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MANAGEMENT BRIEF

Evaluating the Efficacy of Using Time-Lapse Cameras to Assess Angling Use: An Example from a High-Use Metropolitan Reservoir in Arizona

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Abstract
Creel surveys are the most common angler use survey used by fisheries managers but can be time intensive and expensive to conduct. Time-lapse cameras have been evaluated as a cost-efficient alternative to creel surveys on small lakes, streams, and nearshore marine systems but have yet to be evaluated on a reservoir. The objectives of this study were to evaluate the feasibility of using time-lapse cameras to assess angling use on a high-use reservoir and provide methodology for use by fisheries managers. One time-lapse trail camera was installed at a heavily used boat ramp at Lake Pleasant, a large reservoir located near Phoenix, Arizona, from December 2015 to May 2016. A single observer counted fishing and recreational boats and tracked individual fishing boat trips using a randomized schedule. Camera data were first validated against creel counts conducted in person, and subsequent corrected counts were used to estimate both angling and boating use for the study period. Camera counts were easily corrected using the validation approach and were more cost effective than traditional creel survey methods. Overall, we found that time-lapse cameras can efficiently and accurately collect angler use data on a high-use reservoir and thus provide a useful alternative to stand-alone creel surveys.

Anglers play a pivotal role in the fisheries management process, and understanding factors that affect angling use is essential for proper management. Without proper understanding of angling dynamics, regulations, and other management actions that depend on stakeholder use can ultimately fail. However, owing to the complexity of understanding and predicting human behavior, gathering accurate angler use data can be the most difficult aspect of the fisheries management process (McMullin and Pert 2010).

Numerous survey types are available to managers seeking to sample angler use, including mail and online questionnaires, licenses and permits, and creel surveys (Malvestuto 1996). Creel surveys are the most common method of sampling angling use and also provide data needed for effort and catch estimates (Pollock et al. 1994). Several design options are available for creel surveys, including roving or access-point creel surveys, and the choice is influenced by logistical considerations and the objectives of the creel survey (Malvestuto 1996). All creel surveys require contact with the angler, and this typically makes creel surveys expensive in terms of cost (salary) and time (Isermann and Paukert 2010). Managers are often tasked with overseeing several bodies of water concurrently, and thus it can be difficult to sufficiently survey frequently enough to gain an accurate portrayal of angling use. In addition, in some instances managers may not need to gather harvest data and are only interested in factors that may drive angling use to target stockings or facility improvements. Therefore, a situational need exists for a new survey method that is both cost and time efficient and provides an alternative to creel surveys.

In recent years digital time-lapse trail cameras have been increasingly studied as an alternative method to sample anglers (e.g., Smallwood et al. 2012; Greenberg and Godin 2015; van Poorten et al. 2015; Hining and Rash 2016; Lancaster et al. 2017). Time-lapse cameras are considered more cost efficient because one can set cameras to record angler presence on a body of water without the physical presence of creel clerks (Smallwood et al. 2012; Greenberg and Godin 2015; Hining and Rash 2016). While increased time is needed to analyze camera images, this time needed is less than that of traditional creel surveys (Kristine 2012; Smallwood et al. 2012). In addition, one can set up multiple cameras on a single water body or place several cameras on different lakes and streams to increase sampling efficiency.

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Managers must consider a number of factors when deciding to use time-lapse cameras to assess angler use. Greenberg and Godin (2015) introduced four steps to use when employing cameras to assess angler use: (1) proper camera placement and image capture, (2) image retrieval and storage as an image set, (3) image analysis, and (4) calculating recreational angling effort. While these steps may seem apparent, careful thought must be taken at each step to ensure the success of using time-lapse cameras. Incorrect camera placement can impede the ability of image capture and result in inaccurate angler use data. Furthermore, managers must decide, based on the objective of the survey, the interval between camera images. If these intervals are too long, cameras may not capture enough images to gather accurate data (especially on higher-use systems). Conversely, capture intervals that are too frequent can result in an unnecessarily large number of images, which slows the analysis process. While cameras reduce "on the ground" personnel hours, cameras must still be checked for continued use (battery changes and categorizing the images taken). Analysis of collected images represents the most time-consuming component of camera use. Technicians must be adequately trained to gather data from images, and protocols must be sufficient to ensure standard analysis between images. Finally, calculating angler use from camera images is the end goal of the process. Data derived from cameras should be validated against traditional methods so they can be corrected if any bias is detected (van Poorten et al. 2015).

Time-lapse cameras have been used previously to assess angler use on smaller, limited-access streams (Kristine 2012; Hining and Rash 2016), smaller remote lakes (Greenberg and Godin 2015), and on nearshore marine fisheries (Smallwood et al. 2012). Streams typically consist of few access points, concentrating angler use and providing an optimal area for camera placement (Hining and Rash 2016). On smaller lakes cameras can record all or a majority of the fishable surface allowing for simple analysis (Greenberg and Godin 2015). Similarly, nearshore marine fisheries can record a majority of the study area and often do not have to contend with nonfishing recreational use (Smallwood et al. 2012). However, time-lapse cameras have yet to be evaluated for use in larger reservoirs. The inherent problems in using camera technology on reservoirs are the ability to (1) discern fishing from recreational boats given the field of view of the cameras and (2) properly design surveys and analyze camera data to accurately capture angling activity in a higher-use system. For time-lapse cameras to continue to grow as a management tool, different water body types must be evaluated. Therefore, the objectives of this study were to evaluate time-lapse cameras on a large, high-use reservoir, determine methodology for appropriate analysis, and provide managers an example of how they may use data collected via time-lapse cameras to estimate angler use.

METHODS

Study site and camera placement.— Lake Pleasant, a 4,168-ha reservoir located in central Arizona near the city of Phoenix was used as our study site (Figure 1). Lake Pleasant was chosen as our study site for two main reasons. First, Arizona Game and Fish Department personnel were conducting a standard access point creel survey on Lake Pleasant, creating an opportunity to compare camera data with creel data for validation purposes. Second, Lake Pleasant is located within the Phoenix metropolitan area and thus served as a model study area to evaluate a high-use reservoir serving a broad spectrum of recreational activities. Phoenix is the fifth largest city by population and the fastest-growing major city in the United States (U.S. Census Bureau 2017), and Lake Pleasant has historically been the highest fishing-use lake within the state of Arizona (Pringle 2004).

One time-lapse trail camera (Plotwatcher Pro; 1,280 × 720 pixel resolution, 54° cone viewing angle) was installed at a high-use public boat ramp at Lake Pleasant (Figure 1). Cameras were also initially placed at a second public boat ramp at Lake Pleasant but were discontinued due to low visibility of the boat ramp given existing infrastructure. The camera was installed approximately 2 m off the ground and disguised within a wooden bird box to discourage vandalism. The camera was programmed to record an image every 5 s during daylight hours, and personnel checked cameras every 14 d to change batteries and swap data storage cards. Images were recorded from December 21, 2015, to May 8, 2016, (20 total weeks of image capture) to capture the likely highest angling period of the year due to the high summer and fall temperatures in the Phoenix metropolitan area.

Standard access point creel survey.— During the study period, a traditional creel survey was conducted at Lake Pleasant on the two public boat ramps and one private boat ramp by following the standard protocol for surveys in Arizona (AGFD 2004). Creel survey days were conducted equally at all three ramps and also comprised equal days of morning and afternoon time periods that were randomly assigned a priori. Creel clerks counted confirmed fishing vessels during the creel survey period, recorded the number of anglers per fishing vessel, and recorded fishing start and end times for each angler.

Image analysis.— Cameras automatically compressed images into a video file, and images were analyzed using VLC media player version 2.2.6 (VideoLAN Organization, Paris). A single technician was used to analyze images to reduce variability in the analysis. Prior to image analysis, the technician was trained using a developed

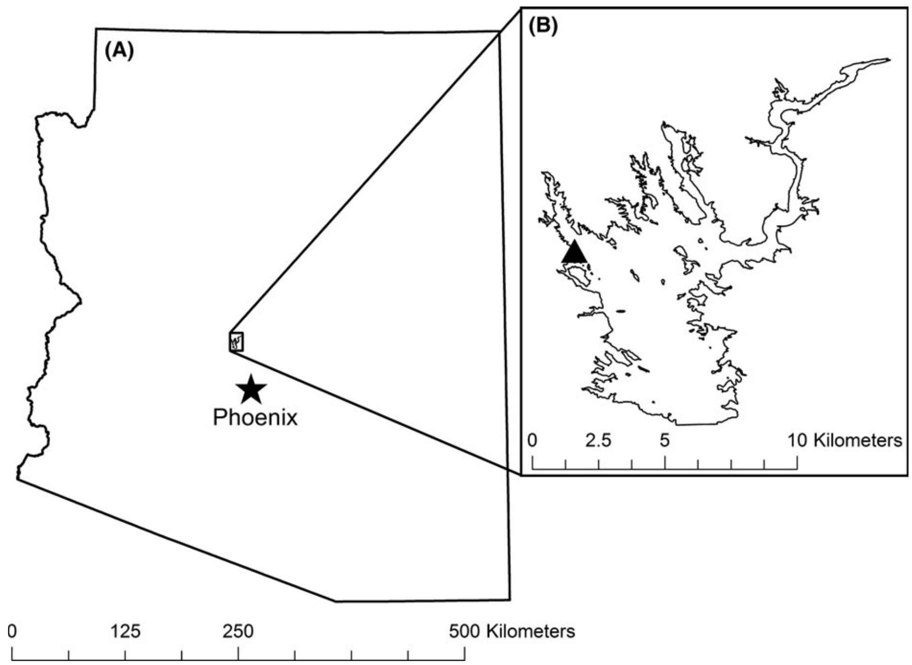

FIGURE 1. **(A)** Location of study site near Phoenix, Arizona, and **(B)** Lake Pleasant. Solid triangle denotes location of camera placement.

standard protocol and validated using a second trained observer for accuracy. A standard definition of fishing boats was developed a priori to discern nonfishing recreational boats (hereafter recreational boats) within images. A fishing boat was defined as: (1) any floating vessel designed explicitly for fishing purposes such as a bass-fishing boat; (2) any floating vessel containing specific fishing equipment such as fishing rods, trolling motors, nets, buckets, or fish finders; (3) any floating vessel containing persons within the vessel displaying behavior patterns that would indicate beyond a reasonable doubt that persons are using fishing gear such as rigging poles and casting.

To assess average trip length, the technician recorded time of entry and exit for each fishing boat along with specific notes to assist with recognition of individual boats when exiting. Recreational boats were also recorded upon exit and, at the end of each day, the numbers of fishing and recreational boats were tallied. Boats that were launched during the day of study but did not exit were not counted in daily tallies. When the technician was unsure whether a boat was fishing or recreational, the technician consulted with a second trained observer for determination. When no consensus was reached the boat was counted as recreational. Video was watched at no more than 0.40× normal speed when boats were present and no more than 0.25× normal speed when encountering heavy boat traffic. Each video was watched completely through once and then watched a second time to verify tallied boat counts.

Data analysis.— As the traditional creel survey was conducted for either morning or afternoon periods, camera images were only analyzed during the recorded time periods by the creel clerk. To assess overall angling use, the number of fishing boats exiting the study boat ramp was first correlated between camera images and the traditional creel survey between paired days of camera analysis and the creel surveys to evaluate accuracy of camera fishing boat definition (12 total paired days; Figure 2). Subsequently, a correction equation was developed to account for any over- or underestimation of fishing boat counts derived from the camera analysis, as done in previous studies evaluating time-lapse cameras (van Poorten et al. 2015). Thus, by using a correction equation, managers can easily account for any bias associated with a priori definitions they are using for camera analysis. Recreational boat totals were then corrected by subtracting the number of corrected fishing boats from the weekly total boat count (i.e., corrected recreational boat weekly count = total boat weekly count – corrected fishing boat weekly count). All corrected boat totals were then rounded to the nearest whole integer. To assess angling use over the entire study period, a stratified "camera creel" schedule was developed independent of the in-person creel survey to provide managers an example of how time-lapse cameras can be used to estimate angling use over a longer temporal period. As with previous studies evaluating the efficacy of cameras to assess angling use, days were first categorized as either weekday or weekend and public holiday for analysis (Hartill et al. 2016; Hining and Rash 2016; Keller et al. 2016). Each week was analyzed separately to track temporal trends, with one weekday and one weekend day each week

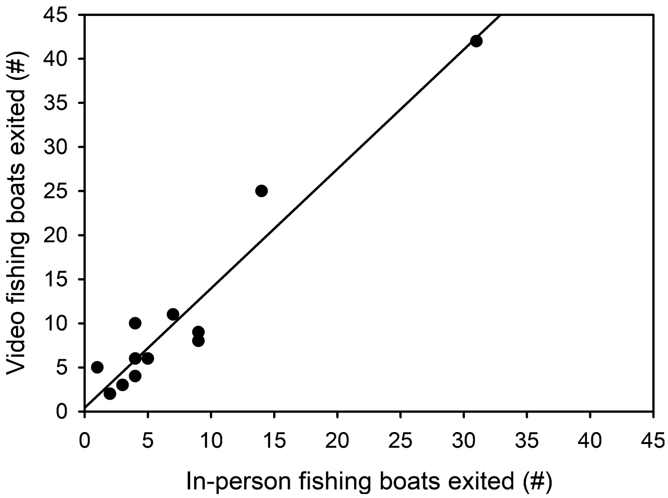

FIGURE 2. Relationship between fishing boats counted in person that exited (*y*-axis) and fishing boats counted by camera that exited (*x*-axis) at the study ramp at Lake Pleasant between December 2015 and May 2016.

analyzed for the study period (20 total weeks × 2 d analyzed per week = 40 complete days analyzed). A random date generator was used to ensure an equal number of weekdays and weekend days were watched (e.g., four Mondays, four Tuesdays, and so on; 10 Saturdays and 10 Sundays). Weekdays and weekend days were thus assumed to be representative of the unwatched days for each study week. During the independent "camera creel" analysis, entire days (i.e., from dawn to dusk) were watched and analyzed by the technician.

To estimate both fishing and recreational boat use for each week, each weekday and weekend day analyzed was extrapolated to be representative of their respective strata (each weekday multiplied by five and each weekend day multiplied by two); weekday and weekend day estimates were then summed to calculate a week total. To estimate angling effort, the number of fishing boats and anglers counted from the traditional creel survey were first correlated to determine whether a linear relationship existed. Subsequently creel fishing boat and angler counts were regressed to develop a predictive equation for anglers derived from fishing boat counts. The number of fishing boats counted from the camera analysis (corrected using the methodology described above) was then converted to angler totals using the regression equation derived from creel fishing boat and angler counts. The number of estimated anglers for each week was then multiplied by the average trip length for all fishing boat trips during the study period to obtain a total estimate of angling hours for each week. Overall average trip length was used as low variability existed for average trip length for each week during the study period. To provide a comparison of angling effort estimated from the traditional creel, total angling effort at the study ramp was calculated using methods for the standard access point exit creel survey from Pollock et al. (1994). For each individual traditional creel day, trip lengths as reported by anglers were first combined to calculate a daily sum of trip hours. Traditional creel days were subsequently split into weekday and weekend day strata, and the average total trip hours for each stratum was used to estimate angling effort for the unsampled days during the study period. SigmaPlot version 11.2 (Systat Software, San Jose, California) was used for data analysis.

RESULTS

Fishing boat counts derived from the in-person creel and camera images were closely related to each other (Pearson correlation coefficient = 0.964, $P < 0.001$; Figure 2) and allowed for the subsequent correction of fishing boat counts from camera images [in-person fishing boats = (camera fishing boats × 0.6856) + 0.2655]. In addition, the relationship between the in-person fishing boat count and in-person anglers was also strong (Pearson correlation coefficient = 0.998, $P < 0.001$; Figure 3) and allowed for subsequent calculation of estimated angling use for the study period [in-person angler count = (corrected fishing boats × 2.2074) − 2.5237].

Over the course of the study period 5,370 boats were counted exiting the study ramp at Lake Pleasant. The mean weekly total boat count was 269 boats (SE, 32), with weekly estimates ranging from 19 boats (week of January 4) to 503 boats (week of April 18; Figure 4). Overall boating use was low until the week of February 1; after this date use increased until the end of the study period (Figure 4). Fishing and recreational boat use was

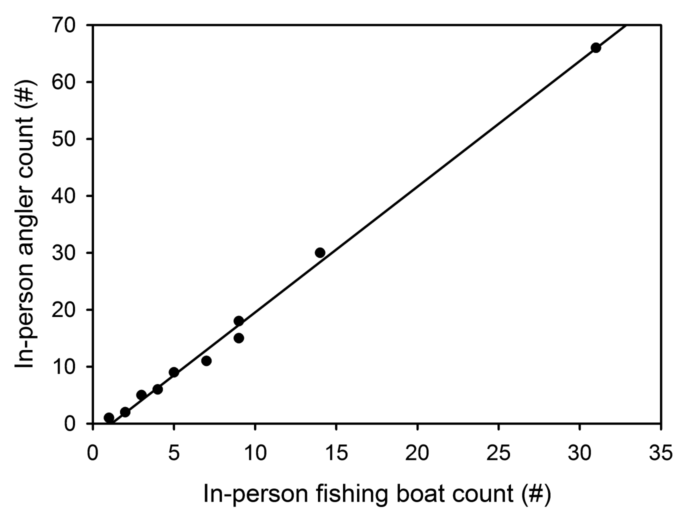

FIGURE 3. Relationship between anglers counted in person that exited (*y*-axis) and fishing boats counted in person that exited (*x*-axis) at the study ramp at Lake Pleasant between December 2015 and May 2016.

comparable until mid-March, and then fishing boat use decreased thereafter (Figure 4). The mean weekly fishing boat count was 124 boats (SE, 14) with weekly estimates ranging from 13 boats (week of January 4) to 210 boats (week of February 15). The mean weekly recreational boat count was 145 boats (SE, 20), and weekly estimates ranged from six boats (January 4) to 309 boats (week of April 18). Based on fishing trips pooled for all days (n = 1,024), the mean fishing trip length was 4.82 h (SE, 0.07) at Lake Pleasant during the study period. The mean weekly angling effort estimate was 809.31 h (SE, 90.33), and weekly estimates ranged from 89.91 to 1,372.32 h. The total angling effort for the study period derived from the time-lapse cameras was estimated to be 16,186.21 h while the total angling effort derived from the traditional creel was estimated to be 22,359.12 h (SE, 349.23).

Time needed to analyze camera images was dependent on the number of boats exiting the study ramp, and busier traffic days took longer than other days. Days analyzed with fewer than 15 boats exiting took an estimated 1.5 h to complete, 16–30 boat-days took 3 h to complete, 31–50 boat-days took 5.5 h to complete, and days with more than 50 boats exiting took an estimated 7 h to complete. Initial set-up at Lake Pleasant took 2 h, and biweekly maintenance was 1.5 h per trip (10 trips total). Combined with the actual camera analysis (including data entry), an estimated 188 h was needed to sample the entire 40-d period.

DISCUSSION

Overall, time-lapse cameras appear to be an excellent supplement to stand-alone creel surveys to assess angler use on reservoir fisheries. Camera-derived fishing boat counts were strongly related to the creel survey counts

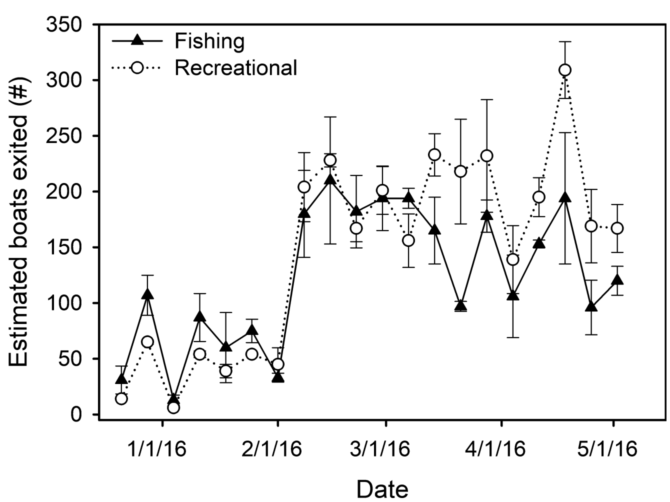

FIGURE 4. Weekly estimates derived from time-lapse cameras of fishing and recreational boats that exited the study ramp at Lake Pleasant between December 2015 and May 2016. Error bars represent ±SE.

(Figure 2). Overall boating use was relatively low until the first week of February (Figure 4). In addition, fishing and recreational boat counts were comparable until mid-March, after which recreational boats comprised the majority of boats exiting. As with previous studies (van Poorten et al. 2015; Keller et al. 2016), our study demonstrates the importance of validating camera-derived data with data obtained from creel surveys. While our fishing boat definition did result in an overestimation of fishing boats from camera images in some cases (Figure 2), validation by using the traditional creel survey allowed for a simple correction. The overestimation of fishing boats is likely attributed to the inherent difficulty in independently assigning boats as fishing or recreational boats as some “fishing” boats may not have been actively fishing. Therefore, validation of camera images should likely be used in conjunction with any project using time-lapse cameras to allow for correction. Without validation, data from camera images could be inaccurate and thus result in a poor comparison with creel surveys. Validating camera images with in-person data could also incorporate other data typically gathered from creel surveys. For example, cameras alone cannot gather data on fish harvest by anglers, information which is needed by mangers to set regulations and drive management actions. Thus, validation of camera data could incorporate harvest data into the subsequent analysis (obtained by the traditional creel survey) allowing for an estimate of harvest in addition to angler use. Future camera studies should try and integrate harvest data into their validation and test the accuracy of harvest estimates derived from time-lapse cameras.

The estimates of angling effort derived from time-lapse cameras were lower overall than those from the traditional creel surveys for the study ramp for the 20-week period (16,186.21 h compared with 22,359.12 h). However, the difference in the angling effort estimates can likely be explained by the nature of fishing at Lake Pleasant and the limitation of the time-lapse cameras used in our study. Lake Pleasant has a significant Striped Bass *Morone saxatilis* fishery (Stewart and Burrell 2013), and one of the common methods for anglers is fishing at night when Striped Bass can be more active. The cameras used in our study did not have the capability to record images at night, and thus this angling use was not factored into the overall estimated angling effort. When overnight trip hours were removed (i.e., boats launched during nighttime hours) the angling effort from the traditional creel survey was subsequently estimated to be 17,888.38 h (SE, 304.87), comparable with the estimate derived from the time-lapse camera. Therefore, if managers intend to use time-lapse cameras on fisheries with significant nighttime fishing, they should be aware that this effort will not be factored into the overall angling estimate or invest in time-lapse cameras with nighttime capability.

Our results were consistent with previous studies that have documented the cost-effectiveness of using time-lapse cameras to assess angling use compared with traditional creel surveys (e.g., Smallwood et al. 2012; Hining and Rash 2016; Lancaster et al. 2017). The analysis of the 40 d for angler use using time-lapse cameras in our study took 188 h and included the time for camera set-up and maintenance and data entry–quality control (an average of 4.7 h per day analyzed). By comparison, as an example, a traditional creel survey may take 9 h per day sampled: 2 h of drive time, 6 h of the actual creel survey, and 1 h of data entry–quality control. Therefore, to sample 40 d using the traditional creel survey would take 360 h, nearly double the amount of time needed to complete the camera analysis. In addition, the time-lapse cameras are able to record the entire daylight period of the sampling day, while the traditional creel survey can only sample a subset of the sampling day. Overall time-lapse cameras gathered greater amounts of angler-use data more efficiently compared with the traditional creel survey in our study; however, managers should be cognizant that the cost-effectiveness of time-lapse cameras could be dependent on the water body given the fishery objectives of managers.

Our study is the first to evaluate using time-lapse cameras to assess angler use on a large reservoir. While we found that time-lapse cameras can be used to accurately assess angling use, we did encounter challenges in using time-lapse cameras. Smallwood et al. (2012) noted that camera placement and field of view are the principal factors that affect the quality of camera-derived data. Concerns over privacy affected both the duration and locations at which we could install cameras at Lake Pleasant. Managers need to work with stakeholders and external partners to take these concerns into consideration and determine acceptable methodology and camera placement for the parties involved (Lancaster et al. 2017). Another challenge in using time-lapse cameras on reservoirs is that reservoir water levels are often not static. Lake Pleasant can undergo dramatic changes in water level fluctuation throughout the year (Stewart and Burrell 2013), affecting the ability of technicians to analyze images depending on camera placement. Reservoir levels increased steadily throughout our study period; surface water level elevation on Lake Pleasant rose from 510.92 m on December 21, 2015, to 517.06 m at the conclusion of the study on May 8, 2016 (Central Arizona Project, unpublished data). When reservoir levels were low, the camera was farther away from the edge of the boat ramp, adding increased analysis time in discerning individual boats. Conversely, when water levels were high boats had a reduced amount of time within the field of view, requiring the technician to replay images to discern individual boats. Therefore, managers need be cognizant of seasonal water level changes when installing time-lapse cameras on reservoirs for future studies.

While time-lapse cameras do have some limitations compared with creel surveys, our study (and others) demonstrate the utility of time-lapse cameras for managers and should be incorporated into traditional fisheries management activities. As managers increasingly encounter budgetary constraints for creel surveys, alternative cost-effective strategies will be needed for continuing adaptive management. For cameras to become more integrated in fisheries surveys, managers need to be willing to try this new technology and avoid staying with the status quo. Therefore, future studies will be crucial for the adoption of camera technology as a standard survey technique in fisheries management. In addition, while this study focused on evaluating time-lapse cameras to estimate angling use, the use of cameras on large multi-use reservoirs likely has broader implications for lake managers. Managers could also use time-lapse cameras to track recreational usage and subsequently target specific reservoir areas for improvement or increased management. Overall, based on our study and previous studies, time-lapse cameras do provide a cost-effective, accurate, and useful alternative to traditional stand-alone creel surveys.

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REFERENCES

AGFD (Arizona Game and Fish Department). 2004. Standard fish sampling protocol for state of Arizona waters. Arizona Game and Fish Department, Phoenix.

Greenberg, S., and T. Godin. 2015. A tool supporting the extraction of angling effort data from remote camera images. Fisheries 40:276–287.

Hartill, B. W., G. W. Payne, N. Rush, and R. Bian. 2016. Bridging the temporal gap: continuous and cost-effective monitoring of dynamic recreational fisheries by web cameras and creel surveys. Fisheries Research 183:488–497.

Hining, K. J., and J. M. Rash. 2016. Use of trail cameras to assess angler use of two remote trout streams in North Carolina. Journal of the Southeastern Association of Fish and Wildlife Agencies 3:89–96.

Isermann, D. A., and C. P. Paukert. 2010. Regulating harvest. Pages 185–212 *in* W. A. Hubert and M. C. Quist, editors. Inland fisheries management in North America, 3rd edition. American Fisheries Society, Bethesda, Maryland.

Keller, K., A. S. Steffe, M. Lowry, J. J. Murphy, and I. M. Suthers. 2016. Monitoring boat-based recreational fishing effort at a nearshore artificial reef with a shore-based camera. Fisheries Research 181:84–92.

Kristine, D. 2012. Use of trail cameras to assess angler use on limited access streams managed under wild Brook Trout enhancement regulations in north central Pennsylvania during 2012. Pennsylvania Fish and Boat Commission, Bellefonte.

Lancaster, D., P. Dearden, D. R. Haggarty, J. P. Volpe, and N. C. Ban. 2017. Effectiveness of shore-based remote camera monitoring for quantifying recreational fisher compliance in marine conservation areas. Aquatic Conservation: Marine and Freshwater Ecosystems 2017:804–813.

Malvestuto, S. P. 1996. Sampling the recreational creel. Pages 591–623 *in* B. R. Murphy and D. W. Willis, editors. Fisheries techniques, 2nd edition. American Fisheries Society, Bethesda, Maryland.

McMullin, S. L., and E. Pert. 2010. The process of fisheries management. Pages 133–155 *in* W. A. Hubert and M. C. Quist, editors. Inland fisheries management in North America, 3rd edition. American Fisheries Society, Bethesda, Maryland.

Pollock, K. H., C. M. Jones, and T. L. Brown. 1994. Angler survey methods and their applications in fisheries management. American Fisheries Society, Bethesda, Maryland.

Pringle, T. 2004. Statewide survey of 2001 Arizona anglers. Arizona Game and Fish Department, Fisheries Technical Report 03-01, Phoenix.

Smallwood, C. B., K. H. Pollock, B. S. Wise, N. G. Hall, and D. J. Gaughan. 2012. Expanding aerial-roving surveys to include counts of shore-based recreational fishers from remotely operated cameras: benefits, limitations, and cost effectiveness. North American Journal of Fisheries Management 32:1265–1276.

Stewart, W. T., and M. Burrell. 2013. Striped Bass dispersion and effects on fisheries management in Lakes Mohave and Pleasant, Colorado River basin. Pages 431–448 *in* J. S. Bulak, C. C. Coutant, and J. A. Rice, editors. Biology and management of inland Striped Bass and hybrid Striped Bass. American Fisheries Society, Symposium 80, Bethesda, Maryland.

U.S. Census Bureau. 2017. Annual estimates of the resident population for incorporated places of 50,000 or more, ranked by July 1, 2016 population: April 1, 2010 to July 1, 2016. U.S. Census Bureau, Population Division, Washington, D.C.

van Poorten, B. T., T. R. Carruthers, H. G. M. Ward, and D. A. Varkey. 2015. Imputing recreational angling effort from time-lapse cameras using a hierarchical Bayesian model. Fisheries Research 172:265–273.