel. The gold dot represents the mean live oyster for each cultch density.*

This graph suggests that there was an increase in the number of live spat at each station in the first year 2015, but that this declined by the end of the study in 2019. We will now take a closer look at these count data by season, year, and station.

Table 2. Summary stats of live spat counts from Hotel Bar in period 2.

|  |  |
| --- | --- |
| "Mean" | 623.55 |
| "Median" | 173 |
| "SD" | 1118.85 |
| "Var" | 1251830.61 |
| "CV" | 1.79 |
| "SE" | 91.66 |
| "L95SE" | 443.9 |
| "U95SE" | 803.2 |
| "BSMEAN" | 626.06 |
| "L95BS.2.5%" | 452.9 |
| "U95BS.97.5%" | 810.97 |

Table 3. Summary stats of live spat counts from Hotel Bar in period 9.

|  |  |
| --- | --- |
| "Mean" | 1.41 |
| "Median" | 0 |
| "SD" | 2.62 |
| "Var" | 6.86 |
| "CV" | 1.86 |
| "SE" | 0.21 |
| "L95SE" | 0.99 |
| "U95SE" | 1.83 |
| "BSMEAN" | 1.4 |
| "L95BS.2.5%" | 1 |
| "U95BS.97.5%" | 1.88 |

Table 2 and Table 3 support observations from Figure 2 of large changes over time in live oyster spat counts.

I then plotted the “total weight” (y axis) data provided by FWC and made a plot of total weight by period for each Station (panel of graph) and period (x axis).

Chart

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*Figure 3. The total weight (y-axis) of material (live and dead cultch I am assuming) from each quadrat by period for each Station (panel of the graph) and period (x-axis). The red dot is the mean value.*

Figure 3 suggests the amount of material (weight) declined over time.

If we go back and look at counts of live spat by period and station you can see that most of the declines in live oysters happened between period 2 (winter 2015/2016) and 3 (summer 2016).

A picture containing calendar

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*Figure 4*

I then fit seven different GLM models to these data assuming the data followed a negative binomial distribution. Because the variance of live oyster counts is much higher than the mean in all periods negative binomial is a good assumption. Models compared were

m1 <- glm.nb(LiveSpat ~ Period + offset(log(Num\_quads)), data = d5)

m2 <- glm.nb(LiveSpat ~ Period + StationName + offset(log(Num\_quads)),

data = d5)

m3 <- glm.nb(LiveSpat ~ Period \* StationName + offset(log(Num\_quads)),

data = d5)

m4 <- glm.nb(LiveSpat ~ Cultch + offset(log(Num\_quads)), data = d5)

m5 <- glm.nb(LiveSpat ~ Cultch + Period + offset(log(Num\_quads)), data = d5)

m6 <- glm.nb(LiveSpat ~ Cultch + Period + StationName +

offset(log(Num\_quads)), data = d5)

m7 <- glm.nb(LiveSpat ~ Cultch + Period + StationName + season +

offset(log(Num\_quads)), data = d5)

m8 <- glm.nb(LiveSpat ~ Drills + offset(log(Num\_quads)), data = d5)

m9 <- glm.nb(LiveSpat ~ Cultch + Period + StationName + season + Drills +

offset(log(Num\_quads)), data = d5)

and each model includes the number of quadrats as an offset to account for the differences in quadrats collected in each period. I am predicting the counts (not density) while controlling for the amount of effort (number of quadrats). We then assess how Period, Cultch density, Station, Season and the mean number of Drills influence these counts. The best-fit model from an AIC perspective was m9 (cultch+period+station+season+drills)which was about 118 AIC units lower than model 8 (drills).

Model selection based on AIC:

K AIC Delta\_AIC AICWt Cum.Wt LL

cultch+period+station+season+drills 8 1024.84 0.00 1 1 -504.42

drills 3 1142.75 117.92 0 1 -568.38

cultch+period+station+season 7 1855.38 830.54 0 1 -920.69

cultch+period+station 6 1883.05 858.21 0 1 -935.52

period \* station 7 1926.83 902.00 0 1 -956.42

period + station 5 1927.52 902.68 0 1 -958.76

cultch + period 4 1934.68 909.85 0 1 -963.34

period 3 1973.16 948.33 0 1 -983.58

cultch 3 2021.93 997.09 0 1 -1007.97

but when you look at the results of m9

> summary(m9)

Call:

glm.nb(formula = LiveSpat ~ Cultch + Period + StationName + season +

Drills + offset(log(Num\_quads)), data = d5, init.theta = 1.451595305,

link = log)

Deviance Residuals:

Min 1Q Median 3Q Max

-2.7676 -0.9507 -0.1901 0.4075 2.4459

Coefficients:

Estimate Std. Error z value Pr(>|z|)

(Intercept) 6.5325682 0.5894382 11.083 < 2e-16 \*\*\*

Cultch 0.0053369 0.0007606 7.017 2.27e-12 \*\*\*

Period -0.6578224 0.0797664 -8.247 < 2e-16 \*\*\*

StationNameNFWF Dry Bar -2.6292104 0.2680035 -9.810 < 2e-16 \*\*\*

StationNameNFWF Hotel Bar -0.8723838 0.2526959 -3.452 0.000556 \*\*\*

seasonWinter 0.9307573 0.1973669 4.716 2.41e-06 \*\*\*

Drills 0.1221744 0.0951477 1.284 0.199124

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Negative Binomial(1.4516) family taken to be 1)

Null deviance: 356.921 on 74 degrees of freedom

Residual deviance: 83.653 on 68 degrees of freedom

(45 observations deleted due to missingness)

AIC: 1024.8

Number of Fisher Scoring iterations: 1

Theta: 1.452

Std. Err.: 0.222

2 x log-likelihood: -1008.836

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You see that Drills is not significant. Cultch, Period, Station and Season were all significant factors in the model. Cultch had a positive relationship with the number of live spat and for every unit (cubic yard) increase in cultch there was a 0.005 increase in the number of live spat. In simpler terms for every 100 cubic yards of fossil shell, there was an increase of about 0.5 live spat. Period of time had a negative relationship with the number of live spat and for each period of time, the number of live spat declined on average by about 0.66. When Station is examined these are mean effects which are reported as differences from the baseline factor (ordered alphabetically, so Bulkhead is first). Dry Bar was lower by about 2.15 live oyster spat per cubic yard shell and Hotel Bar by about 2.64 live oyster spat per cubic yard of shell (2.15+0.49 = 2.64) Higher live oyster spat were observed on average in winter (about 1.07) than in summer.

If you examine the results of the same model but without mean number of Drills (m7), the overall results are similar

> summary(m7)

Call:

glm.nb(formula = LiveSpat ~ Cultch + Period + StationName + season +

offset(log(Num\_quads)), data = d5, init.theta = 1.17729948,

link = log)

Deviance Residuals:

Min 1Q Median 3Q Max

-2.5887 -1.0438 -0.3363 0.3793 1.7829

Coefficients:

Estimate Std. Error z value Pr(>|z|)

(Intercept) 5.5618182 0.3062631 18.160 < 2e-16 \*\*\*

Cultch 0.0060525 0.0005979 10.123 < 2e-16 \*\*\*

Period -0.5726926 0.0378345 -15.137 < 2e-16 \*\*\*

StationNameNFWF Dry Bar -2.1512225 0.2071858 -10.383 < 2e-16 \*\*\*

StationNameNFWF Hotel Bar -0.4924178 0.2064003 -2.386 0.017 \*

seasonWinter 1.0676521 0.1729641 6.173 6.71e-10 \*\*\*

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Signif. codes: 0 ‘\*\*\*’ 0.001 ‘\*\*’ 0.01 ‘\*’ 0.05 ‘.’ 0.1 ‘ ’ 1

(Dispersion parameter for Negative Binomial(1.1773) family taken to be 1)

Null deviance: 526.44 on 119 degrees of freedom

Residual deviance: 135.65 on 114 degrees of freedom

AIC: 1855.4

Number of Fisher Scoring iterations: 1

Theta: 1.177

Std. Err.: 0.138

2 x log-likelihood: -1841.375

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I then used the parameters from m7 and predicted the number of live oyster spat in winter and summer for period 9

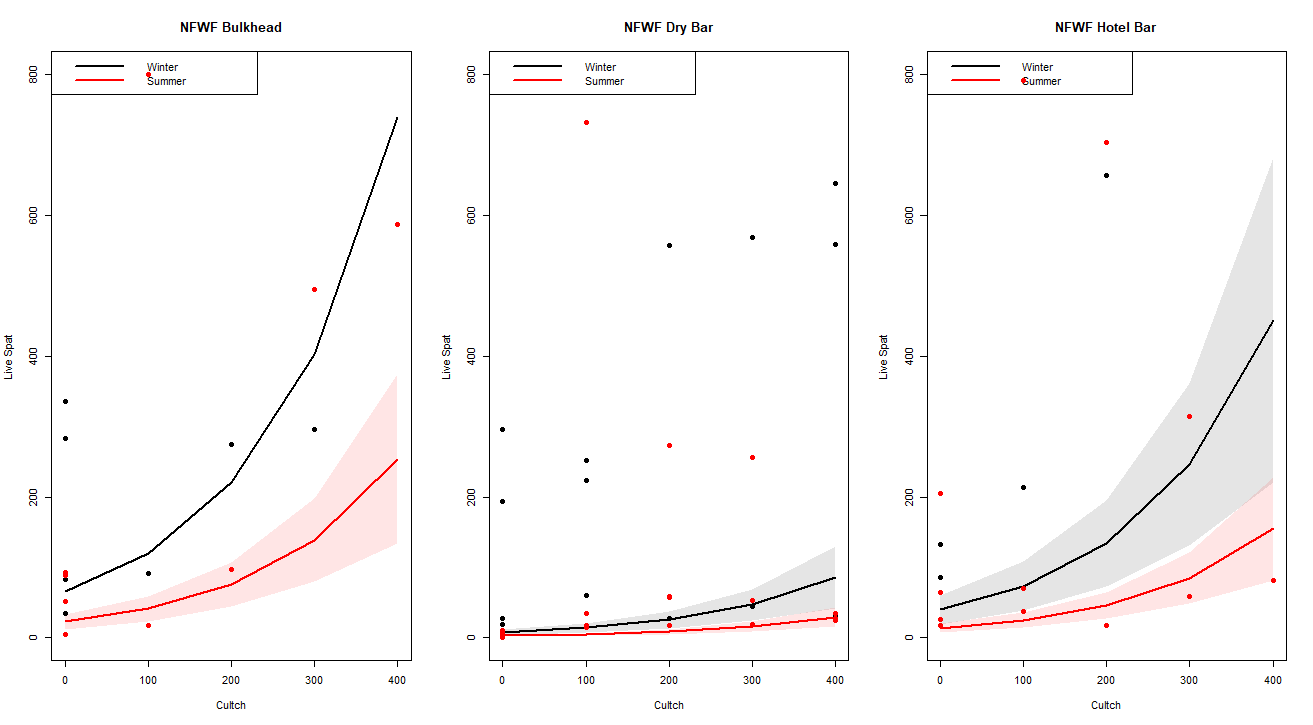


Figure 5. Predicted live oyster spat (y-axis) at each Station (panels) for winter (black line) and summer (red line) at different cultch densities (x-axis). Black dots are observed data for winter and red dots are observed data for summer. Shaded area is the 95% confidence limits on the predicted values.

What this plot highlights is that the model is not very good at predicting the number of live spat. While m9 is the best fitting model from an AIC perspective and models m9 and m7 have similar parameters, neither are very good models. This is likely because the number of live oysters is so low at each location and at each clutching density after period 2.

I then went back and included the Total Weight of cultch material in each sample in these same models. Total Weight was significant, but, for every 100 units of total weight there was only an increase of about 0.2 live oyster spat.