Striped Bass in the San Joaquin River Restoration Area: Population and Bioenergetics Modeling

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Purpose

Use mark/recapture data from Striped Bass caught in the Restoration Area to model predation impacts on emigrating juvenile salmon.

Methods

Striped Bass Captures and Recaptures

Striped Bass captured between 2019 -2021 in Reaches 4b and 5 of the Restoration Area during of SJRRP's Central Valley Steelhead Monitoring and Adult Spring-Run Chinook Salmon Monitoring, Trap and Haul Programs.[1,2]

Measured Total Length (TL) and scanned for a Passive Integrated Transponder (PIT) tag. If undetected, a new tag was implanted.

Striped Bass Population Model

Created individual capture histories to test POPAN models in Program Mark (Rmark) designed for open populations and based on the Jolly-Seber method using the link function mlogit.

Tested 3 combinations of estimated parameters (Fixed vs. Variable):

ϕ - probability of surviving between occasions i and i+1

p - probability of capture at occasion i

pent - probability that an animal from the super-population (N) would enter the population between occasions i and i + 1 and survive to the next sampling occasion i + 1 (birth & immigration)

Selected top model by lowest small-sample corrected Akaike information criterion (AICc), difference between the lowest AICc to other models (ΔAICc) and AICc weight[3,4].

Striped Bass Bioenergetics Model

Three age classes defined by TL in millimeters (mm) [5]:
Age-1 (150-300 mm), Age-2 (300-400 mm), and Adult (> 400mm).

Ran simulations by each age class, month and test variable (water temperature or diet).

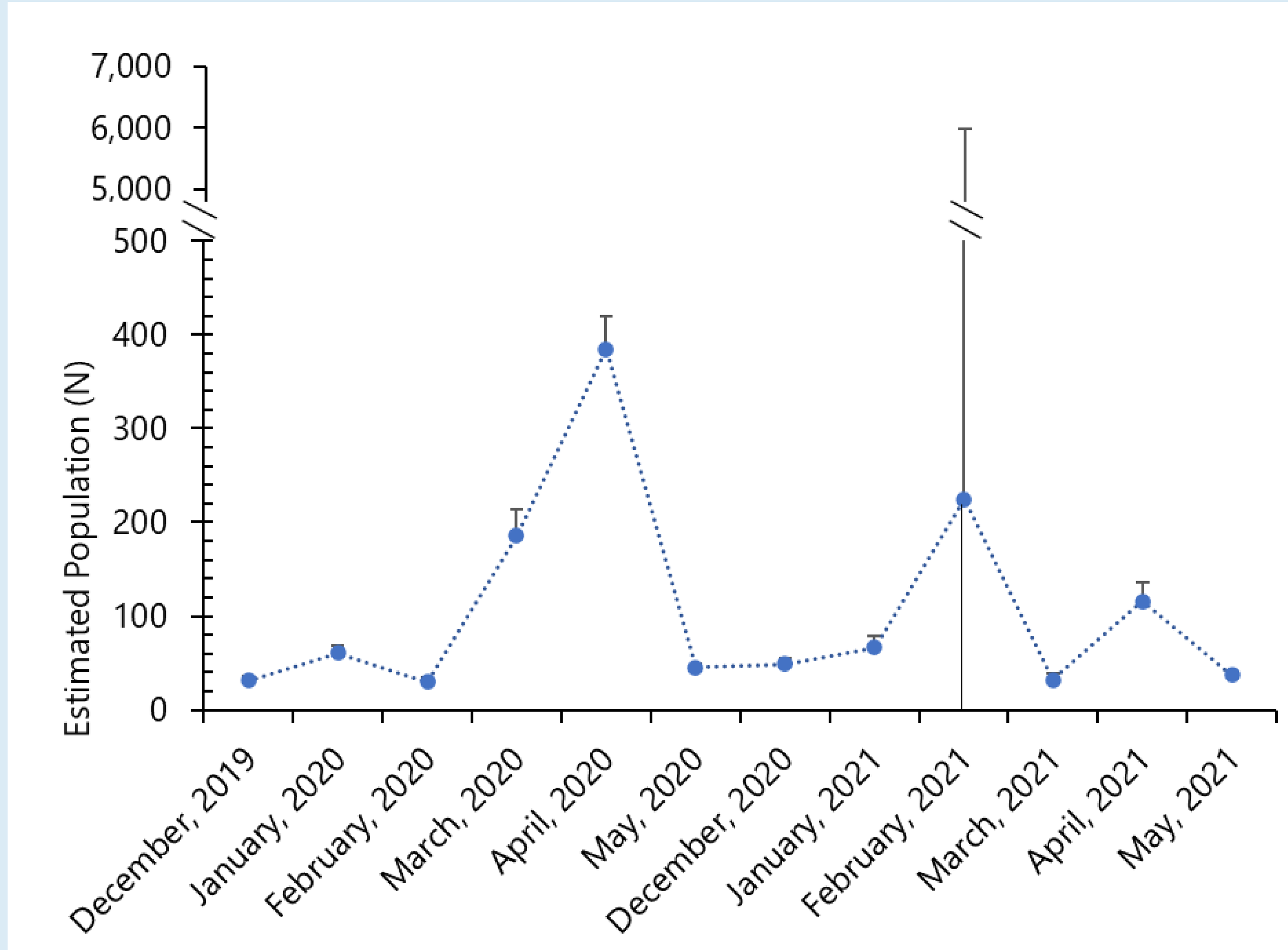
Parameters for simulations run in Fish Bioenergetics 4.0[6]:

Initial Settings	Species	Striped Bass *(by Age Class)*
Initial Settings	Fit to	P-value (proportion of Cmax) *Varied by average monthly water temperature*[7]
Initial Settings	Initial weight (monthly)	Derived from measured length and published length-weight relationships[8]
Initial Settings	Oxycalorific coefficient	13,560 Joules Per Gram (J/g) O2[9]
Input Files	Temperature	Average monthly 2021 San Joaquin River data from California Data Exchange Center Newman (SMN) gauging station *Simulations added 1 or 2 degrees Celsius*
Input Files	Prey Energy Density	4800 J/g[10]
Input Files	Prey Proportions (Diet_prop)	10%[11], 50%, and 80%[11] *10% Used for temperature simulations*
Input Files	Predator Energy Density (Pred_E)	5660 J/g, 6860 J/g, and 7681 J/g[9] *Increased with Age Class*

Output combined with POPAN results averaged by month to estimate total consumption in grams (g) per month.

Individual fish consumed (N) was estimated using length-at-date regressions and raw data collected during the SJRRP's juvenile salmon rotary screw trap efforts in the upper reaches of the Restoration Area[12].

Results



Striped Bass super-population estimates (N) and standard errors for each sampling month/year. Estimates are total abundance of Striped Bass that both inhabit and "visit/migrate" into the sampling area during the sampling period. Maximum estimated population occurred in April 2020 (N = 384.5; SE ± 36.0) and smallest in February 2020 (N = 29.9; SE ± 4.7).

373 Striped Bass were captured (December 2019 – May 2021) with a recapture rate of 6 percent (n = 21).

The top POPAN model allowed ϕ to vary by the additive effects of month and year, pent to vary by day, and p to remain fixed.

ϕ (~Month + Year) p(~1) pent(~time) N(~1)

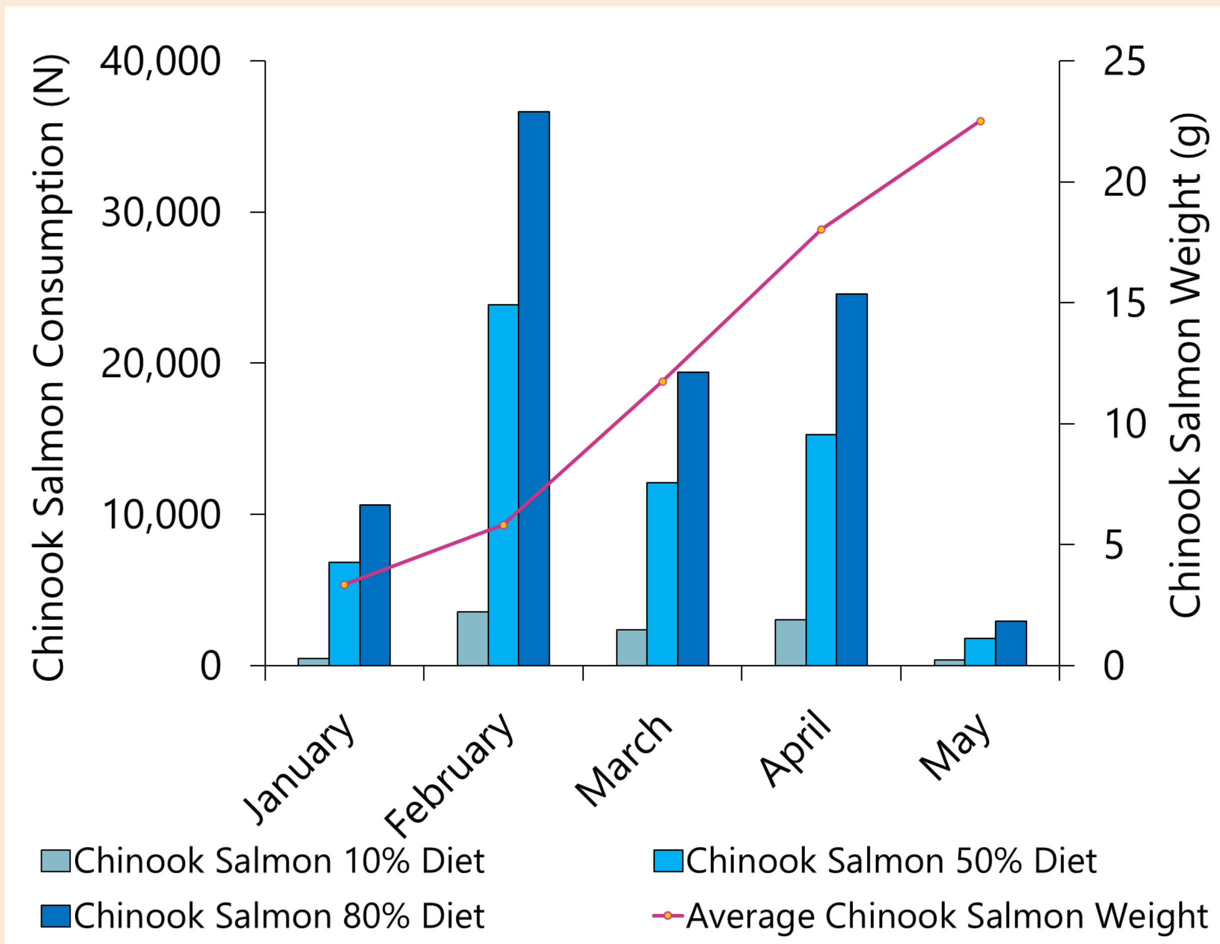
	Water Temperature[A]		
	6 to 10°C	11 to 30°C	> 30°C
p Value: Striped Bass Age-1	0.26	0.98	0.85
p Value: Striped Bass Age-2	0.26	0.98	0.90
p Value: Striped Bass Age-3+	0.32	0.98	0.85

[A] Average water temperature of month and age-class determines which p-value to use in bioenergetics model. Adapted from temperature studies on Striped Bass.[7]

	January	February	March	April	May
Striped Bass Age-1 Weight (g)[B]	109.1	86.9	141.6	109.4	225.8
Striped Bass Age-2 Weight (g)	491.3	596.9	582.6	571.9	529.4
Striped Bass Age-3+ Weight (g)	1,661.4	1,510.6	1,919.4	1,417.6	1,435.4
Chinook Salmon Weight (g)[C]	3.4	5.8	11.8	18.0	22.5
San Joaquin River Temp. 2021 (°C)[D]	9.5	12.1	13.2	18.5	20.8

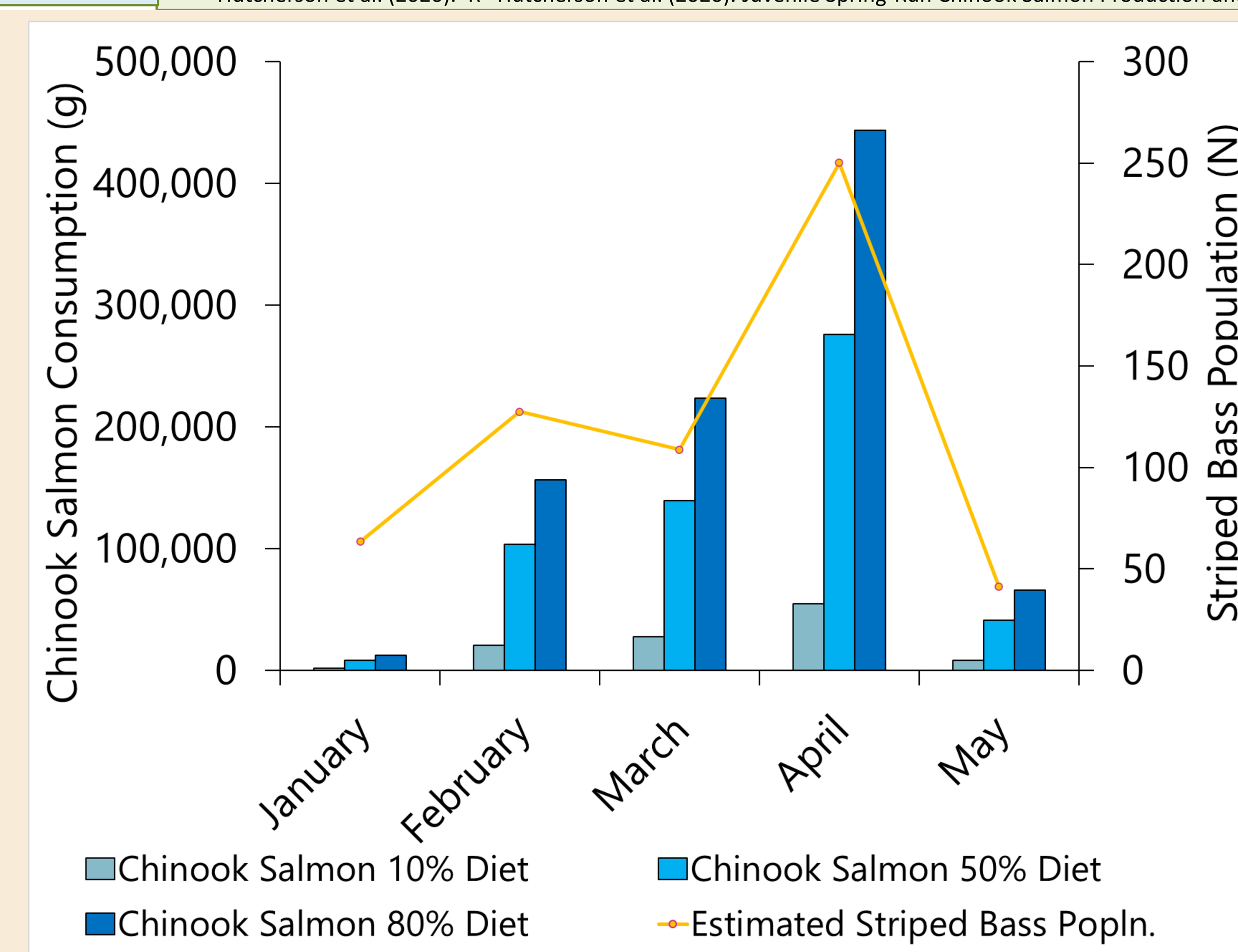
[B] Striped Bass weights calculated from measured length during SJRRP monitoring 2018-2021[8]
[C] Chinook Salmon weights measured in RST operations between 2017 and 2022[12]
[D] Average temperature measured in San Joaquin River at SMN gauging station.

[1]Root & Sutphin. (2021). San Joaquin River Steelhead Monitoring Plan 2020-2021. SJRRP.
[2]Sutphin & Root. (2021). Adult Spring-Run Chinook Salmon Monitoring and Trap and Haul in the San Joaquin River: 2020 Monitoring and Analysis Report. SJRRP.
[3]Cooch & White. (2020). Program MARK: a Gentle Introduction. CSU, Fort Collins, Colorado, USA.
[4]Burnham & Anderson. (2002). Model Selection & Multi-Model Inference (2nd Edition). 496 p.
[5]Mansueti. (1961). Age, growth, and movements of the striped bass, Roccus saxatilis, taken in size selective fishing gear in Maryland. *Chesapeake Science*, 2, 9-36.
[6]Deslauriers, et al. (2017). Fish bioenergetics 4.0: An R-based modeling application. *Fisheries*, 42, 586-596.
[7]Hartman & Brandt. (1995). Comparative energetics and the development of bioenergetics models for sympatric estuarine piscivores. Can. J. Fish. Aquat. Sci. 52, 1647-1666.
[8]Nobriga & Branch. (2009). Bioenergetics modeling evidence for a context-dependent role of food limitation in California's Sacramento-San Joaquin Delta. *CFG*, 95(3), 111-121.
[9]Loboschefsky, et al. (2012). Individual-level and population-level historical prey demand of San Francisco Estuary Striped Bass using a bioenergetics model. *SFEWS*, 10(1).
[10]Adrean. (2011). Caspian Tern (Hydroprogne caspia) foraging ecology and predation on juvenile salmonids in San Francisco Bay, Ca. MSc Thesis. Oregon State University.
[11]Sabal, et al. (2016). Habitat alterations and a nonnative predator, the striped bass, increase native chinook salmon mortality in the Central Valley, Ca A. *N. Am. J. Fish. Manag.* 36(2), 309-320.
[12]Hutcherson and Sutphin. (2023). Length-at-date for juvenile Chinook Salmon (*Oncorhynchus tshawytscha*) in the San Joaquin River Restoration Program Area: Rotary screw trap sampling in San Joaquin River, 2017–2020. USBR. TSC.
[13]Hutcherson et al. (2020). R[12]Hutcherson et al. (2020). Juvenile Spring-Run Chinook Salmon Production and Emigration in the San Joaquin River Restoration Area: 2018-19 Monitoring and Analysis. SJRRP.



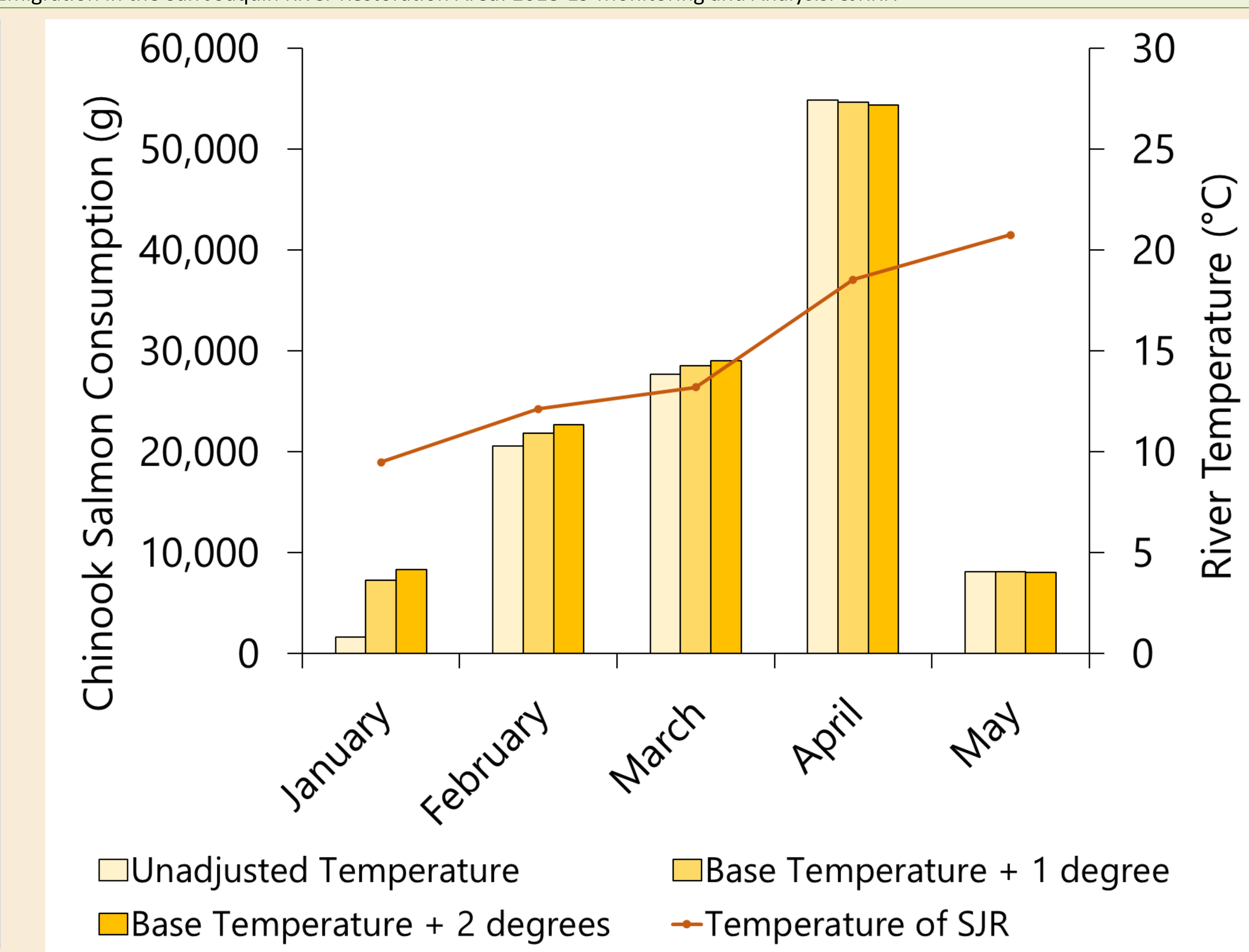
Simulated Chinook Salmon consumption (#individuals; N) by Striped Bass over 3 different percentages of Striped Bass Diet.

Total consumption increased proportionally with change in percent of Chinook Salmon in the diet from 10 percent (N_{Total} = 9,789) to 80 percent (N_{Total} = 94,159).



Simulated Chinook Salmon biomass consumption (g) by Striped Bass over 3 different percentages of Striped Bass Diet.

Biomass consumption was highest during March and April when populations of Striped Bass are also estimated to peak.



Simulated Chinook Salmon biomass consumption (g) over 3 different San Joaquin River temperatures regimes (measured temp. with no adjustment, adding 1 degree Celsius and adding 2 degrees Celsius).

Discussion

Striped Bass in the Restoration Area have the potential to consume large amounts of juvenile salmon during their emigration. Understanding the dynamics of the Striped Bass population and estimated Chinook Salmon consumption can help identify the most effective timing and locations for management actions, such as predator removals or juvenile salmon releases. The POPAN model suggests that the population of Striped Bass in Reaches 4b and 5 of the Restoration Area is highest between March and April, which overlaps with juvenile salmon smolt emigration.[13] While highest consumption of individual salmon was estimated during February, when salmon are smaller and less developed, large numbers of juvenile salmon are less likely to be in the lower reaches at that time[12]. Changes in Striped Bass diet composition results in proportional increases with Salmon biomass consumption. Simulated temperature increases between March and April did not significantly affect consumption, indicating Striped Bass may have reached their optimal feeding temperature. Only a large reduction in temperature (i.e. to less than 10°C) could reduce metabolic optimization and, potentially, predation on Chinook Salmon.

Results of these simplistic models should be interpreted cautiously; they are based on a small dataset across a short time frame and do not account for prey availability. More data are needed on the feeding frequency and diet composition of Striped Bass within the San Joaquin River, as well as the impacts of other predators within the system. Non-lethal stomach content sampling of captured fish (i.e., gastric lavage) and subsequent DNA and/or physical analysis would help answer these questions (particularly useful if individuals are recaptured) and identify any temporal or size-dependent effects on diet composition. Striped Bass have shown variability in behavior and diet[11] and the more data from within the Restoration Area, the more accurately models can aid management decisions.