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MANAGEMENT BRIEF

Social Fish-Tancing in Wisconsin: The Effects of the COVID-19 Pandemic on Statewide License Sales and Fishing Effort in Northern Inland Lakes

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Abstract
The first year of the COVID-19 pandemic in 2020 was associated with an "anthropause" in many industries, initially reducing greenhouse gas emissions and other negative anthropogenic influences. However, outdoor recreation has exploded in popularity in response to closures of indoor recreation options, increased free time, and/or increased levels of stress. We tested for the effects of the COVID-19 pandemic on the sale of fishing licenses in Wisconsin and on vehicle counts that were observed at public lake access points in Vilas County, Wisconsin, in 2020. In the summer of 2020, fishing license sales in Wisconsin, USA, increased, particularly among first-time license purchasers for whom cumulative sales in 2020 increased by 71% and 35% compared with the previous 5-year average for Wisconsin residents and nonresidents, respectively. Changes in the vehicle counts at lake access points in the summer of 2020 varied considerably by lake. However, lakes with greater proportions of public shoreline experienced pandemic-associated increases in lake visitors. Our results suggest that the distribution of recreational fishing effort in Wisconsin changed during the pandemic, potentially placing additional harvest pressures on hot spot inland lakes.

One of the early side effects of the COVID-19 pandemic has been the "anthropause" in the summer of 2020 (Rutz et al. 2020). Reduced movement and activity of humans within many industries has resulted in varied social, ecological, and economic responses globally (Searle et al. 2021). Given the vulnerability of inland waters to human influences (Dudgeon et al. 2006), the effects of the pandemic on inland fisheries have been of particular research interest (Cooke et al. 2020; Stokes et al. 2020). Pandemic-related reductions in polluting industries and commercial fishing effort may have temporarily released many fish stocks from a variety of anthropogenic pressures during mid to late 2020. However,

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the direction of global changes in these pressures is most likely mixed (Cooke et al. 2020). Economic hardship and food insecurity, for example, have also resulted in increased subsistence harvest of some fishes (Stokes et al. 2020). In addition, commercial fishers have implemented a variety of adaptation strategies (e.g., switching species or direct sales to customers) in response to the first year of the pandemic, often maintaining their overall landings in spite of decreased market prices and supply chain disruptions (Smith et al. 2020). Globally, the effects of the early pandemic on inland stocks during mid to late 2020 have varied, depending in part on a country's economic development (Stokes et al. 2020). Within countries that are classified as "developed," the primary or sole consumptive use of inland waters is recreational fishing (FAO 2012).

As lockdown orders have reduced travel opportunities and limited indoor recreation options, the demand for fishing and many other outdoor activities has increased (Derks et al. 2020; Landry et al. 2020; Morse et al. 2020). Closures of public parks, travel restrictions, and fear of contracting or spreading disease resulted in decreases in outdoor recreation toward the beginning of the pandemic in March 2020, particularly among urban residents (O'Connell et al. 2020:19; Rice et al. 2020). However, as the relative safety of outdoor activities became apparent, increases in free time associated with stay-at-home orders, unemployment, and the lack of indoor recreational activities resulted in an influx of new participants into outdoor recreation in the United States and Europe (Derks et al. 2020; van Leeuwen et al. 2020). New participants also tended to choose outdoor recreational sites close to home, particularly urban residents (Landry et al. 2020; Rice et al. 2020). Recreational fisheries have largely remained open within the United States during the pandemic (Paradis et al. 2021). Anglers were therefore limited more by their willingness or ability to travel to fishing sites than by any top-down restrictions on fishing.

To test whether these broader trends in outdoor recreation during the first summer of the pandemic manifested at a local scale in Wisconsin, we compared fishing license sales, vehicle counts at lake access points, and proportions of boats observed fishing during the summer of 2020 with those from previous years (2018 and 2019). Given the observed reductions in travel distance by outdoor recreationists (Rice et al. 2020), we hypothesized that reduced numbers of out-of-state anglers would be associated with changes in vehicle numbers at lake access points, a proxy for fishing effort. Because lakes vary widely in their accessibility, size, and other characteristics, we anticipated that the effects of the pandemic on fishing effort may vary by lake. We hypothesized that larger lakes or lakes with lower building densities would be attractive to anglers wishing to avoid crowds. Due to the popularity of lakeside camping, we also expected lakes that are associated with public campgrounds to attract more visitors during the pandemic. Finally, lakes that are surrounded by more public lands were expected to have a more pristine appearance and potentially attract more visitors wishing to experience nature. Although numerous survey-based studies have evaluated the effects of the pandemic on recreational anglers (Howarth et al. 2021; Midway et al. 2021; Pita et al. 2021), pandemic-related restrictions have precluded collecting many empirical observations (Gundelund and Skov 2021; but see Ryan et al. 2021; Bunt and Jacobson 2022). A reduction in fishing effort associated with pandemic-related reductions in out-of-state tourism would result in reduced revenue from license sales and reduced spending in counties that rely on recreational fishing tourism. Conversely, increased fishing effort during the pandemic could increase revenue and potentially the exploitation rates of fish populations. By (1) understanding the overall effect of the pandemic on fishing effort and (2) identifying potential hot spots of additional fishing effort, fisheries managers can account for the numbers and preferences of new anglers to the fishery in their decision making and lake monitoring.

METHODS

Study site.— Wisconsin contains about 15,000 lakes, most of which are concentrated in the northern and eastern glaciated regions (WDNR 2009). These lakes vary greatly in surface area, ranging from 0.5 to 53,394 ha, and they support a variety of coolwater and warmwater species that are popular with anglers, including Walleye *Sander vitreus*, Bluegill *Lepomis macrochirus* and other sunfishes *Lepomis* spp., Black Crappie *Pomoxis nigromaculatus*, Largemouth Bass *Micropterus salmoides*, Smallmouth Bass *M. dolomieu*, Yellow Perch *Perca flavescens*, Northern Pike *Esox lucius*, and Muskellunge *Esox masquinongy*. The Ceded Territory (the northern third of the state), was ceded to the United States by the Lake Superior Chippewa (Ojibwe) Tribes in the treaties of 1837 and 1842. Fisheries in the Ceded Territory are comanaged by state and Tribal governments. Vilas County lies within the Ceded Territory and the glaciated Northern Highlands Lake District (NHLD). Although the county is less densely populated than much of the state, it is an economically important destination for fishing tourism (Peterson et al. 2003; Shapiro 2006). Over 40% of Vilas County is comprised of public lands, which are largely undeveloped and open to recreation, including the Northern Highland American Legion State Forest, the Chequamegon-Nicolet National Forest, and the Vilas County Forest. Of the 1,318 natural lakes in the county, 175 have public access. These lakes vary widely in surface area, accessibility, and fish species composition (WDNR 2009), as well as in the fishing effort that these characteristics attract (Trudeau et al. 2021). It is therefore essential to account for lake-specific differences in mean fishing effort as well as potential variation in the response of fishing effort to the COVID-19 pandemic during the summer of 2020.

License sales.— The Wisconsin Department of Natural Resources (WDNR) collects data on fishing license sales to Wisconsin residents, nonresidents, and first-time buyers in both of these groups. Fishing licenses are required for anglers 16 years and older. For Wisconsin residents, an annual general fishing license is US$20, and a nonresident annual fishing license costs $50. Reduced-price first-time buyer licenses are available for those who have never fished in Wisconsin and those who have not held a Wisconsin fishing license for 10 years or more. First-time buyer annual licenses cost $5 for Wisconsin residents and $25.75 for nonresidents. Daily cumulative license sales between March 1 and September 24, 2020, were compared with the same date range in 2018 and 2019 and to the average of cumulative sales in the past 5 years (2015–2019). The license sales for resident and nonresident regular and first-time buyer licenses were compared to test for changes that were associated with the COVID-19 pandemic.

Boat landing vehicle counts.— Instantaneous counts of vehicles at 38 lake access points in Vilas County, Wisconsin, were collected during the summers of 2018, 2019, and 2020. As part of another study, the counts for the summers of 2018 and 2019 took place hourly during 8-h angler-intercept creel survey shifts at lake access points (Trudeau et al. 2021). The creel survey shifts were randomly distributed among the lakes and stratified by weekends/weekdays and mornings/evenings. Thirty-eight lakes were selected as part of a multiobjective study of the NHLD region. The selection criteria included a requirement that the lakes did not cross county or state borders, spanned a gradient of Largemouth Bass populations, had conductivity values that allowed electrofishing, and had a maximum size of 250 ha. In 2018, 16 of the selected lakes were surveyed. In 2019, the 22 remaining lakes were surveyed as well as 5 that had also been surveyed in 2018.

To maintain social distancing in the summer of 2020, a bus-route survey design was used to collect the vehicle counts. An efficient route was planned between all 38 previously surveyed lakes. During a survey shift, a random starting lake was selected. Instantaneous counts of vehicles at the lake access points were then collected at each stop on the route until the end of the shift. The bus-route surveys took place as schedules allowed, and each lake on the route was observed between 9 and 20 times between June 7 and August 14, 2020. No COVID-related restrictions on outdoor activities were in place during this time in Wisconsin. Two sets of outlier counts were removed prior to our analysis: on July 4, 2020, an unusually high number of vehicles (23) was observed at Black Oak Lake. Black Oak Lake is a popular swimming and recreational boating lake with a public beach, and it is located close to the town of Land O'Lakes, Wisconsin. July 4 is a highly popular day for recreational boating and swimming at this lake. To avoid an outsized effect on the mean vehicle counts for 2020 and because 10 observations on July 4, 2018, at the same lake were completed improperly (only fishing boats were counted, not recreational boaters or swimmers), all July 4 observations (11 in total, 10 hourly counts and 1 bus-route count) were removed from the analysis.

Observations of fishing boats.— The vehicle counts did not differentiate between anglers, other recreational boat users, or other nonboating lake visitors, so it would be unclear whether any observed changes in the vehicle counts reflected a change in fishing effort. Therefore, we compared the proportion of boats that was observed fishing during the boat-based counts of fishing effort in 2018 and 2019 with dock-based observations of the proportions of boats that was observed fishing in 2020. In 2018 and 2019, the boat-based counts of fishing effort took place at two randomly selected times during 8-h creel shifts that were randomly assigned to the morning (0530–1330 hours) or evening (1330–2130 hours). During these counts, the number of boats on the lake was recorded and each boat was described as fishing or not fishing. During the summer of 2020, these boat-based counts were not possible. Instead, to estimate the proportion of boats on the lake that were fishing, a count of fishing (defined as boats with fishing equipment, such as rods, visible) and nonfishing boats was taken at the boat launch dock. Thus, only boats that were visible from the boat launch dock were included in this count. Although the shore-based counts potentially observed only a fraction of the boats on the lake, the visible proportion of boats that was fishing should be comparable to those that we observed during the full-lake counts.

Lake characteristics.— We obtained lake surface areas from the WDNR lake database (WDNR 2009). We calculated building density (buildings per kilometers shoreline) within 200 m of each lake's shoreline using GIS data obtained from the WDNR and Vilas County. Campgrounds that were located on lakes were identified using the WDNR website that describes camping opportunities in the Northern Highland American Legion State Forest ("Camping"; available: https://dnr.wisconsin.gov/topic/StateForests/nhal/recreation/camping). We used the Vilas County Owner Listings MapApp (https://maps.vilascountywi.gov/) to estimate the proportion of lake shorelines made up of public lands. Public lands were defined as lands that were owned by federal, state, county, or municipal governments or agencies.

Data analysis.— We used a hypothesis-driven model selection approach to test for the effects of the first summer of the COVID-19 pandemic on instantaneous vehicle counts. We fit negative binomial generalized linear mixed models (GLMM) with a log link to the vehicle counts using the lme4 package in R version 4.1.0 (Bates et al. 2015:4; R Core Team 2021). Each model included the quadratic effect of hour of day as a fixed effect. Hour of day was centered and scaled to aid convergence. In addition, indicator variables describing month, weekends or holidays, and the occurrence of adverse weather (i.e., heavy rain, storm clouds, or heavy wind) were included as fixed effects in all of the models. All of the models also included lake-specific random intercepts. A null candidate model representing the hypothesis that no changes in vehicle counts occurred during the summer of 2020 contained no additional predictors. Two additional candidate models tested for the influence of the COVID-19 pandemic. The first of these two models included a COVID-19 indicator variable as a fixed effect, which would predict a consistent mean effect of summer 2020 on vehicle counts across all lakes. The second model included COVID-year observations as a random slope, meaning that the value of the lake-specific random intercept was allowed to vary between COVID and non-COVID years. With this random effect structure, the pandemic was allowed to have different effects on vehicle counts at different lakes. Because the vehicle counts were collected using different methods in different years, direct comparisons of counts between years would be misleading. Therefore, the mean changes in vehicle numbers between COVID and non-COVID years by lake were produced through the GLMM predictions for weekday counts in May at 1337 hours (the mean time of day in our observations) under normal weather conditions.

The model assumptions were tested with the DHARMa package (Hartig 2019). Two outlier values from 2020 that had an excess effect on the model estimates were detected with the package's testOutliers function. Because these observations were both from 2020 and would therefore have biased the estimated COVID-year effect upward, they were removed from the analysis. We compared candidate models using corrected Akaike information criterion (AIC) scores and weights, with a cutoff of $\Delta AIC_c > 2$ indicating a worse model fit than the model with the minimum AIC_c value (Burnham and Anderson 2002). We estimated the P-values for the parameter estimates by using log-likelihood ratio (LLR) testing of nested models. The marginal and conditional pseudo r^2 values were calculated using the trigamma method (Bartoń 2020).

Further explaining the effects of a COVID year on fishing effort on different lakes is relevant to fisheries managers. Therefore, we fit an additional GLMM with the same random effects structure and additional fixed effects that described the lake characteristics: lake surface area (ha), the presence of public campgrounds, building density within 200 m of the lake shore, and the proportion of public lands making up the shoreline. The interactions of these predictors with the COVID-year indicator variable tested whether these characteristics influenced the changes in vehicle traffic that were associated with the COVID-19 pandemic in the summer of 2020 (i.e., whether larger lakes, for example, experienced higher vehicle traffic during 2020 than during previous years).

COVID year effects on probability of fishing.— We used a binomial generalized linear mixed effects model to test for any change in the log odds that an observed boat was engaged in fishing during the summer of 2020. Similar to the models fit to the observations of vehicle counts, the fixed effects accounted for differences in fishing probability associated with time of day and seasonality. Monthly indicator variables and a quadratic time of day effect were included as fixed effects. A COVID-year indicator was included as a fixed effect to test the overall effect of the summer of 2020 on fishing probability across lakes. The random intercepts by lake accounted for mean differences in fishing probability between lakes, and a random slope by COVID year allowed the change in fishing probability associated with 2020 to vary by year. This maximal random effects structure was verified by comparing the AIC_c scores of the random slopes model with an otherwise-identical random intercept model. The pseudo r^2 values were estimated using the delta method (Bartoń 2020).

RESULTS

Fishing License Sales

Beginning in April 2020, fishing license sales to Wisconsin residents were higher than they were in previous years (Figure 1A). By September 30, 2020, cumulative resident license sales had increased by 8% in comparison with the average cumulative sales of the previous 5 years (2015–2019). Contrary to our expectations, nonresident annual fishing license sales also increased by a similar margin of 7.5%. Both sales of resident and nonresident licenses, however, were within the 95% confidence interval of the past 5 years' average sales.

Although total annual license sales showed modest growth, sales of first-time-buyer (FTB) fishing licenses boomed in 2020. The WDNR offers a reduced-price license to purchasers who have not held a Wisconsin fishing license for at least 10 years. The cumulative sales of this license to Wisconsin residents in 2020 increased by 71% compared with the previous 5-year average (Figure 1C), well outside the bounds of sales for the previous 5 years. Among nonresidents, FTB license sales increased by 35%. Notably, 87% of the increase in annual nonresident sales illustrated in Figure 1B came from this increase in FTB licenses. For resident license sales, 47% of the increase in sales came from FTB licenses.

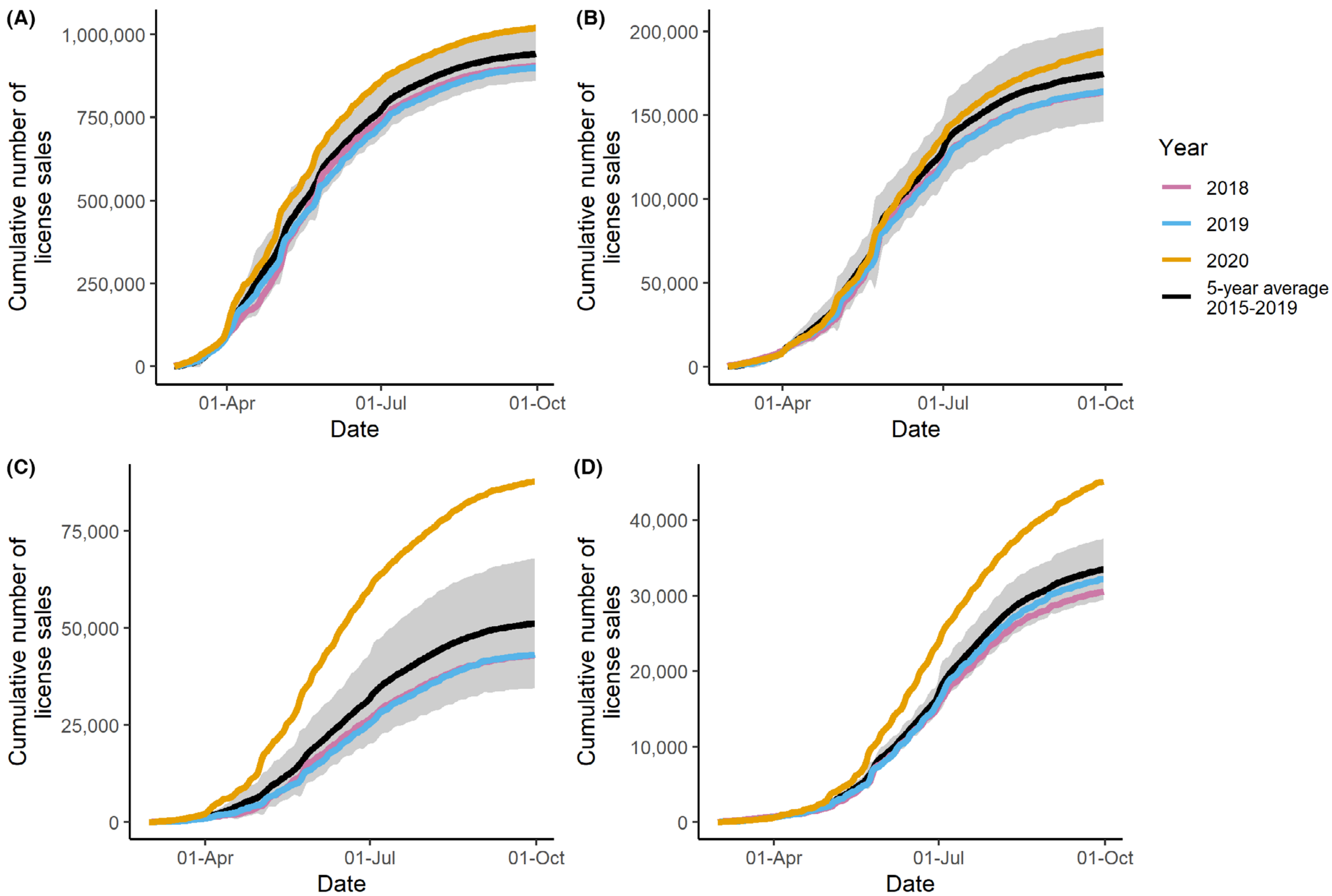

FIGURE 1. Cumulative sales of **(A)** all Wisconsin resident licenses, **(B)** all nonresident licenses, **(C)** Wisconsin resident first-time buyer licenses, and **(D)** nonresident first-time buyer licenses in 2020 compared with 2018, 2019, and the previous 5-year average. The gray ribbons indicate 95% confidence intervals around the 5-year average of license sales between 2015 and 2019. Note the differences between plots in the scales of the *y*-axis.

Boat Landing Vehicle Counts

The change in raw vehicle counts associated with the summer of 2020 varied considerably by lake (Figure 2). Notable increases in mean vehicle counts occurred at Allequash (AQ), Black Oak (BK), Day (DY), Irving (IV), and Little Arbor Vitae (LV) lakes. Estimating the effects of the COVID-19 year, however, required accounting for differences in time of day and seasonality among lake-specific observations. The best-fitting candidate model that did not include lake characteristics as predictors included a fixed effect indicating the COVID year (2020), a lake-specific random intercept accounting for mean differences in visitor counts among lakes, and a random slope allowing lake intercepts to vary by the COVID year (Table 1). This result confirms that the effect of the COVID year on the number of lake visitors varied by lake. No significant effect of the COVID year on mean vehicle counts was detected ($P = 0.06$, Table 2). The mean vehicle counts were highest in June, where they were 60% higher than were those for May ($P < 0.0001$, Table 2). The vehicle counts peaked at midday, and they were 39% higher on weekends and holidays ($P < 0.0001$, Table 2). During poor weather conditions, 51% fewer vehicles were observed ($P < 0.0001$, Table 2).

The lakes showed considerable variation in mean vehicle counts (i.e., lake-specific random intercept values, $\sigma = 1.17$) and the effects of the COVID-19 year (i.e., the lakes' random slope values, $\sigma = 0.57$). The lakes that experienced increased vehicle numbers during 2020 appeared to be clustered in the north-central part of the county (Figure 3). The percent changes in mean vehicle counts varied widely among the lakes, ranging from a 257% increase in vehicles at Partridge Lake to a 66% decrease at Oxbow Lake. The largest changes in the absolute mean vehicle counts were observed at Irving Lake (+2.2 vehicles) and Oxbow Lake (−1.04 vehicles).

Because the effect of the COVID year on vehicle counts varied greatly by lake, lake characteristics were introduced to the GLMM to test for explanations for these different responses. Although no significant main effect of the

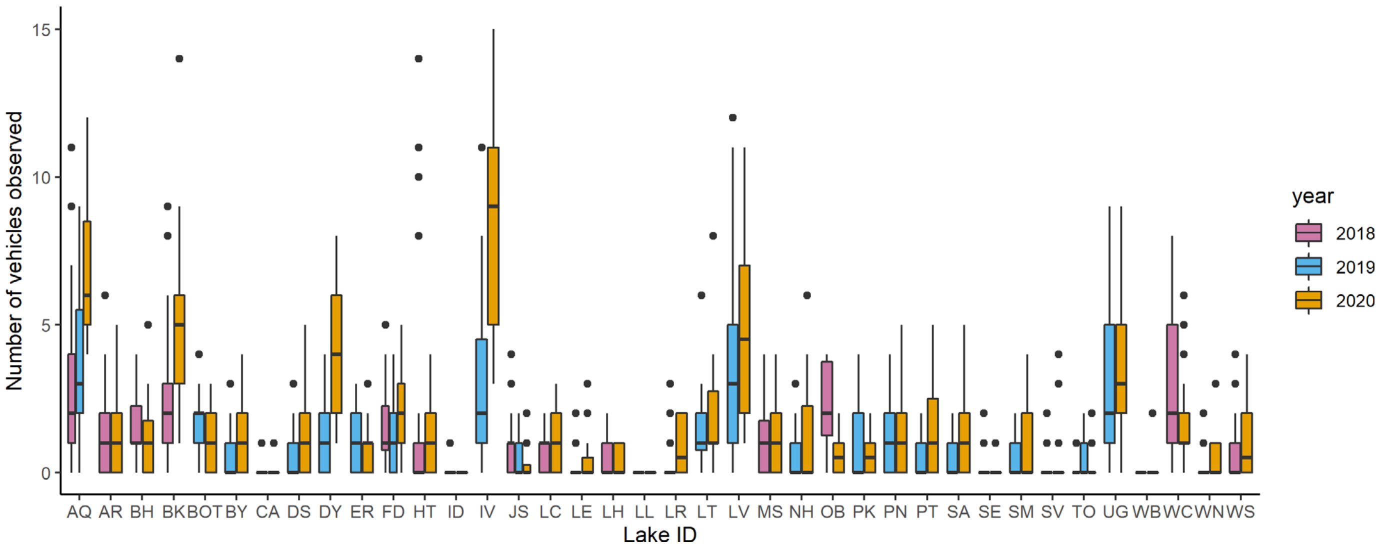

FIGURE 2. Distribution of vehicle count values in 2018, 2019, and 2020 at 38 Vilas County, Wisconsin, lakes. Note that 13 outlier values at Black Oak (BK) and Silver (SV) lakes have been removed from this visualization.

TABLE 1. Model selection results for GLMMs testing for the effect of the COVID year on vehicle counts at 38 Vilas County, Wisconsin, lake access points. Bold font indicates the best fit model.

Model random effects structure	Degrees of freedom	AIC_c	ΔAIC_c	Weight
Random lake intercept only	10	5,860.7	63.6	0
COVID year + random lake intercept	11	5,845.1	48	0
COVID year + random lake intercept and slope	**13**	**5,797.1**	**0**	**1**

COVID year was detected, we found a positive interaction effect with the proportion of public shoreline. Lakes with entirely public shoreline attracted 103% more vehicles in 2020 compared with the previous 2 years ($P = 0.03$, Table 3). Larger lakes ($P < 0.0001$) and lakes with campgrounds ($P = 0.03$, Table 3) also experienced significantly higher vehicle traffic during all years of the survey.

Proportion of Boats Angling

Recreational anglers made up 48.4, 64.2, and 64.3% of all observed boats during 2018, 2019, and 2020, respectively (Figure S1 available in the Supplementary Materials in the online version of this article). We detected no significant effect of the COVID year on the probability of an observed boat engaging in fishing. However, during the COVID year, boats on larger lakes were more likely to be observed fishing than in previous years ($P = 0.01$, Table 4). In all years, boats were less likely to be fishing on the lakes with greater building densities on and near their shoreline ($P = 0.03$). The log odds of fishing showed a quadratic response to time of day; boats were more likely to be fishing in the morning and evening. The probability of fishing also declined over the summer: boats in July and August were 34% and 43%, respectively, less likely to be fishing than were boats in May.

DISCUSSION

During the first summer of the COVID-19 pandemic, fishing license sales in Wisconsin substantially increased, particularly among first-time buyers. Contrary to our expectations that the pandemic would decrease visits by out-of-state anglers, both resident and nonresident license sales increased in 2020. Much of the increase in nonresident fishing license sales came from first-time buyers, suggesting that angling tourism in Wisconsin attracted new groups of anglers during 2020. According to a survey conducted by the WDNR, these first-time buyers were younger, more likely to identify as an underrepresented gender among anglers (i.e., women or nonbinary/other), and somewhat more racially diverse than were previously existing license holders (Beardmore 2021). Similar influxes of new anglers associated with COVID-19 have also been documented elsewhere in the USA (Midway et al. 2021), Canada (Howarth et al. 2021), and Denmark (Gundelund and Skov 2021). However, not all of the new license holders in Wisconsin were new anglers. Based on the same WDNR survey, 28%

TABLE 2. Parameter estimates for the best-fit negative binomial GLMMs estimating the effect of the COVID year on vehicle counts at lake access points. Bold font indicates significant parameters; $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

Parameter	Estimate (SE)	χ^2	*P*
Intercept	−0.862 (0.216)		
June	**0.472 (0.104)*** **	**21.279**	**<0.0001**
July	**0.269 (0.103)** **	**6.887**	**0.009**
August	**0.265 (0.115)* **	**5.333**	**0.021**
Hour of day	**2.357 (0.169)*** **	**212.529**	**<0.0001**
Hour of day^2	**−2.369 (0.170)*** **	**213.480**	**<0.0001**
Weekend or holiday	**0.331 (0.053)*** **	**38.448**	**<0.0001**
Adverse weather	**−0.722 (0.134)*** **	**31.825**	**<0.0001**
COVID-19 year	0.235 (0.121)	3.620	0.057
Log likelihood	−2,885.4		
σ Lake random intercept	1.169		
σ COVID year: lake random slope	0.565		
Correlation of lake intercept and COVID year	−0.31		
Marginal r^2	0.079		
Conditional r^2	0.497		

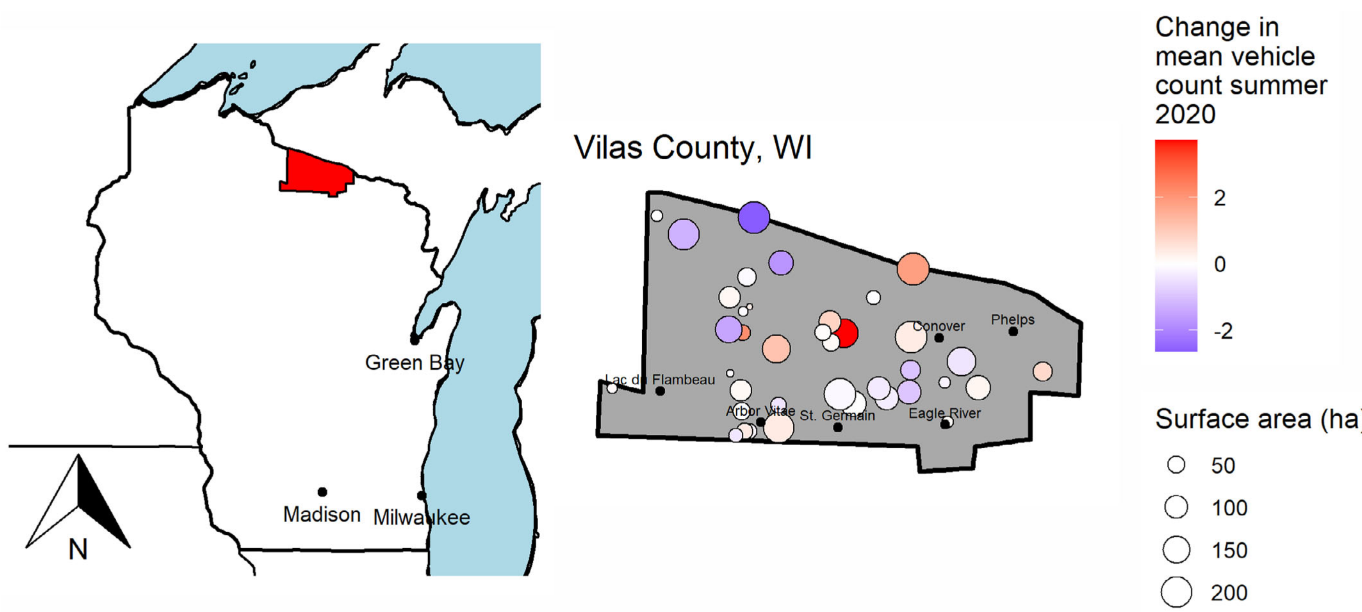

FIGURE 3. Changes in mean vehicle counts in the COVID year for each lake surveyed in Vilas County, Wisconsin. These mean counts are derived from GLMM predictions for an average weekday in May at mean time of day (1337 hours).

of the first-time license buyers were experienced anglers who were fishing in Wisconsin for the first time (Beardmore 2021). In the open-ended survey responses, these out-of-state anglers stated that they had previously traveled to Canada to fish. In 2020, the USA–Canada border was closed due to the pandemic, which prevented these sorts of fishing trips (Paradis et al. 2021). Therefore, Wisconsin may have presented an alternative fishing location for anglers who would typically travel to Canada.

Not everyone who purchases a fishing license goes fishing, so we used previously collected instantaneous counts of vehicles at lake access points to investigate empirical changes in vehicle counts during 2020 as a proxy for fishing effort. Different lakes showed different pandemic-related responses of lake visitors. These among-lake differences suggest that, at least in Vilas County, new anglers may have been most attracted to a subset of the lakes that we surveyed. When we incorporated several lake

TABLE 3. Parameter estimates for the best-fit negative binomial GLMM estimating the effects of lake characteristics and the COVID year on vehicle counts at lake access points. Bold font indicates statistically significant parameters; $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$.

Parameter	Estimate (SE)	χ^2	P
Intercept	−0.813 (0.222)		
June	**0.480 (0.104)*** **	**22.096**	**<0.0001**
July	**0.270 (0.103)** **	**6.987**	**0.008**
August	**0.266 (0.115)***	**5.427**	**0.020**
Hour of day (scaled)	**2.354 (0.169)*** **	**212.185**	**<0.0001**
Hour of day^2 (scaled)	**−2.365 (0.170)*** **	**212.887**	**<0.0001**
Weekend or holiday	**0.332 (0.053)*** **	**38.659**	**<0.0001**
Adverse weather	**−0.723 (0.134)*** **	**31.982**	**<0.0001**
COVID year	−0.055 (0.158)	0.122	0.727
Lake surface area (ha; scaled)	**0.711 (0.141)*** **	**19.493**	**<0.0001**
Proportion shoreline public lands	−0.531 (0.555)	0.904	0.342
Building density within 200 m (scaled)	−0.056 (0.184)	0.093	0.761
Campground presence	**1.088 (0.509)***	**4.358**	**0.037**
COVID year × lake surface area (scaled)	−0.002 (0.103)	0.000	0.987
COVID year × proportion shoreline public	**0.941 (0.423)***	**4.835**	**0.028**
COVID year × building density (scaled)	0.157 (0.134)	1.381	0.240
COVID year × campground presence	0.229 (0.364)	0.390	0.532
Log likelihood	−2867.9		
σ Lake random intercept	0.820		
σ COVID year: lake random slope	0.485		
Correlation of lake intercept and COVID year	−0.42		
Marginal r^2	0.215		
Conditional r^2	0.378		

characteristics into our analysis, we found that vehicle counts tended to increase in 2020 primarily among lakes that are surrounded by more public lands. The public lands on lake shorelines in Vilas County tend to be forested, which may influence the water quality or the availability of littoral habitat for fish populations (Christensen et al. 1996). However, no effect of shoreline building density was detected, suggesting that the inverse proportion of natural shoreline did not influence the lake-specific changes in fishing effort. Instead, anglers may enjoy easier access to lakes that are not surrounded by private properties. Therefore, maintaining public ownership of these shorelines and/or public access to lakes may be an important step toward retaining this new group of anglers. As potential new hot spots of fishing effort, lakes that are surrounded by more public lands should also be monitored for the potential effects of increased fishing effort on fish populations.

Although we could not distinguish between vehicles that had traveled to the lake to fish from vehicles that were carrying recreational boaters and other lake visitors, the similarity in proportions of boats that were observed fishing among years suggests that a similar proportion of vehicles was associated with fishing in 2020 compared with the previous 2 years. For lakes that are surrounded by a greater proportion of public lands, an increase in vehicles would then most likely correspond to an increase in fishing boats, assuming that the proportions of boats that was observed fishing were not influenced by our shore-based counts for 2020. In addition, although larger lakes did not experience any significant change in vehicle counts among years, the higher proportion of boats that was observed fishing during 2020 may also suggest increased fishing effort at larger lakes. Therefore, the increase in vehicle counts may have reflected a corresponding increase in fishing effort, particularly at larger lakes and lakes with more natural shoreline. This potential increase in fishing effort that we observed in Vilas County, Wisconsin, corresponded with similar increases in fishing effort that have been detected through surveys (Midway et al. 2021) and, where available, empirical observations (Ryan et al. 2021; Bunt and Jacobson 2022).

Although our results corresponded to a potential pulse in fishing effort on lakes that are surrounded by public lands in Vilas County during the first summer of the pandemic, several caveats remain. The vehicle count surveys took place for only two summers prior to the pandemic and one summer during the pandemic. The differences in vehicle traffic that were attributed to the COVID year could instead be attributed to interannual variation in

TABLE 4. Binomial GLMM predicting the effects of seasonality, time of day, lake characteristics, and the COVID year on the probability of an observed boat engaging in fishing activities. Adverse weather is not included as a predictor because the occurrence of adverse weather precluded boat-based counts and bus-route surveys. Bold font indicates statistically significant parameters; $*P < 0.05$, $**P < 0.01$, $***P < 0.001$.

Parameter	Estimate (SE)	χ^2	P
Intercept	1.469 (0.367)		
June	−0.536 (0.347)	2.486	0.115
July	**−1.376 (0.334)*** **	**18.575**	**<0.0001**
August	**−1.196 (0.354)*** **	**12.168**	**0.0005**
Hour of day	**−3.614 (0.478)*** **	**62.551**	**<0.0001**
Hour of day^2	**3.543 (0.475)*** **	**59.851**	**<0.0001**
Weekend or holiday	−0.125 (0.128)	0.914	0.339
COVID-19 year	0.194 (0.300)	0.404	0.525
Lake surface area (ha) (scaled)	−0.125 (0.143)	0.753	0.385
Proportion shoreline public lands	−0.046 (0.621)	0.005	0.942
Building density within 200 m (scaled)	**−0.423 (0.194)***	**4.546**	**0.033**
Campground presence	0.321 (0.535)	0.353	0.553
COVID year × lake surface area (scaled)	**0.447 (0.183)***	**4.546**	**0.012**
COVID year × proportion shoreline public	0.883 (0.826)	1.169	0.280
COVID year × building density (scaled)	0.366 (0.252)	2.141	0.143
COVID year × campground presence	−1.077 (0.669)	2.587	0.108
Log likelihood	−976.6		
σ Lake random intercept	0.624		
σ COVID year: lake random slope	0.607		
Correlation of lake intercept and COVID year	−0.08		
Marginal r^2	0.13		
Conditional r^2	0.23		

vehicle traffic to these lakes. We also excluded lakes from our sampling framework that were too large for a previous project's survey methodology (i.e., larger than 250 ha). Several larger lakes are located near population centers that are outside of public lands and were likely popular angling destinations. The omission of these lakes may have overemphasized the importance of public lands in predicting the distribution of fishing effort across the landscape and underemphasized the importance of lake size and accessibility.

The agreement between fishing license sales data at the state level and our vehicle count data within Vilas County suggests that the first summer of the pandemic was associated with increased fishing activity on northern Wisconsin inland lakes. However, Vilas County represents only a subset of Wisconsin's inland lake fishing opportunities. Among respondents to the WDNR's survey of first-time license buyers, notable differences in destination counties were present among new anglers, reactivated anglers, and active anglers who were fishing in Wisconsin for the first time (Beardmore 2021). When they were asked about their favorite fishing experiences in 2020, new anglers more frequently described trips to Dane and Door counties than to Vilas County. Dane County is largely urban, featuring the state capital as well as the Yahara chain of lakes. Door County is a sparsely populated peninsula surrounded by Lake Michigan and a popular destination for Great Lakes fishing and other forms of outdoor recreation. In contrast, reactivated and active anglers more frequently described Vilas County as a location of their best fishing trips. Thus, our observations of lake visitors represent a limited snapshot of the pulse of anglers that entered the Wisconsin inland lake fishery during the first year of the COVID-19 pandemic.

We found that the COVID-19 pandemic was associated with increased purchases of fishing licenses in Wisconsin and potentially increased fishing effort in Vilas County. In addition, a considerable number of first-time anglers purchased fishing licenses during the summer of 2020. This increase in first-time license buyers represents an opportunity for Wisconsin's Recruitment, Retention, and Reactivation program. First-time license buyers were more likely to be women and less than 30 years old compared with return license buyers (Beardmore 2021). If these anglers are retained, a silver lining of the COVID-19 pandemic may be a diversification of fisheries stakeholders and their values. Increased investment in the state's fisheries resources by a greater diversity of stakeholders could present an opportunity for increased public engagement in ecosystem-based management of inland lakes.

CONCLUSION

Continued monitoring of fishing effort will reveal whether this pandemic-related pulse of participation will continue and how the entrance of new anglers to the fishery could change the distribution of fishing effort across inland lakes. Collecting observations of fishing effort from remote sensing data (Provost et al. 2021) using machine learning techniques (Sasamal and Mallenahalli 2019) is one promising approach to increasing the spatial and temporal resolution of lake monitoring. In particular, expanding this monitoring across more counties and a greater size distribution of lakes could aid managers in detecting and responding to similar pulses of recreational fishing effort associated with future crises, such as an economic recession. Of the new anglers surveyed by the WDNR, 44% reported spending less than $25 to begin fishing. In addition to their economic importance for fishing destinations, recreational fisheries can also be important sources of food (Embke et al. 2020; Nyboer et al. 2022). In a potential future recession, where unemployment increases and income inequality accelerates, fisheries with a lower barrier to entry such as Wisconsin Bluegill fishing may constitute an important supplemental food source. Thus, there are social and economic incentives for maintaining public ownership of shorelines around hot spots of recreational fishing effort for maintaining fishing effort and supporting robust fish populations.

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SUPPORTING INFORMATION

Additional supplemental material may be found online in the Supporting Information section at the end of the article.