Catchability of largemouth bass (*Micropterus salmoides*) on coarse woody habitat in a Northern USA temperate lake

Elizabeth Wildenhain

University of Notre Dame Environmental Research Center, Land O'Lakes, WI 54540

Mentor: Jake Ziegler

Abstract

Coarse woody habitat (CWH), composed of dead treefall, has declined in lakes with shoreline development. Some areas have thus begun to instate CWH restoration programs, but the effects of reintroducing CWH are not fully understood. As many of these lakes are used for recreational fishing, the effect on fish catchability is of particular interest. Toward this end, we measured the catchability of largemouth bass (*Micropterus salmoides*) by angling at coarse woody and exposed sites on Long Lake in Gogebic County, Wisconsin. Catchability was estimated from tagged bass recapture frequency at each site. A multiway repeated-measures ANOVA indicated a significant increase in catchability at CWH sites. We also examined the effect of time of day on catchability and found a significantly higher catchability in the evening compared to the morning. An increase in catchability at CWH sites has both drawbacks and benefits: CWH restoration could lead to overfishing but could also be used as a replacement for stocking to keep catch rates high. Although further studies are necessary to determine the cause of these increases in catchability, our results could help CWH restoration projects develop appropriate procedures and countermeasures to ensure the benefits of CWH reintroduction are achieved.

Keywords: catchability, coarse woody habitat, fish habitat restoration, *Micropterus salmoides*, recreational fishery management, University of Notre Dame Environmental Research Center.

Introduction

Coarse woody habitat (CWH) "reefs"—accumulations of dead treefall—are a common feature of undisturbed lakes in forested regions. However, CWH reefs have declined in developed areas due to removal of trees from and around lakes (Czarnecka 2016; Christensen et al. 1996). Loss of CWH can decrease littoral diversity, disrupt lake predator-prey interactions, and alter fish behavior (Czarnecka 2016; DeBoom and Wahl 2013). Recognition that a lack of CWH can negatively affect these ecological characteristics has led to management in some developed areas to restore CWH by intentional introduction of wood to the littoral zone (Czarnecka 2016). The success of these projects, however, has been ambiguous, and the effects of increased CWH on other factors is often not fully understood or considered in the development of restoration plans (Czarnecka 2016). One such unexamined factor is the effect of CWH on fish catchability.

Catchability, a measure of the ease of capture of a particular fish population, can determine population declines for some species. For example, aggregation of northern cod (*Gadus morhua)* around habitat structure can lead to increased catchability independent of total population density (Rose and Kulka 1999). Catchability is defined as the fraction of fish stock collected per unit effort (equation 1),

$$q = \frac{C/N}{E}, \tag{1}$$

where *C/N* is an individual capture probability and E is total effort. The catchability of a species in a particular lake can be estimated using a tagged fish population and the equation (equation 2)

$$q_i = \frac{R_i \times A}{M_{a,i} \times E_i}, \tag{2}$$

where R_i is the total number of recaptures, *A* is the surface area of the lake, $M_{a,i}$ is the total number of tagged individuals, and E_i is effort in hours (Hangsleben et al. 2013). Catchability varies in response to factors such as species, season, lake, and fish behavior (Hangsleben et al. 2013; Rose and Kulka 1999).

Restoration of CWH in developed areas could induce aggregation behavior in fish and increase their catchability in the restored lakes. In the pacific northwest, for example, lakes with shoreline development—and thus lower CWH—exhibit less fish aggregation, suggesting that restoration of CWH may in contrast lead to higher fish aggregation and catchability (Scheuerell and Schindler 2004). Further, the aggregation of northern cod (*Gadus morhua)* around habitat structure leads to increased catchability independent of total population density and is the hypothesized cause of the collapse of the cod fishery in 1992 (Rose and Kulka 1999; Hutchings 1996). It is thus possible that restoring CWH could lead to overfishing in these lakes if countermeasures are not considered. Therefore, directly characterizing the relationship between CWH and fish catchability is of applied ecological importance.

In this study we examined the effect of shoreline CWH on fish catchability by comparing catchability of largemouth bass (*Micropterus salmoides*) on CWH reefs to that of exposed sites lacking CWH structure. Largemouth bass are a primarily littoral species whose behavior is influenced by CWH abundance: higher CWH causes bass to act more as sit-and-wait predators and to decrease their home range, in contrast to exposed areas, where they actively seek prey and have larger home ranges (Essington and Kitchell 1999; Ahrenstorff et al. 2008). Based on this and the increase in catchability associated with aggregation around habitat structure, we hypothesized that bass catchability would increase on CWH reefs. In this study we also assessed catchability at different times of day. Understanding the unintended effects of management practices like CWH restoration can inform appropriate responses and regulations that should be put in place when such management is carried out, which could prevent undesirable ecological effects.

Materials and Methods

We conducted our study on Long Lake in the University of Notre Dame Environmental Resource Center (UNDERC) in Vilas County, Wisconsin and Gogebic County, Michigan. Long Lake is divided into two basins (East and West Long) with separate populations of largemouth bass (*Micropterus salmoides*), which have been previously marked with internal electronic tags. Each basin has a mixture of CWH and exposed habitat.

To identify coarse woody and exposed sites for sampling, we surveyed both basins for CWH and exposed habitat. On both East and West Long, we selected six sites of each habitat type (coarse woody and exposed) for a total of twelve sites per basin. CWH sites contained three or more logs of at least 150 cm in length and 5 cm in diameter, while exposed sites contained fewer than three such logs. We chose our exposed and CWH sites such that they differed markedly in CWH (i.e. in number of logs), were distributed around the entirety of the lake perimeter, and were not immediately adjacent to each other in order to minimize recapture of the same individual at multiple sites. Each site contained ten meters of shoreline, which we marked with flags on shoreline vegetation to facilitate locating the sites during data collection.

During mid to late June, we assessed the catchability of largemouth bass at each site on the two basins. We estimated catchability for 4 days per basin, starting at both 8 am and 4 pm. This was done by angling from a boat for 10 min at each site and recording the number of tagged bass caught (R_i). The lure used was a rubber artificial worm (YUM Dinger®). We identified captured individuals with an electronic tag reader, held them until sampling at the site was completed, and then released them at the same site. For both morning and afternoon samplings, we randomized the order we visited the sites.

For each measure of bass recapture we estimated catchability using equation (2) where R_i is the total number of tagged bass caught at the site, A is the surface area of the entire basin (East or West Long), $M_{a,i}$ is the total number of tagged bass in the basin, and E_i is effort in hours. To control for any potential effects of time of day on bass catchability, we performed a multiway repeated-measures ANOVA on the mean catchability values for each site, treating habitat (CWH or exposed) and time of day (morning or evening) as factors and basin (East or West) as a block. Because bass are primarily littoral, we also calculated an adjusted catchability using shoreline perimeter in place of lake area and repeated the statistical analysis. To compare catchability on coarse woody sites at two population sizes, we calculated catchability using equation 2 without the area term. We then performed a randomized-block repeated-measures ANOVA on CWH site catchabilities with basin (East or West) as a factor and time of day (morning or evening) as a block. All statistical tests were performed in R (R Core Team 2013).

Results

A multiway repeated-measures ANOVA on the catchability estimates using lake area indicated that catchability was significantly higher at CWH than exposed sites (mean ± SE; coarse, 0.0465 ± 0.0048; exposed, 0.0232 ± 0.0048; $F_{1,21} = 9.962$, $p < 0.005$; fig. 1). A multiway repeated-measures ANOVA on the catchability estimates using shoreline perimeter likewise showed a significant increase in catchability at coarse woody sites (mean ± SE; coarse, 0.0121 ± 0.0013; exposed, 0.0060 ± 0.0013; $F_{1,21} = 8.981$, $p < 0.01$; fig. 2).

The multiway repeated-measures ANOVA using catchability calculated from lake area also indicated significantly higher catchability in the morning compared to the evening (mean ± SE; morning, 0.0236 ± 0.0056; evening, 0.0461 ± 0.0053; $F_{1,22} = 10.178$, $p < 0.005$; fig. 3). Similarly, the multiway repeated-measures ANOVA on catchability calculated from shoreline perimeter revealed a significant increase in catchability in the evening (mean ± SE; morning, 0.0062 ± 0.0016; evening, 0.0119 ± 0.0015; $F_{1,22} = 8.985$, $p < 0.01$; fig. 4).

A randomized-block repeated-measures ANOVA on catchability calculated from two population sizes indicated no significant difference between East Long and West Long at coarse woody sites (mean ± SE; West Long, 0.0106 ± 0.0020; East Long, 0.0109 ± 0.0020; $F_{1,10} = 0.013$, $p << 0.05$; fig. 5).

Discussion

Our results indicate a significant increase in bass catchability at sites with CWH. The reason for this increase is likely due to the role of CWH as habitat structure, which can induce fish aggregation (García-Charton and Pérez-Ruzafa 2001). Further, previous studies have indicated that largemouth bass tend to decrease both their home ranges and active searching for prey (Ahrenstorff et al. 2008). It is therefore likely that CWH induces bass aggregation, which couples with a stationary behavior and sit-and-wait predation, leading to higher catchability at CWH sites. We did not directly measure fish aggregation levels, but our results suggest future studies should measure the relationship between CWH and largemouth bass aggregation or between largemouth bass aggregation and catchability.

Increased largemouth bass catchability on CWH has implications for lake fisheries management, especially if a similar catchability increase occurs with other fish species. Restoration initiatives, such as the "Fish Sticks" projects by Wisconsin Department of Natural Resources, must account for increased catchability as CWH is added to previously depleted lakes (Wisconsin Department of Natural Resources 2016). Such projects ought to take appropriate countermeasures to avoid overfishing, such as reducing bag limits on fish taken from lakes with restored CWH or encouraging catch- and-release, so that the potential benefits of CWH are realized.

This increase in catchability could, however, be useful in lakes that are stocked to keep catch rates high. Stocking fish is an expensive endeavor: for example, a complete stocking project of largemouth bass in the Harris Chain of Lakes, FL cost almost $500,000 between 2004 and 2013 (Canfield et al. 2013). In contrast, reintroduction of CWH is relatively inexpensive and requires little maintenance (Lester and Boulton 2008). If CWH restoration can significantly increase the catchability of bass, and potentially other species, this could offer a more economical method of maintaining high catch rates in frequently fished lakes. Because CWH has ecological additional benefits like providing refuge for young of the year fish—which is important for natural recruitment and stock rebuilding—CWH restoration may reduce reliance on stocking and could better preserve recruitment and fish stocks in heavily fished lakes (Schindler et al. 2000, Walters and Kitchell 2001, Sass et al. 2006). These benefits would only manifest if fishing is catch-and-release on the restored lake, as harvesting without stocking would deplete the fish population. Angler satisfaction is often determined by catch rate and fish size, both of which can be maximized in a catch-and release-system (Beardmore et al. 2014). Further, a 2011 survey of northern Wisconsin sport fish catch-and-release rates found that high proportions of fish caught are released by anglers, with nearly all largemouth and smallmouth bass released after capture (Gaeta et al. 2013). Thus increasing catch rates by CWH reintroduction deserves consideration as a replacement for stocking despite its restriction to catch-and-release programs.

One concern of increased catchability at CWH sites is high catch rates even at low population densities, a phenomenon known as "hyperstability" (Hilborn and Walters 1992). Hyperstability can mask population collapse in fisheries by suggesting a constant population size while the fish population in fact declines, which has been the case in barred sand bass, kelp bass, and rainbow trout fisheries (Erisman et al. 2011; Ward et al. 2013). In our study, the population sizes of tagged largemouth bass differed between East and West long (356 and 461 tagged individuals respectively), but we found no significant difference in catchability at coarse woody sites between basins when calculating catchability from population size. This result agrees with the hypothesis that increased catchability with high CWH abundance poses a threat of hyperstability.

Bass population densities were relatively high in both basins, however, and other factors (such as levels of dissolved organic carbon) varied between the basins. To more fully examine the risk of hyperstability at sites with increased CWH, a study of catchability at varying bass densities could be done by temporarily removing a portion of the bass population in one basin, in order to artificially decrease the population density in one basin. If high catch rates are maintained in CWH areas despite a decrease in fish density, hyperstability in response to higher CWH levels is a concern that should be considered in fishery management. This would also reinforce our conclusions about the drawbacks and benefits of CWH restoration: high catch rates at low densities could lead to overfishing or could be used as a management technique in place of fish stocking if proper catch regulations are adopted and followed.

Our results also indicate an increase in bass catchability in the evening when compared to the morning. As water temperature alters bass activity levels, this difference in catchability could be related to temperature or other weather variation throughout the day (Hasler et al. 2009). A future study examining the relationship between various weather conditions (especially temperature) and bass catchability could help determine if this is the cause of increased catchability later in the day. Comparing CWH and exposed sites in such a study would be of interest as well. Perhaps CWH increases catchability more at colder water temperatures, as bass tend to be less active in colder conditions and may therefore aggregate in a more stationary manner around habitat structure. The results of such studies, combined with our conclusion that CWH increases bass catchability, could further inform CWH restoration projects to develop appropriate fishing regulations, thus helping to ensure that the benefits of CWH reintroduction are achieved.

In conclusion, our study revealed that the catchability of largemouth bass is significantly higher in the presence of CWH and in the evening. Further studies would aid in uncovering more precise reasons for these increases. In the meantime, knowledge of these trends can inform present fishery management programs involving CWH restoration.

Acknowledgements

Special thanks to Jake Ziegler for continued guidance throughout the study. Thanks also to the class T.A.s Catherine McQuestion and Kristin Bahleda for constructive criticism and advice. I would like to give special thanks to the Bernard J. Hank Family Endowment for their generous support. I would also like to extend my gratitude to the entire UNDERC class for assistance and support throughout the project, especially Rodrigo Rivero for accompanying me frequently in the field. Thank you also to my family for helping to make this summer research possible.

Literature Cited

Ahrenstorff, T. D., G. G. Sass, M. R. Helmus. 2008. The influence of littoral zone coarse woody habitat on home range size, spatial distribution, and feeding ecology of largemouth bass (*Micropterus salmoides*). *Hydrobiologia* 623(223).

Beardmore, R., L. M. Hunt, W. Haider, M. Dorow, and R. Arlinghaus. 2014. Effectively managing angler satisfaction in recreational fisheries requires understanding the fish species and the anglers. *Can. J. Fish. Aquat. Sci.* 72:1-14.

Christensen, D. L., B. R. Herwig, D. E. Schindler, and S. R. Carpenter. 1996. Impacts of lakeshore residential development on coarse woody debris in north temperate lakes. *Ecological Applications* 6(4):1143-1149.

Canfield, D. E., D. J. Pecora, K. W. Larson, J. Stephens, and M. V. Hoyer. 2013. Stocking wild adult Florida largemouth bass (*Micropterus salmoides floridanus*): An additional fish management tool. *Lakes & Reservoirs: Research & Management* 18(3):239-245.

Czarnecka, M. 2016. Coarse woody debris in temperate littoral zones: implications for biodiversity, food webs, and lake management. *Hydrobiologia* 767(1):13-25.

DeBoom, C. S., and D. H. Wahl. 2013. Effects of coarse woody habitat complexity on predator-prey interactions of four freshwater fish species. *Trans. Am. Fish. Soc.* 142: 1602-1614.

Erisman, B. E., L. G. Allen, J. T. Claisse, D. J. Pondella II, E. F. Miller, J. H. Murray. 2011. The illusion of plenty: hyperstability masks collapses in two recreational fisheries that target fish spawning aggregations. *Canadian Journal of Fisheries and Aquatic Sciences* 68(1):1705-1716.

Essington, T. E. and J. F. Kitchell. 1999. New perspectives in the analysis of fish distributions: A case study on the spatial distribution of largemouth bass (*Micropterus salmoides*). *Canadian Journal of Fisheries and Aquatic Sciences* 56:52-60.

Gaeta, J. W., A. W. Latzka, B. Provencher, and S. R. Carpenter. 2013. Catch-and-Release Rates of Sport Fishes in Norther Wisconsin from an Angler Diary Survey. *North American Journal of Fisheries Management* 33(3):606-614.

García-Charton, J. and Pérez-Ruzafa, Á. 2001. Spatial pattern and the habitat structure of a Mediterranean rocky reef fish local assemblage. *Marine Biology* 138: 917.

Hangsleben, M. A., M. S. Allen, and D. C. Gwinn. 2013. Evaluation of electrofishing catch per unit effort for indexing fish abundance in Florida lakes. *Trans. Am. Fish. Soc.* 142(1):247-256.

Hasler, C. T. C. D. Suski, K. C. Hanson, S. J. Cooke, D. P. Philipp, and B. L. Tufts. Effect of water temperature on laboratory swimming performance and natural activity levels of adult largemouth bass. *Canadian Journal of Zoology* 87(7):589-596.

Hilborn, R. and C. J. Walters. 1992. Quantitative fisheries stock assessment: choice, dynamics and uncertainty. Chapman and Hall, New York.

Hutchings, J. A. 1996. Spatial and temporal variation in the density of northern cod and a review of hypotheses for the stock's collapse. *Canadian Journal of Fisheries and Aquatic Sciences* 53(5):943-962.

Lester, R. E., and A. J. Boulton. 2008. Rehabilitating Agricultural Streams in Australia with Wood: A Review. *Environmental Management* 42:310.

Rose, G. A., and D. W. Kulka. 1999. Hyperaggregation of fish and fisheries: how catch-per-unit-effort increased as the northern cod (*Gadus morhua*) declined. *Canadian Journal of Fisheries and Aquatic Sciences* 56(S1):118-127.

Sass, G. G., C. M. Gille, J. T. Hinke, and J. F. Kitchell. 2006. Whole-lake influences of littoral structural complexity and prey body morphology on fish predator-prey interactions. *Ecology of Freshwater Fish* 15:301-308.

Schindler, D. E., S. I. Geib, M. R. Williams. 2000. Patterns of Fish Growth along a Residential Development Gradient in North Temperate Lakes. *Ecosystems* 3:229-237.

Scheuerell M. D., and D. E. Schindler. 2004. Changes in the spatial distribution of fishes in lakes along a residential development gradient. *Ecosystems* 7(1):98-106.

Walters C. and J. F. Kitchell. 2001. Cultivation/depensation effects on juvenile survival and recruitment: implications for the theory of fishing. *Can. J. Fish. Aquat. Sci*. 58:39-50.

Ward, H. G. M., Askey, P. J., Post, J. R. 2013. A mechanistic understanding of hyperstability in catch per unit effort and density-dependent catchability in a multistock recreational fishery. *Canadian Journal of Fisheries and Aquatic Sciences* 70(10):1542-1550.

Wisconsin Department of Natural Resources. 2016. Fish sticks: Improving lake habitat. Available: http://dnr.wi.gov/topic/fishing/outreach/fishsticks.html. (July 15, 2016).

Figures

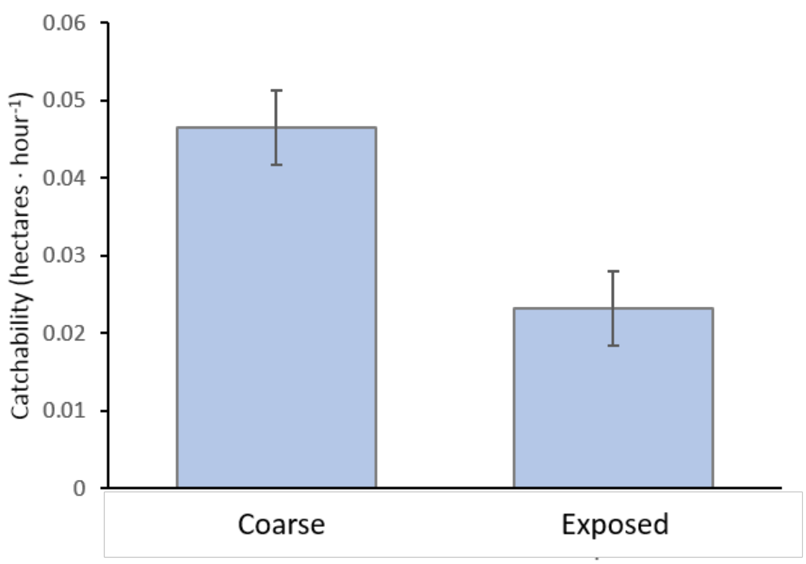

Fig. 1. Comparison of bass catchability calculated with lake area at coarse woody and exposed sites. Catchability was calculated from tagged bass recapture frequency and lake area (equation 2) at coarse woody and exposed sites in both West and East Long. A multiway repeated-measures ANOVA with habitat and time of day as factors and basin as a block indicated that catchability was significantly higher at CWH than exposed sites ($F_{1,21} = 9.962$, $p < 0.005$).

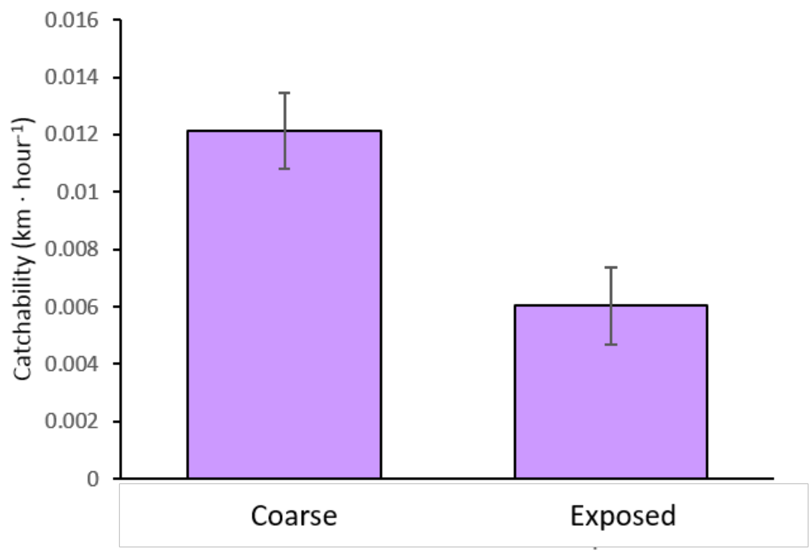

Fig. 2. Comparison of bass catchability calculated with shoreline perimeter at coarse woody and exposed sites. Catchability was calculated from tagged bass recapture frequency and lake perimeter at coarse woody and exposed sites in both West and East Long. A multiway repeated-measures ANOVAv with habitat and time of day as factors and basin as a block indicated that catchability was significantly higher at CWH than exposed sites ($F_{1,21} = 8.981$, $p < 0.01$).

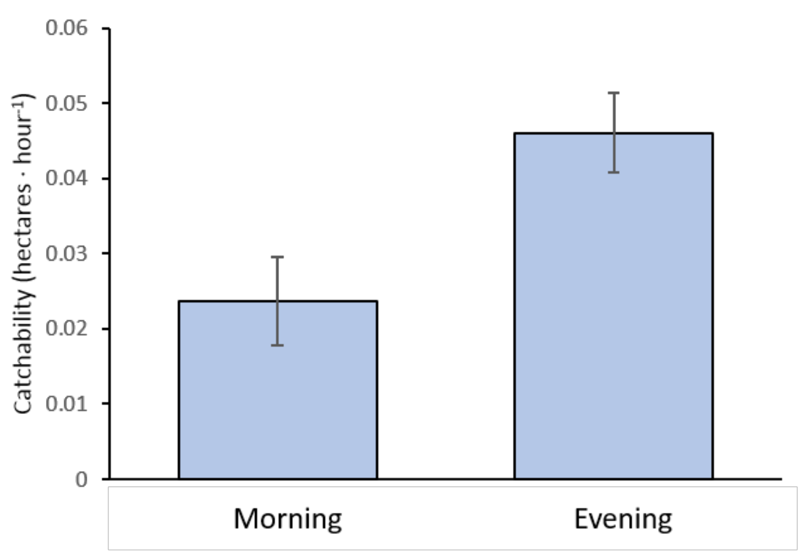

Fig. 3. Comparison of bass catchability calculated with lake area in the morning and evening. Catchability was calculated from tagged bass recapture frequency and lake area (equation 2) in the morning and evening at all sites in both West and East Long. A multiway repeated-measures ANOVA with habitat and time of day as factors and basin as a block indicated that catchability was significantly higher in the evening than in the morning ($F_{1,22} = 10.178$, $p < 0.005$).

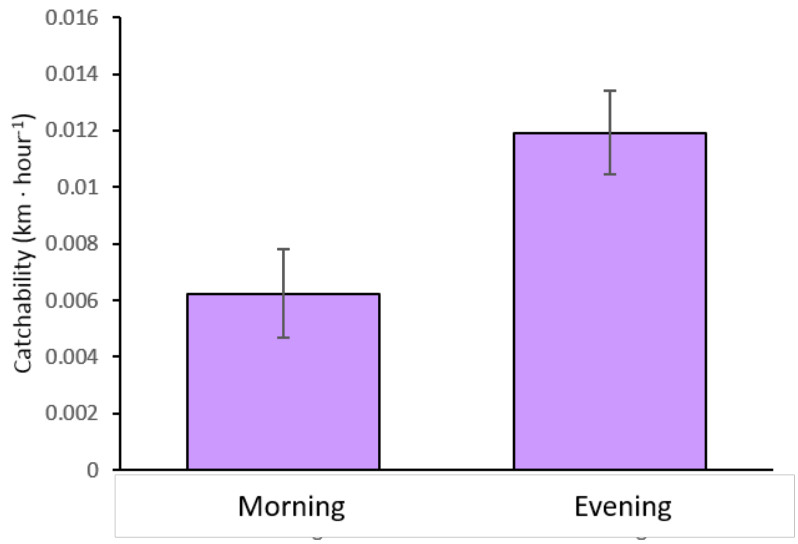

Fig. 4. Comparison of bass catchability calculated with shoreline perimeter in the morning and evening. Catchability was calculated from tagged bass recapture frequency and lake perimeter in the morning and evening at all sites in both West and East Long. A multiway repeated-measures ANOVA with habitat and time of day as factors and basin as a block indicated that catchability was significantly higher in the evening than in the morning ($F_{1,22} = 8.985$, $p < 0.01$).

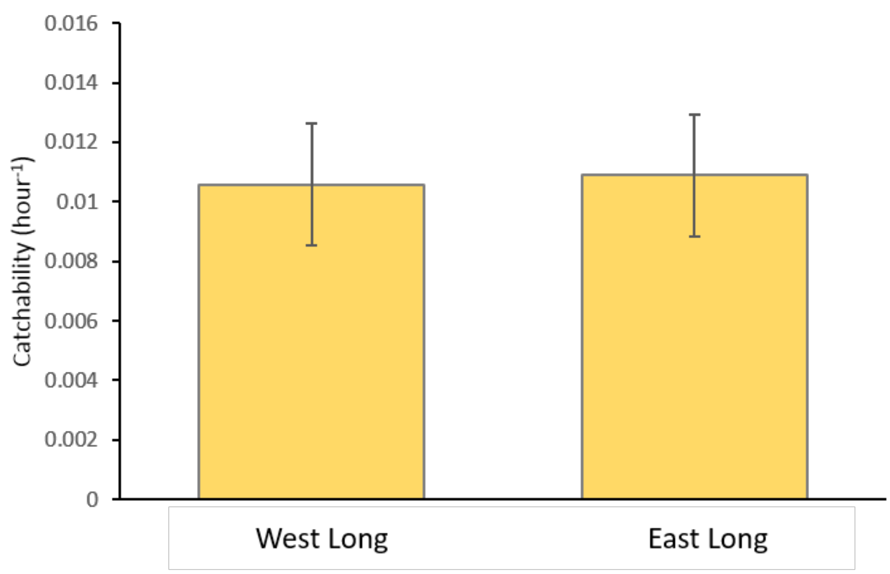

Fig. 5. Comparison of bass catchability in the two basins at coarse woody sites. To compare catchabilities across population densities at the coarse woody sites, catchability for each basin was calculated from equation 2 without the area term. A randomized-block repeated-measures ANOVA with basin as a factor and time of day as a block indicated that there was no significant difference in catchability at coarse woody sites across basins (mean ± SE; West Long, 0.0106 ± 0.0020; East Long, 0.0109 ± 0.0020; $F_{1,10} = 0.013$, $p << 0.05$).