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Effects of disturbance on fish communities at boat ramps in the Sacramento-San Joaquin River Delta

Rick Wilder and Abigail Warwas
Delta Juvenile Fish Monitoring Program, U.S. Fish & Wildlife Service, Stockton, CA <rick_wilder@fws.gov>

Introduction
Human disturbance abounds in the Sacramento-San Joaquin River Delta. In addition to extensive water export and shipping practices, the Delta is used for a variety of recreational activities that may disturb aquatic resources, particularly fish. Despite high recreational use, little is known about whether these activities disturb fish communities. Boat ramps offer a particularly appropriate location to examine effects of disturbance on fish communities because they are subject to high disturbance owing to their primary purpose: the launching and retrieval of boats (Figure 1).

The Delta Juvenile Fish Monitoring Program (DJFMP) has sampled beaches and boat ramps for the past 30 years to monitor the distribution and relative abundance of juvenile fishes throughout the Sacramento-San Joaquin River Delta. Although boat ramps provide convenient access, consistency among samples, and suitable habitat for many fish species, there are several concerns regarding their use as historical monitoring sites. For example, boat ramps are inherently subject to higher disturbance levels than beaches. The DJFMP has addressed this issue in the past by waiting 15 minutes before conducting a sample if a disturbance is observed. This wait time was presumed to be sufficient for the site to return to pre-disturbance conditions (L. McLaughlin, *pers. comm.*). However, this has led to extensive wait times and even cancellations of sampling during busy boating periods.

The goal of this study was to determine the effects of disturbance on fish communities at boat ramps. The purpose was two-fold: (1) to gain knowledge of short-term (<5 minutes) effects of disturbance caused by recreational activity on fish communities, and (2) to provide the DJFMP with information concerning when to sample if a disturbance has occurred in a sample site.

Figure 1. Sacramento River anglers launch their boat at Knight's Landing with seine net in foreground.

Methods
We examined the effects of disturbance on fish between 09 Feb 2006 and 07 Sep 2006 at 15 boat ramps used by the DJFMP as historical monitoring sites (Figure 2). Boat ramps were seined with a 15 m x 1.2 m net with 3 mm Delta mesh. After a sample, all fish were identified to species and measured. To convert fish counts to catch per unit effort (CPUE), dimensions of each seine were recorded and volume was calculated as effort.

One of three levels of disturbance (none, low, and high) was assigned to each sample. These levels were based on timing, location, and magnitude of the disturbance event (Table 1, Figures 1, 3). Sites were divided into three regions based on geographic location (Sacramento River, San Joaquin River, and Delta).

We then compared CPUE and species richness among levels of disturbance. Because count data are inherently non-normally distributed, we conducted Kruskal-Wallis ANOVAs with sites as replicates (n = 15 sites). When necessary, Tukey type multiple comparisons tests were used to determine whether CPUE differed among disturbance levels. Richness data were determined to be normally distributed (Shapiro-Wilkes test, P > 0.05) and, therefore, a blocked ANOVA (blocks = sites) was conducted to determine effects of disturbance levels on species richness.

Table 1. Criteria used to determine disturbance levels at boat ramps.

	Time (minutes)		
Disturbance	<2	2-5	>5
Ducks in site	Low	None	None
1 person and/or dog in site	Low	None	None
>1 person and/or dog in site	High	Low	None
Docked or running boat (<6.7 m away)	Low	None	None
Boat launching/retrieving on ramp (<6.7 m away)	High	Low	None

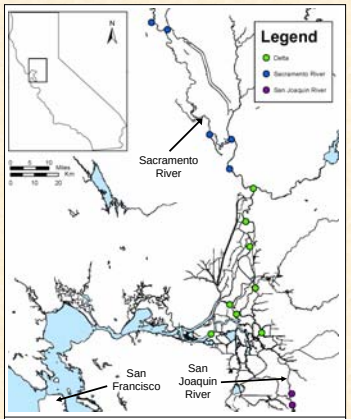

Figure 2. Map of boat ramps used in current study.

Figure 3. Woman walks her dog through sample site at Garcia Bend boat ramp.

Results
We caught a total of 29,744 fish from 37 species in 363 samples (273 samples with no disturbance, 29 with low disturbance, and 61 with high disturbance). The three most abundant species caught were inland silverside (8,170 fish), Chinook salmon (4,687), and Sacramento splittail (4,637).

CPUE
All sites combined
There were no differences among disturbance levels in CPUE of all species combined (P > 0.05; Table 2, Figure 3). The CPUE of all native fish combined was marginally greater when there was no or high disturbance (P = 0.06), but there was no difference in CPUE of all non-native fish among disturbance levels (P > 0.05).

We found significant differences among disturbance levels in CPUE of Chinook salmon (P = 0.005), Sacramento splittail (P = 0.025), and threadfin shad (P < 0.05, Table 2, Figure 3). For all three species, CPUE was greatest when there was no disturbance. There were no other species-specific differences in CPUE among disturbance levels.

By region
In the Delta region, CPUE of both Chinook salmon (P = 0.08) and golden shiners (P = 0.054) was marginally greater when there was no disturbance compared to low or high levels of disturbance (Table 2).

In the Sacramento River region, CPUE of splittail was greatest with no disturbance and lowest in low disturbance (P = 0.02, Table 2). Although not statistically significant, an identical trend was observed in both Chinook salmon (P = 0.09) and all natives combined (P = 0.07).

In the San Joaquin River region, there was a non-significant trend that CPUE of logperch was greater in high disturbance than in no or low disturbance (P = 0.09, Table 2).

There were no other differences in CPUE among disturbance levels by region.

Species richness
After removing the effect of site, there were no differences among disturbance levels in species richness of all fish ($F_{2,24}$ = 1.11, P = 0.35), all natives ($F_{2,24}$= 0.43, P = 0.66), or all non-natives ($F_{2,24}$ = 1.30, P = 0.29).

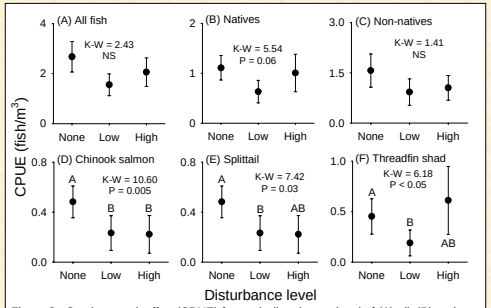

Figure 3. Catch per unit effort (CPUE) for each disturbance level of (A) all, (B) native, and (C) non-native fish, and (D-F) species with significant differences among disturbance levels. K-W = Kruskal-Wallis test statistic. Note change of scale among panels.

Table 2. Results (P-values) of Kruskal-Wallis tests to determine the effects of disturbance on CPUE of all fish, all natives, all non-natives, and each common species. Results are reported for all sites combined and by region. Results where P < 0.05 are indicated in bold. N/A = insufficient replication to conduct data analysis.

		By region		
Species	All sites combined	Delta	Sacramento River	San Joaquin River
All fish	0.30	0.37	0.30	0.28
All native fish	0.06	0.22	0.07	0.18
All non-native fish	0.50	0.43	0.90	0.18
Carp	0.11	0.61	0.81	0.10
Chinook salmon	**0.005**	0.08	0.09	0.46
Fathead minnow	0.30	0.66	0.52	0.32
Golden shiner	0.10	0.054	0.42	0.52
Largemouth bass	0.20	0.26	0.99	0.10
Logperch	0.30	0.98	0.73	0.09
Mosquitofish	0.14	0.35	0.54	0.10
Inland silverside	0.16	0.18	0.96	N/A
Prickly sculpin	0.53	0.98	0.34	N/A
Red shiner	0.85	0.18	0.77	N/A
Sacramento pikeminnow	0.77	0.90	0.68	N/A
Sacramento sucker	0.29	0.18	0.11	N/A
Sacramento splittail	**0.03**	0.36	**0.02**	0.17
Threadfin shad	**0.046**	0.11	0.36	0.85

Discussion
Our results indicate that disturbance affected the relative abundance of few species of fish at boat ramps (Table 2). However, the three species that were significantly affected are species of conservation interest:

- **Chinook salmon** abundance was negatively affected by all levels of disturbance (Table 2; Figure 3D). The winter-run race of Chinook salmon is listed under the Endangered Species Act (ESA) as endangered, spring-run as threatened, and fall-run and late fall-run as candidate species. Chinook salmon was the third most abundant species caught in our sampling;
- **Sacramento splittail** abundance was negatively affected by low levels of disturbance (Table 2; Figure 3E). Splittail, which has been listed as threatened in the past (1999-2003), is currently listed under the ESA as a species of special interest and as a target species for the CALFED Bay-Delta Program. Splittail was the second most abundant species caught in sampling;
- **Threadfin shad** abundance was negatively affected by low levels of disturbance (Table 2; Figure 3F). Threadfin shad is one of four fish species that has experienced precipitous population declines as identified by the Pelagic Organism Decline (POD) work team.

There were no effects of disturbance on species richness. Although the effects of disturbance on species composition and diversity were not assessed here, we plan to evaluate them once sufficient data have been collected.

Recommendation
Given these results, the DJFMP and other fish monitoring programs should consider disturbance in future assessment of fish communities at boat ramps. We recommend that, if a disturbance is witnessed before sampling, there should be a waiting period of at least 5 minutes to allow the fish community to return to a less disturbed state, particularly if splittail, salmon, or threadfin shad are likely to be caught.

Future Directions
- Using the current data, determine the effects of disturbance fish grouped by life history characteristics (e.g., trophic level, location in water column, size, and life stage).
- Investigate longer-term effects of disturbance (>5 minutes after disturbance) on fish to determine at what point conditions return to completely undisturbed levels.
- Separate the effects of various characteristics of a disturbance (e.g., distance from, time since, and magnitude of a disturbance) on the fish community.
- Manipulate disturbance levels experimentally to determine the effects of disturbance on fish communities.

Extra text

Intro

Effects of disturbance on fish communities has been well documented throughout the world (REFS). The large majority of these studies have focused on long term or large scale disturbances, such as overfishing, permanent alterations of fish habitat, and exotic species invasions. Few studies have focused on relatively short-term, acute disturbances, such as boat traffic.

EXTRAS

Table 1. Criteria used to determine disturbance levels

Disturbance level	Criteria
None	No apparent disturbance in past 5 minutes . . .
Low	2-5 minutes: >1 person and/or dog in site Boat launching/retrieving on ramp (<6.7 m away) <2 minutes: Ducks in site 1 person and/or dog in site Docked or running boat (< 6.7 m away)
High	<2 minutes: >1 person and/or dog in site Boat launching/retrieving on ramp (<6.7 m away)