



The impact of the COVID-19 pandemic on a recreational rainbow trout (*Oncorhynchus mykiss*) fishery

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Abstract There has been a recent flurry of publications describing the potential effects of the COVID-19 pandemic on both commercial and recreational fisheries. As of yet, studies have only provided insights from researchers or industry experts detailing perceived consequences, or from survey data indicating modifications in angler activity levels and behaviours. Using real recreational fisheries data from an ongoing radio telemetry study (2018–present), we explored changes in the relative exploitation rates of rainbow trout (*Oncorhynchus mykiss*; Walbaum 1792) in the Saugeen River, Ontario, a tributary to Lake Huron, before compared to during the pandemic. Restrictions on site access that affected the implementation of important management activities that usually support this popular fishery are also discussed. During the initial phase of complete public lock-downs imposed during spring 2020, angler exploitation rates decreased to half that reported prior to the pandemic. Fishway operations were temporarily suspended and hatchery efforts were interrupted. Once restrictions began to ease in fall 2020, there was an eight-fold increase in overall exploitation rate and a four and a half-fold increase in harvest rate compared to seasons prior to the pandemic. While the full impact of the ongoing pandemic on the Lake Huron fishery is not

likely to be fully realized for several years, the potential effects on future return run sizes may need to be considered by fisheries managers monitoring trends in population escapement.

Keywords Recreational angling · Fish passage · Fisheries management · Hatchery stocking · Radiotelemetry · Steelhead

Introduction

The impacts of COVID-19 were unforeseen, unprecedented in recent times and undoubtedly affected nearly everyone, changing our behavioural patterns and the activities occurring in our professional and personal lives. In Ontario, Canada, a State of Emergency and strict lockdowns began on March 17, 2020, with the closure of Provincial parks, conservation authorities and nearly all outdoor amenities following soon after (Westoll 2020). While the closure of access points, parking lots and boat launches was met with mixed reaction from recreational anglers (Paradis et al. 2020), fish researchers realized this would likely lead to limited angling pressure and reduced exploitation (Cooke et al. 2021) during important spring spawning migrations. In retrospect, this brief respite was fleeting and temporary at best. Ontario's State of Emergency extended through to July 15 (Howarth et al. 2021). As outdoor spaces began to reopen in May (Nielsen 2020) amid the continued closure

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or cancellation of most indoor services and activities and restrictions on mobility and distancing, people responded by heading outside, many to go angling (Helsdon 2020; McEwan 2020).

While the popularity of recreational angling fluctuates, surges have often occurred in response to periods of economic uncertainty and hardship as well as increased “leisure time.” Increases in the number of people participating in recreational angling were noted during the Great Depression (Gearheart 2018), post-World War II (Lester et al. 2003), and more recently, the 2008 recession (Szep 2009; Banse 2011). The act of angling provides a relatively cheap family-friendly activity good for mental health, physical exercise, and occasionally, an all too necessary food source and hobby to fill time (Tufts et al. 2015; Hunt and McManus 2016). From 1975 to 2010, Canada averaged 4.5 million licensed anglers, who caught 255 million and harvested 133 million fish annually (Brownscombe et al. 2014). In the most recent national recreational angling survey conducted in 2015, there were 2.6 million active resident anglers in Canada (3.2 million licenced resident, Canadian and other non-resident anglers total), each of which fished an average of 16 days and harvested an average of 20 fish, with 754,617 resident anglers in Ontario alone (DFO 2019). These numbers likely increased during the pandemic. Recreational fishing license sales increased by 8–30% per province and sales in Ontario increased by 20% relative to previous years (McEwan 2020); note that the number of licensed anglers does not include senior citizens (65+) or children under 18. This figure was mirrored by the 20% of respondents to an Ontario angler survey who identified themselves as a new or resuming angler in a study conducted by Howarth et al. (2021). It is this vast number of new or returning anglers who were considered responsible for the surge of fishing tackle sales across Canada and the USA during the summer of 2020 (Helsdon 2020; NPAA 2020).

Travel restrictions, bans and border closures meant Canadian non-resident and foreign angling tourism within and across Canada was all but non-existent during 2020 (and continuing into 2021). In response, the Canadian government began promoting domestic tourism in the summer and fall of 2020, encouraging residents to discover local attractions with a large proportion of federal tourism funds dedicated to southern Ontario (MacGregor 2020; The Canadian Press

2020). While Ontario has a vast number of waterbodies, angling opportunities were likely spatially concentrated for the increased number of anglers as some townships and municipalities decided to restrict angling altogether. The town of Port Hope, for example, blocked access along the length of the Ganaraska River (tributary to Lake Ontario) and strongly enforced a no-angling order to reduce public crowding during the notoriously popular tourist and angler season in the fall (Ibrahim 2020).

The Saugeen River, which flows to Lake Huron near Southampton, Ontario (Fig. 1), is another major fishing destination and arguably one of the most popular and largest recreational salmonid fisheries in Ontario and perhaps even inland Canada (ECCC and US EPA 2018). Anglers target rainbow trout (adfluvial fish also referred to as steelhead) in the winter, spring and fall and Salmon in late summer and early fall. Although the portion of the river accessible to migrating salmonids is 101 km long (up to the Hanover Dam in Hanover, Ontario) many anglers target fish below Denny’s Dam which is located just ~5 km upstream from Lake Huron. From fall 2015 to spring 2016 anglers spent ~80,000 rod hours targeting rainbow trout along this stretch of the river alone, resulting in the harvest of over 7000 fish (Borgeson et al. 2020). Note that an extended fishing season is open to anglers within this stretch of the river with fishing permitted year-round from concrete abutments ~275 m downstream of Denny’s Dam to the mouth with Lake Huron. In order to ensure that migrating salmonids are able to continue past Denny’s Dam to spawn upstream, a modified pool-weir-orifice type fishway is operated by the Ontario Ministry of Natural Resources and Forestry (OMNRF; dam owners) and by volunteers from the Ontario Steelheaders (OS) and Lake Huron Fishing Club (LHFC) who monitor the fishway each year during the spring and fall salmonid runs. This support team conducts a trapping program to collect information on fishway use, sex ratios and the proportion of wild versus hatchery fish. Gametes are also collected for two community hatcheries operated by the LHFC who stock yearling rainbow trout at multiple locations within the watershed. These important fishery support activities were impeded by closures and other social restrictions caused by the pandemic.

While there has been a recent flurry of publications related to the impacts of COVID-19 on both

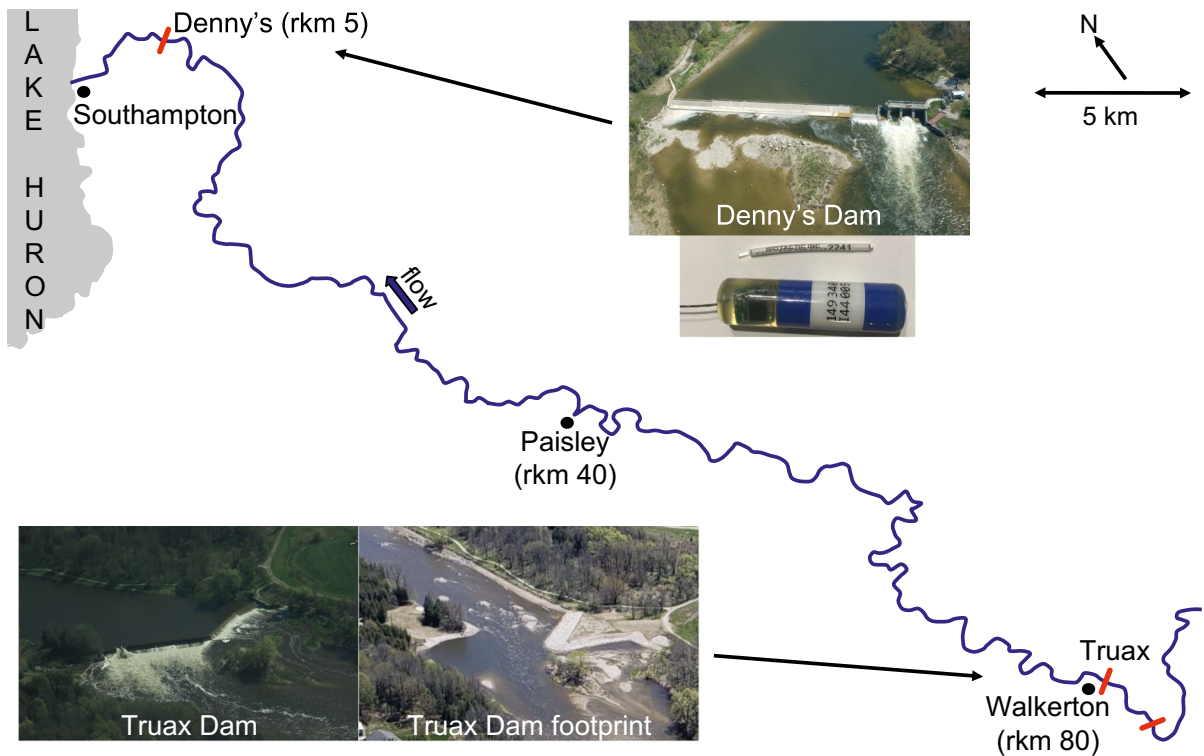


Fig. 1 The Saugeen River study area between Southampton and Walkerton, Ontario, showing dam locations and anchor tag and radio-transmitter details. The Saugeen River is in blue, dams are denoted by red bars and significant locations with

corresponding river kilometres upstream from Lake Huron are given. Note that the Truax Dam was removed August 2019, and is shown before and after removal

commercial and recreational fisheries (e.g., Cooke et al. 2021; Bennett et al. 2020; Howarth et al. 2021; Midway et al. 2021; Stokes et al. 2020), these studies have provided insights from fisheries researchers related to perceived consequences and/or relied on survey data from experts or anglers. No report has yet included real fisheries data to evaluate the impacts of COVID-19 on fish populations in 2020–2021. To measure changes in relative angling pressure, we explored, a posteriori, rainbow trout exploitation rates in the Saugeen River before and during the pandemic using tagging and angler recapture data from an ongoing radio telemetry study (2018–present). We also summarize changes in fishway operations as well as hatchery and stocking programs that were negatively affected by restrictions imposed during initial pandemic lockdowns. As recreational angling can have serious direct and indirect impacts on the state of fish populations and the ecosystem as a whole (Lewin et al. 2006), changes in exploitation rates and

fishery support operations are key considerations for fisheries managers tasked with ensuring sustained abundant salmonid runs.

Methods

Fifty adult rainbow trout were tagged each spring and fall beginning in 2018. Fish were captured in the fishway trap at Denny’s Dam and were electro-sedated, measured (mm TL), weighed (g), sexed, noted for origin (hatchery or wild) and then externally tagged near the dorsal fin with an anchor tag. Each fish was then surgically implanted with a radio-transmitter with an approximate 3-year battery life and released ~5 m upstream of the dam. Tagging occurred on April 23 and October 15–16, 2018, April 26 and October 28, 2019 and October 17 and November 7, 2020. Public lockdowns closed the Denny’s Dam fishway in spring 2020 and no new fish were able to be tagged.

Two-hundred and fifty fish were tagged by fall 2020. Both the plastic anchor tag and radio-tag included a unique fish identification number and contact details so that angler recaptures could be reported (Fig. 1).

After release, fish were continuously tracked with a combination of several fixed receiver stations located at key points of passage within the main-stem of the Saugeen River, as well as through a combination of land (by truck and foot) and aerial (by small-aircraft) mobile surveys. For this study, spring tracking was conducted from March or April to June, and fall/winter tracking (hereafter referred to as fall) was conducted from October to March of the following year. In addition to tags recovered from angler harvests, those that remained stationary for at least 1 year, likely due to natural mortality, were considered inactive and were removed from the total number of tags remaining within the population of fish available to be tracked (see Biotactic Inc. 2021 for further information regarding the ongoing radio telemetry study). A total of 50 fish were available to be tracked spring 2018, 93 fish were available fall 2018, 135 spring 2019, 171 fall 2019, 165 spring 2020 and 208 fish remained within the total population of tagged fish in fall 2020. Harvest and exploitation rates were calculated from angler recapture data. Harvest rates were determined by dividing the number of angler reported harvests by the number of newly tagged fish or the total number of remaining tagged fish for each season. Exploitation rates were determined by dividing the combined number of angler reported capture-releases and harvests by the total number of remaining tagged fish for each season. Pre-pandemic seasons included spring 2018-fall 2019 and pandemic seasons included spring 2020 and fall 2020. Exact goodness-of-fit tests were conducted using the XNomial package in R version 4.0.3 (R Core Team 2020) and an $\alpha \leq 0.05$ to determine if harvest and exploitation rates and catch proportions during the pandemic differed significantly from those prior to the pandemic.

Results

A total of 7 capture-releases and 19 capture-harvests were reported by anglers since the initiation of the radio telemetry study on April 23, 2018 until the end of the fall 2020 season on March 19 2021 (Table 1). Prior to the pandemic, the overall degree

Table 1 Angler capture-release and capture-harvest data by season in the Saugeen River. New is the number of fish tagged during the season and Total is the number of tagged fish remaining within the population available to be caught. Exploitation is the percent of combined release and harvest for either group of fish

Season	Tags (n)	Release (n)	Harvest (n)	Exploitation (%)
Spring 2018				
New	50	0	0	0
Total	50	0	0	0
Fall 2018				
New	50	0	3	6
Total	93	0	3	3
Spring 2019				
New	50	1	1	4
Total	135	1	2	2
Fall 2019				
New	50	0	1	2
Total	171	0	4	2
Spring 2020				
New	0			
Total	165	0	1	1
Fall 2020				
New	50	6	6	24
Total	208	6	9	7

of exploitation averaged 3% of the newly tagged fish (range 0–6%) and averaged 2% of the total remaining tagged population (range 0–3%) across included seasons. During the pandemic, the overall degree of exploitation decreased to 1% of the total remaining tagged population in spring 2020, although not significantly different from that found prior ($p=1$). Again, no new fish were able to be tagged due to COVID-19 restrictions. In fall 2020, exploitation of the newly tagged population was 24%, increased significantly relative to the pre-pandemic average ($p<0.001$). Exploitation also rose, however not significantly, to 7% of the total remaining tagged population ($p=0.180$). Considering harvest rates alone, the average and ranges for the newly tagged and total remaining tagged populations were the same as for exploitation prior to the pandemic, with all but 1 fish recapture harvested. During spring 2020, the harvest rate was again just 1% of the total remaining population ($p=1$), while this rate increased

significantly ($p=0.035$) to 12% of the newly tagged population and non-significantly ($p=0.688$) to 4% of the total remaining population fall 2020. Of the total number of recaptures, 86% of released fish and 47% of harvests occurred in the fall 2020 season alone. This increase in exploitation was found both above and below Denny's Dam. Only one capture occurred within the river system upstream of Denny's Dam prior to the pandemic; however, four captures occurred between the towns of Paisley and Walkerton in fall 2020 (Fig. 1). In spring 2019, 23 fish were detected downstream from Denny's Dam and 3 recaptures occurred (13%), while the proportion decreased in spring 2020 with only 1 recapture of the 14 fish (7%) detected downstream ($p=0.263$). In fall 2019, 24 of the newly tagged fish were detected downstream from Denny's Dam and only 1 recapture occurred (4%) while the proportion increased significantly in fall 2020 with 8 recaptures of the 12 newly tagged fish (67%) detected downstream ($p < 0.001$).

Discussion

COVID-19 created a perfect storm of disruption for the Saugeen River rainbow trout fishery. As predicted in Cooke et al. (2021), angling pressure, as indicated by numbers of recaptured fish, appears to have reduced slightly during the spring 2020 season and then increased significantly in fall 2020 relative to levels prior to the pandemic. The increased number of anglers present downstream of Denny's Dam did not go unnoticed, and there were calls to the Town of Saugeen Shores to complain about the "slaughter" (LHFC 2021; K. Mullen pers. comm.). While the negative consequences of commercial angling on fisheries resources is well reported, recreational anglers can also have a significant impact, with recreational angling often now the only use of fish stocks in most freshwater systems (Lewin et al. 2006; Post et al. 2002). Based on recapture data from our ongoing radio telemetry study, angler exploitation rates in the Saugeen River increased by a factor of 8 for the newly tagged population and by a factor of 3.5 for the total remaining tagged population during versus before the pandemic started, with harvests alone increasing by a factor of 4.5 for newly tagged fish and 2.5 for the total remaining tagged population. These rates are certainly

underestimates of the degree of angler exploitation as some anglers do not report tags, while others, such as several who expressed regret at harvesting a tagged fish, may not initially notice the tag especially when angling during low light conditions. When asked, very few anglers who reported tags claimed to be aware of the ongoing study, and all either reported the tag to inquire about its purpose or to ensure that a harvested fish was still safe to consume.

Anglers spent ~80,000 rod hours targeting Saugeen River rainbow trout from fall 2015 to spring 2016, and harvested 7000 fish downstream of Denny's Dam (Borgeson et al. 2020). Approximately 54% of this effort (OMNRF unpublished data), and by extension, 3780 fish were harvested in the fall. Using these numbers as a base, even if only temporarily elevated, the increased angling pressure found in fall 2020 may have had a significant impact on the number of fall-run fish able to ultimately reproduce. Considering a four-fold increase in the number of harvests, at least 15,120 fish would have been removed from the river before they had a chance to spawn in the spring. Based on the 3220 harvests that occurred in spring 2016, the slight 1% decrease in harvests in spring 2020 would have only lead to an additional 32 fish being able to potentially reproduce. As such, the benefit of the brief respite was likely far outweighed by the pressure from the subsequent angling boom. Note that at the time this manuscript was submitted, the spring 2021 angling season was underway and Ontario was again in the middle of a province-wide lockdown initiated on April 8 that extended until near the end of the monitoring period (Katawazi 2021). While public parking areas and parks remained open for day-use, similar to spring 2020, outdoor amenities such as boat launches and camping grounds were closed. Importantly, this included a fishing camp located ~300 m downstream of Denny's Dam within the Denny's Dam conservation area. Tagging of an additional 50 rainbow trout was able to be conducted by Biotactic Inc in spring 2021. A total of 3 angler reported captures occurred, 1 capture-release of an individual in the greater remaining tagged population and 2 capture-harvests of newly tagged fish, all downstream of Denny's Dam by day trippers. This equates to a 4% exploitation rate of the newly tagged fish and a 1% exploitation rate of the total remaining tagged population.

In addition to changes in angling pressure, the Saugeen River rainbow trout fishery was also affected by pandemic-related changes in Denny's Dam fishway operations as well as hatchery and stocking programs. As mentioned above, pandemic restrictions negatively affected fishway operations during the spring 2020 season. No trapping was able to be conducted, disrupting both long-term population monitoring data collection, as well as the collection of gametes for culture and stocking in 2021 (LHFC 2020, 2021). Both community hatcheries run by the LHFC were also forced to close, necessitating the premature release of fish. Stocked yearling rainbow trout are usually released at multiple locations in the Saugeen River in May or June, but in 2020 ~64,000 fish were released in a single location in Walkerton by April 10 (LHFC 2020; K. Mullen pers. comm.). Similar decreased, compromised or absent supplemental stocking in 2020 and 2021 occurred at more hatcheries than just those run by the LHFC. Indeed the state of Michigan also heavily stocks Lake Huron and as with the LHFC, stocking in 2020 took place earlier than in the previous year with the number of stocking locations reduced to decrease travel, and no gametes collected for 2021 stocking (Haglund 2020; Michigan DNR; O'Keefe 2021). There is likely significant mixing of populations and, despite supposed spawning site fidelity, tagging data show that there is substantial straying and movement of rainbow trout across the USA and Canadian border including to and from the Saugeen River (Biotactic Inc. unpublished data). In 2017, 86,137 rainbow trout were stocked in the Saugeen River — 56,137 yearlings by the LHFC and 30,000 by the OMNRF, with a total of 558,124 rainbow trout stocked within Ontario waters and at least 136,312 within Michigan waters of Lake Huron (OMNRF unpublished data; Michigan DNR). While stocking surely creates angling opportunities, this supplementation can mask declines in wild stocks and may even act to depress them further (Post et al. 2002). While the cumulative effects of this disruption of stocking activities combined with the potential reduced production due to changes in angling pressure will be difficult to disentangle from natural inter-annual variation in return run sizes, any decrease in runs in 2024–2028 may be partially attributed to the COVID-19 pandemic and may

indicate a more degraded wild population than currently realized.

Note that within this study, we have used the number of angler reported recaptures as a proxy for the amount of exploitation and by extension fishing pressure within the Saugeen River. Unfortunately, based on our data, it is not possible to draw formal conclusions on the exact nature of the increase in angler-reported recaptures. Nonetheless, whether due to an increase in the number of licenced (and/or unlicensed senior and youth) anglers as might have occurred based on Howarth et al. (2021) and McEwan (2020), or an increase in the number of fishing trips by the same number of anglers as suggested by Midway et al. (2021) and Morse et al. (2020), or some combination of the two, these options all equate to an increase in fishing pressure. These options would also equate to an increase in the total number of rod hours spent by anglers in the Saugeen River targeting fish, which is a metric used by the OMNR to quantify recreational-fishing effort (Borgeson et al. 2020). We acknowledge that it is also possible that the increased number of recaptures of tagged fish was due to natural variation in run size, with it possible that a reduced number of rainbow trout entered the system from Lake Huron such that a greater proportion of fish were tagged. However, as only 50 fish were tagged each season and only 12 of these fish were detected downstream of Denny's Dam, we consider this possibility less likely. Indeed, combined with the recapture of a greater number of fish upstream of Denny's Dam and anecdotal observations of increased numbers of anglers present downstream of the dam during the regular land-based mobile tracking surveys conducted each season by Biotactic staff, as well as reports from G. McAlpine, K. Mullen and the LHFC (2021), we feel that a combination of the first two explanations is more than likely. While our spring 2020 results may also have been affected by natural variation in return run size affecting the proportion of fish with tags, 14 previously tagged fish were detected downstream (total of 45 detected throughout the system) during tracking. In our opinion, it is more likely that the closure of access points, parking lots and parks reduced the number of anglers and the amount of fishing effort spent during this season. Our spring 2020 findings are supported by Howarth et al. (2021) who also found that anglers generally fished less and kept a smaller proportion of fish from March 17 to July 15, 2020

than during the same timeframe a year earlier. It is worth-mentioning that while fish are delayed downstream of Denny's Dam and thus are perhaps more available to anglers, fish are able to freely migrate once upstream with the next dam, Truax Dam located in Walkerton, removed in August 2019 to enhance fish passage within the system. The four captures which occurred between Paisley and Walkerton in fall 2020 are perhaps then even more indicative of the likely increased rod hours required to catch such fish.

While we have used the situation in the Saugeen River as an example, it is surely not unique. Angling license sales increased in 2020 compared to 2019 around the world (Cooke et al. 2021), many fishway operations such as manual fish lifts and stocking efforts for various species were suspended, altered and cancelled in 2020 (e.g., Kennedy 2020; Wheeler 2020) and the field operations, data collection and fisheries monitoring usually performed by managers and researchers were reduced (Link et al. 2021; Miller-Rushing et al. 2021). An anthropause may have occurred on a global or even national scale in terms of travel (Rutz et al. 2020); however, at a more local scale, human-nature-wildlife interactions appear to have decreased over only a limited temporal context. Outdoor-enthusiasts, especially those in urban settings, reported less activity during early complete lockdowns due to restrictions on distances necessary to participate in such activities (Rice et al. 2020). Over the course of the pandemic, however, more people reported participating in outdoor activities such as hiking, foraging, bird watching and hunting than did before the pandemic (Morse et al. 2020; Hamedy 2021). It is currently unknown if our return to outdoor activities will be permanent or if this apparent trend will disappear once international travel, concerts, sporting events, social gatherings at restaurants and a myriad of other activities resume. It is possible that people who have added fishing as a new hobby during the pandemic, will continue the sport into the post-pandemic future, just as people did with their new-found hobbies after the Great Depression (Hamedy 2021). Continued long-term monitoring will be needed to determine the full impact of the COVID-19 pandemic on the steelhead/rainbow trout fishery in the Saugeen River and Lake Huron, and more work should be conducted to determine the extent to which the patterns found within this system are mirrored elsewhere around the world and to which behavioural

shifts, identified as a response to the pandemic, will lead to a life-long change in human use of nature.

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Data availability Not applicable.

Code availability Not applicable.

Declarations

Ethics approval and consent to participate All tagging was completed under valid Licences to Collect Fish for Scientific Purposes issued to Biotactic Inc. by the Ontario Ministry of Natural Resources each year.

Consent for publication Not applicable.

Conflict of interest The authors declare no competing of interests.

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