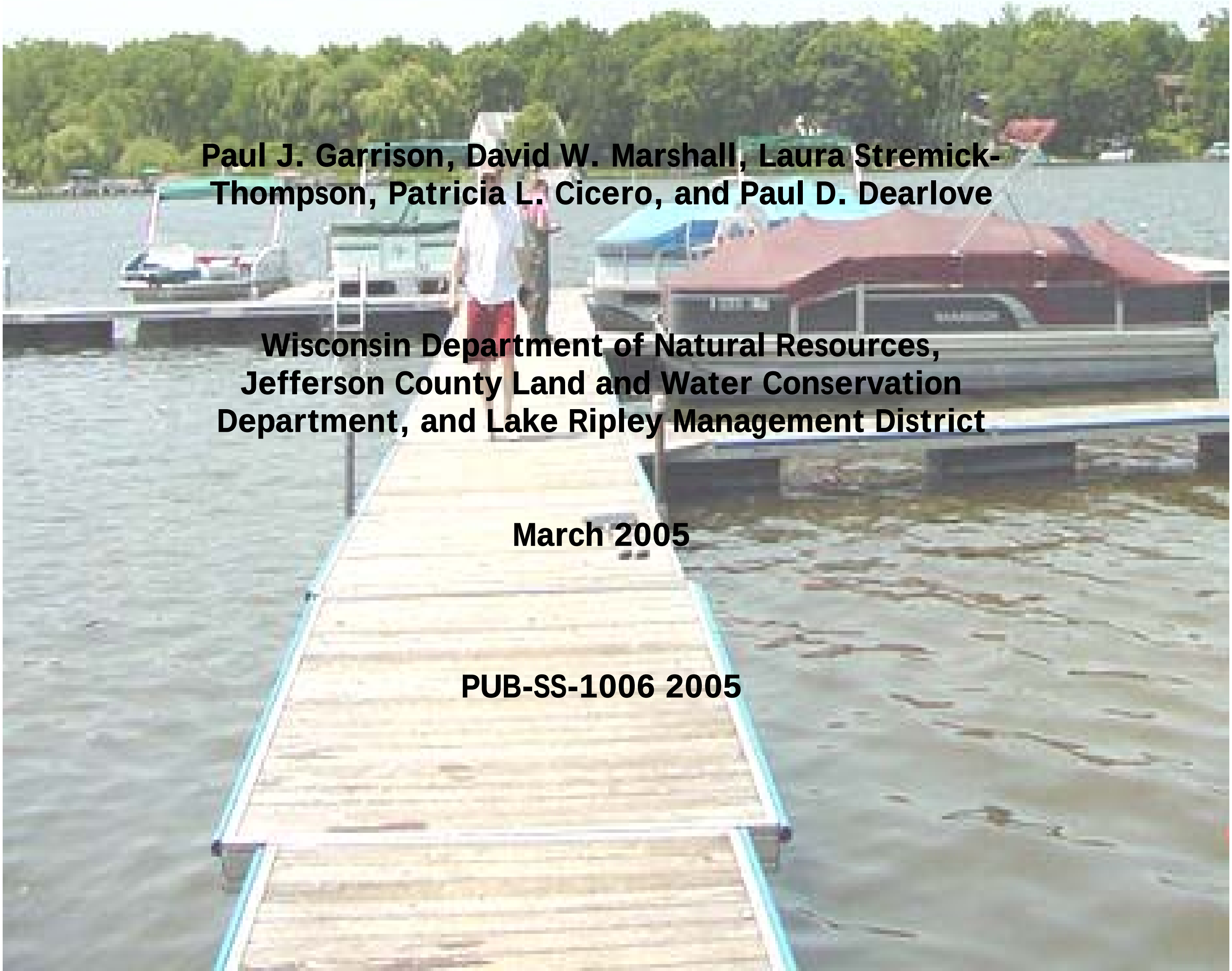
EFFECTS OF PIER SHADING ON LITTORAL ZONE HABITAT AND COMMUNITIES IN LAKES RIPLEY AND ROCK, JEFFERSON COUNTY, WISCONSIN



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Abstract

The direct and indirect ecological effects of pier shading were evaluated on two calcareous lakes in southeast Wisconsin. Sunlight availability and the response of macrophytes, macroinvertebrates, and both juvenile and small non-game fishes were evaluated under piers and within nearby control sites. Findings revealed significant shading under piers with a corresponding reduction in aquatic plant abundance, as well as a shift in community composition to one dominated by shade-tolerant species. The median biomass under the piers was 5 grams compared with 107 grams in the control sites. The resulting loss of macrophyte habitat under piers translated into a reduction in macroinvertebrate numbers. The median number of macroinvertebrates under the piers was 23 compared with 61 in the control sites. Juvenile Centrarchid fishes showed preference for abundant macrophyte cover found in control areas. Mean fish catch rates under piers (11.2) were statistically lower than catch rates within plant beds (38.7). Results suggest that the proliferation of piers and other near-shore structures are contributing to the degradation of littoral zone habitat and biological diversity.

Introduction

Native aquatic plant communities play an important role in the health of fisheries and aquatic ecosystems (Becker 1983, Engel 1985, Janecek 1988). Emergent, floating-leaf and submergent macrophytes help stabilize soft sediments, reduce turbidity by trapping suspended particulates, provide habitat for attached algae and bacteria which compete for the same nutrients that fuel algae blooms, and absorb wave energy that contributes to shoreline erosion. They also serve as critical habitat for fish and other aquatic life by acting as food sources, providing spawning and juvenile rearing areas, affording camouflage and structural refuge from predators, and producing dissolved oxygen required by aerobic organisms.

As human development along lake shorelines increases, so does the proliferation and use of structures for purposes of access and recreation. Piers and similar structures have both a site specific and cumulative effect on shallow-water plant communities and the habitat functions they provide (Engel and Pederson 1998, Bryan and Scarnecchia 1992, Jennings et al 2003). Prior investigations have considered the overall impacts of development on freshwater littoral zone habitat, but few studies have specifically studied the impacts of piers, which are typically an integral component of shoreline development and function as focal points for riparian access to public waters. Piers have been linked to declines in emergent and floating-leaf plants, as well as reduced fish growth rates (Radomski and Goeman 2001, Schindler et al. 2000, Scheuerell and Schindler, 2004). Studies that focused on the impacts of shading on coastal eelgrass *(Zostera marina)* and seagrass *(Halodule wrightii)* found that piers may directly alter aquatic plant habitat by reducing or eliminating photosynthesis (Loflin 1995, Burdick and Short 1999, Shafer 1999).

This study evaluates the direct and indirect ecological effects of pier shading within two, calcareous lakes in southern Wisconsin – lakes Ripley (N43°0’4”; W88°59’28”) and Rock (N43°4’42”; W88°55’51”). Emphasis was placed on evaluating the response of plant communities and associated fauna to shading. Light intensity was measured under piers and within nearby control sites, while the relative abundance and biomass of macrophytes were compared to assess direct effects of shading. Macroinvertebrate and small and juvenile fish communities were sampled to assess potential indirect effects of shading on habitat preferences.

Study Sites

The focus of the study was on lakes Ripley and Rock, two calcareous, mesotrophic drainage lakes situated in Jefferson County, Wisconsin. Both lakes are heavily developed, with approximately five miles separating the two water bodies. Each lake is described in Table 1 and accompanying bathymetric maps (Figures 1 and 2).

Figure 1. Bathymetric map of Lake Ripley showing the study sites.

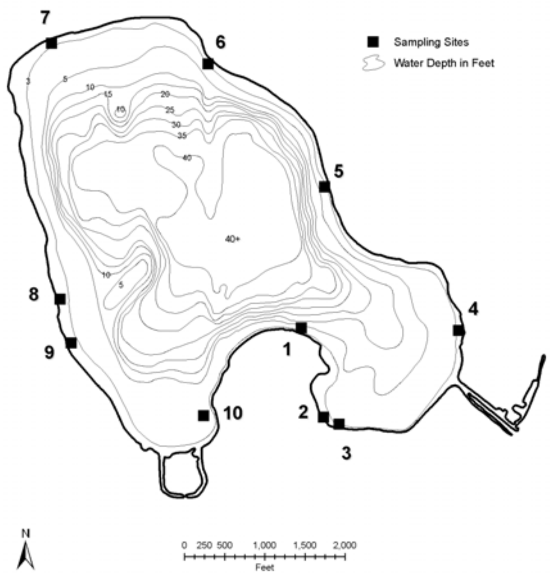


Figure 2. Bathymetric map of Rock Lake showing the study sites.

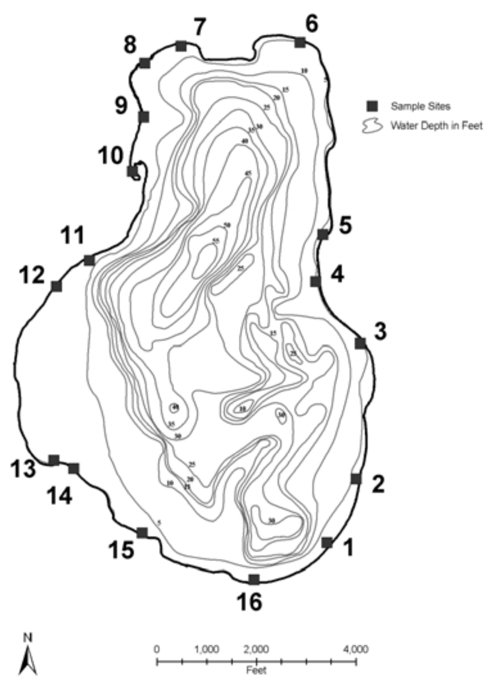


Table 1. Characteristics of lakes Ripley and Rock.

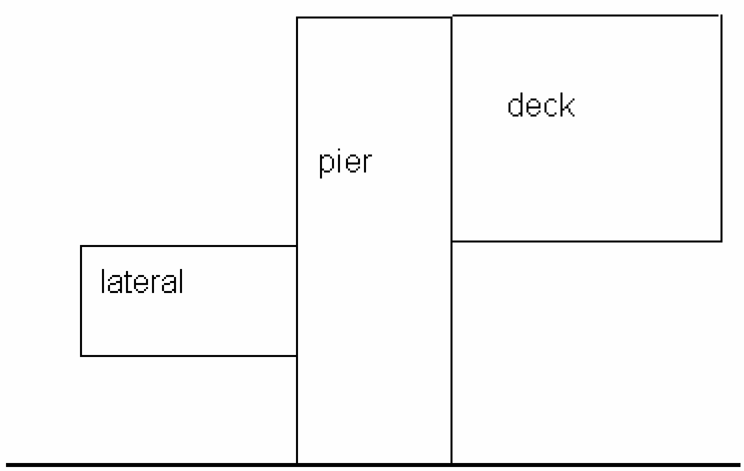
	RIPLEY	**ROCK**
Surface Area	418 acres	1,161 acres
Maximum Depth	44 feet	56 feet
Mean Depth	18 feet	16 feet
Shore Length	4.4 miles	7.0 miles
% of Shore Armored	36%	44%
% of Shore Undeveloped	22%	11%
Pier Density	54.3 mi^{-1}	28.3 mi^{-1}
Home Density	37.8 mi^{-1}	37.3 mi^{-1}
Maximum Extent of Plant Growth	12 feet	15 feet
Surface Area < 5 Ft.	34.3%	20.6%
Surface Area < 10 Ft.	46.3%	41.5%
Average Summer Secchi Depth	6 feet	8 feet
Average Summer Phosphorus	20 $\mu g\ L^{-1}$	34 $\mu g\ L^{-1}$
Aquatic Plant Species (2001)	14	18

Methods

Site selection

A total of 26 piers were selected that included 10 piers on Lake Ripley and 16 piers on Rock Lake. Piers were selected to represent a range of shoreline development, orientations, structural attributes, and overall sizes. Pier dimensions and site conditions were recorded for each site. Figure 3 is an example of a pier with laterals and a deck. Piers located in areas with obvious substrate manipulation (e.g. sand placement) or ongoing aquatic plant control, were excluded from this study.

Figure 3. Diagram of a representative pier structure.



All pier sites had a paired control site of similar water depth for sampling of light, plants, and macroinvertebrates. Control sites were located in nearby areas with representative substrates and shoreline conditions. In most cases, a pier site and its corresponding control site were located within the same riparian property boundaries. At pier sites with sparse or no vegetation (9 of 26 sites), remote locations were used for the fish sampling.

Light

Apogee Quantum meters were used to measure the light intensity of photosynthetically available wavelengths between 400 and 700 nanometers. The meters were equipped with digital displays that provided instantaneous light measurements from submersible sensors. Each remote sensor was connected to the hand-held display unit by 6 m of cable. Snorkel divers held the submersible sensor in a vertical position either at the top of the plant bed or, if no plants were present, near the lake bottom. Light measurements were made on two or three separate dates at each pier site during June and July. When multiple measurements were made the mean value was used in the analysis. All measurements were recorded between 10:00 and 16:00 hrs, and at water depths ranging from 1.5 to 5 ft. Paired units were used to simultaneously determine light intensity under piers and at adjacent, control sites. Sensor readings under piers were taken directly beneath the centerline of the structure.

Plants

The plant coverage at each paired site was visually estimated using the scale: no plants, <10%, 10-40%, 40-70%, 70-100%, and 100%. In some cases, coverage was estimated at multiple locations under the structures to evaluate the effects of lateral and deck sections. All sampling plots were randomly chosen. Plants (with roots excluded) were then hand harvested within a 0.1 m^2 square. Plant biomass was measured in terms of wet weight after excess water was removed with a salad spinner.

Macroinvertebrates

Macroinvertebrate samples were collected with a D-frame net. Six sweeps were made at each site, and combined samples were preserved with 95% ethanol. Macroinvertebrates were later sorted and identified to a minimum level of family.

Fish

18 x 24-in. square minnow traps with double tunnels and 0.25-in. hardware mesh were used to sample fish under piers and within control sites where vegetation was present. The traps were set with funnels oriented parallel to the shoreline, non-baited, and deployed for approximately 24 hrs per site. In areas where aquatic vegetation was generally absent, control minnow traps were deployed in more remote locations where vegetation was present. Minnow traps were deployed under all 26 piers and another 24 traps were placed within aquatic plant beds away from piers.

Results

Pier dimensions

The 10 piers studied on Lake Ripley averaged 4.3 ft in width, while the 16 piers on Rock Lake averaged 3.8 ft in width. Surface areas for piers (including lateral extensions and decks) averaged 546 sq ft for Lake Ripley and 370 sq ft for Rock Lake. Seven of the study piers on Lake Ripley consisted of attached decks averaging 172 sq ft. Rock Lake had 13 piers with attached decks that averaged 196 sq ft. Table 2 lists the structural dimensions of all of the study piers.

Table 2. Dimensions of study piers.

	Orientation of main pier	Width (ft)	Distance from shore (ft)	Height above water (ft)	Deck area (ft^2)	Total structure area (ft^2)	Plank Spacing (in)
Ripley							
1	NE	4.8	41	0.0		432	0.0
2	N	4.0	65	1.9		349	0.5
3	N	4.1	35	1.6	40	195	0.5
4	W	4.0	54	2.1	128	311	0.0
5	W	4.0	113	1.3	200	874	0.5
6	WSW	6.1	80	1.6	269	684	0.0
7	SE	3.0	65	1.7	438	585	.0.0
8	E	3.0	117	.8	95	574	0.6
9	NE	4.0	45	1.3	32	192	0.7
10	WNW	6.3	120	.8		1268	0.3
Rock							
1	NW	3.0	119	1.7	192	566	0.3
2	W	4.0	57	1.5	204	366	0.0
3	SW	4.0	57	1.4	33	269	0.5
4	W	3.3	49	1.3	61	196	0.0
5	W	4.0	58	2.2	261	474	0.5
6	SW	4.0	30	1.3	119	201	0.4
7	SW	3.3	66	1.0	739	1585	0.5
8	SE	3.3	42	0.8		139	0.3
9	E	4.0	40	2.1	280	383	0.5
10	E	4.0	24	1.2	40	120	0.5
11	SE	4.0	44	0.2	120	264	0.0
12	SE	4.0	47	1.8	147	309	0.5
13	N	5.3	45	1.1	95	280	0.0
14	NE	4.0	55	1.5	261	428	0.5
15	N	3.0	47	1.6		142	0.6
16	N	4.0	41	1.4		201	0.6

Light

Significant shading was measured under all of the structures. Mean percent light intensity for control sites averaged 44% in Rock Lake and 38% in Lake Ripley, indicating better water clarity in Rock Lake. Conversely, significantly lower light intensity values were found under piers extending perpendicular from shore (mean = 5%, $P = 0$), lateral sections (mean = 3%, $P < .01$) and deck sections (mean = 2%, $P < .01$). Although not statistically significant, shading increased the closer the pier decking was to the water surface (Figure 4). Pier width also adversely affected light penetration, with wider piers allowing less light to reach the lake bottom (Figure 5). The plank spacing ranged from 0 to 0.7 in. While lack of spacing severely reduced light penetration under the pier, a range of plank spacing of 0.3 to 0.7 in. did not make a significant difference in the amount of light under the pier.

Figure 4. Percent light availability under piers as function of width.

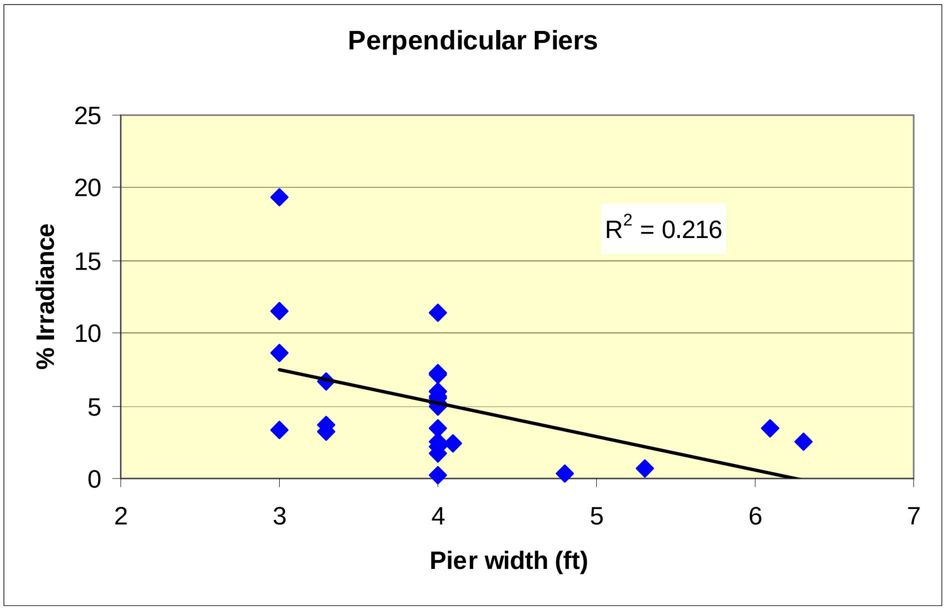
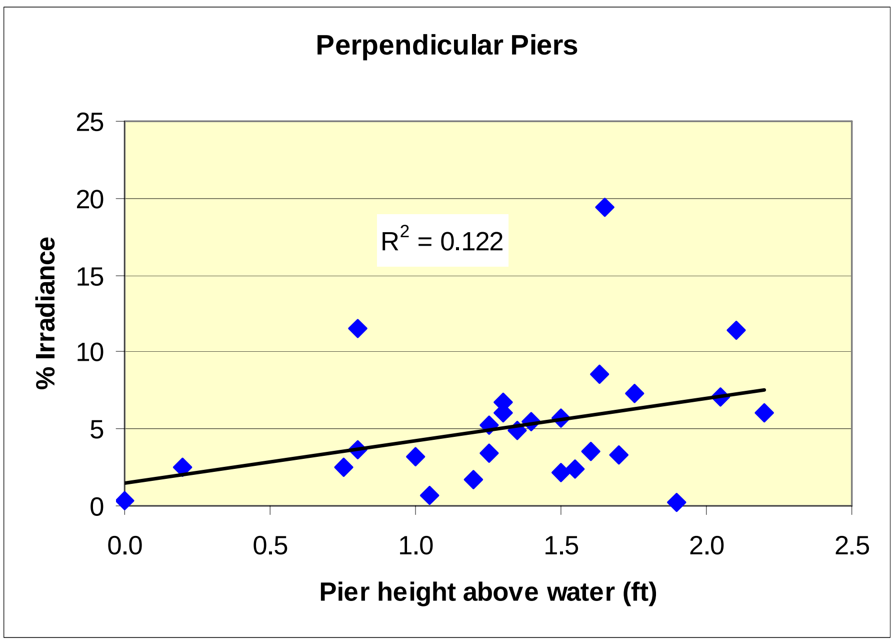


Figure 5. Percent light availability under piers as function of height.



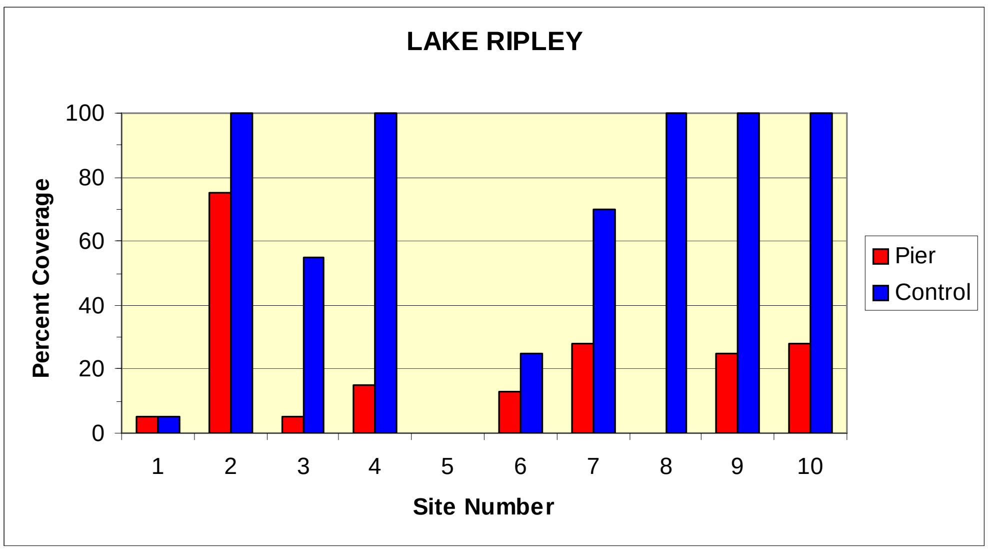
In general, piers with east-west orientations experienced more shading under the perpendicular sections when compared with the lateral sections. This is likely because sections that face north or south receive greater amounts of light as the sun moves through the sky. In both lakes, shading under decks was 2 to 3 times that under perpendicular piers.

Aquatic Plants

In Lake Ripley, the dominant plants were muskgrass (*Chara*), sago pondweed (*Potamogeton pectinatus*), and wild celery (*Vallisneria*). Muskgrass was more common in the control areas while wild celery was more common under the piers. Sago was found equally under the piers or in the control areas. In Rock Lake, the most common plants were muskgrass, wild celery, and Eurasian water milfoil (*Myriophyllum spicatum*). As in Lake Ripley, muskgrass was more common in the control areas while wild celery was more common underneath the piers. Milfoil was found equally underneath the piers or in the control areas.

In Lake Ripley, only one site was largely devoid of macrophytes both under the piers and in the nearby control areas (Figure 6). Two other sites in Lake Ripley had sparse plant growth in the control sites. All of these sites had bottom substrate with cobble present which is suspected to have restricted growth. At all sites where plants were present in the control areas, coverage was always less under the piers. This was also true of biomass, with the exception of Site 2. In Lake Ripley, the macrophyte coverage averaged 85% in the control areas and 14% under the piers. Mean biomass was 159 g in the control areas versus 6 g under the piers (Table 3).

Figure 6. Plant coverage and biomass in Lake Ripley. Site locations are identified in Figure 1.



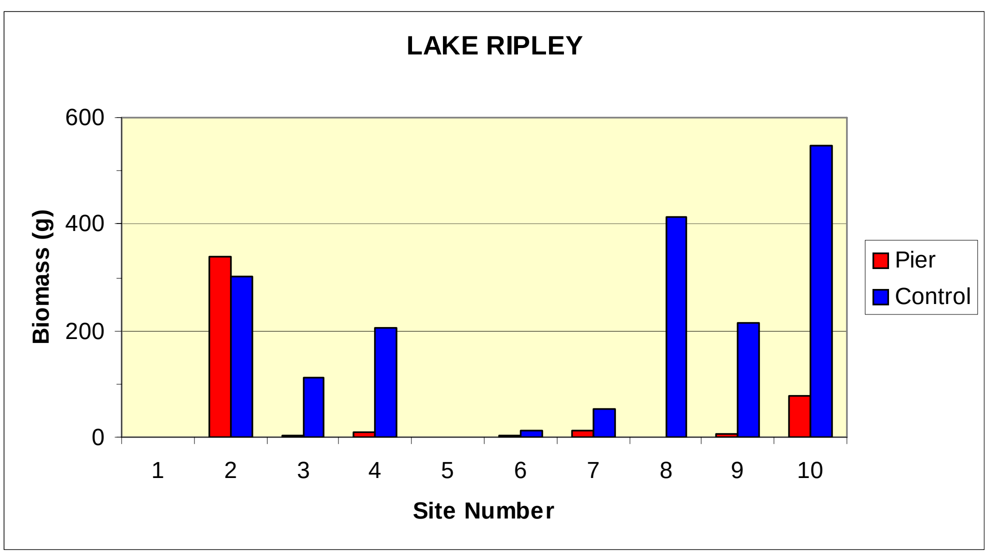
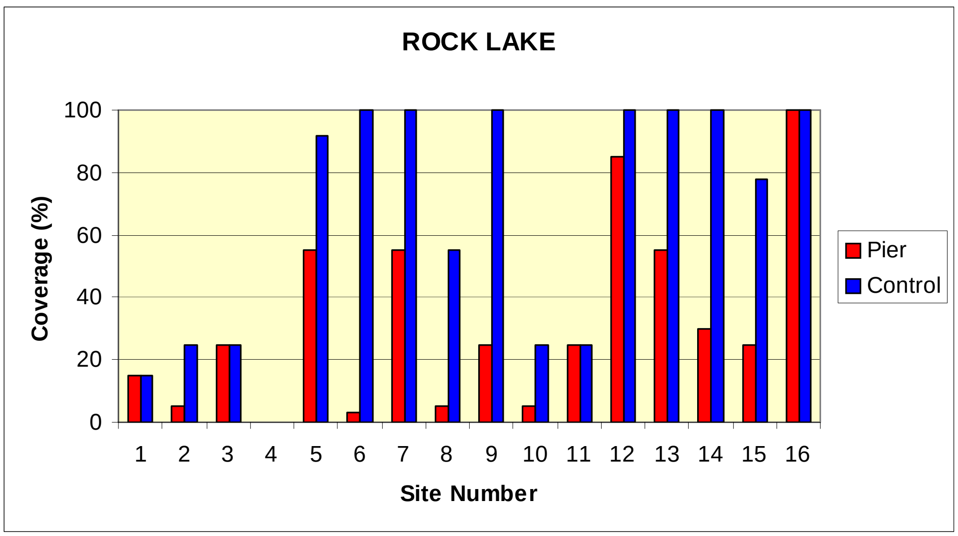


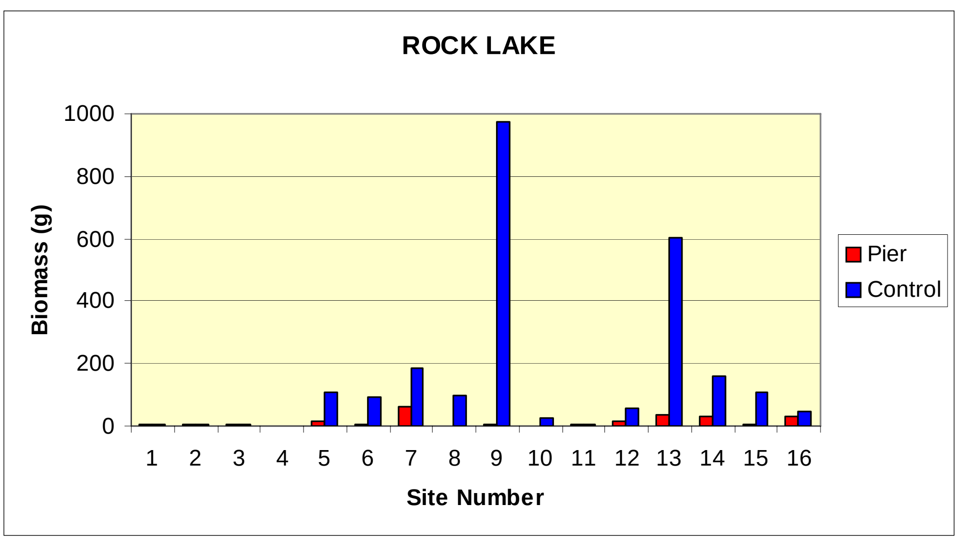
Table 3. Median plant coverage and biomass.

	Piers	Control
Lake Ripley		
Coverage (%)	14	85
Mean Biomass (g)	6	159
Rock Lake		
Coverage (%)	25	85
Mean Biomass (g)	4	75

In Rock Lake, trends in macrophyte growth were similar to those observed in Lake Ripley, with greater coverage found in the control areas. Only one control site in Rock was largely devoid of macrophytes, while five other sites had reduced plant growth. Only three sites had similar coverage under piers and in the nearby control areas. Median macrophyte coverage was 25% under piers and 85% in control areas. At all sites, macrophyte biomass was greater in the control areas (Figure 7). Median macrophyte biomass was 4 g under piers and 75 g in the control areas (Table 3).

Figure 7. Plant coverage and biomass in Rock Lake. Site locations are identified in Figure 2.



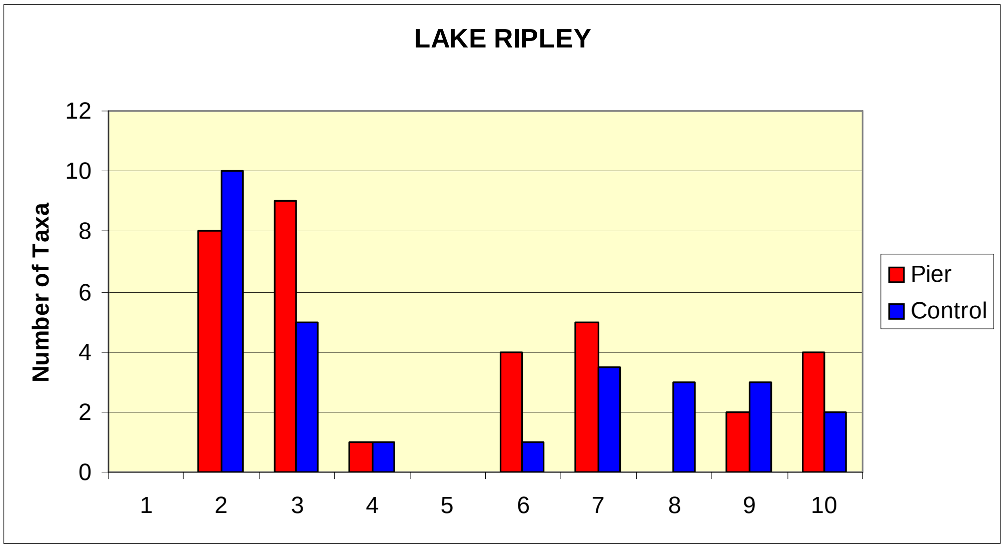


Macroinvertebrates

The most common macroinvertebrates sampled in both lakes were snails and scuds (*Hyallela*). Insects of the order Diptera were also important. A maximum of 10 macroinvertebrate groups were collected in Lake Ripley and 12 in Rock Lake. No macroinvertebrates were found at two sites in Lake Ripley and four sites in Rock Lake.

While not all sites contained macroinvertebrates, those that did showed similar numbers of groups under piers compared to control sites (Figures 8 and 9). The highest number of taxa (12) were found in three control sites in Rock Lake. However, pier and control sites for both lakes were similar in terms of the median number of taxa present.

Figure 8. Mean macroinvertebrate species richness and counts for Lake Ripley. Site locations are identified in Figure 1.



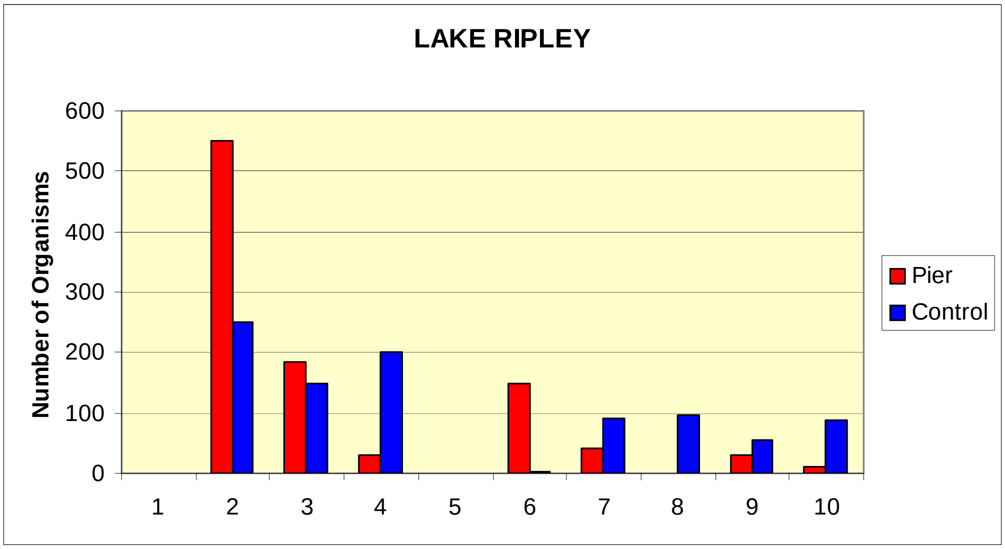
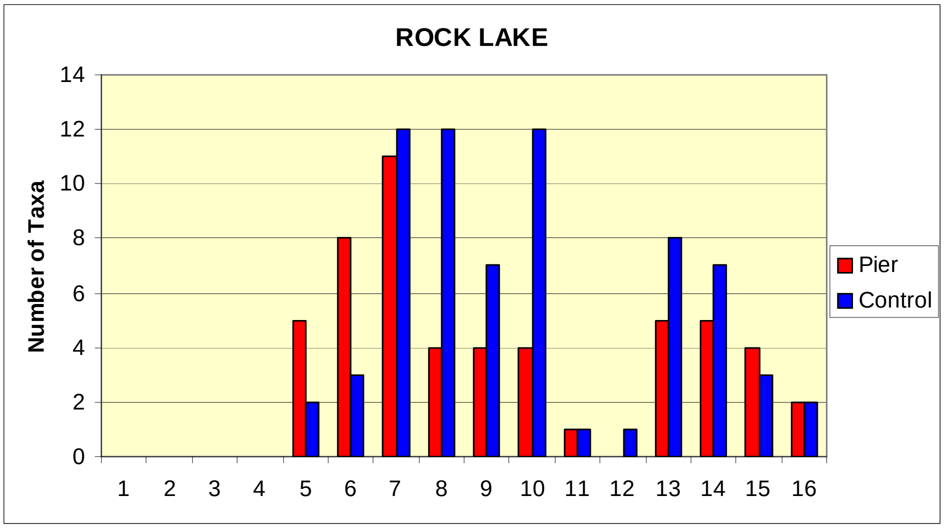
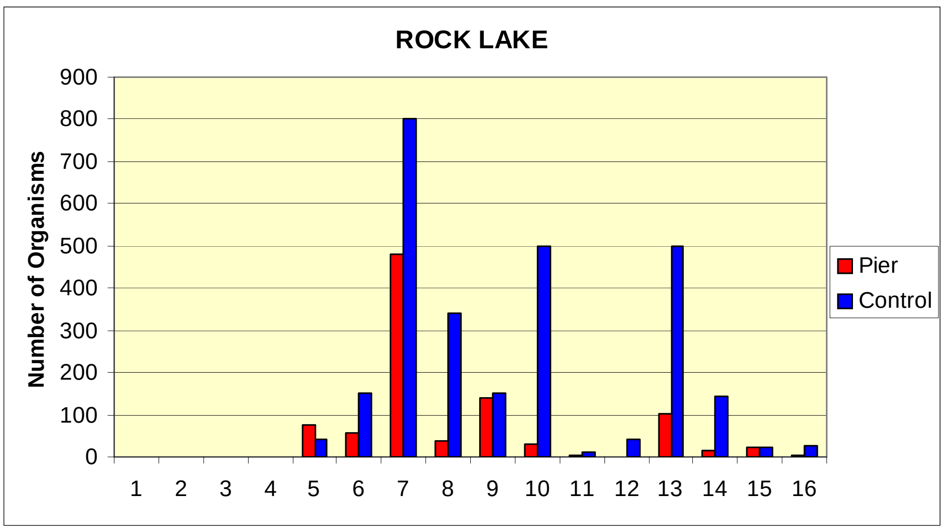


Figure 9. Mean macroinvertebrate species richness and counts for Rock Lake. Site locations are identified in Figure 2.





The greatest differences between pier and control sites with respect to macroinvertebrates were in total numbers collected. In Lake Ripley, greater numbers were generally found in the control areas, with the exception of Sites 2, 3, and 6 (Figure 8). Site 2 was dominated by Gerromorpha—an organism that resides on the water surface and may therefore not be as macrophyte dependent (Hilsenhoff 1995). Site 6 was dominated by snails.

In Rock Lake, at all sites where macroinvertebrates were found, there were higher numbers in the control areas, with the exception of Site 5 (Figure 9). Large differences in macroinvertebrate numbers were attributable to high numbers of snails.

In both lakes when examining all of the sites together, there were considerably more macroinvertebrates found in the control areas. In Lake Ripley, the median number of organisms found under piers was 19, while the median for the control areas was 43. Macroinvertebrate numbers were higher in Rock Lake, with a median of 30 organisms under piers and 90 in the control areas.

Fish Abundance

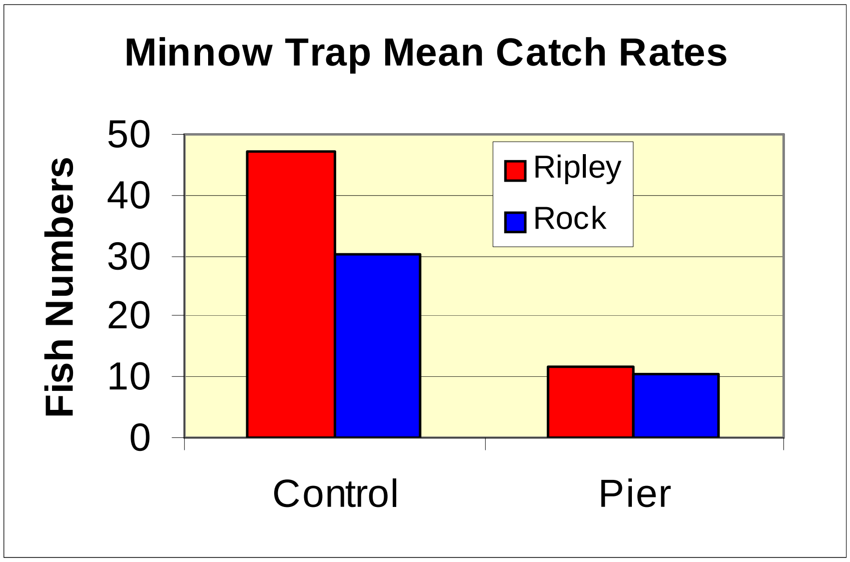
Table 4. Fish Relative Abundances

	Common Name	Scientific Name	Control	Pier
Ripley	mudminnow	*Umbra limi*	<1%	<1%
	bluntnose minnow	*Pimephales notatus*	<1%	<1%
	yellow bullhead	*Ameiurus natalis*	0	<1%
	tadpole madtom	*Noturus gyrinus*	<1%	<1%
	bluegill	*Lepomis macrochirus*	79%	73%
	pumpkinseed	*Lepomis gibbosus*	5%	1%
	green sunfish	*Lepomis cyanellus*	<1%	0
	largemouth bass	*Micropterus salmoides*	7%	14%
	smallmouth bass	*Micropterus dolomieu*	<1%	3%
	rock bass	*Ambloplites rupestris*	<1%	<1%
	black crappie	*Pomoxis nigromaculatus*	<1%	0
	hybrid bluegill/pumpkinseed	*Lepomis macrochirus x Lepomis gibbosus*	<1%	0
	yellow perch	*Perca flavescens*	6%	4%
Rock	tadpole madtom	*Noturus gyrinus*	0	<1%
	bluegill	*Lepomis macrochirus*	91%	89%
	pumpkinseed	*Lepomis gibbosus*	0	1%
	green sunfish	*Lepomis cyanellus*	0	<1%
	largemouth bass	*Micropterus salmoides*	3%	3%
	smallmouth bass	*Micropterus dolomieu*	0	1%
	rock bass	*Ambloplites rupestris*	3%	2%
	yellow perch	*Perca flavescens*	3%	2%

A total of 13 species (including one hybrid) were collected from Lake Ripley and 8 species from Rock Lake. Juvenile bluegills were most abundant, comprising approximately 91 percent of the catch in Rock Lake and 79 percent in Lake Ripley. Overall, juvenile Centrarchids (bluegill, green sunfish, rock bass, pumpkinseed, black crappie and smallmouth and largemouth bass) represented over 90% of the fish collected from both lakes.

Minnow trap catch rates were significantly different between piers and control sites, with significantly higher ($P < .01$) numbers of fish found in control sites than under piers (Figure 10). Within control sites, fish catch rates ranged from 4 to 62 fish per night in Rock Lake and 7 to 78 fish per night in Lake Ripley. Under piers, fish catch rates ranged from 0 to 46 fish per night in Rock Lake and from 0 to 41 fish per night in Lake Ripley. The lowest fish catch rate in Rock Lake was from a trap deployed in a small, isolated plant bed adjacent to Site 2. The small fragmented aquatic plant bed represented a very scarce form of plant habitat along a heavily developed shoreline. In Lake Ripley, the lowest fish catch rate was from a trap deployed in a monotypic lily pad bed (near Site 10) where seasonally low dissolved oxygen levels (< 5 mg L^{-1}) were measured.

Figure 10. Mean fish catch rates.



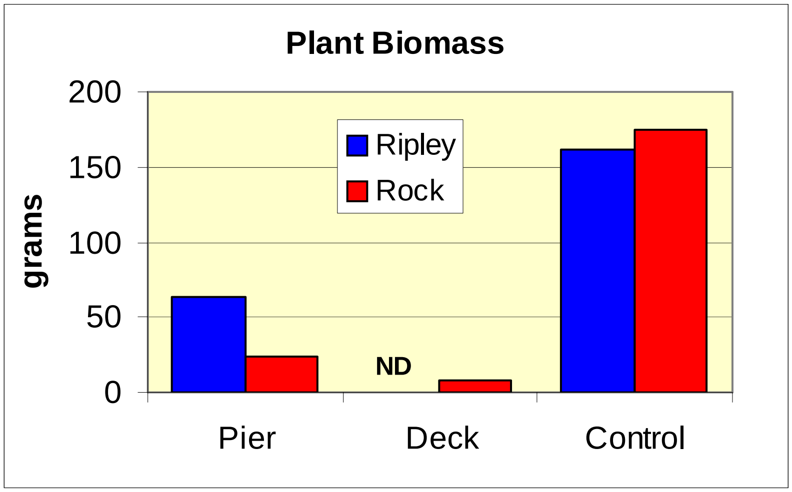
Comparing samples taken under piers, the upper 33rd percentile of minnow trap results (ranging from 12 to 46 fish per night) coincided with higher aquatic plant cover, with maximum plant cover ranging from 40 to 100% (mean = 87%). The lower 67th percentile of sample results (0 to 8 fish per night) occurred in habitat with maximum cover values ranging from 0 to 100% (mean = 51 %). Based upon percent cover, the habitat differences were statistically different ($P = .03$). While percent aquatic plant cover suggested higher fish catch rates near higher plant cover, neither plant biomass ($R^2 = .09$) nor shading ($R^2 = .05$) data were predictive of fish catch rates. Overall, fish were more abundant under piers in close proximity to healthy, unfragmented aquatic plant beds and shorelines with lower pier densities ($P < .01$).

Discussion

Pier impacts on light penetration

Consistent with pier shading investigations conducted on coastal waters (Burdick and Short 1999, Shafer 1999), results of this study documented a nearly 10-fold reduction in light availability underneath piers. Largely as a result of the increased shading, macrophyte growth was also considerably less under the piers when compared with the control sites (Figure 11). Burdick and Short (1999) identified pier height as the most important factor affecting light intensities and macrophyte densities, with pier width and orientation also being important factors. In our study, pier width and height above the water did not have a significant affect upon plant growth, nor did orientation. This is despite the fact that piers orientated north and south generally had less shading than piers that were orientated east and west. Apparently the increased light penetration was not great enough to stimulate plant growth. Decks, because of their larger size and thus greater capacity to reduce light penetration, reduced plant growth more than linear piers. Garrison et al. (1999) found that large decks effectively prevented plant growth as well as macroinvertebrate colonization in two lakes in northern Wisconsin. The decks in these lakes were much larger than the ones in this study.

Figure 11. Mean plant biomass comparisons.



Macrophyte community response

Macrophyte biomass under piers was significantly reduced compared to control sites, but plant productivity could not be predicted based on light data alone. These results suggest that macrophytes are not affected by light intensity alone but other factors, such as substrate. At a few piers, for example, the surrounding area was devoid of macrophytes due to cobble substrate.

Shading below piers altered the plant community structure when growth was present. Muskgrass was found in greater frequency in control areas (69%) compared to shaded areas under piers (36%); whereas wild celery was more common under piers (38%) compared to control areas (25%). While these differences may partially reflect the effects of motorboat-induced turbulence and scouring (Asplund and Cook 1997) that can favor low growing plants, wild celery is particularly well adapted to growing in low light conditions (Titus and Adams 1979).

Under larger deck sections, wild celery and muskgrass were often the only plants found, but their biomass was relatively low compared to that of a mixed plant community in control areas. These observations are consistent with shaded eelgrass plots with shoot densities 40-47% lower than in control areas (Shafer 1999, Burdick and Short 1999). Wild celery shoot height and chlorophyll pigment were observed to be higher under piers, which are consistent with similar reports for coastal eelgrass (Burdick and Short 1999) and seagrass (Shafer 1999).

While wild celery and muskgrass appeared to thrive better than other species under piers, "dead areas" were found devoid of plants near the midpoints below decks and wider pier sections. These areas are believed to receive the lowest cumulative light over a 24-hr period. Overall, light-intensity measurements under the piers were lower than minimum levels of 14-18% needed to support seagrass in coastal areas (Shafer 1999). In Trout Lake, wild celery was found growing where light intensity was only 4.5% (Spence and Chrystal 1970). In the present study, lower light levels were frequently found below piers (<3%), and particularly deck sections (<2%).

Macroinvertebrate community response

While the macrophyte community was clearly adversely impacted by piers, the impact on the macroinvertebrate community was more variable. Generally more macroinvertebrates were found in the control areas compared with under the piers (Figure 12). Exceptions occurred when either plant growth was low in the control site because of unsuitable substrate or because an alternative habitat (filamentous algae) was available under the piers.

Figure 12. Mean macroinvertebrate count comparisons (decks excluded).

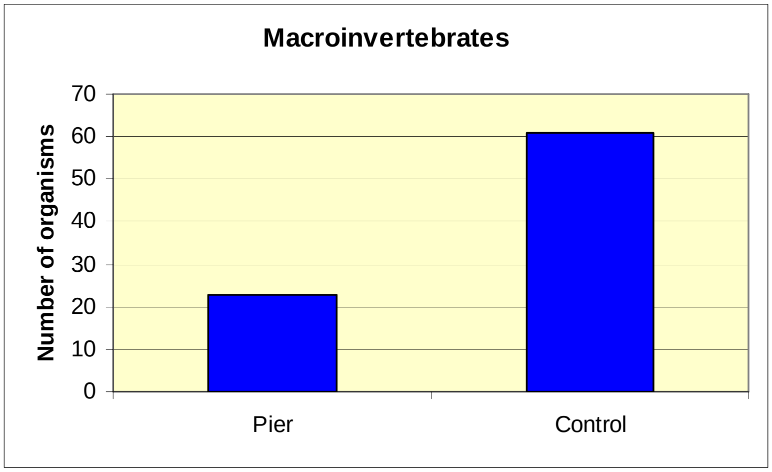
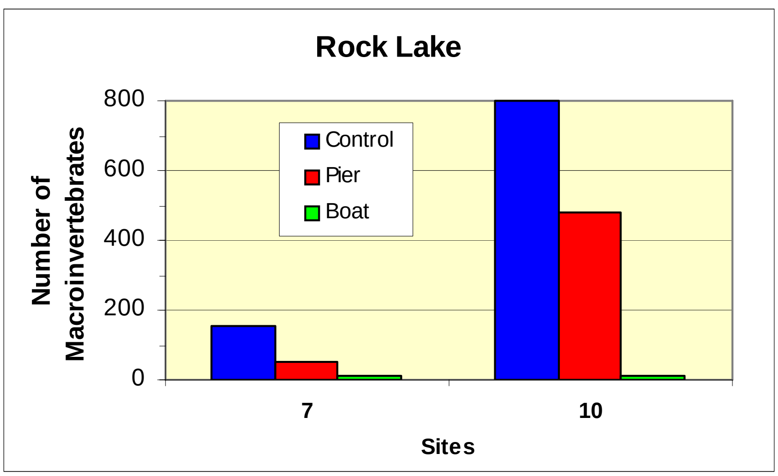


Figure 13. Macroinvertebrate counts from two Rock Lake sites where boat shading was evaluated. Site locations are identified in Figure 2.



Although the plant and macroinvertebrate communities were reduced underneath the piers compared with the control sites, the adverse impact of shading is not limited to piers. Underneath boats at two sites in Rock Lake, Sites 6 and 7, the shading was greater than under piers. Under the boats there were no plants and the number of macroinvertebrates was greatly reduced (Figure 13).

Fish community response

Minnow trap surveys demonstrated that juvenile Centrarchids exhibit an overall preference for aquatic plant beds away from piers. This preference was clear despite the inability to predict fish catch rates based either on plant biomass next to piers ($R^2 = .09$) or total pier surface area ($R^2 = .05$). The ability to predict fish abundance was more effective when habitat was considered on larger scales (Jennings et al. 1999). The piers with the greatest numbers of juvenile Centrarchids were generally located in areas with lower pier densities and in close proximity to designated "Sensitive Areas."[1]

Where disturbance around piers was evident (Lake Ripley, Sites 4 and 10), significantly reduced numbers of fish were found under the piers compared to the control areas. The data suggest that shading alone is only part of the disturbance, and that the impact of a pier can increase beyond the shaded zone due to factors such as motorboat scour, plant raking, and other near-shore activities.

Lower pier densities typically occurred near or within DNR designated Sensitive Areas. Based on field observations, the highest catch rates under piers occurred where the structures were built in close proximity to floating-leaf aquatic plant beds. These conditions were typical of Sensitive Areas and coincided with infrequent human use. The lowest catch rates under piers generally occurred in areas with higher pier densities with relatively sparse aquatic vegetation. An exception was Pier 6 on Lake Ripley, where the pier was located on a relatively undeveloped lot along an otherwise heavily developed shoreline. While aquatic plants were relatively scarce at this location, overhanging woody snags provided fish habitat. In addition, boats were not used at the site and human activities around the structure appeared to be infrequent.

Shoreline seining conducted on both lakes in 2004 (WDNR unpublished data), found diverse non-game fish populations (Cyprinidae, darters, brook silversides) representing 59% of the total catch in Lake Ripley and 26% of the catch in Rock Lake. Given the relatively high percentages of juvenile Centrarchids in the minnow traps compared to non-game species, the habitat preferences of non-game species could not be ascertained. This was most likely due to the overall high abundance of juvenile Centrarcids in both lakes, behavioral aggression of Centrarchids, and gear selectivity toward juvenile Centrarchids.

Historically, both lakes supported populations of intolerant or rare fish species, including pugnose shiner (*Notropis anogenus*), blackchin shiner (*Notropis heterodon*), blacknose shiner (*Notropis heterolepis*), banded killifish (*Fundulus diaphanus*) and least darter (*Etheostoma microperca*) (Fago 1992), which are species dependent on aquatic plants (Becker 1983, Lyons 1992, Lyons et al. 2000). Shoreline seining surveys conducted in 1995, 2000 and 2001 did not detect the presence of these species in Rock Lake. In 2004, three of the five species (pugnose shiner, blackchin shiner, and least darter) were found in 3 of 12 sampling sites on Rock Lake. These 3 sites were located within designated Sensitive Areas. Banded killifish and blacknose shiners have not been found in Rock Lake since 1974. Shoreline seining conducted on Lake

[1] "Sensitive Areas" are identified through DNR surveys as critical to fish and wildlife and water quality, designated as such in state administrative rules, and often protected by local ordinances. They are typically characterized by an abundance of diverse, native aquatic plant communities or other unique habitat features. On Lake Ripley, for instance, a riparian property owner who wishes to expand or place a new pier in a Sensitive Area must get a DNR permit to ensure that the structure is sited, designed and built to minimize damage. On Rock Lake, all watercraft are required to go no faster than slow-no-wake speeds in designated sensitive areas.

Ripley in 1974-75 (Fago 1992) found abundant populations of the five sensitive fish species, but seining in 1996, 2001 and 2004 failed to find them.

Conclusions

Since the 1970s, there has been minimal change in open water trophic conditions (P. Garrison unpublished paleoecological data, WDNR unpublished data) but a dramatic increase in riparian development around each of the lakes. In Rock Lake, pier numbers increased from 96 in 1950, to 142 in 1963, to 276 in 1996. Pier densities in 2004 were 54.3 piers mi^{-1} on Lake Ripley and 28.3 piers mi^{-1} on Rock Lake. In Lake Ripley, littoral zone habitat encompassing water depths of 3 ft or less, represents 8.4% of the lake surface area. Based on piers sampled during this study, an average pier area of 546.4 sq ft represents total shading of the near-shore littoral zone of approximately 3 acres or 8.6%.

In addition to nearshore area shaded by pier structures, motorboat activity associated with the piers also will adversely impact the plant community through direct cutting by propellers and contact with boat hulls (Haslam 1978, Liddle and Scorgie 1980, Asplund and Cook 1997). The reduction in plant growth will have an adverse impact on higher levels in the food chain as evidenced by reduced macroinvertebrates and fish numbers underneath the piers. Cumulatively, the overall habitat effects of shading are just a portion of the total disturbances and fragmentation around piers.

This study has confirmed other work that found an adverse impact of shoreline development upon fish communities. The reduced relative abundance of juvenile Centrarcids under piers in our study supports other studies that found negative impacts of shoreline development on littoral fish communities (Christiansen et al. 1996, Jennings et al. 1999, Schindler et al. 2000, Olden and Jackson 2001, and Scheuerell and Schindler 2004). Many of these studies found that with increased development there was a loss of refugia and resource heterogeneity. The current study indicates that placement of piers alters macrophyte growth and ultimately habitat for macroinvertebrates and fish. This results in a loss of biocomplexity in a lake’s littoral zone ecosystem.

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