Western Fisheries Research Center
Klamath Falls Field Station

Near-Shore and Off-Shore Habitat Use by Endangered Juvenile Lost River and Shortnose Suckers in Upper Klamath Lake, Oregon: 2006 Data Summary

By Summer M. Burdick, U.S. Geological Survey, Alexander X. Wilkens, Bureau of Reclamation, and Scott P. VanderKooi, U.S. Geological Survey

Open-File Report 2007-1356

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
DIRK KEMPTHORNE, Secretary

U.S. Geological Survey
Mark D. Myers, Director

U.S. Geological Survey, Reston, Virginia 2008

For product and ordering information:
World Wide Web: http://www.usgs.gov/pubprod
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment:
World Wide Web: http://www.usgs.gov
Telephone: 1-888-ASK-USGS

Suggested citation:
Burdick, S.M., Wilkens, A.X., and VanderKooi, S.P., 2008, Near-shore and off-shore habitat use by endangered juvenile Lost River and shortnose suckers in Upper Klamath Lake, Oregon: U.S. Geological Survey Open-File Report 2007-1356, 30 p.

Contents

Figures

Tables

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)
pound, avoirdupois (lb)	0.4536	kilogram (kg)

SI to Inch/Pound

Multiply	By	To obtain
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
kilometer (km)	0.6214	mile (mi)
kilometer (km)	0.5400	mile, nautical (nmi)
meter (m)	1.094	yard (yd)
	Mass	
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound avoirdupois (lb)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$°F=(1.8\times°C)+32$$

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Near-Shore and Off-Shore Habitat Use by Endangered Juvenile Lost River and Shortnose Suckers in Upper Klamath Lake, Oregon: 2006 Data Summary

By Summer M. Burdick[1], Alexander X. Wilkens[2], and Scott P. VanderKooi[1]

Introduction

Lost River suckers *Deltistes luxatus* and shortnose suckers *Chasmistes brevirostris* , listed as endangered in 1988 under the Endangered Species Act, have shown infrequent recruitment into adult populations in Upper Klamath Lake (NRC 2004). In an effort to understand the causes behind and provide management solutions to apparent recruitment failure, a number of studies have been conducted including several on larval and juvenile sucker habitat use. Near-shore areas in Upper Klamath Lake with emergent vegetation, especially those near the mouth of the Williamson River, were identified as important habitat for larval suckers (Cooperman and Markle 2000; Reiser et al. 2001). Terwilliger et al. (2004) characterized primary age-0 sucker habitat as near-shore areas in the southern portion of Upper Klamath Lake with gravel and cobble substrates. Reiser et al. (2001) provided some evidence that juvenile suckers use habitats with emergent vegetation, but nothing concerning the extent or timing of use.

The U.S. Geological Survey (USGS) began investigating the importance of near-shore and off-shore habitats with and without emergent vegetation for juvenile suckers in 2000. We found substantial numbers of juvenile suckers using these habitats near the mouth of the Williamson River into late August (VanderKooi and Buelow 2003). The distribution and relative abundance of juvenile suckers showed high spatial variability throughout the summer for all species combined, Lost River suckers, and shortnose suckers (VanderKooi et al. 2006; Hendrixson et al. 2007a). Results from sampling near-shore areas in 2002 suggested juvenile sucker proximity to shoreline changes depending on the presence or absence of shoreline vegetation (VanderKooi et al. 2006), whereas in 2004 and 2005 results were equivocal (Hendrixson et al. 2007a, 2007b).

Research by USGS of juvenile suckers in Upper Klamath Lake conducted since 2000 provides a valuable long-term data set which can be used to evaluate multi-year trends in juvenile sucker relative abundance and habitat use. Data on the relative abundance of juvenile suckers and their habitat use patterns will provide valuable information to guide restoration and management decisions in the Upper Klamath Basin. Information on juvenile sucker catch rates may also be valuable for evaluating year class success, estimating early life stage survival rates, and predicting upper bounds of future recruitment to adult spawning populations.

We continued sampling juvenile suckers in 2006 as part of an effort to develop bioenergetics models for juvenile Lost River and shortnose suckers. This study required us to collect fish to determine growth rates and energy content of juvenile suckers. We followed the

[1] U.S. Geological Survey
[2] Bureau of Reclamation

sampling protocols and methods described by Hendrixson et al. (2007b) to maintain continuity and facilitate comparisons with data collected in recent years, but sampled at a reduced level of effort compared to previous years (approximately one-third) due to limited funding. Here we present a summary of catch data collected in 2006. Bioenergetics models will be reported separately.

Methods

Near-Shore Sampling

From 11 July to 15 September 2006 we investigated the use of near-shore habitat by juvenile suckers in two shoreline areas of Upper Klamath Lake, Oregon: the northeastern side of the lake, from the mouth of the Williamson River to Hagelstein Park (north), and the south end of the lake, south of Howard Bay on the west shore and Hanks Marsh on the east shore and around Buck Island (south; Figure 1). To select sites we used stratified-random sampling based on the total area of six substrate classes (cobble, boulder, inter-mix, gravel, sand, and fines), divided evenly between the north and south areas of the lake. We sampled six sites in the north and six in the south each week (three sites per day; Table 1). Throughout the summer we set 216 nets for a total of 4660 net hours. Nets were set between 08:35 and 17:43 and pulled between 07:57 and 14:11. On average the mid point in fishing times occurred at 23:43. Soak time for individual nets ranged from 14.7 to 28.6 hours with a median of 21.2 hours. We assigned a secondary habitat classification to each site based on the presence or absence of the dominant vegetation occurring at each site.

The six substrate types used to stratify sampling were based on the dominant particle size observed during a 1994 survey conducted by Oregon State University (D. Simon, unpublished data). When possible, substrate composition was confirmed visually or by probing the lake bottom with 3.0 x 0.013 m PVC pipe which doubled as a device used to measure water column depth; otherwise substrate was assumed to have remained unchanged since 1994. When conducted, visual or physical substrate confirmation was always positive, suggesting substrate was also correctly classified at unchecked sites.

Fish were collected using 0.9-m diameter fyke nets constructed of 6.4-mm delta mesh and equipped with a 0.9 x 9.1-m lead, two 0.9 x 4.6-m wings, five 0.9-m diameter hoops and two internal fykes. Fyke nets were used in this study because they are an effective gear type widely used in fisheries, low mortality is associated with their use (Hubert 1996), and they have been successfully used to sample juvenile suckers in the Upper Klamath Basin (VanderKooi and Buelow 2003; Terwilliger et al. 2004; VanderKooi et al. 2006). Fyke nets were set overnight in pairs at each sample site with the lead of one net oriented toward shore and the other located in close proximity, but oriented away from shore.

Off-Shore Sampling

We investigated the use of off-shore habitat by juvenile suckers in Upper Klamath Lake along five transects running roughly perpendicular to shore from 11 July through 14 September 2006. We set 75 trap nets for a total of 1641 net hours at five transect locations. Transects were located at five sites: approximately 2 km east of the mouth of the Williamson River (Williamson River East), approximately 2 km south of Modoc Point, immediately north of Hagelstein Park, at the western-most extent of Hanks Marsh, and south of Cove Point (Figure 1). Four of the five transects were sampled once each week with trap nets set 50 and 200 m from shore (Table 2). One transect was removed from the sampling schedule each week on a rotating basis. A third net was set at 100 m from shore at Cove Point on 11 July and at Modoc Point and Williamson River East on

17 July. Nets were set 100 and 400 m from shore at Cove Point and Hanks Marsh, and at 200 and 600 m at Williamson River East during the week of 11 September when sites closer to shore were no longer deep enough to effectively sample.

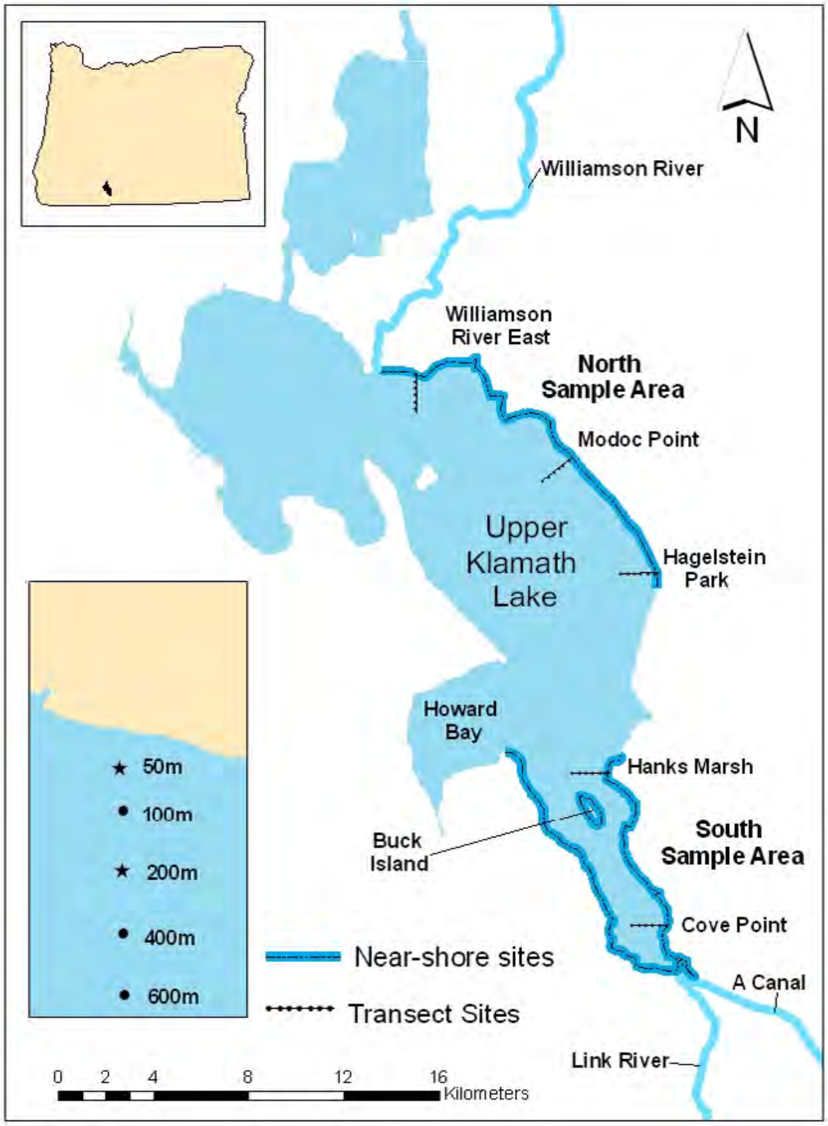

Figure 1. Map of juvenile sampling locations in Upper Klamath Lake, Oregon during the summer of 2006. Near-shore sampling locations in the north and south areas of the lake are indicated by thick lines; transect locations are indicated with dotted lines. The inset in the lower left is representative of net locations along each transect and is not drawn to scale. Stars in the inset indicate the locations along transects where most sampling took place.

Table 1. Number of nets set over each substrate type sampled each week in near-shore areas of Upper Klamath Lake, OR in 2006. Substrate classes are based on the dominant particle size observed during a 1994 survey conducted by Oregon State University (D. Simon, unpublished data). Definitions and particle sizes for each substrate are given in Hendrixson et al. (2007a). Each site was sampled with a pair of nets, with one net set facing away from shore and another facing toward shore. An equal number of nets were set in both the north and south areas in each substrate type.

	Substrate						
Week	Boulder	Cobble	Fines	Gravel	Inter-mix	Sand	Total
11-Jul	0	2	2	0	0	2	6
17-Jul	4	4	4	4	4	4	24
24-Jul	4	4	4	4	4	4	24
31-Jul	4	4	4	4	4	4	24
7-Aug	4	4	4	4	4	4	24
14-Aug	4	4	4	4	4	4	24
21-Aug	4	4	4	4	4	4	24
28-Aug	4	4	4	4	4	4	24
5-Sep	2	2	4	4	2	4	18
11-Sep	4	4	4	2	6	4	24
Total	34	36	38	34	36	38	216

Table 2. Number of nets set along transects in Upper Klamath Lake by distance from shore in 2006. Transects were set perpendicular to shore at four of five sites each week. Distance from shore is given in meters.

	Distance From Shore (m)					
Transect	50	100	200	400	600	Total
Cove Point	6	3	6	2	0	17
Hanks Marsh	6	1	6	1	0	14
Hagelstein Park	7	0	7	0	0	14
Modoc Point	7	1	7	0	0	15
Williamson River East	6	8	0	0	1	15
Total	32	13	26	3	1	75

Fish were collected in overnight sets of trap nets constructed of 6.4-mm delta mesh that consisted of a 1.2 x 16.0-m lead followed by a rectangular frame (1.2 m x 1.8 m x 1.0 m). The trap frame led into four 1.0-m diameter circular hoops spaced 1.0 m apart and contained three internal fykes. Trap nets were chosen for use in this study because they have similar positive attributes to fyke nets, which are listed above. Nets were set between 09:02 and 16:36 and pulled between 07:59 and 15:20 hours. Soak times varied between 17.4 and 27.4 hours with a median of 22.8 hours.

Protocols for Handling, Identifying, Quantifying, and Preserving Fish

Fish captured in fyke and trap nets in 2006 were identified to species (sucker spp. were initially only identified to family and sculpin spp. to genus) and counted. Standard length was recorded for all suckers. We used weekly length frequency data to separate age-0 from age-1 or older suckers caught in our nets. Due to difficulty in identifying juvenile suckers to species in the field, a proportion (14%) were sacrificed and preserved for later identification. Sacrificed fish were placed on ice in the field, weighed to the nearest 0.1 g upon return to the laboratory, and either frozen for future energy content analysis or preserved in 95 % ethanol. Juvenile suckers were identified to species using a method that employs a combination of techniques including vertebral counts, lip morphology, and gill raker counts (Markle et al. 2005).

Catches were sub-sampled for all species except suckers when catches exceeded 2 to 3 kg, and all fish were sub-sampled when catches exceeded approximately 200 suckers. Prior to sub-sampling, fish larger than approximately 200 mm were enumerated and removed from the sample prior to weighing to avoid unrepresentative extrapolations. The remaining catch was weighed by spring scale and placed in a large water-filled tub. The contents of the tub were thoroughly mixed and approximately 1 to 2 kg was removed by dip net and weighed by spring scale. Fish in the sub-sample were identified to species (sucker spp. were initially only identified to family and sculpin spp. to genus) and counted.

Summarizing Data

We summarized data collected in both near-shore and off-shore sampling. Catch per unit effort (CPUE) was calculated as the number of fish per hour of soak time. The estimated number of each sucker species in a catch was obtained by multiplying the species proportion in the sacrificed sub-sample by the total number of juvenile suckers caught. We estimated the number of each non-sucker species in the total catch by extrapolation using the ratio of sub-sample weight to total weight. Sub-sample species composition was assumed to be representative of the total catch.

Figures summarizing CPUE data were created for juvenile Lost River suckers, shortnose suckers, and for a combination of all sucker species combined. We created graphical displays of mean CPUE by net orientation (toward or away from shore), substrate, secondary habitat classification, area (north and south), and week. For off-shore sampling we created graphical displays of mean CPUE by transect, and week. Catch per unit effort of non-sucker species was summarized by substrate, secondary habitat type, transect location, distance from shore, and week.

We plotted mean weekly sucker length and weight, using measurements taken from sacrificed fish. Large outliers were considered to be age-1 or older fish and were excluded from mean length and weight plots. We examined growth by fitting the power function described by Anderson and Neumann (1996) to weight-length data for both shortnose and Lost River suckers caught in near-shore and off-shore net sets. The power function is written as $W = aL^b$, where W is weight, L is length and a and b are parameters. A value of b equal to 3.0 indicates isometric growth, meaning that fish do not become more or less rotund as length increases (i.e., body shape remains the same as fish grow).

Results and Discussion

Near-Shore Sampling

We caught 10,399 juvenile suckers in near-shore net sets during 2006. Fish of at least one species were present in all nets and suckers were present in 75% of all nets. Due to high numbers of suckers captured, only 51.8% were measured. Juvenile sucker species composition differed from recent years when Lost River suckers were the most common sucker in near-shore sampling. In 2006, near-shore catches of suckers were composed of 50.3% shortnose sucker, 43.4% Lost River sucker, 6.2% unidentified sucker and 0.1% Klamath largescale sucker *Catostomus snyderi*. For comparison, sucker species composition was 54.0% Lost River sucker, 30.0% shortnose sucker, 13.6% unidentified sucker and 1.8% Klamath largescale sucker in 2004 (Hendrixson et al. 2007a) and 52.6% Lost River sucker, 32.3% shortnose sucker, 14.0% unidentified sucker and 1.1% Klamath largescale sucker in 2005 (Hendrixson et al. 2007b).

Mean weekly CPUE was low for juvenile suckers during the weeks of 10 July to 24 July. Peak catches for both Lost River and shortnose suckers occurred during the week of 31 July followed by a general decline through the completion of sampling the week of 11 September (Figure 2). This seasonal pattern in catch rates was observed in both north and south areas; however, catch rates were generally higher in the north for both species (Figure 3). Mean weekly CPUE of Lost River and shortnose suckers was at least an order of magnitude greater in 2006 than in the previous two years (Figure 4). Peak CPUE occurred during the same week in 2005 (Hendrixson et al. 2007b) as in 2006 for both species (Figure 4). In contrast, peak CPUE occurred in 2004 during the week of 22 August for Lost River suckers and 29 August for shortnose suckers (Hendrixson et al. 2007a; Figure 4).

Juvenile suckers were caught over all substrate types sampled in 2006. For both Lost River and shortnose suckers, mean seasonal CPUE was highest over gravel and cobble, moderate over boulders, inter-mix, and sand, and lowest over fines (Figure 5a). The highest to lowest percentage of positive catches (nets that caught at least one individual of a species) for Lost River suckers occurred over cobble (61.6%), followed by sand (52.6%), gravel (50.0%), and inter-mix (41.7%). Slightly lower percentages of positive catches occurred over boulder (35.3%), and fines (26.3%; Figure 5a). For shortnose suckers the order of percentage of positive catches by substrate from highest to lowest was sand (68.4%) > cobble (63.9%) > gravel (55.9%) > inter-mix (52.8%) > boulder (47.1%) > fines (42.1%; Figure 5a).

The order of juvenile sucker CPUE and percent positive catch by substrate has been variable year to year. Mean CPUE was highest for Lost River and shortnose suckers over inter-mix and cobble substrates in 2004 (Hendrixson et al. 2007a) and highest over sand and gravel for Lost River suckers and cobble for shortnose suckers in 2005 (Hendrixson et al. 2007b). Percent positive catches were highest for Lost River suckers over inter-mix in 2004 and sand in 2005 and highest for shortnose suckers over cobble in 2004 and inter-mix in 2005.

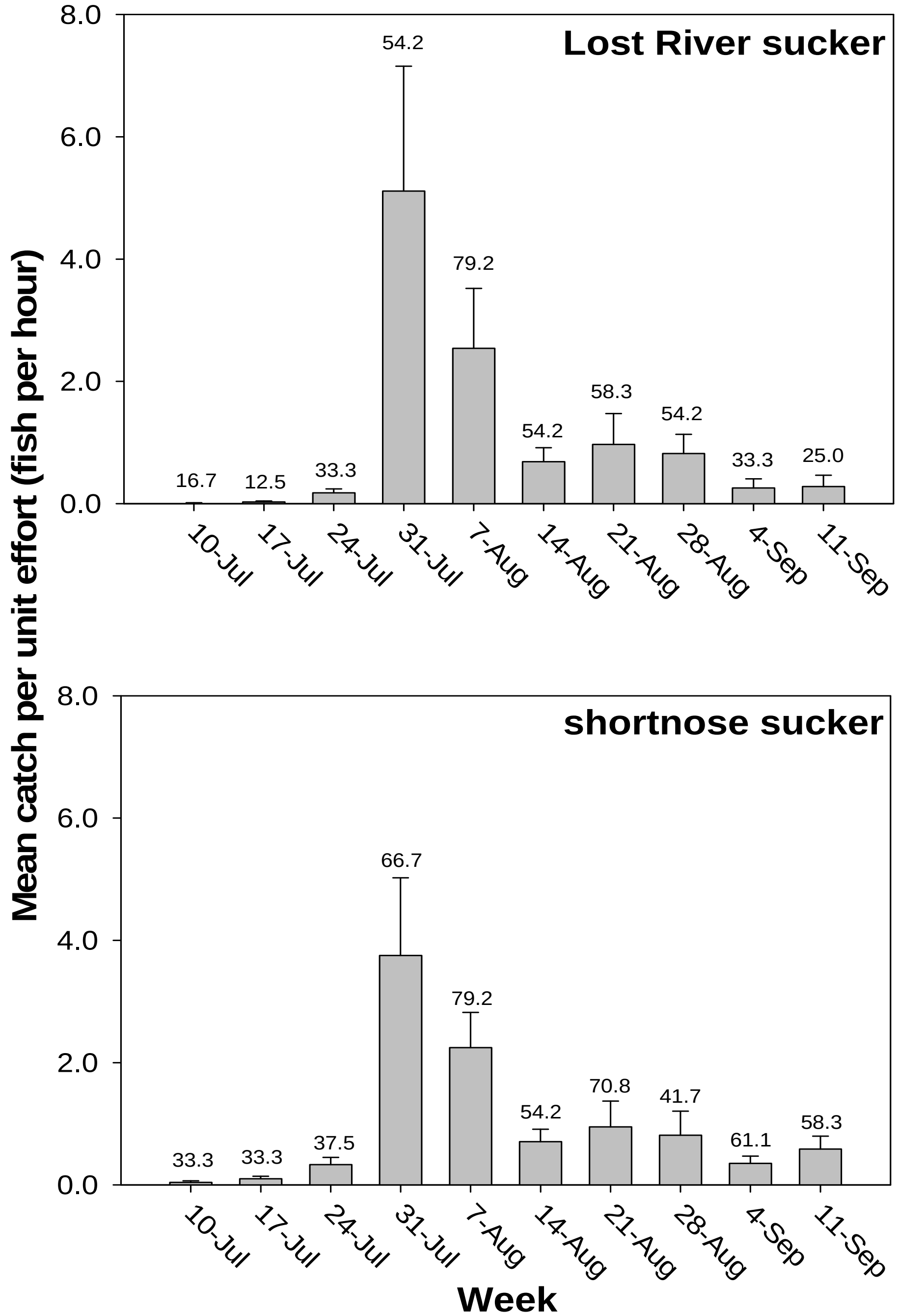

Figure 2. Mean weekly catch per unit effort (fish per hour) and standard error of juvenile Lost River and shortnose suckers captured by fyke net in near-shore areas of Upper Klamath Lake, Oregon, in 2006. The percentage of nets that captured at least one sucker is given for each week.

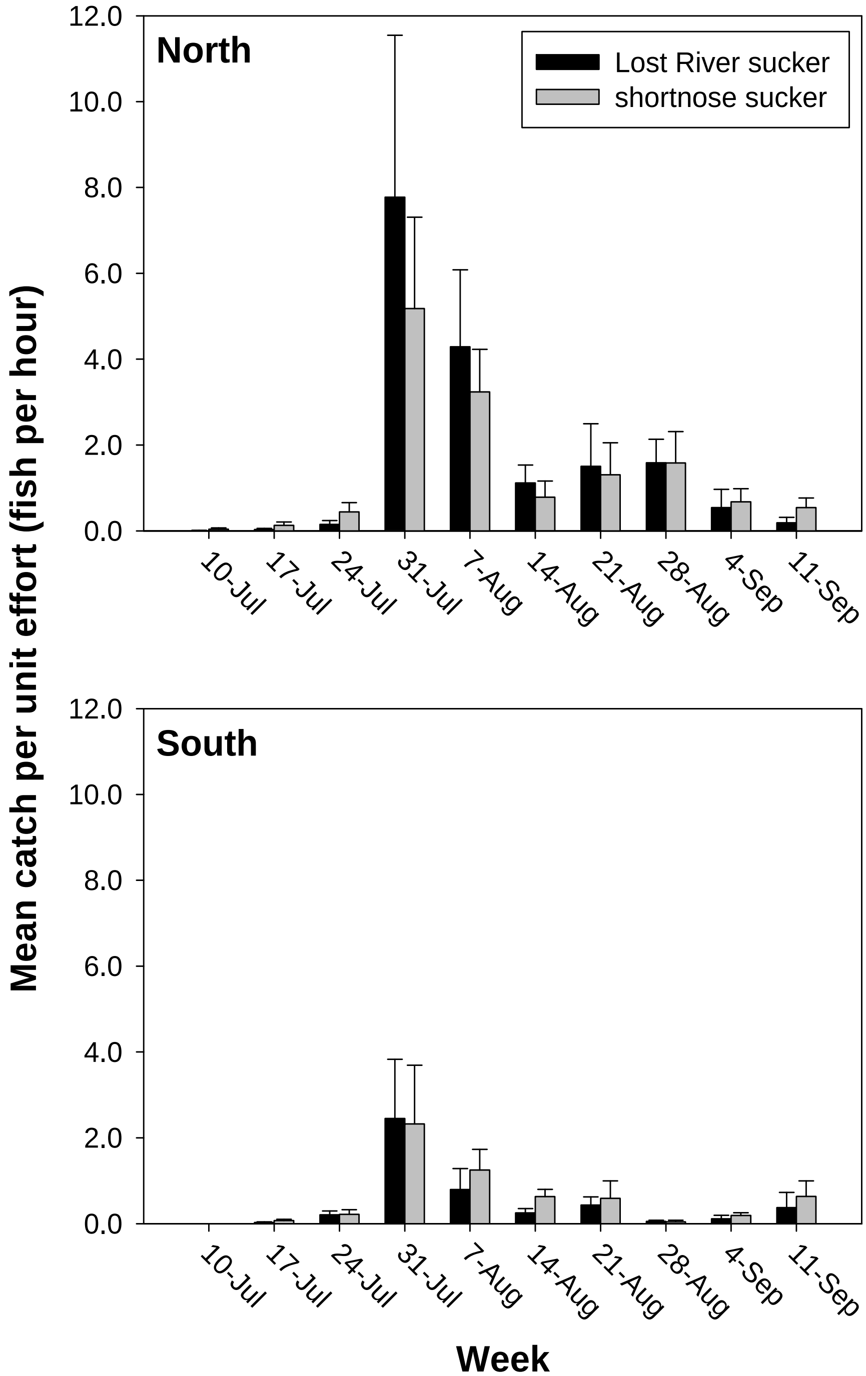

Figure 3. Mean weekly catch per unit effort (fish per hour) and standard error of juvenile Lost River and shortnose suckers captured by fyke net in near-shore areas of Upper Klamath Lake, Oregon, in 2006. The two areas sampled, North and South, are shown in Figure 1.

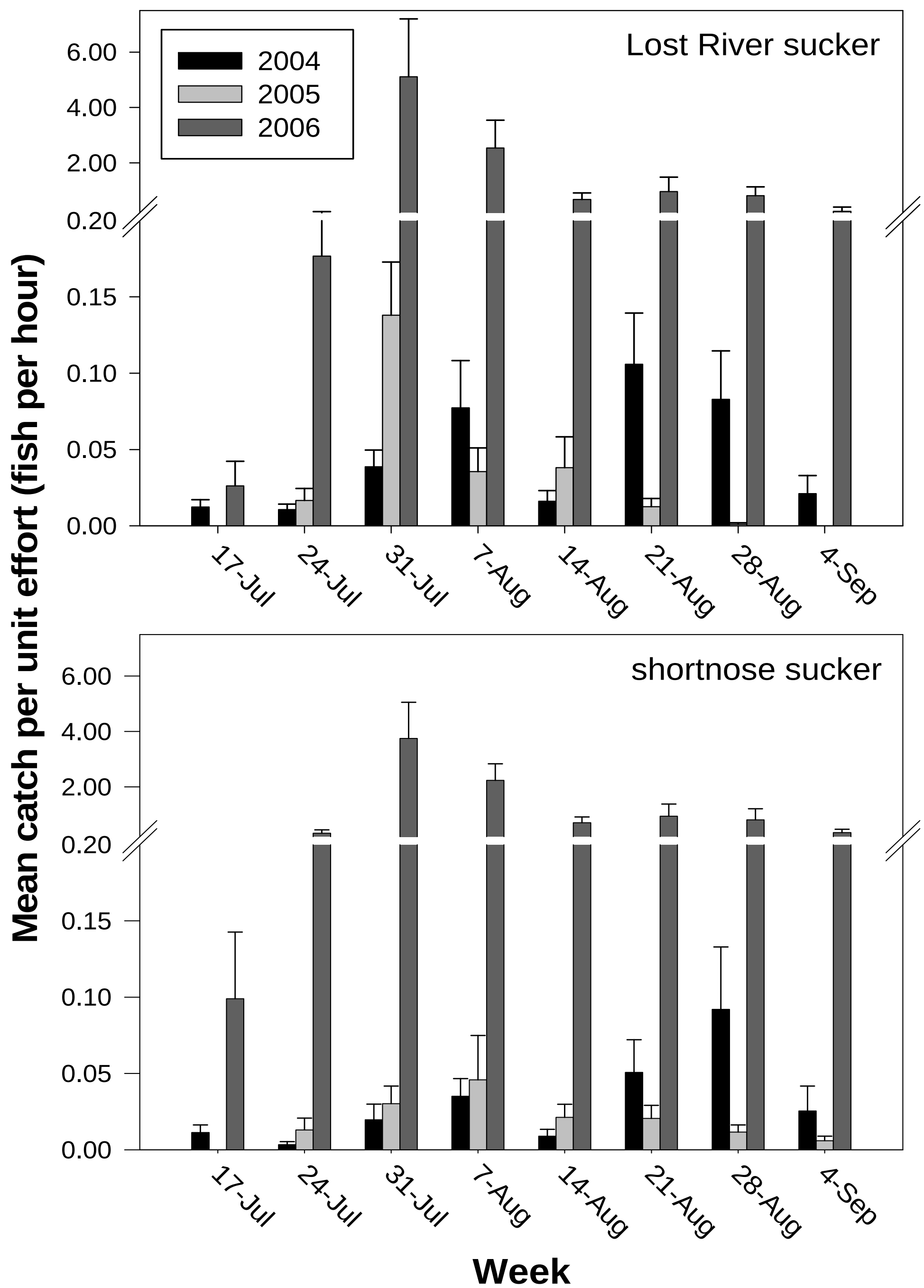

Figure 4. Mean weekly catch per unit effort (fish per hour) and standard error of juvenile Lost River and shortnose suckers captured by fyke net in near-shore areas of Upper Klamath Lake, Oregon, from 2004 to 2006. Data obtained from Hendrixson et al. (2007a) for 2004 and Hendrixson et al. (2007b) for 2005.

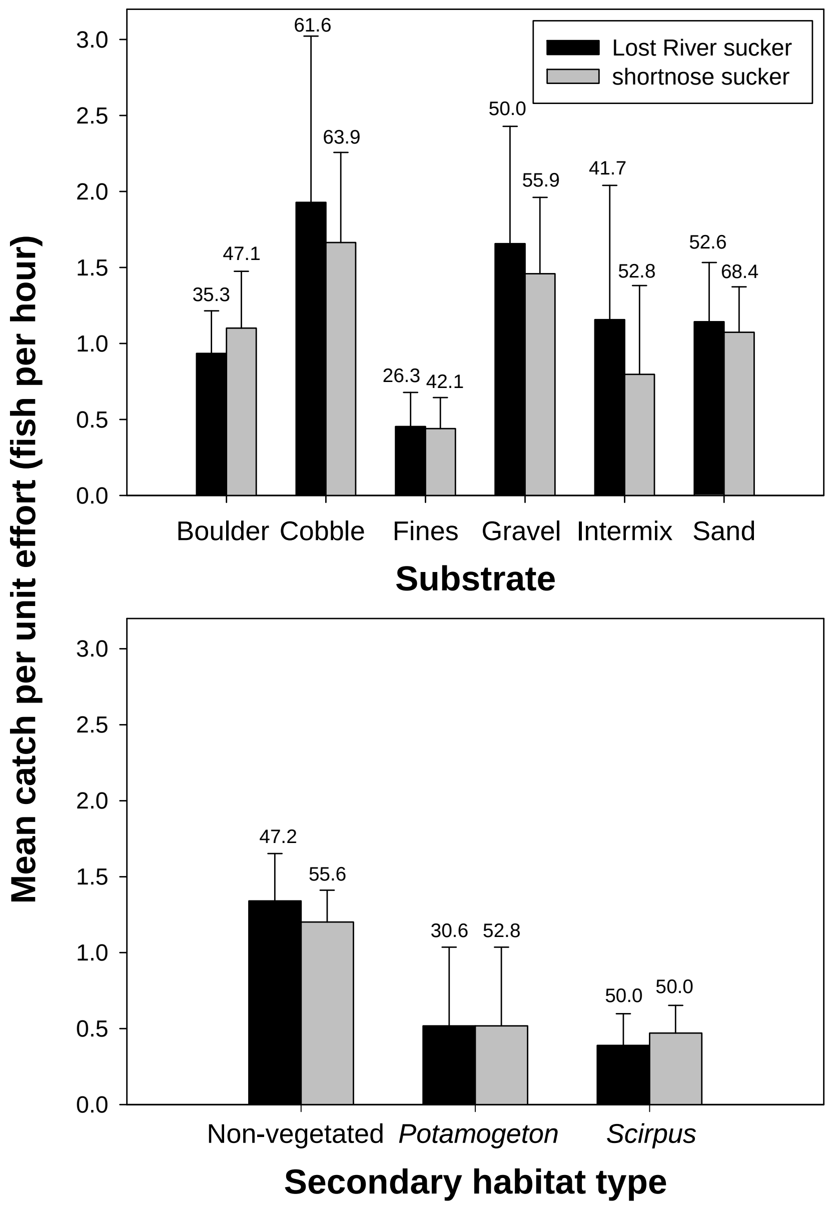

Figure 5. Mean seasonal catch per unit effort (fish per hour) and standard error by substrate (top) and secondary habitat type (bottom) of juvenile Lost River and shortnose suckers captured by fyke net in near-shore areas of Upper Klamath Lake, Oregon in 2006. The percentage of nets that captured at least one sucker is given for each species by substrate or habitat type. The numbers of sites sampled in each substrate type each week are listed in Table 1. The numbers of sites sampled for each of the secondary habitat types is as follows: Non-vegetated n = 178; *Potamogeton* n = 36; *Scirpus* n = 2.

Mean seasonal CPUE was higher for both Lost River and shortnose suckers at non-vegetated sites than sites with *Scirpus spp*. or *Potamogeton spp*. in 2006 (Figure 5b). For Lost River suckers the percentage of positive sucker catches was greatest at sites with *Scirpus spp*. (50.0%), followed by non-vegetated sites (47.2%) and sites with *Potamogeton spp*. (30.6%). The highest percentage of positive catches for shortnose suckers occurred in non-vegetated sites (55.6%), followed by sites with *Potamogeton spp*. (52.8%) and *Scirpus spp*. (50.0%; Figure 5b). Direct comparisons of catches by secondary habitat type among years were not possible due to the small number or absence of sampling at sites with certain types of vegetation (i.e., *Scirpus spp*. and *Salix spp*.) in 2006.

Some trends in mean CPUE for juvenile Lost River and shortnose suckers were observed when net orientation was examined by substrate and secondary habitat type. Mean seasonal CPUE for both Lost River and shortnose suckers was higher in nets facing toward shore over all substrate types except gravel (Figure 6). Catch rates were higher for both species in nets facing toward shore in non-vegetated sites and sites with *Potamogeton spp*. (Figure 7). However, in 2006 no nets were set facing toward shore in *Scirpus spp*., therefore a comparison between net orientations could not be made for this habitat type. Limited or no sampling in certain habitats also prevented among-year comparisons. Mean CPUE among secondary habitat types may vary for a number of reasons, including interactions between substrate and vegetation, and differential capture efficiency among habitats. Therefore, we caution readers against drawing conclusions from summary statistics presented in this report.

Mean standard lengths (SL) and weights of age-0 suckers captured in near-shore areas steadily increased throughout the 2006 sampling season for all sucker species combined, Lost River suckers, and shortnose suckers (Figures 8 and 9). For all juvenile sucker species combined, mean (± SE) SL of all captured fish and weights of sacrificed fish were 40.9 ± 1.4 mm and 1.2 ± 0.2 g at the start of sampling (the week of 10 July) and 73.5 ± 1.4 mm and 6.8 ± 0.3 g the last week of sampling (the week of 11 September). Mean SL of Lost River suckers was greater than shortnose suckers for all weeks of sampling except the week of 7 August (Figure 8). In contrast, the greatest mean weekly weight alternated between Lost River and shortnose suckers on a near weekly basis with Lost River suckers being heavier the last week of sampling (Figure 9). Fitting the power curve described by Anderson and Neumann (1996) to juvenile Lost River sucker weight-length data (Figure 10) yields the equation;

$$\text{Weight} = (2.286\text{x}10^{-5}) \cdot \text{Length}^{2.897},\ r^2 = 0.98.$$

Fitting this curve to juvenile shortnose sucker weight-length data (Figure 10) yields the equation;

$$\text{Weight} = (3.344\text{x}10^{-5}) \cdot \text{Length}^{2.829},\ r^2 = 0.96.$$

Mean SL (± SE) of age-0 suckers (all species combined) captured near-shore during the week of 17 July in 2006 (44.2 ± 0.6) was slightly greater than the mean SL during the first week of sampling in previous years; 38.0 ± 0.9 mm the week of 19 July 2004 and 43.5 ± 4.9 mm the week of 18 July 2005 (Hendrixson et al. 2007a, 2007b). Mean SL (± SE) during the week of 4 September in 2006 (69.8 ± 0.9) was greater than at the conclusion of sampling in 2004 (61.3 ± 4.1 mm the week of 6 September) and 2005 (57.6 ± 2.0 mm the week of 5 September). Species comparisons in 2004 and 2005 showed Lost River suckers were consistently longer than shortnose suckers (Hendrixson et al. 2007a, 2007b). Weights were not measured in past years, thus among year comparisons of weights and weight-length relations could not be made.

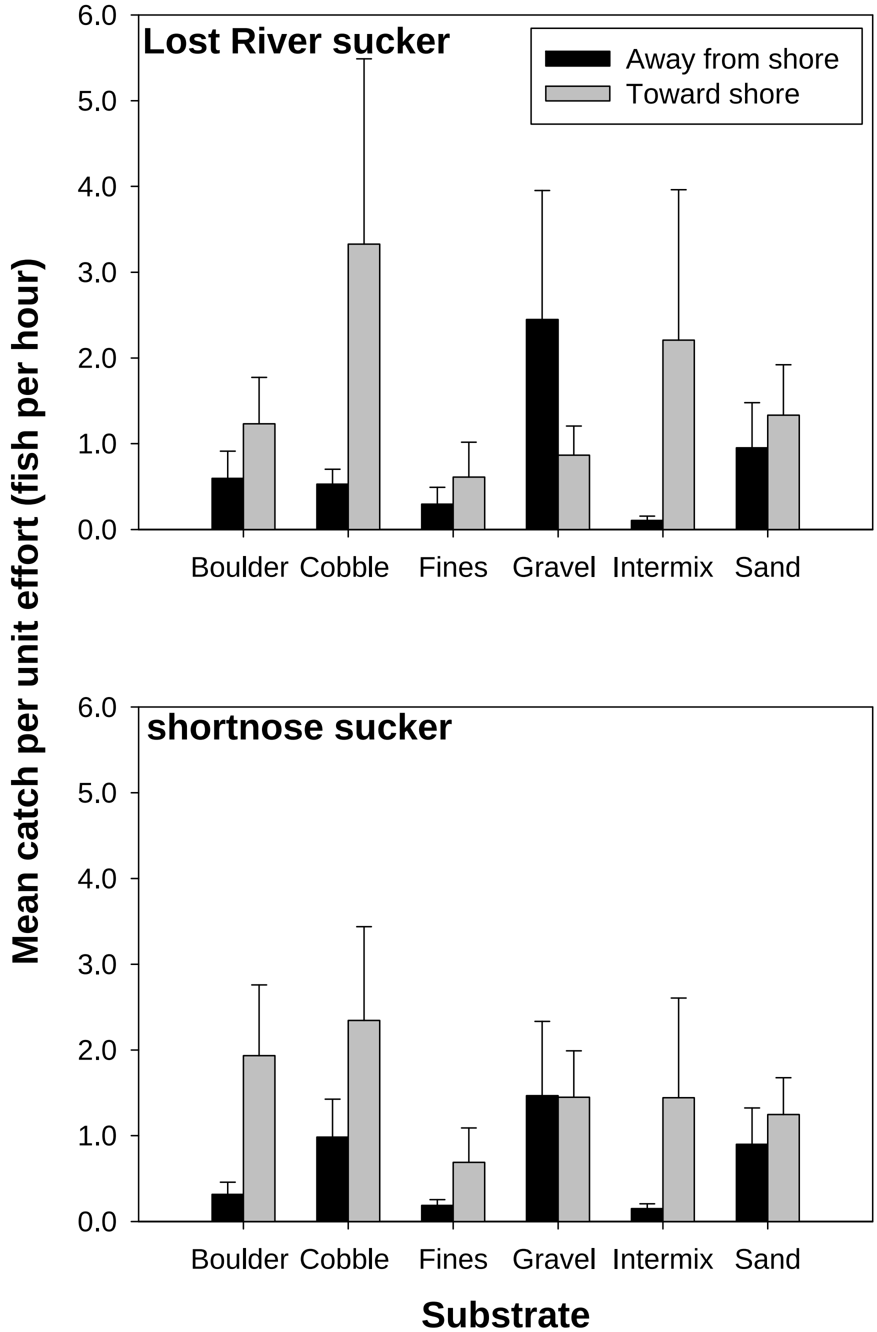

Figure 6. Mean seasonal catch per unit effort (fish per hour) and standard error, by net orientation and substrate, of juvenile Lost River and shortnose suckers captured by fyke net in near-shore areas of Upper Klamath Lake, Oregon in 2006. Nets were set in pairs, such that the mouth of one net faced toward shore, and the mouth of the other net faced away from shore. The numbers of sites sampled in each substrate type each week are listed in Table 1.

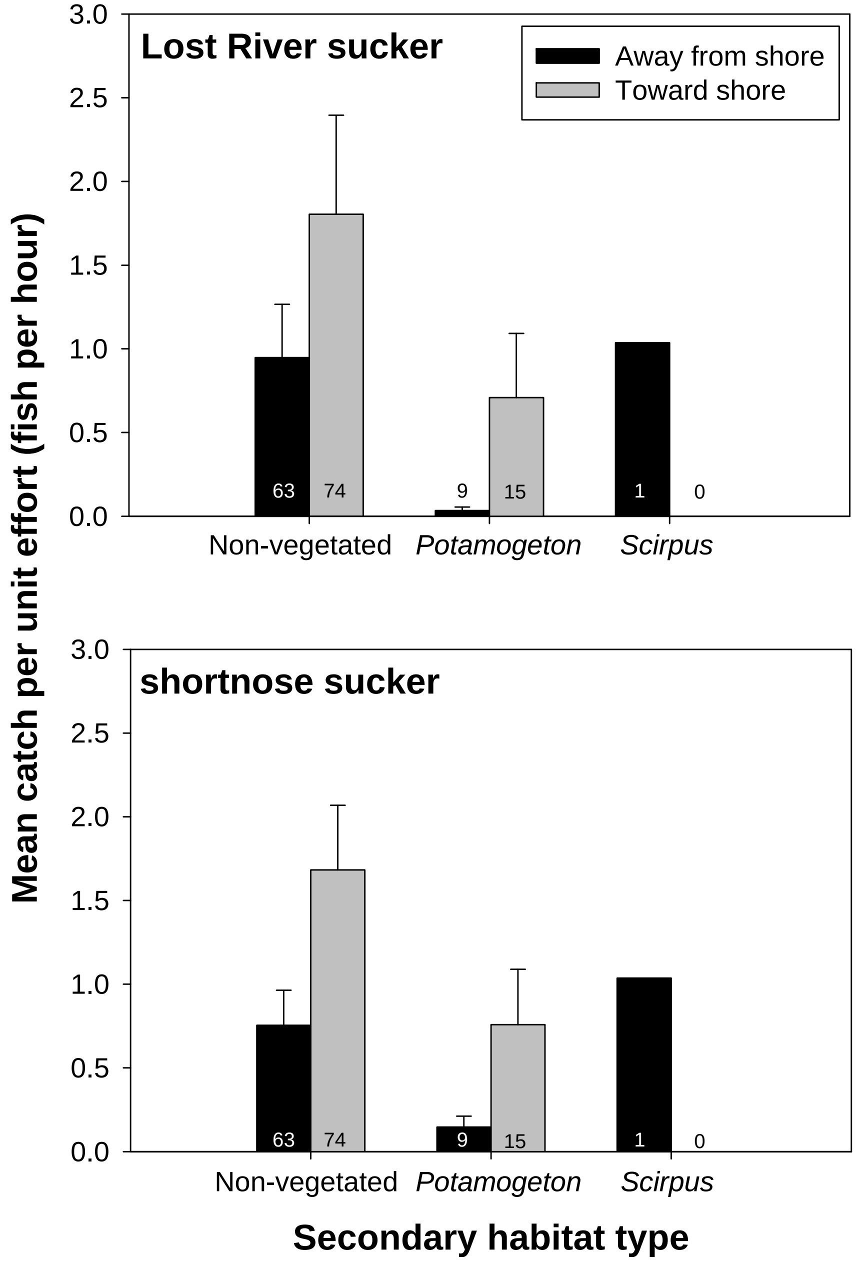

Figure 7. Mean seasonal catch per unit effort (fish per hour) and standard error, by net orientation and secondary habitat type, of juvenile Lost River and shortnose suckers captured by fyke net in near-shore areas of Upper Klamath Lake, Oregon in 2006. Nets were set in pairs, such that the mouth of one net faced toward shore, and the mouth of the other net faced away from shore. The numbers of sites sampled in each secondary habitat type are given.

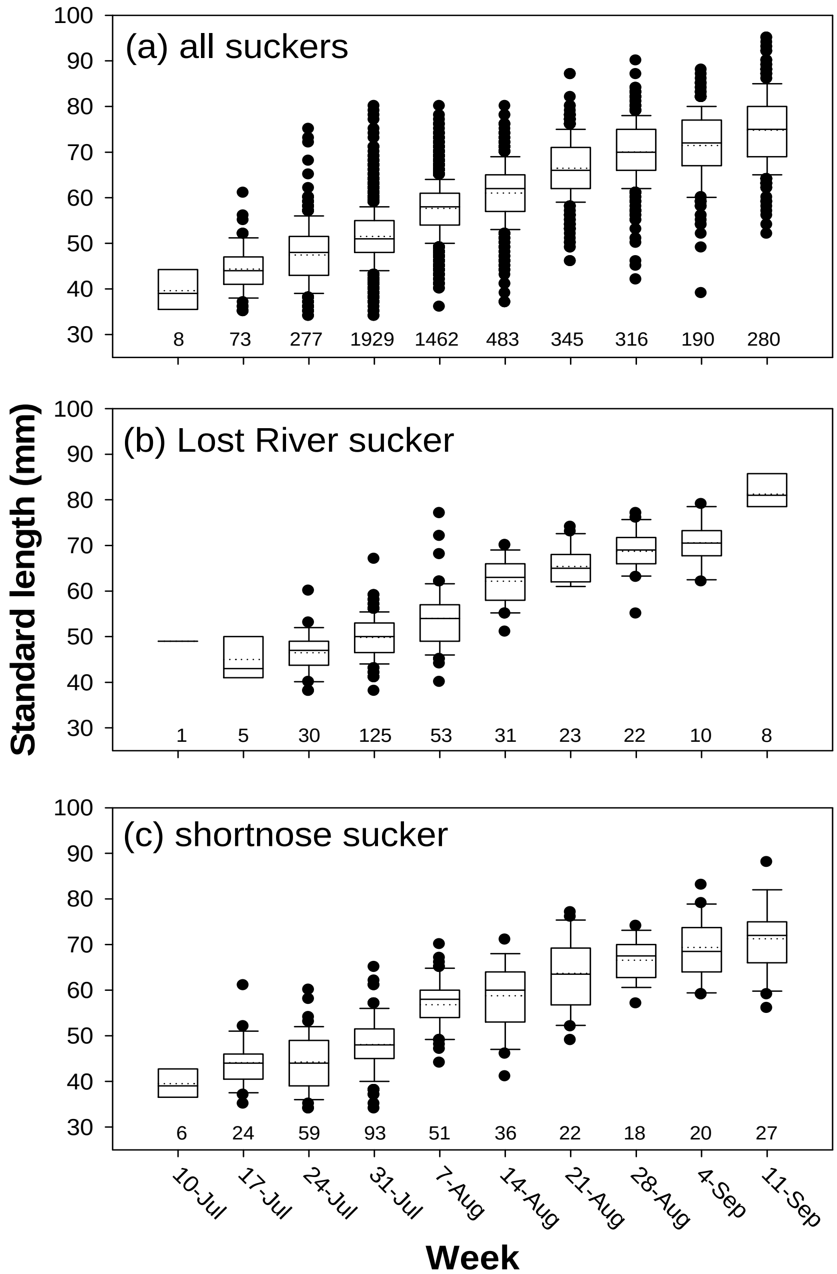

Figure 8. Box plots of standard lengths (mm) of all age-0 sucker species combined (a), and sacrificed Lost River (b) and shortnose suckers (c) captured by fyke net in near-shore areas of Upper Klamath Lake, Oregon in 2006. Nineteen suckers determined to be age-1 or older based on longer than expected length at age were removed from figure a, one Lost River sucker was removed from figure b, and two shortnose suckers were removed from figure c. Box plots indicate 25th, 50th (median), and 75th percentiles, the dotted line indicates the mean, whiskers indicate the 10th and 90th percentiles, and dots indicate outliers in observed data. Numbers of fish used for each plot are given by week.

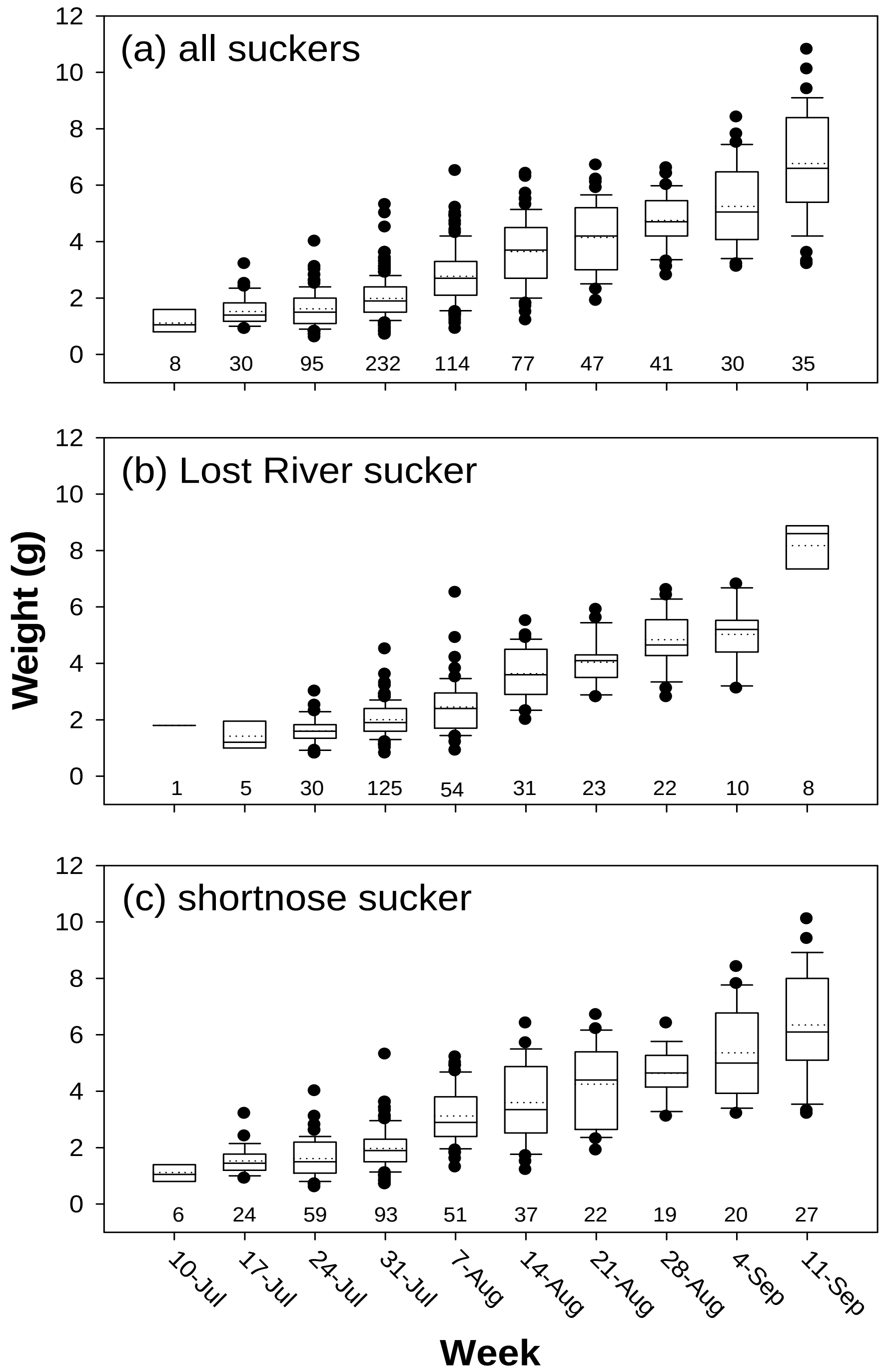

Figure 9. Box plots of weights (g) for all age-0 sucker species combined (a), and sacrificed Lost River (b) and shortnose suckers (c) captured by fyke net in near-shore areas of Upper Klamath Lake, Oregon in 2006. Nineteen suckers determined to be age-1 or older based on longer than expected length at age were removed from figure a, one Lost River sucker was removed from figure b, and two shortnose suckers were removed from figure c. Box plots indicate 25th, 50th (median), and 75th percentiles, the dotted line indicates the mean, whiskers indicate the 10th and 90th percentiles, and dots indicate outliers in observed data. Numbers of fish used for each plot are given by week.

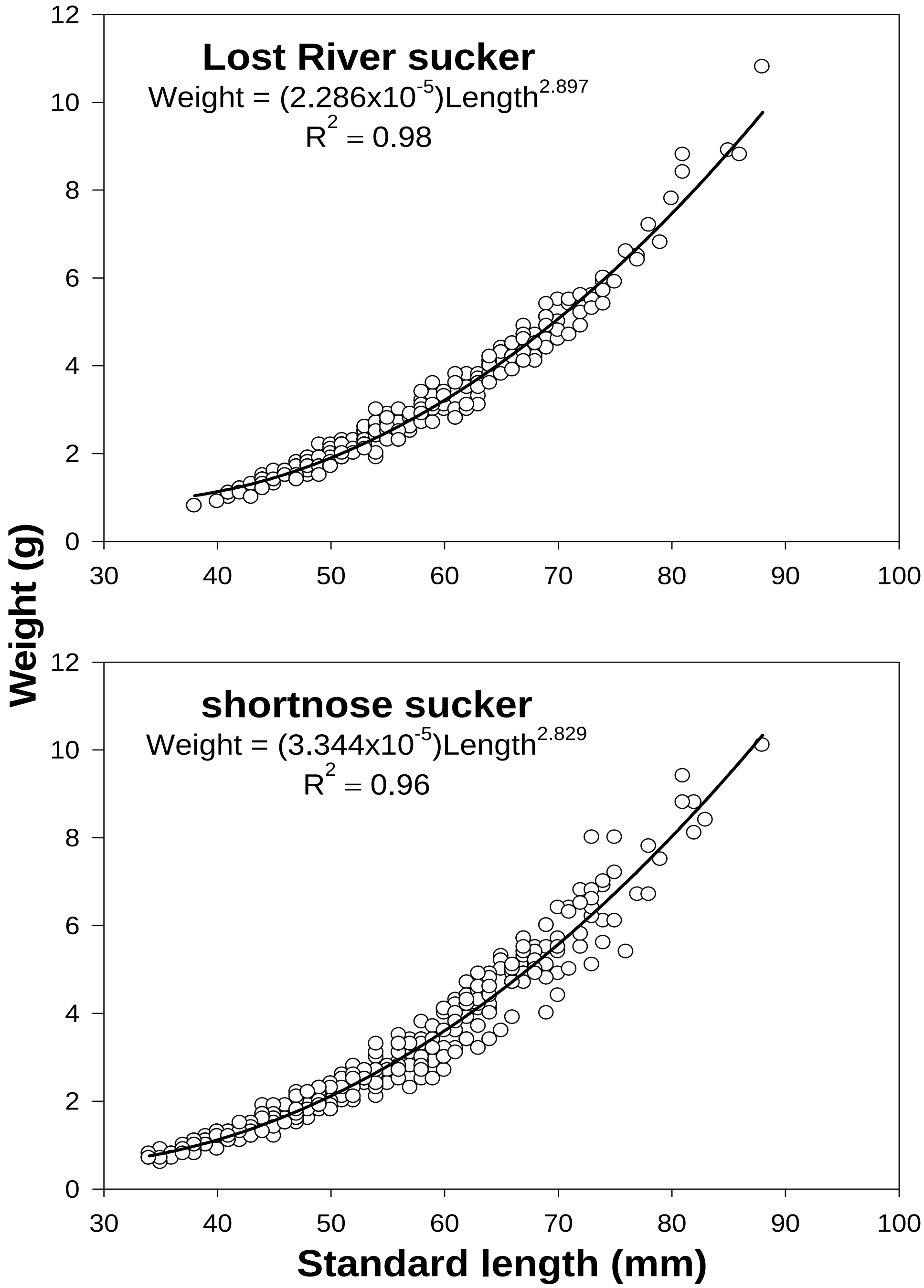

Figure 10. Relation between weight (g) and standard length (mm) of sacrificed juvenile Lost River and shortnose suckers captured by fyke net in near-shore areas of Upper Klamath Lake, OR in 2006. One Lost River sucker and two shortnose suckers determined to be age-1 based on longer than expected length at age were excluded.

Nineteen of the measured suckers were considered age-1 or older based on longer than expected length (81 to 143 mm SL) on date of capture. Eighteen of the age-1 or older suckers were caught in non-vegetated sites and one was caught in *Potamogeton* spp. Eight age-1 or older suckers were caught over gravel, five over sand, three over inter-mix substrate, two over boulders, and one over fines. Five of the age-1 or older suckers were caught in the north and fourteen in the south. Only three of the age-1 or older suckers were sacrificed and identified to species. Of these, two were shortnose suckers and one was a Lost River sucker.

Catches of age-1 suckers have always been low and sporadically distributed throughout the lake. In 2004, only four were captured in near-shore areas (95 to 100 mm SL): three in the north and one in the south and all over cobble substrate (Hendrixson et al. 2007a). In 2005 we caught 17 age-1 suckers (83 to 124 mm): nine in the north and eight in the south. These fish were caught over a variety of substrates: seven over fines, five over gravel, two over cobble, two over inter-mix, and one over sand (Hendrixson et al. 2007b). Each year three age-1 suckers were sacrificed and identified to species; in 2004 all were shortnose suckers and in 2005 two were shortnose suckers and one was a Klamath largescale sucker.

Overall catches and percentages of near-shore nets that caught at least one non-sucker fish species were high. The order of highest to lowest mean CPUE by more common species was yellow *perch Perca flavescens* > fathead minnow *Pimephales promelas* > blue chub *Gila coerulea* > tui chub *G. bicolor* > sucker spp. > brown bullhead *Ameiurus nebulosus* > sculpin spp. *Cottus* spp. > pumpkinseed *Lepomis gibbosus*. Other species caught infrequently in our near-shore nets included lamprey *Lampetra spp*., largemouth bass *Micropterus salmoides*, and speckled dace *Rhinichthys osculus*. Sculpin spp. had the widest distribution and were captured in 92% of nets, followed by yellow perch in 87% of nets, fathead minnow in 84% of nets, blue chub in 83% of nets, and tui chub in 82% of nets. The percentage of nets that captured brown bullhead (45%), pumpkinseed (29%), largemouth bass (11%), and lamprey (10%) were much smaller. Speckled dace were only captured in one net in the south end of the lake over inter-mix substrate on 26 July.

Some trends in mean CPUE for non-sucker species captured near-shore were apparent when compared by substrate, secondary habitat type, area of the lake, and week. Yellow perch dominated catches in the north, whereas fathead minnows were most abundant in the south (Figures 11 to 13). Mean CPUE combined for all species was greater in non-vegetated sites than in *Potamogeton* spp. sites (Figure 12). Yellow perch CPUE peaked four weeks earlier in the south than in the north (Figure 13). Fathead minnow CPUE appeared somewhat bimodal, with a smaller peak occurring during the week of 31 July and a second and larger peak occurring during the week of 4 September (Figure 13).

Non-sucker catch rates and habitat use patterns were generally variable year to year with a few notable consistencies. In 2004, fathead minnow were most abundant fish species captured (Hendrixson et al. 2007a) while yellow perch were most abundant in 2005 (Hendrixson et al. 2007b). As observed in 2006, mean CPUE was greater in the north for yellow perch and greater in the south for fathead minnow in both 2004 and 2005 (Hendrixson et al. 2007a, 2007b). Fathead minnow catches also consistently increased in mid to late August in all years. Sculpin spp. consistently had the widest distribution, being present in over 90% of nets set near-shore since 2004.

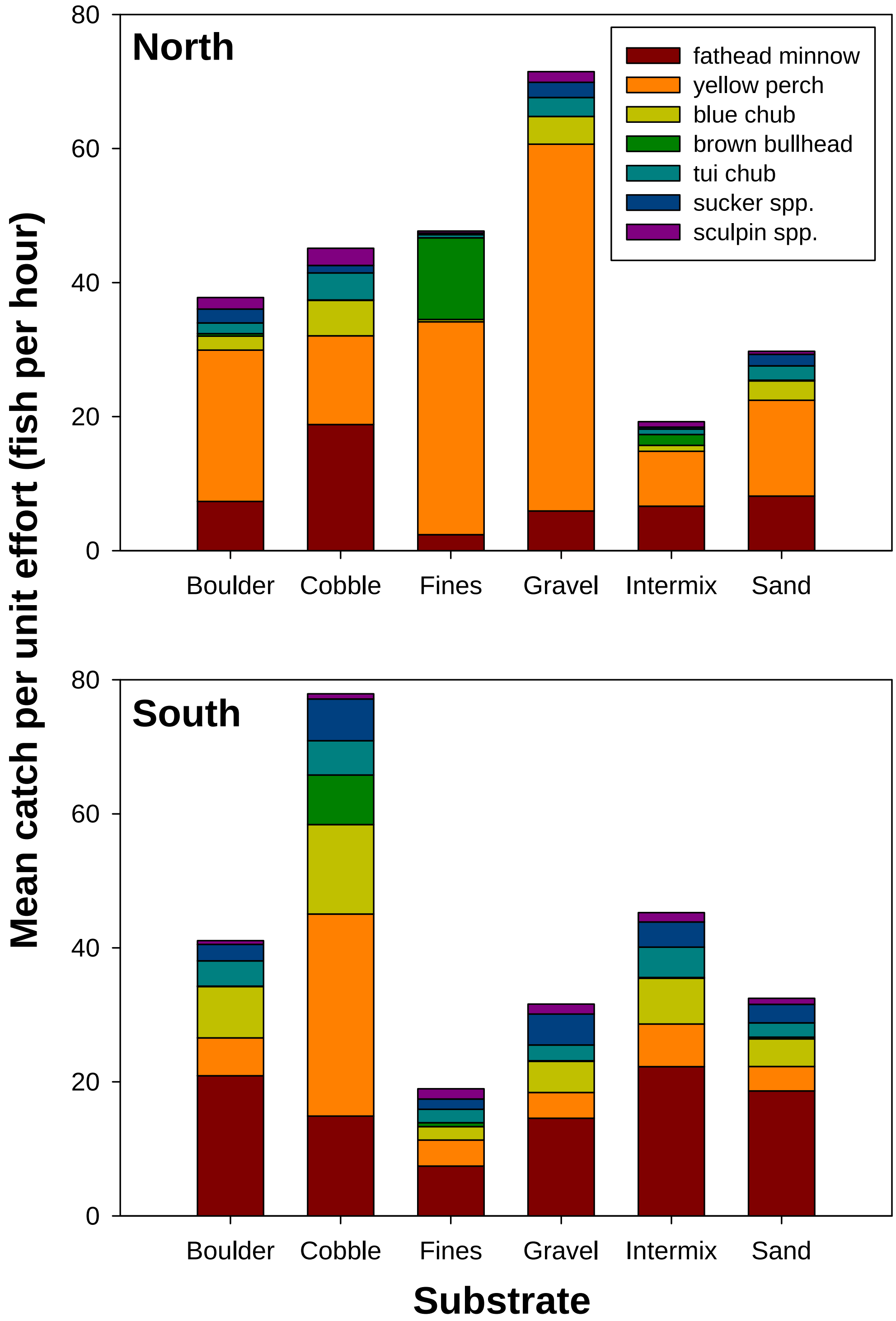

Figure 11. Mean seasonal catch per unit effort (fish per hour) of fish species captured by fyke net in near-shore areas of Upper Klamath Lake, OR in 2006 over six categories of substrate. The two areas sampled, North and South, are shown in Figure 1. The numbers of sites sampled in each substrate type each week are listed in Table 1.

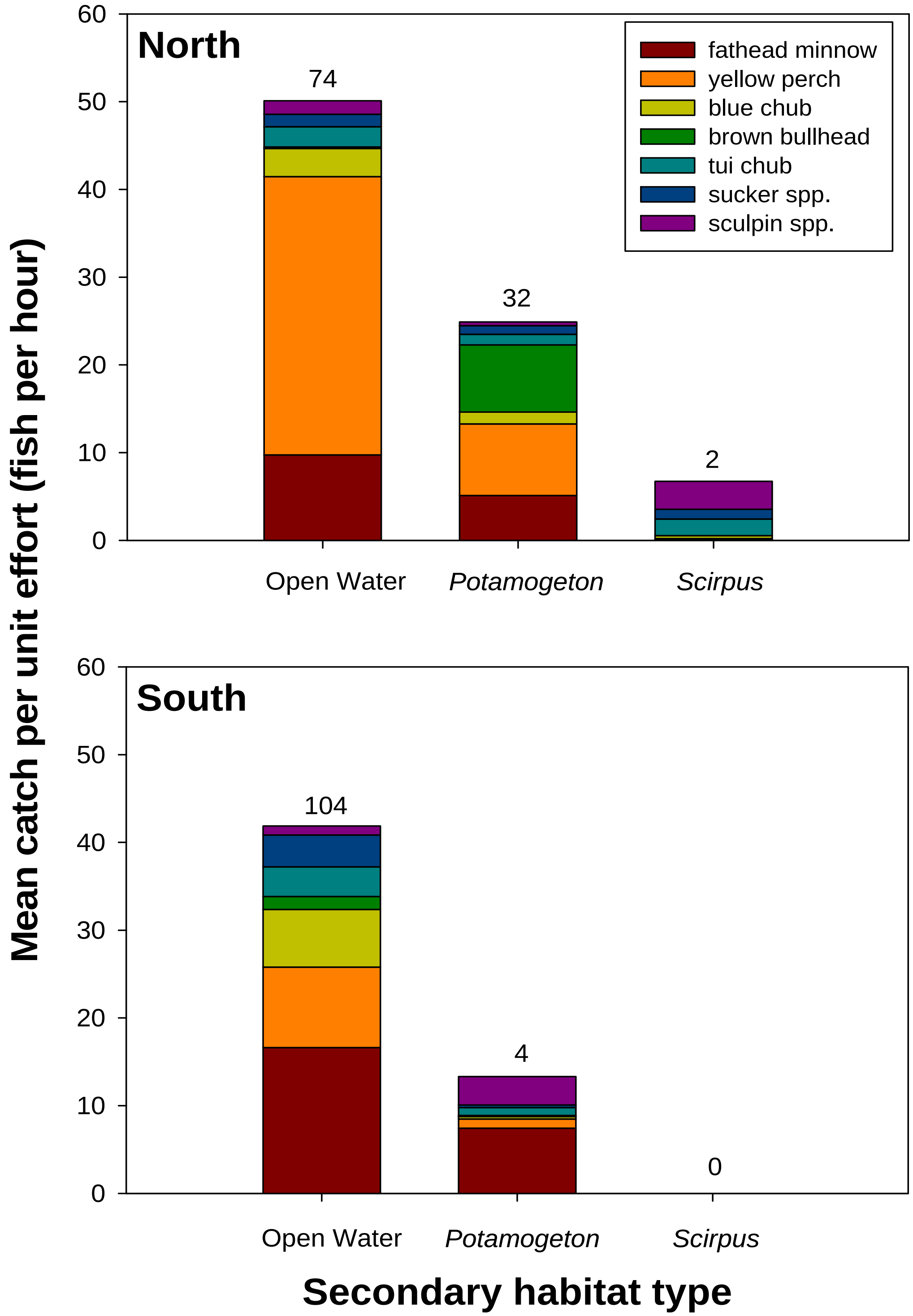

Figure 12. Mean seasonal catch per unit effort (fish per hour) of fish species captured by fyke net in near-shore areas of Upper Klamath Lake, Oregon in 2006 in three secondary habitat types. The two areas sampled, North and South, are shown in Figure 1. The numbers of sites sampled in each secondary habitat type are given.

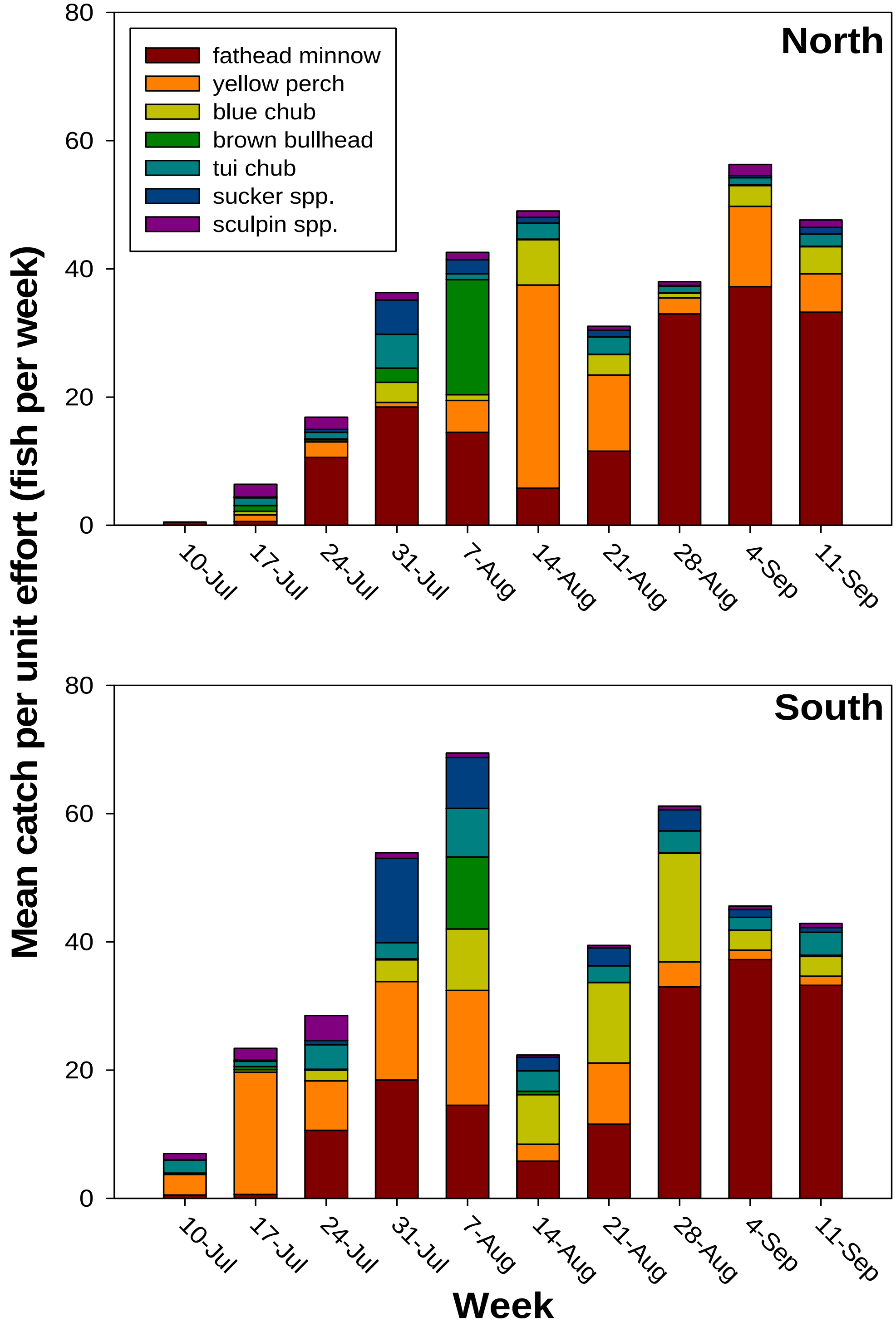

Figure 13. Mean weekly catch per unit effort (fish per hour) of fish species captured by fyke net in near-shore areas of Upper Klamath Lake, Oregon in 2006. The two areas sampled, North and South, are shown in Figure 1. The numbers of sites sampled each week by area are given in Table 1.

Off-Shore Sampling

We captured a total of 9,059 juvenile suckers in off-shore nets. Suckers, which were captured in 89.3% of all trap nets, were comprised of 53.0% Lost River suckers, 37.0% shortnose suckers, 9.5% unidentified suckers, and 0.5% Klamath largescale suckers. Klamath largescale suckers were only found in nets at Williamson River East, Hagelstein Park, and Hanks Marsh. The order of most abundant to least abundant sucker species was the same as in 2004 and 2005. In 2004, sucker species composition was 76.0% Lost River sucker, 21.0% shortnose sucker, 2.8% unidentified sucker and 0.9% Klamath largescale sucker (Hendrixson et al. 2007a) and 70.2% Lost River sucker, 17.8% shortnose sucker, 10.9% unidentified sucker and 1.1% Klamath largescale sucker in 2005 (Hendrixson et al. 2007b).

Mean weekly CPUE peaked for Lost River suckers the week of 31 July at Williamson River East, Hagelstein Park, and Hanks Marsh and the week of 7 August at Modoc Point and Cove Point (Figure 14). For shortnose suckers, peak catches occurred the week of 31 July at Hagelstein Park and Hanks Marsh, the week of 7 August at Modoc Point and Cove Point and the week of 21 August at Williamson River East. The order of highest to lowest mean seasonal CPUE by transect was the same for Lost River and shortnose suckers: Cove Point > Hagelstein Park > Hanks Marsh > Modoc Point > Williamson River East (Figure 15).

As in near-shore nets, mean seasonal CPUE of both Lost River and shortnose suckers was much greater at all transects in 2006 than in 2004 or 2005 (Figure 15). Increases ranged from approximately three-fold to well over an order of magnitude. Timing of peak catches in 2005 was similar to 2006 for both species with the highest catches at almost all sites occurring in late July or early August (Hendrixson et al. 2007b). In 2004, mean CPUE peaks occurred as early as the week of 9 August at Williamson River East for both species and as late as the week of 23 August at Hagelstein Park for shortnose suckers and the week of 30 August at Hanks Marsh for Lost River suckers (Hendrixson et al. 2007a).

The order of highest to lowest mean seasonal juvenile sucker CPUE by transect has been somewhat variable year to year. Mean CPUE of Lost River suckers was greatest at Hagelstein Park and lowest at Modoc Point in 2004 (Hendrixson et al. 2007a) and greatest at Cove Point and lowest at Hanks Marsh in 2005 (Hendrixson et al. 2007b). For shortnose suckers, mean CPUE was greatest at Hagelstein Park and lowest at Hanks Marsh in 2004 (Hendrixson et al. 2007a) and greatest at Cove Point and lowest at Hanks Marsh in 2005 (Hendrixson et al. 2007b).

Mean SL and weights of juvenile suckers captured off-shore generally increased week to week throughout the 2006 sampling season for all species combined, Lost River suckers, and shortnose suckers (Figures 16 and 17). For all juvenile sucker species combined, mean (± SE) SL of all captured fish and weights of sacrificed fish were 41.2 ± 0.7 mm and 1.2 ± 0.1 g at the start of sampling (the week of 10 July) and 74.7 ± 1.6 mm and 6.7 ± 0.4 g the last week of sampling (the week of 11 September). Mean SL of Lost River suckers was greater than shortnose suckers for all weeks of sampling except the weeks of 14 and 21 August. Similar to results from near-shore sampling, the greatest mean weight alternated between the two species with Lost River suckers being heavier the last week of sampling. Fitting the power curve described by Anderson and Neumann (1996) to juvenile Lost River sucker weight-length data (Figure 18) yields the equation;

$$\text{Weight} = (1.501\text{x}10^{-5}) \cdot \text{Length}^{2.998},\ r^2 = 0.98.$$

Fitting this curve to juvenile shortnose sucker weight-length data (Figure 18) yields the equation;

$$\text{Weight} = (1.557\text{x}10^{-5}) \cdot \text{Length}^{3.017},\ r^2 = 0.97.$$

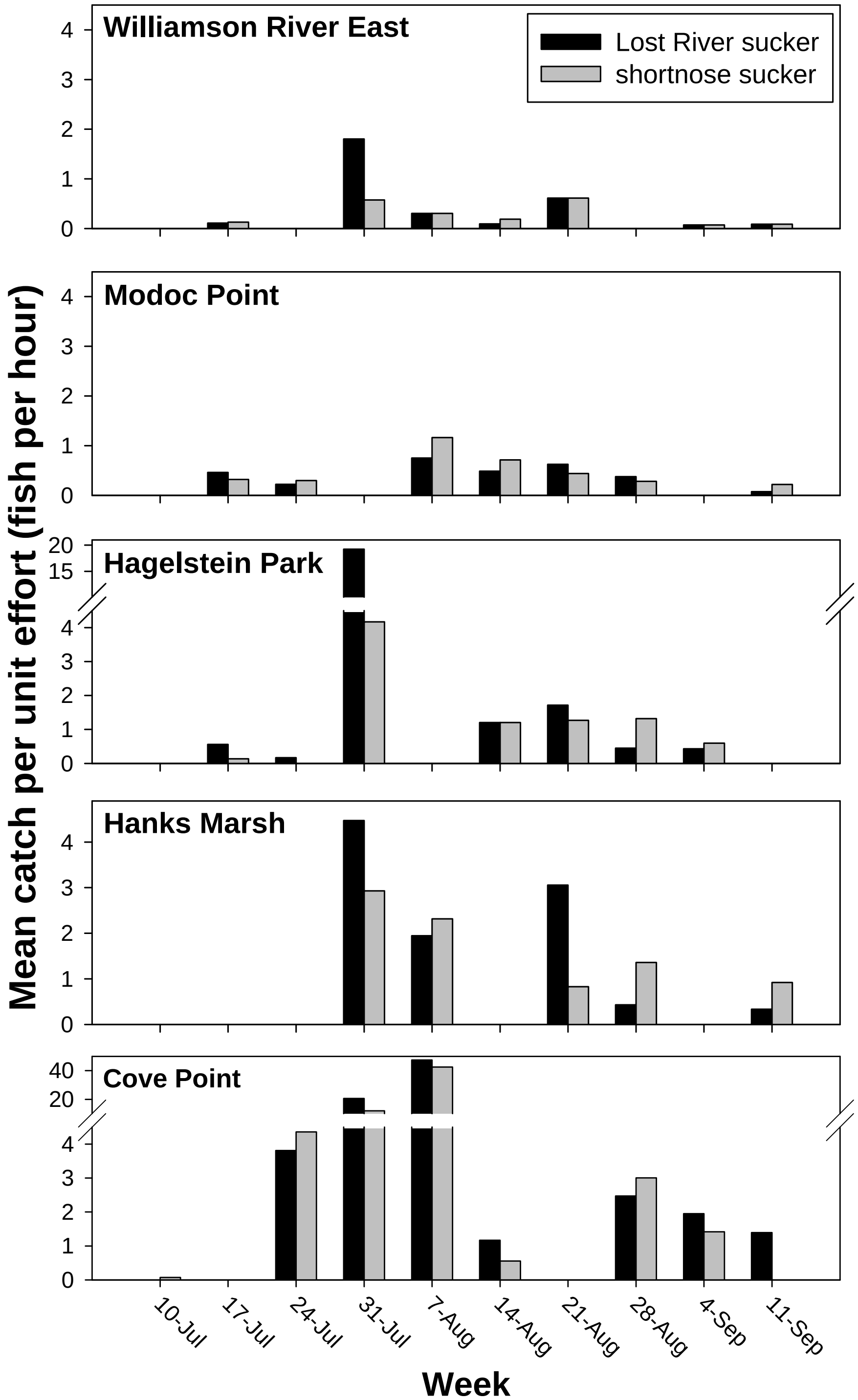

Figure 14. Mean weekly catch per unit effort (fish per hour) of juvenile Lost River and shortnose suckers captured by trap net in off-shore areas of Upper Klamath Lake, Oregon in 2006. Two trap nets were set and fished overnight along each transect primarily at points 50 and 200 m from shore (see Methods for other distances sampled). Transect locations are shown in Figure 1. Four of the five transects were sampled each week. Standard errors were not calculated as only two nets were set at each site each week.

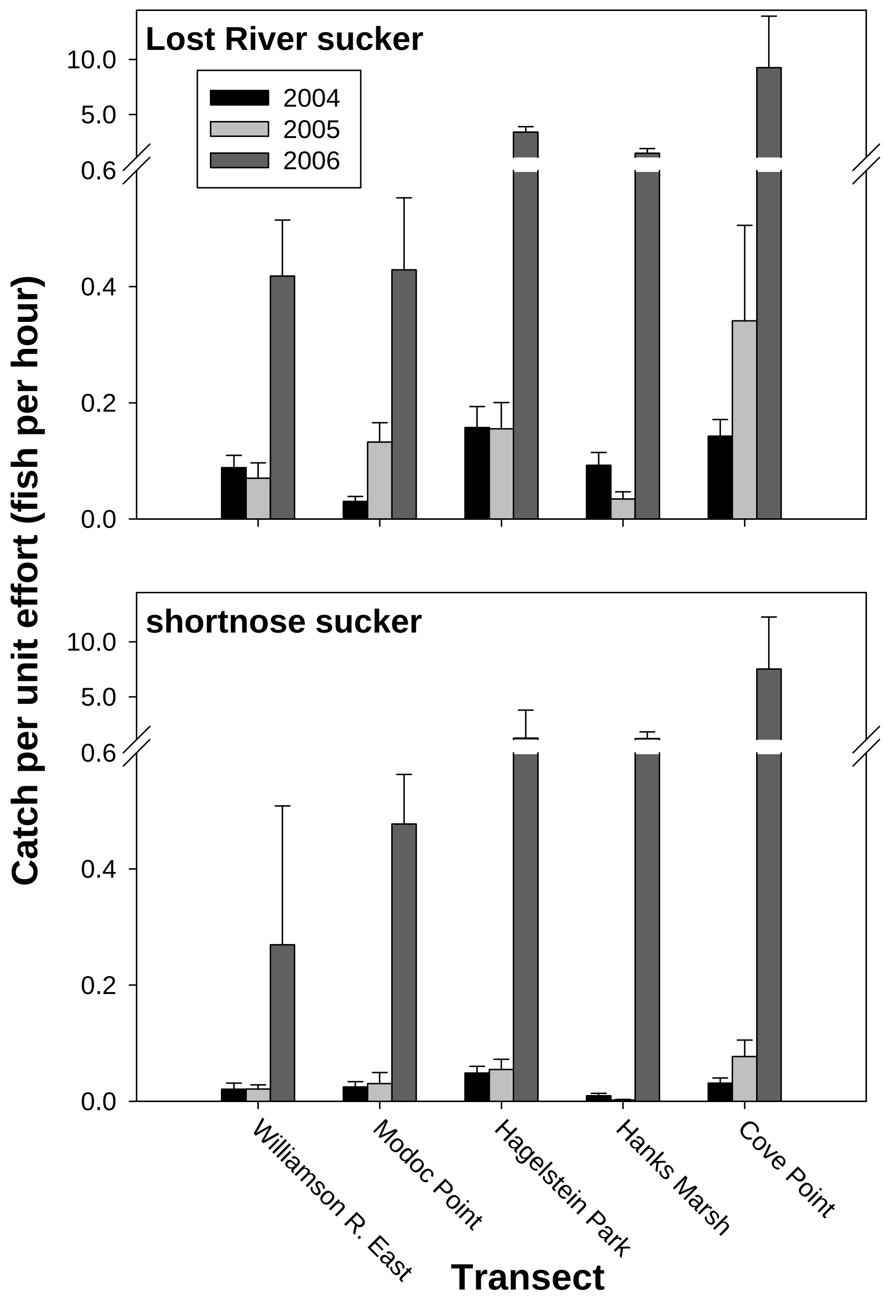

Figure 15. Mean seasonal catch per unit effort (fish per hour) and standard error of juvenile Lost River and shortnose suckers captured by trap net in off-shore areas of Upper Klamath Lake, Oregon from mid July to mid September in 2004, 2005, and 2006. In 2004 and 2005 six trap nets were set and fished overnight along each transect beginning with the point nearest shore where water depth was 1 m and at points 50, 100, 200, 400, or 600 m from shore. In 2006, two trap nets were set and fished overnight along each transect, primarily at points 50 and 200 m from shore (see Methods for other distances sampled). Transect locations are shown in Figure 1. In 2006, four of the five transects were sampled each week.

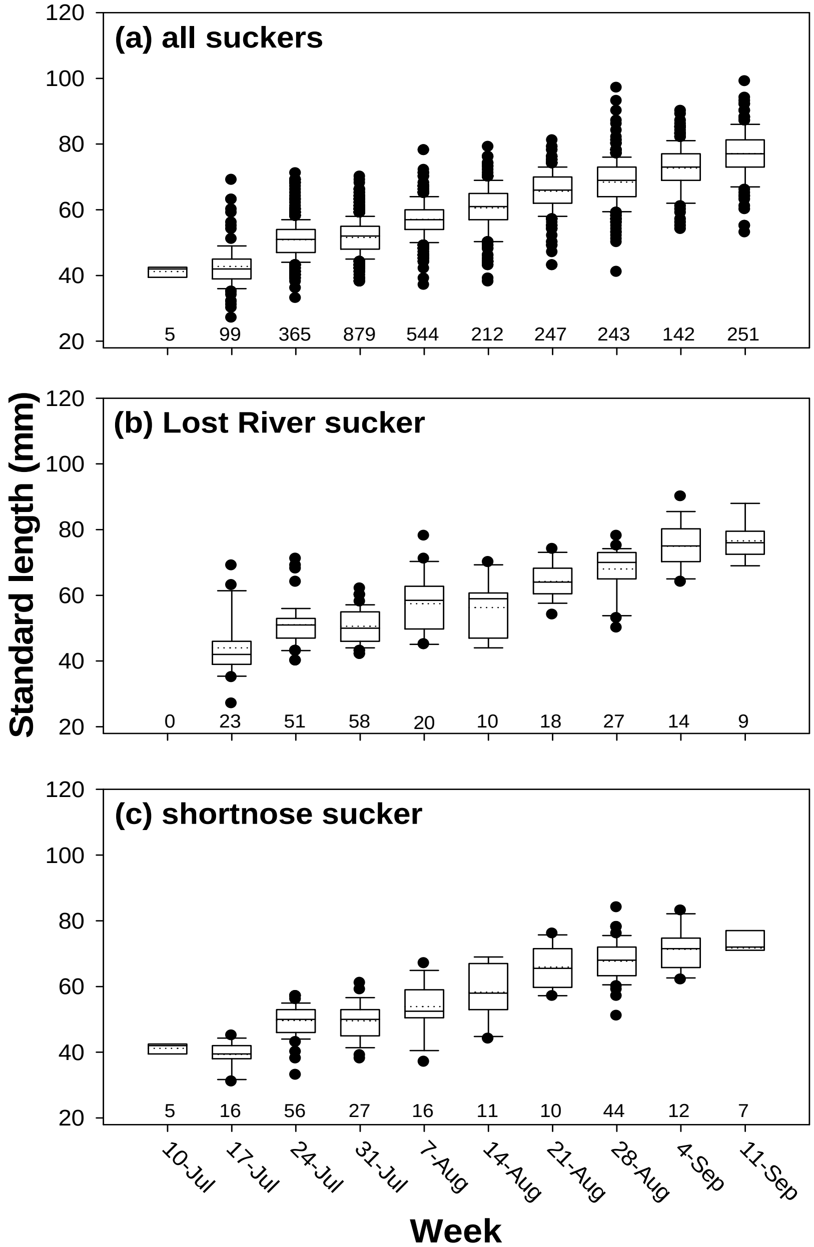

Figure 16. Box plots of standard lengths (mm) for age-0 juvenile suckers, by week, for all sucker species combined (a), and for sacrificed Lost River (b) and shortnose suckers (c) captured by trap net in off-shore areas of Upper Klamath Lake, Oregon in 2006. Two trap nets were set and fished overnight along each transect primarily at points 50 and 200 m from shore (see Methods for other distances sampled). Transect locations are shown in Figure 1. Four of the five transects were sampled each week. Seventeen suckers determined to be age-1 based on longer than expected length at age were removed from figure a, one Lost River sucker was removed from figure b, and three shortnose suckers were removed from figure c. Box plots indicate 25th, 50th (median), and 75th percentiles, the dotted line indicates the mean, whiskers indicate the 10th and 90th percentiles, and dots indicate outliers in observed data. Numbers of fish used for each plot are given by week.

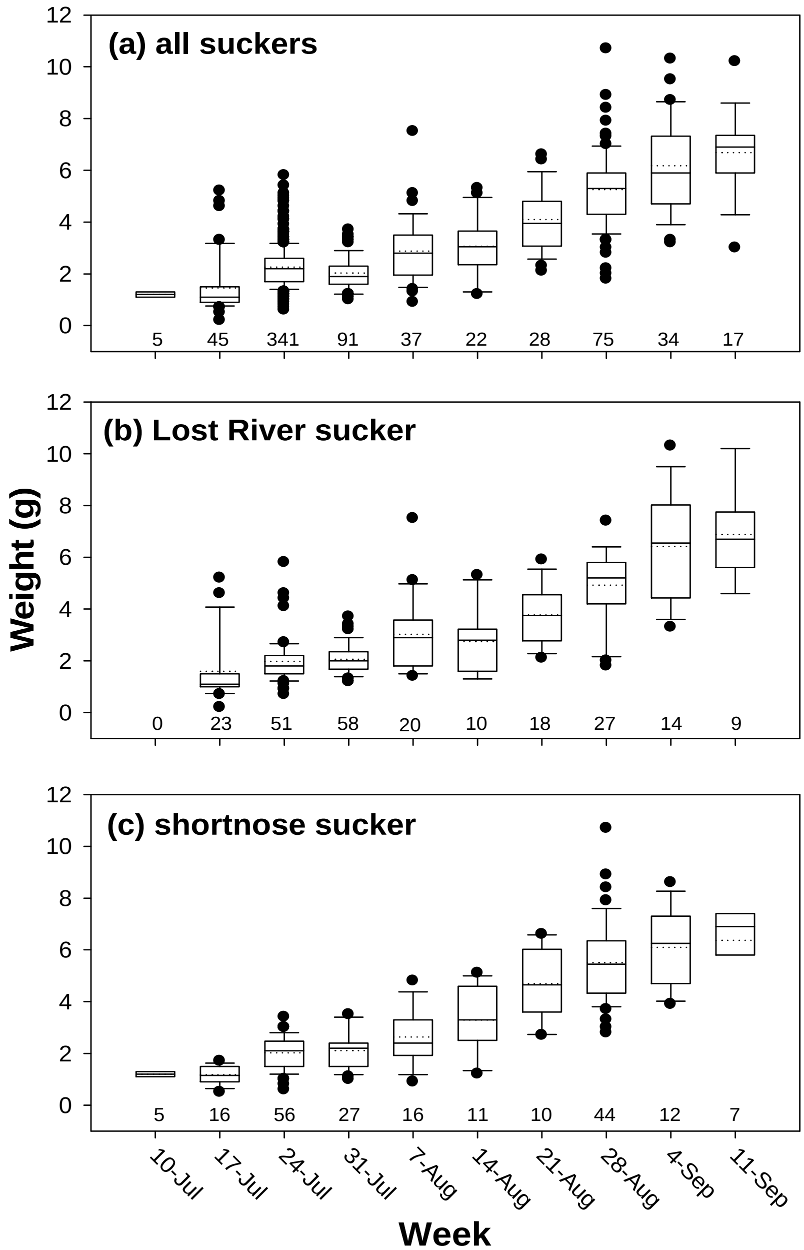

Figure 17. Box plots of weights (g) for age-0 juvenile suckers, by week, for all sucker species combined (a), for sacrificed Lost River (b) and shortnose suckers (c) captured by trap net in off-shore areas of Upper Klamath Lake, Oregon in 2006. Two trap nets were set and fished overnight along each transect primarily at points 50 and 200 m from shore (see Methods for other distances sampled). Transect locations are shown in Figure 1. Four of the five transects were sampled each week. Suckers determined to be age-1 based on longer than expected length at age were excluded including 17 from figure (a), 1 from figure (b), and 3 from figure (c). Box plots indicate 25th, 50th (median), and 75th percentiles, the dotted line indicates the mean, whiskers indicate the 10th and 90th percentiles, and dots indicate outliers in observed data. Numbers of fish used for each plot are given by week.

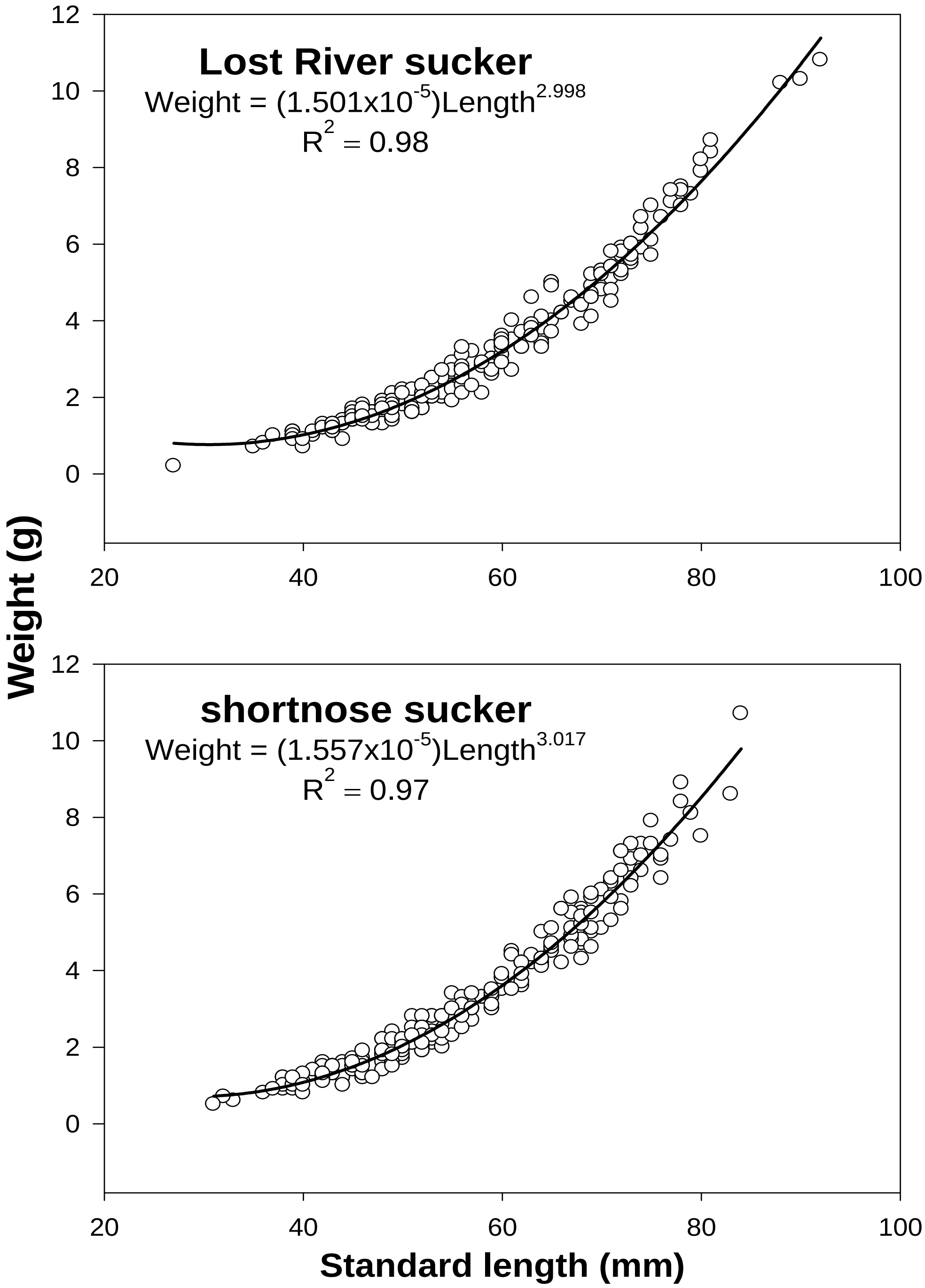

Figure 18. Relation between weight (g) and length (mm) of sacrificed juvenile Lost River and shortnose suckers captured by trap net in off-shore areas of Upper Klamath Lake, Oregon in 2006. Two trap nets were set and fished overnight along each transect primarily at points 50 and 200 m from shore (see Methods for other distances sampled). Transect locations are shown in Figure 1. Four of the five transects were sampled each week. One Lost River sucker and three shortnose suckers determined to be age-1 based on larger than expected length at age, were excluded.

Mean SL (± SE) of all age-0 suckers during the week of 17 July in 2006 (42.7 ± 0.7) was slightly greater to those observed at the start of the sampling season in previous years: 39.3 ± 1.5 mm the week of 19 July 2004 and 41.8 ± 1.7 mm the week of 18 July 2005 (Hendrixson et al. 2007a, 2007b). Similarly, mean SL (± SE) of age-0 suckers caught during the week of 4 September in 2006 (72.7 ± 0.6) was slightly greater than in 2004 (70.6 ± 4.5 mm the week of 6 September) and 2005 (68.6 ± 2.3 mm the week of 12 September). Species comparisons in 2004 and 2005 showed Lost River suckers were consistently longer than shortnose suckers except for the week of 26 July 2004 (Hendrixson et al. 2007a, 2007b). Weights were not measured in past years, thus among year comparisons of weights and weight-length relations could not be made.

Seventeen juvenile suckers captured were considered age-1 or older based on longer than expected length (88 to 170 mm SL) on date of capture. Seven were captured at Williamson River East, two at Modoc Point, five at Hagelstein Park, one at Hanks Marsh, and two at Cove Point. Six of these were sacrificed and identified to species. One was identified as a Lost River sucker, two as Klamath largescale suckers, and three as shortnose suckers.

As with results from near-shore nets, off-shore catches of age-1 suckers have always been low and sporadically distributed throughout the lake. In 2004 only four were captured in off-shore sampling (85 to 97 mm SL): three at Williamson River East and one at Hagelstein Park (Hendrixson et al. 2007a). We caught 19 age-1 or older suckers in 2005 (86 to 153 mm SL): eleven at Williamson River East, four at Hagelstein Park, one at Hanks Marsh, and three at Cove Point (Hendrixson et al. 2007b). Of those sacrificed and identified to species in 2004, one was a shortnose sucker and two were Klamath largescale suckers. Only one age-1 sucker, identified as a Lost River sucker, was sacrificed in 2005.

Overall catches and percentages of off-shore nets that caught at least one non-sucker fish species were high. The order of highest to lowest mean CPUE overall was fathead minnow > yellow perch > sucker spp. > blue chub > tui chub > sculpin spp. > brown bullhead > other species. Other species caught in small numbers along transects included pumpkinseed, lamprey, largemouth bass, and redband trout *Oncorhynchus mykiss* ssp. Tui chub, blue chub, fathead minnow, and yellow perch were captured in 91% or more of nets. Sculpin spp. were captured in 87% of nets. Species captured in a smaller proportion of nets included lamprey (31%), brown bullhead (29%), and pumpkinseed (23%). Only two largemouth bass and five redband trout were captured in off-shore nets. Suckers comprised 17% of the overall catch at Cove Point, 12% at Hagelstein Park, 11% at Hanks Marsh, 5% at Williamson River East, and 2% at Modoc Point. Overall species composition in off-shore catches has been somewhat variable year to year with fathead minnow the most abundant fish species in 2004 catches (Hendrixson et al. 2007a) and yellow perch most common in 2005 (Hendrixson et al. 2007b). Blue chub, tui chub, and sculpin spp. consistently had the widest distribution, being present in over 92% of nets set off-shore since 2004.

Seasonal trends in CPUE were apparent for several species. Yellow perch were captured at a higher rate early in the season from 17 July to 7 August, whereas fathead minnow were captured at higher rates after 7 August (Figure 19). Although seasonal trends in non-sucker CPUE were variable year to year, there were some similarities. Yellow perch catches were highest in late July or early August and fathead minnow catches consistently increased in mid to late August in all years (Hendrixson et al. 2007a, 2007b).

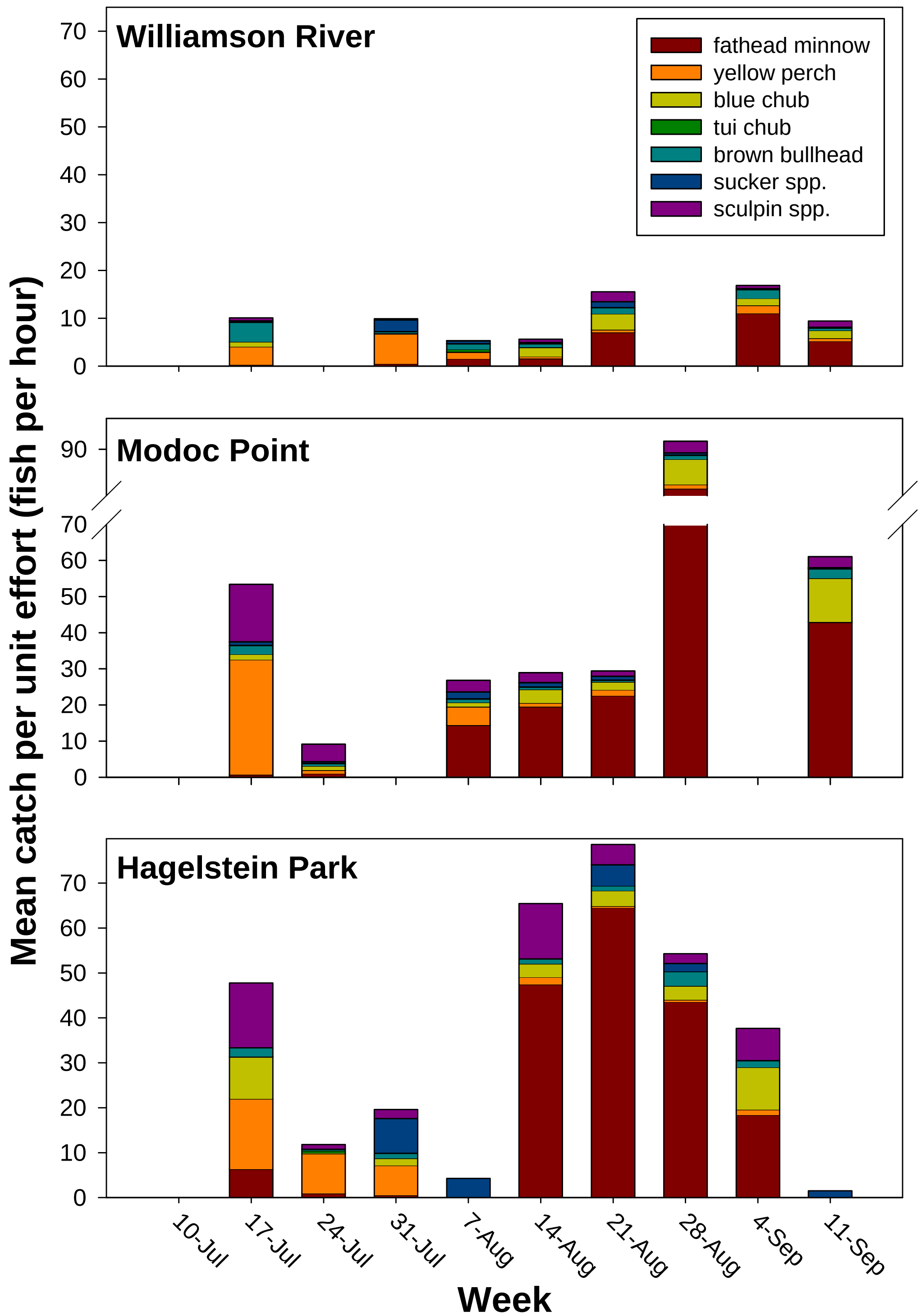

Figure 19. Mean weekly catch per unit effort (fish per hour) of fish species captured by trap net in off-shore areas of Upper Klamath Lake, Oregon in 2006. Two trap nets were set and fished overnight along each transect primarily at points 50 and 200 m from shore (see Methods for other distances sampled). Transect locations are shown in Figure 1. Four of the five transects were sampled each week.

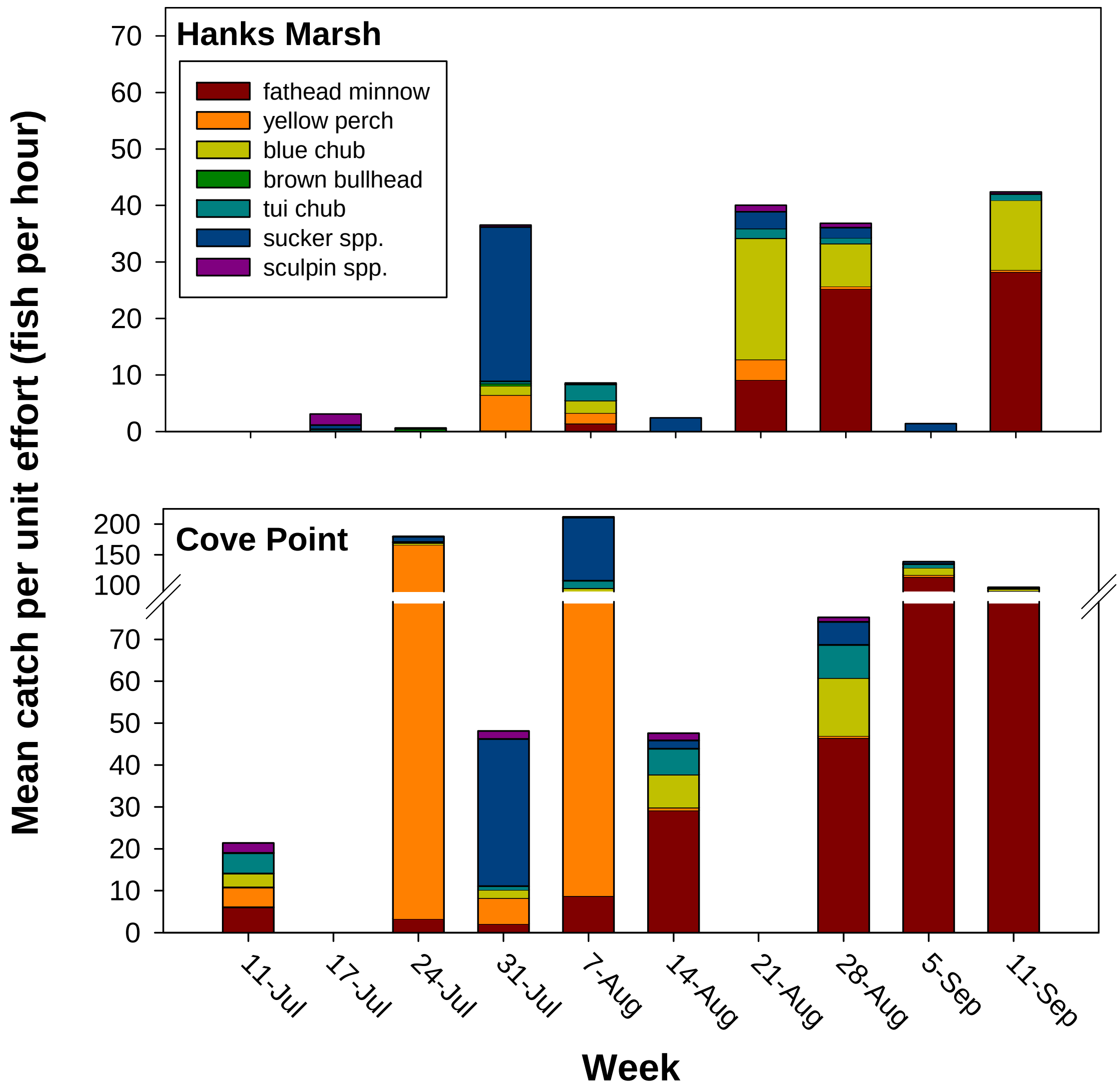

Figure 19. Continued.

Acknowledgments

We thank Christine Adelsberger and Melissa Bernhardt for help with data collection, Dave Simon for providing substrate data and help with sucker species identification, Greta Blackwood for database setup and management and Rip Shively for help with the study design and overall guidance for running the study. This work was funded by the Bureau of Reclamation (Interagency Agreement 05AA204046) and the U.S. Geological Survey.

References Cited

Anderson, R.O. and R.M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447-482 *in* B.R. Murphy and D.W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Cooperman, M., and D.F. Markle. 2000. Ecology of Upper Klamath Lake shortnose and Lost River suckers. 2. Larval ecology of shortnose and Lost River suckers in the lower Williamson River and Upper Klamath Lake. 1999 Annual Report (partial). Report of Oregon State University, Department of Fisheries and Wildlife to U.S. Biological Resources Division, U.S. Geological Survey and Klamath Project, Bureau of Reclamation, Klamath Falls, Oregon.

Hendrixson, H.A., S.M. Burdick, B.L. Herring, and S.P. VanderKooi. 2007a. Near-shore and offshore habitat use by endangered, juvenile Lost River and shortnose suckers in Upper Klamath Lake, Oregon. Annual Report 2004. Report of U.S. Geological Survey, Western Fisheries Research Center, Klamath Falls Field Station to the Bureau of Reclamation, Mid-Pacific Region, Klamath Falls, Oregon.

Hendrixson, H.A., S.M. Burdick, A.X. Wilkens, and S.P. VanderKooi. 2007b. Near-shore and off-shore habitat use by endangered, juvenile Lost River and shortnose suckers in Upper Klamath Lake, Oregon. Annual Report 2005. Report of U.S. Geological Survey, Western Fisheries Research Center, Klamath Falls Field Station to the Bureau of Reclamation, Mid-Pacific Region, Klamath Falls, Oregon.

Hubert, W.A., 1996. Passive capture techniques. Pages 157-192 *in* B.R. Murphy and D.W. Willis editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

Markle, D.F., M.R, Cavalluzzi, and D.C. Simon. 2005. Morphology and taxonomy of Klamath Basin suckers (Catostomidae). Western North American Naturalist 65(4):473-489.

National Research Council (NRC). 2004. Endangered and threatened fishes in the Klamath River Basin. The National Academies Press, Washington, D.C.

Reiser, D.W., M. Loftus, D. Chapin, E. Jeanes, and K. Oliver. 2001. Effects of water quality and lake level on the biology and habitat of selected fish species in Upper Klamath Lake. Report of R2 Resource Consultants to the Bureau of Indian Affairs, Portland, Oregon.

Terwilliger, M.R., D.C. Simon, and D.F. Markle. 2004. Larval and juvenile ecology of Upper Klamath Lake suckers: 1995-2003. Final Report presented to the Bureau of Reclamation, Klamath Falls, Oregon by the Oregon Cooperative Research Unit, Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

VanderKooi, S.P. and K.A. Buelow. 2003. Near-shore habitat use by endangered juvenile suckers in Upper Klamath Lake, Oregon. Annual Report 2001. Report of U.S. Geological Survey, Western Fisheries Research Center, Klamath Falls Field Station to the Bureau of Reclamation, Mid-Pacific Region, Klamath Falls, Oregon.

VanderKooi, S.P., H.A. Hendrixson, B.L. Herring, and R.H. Coshow. 2006. Near-shore habitat use by endangered juvenile suckers in Upper Klamath Lake, Oregon. Annual Report 2002 – 2003. Report of U.S. Geological Survey, Western Fisheries Research Center, Klamath Falls Field Station to the Bureau of Reclamation, Mid-Pacific Region, Klamath Falls, Oregon.