Diet of Invasive White Perch in Sooner Lake, Oklahoma

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Abstract: White Perch *Morone americana* are native to the Atlantic Coast of North America. Outside of their native range, White Perch quickly dominate fish communities, and they can compete with native fish species. White Perch were discovered in Sooner Lake, Oklahoma in 2006. However, little has been done to understand the potential impacts of White Perch in Sooner Lake. Therefore, from April 2015 – June 2016 White Perch were collected monthly from Sooner Lake to analyze food habits. White Perch diets were described seasonally (spring, summer, fall, winter) and by size classes (sub-stock, stock, quality, preferred, memorable) using percent composition by number, percent weight, and frequency of occurrence. In spring, White Perch diets were dominated by zooplankton. During summer, White Perch consumed primarily invertebrate prey, however, White Perch transitioned to a predominately fish diet in fall and winter. Sub-stock sized fish ate mostly invertebrates and zooplankton. However, as fish size increased White Perch consumed larger amounts of fish, which became the predominate prey at quality and preferred size classes. The shift in diet (seasonally and by size) from zooplankton to invertebrates and fish suggests that White Perch may compete with resident sport fishes for these resources in Sooner Lake.

Introduction

White Perch *Morone americana* populations have become established in inland lakes and reservoirs in many states outside of its native range through intentional (Zuerlein 1981) or unintentional movements (Wong et al. 1999; Harris 2006; Kuklinski 2007). White Perch is native to the Atlantic Coast of North America where it inhabits estuarine, freshwater, and marine environments (Scott & Crossman 1973). In its native range, the White Perch is a commercially and recreationally valuable species (Manuseti 1961). Because of its importance as a sportfish in its native range and the habitat suitability for this species in several Nebraska reservoirs, White Perch were introduced by Nebraska Game and Parks Division to create additional recreational fishing opportunities (Zuerlein 1981). However, these populations were quickly dominated by a high density of small-bodied White Perch.

Upon establishment, White Perch tend to become overabundant in inland lakes and reservoirs, resulting in slow growing, stunted populations (Kuklinski 2007; Gosch et al. 2010; Bethke et al. 2014). Because of the small average size of fish in stunted populations, it typically has little or no recreational value (Kuklinski 2007; Gosch et al. 2010). Furthermore, White Perch reach reproductive maturity at age-1 and tolerates a variety of habitats, which results in quick establishment in some aquatic systems with the potential to dominate or alter fish communities (Zuerlein 1981). White Perch can affect native fish populations following introduction (Kuklinski 2007). In a study evaluating interactions between White Perch and Yellow Perch *Perca flavescens* in Lake

Erie, Parrish and Margraf (1990) concluded that invasion of White Perch had negatively affected Yellow Perch populations, especially in the western basin of the lake. Furthermore, Madenjian et al. (2000) suggested that invasion of White Perch in Lake Erie has reduced White Bass *Morone chrysops* recruitment through interaction during the early life history of these species. Schaeffer and Margraf (1987) found that adult White Perch may affect Walleye *Sander vitreus* and White Bass recruitment via egg predation, as eggs comprised a large percentage of White Perch diets in April and May. In reservoir systems, diet investigations suggest that White Perch feed primarily on invertebrates, which may affect early life stages of sport fish species through competition for these resources (Harris 2006, Kuklinski 2007, Gosch et al. 2010), resulting in poor survival and recruitment.

In Oklahoma, Kuklinski (2007) investigated potential consequences of White Perch invasion on native species in Kaw Lake, Oklahoma. White Perch were discovered in Kaw Lake in 2000 as a result of emigration from populations in Nebraska and Kansas to Oklahoma through the Arkansas River system (Kuklinski 2007). It was determined at low population abundance, White Perch do not appear to be negatively impacting White Bass or White Crappie *Pomoxis annularis* populations (Kuklinski 2007). However, there was high diet overlap between White Perch and juvenile White Bass. Competition for food resources could affect White Bass population levels if White Perch abundance increases through time.

Since the initial discovery in Kaw Lake, White Perch has been found in Keystone Lake (2004) and Sooner Lake (2006; Oklahoma Department of Wildlife Conservation, unpublished data). White Perch abundance in Sooner Lake has been increasing since establishment. Conversely, Largemouth Bass *Micropterus salmoides*, White Bass, Channel Catfish *Ictalurus punctatus*, and hybrid Striped Bass *Morone saxitilis x M. chrysops* abundances have decreased in Sooner Lake (Copeland 2016). Although White Perch are present at a high abundance, the Sooner Lake population is characterized as a non-stunted population with fish reaching 8 years in age and exceeding 300 mm total length (Porta and Snow 2017). Porta and Snow (2017) found disparities among condition values when evaluating White Perch by size classes. Smaller fish (<200 mm TL) had lower mean relative weights, whereas larger fish (>200 mm TL) had higher mean relative weights, suggesting that intraspecific competition may be high and that larger fish may outcompete smaller fish for food resources or there may be differences in food items consumed. In this scenario, it would be beneficial to know if differences in diet are driving differences in condition among size classes of White Perch in this population.

Besides the initial investigation by Kuklinski (2007) following the introduction of White Perch into Kaw Lake, little has been done to understand potential impacts of White Perch invasion on other aquatic systems in Oklahoma. Therefore, our objectives are to evaluate food habits of White Perch in Sooner Lake, Oklahoma. Also, because diet information was collected from the subsample of White Perch used to evaluate Sooner Lake population characteristics (Porta and Snow 2017), it may be possible to determine whether diet differences contributed to differences in size-specific condition observed in that study. Finally, because the Sooner Lake White Perch population is non-stunted, we can compare White Perch diets from this population to observations in Kuklinski (2007) for a stunted White Perch population in Kaw Lake, Oklahoma.

Methods

Study area

Sooner Lake is a 2,185 ha reservoir located in north central, Oklahoma that is owned and operated by Oklahoma Gas and Electric Company. The Sooner Lake water level is maintained by pumping water from the Arkansas River, which allowed White Perch to enter the reservoir.

Study design

White perch were collected from Sooner Lake monthly from April 2015-June 2016 (with the exception of May 2016 because of equipment breakdown), using boat-mounted electrofishing (pulsed DC, high voltage, Smith Root 7.5 GPP) and experimental gillnets (61 m long x 1.8 m deep and constructed of eight 7.6 m panels [12.7 mm, 15.9 mm, 19.1 mm, 25.4 mm, 38.1 mm, 50.8 mm, 63.5 mm, and 76.2 mm bar mesh]). A multi-gear approach was implemented to ensure that all size classes of white perch were represented in the sample (Kuklinski 2007, Feiner et al. 2012, Bethke et al. 2014), and day and night surveys were conducted to ensure no diel differences in size structure. Each monthly sample consisted of twelve electrofishing transects (600 sec/transect; 7,200 sec of total pedal time) and four experimental gill nets set perpendicular to the shoreline at various depth contours. Sites were chosen randomly by laying a 300 m^2 grid over the map of the lake in ArcGIS, individually numbering each grid square and using a random number generator to select the grid to be sampled. New electrofishing and gillnetting sites were randomly selected monthly (Porta and Snow 2017).

Following capture, each fish was measured for total length (TL; mm) and weight (g). Fish were placed on ice until they could be processed in the laboratory. In the laboratory, stomach contents from fish were removed, identified to the finest taxonomic level possible (order or family for invertebrates, species for fish), and enumerated. Percent occurrence (the percentage of stomachs in the sample containing a particular diet item), percent composition by number (number of individuals of a given prey type divided by the total number of prey items counted from a given predator stomach), and percent weight (weight of individuals of a given prey type divided by the total weight of prey items from a given predator stomach) of prey items (Bowen 1996) were calculated for White Perch by season (spring =March-May, summer=June-August, autumn =September-November, winter =December-February) and size class (sub-stock =<130 mm, stock=130-199 mm, quality=200-249 mm, preferred= 250-299, memorable=300-379 mm, trophy=>380 mm; Gabelhouse 1984).

Results

A total of 574 White Perch ranging from 56-308 mm TL were collected from Sooner Lake for diet analysis (Table 1 and 2). Diets of White Perch were diverse, consuming 29 different prey items. Of the 574 fish collected for diet analysis, 150 had empty stomachs (26%). Dipterans (29.97%) dominated White Perch diets by percent occurrence, followed by amphipods (18.12%), cladocerans (13.59%), copepods (12.02%), and ephemeropterans (10.28%). All other prey items contributed <10% by occurrence. Zooplankton comprised 96.24% of all diet items by percent total number (70.01% and 26.22% for cladocerans and copepods, respectively). However, fish dominated White Perch diets by percent total weight (47.62%). Threadfin Shad *Dorosoma petenense* (18.96%), Gizzard Shad *Dorosoma cepedianum* (13.27%), and Inland Silversides *Menidia beryllina* (10.03%) contributed most to total fish weight. All other fish represented 5.36% by total weight. Invertebrates comprised a substantial portion of the total weight of prey items (37.75%), with ephemeropterans (13.23 %) and dipterans (10.42 %) contributing the bulk of invertebrate prey items. Zooplankton contributed to 11.19% of the total percent by weight.

A total of 142 sub-stock sized fish were evaluated for diet analysis, and 30 (21.13%) had empty stomachs (Table 1). Sub-stock sized White Perch consumed mostly zooplankton by number (98.37%), however invertebrate prey items comprised slightly more of the diet by weight (52.69%) followed by zooplankton (45.94%). Dipterans occurred most frequently in diets of sub-stock sized White Perch (44.37%), followed by copepods (28.87%), cladocerans (20.42%), and amphipods (19.01%). Sub-stock sized White Perch rarely ate fish. A total of 183 stock sized fish were evaluated for diet analysis, and 51 (27.87%) had empty stomachs. Stock sized White Perch consumed mostly zooplankton by number (94.40%), however this comprised only 13.36% by weight. Invertebrates dominated stock sized White Perch diets by weight (57.59%), followed by fish (28.79%). Dipterans (27.87%) and amphipods (27.32%)

Table 1. Size-specific diets of White Perch collected from Sooner Lake, Oklahoma from April 2015 – June 2016.

	Size														
	Substock (N=142)			Stock (N=183)			Quality (N=115)			Preferred (N=132)			Memorable (N=2)		
Diet Item	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence
Zooplankton															
Cladocera	67.818	26.305	20.420	60.449	7.385	8.200	84.941	5.250	9.570	85.876	8.150	16.670	99.190	44.100	20.42
Copepoda	30.547	19.640	28.870	33.948	5.974	10.930	5.585	0.820	4.350	10.015	0.516	2.270			
Total Zooplankton	**98.365**	**45.944**		**94.398**	**13.359**		**90.526**	**6.070**		**95.890**	**8.666**		**99.190**	**44.100**	
Fish															
Bluegill							0.008	1.420	0.870						
Gizzard Shad				0.013	14.466	2.730	0.041	10.270	4.350	0.058	16.048	7.580			
Inland Silverside	0.003	1.253	1.410	0.028	12.916	4.370	0.107	10.600	8.700	0.077	9.828	9.090			
Largemouth Bass							0.060	7.110	3.480						
Threadfin Shad							0.099	13.170	6.090	0.116	31.307	9.090	0.270	55.660	50.00
White Perch							0.008	1.420	0.870	0.029	3.395	2.270			
Unidentified Fish				0.015	1.412	2.730	0.017	1.010	1.740	0.019	0.813	3.030			
Total Fish	**0.003**	**1.253**		**0.056**	**28.794**		**0.340**	**45.000**		**0.299**	**61.390**		**0.270**	**55.660**	
Fish Eggs							0.040	0.110	0.870						
Invertebrates															
Amphipoda	0.400	6.211	19.010	2.080	8.071	27.320	1.458	2.720	13.040	0.796	1.459	9.090			
Anostraca	0.009	5.496	1.410	0.010	1.057	0.550	0.115	2.270	0.870						
Arachnida				0.003	0.021	0.550				0.068	0.144	1.520			
Coleoptera	0.004	0.028	0.700	0.008	0.835	1.640									
Corbicula							0.017	6.140	0.870						
Crayfish				0.008	2.748	1.640				0.005	4.565	0.760			
Diptera	0.788	20.366	44.370	2.377	14.521	27.870	4.251	7.810	24.350	1.674	9.322	21.970	0.405	0.180	50.00
Dreissena	0.026	0.612	4.930	0.073	3.722	4.370	0.058	0.014	0.870	0.068	0.094	2.270			
Ephemeroptera	0.020	13.085	4.930	0.371	16.957	14.210	0.873	17.140	9.570	0.569	10.724	11.360			
Gastropoda							0.010	0.001	0.870						
Hemiptera				0.010	0.761	1.090	0.148	0.330	0.870	0.077	0.174	1.520			
Hymenoptera										0.043	0.099	1.520			
Isopoda	0.001	0.243	0.700	0.015	0.486	1.090									
Megaloptera				0.005	0.012	1.090									
Nematoda				0.005	<0.001	0.550							0.135	0.060	50.00
Odonata	0.121	2.616	7.750	0.457	5.010	14.750	0.445	2.390	6.960	0.024	0.023	3.790			
Ostracoda	0.228	3.700	3.520				0.536	1.550	1.740						
Plecoptera	0.003	0.165	0.700	0.028	3.182	3.830	0.585	1.340	2.610						
Trichoptera	0.030	0.173	1.410	0.040	0.213	1.640	0.469	0.360	2.610	0.439	0.479	3.030			
Total Invertebrates	**1.630**	**52.693**		**5.489**	**57.593**		**8.964**	**42.065**		**3.763**	**27.084**		**0.540**	**0.240**	
Unknown Items	0.001	1.099	0.700	0.058	0.254	1.090	0.132	6.750	9.570	0.048	2.861	6.820			
Empty			**21.13**			**27.87**			**26.96**			**28.79**			

occurred most frequently in diets of stock sized White Perch, followed by odonata (14.80%) and ephemeroptera (14.21%). A total of 115 quality sized fish were evaluated for diet analysis, and 31 (26.96%) had empty stomachs. Quality sized White Perch consumed mostly zooplankton by number (90.53%), but this made up only 6.07% of prey weight. Fish comprised the highest prey weight (45.00%) of quality sized White Perch. Dipterans (24.35%) and amphipods (13.04%) occurred most often in quality sized White Perch diets. All other prey items occurred in <10% of quality sized White Perch diets. A total of 132 preferred sized fish were evaluated for diet analysis, and 38 (28.79%) had empty stomachs. Preferred sized White Perch consumed mostly zooplankton by number (95.89%), but this made up only 8.67% of prey weight. Fish dominated

Table 2. Seasonal diets of White Perch collected from Sooner Lake, Oklahoma from April 2015 – June 2016.

	Season											
	Spring (N=140)			Summer (N=108)			Fall (N=168)			Winter (N=158)		
Diet Item	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence	Percent Composition	Percent Weight	Percent Occurrence
Zooplankton												
Cladocera	87.137	47.134	45.710				98.074	2.271	7.740	7.751	0.100	0.630
Copepoda	8.366	6.846	16.430	14.650	0.054	2.780				86.899	6.488	27.220
Total Zooplankton	**95.503**	**53.980**		**14.650**	**0.054**		**98.074**	**2.271**		**94.650**	**6.588**	
Fish												
Bluegill				0.230	1.392	0.930	0.002	1.782	0.600			
Gizzard Shad				1.370	6.786	5.560	0.014	27.911	4.760	0.018	14.106	3.800
Inland Silverside	0.003	0.441	0.710	2.970	6.815	9.260	0.022	14.191	7.140	0.036	15.986	5.700
Largemouth Bass				1.600	6.961	3.700						
Threadfin Shad				0.920	2.439	3.700	0.016	21.776	4.760	0.061	49.923	5.060
White Perch				1.370	4.063	2.780	0.002	1.782	0.600			
Unidentified Fish	0.023	3.902	5.710	0.460	0.835	1.850				0.003	0.055	0.630
Total Fish	**0.025**	**4.342**		**8.920**	**29.291**		**0.056**	**67.442**		**0.118**	**80.069**	
Fish Eggs	0.010	0.212	0.710									
Invertebrates												
Amphipoda	0.822	9.093	27.140	0.687	0.015	0.930	0.533	2.954	12.500	1.983	3.780	27.850
Anostraca				5.490	3.898	3.700						
Arachnida							0.024	0.255	1.790			
Coleoptera				1.140	0.323	2.780	0.002	0.140	0.600			
Corbicula				0.460	6.014	0.930						
Crayfish				0.460	1.103	1.850	0.002	7.662	0.600	0.003	0.445	0.630
Diptera	2.387	18.258	50.710	31.810	14.898	22.220	0.726	6.852	22.620	2.050	3.377	24.680
Dreissena	0.040	0.276	3.570	0.230	0.006	0.930	0.067	2.258	5.950	0.023	0.151	1.900
Ephemeroptera	0.312	7.150	14.290	30.200	36.756	17.590	0.017	0.528	2.380	0.299	1.378	10.130
Gastropoda							<0.001	0.001	0.600			
Hemiptera							0.060	1.120	2.980			
Hymenoptera							0.014	0.166	1.190			
Isopoda	0.015	0.528	1.430				0.002	0.032	0.600			
Megaloptera										0.005	0.008	1.270
Nematoda	0.003	0.001	0.710							0.005	<0.001	0.630
Odonata	0.050	0.213	6.430	1.370	0.564	2.780	0.219	4.437	11.900	0.410	1.263	12.030
Ostracoda	0.305	1.405	2.860				0.103	1.736	1.190	0.092	0.014	0.630
Plecoptera				1.830	1.632	5.560	0.014	1.165	1.790	0.171	0.474	1.270
Trichoptera	0.462	2.296	8.570									
Total Invertebrates	**4.395**	**39.220**		**73.677**	**65.207**		**1.782**	**29.305**		**5.041**	**10.889**	
Unknown Items	0.010	2.245	2.860	2.750	5.448	5.560	0.011	2.775	4.170	0.069	2.454	3.800
Empty			**16.43**			**26.85**			**29.76**			**30.38**

the prey weight (61.39%) of quality sized White Perch. Dipterans (21.97%), cladocerans (16.67%), and ephemeropterans (11.36%) occurred most often in preferred sized White Perch diets. All other prey items occurred in <10% of preferred sized White Perch diets. Only 2 memorable sized White Perch were captured for diet analysis and both contained diet items. Fish comprised the bulk of memorable sized White Perch diets (55.66%), followed closely in weight by zooplankton (44.10%).

White perch were collected across all seasons for diet analysis (Table 2). During spring, 140 White Perch were collected for diet analysis. Of these fish, 23 (16.43%) had empty stomachs. White Perch containing diet items consumed 15 different prey items. Zooplankton dominated the spring diets by number (95.50%) and weight (53.98), although invertebrates, particularly dipterans (18.26%), amphipods (9.09%), and ephemeropterans (7.15%) contributed substantially by weight. Dipterans occurred most frequently in the spring diets of White Perch (50.70%), followed by cladocerans (45.71%), ephemeropterans (27.14%), copepods (16.43%) and amphipods (14.30%). Fish eggs were rarely consumed by White Perch in spring. In summer, 108 White Perch were collected, of which 29 (26.85%) were empty. White Perch consumed 19 different prey items during summer. Summer diets were dominated by invertebrates by number (73.68%) and weight (65.21%). Dipterans and ephemeropterans dominated summer White Perch diets by number (31.81% and 30.20% for dipterans and ephemeropterans, respectively) and weight (36.76% and 14.90% for ephemeropterans and dipterans, respectively). Dipterans occurred most frequently in the summer diets of White Perch (22.22%), followed by ephemeropterans (17.60%). During fall, 168 White Perch were collected of which 50 (29.76%) were empty. White Perch consumed 20 different prey items during fall. Zooplankton dominated White Perch diets by number (98.07%), however contributed little to weight (2.27%). Fish comprised the highest percentage by weight (67.44%), consisting mostly of Gizzard Shad (27.91%) and Threadfin Shad (21.78%). Invertebrates contributed to 29.31% by weight to fall diets, consisting mostly of crayfish (7.66%), dipterans (6.85%), and odonates (4.44%). Dipterans occurred most frequently in the fall diets of White Perch (22.62%), followed by amphipods (12.50%) and odonata (11.90%). During winter, 158 White Perch were collected for diets analysis and 48 (30.38%) were empty. White Perch consumed 17 prey items during winter. Zooplankton dominated White Perch diets by number (94.65%), however contributed little to weight (6.59%). Fish comprised the highest percentage by weight (80.07%), consisting mostly of Threadfin Shad (49.92%), Inland Silversides (15.99%), and Gizzard Shad (14.11%). Amphipods occurred most frequently in the winter diets of White Perch (27.85%), followed by copepods (27.22%) and dipterans (24.68%).

Discussion

White Perch are adaptive predators that switch feeding patterns to cope with changing prey availability (St-Hilaire et al. 2002). Previous research suggests that White Perch diets can be variable, making this species very adaptable to different environments and habitat types. In Sooner Lake, White Perch transitioned to different prey items depending on season. During spring, White Perch consumed large amounts of zooplankton, transitioning to predominately invertebrates by summer. Couture and Watzin (2008) also documented a transition from zooplankton to invertebrates, which occurred when zooplankton densities declined during summer. In Sooner Lake, White Perch transitioned to a fish dominated diet (65-80% by weight) in fall and winter. Stein (2001) found that dipterans dominated White Perch diets during spring, summer, and fall, but switched to primarily fish during winter. Similarly, Elrod et al. (1982) found that adult White Perch consumed dipterans in spring and summer, but ate fish during fall. Schaeffer and Margraf (1986) found that cladocerans and chironomids were important to White Perch in Lake Erie during June and July, but transitioned to Gizzard Shad during August and September.

White Perch in this study consumed a substantial amount of fish, particularly at larger sizes. In Sooner Lake, quality (200-249 mm) and preferred (250-299 mm) sized White Perch had diets dominated by fish (45-61%). Gosch et al. 2010 found that White Perch began consuming fish between 130-160 mm. Similar to our results, Stein (2001) found that White Perch in Browning Oxbow, Kansas exhibited differences in diet among life stages, with small fish (young-of-the-year) feeding heavily on zooplankton, whereas adults (age-l and older) consumed primarily aquatic insects and fish. At small sizes (sub-stock and stock size classes), White Perch in Sooner Lake consumed mostly zooplankton and invertebrates. The transition from zooplankton and invertebrates to fish prey may explain the differences in size specific condition of White Perch in this population (Porta and Snow 2017).

The Sooner Lake White Perch population is characterized as a non-stunted population (Porta and Snow 2017). Gosch et al. 2010 found that stunted and non-stunted populations of White Perch in Nebraska had very similar diets (both consuming primarily invertebrates), and suggested that shifting from a stunted to non-stunted state will not change food habits of these populations. Similarly, Kuklinski (2007) found that stunted White Perch in Kaw Lake, Oklahoma consumed primarily insects. However, we found that Sooner Lake White Perch transition from zooplankton and invertebrates to fish seasonally and by size classes. The transition to fish prey may influence growth of White Perch in Sooner Lake and may be why this population is currently in a non-stunted state (Porta and Snow 2017).

White Perch in Sooner Lake rarely consumed fish eggs. White Perch can be voracious egg predators in systems that they invade (Schaeffer and Margraf 1987). The consumption of eggs by White Perch may affect recruitment of other species in those systems (Schaeffer and Margraf 1987; Madenjian et al. 2000). It appears unlikely that fish egg consumption by White Perch will affect fish recruitment in Sooner Lake, Oklahoma. However, White Perch may compete directly with the resident sportfish in Sooner Lake for forage resources.

The shift in diet from zooplankton to invertebrates and fish suggests that White Perch may compete with resident sport fishes for these resources. Sooner Lake White Perch consume considerable amounts of zooplankton, invertebrates, and fish. This may explain why Largemouth Bass, White Bass, Channel Catfish, and hybrid Striped Bass abundances have decreased in Sooner Lake since establishment of White Perch (Copeland 2016). Previous research suggests that White Perch can affect native fish species following introduction. Parrish and Margraf (1990) discovered that White Perch had negatively affected Yellow Perch populations in Lake Erie following introduction of White Perch. Similarly, Madenjian et al. (2000) linked a reduction in White Bass recruitment with invasion of White Perch in Lake Erie, suggesting that competition at early life stages is driving this relationship. Future research should be directed toward understanding trophic relationships between White Perch and resident species in Sooner Lake to determine if competition or predation lead to species declines in this system.

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