Articles
Population Characteristics of Yellow Perch in Dead Lake, Florida

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Abstract
In Florida, the Yellow Perch *Perca flavescens* is known to exist only in the Apalachicola River watershed. We conducted a 2-y study (2015–2016) to assess population characteristics of Yellow Perch in Dead Lake, Florida. We also measured summertime (June–September 2016) water temperatures to identify temperature differences between two sections (West Arm Creek and the main pool) of Dead Lake. Using electrofishing, we collected 564 Yellow Perch ranging from 72 to 343 mm total length from West Arm Creek. An age sample showed Yellow Perch ranged in age from 0 to 6 y and strong year classes were produced in 2013 and 2015. High mean total length at age suggests Yellow Perch in Dead Lake are a fast-growing population, likely a result of limited abundance and a long growing season. This study showed low mean relative weight (*Wr*, 2015: 70; 2016: 67), which is similar to other southeastern populations. Stomach contents and diet analysis showed no differences between age groups, which suggests that Yellow Perch are opportunistic feeders. Dead Lake showed high water temperatures (≥28°C) during the summer months, but the spring-fed Stone Mill Creek may provide thermal refugia that allow fish to avoid stressful temperatures in the main pool of Dead Lake in summer. Limited awareness among anglers, coupled with low abundance and the fish’s limited range in the state, likely contributes to the lack of exploitation of Yellow Perch in Florida.

Keywords: electrofishing; Florida; population; Yellow Perch

Received: August 6, 2018; Accepted: May 9, 2019; Published Online Early: May 2019; Published: December 2019

Citation: Bisping S, Alfermann T, Strickland P. 2019. Population characteristics of yellow perch in Dead Lake, Florida. *Journal of Fish and Wildlife Management* 10(2):296–303; e1944-687X. https://doi.org/10.3996/082018-JFWM-068

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Introduction

The Yellow Perch *Perca flavescens* is a popular sportfish across North America, with a geographical range extending from Canada throughout the United States. In the northern parts of the United States, the Yellow Perch is an important recreational and commercial sportfish species (Marsden and Robillard 2004; Isermann et al. 2005; Sepulveda-Villet et al. 2009), but in southern regions they remain relatively unimportant to anglers. Clugston et al. (1978) suggests Yellow Perch are rarely targeted by anglers in the south because of limited abundance and some populations existing outside their natural range. However, Yellow Perch is native to the
Yellow Perch from the Mobile Bay drainage date to 1850–1860 (Smith-Vaniz 1968), but a few nonnative populations have resulted from stockings efforts (Clugston et al. 1978; Willis et al. 1991; Fitzpatrick and Overton 2007; Roberts 2012). In Florida, Yellow Perch exist only in limited populations in the Apalachicola River watershed (Robins et al. 2018). Yellow Perch were first collected in Florida in the 1950s from the Apalachicola River and are thought to be native (Smith-Vaniz 1968; Robins et al. 2018). The Yellow Perch population in Florida’s Dead Lake is the southernmost U.S. population (30.12°N, 85.20°W; Fuller and Neilson 2019).

Yellow Perch is a well-studied species in its northern extent, yet few studies address its life history and population characteristics in southeastern populations (Clugston et al. 1978; Fitzpatrick and Overton 2007; Roberts 2012). No studies have explored the population characteristics of Yellow Perch in Florida. Florida has a subtropical climate, and high summer water temperatures may affect recruitment, growth, and survival of Yellow Perch as it does in other Perca spp. (Sandström et al. 1995; Helbo et al. 2005). Therefore, our objectives were to 1) describe population characteristics of Yellow Perch, and 2) identify summertime (June–September) water temperature of Dead Lake. Specifically, we sought to evaluate size, structure, condition, growth, and mortality of Yellow Perch to provide insight on an undescribed population in Florida. We also assessed water temperature differences between two sections (West Arm Creek and the main pool) of Dead Lake.

Study Area

Dead Lake is a 1,354-ha natural lake located in northwestern Florida (Calhoun and Gulf counties) on the downstream portion of the Chipola River. In 1960, a sheet-pile cofferdam was installed near the outflow of the lake. Between 1987 and 1989, the dam was removed to restore natural flow of the old river channel along with fish passage and boat navigation (Hill et al. 1994). Dead Lake is a tannin-stained lake with pH ranging from 6.0 to 7.7 and total hardness ranging from 32 to 99 mg/L (Ager and Land 1984). The aquatic habitat primarily consists of dead and living bald cypress Taxodium distichum and white tupelo Nyssa ogeche. West Arm Creek (hereafter referred to as West Arm) is a large tributary of Dead Lake located on the southwest side and is smaller than the lake’s main pool (West Arm, 145 ha; main pool, 1,209 ha) but comprises similar habitat and water depths (Figure 1). West Arm receives water inputs from Stone Mill Creek, a spring creek located on the northwest side of West Arm. Sampling by the Florida Fish and Wildlife Conservation Commission (FWC) has shown low electrofishing catch rates (<0.04 fish/min) of Yellow Perch throughout Dead Lake (FWC, unpublished data), but fish surveys and angler reports indicate that the greatest concentration of Yellow Perch in Dead Lake is in West Arm (FWC, unpublished data; Figure 1).

Methods

We collected Yellow Perch in September and October in 2015 and 2016 in West Arm (Figure 1) using a boat-mounted electrofisher (Smith-Root Model 7.5 GPP, 1,000 volts, 120 pulses/s, 6–8 amps). Prior standardized sampling resulted in low catch rates of Yellow Perch, so we used a nonrandom sampling design attempting to collect as many fish as possible by targeting potential Yellow Perch habitat exclusively in West Arm. We measured all collected Yellow Perch to the nearest millimeter total length (mm TL), weighed them to the nearest gram (g), and sacrificed a subsample (<10 fish/cm group; Devries and Frie 1996) of fish by placing them on ice and transporting them to the laboratory for diet and age analysis. In the laboratory, we determined the sex of each fish, identified their stomach contents, and removed sagittal otoliths for age analysis. We placed whole otoliths in a black-bottomed petri dish filled with water and examined them using a dissecting microscope. For all fish ≥3 years of age, we used a transverse cross section of the otolith to verify the age. We sectioned otoliths using a South Bay Technology (Model 650; San Clemente, CA) low-speed saw and mounted the sections on microscope slides using epoxy resin (Thermo Fisher Scientific Cytoseal 280; Waltham, MA). For age estimation, we counted annuli with the aid of a compound microscope. Two readers aged each fish, and a third reader resolved any age discrepancies.

We generated an age–length key to assign ages to unaged Yellow Perch for each year’s sample as described in Devries and Frie (1996). We then estimated growth using a von Bertalanffy growth model fitted to the length-at-age data. The equation states:

\[ L_t = L_\infty \left(1 - e^{-K(t-t_0)}\right), \]

Where \( L_t \) is length at time \( t \), \( L_\infty \) is the theoretical asymptotic length, \( K \) is the growth coefficient, and \( t_0 \) is the theoretical age when length is zero (Ricker 1975). We estimated growth parameters (\( L_\infty, K, \) and \( t_0 \)) for each year and compared differences between years using likelihood ratio tests in the fishmethods package in Program R 3.2.1 (R Core Team 2017). To examine differences in growth between males and females, we combined data from both years and compared von Bertalanffy growth model parameters between sexes using likelihood ratio tests in fishmethods. Furthermore, to compare growth of the Dead Lake Yellow Perch population to range-wide averages, we used the relative growth index and standard length equation described in Jackson et al. (2008).

We estimated total annual mortality (\( A = 1 - e^{-z} \)) using a weighted catch-curve analysis as described in Miranda and Bettoli (2007). We estimated total instantaneous mortality (\( Z \)) using the absolute slope value of a weighted linear catch-curve regression (Miranda and Bettoli 2007). We calculated the weighted linear regression parameters by minimizing the sum of least squares using the regression data analysis tool in Program Excel. Year classes were missing from the 2016 sample, which
occurrence of prey groups for both years and age groups (because samples were small, we grouped all fish age 3 or older for comparison).

In 2016, we monitored water temperatures in Dead Lake for 4 mo (1 June 2016–30 September 2016) with Onset HOBO temperature data loggers (model UA-001-08) to measure temperatures during summer months and identify differences between the two sections of the lake. We deployed three temperature loggers in West Arm and one in the main pool (Figure 1). We set the loggers to record water temperature 4 times/d (at 0000, 0600, 1200, and 1800 hours). We attached each logger to a cypress tree with galvanized cable and a lead weight (170–230 g). We attempted to place the loggers at or near the bottom of the lake at similar depths. Water level varied, so we placed loggers in deep enough water (>3 m) to ensure continuous submersion. We calculated the mean monthly temperatures for each logger by pooling all daily recordings for each month. We statistically compared the mean monthly temperature between sections using a two-sample t-test assuming equal variances using the data analysis tool in Excel. We considered results of statistical comparisons significant at α = 0.05.

Results

We sampled 564 Yellow Perch (2015, n = 271; 2016, n = 293) ranging in TL from 72 to 347 mm and in weight from 3 to 431 g. We sacrificed 382 fish (2015, n = 178; 2016, n = 204) ranging in age from 0 to 6 y (we collected no age-4 or age-6 fish in 2016; Table 1; Table S1, Supplemental Material). Most of the 2015 and 2016 samples consisted of fish from two year classes. The 2013- and 2015-year classes combined for percent contribution 81.1% and 73.4% of the 2015 and 2016 samples, respectively (Table 1). We sampled few fish above age 4, resulting in <5% contribution in both years sampled (2015, 3.8%; 2016, 2.1%; Table 1). In 2015 and 2016, we sampled no Yellow Perch of 118–140 mm TL, resulting in a gap between age-0 and age-1 fish (Table 1). Mean TL of Yellow Perch reached stock size (≥130 mm TL) by age 1 and approached preferred size (250 mm TL) by age 2 (Gabelhouse 1984; Table 1). The VBGM equation for 2015 and 2016 were 345.5(1 – e⁻⁰.⁴₆ᵗ( – ⁰.⁶⁰)) and 355.2(1 – e⁻⁰.⁴⁶ᵗ( – ⁰.⁶³)), respectively. We found no statistical difference between growth parameters estimated in 2015 and 2016 (L₀ 2015 = L₀ 2016, df = 1, P = 0.35; K 2015 = K 2016, df = 1, P = 0.43; t₀ 2015 = t₀ 2016, df = 1, P = 1.00; Lₘ 2015 = Lₘ 2016, K 2015 = K 2016, t₀ 2015 = t₀ 2016, P = 0.16). The VBGM equation for females and males 360.9 (1 – e⁻⁰.⁴₈ᵗ( – ⁰.₅₆)) and 330.4(1 – e⁻⁰.⁵₁ᵗ( – ⁰.₄₆)), respectively (Figure 2). The L₀ growth parameter was significantly larger for females compared with males (L₀ females = L₀ males, df = 1, P = 0.05), but K and t₀ growth parameters were not significant (K females = K males, df = 1, P = 0.53; t₀ females = t₀ males, df = 1, P = 0.48). Furthermore, the mean total lengths for females were greater at all age groups (Figure 2). The overall relative growth index for 2015 and 2016 was 188 and 196, respectively. All age groups (age

![Figure 1. Aerial outline of Dead Lake, located in Gulf and Calhoun counties, Florida. We conducted sampling in West Arm Creek (shaded in gray) in September and October 2015 and 2016. The red markers represent locations of recovered water-temperature data loggers. Temperature loggers measured data from 1 June 2016–30 September 2016. The black markers represent locations from unrecovered loggers.](image-url)
Table 1. Mean total length (TL; mm), size range, percent composition (% Comp), and relative growth index (RGI) by age group (0–6) of Yellow Perch *Perca flavescens* collected in 2015 and 2016 from Dead Lake, Florida. The number in parentheses for mean total length represents the total number of fish collected (N). The number in parentheses for RGI represents standard deviation.

| Year | Age group |
|------|-----------|
|      | 0         | 1         | 2         | 3         | 4         | 5         | 6         |
| 2015 | Mean      | 94 (131)  | 182 (40)  | 244 (89)  | 291 (1)   | 305 (8)   | 297 (1)   | 343 (1)   |
|      | Range     | 72–117    | 158–225   | 172–307   | 291       | 287–337   | 297       | 343       |
|      | % Comp    | 48.3      | 14.8      | 32.8      | 0.4       | 3.0       | 0.4       | 0.4       |
|      | RGI       | n/a       | 224 (21)  | 177 (22)  | 164 (n/a) | 148 (8)   | 130 (n/a) | 141 (n/a) |
| 2016 | Mean      | 89 (51)   | 179 (158) | 250 (21)  | 284 (57)  | n/a       | 326 (6)   | n/a       |
|      | Range     | 77–99     | 141–243   | 215–284   | 234–323   | n/a       | 312–347   | n/a       |
|      | % Comp    | 17.4      | 53.9      | 7.2       | 19.5      | 0.4       | 3.0       | 0.4       |
|      | RGI       | n/a       | 223 (31)  | 183 (16)  | 160 (11)  | n/a       | 143 (6)   | n/a       |

1–6) were above the 95 percentile values for growth (Jackson et al. 2008; Table 1).

The combined weighted catch-curve analysis estimated a total $Z$ of $-0.92$, resulting in 60% total $A$ (Figure 3). Mean $W_r$ in 2015 and 2016 were 70 and 67, respectively. In 2015 and 2016, mean $W_r$ was not significantly different between length groups (stock–quality, quality–preferred, preferred–memorable, and memorable–trophy: ANOVA, 2015: $F_{3,136} = 0.80$, $P = 0.49$; 2016: $F_{3,236} = 2.39$, $P = 0.07$).

We examined a total of 309 fish ($\geq$age 1) for stomach contents (2015, $n = 129$; 2016, $n = 180$). In 2015, most stomachs (71%) contained invertebrates, but in 2016, only 34% contained invertebrates. Moreover, fish were present in 27% of stomachs in 2016, but in 2015 only 10% contained fish (Figure 4). Invertebrate prey included crayfish *Procambarus* spp. and grass shrimp *Palaeomonetes* spp. Fish prey included Taillight Shiners *Notropis maculatus*, Brook Silversides *Labidesthes sicculus*, juvenile sunfish *Lepomis* spp., and juvenile catfish (various genera).

We recovered only two temperature loggers (one from West Arm and one from the main pool of Dead Lake; Figure 1; Table S2, Supplemental Material). Two temperature loggers were lost due to equipment failure (i.e., broken cables). During the summer months, the temperature loggers recorded for 98 d; they recorded no data from 11 July 2016 through 3 August 2016 due to equipment malfunction (i.e., dead batteries). Mean monthly summer water temperature in West Arm was significantly lower in all months compared with the main pool of Dead Lake (June: $t = -22.73$, $df = 238$, $P = 1.39 \times 10^{-10}$; July: $t = -10.03$, $df = 78$, $P = 1.12 \times 10^{-15}$; August: $t = -21.75$, $df = 222$, $P = 6.36 \times 10^{-57}$; September: $t = -25.34$, $df = 238$, $P = 1.55 \times 10^{-69}$, Table 2). In the main pool, the temperature was above 28°C for 81 d (83% of deployment) with a maximum temperature of 32.7°C (23 September 2016 at 1800 hours). In West Arm, the temperature was above 28°C for only 7 d (8% of deployment) with a maximum temperature of 28.9°C (9 July 2016 at 1800 hours).

### Discussion

The Yellow Perch population in Dead Lake exhibits fast growth compared with other populations within their range (Clugston et al. 1978; Fitzpatrick and Overton 2007; Jackson et al. 2008; Roberts 2012). The mean length-at-age data along the relative growth index shows fast growth rates throughout all age groups. We attribute the fast growth rates to a long growing season and small population size. Long growing seasons at lower latitudes have been positively correlated with growth rates in other fish species (Garvey and Marschall 2003, Heibo et al. 2005; Fitzpatrick and Overton 2007). Heibo et al. (2005) showed latitudinal differences in Eurasian Perch *Perca fluviatilis* resulting in southern populations experiencing faster growth and higher mortality rates. One caveat with our comparison with other populations is differences in collection times (i.e., spring vs. autumn) between studies. Our study collected fish in the autumn (i.e., September and October), which might bias high when comparing growth rates to other populations. However, even with adjusting ages (e.g., age 1 changed to age 2), fish in our sample still fell within the 90th to 95th percentile when compared with growth percentiles developed by Jackson et al. (2008). Therefore, even with shifting ages to account for collection time, the Dead Lakes population exhibit fast growth compared with other populations within their range.

In Dead Lake, female Yellow Perch experience faster growth in all age groups compared with males. Sex-specific growth rates occurs in many fish species (e.g., Suwannee Bass *Micropterus notius* [Bonvechio et al. 2005], Largemouth Bass *Micropterus sordidus* [Schramm and Smith 1988, Walleye *Sander vitreus* [Henderson et al. 2003]), including Yellow Perch (Uphoff and Schoenebeck 2012) and is usually related to spawning activities. However, Schoenebeck and Brown (2012) suggest sex-specific growth rates may result from other anaerobic activities (e.g., foraging for prey and predator avoidance) coupled with spawning activities of male Yellow Perch. Sex-specific growth rates should play an important role when managing recreational fishing regulations (i.e., bag and size limits). In systems with sex-specific growth rates,
fishing regulations (i.e., minimum length limits) can increase the number of larger females being harvested due to vulnerability (more females available for harvest), potentially resulting in negative impacts to recruitment. In Florida, Yellow Perch are a largely unexploited sportfish, similar to populations in other parts of the southeast United States (Clugston et al. 1978; Hackney and Holbrook 1978). Creel data show no directed effort or catch of Yellow Perch in Dead Lake, which indicates limited exploitation (FWC, unpublished data). Currently, no recreational bag or size limits exist on Yellow Perch in Florida. If exploitation increased within Dead Lake, sex-specific growth rates should be considered when determining recreational fishing regulations.

The Dead Lake population showed two cohorts (i.e., the 2013 and 2015 year classes) dominating the sample in both years, suggesting variable recruitment. Other studies have shown Yellow Perch recruitment can vary among populations depending on many biotic factors (e.g., predation and cannibalism; Sanderson et al. 1999) and abiotic factors (e.g., water level, water temperature, and photoperiod; Clady 1974; Sandström et al. 1997; Ward et al. 2004; Kaemingk et al. 2014). Interestingly, we found a gap between age-0 and age-1 fish, suggesting fast growth or a short spawning period. Isermann et al. (2007) suggested that variable recruitment could help promote faster growth within the population, likely due to density-dependent variables. Moreover, Isermann and Willis (2008) observed short hatching periods (5–11 d) for Yellow Perch in South Dakota, which increases the risk of poor recruitment due to environmental stochasticity. If the spawning period in Dead Lake is short, abiotic factors may significantly affect recruitment. However, additional research is needed to determine the duration of the spawning period and the cause of the variable recruitment of Yellow Perch in Dead Lake.

Yellow Perch in Dead Lake had low mean Wr, which is consistent with other southeastern populations (Willis et al. 1991; Roberts 2012). Many factors (e.g., trophic state, prey availability, and interspecific competition) may affect Wr in fish populations (Willis et al. 1991; Blackwell et al. 2000). Even with the low Wr, the Yellow Perch did not appear in poor condition. Roberts (2012) suggested that Yellow Perch in the southeastern United States might have higher metabolic rates, which renders them unable to build fat reserves in summer. Moreover, seasonal variation in Wr need to be considered when evaluating condition of fish species (Willis et al. 1991). Fitzpatrick and Overton (2007) suggest that collection times (i.e., during the spawn) can affect condition factors of Yellow Perch. Wr can vary seasonally and across the geographical range of a species, so managers should set realistic Wr objectives for their specific populations (Carlander 1977; Willis et al. 1991).

Percent contributions of stomach contents were similar throughout age groups, which suggests the diet differences we detected between years were likely due to changes in prey availability. Invertebrates occurred

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**Table 2.** Mean monthly water temperatures (°C) from two data loggers in Dead Lake, Florida (one each in West Arm and main pool of Dead Lake). We collected and logged data four times per day (at 0000, 0600, 1200, and 1800 hours) and recorded a minimum (Min.) and maximum (Max.) temperature for each month. We recorded water data from 1 June 2016 through 30 September 2016; however, we collected no data from 11 July 2016 through 3 August 2016 because of equipment malfunction. Asterisks represent statistical differences (P < 0.05) between sections.

| Month  | West arm Mean | Min.  | Max.  | Main pool Mean | Min.  | Max.  |
|--------|---------------|-------|-------|----------------|-------|-------|
| June   | 25.1*         | 23.1  | 28.1  | 27.8*          | 26.0  | 30.4  |
| July   | 26.1*         | 23.2  | 28.9  | 29.6*          | 26.5  | 32.5  |
| August | 25.6*         | 24.1  | 27.9  | 28.4*          | 24.6  | 31.5  |
| September | 24.4* | 22.2  | 27.0  | 28.0*          | 25.7  | 32.7  |
most frequently in Yellow Perch stomachs in both sampling years and throughout age groups. We found differences in percent contribution of invertebrates between the two years. Initially, we thought the increased presence of fish in the 2016 sample was due to the age-1 cohort (i.e., 2015 year class) becoming more piscivorous, as was documented in Fullhart et al. (2002). Studies have shown Yellow Perch diets vary among fish populations (Clady 1974; Lott et al. 1996; Fullhart et al. 2002; Wilkens et al. 2002; Roberts 2012). For example, Fullhart et al. (2002) found that Yellow Perch (>130 mm) diets consisted primarily of fish, whereas Lott et al. (1996) found that Yellow Perch were rarely piscivorous but primarily ate invertebrates. Yellow Perch are opportunistic feeders and prey generalists; therefore, stomach contents could be a good indicator of prey availability in the system.

Total annual mortality can vary between Yellow Perch populations throughout their range (Goedde and Coble 1981; Bronte et al. 1993; Paukert et al. 2001; Fitzpatrick and Overton 2007; Isermann et al. 2007; Roberts 2012). The Dead Lake population has limited exploitation; therefore, we believe there is limited fishing mortality and the total annual mortality is primary due to natural causes (e.g., trophic state, competition, cannibalism, predation, old age). Dead Lake experiences high water temperatures during the summer months (range: 23.3–32.7°C), which may contribute to the mortality rate. Yellow Perch can survive in a range of temperatures, but their optimal temperature range differs with life stage (Hokanson 1977). Previous studies suggest the optimal temperature range for their growth is 22–28°C, with decreased growth and increased mortality when temperatures exceed 28°C (Tidwell et al. 1999; Brown and Smith 2004). Tidwell et al. (1999) found that age-0 Yellow Perch displayed (in a culture setting) signs of stress (i.e., reduced growth and increased mortality) at temperatures ≥28°C. Few studies have addressed ways in which temperature affects Yellow Perch populations in the southeastern United States, but Roberts (2012) determined that high summer water temperatures played a role in high mortality in Yellow Perch populations in Alabama. Furthermore, West Arm is much smaller than the main pool (West Arm: 145 ha, main pool: 1,209 ha) and so may offer limited summer habitat. Competition for cooler waters in the summer may contribute to the mortality rate, but additional research is needed to determine whether Yellow Perch congregate in West Arm to reduce stress during summer.

Low public awareness coupled with low abundance and limited range likely explain the low exploitation of Yellow Perch in Florida. Although we did not estimate abundance, the low catch rates during previous sampling events (FWC, unpublished data) suggests that the Dead Lake perch population is relatively small, similar to those throughout the southeastern United States (Clugston et al. 1978). Furthermore, many anglers and lake homeowners we talked to during our sampling were unaware that Yellow Perch inhabit Dead Lake. Increasing angler awareness and overall abundance could increase the species’ popularity and help diversify freshwater fishing options in Florida.

Supplemental Material

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Table S1. Yellow Perch *Perca flavescens* collected from West Arm section of Dead Lake, Florida, using boat electrofishing in 2015 and 2016. Included are date (calendar date), length (TL mm), weight (g), sex (M, F, or IM), stomach contents, and age (years).

Table S2. Temperature data from two sections of Dead Lake, Florida. The two sections include West Arm and the main pool. Included are the date (calendar date),
time (military), temperature (°C) from West Arm, and temperature (°C) from main pool of Dead Lake.

Found at DOI: https://doi.org/10.3996/082018-JFWM-068.S2 (23 KB XLSX).

Acknowledgments

We thank J. Hughes for sampling assistance and K. Woodside, C. Paxton, and C. Wiley for providing historical data and information about this population. We thank P. Schueller for statistical help and D. Nelson, C. Anderson. N. Papagiorgio for guidance and editing throughout the writing process. We would also like to thank the journal reviewers and the Associated Editor for time and edits.

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