River Otter Prey Species Study, MVSD 2017 – 2018

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Background

River Otters are important predators on fishes, aquatic birds, and invertebrates, and can therefore have significant influence on the structure of local ecosystems (Bouley et al., 2015). Furthermore, as opportunistic predators that forage near the apex of the trophic pyramid, river otters are critical bioindicators of ecosystem health (Kruuk, 2006). Understanding temporal relationships between predators and prey is critical for recognizing factors that might limit the success of this top carnivore (Kruuk and Conroy, 1987). The need for research on the diet of river otter populations also is important to conserving these top carnivores as diet has direct implications for protecting other aquatic resources. As a potential keystone species in the San Francisco Bay Area aquatic habitat (Bouley et al., 2015), this study has enabled us to gain a better idea of the role river otters might play in the Peyton Slough Wetlands Complex food web.

Diet Characterization Methods

To characterize the diet of river otters using Moorhen and McNabney Marshes, fecal samples (n=49) were collected from known latrine sites during 2017 through 2018 (Table 1). Fecal samples were bagged individually, labeled, and stored at -20°C. Individual samples then were soaked in warm water and denture cleaner (Efferdent, Pfizer Consumer Healthcare, Morris Plains, New Jersey) for > 30 minutes and agitated to separate mucilaginous material from undigested prey remains (Crait and Ben-David, 2006). Samples then were washed with water through three nested sieves (2 mm, 1 mm, and 0.5 mm; Murie and Lavigne, 1985). Recovered fish otoliths, scales, and skeletal material were sorted and stored dry, and arthropods (e.g., insects, crustaceans) were preserved in 70% isopropyl alcohol (Lance et al., 2001). Otoliths, scales, bone, insects, and crustaceans were examined under a dissecting scope and identified to the lowest taxon possible using taxonomic keys (Morrow, 1979; Harvey et al., 2000; Lagler 1947; Oates et al. 1993; Daniels 1996) and photo references. Prey taxa were enumerated using the greatest number of left or right otoliths, insect wing pairs, and crustacean antennules. Otoliths recovered from samples were measured parallel to the sulcus from the anterior

tip of the rostrum to the posterior edge (Lance et al., 2001). Measurements were recorded to the nearest 0.1 mm using digital calipers.

To compensate for degradation of otoliths during digestion, they were graded based on condition of external morphological features (Tollit et al., 1997). Otoliths were scored as having a low, medium, or high degree of digestion. If degraded, the length of each otolith was increased by a correction factor of 30.8%. This correction factor was based the results of a captive feeding study, where the average degradation in length of fish passing through the digestive tract of American mink (*Mustela vison*) was 30.8% (Brzeziński and Marzec, 2002). Otoliths graded as high were included in the enumeration of minimum number of individuals (MNI) per sample, but were not included in the measurements.

Standard length and mass of fishes were estimated using species-specific linear regressions of otolith or bone length from published studies (Harvey et al., 2000; Gürsoy Gaygusuz, 2008). When regression relationships for fish species were not available, relationships for similar species were used; however if relationships for similar species were not available, the average mass reported in the literature of that fish species was used. Length and mass measurements of all insect and crustacean species also were obtained using this method.

Seasons in coastal northern California are not clearly defined by severe climate variables; therefore data were organized into periods of low and high rainfall, and were based on water flow levels in local streams (Josselyn, 1983). Periods of low rainfall occurred during May through October and periods of high rainfall occurred during November through April.

To determine if seasonal food habits of river otters could be described adequately, cumulative number of prey taxa recovered in each sample was plotted against the randomly pooled number of samples. One hundred random samples were re-sampled using the vegan R package version 2.5-2 (Oksanen et al., 2018) to create a mean and variability estimate for each sample. If the curve reached an asymptote or displayed a reduction in variability, an adequate sample size was reached (Ferry and Cailliet, 1996).

The following indices then were used to describe the seasonal prey array consumed by river otters (Krebs, 1999):

Species Richness: S = Number of prey species

Species Diversity: $H' = \left| \left(\sum (pi * \log_2 pi)\right) \right|$, where Pi = proportion of species i

Index values were calculated for each sample, generating a seasonal mean and variance estimate.

Importance of individual prey taxa in river otter diet also was determined for each season using a modified index of relative importance (IRI; Pinkas et al., 1971):

IRI = (Mean %Number+ Mean %Mass)* %Frequency Occurrence.

Originally, prey volume was used in the above equation; however, it was replaced by prey mass because volume can be difficult to measure (Hyslop, 1980). IRI values were calculated for each sample, generating a seasonal mean and variance estimate for all prey species.

Diet Characterization Results

Of the 49 fecal samples collected from river otters in Moorhen and McNabney Marshes, California during 2017-18, all contained at least one prey item. Two taxa were identified to species, one to genus, four to family, two to order, and one to class; and individual fecal samples contained 1 to 5 prey taxa (mean = 1.7551, SE = 0.12553; Fig. 1). Of 193 individual prey occurrences, 165 (85.5%) were crayfish, 23 (11.9%) were fishes, and 5 (2.6%) were insects. Red swamp crayfish (*Procambarus clarkia*) was the predominant crayfish prey species, sand sole (*Psettichthys melanostictus*), Cyprinidae (carps and minnows), Cottidae (sculpins), and Cyprinodontiformes (toothcarps) were the predominant prey fish species that could be identified below class, and darner dragonfly nymph (Aeshnidae) was the predominant insect species consumed by river otters.

It appeared that mean number of species (S) recovered per fecal sample was greater in the wet season (mean = 2.29, SE = 0.286) than the dry season (mean = 1.54, SE = 0.118) and mean diversity of prey taxa (H') consumed by river otters was greater in the wet season (mean = 0.635, SE = 0.099) than the dry season (mean = 0.246, SE = 0.055). However, cumulative prey curves indicated that insufficient fecal samples were collected during the dry (Fig. 2a; n = 35) and wet (Fig. 2b; n = 14) seasons to statistically compare temporal variations in river otter diet.

Eight prey taxa were identified in fecal samples collected during the dry season, however, approximately 97% of the total mean IRI was comprised of only one prey taxa, red swamp crayfish (Table 2; Fig. 3a). Unidentified teleost was the next most important taxa consumed, but accounted for only 2% of the overall mean IRI. Nine prey taxa were identified during the wet season. Similar to the dry season, the majority of prey taxa consumed during the wet season were comprised of red swamp crayfish, followed by Cyprinodontiformes (toothcarps) and unidentified teleost (Table 3; Fig. 3b). Unfortunately, temporal variations of prey taxa importance could not be compared because insufficient fecal samples were collected.

Summary

River otters foraging in or near Moorhen and McNabney Marshes appeared to be opportunistic carnivores that consumed fishes, crustaceans, and insects. The most important prey species consumed by river otters during the 2017-18 sampling period was the red swamp crayfish, an invasive species that is abundant in the San Francisco Bay Area (USFW, 2015). Fishes were the second most important prey species and included sculpins, flatfishes, carp/goldfish, toothcarps, perch-like fishes, and a juvenile sturgeon (*Acipenser* spp.). The juvenile sturgeon was identified tentatively from two dorsal scutes, but needs further validation to confirm the species.

River otter numbers decreased during most of the wet season (December, 2017 through March, 2018) once vegetation cutting, pond dewatering, and construction started. Although it appeared river otters still foraged in the Peyton Slough Wetlands Complex, fewer fecal samples were recovered making diet characterization difficult. Additional samples should be collected to further characterize the diet of river otters foraging in or

near the Peyton Slough Wetlands Complex.

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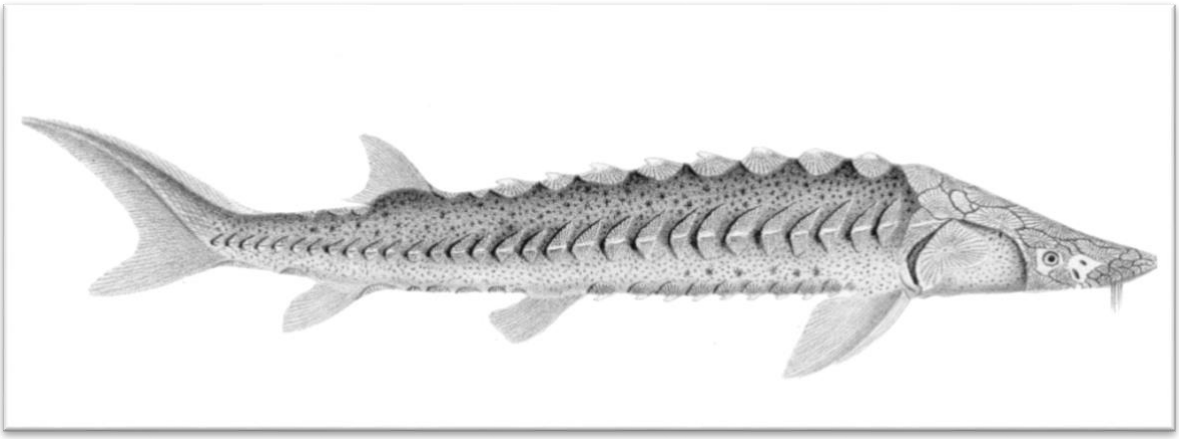
Tables and Figures

Table 1. Number of fecal samples collected in Moorhen Marsh and McNabney Marsh, California between May 2017 and March 2018.

Season	Month	Number of Samples
Dry (May-October)	May	0
	June	0
	July	11
	August	5
	September	5
	October	14
	TOTAL	35
Wet (November-April)	November	9
	December	3
	January	0
	February	0
	March	1
	April	1
	TOTAL	14



Green sturgeon (*Acipenser medirostris*)

Table 2. Mean and standard error (SE) of percentage number (%N) and percentage mass (%M), percentage frequency of occurrence (%FO), and mean and standard error (SE) of index of relative importance (IRI) of prey taxa identified in fecal samples of river otters collected in Moorhen Marsh and McNabney Marsh, California during the 2017 dry season (May-October; n = 35). Prey taxa are listed in order of decreasing IRI.

Prey Taxa	%N		%M		%FO	IRI	
	Mean	SE	Mean	SE		Mean	SE
Procambarus clarkii	86.728	3.622	88.196	3.674	1.000	174.92	7.2
Unidentified Teleost	6.065	3.515	8.010	3.694	0.229	3.217	1.625
Cyprinidae	1.596	0.771	1.039	0.538	0.114	0.301	0.149
Aeshnidae	2.619	2.932	0.008	0.013	0.086	0.225	0.252
Psettichthys melanostictus	2.000	***	2.324	***	0.029	0.124	***
Cottidae	0.317	***	0.351	***	0.029	0.019	***
Cyprinodontiformes	0.357	***	0.002	***	0.029	0.010	***
Perciformes	0.317	***	0.025	***	0.029	0.010	***

Table 3. Mean and standard error (SE) of percentage number (%N) and percentage mass (%M), percentage frequency of occurrence (%FO), and mean and standard error (SE) of index of relative importance (IRI) of prey taxa identified in fecal samples of river otters collected in Moorhen Marsh and McNabney Marsh, California during the 2017-18 wet season (November-April; n = 14). Prey taxa are listed in order of decreasing IRI.

Prey Taxa	%N		%M		%FO	IRI	
	Mean	SE	Mean	SE		Mean	SE
Procambarus clarkii	64.926	7.461	77.349	7.699	1.000	142.276	14.176
Cyprinodontiformes	15.788	3.819	0.130	0.050	0.357	5.685	1.382
Unidentified Teleost	6.786	1.937	8.387	2.205	0.286	4.335	1.184
Cyprinidae	2.579	2.625	3.842	4.251	0.143	0.917	0.982
Cottidae	1.984	1.050	4.163	8.354	0.143	0.878	1.343
Psettichthys melanostictus	4.762	***	2.432	***	0.071	0.514	***
Acipenser spp.	0.794	***	3.689	***	0.071	0.320	***
Aeshnidae	2.381	***	0.007	***	0.071	0.171	***

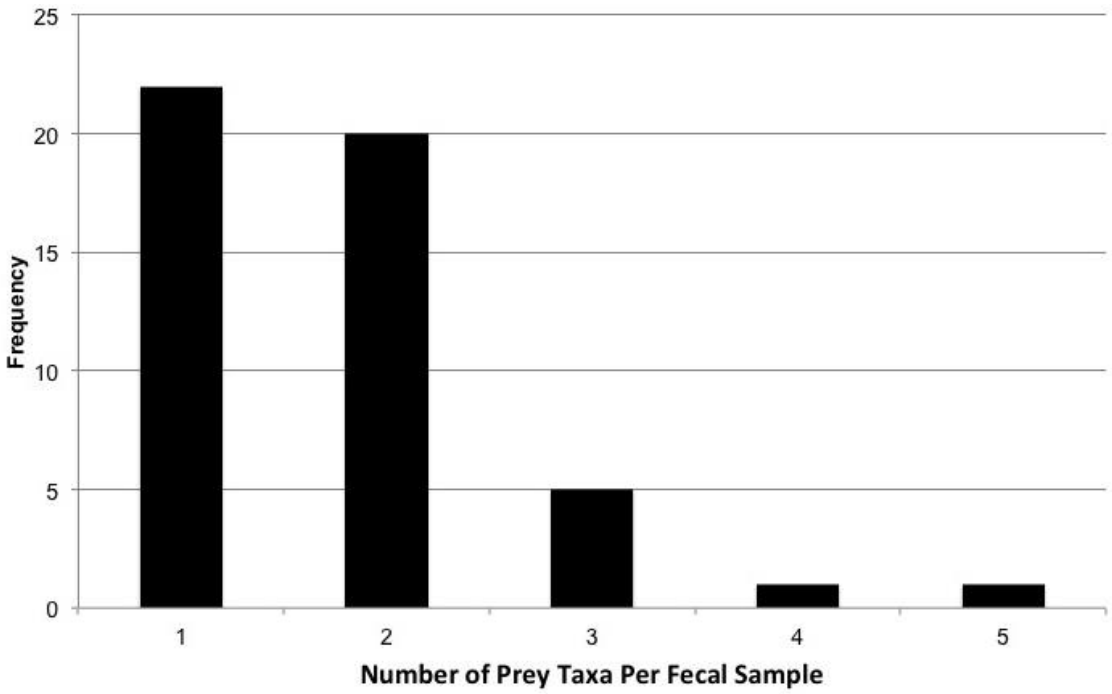


Figure 1. Frequency of number of prey taxa per river otter fecal sample collected from Moorhen and McNabney Marshes, California during the 2017-2018.

Red swamp crayfish (*Procambaris clarkii*)

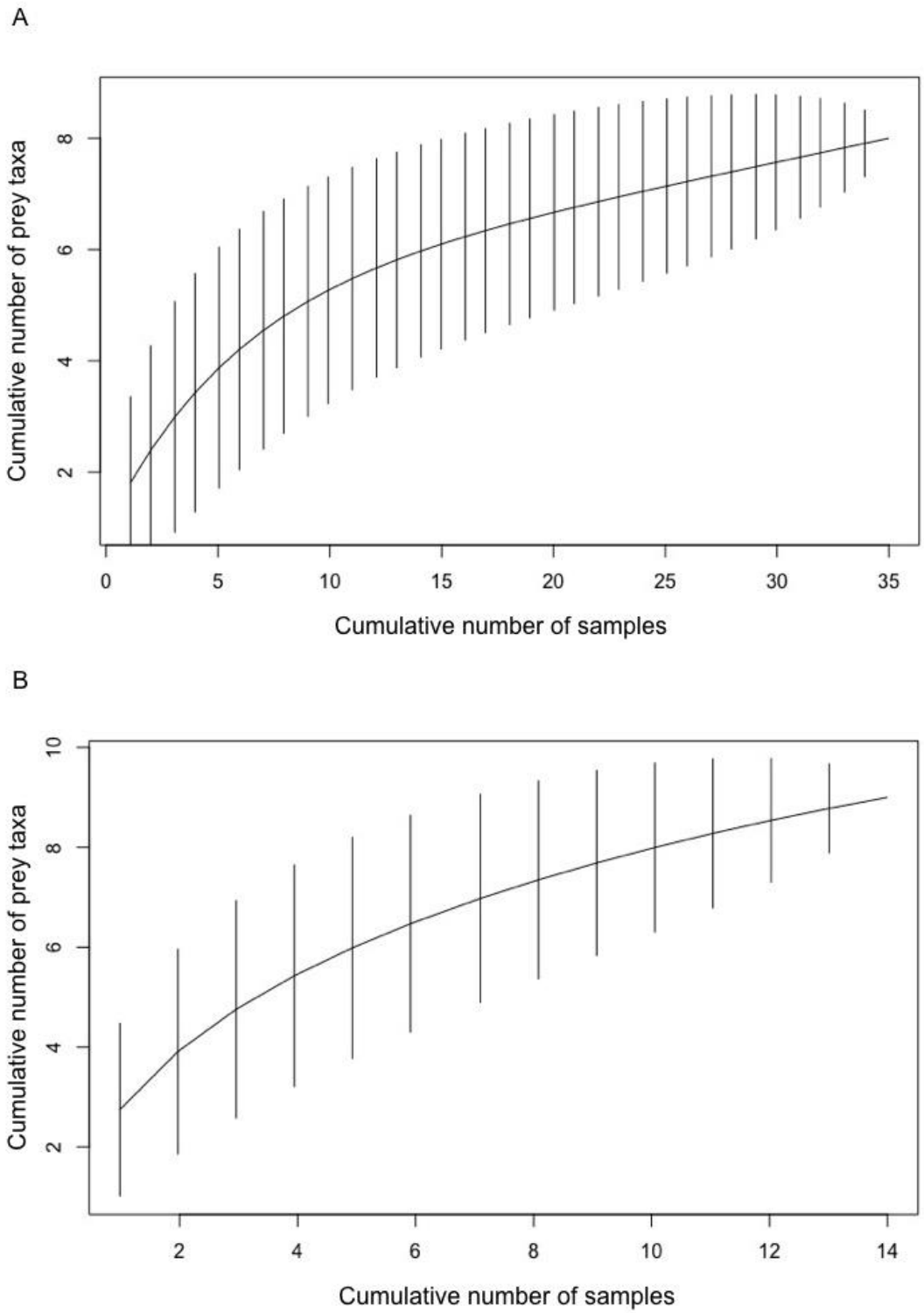


Figure 2. Cumulative number of prey taxa per fecal sample with standard error bars collected during the 2017-18 dry (A) and wet (B) seasons in Moorhen Marsh and McNabney Marsh, California.

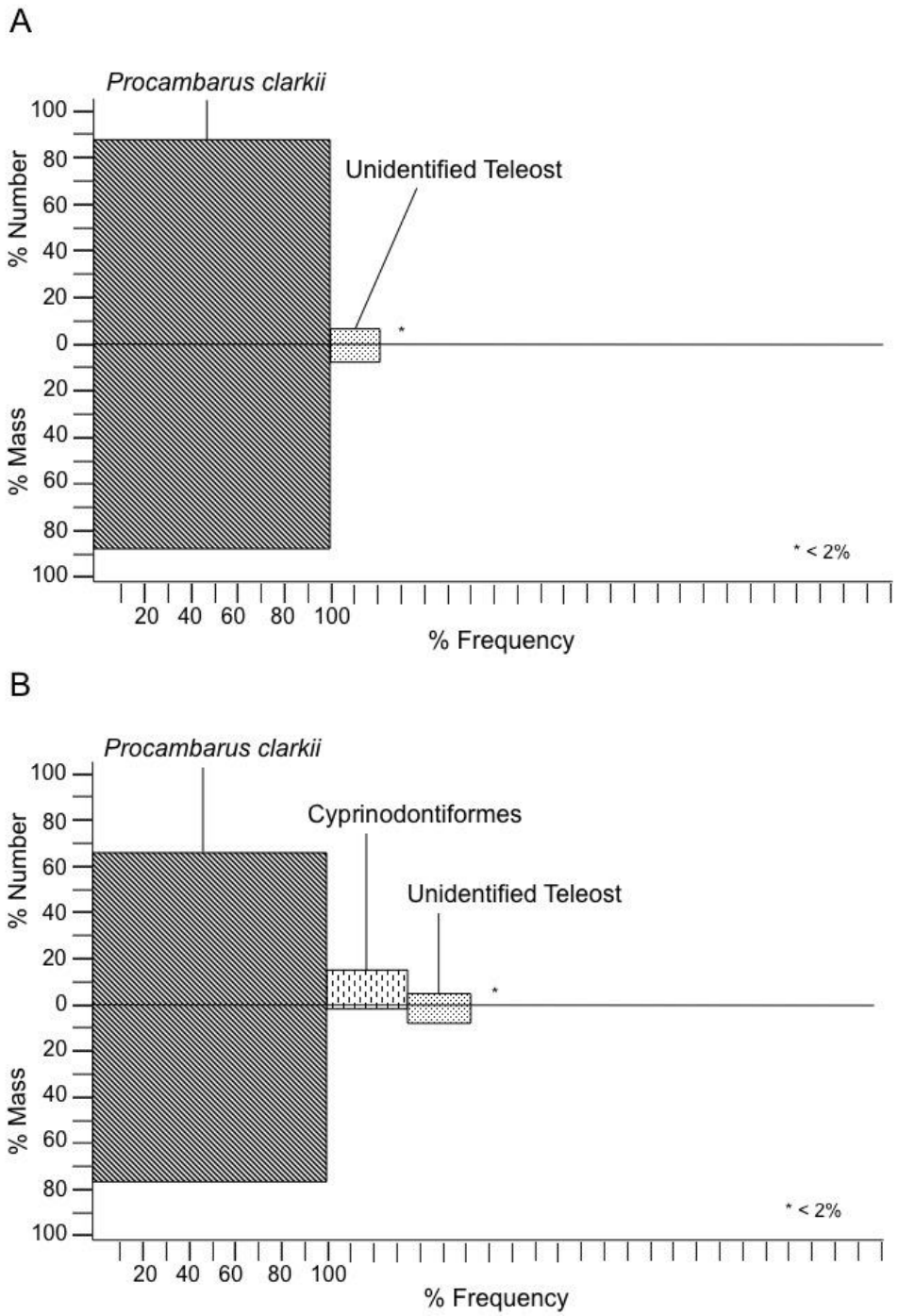


Figure 3. Mean percentage number (%N), mean percentage mass (%M), and percentage frequency of occurrence (%FO) of prey taxa identified in fecal samples of river otters collected in collected in Moorhen Marsh and McNabney Marsh, California during the 2017-18 dry (A) and wet (B) seasons. Only prey comprising >2% of the total mean IRI are depicted.