FACTORS AFFECTING NESTING SUCCESS IN FLORIDA BASS *MICROPTERUS FLORIDANUS*

By

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OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT
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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Thesis Presented to the Graduate School
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Bed fishing in Florida Bass *Micropterus floridanus* fisheries has made nest survival a topic of interest for managers, but Florida Bass nesting has rarely been studied. My objectives were to determine what habitat and temporal characteristics (substrate, depth, water temperature) Florida Bass seek for nesting, to estimate nest survival, and to examine factors that influence nest survival to the swim-up fry stage. Four lakes were snorkeled in north-central Florida each year between 2010-2013 to survey bass nests. Snorkelers found 313 nests, of which 75% were found on vegetation. Guarding male fish were only seen on 64% of active nests, indicating lower nest fidelity than has been reported in other *Micropterus* spp. Florida Bass daily nest survival was estimated at 0.885. The most important factors in determining nest success were presence of a male bass and depth of the nest, whereas sizes of the male bass and of the brood were less important. Habitat and temporal characteristics had minimal effects on nest survival. Stunted growth in the study populations could have decreased power of male size for statistical tests. My results indicate lower nest fidelity for Florida Bass than has been reported for other black basses, but presence of the male was the most effective predictor of nest success.

CHAPTER 1
INTRODUCTION

Black Bass *Micropterus spp.* fishing in Florida is a major source of revenue for the state of Florida and a primary management and research concern for the Florida Fish and Wildlife Conservation Commission (FWC). In 2006, anglers in Florida spent 14 million angler-days fishing for black bass, generating US$1.25 billion in economic impact and supporting 12,000 jobs (U.S. Department of Interior 2006; FWC 2011). Florida Bass *M. floridanus* grow to larger sizes than Largemouth Bass *M. salmoides* (Bailey and Hubbs 1949), and thus the trophy Florida Bass fishery attracts anglers from across the world. Florida Bass are also widely stocked across the United States due to their potential for growth to trophy size (Siepker and Casto-Yerty 2008). Florida Bass nesting has rarely been studied, and there is concern from Florida anglers that fishing bass nests has negative impacts on the populations (FWC 2011). As a result, the FWC has identified Florida Bass nesting as an important research topic.

Male Florida Bass create shallow nests in the substrate where females then deposit their eggs (Miller 1975). The male bass guards the fertilized eggs from predators until after they hatch and become free swimming or “swim-up” fry (Ridgway 1988; Cooke et al. 2002). The male often stays with the swim-up fry until the fry ball disperses. Spawning in north central Florida begins in January and continues through June, starting when water temperatures are 15-17°C and generally peaking in March (Chew 1974; Rogers and Allen 2009).

The success of a brood is determined by a number of physical and biological factors, including size of male, timing of the nest (and associated water temperature), and age of the male bass (Gingerich and Suski 2011; Parkos et al. 2011). Development of a brood from eggs to swim-up fry is a common indicator of a successful nest (Brown 1984). Many spawning attempts are not successful, and brood abandonment is common due to storms, sudden temperature changes, and nest predation (Phillip et al. 1997; Steinhart et al. 2005, Gingerich and Suski 2011). Larger and older male Largemouth Bass create and guard nests that are more successful than smaller, younger conspecifics (Parkos et al. 2011). Size of the male bass is also positively related to nest success in Smallmouth Bass *M. dolomieu* (Gingerich and Suski 2011). In both species, larger bass spawn earlier in the nesting season (Goodgame and Miranda 1993), and thus their fry are larger than their smaller conspecifics and more likely to survive (Miranda and Hubbard 1994; Ludsin and DeVries 1997; Parkos and Wahl 2010). However, Rogers and Allen (2009) found no increase in overwinter survival for earlier-spawned Florida Bass. Size of the brood significantly influences male aggression (Suski and Phillip 2004); larger broods cause male bass to defend more aggressively.

Nest-guarding bass are highly vulnerable to angling. Males guarding larger broods are more likely to strike a lure than those defending small broods (Suski and Phillip 2004). While angling, scientists have managed to hook and land over 50% of bedding males (Phillip et al. 1997; Suski and Phillip 2004). Further, high visibility of bass nests compared to the surrounding substrate can make nests easy to locate for anglers in clear-water systems (Wagner et al. 2006). When a brood's guarding male bass is angled from the nest, the brood is much less likely to be successful owing to nest predation (Suski et al. 2003; Hanson et al. 2008). Probability of nest failure is positively related to the amount of time the fish is held off the nest (Suski and Philipp 2004).

Population-level impacts of bed fishing are unknown. Largemouth Bass recruitment is relatively constant for a range of population densities (Gwinn and Allen 2010; Allen et al. 2011), which could make individual nest success unimportant to recruitment. That is, fewer nests do not necessarily lead to fewer recruits the following year due to density dependent responses in juvenile survival or growth (Walters and Martell 2004). Parkos and Wahl (2010) suggested that managers should focus on nest success in order to improve recruitment in Largemouth Bass populations, and nest success remains a potentially important consideration in a fishery.

Florida Bass nesting success has not been well studied, and there is a need to understand how factors such as fish size, brood size, and habitat influence nest success. A survey of bass anglers performed by the FWC found that bed fishing for bass is a major public concern (FWC 2011). As a result, FWC has identified impacts to nesting success of bass as a priority research need. Largemouth and Smallmouth Bass nesting success has been studied (e.g. Steinhart et al. 2005, Parkos et al. 2011), but little is known about Florida Bass nesting success and their relation to the other *Micropterus* spp. Daily nest survival has only been estimated for Smallmouth Bass (Steinhart et al. 2005; Suski and Ridgway 2007), and nesting factors for Florida Bass have gone similarly unstudied. The objectives of this study were to determine habitat characteristics of Florida Bass nests (such as temperature, substrate, and depth), to assess factors influencing nest success, and to estimate daily nest survival for Florida Bass.

CHAPTER 2
METHODS

Study Site

The four lakes (Big Fish, Devils Hole, Keys, and Picnic Lakes) for this study are located on private, undeveloped land in Putnam County, Florida (Figure B-1). All lakes are relatively shallow and represent a range of trophic statuses (eutrophic to mesotrophic; Canfield and Hoyer 1992). The study lakes range from 3-18 ha in surface area and 2.3-4.0 m mean depth (Canfield and Hoyer 1992).

All four study lakes have abundant populations of Florida Bass *Micropterus floridanus* and Bluegill *Lepomis macrochirus*. Other species include Lake Chubsucker *Erimyzon sucetta*, Warmouth *Lepomis gulosus* in Keys, Picnic, and Devils Hole lakes; Florida Gar *Lepisosteus platyrhincus* in Devils Hole Lake, and Seminole Killifish *Fundulus seminolis* in Big Fish Lake (Canfield and Hoyer 1992).

Snorkeling Surveys

I evaluated brood success at each study lake via nest surveys, beginning with a systematic division of each lake into feasible sampling units. The littoral area (depth 0 – 3 m) of each lake was mapped and divided into transects using ArcMap 9.3 software (ESRI, Redlands, California). The littoral zone of the smaller lakes (< 5 ha; Keys Pond, Big Fish) was divided into four transects of equal area, whereas the littoral zone of larger lakes (> 5 ha; Picnic and Devils Hole) was divided into ten transects of equal area. These transects allowed snorkelers to sample at least two randomly selected transects from each lake on each sample day.

Nest surveys began once Florida Bass spawning began. Water temperature was monitored using Onset® HOBO temperature loggers placed at 1 m water depth. Boat surveys to observe the littoral zone of each lake were conducted once weekly starting before water temperatures approached the lower range of spawning temperatures reported for Florida Bass in Florida (15 - 17°C; Chew 1974). When evidence of spawning activity was observed (i.e. nest building, increased presence of adult bass in the littoral zone), snorkel surveys were initiated.

Snorkel surveys were conducted twice weekly (every three to four days) on all four lakes for the duration of the 2010-2012 spawning seasons and once weekly for the 2013 spawning season. One half of each of the smaller lakes (Keys and Big Fish) was snorkeled during each survey with a quarter of the lake being covered by each of two to three snorkelers. Thus, the entire lake was snorkeled each week (2010-2012) or every two weeks (2013) for these two lakes. In the larger lakes (Picnic and Devils Hole), two to three new transects were randomly chosen for each survey resulting in a total of two to six new transects covered in each lake each week. To cover the littoral zone represented in each transect, snorkelers swam in a zigzag pattern perpendicular to the shoreline out to approximately 3 m depth. Each bass nest observed was marked with an individually numbered tag and the approximate location was described and marked on a map of the lake.

Snorkelers collected a variety of data at each active nest they encountered. Active nests were defined as cleared areas of substrate that contained living eggs and/or larvae. Information collected for each nest included the depth of the nest (m), the developmental stage of the offspring (egg, yolk sac fry or swim-up fry), the relative number of eggs in the nest (nest score 1-5; Kubacki 1992), and a description of the nest substrate. Presence or absence of the male was noted, and when present, the total length of the guarding male was estimated visually to the nearest centimeter.

Observed nests were revisited upon successive survey days until brood success or failure was determined. Snorkelers would revisit each nest on every survey following first detection and note whether the brood was present, whether a swim-up fry ball was in the nearby water column, and whether fungus was present on the eggs. A brood was deemed successful if at least one free-swimming fry was found in association with the nest, while disappearance of the brood or fungus on all eggs resulted in a failed nest. If researchers were unable to find the nest on successive surveys the nest was categorized as an undetermined fate. Once a fate determination was made, nest visits were ended.

Analyses

I used the Program MARK (G. White, Colorado State University, personal communication; available at http://warnercnr.colostate.edu/~gwhite/mark/mark.htm) to conduct a nest survival analysis, which allows for unbiased estimates of daily nest survival for *Micropterus* spp. (Steinhart et al. 2005, Suski and Ridgway 2007). The Program R (R Core Team, Vienna, Austria) package RMark (Laake and Rexstad 2008) was used to create models in program MARK. The MARK nest survival analysis is based on Mayfield (1961), which allows for nests of unknown fate to be included in an analysis. Program MARK uses a maximum likelihood from the binomial distribution with the Mayfield method, providing the ability to compare individual covariates among nests.

I hypothesized that nest survival would be influenced by up to six variables (depth, male presence, lake, nest score, average water temperature on day found, and year), but limiting my analyses to a few combinations of these variables was deemed to be arbitrary. I used multimodel inference (Anderson 2008) in order to evaluate the influence of each variable on nest survival and avoid having to choose a single, “best” model for inference. Therefore, nest survival models were built using all combinations of possible explanatory variables, including up to six parameters, for a total of 64 models. Models were compared using Akaike’s Information Criterion, corrected for finite sample size (AICc; Dinsmore et al. 2002, Burnham and Anderson 2004). I did not test goodness-of-fit for these models, as there is no unbiased, practical method for evaluation of nest survival models (Sturdivant et al. 2007; Walker et al. 2013).

I also used RMark to generate mean daily nest survivals for individual covariates. For each model, an estimate of daily nest survival was generated for each nest. These nest survivals were then averaged across covariates of interest, so nest survival was estimated for each value of each covariate. Finally, the covariate-specific estimates were multiplied by the model’s AICc probability for each model (Anderson 2008). The results are estimates of daily nest survival for each covariate value, weighted by the model probabilities. Higher-ranked models contribute more to the parameter estimates. Thus, relationships between those covariates and nest survival could be inferred.

Finally, I used RMark to compare each predictor variable based on relative importance in all models combined. This approach sums the AICc weights for each model that a variable appears in, allowing a comparison of variable importance across all models evaluated (Anderson 2008). The higher ranked variables in terms of relative importance are the most related to nest survival, whereas lower ranking indicates a variable that is less related to nest survival.

CHAPTER 3
RESULTS

A total of 334 nests were surveyed across four years (2010-2013) of nesting, of which 21 nests were dropped due to incomplete information. The data thus comprised 313 nests with 176 successes for an observed nesting success of 56%. All lakes except Devils Hole exhibited skipped spawning during at least one year (Shaw and Allen 2014). Nest numbers differed greatly among lakes (Big Fish = 17 nests; Devils Hole = 285; Keys = 8; Picnic = 3). Three quarters (75%) of nests incorporated macrophytes in the nest depression, including 20% of nests on Spatterdock *Nuphar advena* and 10% of nests on Maidencane *Panicum hemitomon*. Thus, use of aquatic plants was very common for spawning fish in this study. We observed a nest guarding male on 201 nests, or 64% of the surveyed nests. Depth of the nests increased with increasing Julian date (Figure B-2). Nesting began when lake temperature reached 15°C and ceased above 27°C, with most nesting taking place between 20-24°C (Figure B-3).

In 2013, only two temperature loggers were recovered (from Big Fish and Keys Lakes), so temperatures for nests in Devils Hole Lake (n = 26) were estimated with linear regression models based on data from 2010-2012. The model was significant (F = 13500, df = 426, $P < 0.001$) and thus temperatures were estimated for nests found in Devils Hole during 2013. No nests were found in Picnic Lake in 2013.

Male presence, lake, and depth of nest all appeared in the nest survival models that with the most AICc support, but many models received substantial relative support in the AIC model selection framework (Table A-1). There were five models with ΔAICc < 2 and 26 models with ΔAICc < 8. This infers that no single model or single parameter had very strong support relative to other candidate models. However, the models with the most support shared several parameters in common, including lake, presence of a guarding male bass, and temperature of the lake when the nest was found. Nest score, depth, and year all appeared infrequently in the models that had the strongest support from AICc.

Daily nest survival for all nests was 0.885 ± 0.04 (median ± standard error). Presence of a guarding male and increasing temperature both increased daily nest survival but not substantially (Figure B-4). Nest score did not appear to impact nest survival. The lakes showed some variability in nest survival, but the small sample size in Picnic Lake created wide confidence intervals (n=3; Table A-2). When parameters were ranked by relative importance, male presence was the most important parameter, followed by temperature, lake, and egg score (Table A-3). Year and depth were less important. Overall, my predictor variables had relatively minor impacts on nest survival, but the predictor variables that came out as important were consistent among the most parsimonious models.

CHAPTER 4
DISCUSSION

In this study, I found that male bass presence, depth, nest size, and other factors have little impact on Florida Bass nest survival. Male presence was identified as the most important factor in determining nest survival compared to the other variables. However, the influence of male presence on nest survival was not strong (0.85 with male not observed versus 0.92 if male observed), and thus, none of my predictor variables had very strong effects on nest survival.

Florida Bass nest survival and substrate use in this study was similar to previously published estimates for black basses. Daily nest survival for Florida Bass (0.88) was similar to Smallmouth Bass in other studies (0.86-0.96**;** Steinhart et al. 2005; Suski and Ridgway 2007). No studies on other black basses have estimated daily nest survival, and instead, researchers have relied upon nest success/failure based on presence of swim up fry. My estimates of nest survival are consistent with the values from Steinhart et al. (2005) and Suski and Ridgway (2007). Florida Bass utilized macrophytes for nest habitat, following behavior observed by Chew (1974), who reported 95% of Florida Bass nests on vegetative matter, primarily Maidencane rhizomes. Florida Bass in other studies have likewise shown a preference for both Spatterdock and Maidencane (Bruno et al. 1990).

Prior studies on other basses have found that larger males have a higher nest success rate, guard more eggs, and are more efficient at guarding the nest (Weigmann and Baylis 1995; Gingerich and Suski 2011; Parkos et al. 2011) but I found no strong influence of male length on nest survival. The male bass in this study were often scared off of the nest before the researcher could estimate the size of the fish. Active nests without a guarding bass accounted for 36% of surveyed nests. When analyses were limited to nests with a guarding male bass, male size was not an important variable (compared to the other variables using either AICc ranking or parameter importance). The bass populations in this study did not have a large size distribution (Figure B-5) and exhibited slow growth (Shaw and Allen 2014). Thus, I had only moderate contrast in male size through this study. Because so many nests lacked presence of a visible male, I did not further evaluate male size as a predictor variable in the analyses. I found no evidence that male size influenced nest survival for fish in the size range of these populations, but future studies should investigate whether male size is important for nest success in Florida Bass.

Florida Bass in this study displayed less aggressive nest guarding behavior compared to other *Micropterus* spp. in other studies. Prior studies of black bass have either made no mention of active nests without a guarding male (Gingerich and Suski 2011) or considered a nest to have failed if "parental care was terminated prior to swim-up" (Parkos et al. 2011). Smallmouth Bass studies have similarly targeted male bass on nests or made no mention of active nests without apparent parental care (Lukas and Orth 1995; Gingerich and Suski 2011; Landsman et al. 2011). In this study, presence of a guarding male bass appeared have little effect on daily survival, but a lack of a guarding bass did not indicate a failed nest – 81 broods with no guarding male detected (during any of the nest visits) were successfully raised to the swim-up phase. The guarding males that were sighted tended to swim off immediately, which is unlike reported behavior of *Micropterus* spp. located in northern, colder climates. I believe cases where males were not observed did not mean that a male was not present and guarding, but fish were timid and moved off the nests as snorkelers approached.

How Florida Bass react to predators could be a mechanism for why fish were more timid than Largemouth Bass in other studies. American Alligator *Alligator mississippiensis* is present in virtually every water body in Florida. Florida Bass share these waters and possibly have developed a flight response to large swimming animals. This could explain why Florida Bass leave the nest when a snorkeler approaches, unlike the northern black basses (where alligators as predators do not occur). Florida Bass in this study were timid in guarding the nest against approaching snorkelers, which may infer that they guard their nests less aggressively than largemouth bass at more northern latitudes.

The longer period of favorable spawning temperatures could influence diminished nest-guarding behavior compared to Largemouth and Smallmouth Basses. Florida Bass occur at lower latitude than most *Micropterus* spp., increasing the time period when water temperatures are optimal for spawning. Florida Bass in these lakes spawned several times per year in some cases (Devils Hole Lake, Shaw and Allen 2014), which has been found in other Florida Bass populations (Issac et al. 1998; Waters and Nobel 2004). This could potentially make individual spawning attempts less important to individual fish. However, Florida Bass in other studies have shown greater nest-guarding behavior and greater nest fidelity (N. Trippel, FWC, personal communication). Thus, it is not clear that the lack of aggressive nest guarding in this study results because fish have the potential to re-nest, or if it is a more general pattern for Florida Bass.

Florida Bass nest guarding behaviors have wider implications for freshwater fisheries management. Florida Bass nesting behaviors differ somewhat from other *Micropterus* spp., and patterns identified in other black bass nest survival did not hold true for Florida Bass in this study. Loss of a guarding male bass has a major impact on other bass brood survival (Suski et al. 2003; Suski and Phillip 2004; Steinhart et al. 2005). However, such a loss may have a smaller effect on Florida Bass broods compared to other black bass broods. Loss of a nesting Florida Bass due to angling remains a concern for brood survival. Further, the diminished nest guarding behavior could indicate lowered aggressiveness overall, and previous studies have found Florida Bass are more difficult to catch by angling (Zolczynski and Davies 1976; Kleinsasser et al. 1990) than Largemouth Bass. This reduced vulnerability to angling could further lessen the impact of bed fishing on Florida Bass, and further studies are needed to investigate this topic. The relationship between brood survival and their eventual recruitment to the population remains unclear, but negative impacts on bass populations may be diminished in Florida Bass populations.

APPENDIX A
TABLES

Table A-1. Summary of the top 15 nest survival models compared using Akaike's Information Criterion, corrected for small sample size (AICc).

Model	Parameters	AICc	ΔAICc	weight	Deviance
S(~Lake + Male + Score + Temp)	7	591.22	0.000	0.202	577.12
S(~Lake + Male + Score + Temp + Year)	8	592.29	1.074	0.118	576.17
S(~Lake + Male + Temp)	6	592.67	1.456	0.097	580.60
S(~Lake + Male + Temp + Year)	7	593.00	1.786	0.083	578.91
S(~Depth + Lake + Male + Score + Temp)	8	593.19	1.971	0.075	577.06
S(~Depth + Lake + Male + Score + Temp + Year)	9	594.31	3.089	0.043	576.15
S(~Depth + Lake + Male + Temp)	7	594.56	3.344	0.038	580.46
S(~Male + Score + Temp)	4	594.64	3.422	0.036	586.60
S(~Lake + Male + Score)	6	594.89	3.674	0.032	582.82
S(~Depth + Lake + Male + Temp + Year)	8	594.99	3.770	0.031	578.86
S(~Male + Score + Temp + Year)	5	595.05	3.828	0.030	584.99
S(~Male + Temp + Year)	4	595.08	3.866	0.029	587.05
S(~Depth + Male + Score + Temp)	5	595.64	4.426	0.022	585.59
S(~Male + Temp)	3	595.77	4.554	0.021	589.75
S(~Depth + Lake + Male + Score)	7	596.12	4.901	0.017	582.02

Table A-2. Daily nest survival estimates, standard errors, and upper and lower confidence intervals for model averaged parameters.

	Nests	Daily Survival	SE	Lower Confidence Interval	Upper Confidence Interval
Overall	313	0.89	0.04	0.80	0.97
No Male	112	0.85	0.05	0.74	0.92
Male Present	201	0.92	0.03	0.85	0.95
Big Fish	17	0.90	0.03	0.82	0.94
Devils Hole	285	0.87	0.01	0.85	0.89
Keys	8	0.94	0.04	0.78	0.99
Picnic	3	0.19	5.89	0.00	1.00

Table A-3. Individual parameters ranked by relative importance by summing the AICc model weights for each model that contains the parameter (the strongest weight a parameter can receive is 1.000).

Parameter	Relative Importance	Weight
Male Presence	1	0.996
Temp	2	0.867
Lake	3	0.789
Score	4	0.632
Year	5	0.404
Depth	6	0.298

APPENDIX B
FIGURES

Figure B-1. Map of the four study lakes (Big Fish, Devils Hole, Keys, and Picnic) in north central Florida.

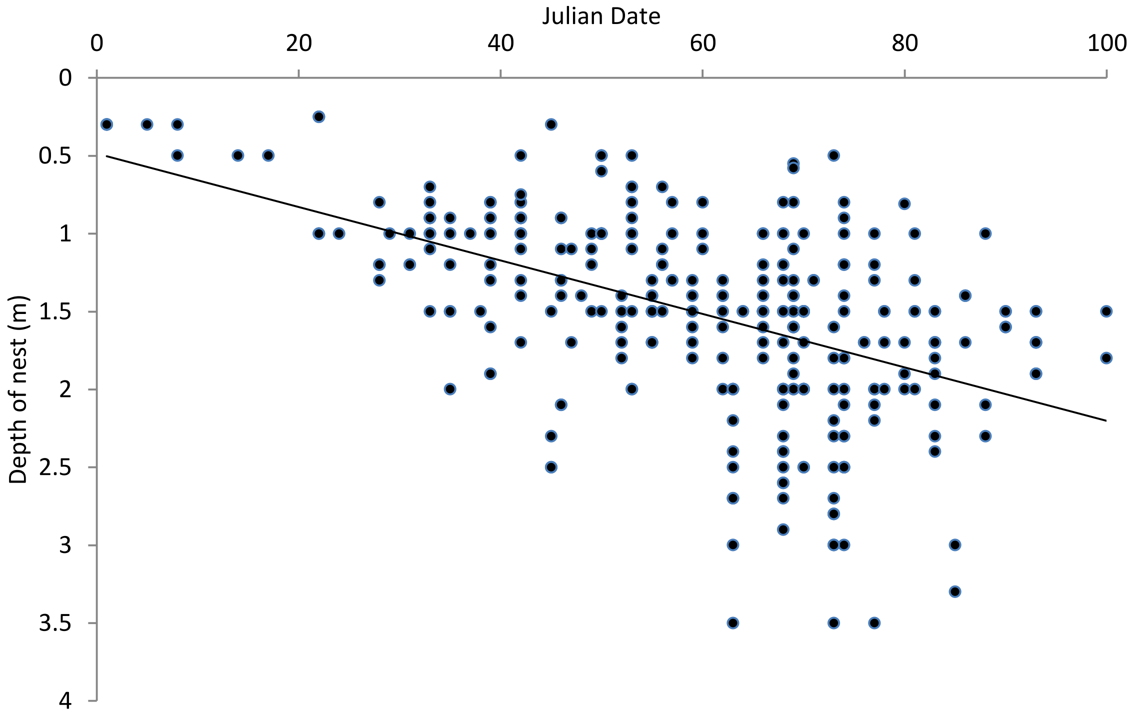

Figure B-2. The depth of nests versus Julian date with a linear regression model ($P < 0.01$, $R^2 = .266$).

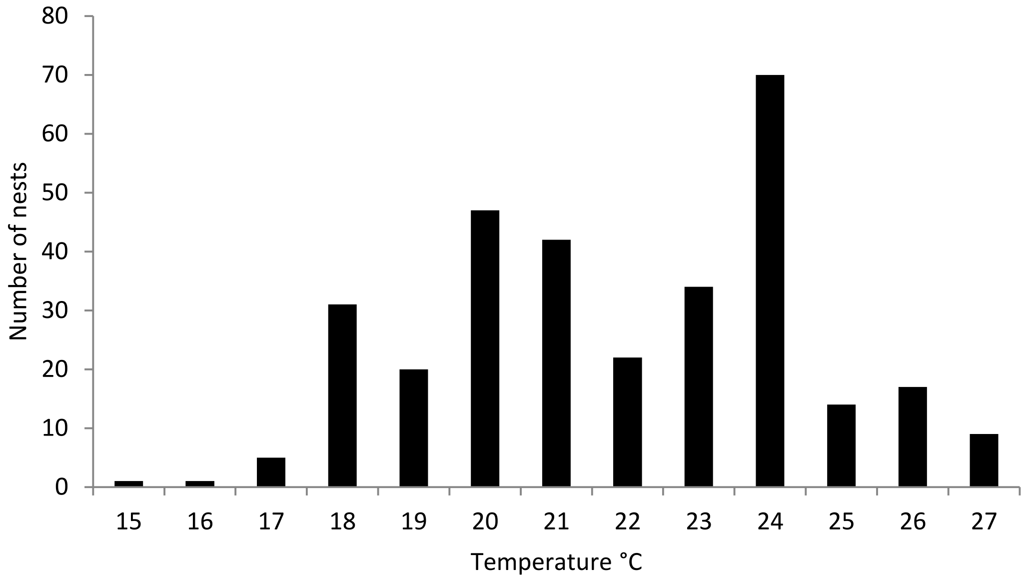

Figure B-3. Frequency plot of nest counted on water temperature (°C).

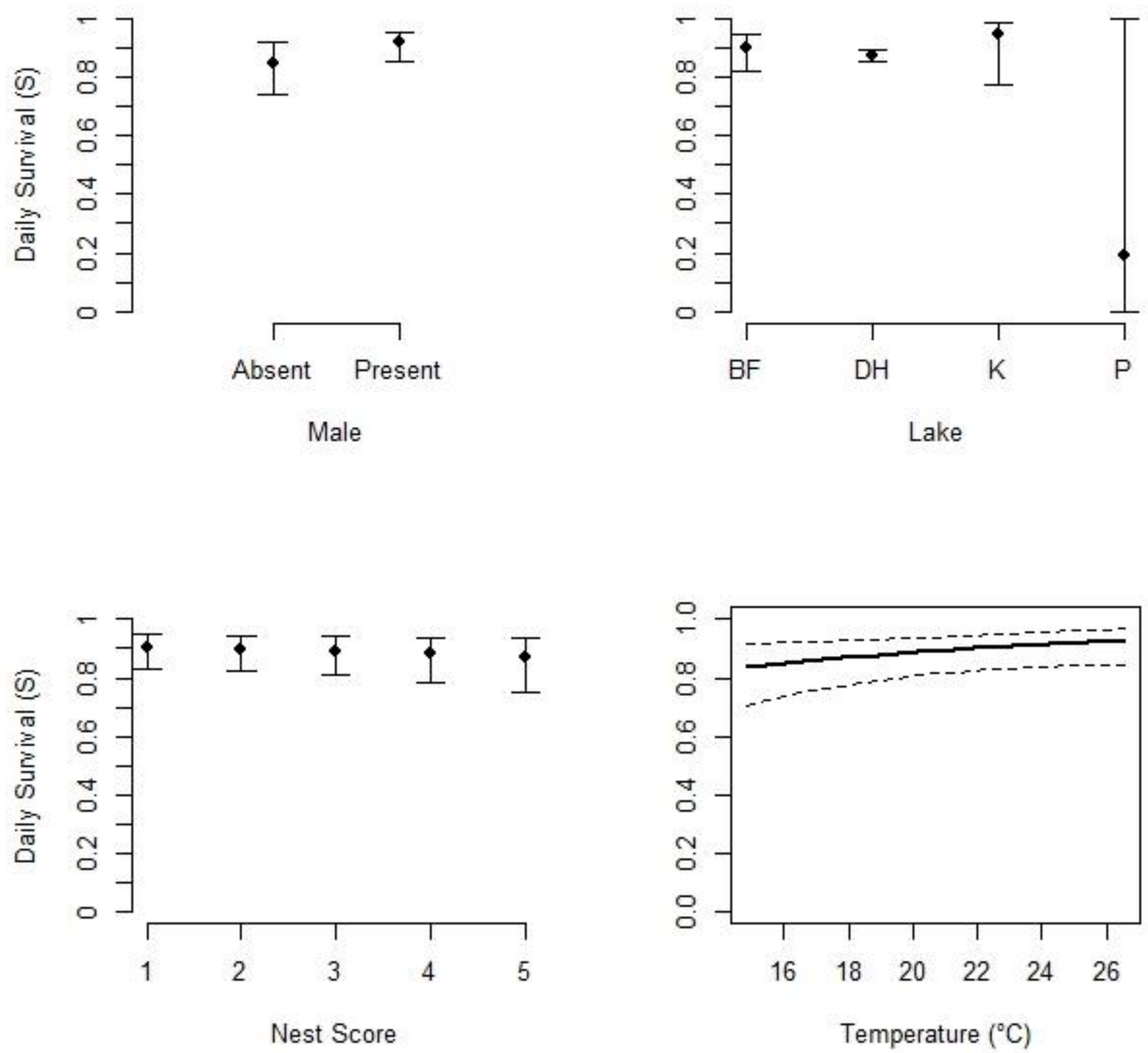

Figure B-4. Daily nest survival estimates and 95% confidence intervals averaged across all models for male presence, lake, nest score, and temperature.

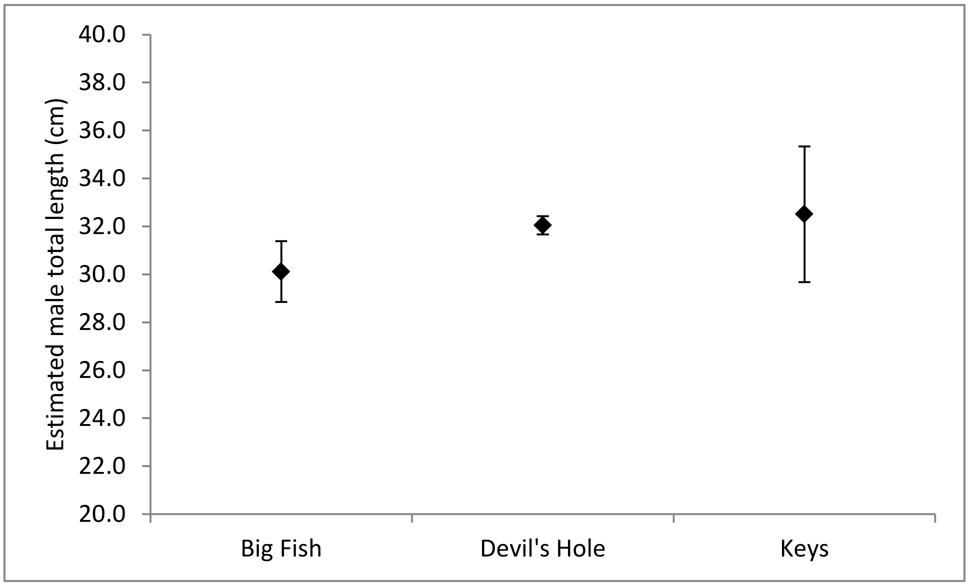

Figure B-5. Mean estimated sizes (total length in cm) for nest-guarding males in three of the four study lakes (mean ± standard error).

APPENDIX B
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BIOGRAPHICAL SKETCH

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