Where Predators and Prey Meet: Anthropogenic Contact Points Between Fishes in a Freshwater Estuary

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Introduction

The Sacramento–San Joaquin Delta has been invaded by several species of non-native predatory fish that are presumed to be impeding native fish population recovery efforts. Since eradication of predators is unlikely, there is substantial interest in removing or altering manmade structures in the Delta that may exacerbate predation on native fish (contact points). It is presumed that these physical structures influence predator-prey dynamics, but how habitat features influence species interactions is poorly understood, and physical structures in the Delta that could be remediated to benefit native fish have not been inventoried completely.

Objectives

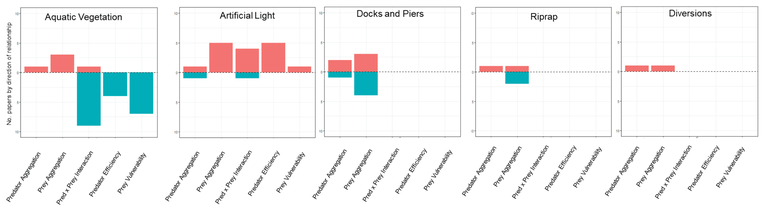
Objective 1 – conduct literature review that focused on determining the effects of predator-prey interactions between fish, based on contact points that are commonly found in the Delta

Objective 2 – performed a geospatial analysis to determine the extent of potential contact points in the Delta

Objective 3 – perform experimental field studies to quantify the effect of contact points on predator-prey interactions in the Delta

Literature Review

Lehman, B. M., Gary, M. P., Demetras, N., & Michel, C. J. (2019). Where Predators and Prey Meet: Anthropogenic Contact Points Between Fishes in a Freshwater Estuary. *San Francisco Estuary and Watershed Science*, *17*(4). https://doi.org/10.15447/sfews.2019v17iss4art4



The number of peer-reviewed articles summarized by direction of the relationship between submerged contact points and five different biotic functions: predator aggregations, prey aggregations, frequency of predator and prey interactions, predator hunting efficiency, and prey vulnerability. Only studies that found significant results were included in the analysis.

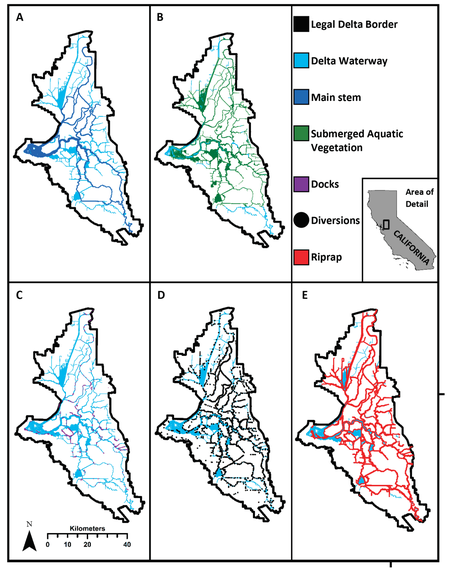
Contact point	Predator aggregation	Prey aggregation	Predator–Prey interaction	Predator efficiency	Prey vulnerability
Submerged aquatic vegetation	S[4] Q[14] P[5]	S[4,8,36] Q[27] P[5]	S[3,4,8,12,17,18,38,39,40,47] Q[9] P[5]	S[3,17,39,40] P[5,12,15,18,38,41]	S[3,10,17,36,39,40] P[5,12,15,18,38,41]
Artificial light	S[1,7]	S[1,7,11,43,45] P[32]	S[1,11,28,29,34,43] P[23,32]	S[11,20,28,29,49] P[7,32]	S[11] P[7,29,32,35]
Docks and piers	S[1,6,19]	S[1,6,19,30,31,33,42]	P[1,6,19,30]	P[6,19,24,30]	P[6,19,24,30,33]
Riprap	S[46] P[26,44]	S[44,46,48]	P[22,26,46]	P[21,26,44]	P[21,26]
Scour holes	P[2,25]	P[2,25]	P[2,25]	P[25]	
Diversions	S[37] Q[13] P[16]	S[16]	P[37] P[16]	P[16]	P[16]

a. Sources:

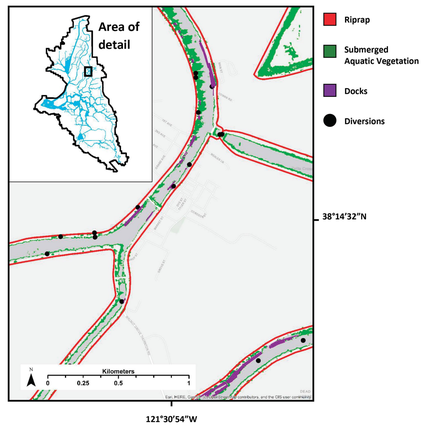
1 Able et al. (2013)
2 Allouche (2002)
3 Anderson (1984)
4 Annett (1998)
5 Baras and Nindaba (1999)
6 Barwick et al. (2004)
7 Becker et al. (2013)
8 Bettoli et al. (1992)
9 Buckel and Stoner (2000)
10 Camp et al. (2012)
11 Cerri (1983)
12 Chacin and Stallings (2016)
13 de Mutsert and Cowan (2012)
14 de Mutsert et al. (2017)
15 Ferrari et al. (2014)
16 Floyd et al. (2007)
17 Gotceitas and Colgan (1987)
18 Gregory (1996)
19 Grothues et al. (2016)
20 Hansen et al. (2013)
21 Heerhartz and Toft (2015)
22 Jorgensen et al. (2013)
23 Kehayias et al. (2018)
24 Kemp et al. (2005)
25 Kinzli and Myrick (2010)
26 Kornis et al. (2017)
27 Lazzari (2013)
28 Mazur and Beauchamp (2003)
29 Mazur and Beauchamp (2006)
30 Moore et al. (2013)
31 Munsch et al. (2017)
32 Nightingale et al. (2006)
33 Ono and SimenstadSchool (2014)
34 Petersen and Gadomski (1994)
35 Riley et al. (2015)
36 Rozas and Odum (1988)
37 Sabal et al. (2016)
38 Sammons and Maceina (2006)
39 Savino and Stein (1982)
40 Savino and Stein (1989)
41 Shoup et al. (2003)
42 Southard et al. (2006)
43 Tabor (2001); Tabor et al. (2004)
44 Tabor (2011)
45 Tabor et al. (2017)
46 Tiffan et al. (2016)
47 Tsunoda and Mitsuo (2018)
48 Venter et al. (2008)
49 Vogel and Beauchamp (1999)

Predator–prey behavior and interaction by contact point type. Effect is ranked as S – significant relationship based on statistical test, NS – non-significant relationship based on statistical test, Q – relationship described quantitatively or qualitatively using actual measurements, but not tested for statistical significance, P – the authors presumed a relationship based on ancillary data, but no appropriate data or statistical test was provided. Studies including salmonids as prey in *red*.

GIS Analysis of Contact Points in the Delta



Maps of known contact points within the legal Sacramento–San Joaquin Delta. Map **A** depicts the waterways and mainstem waterways within the Delta. Map **B** shows submerged aquatic vegetation (SAV) distribution. Map **C** displays visible docks and floating houses, and map **D** shows the diversions throughout the Delta. Map **E** displays riprap throughout the Delta.



Close-up depicting the different types of potential contact points within the Sacramento–San Joaquin Delta: riprap, submerged aquatic vegetation (SAV), docks, and diversions

Estimating predator-prey interactions *in-situ*

Quantifying Relative Predation Rates

Deployed Predation Event Recorders which are drifting or anchored buoys with a live hatchery Chinook salmon smolt attached as bait. Allows us to sample channel and bank habitat and estimate relative predation rates. In Spring 2019:

- 1518 deployments
- At 11 unique reaches throughout the Central Delta.
- Starting April 22nd until June 6th

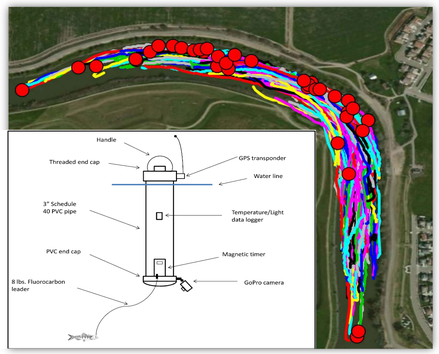
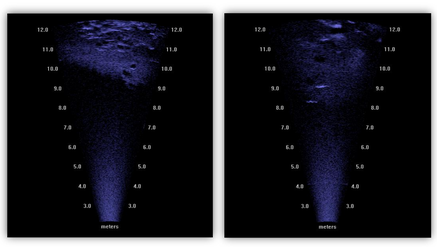


Diagram of a Predation Event Recorder with tethered Chinook smolt (bottom left) Individual PER tracks deployed in a study reach. Each colored line is a separate deployment. Red dots indicate locations of predation events.

Predator Density Estimates

- We used two ARIS sonar cameras to quantify fish predator density around contact points of interest.



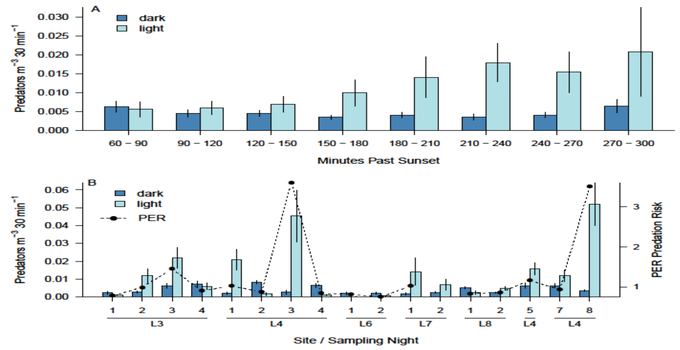
Raw ARIS images. A school of striped bass (left) and a large predator (right)

Results from First Field Season

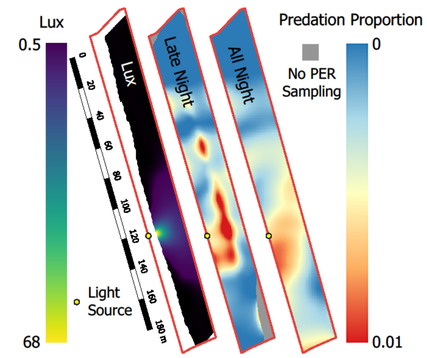
From: Nelson, T.R., & Michel, C. J., Gary, M. P., Lehman, B. M., Demetras, N., Hammen, J.J., Horn, M.J. (2020, in-review). Effects of artificial lighting at night (ALAN) on predator density and salmonid predation.

Our Spring 2019 field study focused on the effect of artificial nighttime illumination on predator-prey interactions

- We installed LED lights on the riverbank at six sites throughout the Central Delta
- Collected ARIS and PER data across multiple nights/weeks with lights on/off
- Conducted nightly light surveys
- Quantified other habitat and environmental characteristics to include in model selection



(A) The density of predator-sized fish aggregating in the illuminated (light blue) and non-illuminated portion of the study reach averaged across the season, as measured using ARIS sonar footage
(B) The density of predator-sized fish for each night of sampling in the illuminated and non-illuminated areas across the study season. Predator risk (as measured using PERs) is plotted with black dots.



- Interpolated light (lux) values for one field site on one sampling night.
- Predation proportion rasters for late night (>180 minutes past sunset) and all night datasets.
- We produced predation proportion rasters by generating kernel densities of all predation event recorder (PER) predation events and dividing these by kernel density of all PER GPS locations

Discussion

- Anthropogenic 'contact points' of predation are widespread throughout the Delta
- Our literature review indicated that artificial illumination and submerged aquatic vegetation are the most well-studied contact points. Given their prevalence throughout the Delta, they likely affect the landscape of interaction between migrating/rearing juvenile salmonids and predatory fish
- Our Spring 2019 field study revealed that areas that artificial illumination increases the density of aggregating large fish and that intense, focused lighting increases predation activity late at night
- Future field efforts will expand our understanding of the effects of multiple different contact points on predator-prey interactions in the Delta

- Fall 2020 we will be conducting similar surveys related to artificial lighting on the Sundial Bridge in Redding, CA
- Spring 2021 we will conduct wide-scale PER surveys across the Delta to further understanding of nighttime illumination, SAV and other habitat features on salmonid predation