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ARTICLE

Incorporating Time-Lapse Digital Cameras into Creel Surveys at Three Alabama Reservoirs

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Abstract
We compared different creel survey methods at three Alabama reservoirs (Harris, Jordan, and Mitchell) to identify approaches that could improve precision. We were particularly interested in whether boat trailer counts from time-lapse photos taken at boat ramp parking lots could be used as an index of fishing effort to improve the temporal coverage of sampling. Angler effort was estimated independently using roving creels, access point creels, and aerial census counts and compared with fixed-location digital camera images of trailers at boat ramps. Digital camera counts of trailers correlated with angler effort from aerial census, access point creel surveys, and roving creel surveys. This finding suggests that time-lapse digital cameras as a sampling method to obtain angler effort may provide a feasible method once calibrated to a system. Best-fitting models for relationships between time-lapse trailer counts and the other creel methods included covariates for season and day type (weekend versus weekday) effects, but not reservoir and time-of-day effects. The inclusion of effort predicted from time-lapse digital cameras incorporated with roving creel surveys did not statistically affect the magnitude of effort estimates but substantially increased the precision of effort estimates.

Monitoring of fisheries for catch and effort is essential for management of inland recreational fisheries (Pollock et al. 1994). Creel surveys are a technique used to obtain information about angler catch, harvest, fishing effort, target species, sociodemographics, and economic impacts (Pollock et al. 1994; Ditton and Hunt 2001). These survey methods give biologists insights about the fishing quality, recreational fishing pressure, and economic importance of the fishery.

Creel surveys are conducted using a variety of sampling methods (Newman et al. 1997). Most commonly employed are intercept surveys (e.g., access point and roving creel surveys; Robson and Jones 1989). However, aerial census counts, mail surveys, and other remote methods are also used. These additional creel survey methods can provide a less labor-intensive approach to obtaining angling data. However, these surveys may be less precise at obtaining both effort and catch data. Which survey to use is often dependent on study location, staff resources, management objectives, and the information desired (Smallwood et al. 2012).

By combining multiple survey techniques, the accuracy and precision can be increased (Pollock et al. 1994). These combined strategies have included aerial surveys and access point creel surveys (Volstad et al. 2006), roving creel surveys and mail surveys (Ditton and Hunt 2001), and access point creel survey and digital camera time-lapse photos (Stahr and Knudson 2018). For example, Stahr

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and Knudson (2018) incorporated the utilization of a time-lapse digital camera at intervals of 5 s to correlate fishing trip length from cameras to access point creel. They determined that the cameras were capable of being used as a supplement to measure angler effort when access creels were not conducted. These multisurvey designs allow for estimates of fishing effort, catch, and harvest to be estimated by correlating effort from the nonintercept survey (Pollock et al. 1994). The incorporation of multiple survey techniques allows for a more complete and cost-effective strategy in estimating catch and harvest data (Smallwood et al. 2012).

Digital cameras are becoming increasingly common in fisheries to obtain estimates of fishing effort (Smallwood et al. 2002; Kristine 2012; Fitzsimmons et al. 2013; Greenberg and Godin 2015; Hining and Rash 2016; Dutterer et al. 2020). They provide an alternative to high-intensity on-site creel surveys (Greenberg and Godin 2015). Digital cameras can be programmed as time-lapse or motion detection. If designed for time-lapse operation, the effort can be estimated based on angler, boat, or trailer counts within the field of view. If the field of view does not provide a census count of anglers, then indices of effort could be developed by relating camera counts and concurrent intercept surveys. One limitation of relating images of trailers to effort is the inability to determine recreational activity (i.e., fishing versus other recreation) based on trailers. With motion detection, a time stamp is available to estimate total effort spent by anyone detected by the camera. A downside to this survey method is the extensive time required to analyze the data gathered from these remote cameras, but this effort may be less than typically required to conduct an intercept creel survey (Kristine 2012; Smallwood et al. 2012; Dutterer et al. 2020).

The addition of digital cameras has been used to estimate effort for systems with few access points (Stahr and Knudson 2018) or areas where the cameras effectively sample the entire system (Smallwood et al. 2012; Fitzsimmons et al. 2013). However, these camera survey methods could be used on systems with multiple access points to provide the same benefits in estimating recreational angler effort. This would aid in the reduction of cost compared to traditional access point or roving creel surveys and potentially provide a new design standard for creel surveys on systems with multiple access points.

Current creel techniques have difficulties in sampling effort and catch on large systems, such as reservoirs, with multiple access points. The objectives of this study were to identify relationships of effort between creel surveys and time-lapse digital cameras at public boat ramps. First, effort was compared from aerial census counts, weekend access creels, and roving creel surveys. Next, precision of effort was compared between seasonal effort estimation from roving creel surveys and the use of a hybrid roving/photo creel. Last, we evaluated the influence of frequency of roving creels on the precision of the hybrid creel design.

METHODS

Study sites.— Three Alabama reservoirs were chosen to assess the usage of digital cameras as an index of effort based on creel survey methods: Harris, Mitchell, and Jordan. These reservoirs were selected to include variation in reservoir size, shoreline development index (SDI), and the number of paved public boat access points to the reservoir (Figure 1). Harris Reservoir is located on the Tallapoosa River and is 4,300 ha. Mitchell and Jordan reservoirs are located on the Coosa River, with Mitchell being 2,360 ha and Jordan being 2,750 ha. The lake portion of the reservoirs was sampled.

The SDI, which relates the shoreline length of a lake to the shoreline length of a perfectly circular lake of equal area, of these three reservoirs ranges from 14 to 19 (Aronow 1982). The SDI increases as lakes become more sinuous and elongated and can increase the risk of anglers not being detected during creel surveys based on large amounts of coves and pockets. Out of the reservoirs sampled, Harris Reservoir is the most complex based on its SDI of 19, with Mitchell having an SDI of 14 and Jordan an SDI of 16. All three reservoirs selected have multiple paved public boat ramps. Harris has six paved boat ramps, Mitchell has two, and Jordan has two. The number of boat ramps impacted how access creels were conducted on each reservoir.

Relationships between time-lapse boat trailer counts and concurrent creel surveys.— Aerial surveys took place from March 4, 2018 to March 2, 2019. Flights were performed in partnership with the Auburn University Aviation Center four times per 28 d, two weekdays and two weekend days. Weekdays were randomly selected between the entirety of the 20 possible weekdays within the 28-d period, dependent on weather and pilot availability. Weekend samples were conducted on the two weekend days per 28-d period that intercept creels were not being performed. All three reservoirs were flown over and sampled during each flight. A single pass over each reservoir occurred at an altitude between 300 and 600 m, during which a census count of boats occurred. Boat counts were separated as angling and recreational boat based on gear and activity observed by boating party during the flight. Flights were only conducted when Auburn Aviation Center visual flight rules were met (i.e., a ceiling greater than 900 m and visibility greater than 8 km). If visual flight conditions were not met, the flight was rescheduled randomly with the remaining days available in the stratum.

Digital cameras were deployed at boat ramps for a remote index of fishing effort. Cameras were set up to

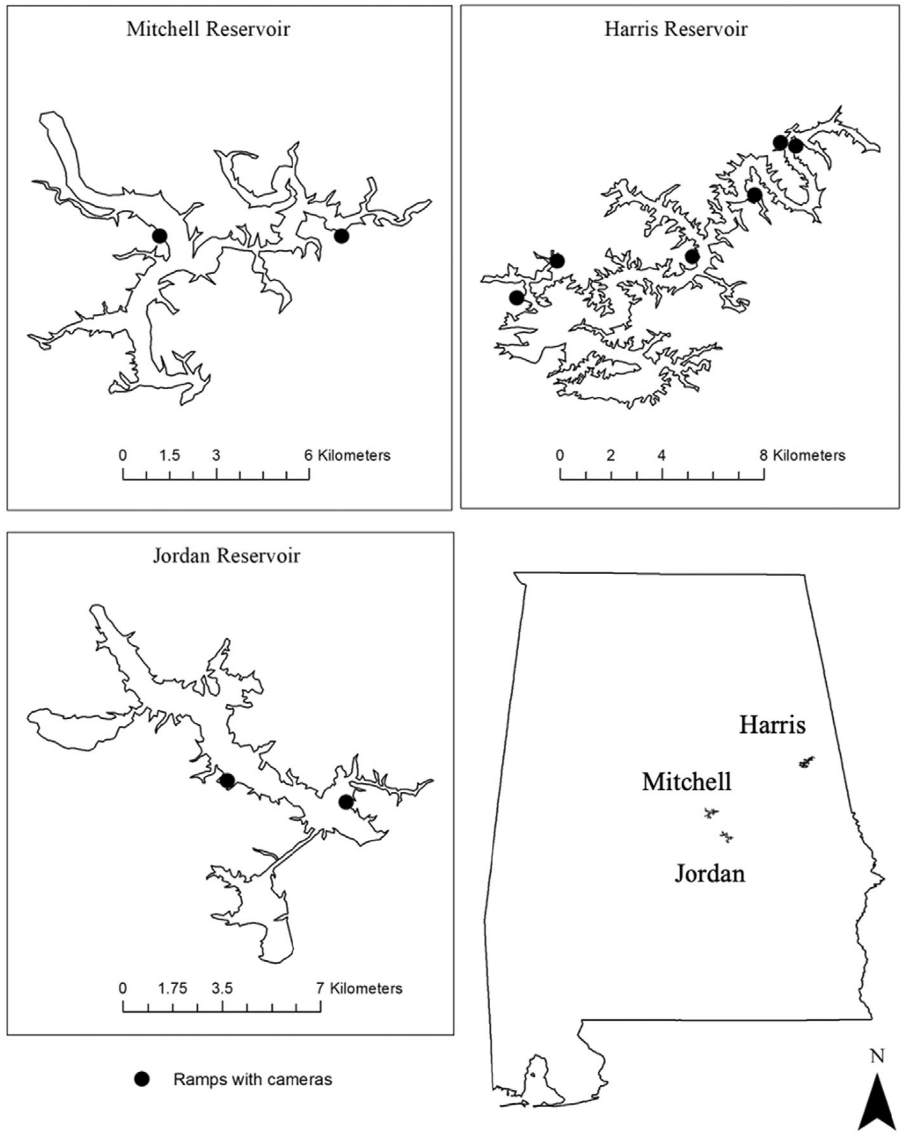

FIGURE 1. Lake portion of Harris, Mitchell, and Jordan reservoirs that were sampled by roving creels. Black dots represent boat ramps that had digital cameras installed for effort estimates.

overlook the parking lots of paved public boat ramps on the reservoirs. These cameras were positioned 4–5 m high and attached to trees adjacent to boat ramp parking lots. Digital cameras were programmed to take a time-lapse photo at one photo per hour. The cameras were angled to maximize the field of view over the boat ramp parking lot. The entire lot was not always fully captured, and any additional overflow parking was likely missed due to the unpredictability of parking locations and the number of trailers; however, the majority of each parking lot was captured. Nine cameras on Harris were split between six paved public ramps, seven cameras on Mitchell between two ramps, and three cameras covering the two ramps on Jordan. Photos were processed by reviewing pictures taken between 0700 and 1900 hours and quantifying the number of boat trailers observed in each picture for each hour. Differentiating angler use versus recreation use was unachievable due to trailer similarities; therefore, trailer counts from cameras were used to calculate total boating effort. Multiple camera detections of individual trailers were accounted for.

The access point creel survey was conducted over a 1-year period concurrent with the cameras, aerials surveys, and roving creels. Two access creel surveys were performed for each reservoir per period of 28 d. These surveys occurred on weekends with a start time of 7.5 h before sunset and extended 30 min past sunset. Ramp location was randomly selected, with equal probability across all ramps that had digital cameras located at them. Anglers were surveyed with standard questions regarding target species, time spent fishing, catch, harvest, and fishing vessel type.

A year-round roving creel was conducted on all three reservoirs following a stratified random design. Stratifications included weekday versus weekend and morning (0700–1300 hours) versus afternoon (1300–1900 hours). Time of sample was randomly chosen with equal probabilities between the two stratifications. Roving creel surveys were conducted four times per reservoir per 28 d, two weekends and two weekdays. Every weekday had the same probability of being sampled. Weekend days were sampled on the same reservoir as the concurrent access creel survey. Angler interviews gathered data on incomplete fishing trips by intercepting the angler on the reservoir by motorboat. The number of anglers was enumerated with a count-as-you-go approach. The roving creel included angler interviews and enumeration from all anglers, including those that did not require a public boat ramp (i.e., shore-based anglers and boat anglers who accessed the reservoir from private docks and ramps). Direction of travel and starting checkpoint location were randomly selected. Each reservoir was broken into six sections of similar size divided by the checkpoints. The checkpoints were to ensure that creel clerks moved forward at a uniform speed to sample each section of the reservoir evenly. A single survey consisted of making one complete loop around the reservoir, interviewing anglers along the way. Anglers were surveyed with standard questions similar to the access creel. Repeat anglers and anglers who refused to be interviewed were tallied for the progressive count.

The first analysis focused on a snapshot in time between aerial census counts of angling boats on the reservoir and the number of trailers observed in digital photos of boat ramp parking lots. To estimate the relationship between aerial census counts of angling boats and the number of trailers observed in digital photos, the digital photographs were analyzed to determine the number of trailers at the closest time to which the flight occurred. All ramps had the number of trailers summed across reservoir to compare with the number of angling boats observed by aerial census. This model included potential covariates of reservoir, season, day type (weekday versus weekend), and time of day (AM versus PM), with the best-fit model determined by stepwise regression.

The second analysis compared camera counts with effort estimates from concurrent access point creel surveys. Trailer effort (hours) was summed across all cameras located at the ramp for the hours the access creel was conducted. Access creel effort was estimated as the sum of interviewed angler-hours multiplied by an expansion factor for anglers not interviewed via

$$ef = \frac{n_{interview} + n_{not}}{n_{interview}},$$

where ef is the expansion factor, $n_{interview}$ is the number of anglers interviewed, and n_{not} is the number of anglers who were not interviewed. A linear model was used to estimate the relationship between daily effort (angler-hours) gathered from access point creels and the sum of trailer hours on the camera(s) located at that ramp. Potential covariates included reservoir, season, and boat ramp, and the best-fit model was determined by stepwise regression. To determine if effort varied across season, an interaction between camera effort and season was included for evaluation. Significance was determined by P-value and releveling of seasonal variables.

The last analysis for this objective tested the relationship between roving creel daily effort (angler-hours) and trailer hours observed by cameras at a reservoir scale. The model related effort (trailer hours) observed from the digital cameras at all boat ramps to that of the concurrent roving creel survey. Angler effort from the roving creel was calculated as a progressive count of anglers multiplied by the number of hours in the sample time slot. Camera effort (trailer hours) was estimated as the sum of trailer hours across all cameras on the reservoir during the time the roving creel was conducted. Independent variables included in the analysis for testing were reservoir, season, day type, and time of day.

Incorporating time-lapse trailer counts into roving creel effort estimates.— The sensitivity of the precision of roving creel-based fishing effort estimates to the inclusion of boat trailer counts from digital time-lapse photos was evaluated by comparing predicted effort and associated standard errors. Baseline seasonal estimates of fishing effort (angler-hours) were made for each reservoir using the roving creel survey data. Roving creels were chosen for this hybrid design as they were the only creel method used that evaluated reservoir-wide effort from both shore and boat angling over the entire reservoir for both weekdays and weekends. The hybrid design was not created for the other survey methods (i.e., flyover census and access creels) due to the surveys being designed to test for associations between concurrent surveys of angling effort and trailer counts instead of a lake-wide prediction of effort.

Total effort for the roving creels was estimated separately for each stratum, which was defined by reservoir, season, day type (weekday versus weekend), and time of day (morning versus afternoon). Total angler effort (e_j; h) for the *ith* day within each stratum was estimated via

$$e_i = a_i t_i,$$

where a_i is the progressive angler count from the roving creel on day i and t_i is the duration of the interval over which the progressive count was taken.

The roving estimate of total angler effort for each stratum was obtained via

$$\hat{e}_h = N_h \bar{e}_h$$

by multiplying the average daily effort ($\bar{e}_h$; h) by the number of days (N) in the stratum (h). The within-stratum variance of the mean effort from the roving creel survey was estimated via

$$v(\bar{e}_h) = {s_h}^2 \frac{1}{n_h}\left(\frac{N_h - n_h}{N_h}\right),$$

where ${S_h}^2$ is the sample variance; N_h is the number of sampling days within stratum h, which for this study was 60 for weekdays and 24 for weekends; and n_h is the number of samples in the stratum h, which was 18 d for both weekday and weekend surveys.

The variance of the creel effort stratum estimate for roving creels was estimated via

$$v(\hat{e}_h) = {N_h}^2 v(\bar{e}_h),$$

which is the variance of the mean effort from the roving creel survey multiplied by the number of sampling days within stratum h. Seasonal effort estimates were obtained by summing across day type and time of day strata within a season, and variance of these estimates were obtained by summing the individual stratum-level variances.

These baseline estimates were compared with estimates in which trailer counts from time-lapse cameras were included as a predictor of fishing effort for sampling periods (i.e., an AM or PM period on a particular day) on which no roving creel survey was conducted. Using the relationship obtained between roving creel effort and time-lapse digital camera effort, effort for the hybrid roving/camera creel was estimated via

$$e = \sum_{i=1}^{n_c} a_i t_i + \sum_{c=1}^{N_h} e_c,$$

where n_c is the number of periods in which a roving creel was conducted, N_h is the number of periods without a roving creel, and e_c is the predicted effort from the regression model between trailer hours from digital cameras and angler-hours from roving creel surveys when roving creel surveys were not conducted.

The variance of the effort estimates was obtained via

$$\sigma_i^2 = \sum_{c=1}^{N_h} \sigma_r^2 + SD_r^2,$$

where σ_r^2 is the variance of the predicted mean effort from the regression model between trailer hours from digital cameras and angler-hours from roving creel surveys and SD_r is the residual standard deviation from the same model. The effort estimates from periods during which roving creels were conducted were assumed to have no variance because obtaining estimates of within-period roving creel variance would have required multiple concurrent roving creels which would have been prohibitively expensive.

The sensitivity of the coefficient of variation (CV) of the effort samples was analyzed by adjusting the relationship of the linear regression based on the number of roving creel samples performed. The CV was averaged over 250 iterations for each unit of roving creel samples. Season-wide estimates of the CV were estimated from sampling 12 times per season up to 60 in increments of six samples. Current samples were randomly bootstrapped to achieve a higher sampling density. This simulation is obtained from our three-reservoir system with a common relationship across all reservoirs that did not include any additional effects of the reservoir. The current sampling protocol used 12 samples per reservoir for a total of 36 samples in a season. Additionally, estimates of effort (hours) per season within lake were compared between pure roving creel survey and hybrid roving/camera creel survey.

RESULTS

Relationships between Time-Lapse Boat Trailer Counts and Concurrent Creel Surveys

Boat ramp trailer counts were a statistically significant predictor of aerial census counts of fishing boats at these reservoirs. The best-fitting model included additive effects of trailer count, season, and day type, and a season × day type interaction ($P < 0.001$, $r^2 = 0.80$, $F_{8,125} = 62.32$, CV = 43.60%; Figure 2). Overall, natural log aerial boat counts increased by a factor of 0.76 per unit increase in natural log boat trailer count ($P < 0.001$). On weekdays, aerial boat counts per unit trailer count were highest in spring, intermediate in summer and winter, and lowest in fall (Figure 2), which suggests that a higher proportion of trailers was associated with fishing boats on weekdays in spring. On weekends, aerial boat counts per unit trailer count were still highest in spring, which exceeded summer and fall counts by 1.42 and 0.51, respectively (Figure 3). However, aerial count per trailer count was lowest in summer. The relationship between boat ramp trailer counts and aerial census counts were consistent across all reservoirs and did not appear in the final model based on stepwise regression.

Access-point creel survey estimates of angler effort were significantly related to concurrent boat ramp trailer counts from digital cameras. The best-fitting model included

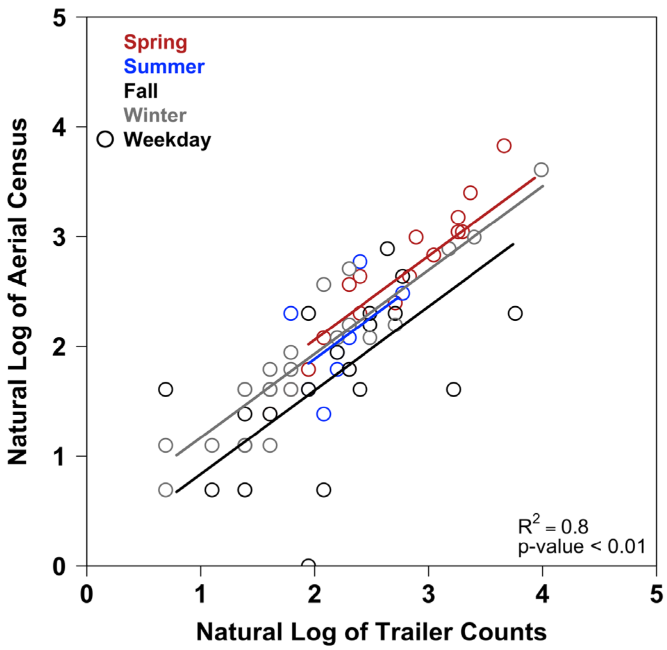

FIGURE 2. Relationship between weekday aerial census counts of angling boats and trailer counts observed from the most proximate time-lapse digital camera photos on the current sample reservoir. Best-fit model composed of an interaction of day type (weekday versus weekend) × trailer count with an additive effect of season.

additive terms for camera effort, season, and a camera effort × season interaction ($P < 0.001$, $r^2 = 0.64$, $F_{8,130} = 29.22$, CV = 70.20%; Figure 4). The relationship between access effort and camera effort was significantly less steep in fall (slope = 0.54; ±0.36 CI) than the other seasons (spring = 1.11, summer = 1.22, winter = 1.24). Reservoir was not significant in the model for the relationship between access point effort and camera trailer effort.

Roving creel survey estimates of angler effort were significantly related to concurrent reservoir-wide trailer counts from digital cameras. The best-fitting model included additive terms for camera effort, season, and day type, and a camera effort × season interaction ($P < 0.001$, $r^2 = 0.64$, $F_{8,130} = 29.22$, CV = 76.14%; Figures 5 and 6). Overall, weekday angler effort was 0.36 natural log hours (±0.27; ±95% CI) less than weekend ($P = 0.01$; Figures 5 and 6). The relationship between roving effort and camera effort was steepest in winter (slope = 0.96; ±0.20 CI) compared to the other seasons (spring = 0.63, summer = 0.32, fall = 0.65). Reservoir was not found to be significant for inclusion in this model.

Incorporating Time-Lapse Trailer Counts into Roving Creel Effort Estimates

The effects of incorporating boat ramp trailer counts into roving creel survey estimates of angler effort varied across seasons and reservoirs. There were no consistent

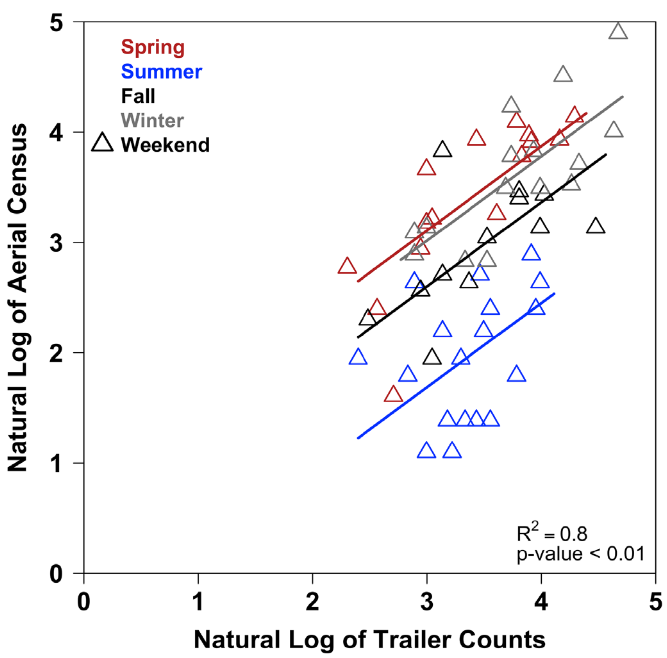

FIGURE 3. Relationship between weekend aerial census counts of angling boats and trailer counts observed from the most proximate time-lapse digital camera photos on the current sample reservoir. Best-fit model composed of an interaction of day type (weekday versus weekend) × trailer count with an additive effect of season.

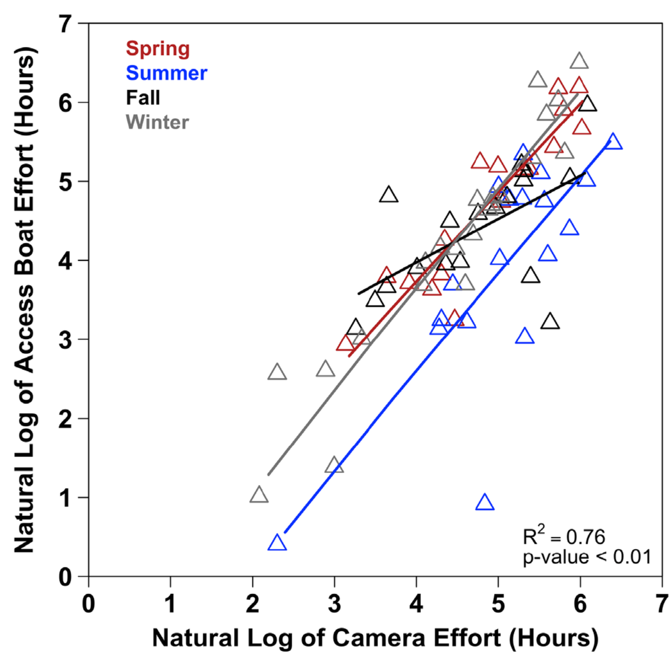

FIGURE 4. Relationship between camera trailer effort from all cameras located at the ramp that the concurrent access creel survey was located and access fishing boat effort. Best-fit model composed of a linear model with an interaction of season × camera effort.

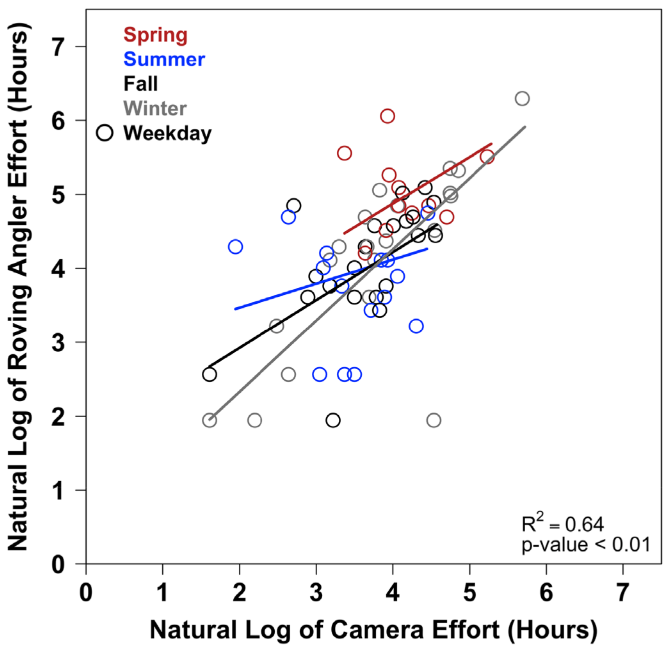

FIGURE 5. Weekday relationship between camera trailer effort and roving fishing effort from concurrent samples. Linear model incorporating a season × camera interaction with an additive effect of day type best explains our data.

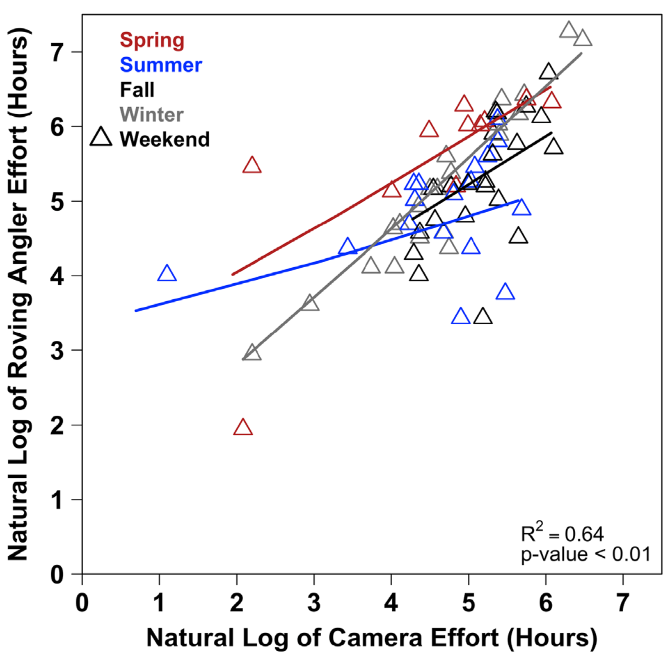

FIGURE 6. Weekend relationship between camera trailer effort and roving fishing effort from concurrent samples. Linear model incorporating a season × camera interaction with an additive effect of day type best explains our data.

changes in the magnitude of effort estimates with the inclusion of trailer counts (Figure 7). For example, spring effort estimates for Harris was 33,320 h from roving creel and 32,165 h from hybrid roving/camera creel. However, the precision of effort estimates increased substantially with the inclusion of the trailer count data, and these improvements in precision were consistent across reservoirs and season (Figure 7). For example, the CV of angler effort (angler-hours) decreased from 74% to 18% at Harris in spring. Similarly, the CV also decreased from 110% to 25% at Mitchell in summer.

The CV of seasonal fishing effort estimates was negatively related to the number of roving creel surveys that were conducted. The CV was highest in summer and fall. The CV at the sampling frequency used for other objectives in this study, 36 samples per season (i.e., 12 samples per reservoir per season), ranged from 27.67% in summer to 15.91% in winter (Figure 8). When the fewest roving creels were conducted, 12 samples per season, the CV ranged from 50.96% to 27.41% when calculating effort estimates for half-day samples.

DISCUSSION

This study suggests that the inclusion of time-lapse digital cameras can increase the precision of angler effort estimates. We found that if 12 roving creels were able to be performed per season to determine the relationship between trailer hours and angler effort from roving creel, then the hybrid survey would have CVs ranging from 27–51% in comparison to CVs of 72–143% from pure roving creel effort estimates at the same sampling frequency. Thus, the hybrid roving/camera creel allows for the inclusion of fishery metrics and a large reduction in error associated with effort estimates. Similarly, Hartill et al. (2016) used CV to determine the precision of annual traffic estimates with a reduction in the number of days surveyed from cameras. They reported precision initially improving with an increase in sampling effort, but the rate of

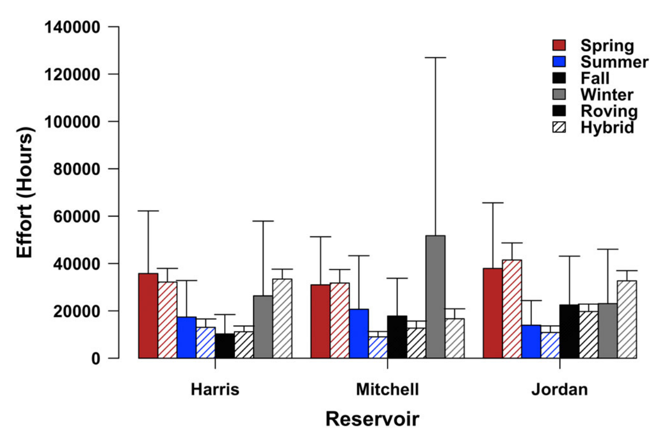

FIGURE 7. Angler effort estimates for roving creel survey and hybrid roving/camera creel expanded over seasons with standard error bars.

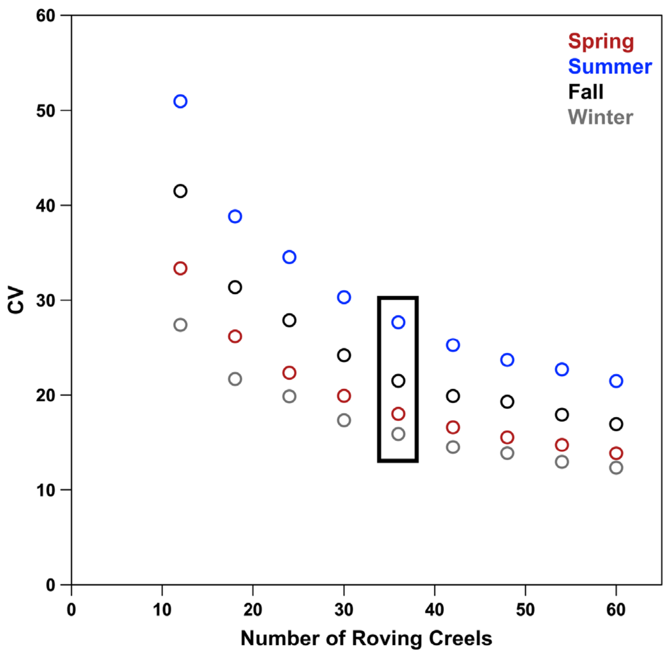

FIGURE 8. Coefficient of variation (CV) as a function of the number of days on which roving creel surveys were conducted in a hybrid survey design that included boat ramp trailers counts from time-lapse digital cameras on days where roving creels were not conducted. The black box signifies the baseline frequency of roving creels that was used during the data collection phase of this analysis. All other data points were obtained via resampling under a range of simulated roving creel frequencies.

improvement greatly decreased with increasing sampling. For their three boat ramps, they could not declare an optimal level of effort but deemed 60 d as suitable for the annual sampling frequency. A reduction in the number of digital photos required to be analyzed could also aide in reduction of creel cost (Afrifa-Yamoah 2021).

We found that time-lapse photos of boat trailers at boat ramp parking lots were significantly associated with independent estimates of angler effort from aerial, roving, and access point surveys. This finding suggests that camera-based trailer count data could serve as a reliable indicator of fishing effort in similar reservoirs. Other investigators are increasingly demonstrating the incorporation of digital photography into creel surveys to observe angling pressure at groynes and shore-based fishing (Smallwood et al. 2012), nearshore artificial reefs (Keller et al. 2016), multiple lakes (Fitzsimmons et al. 2013), and streams (Hining and Rash 2016). However, few have reported on the associations between digital effort counts/indices and independent effort estimates such as aerial or roving creels. Our estimates of strength in these relationships (R^2: 0.64–0.8) was similar to the few estimates that have been reported by other investigators. Hartill et al. (2016) reported R^2 values ranging from 0.71 to 0.77 between trailer counts and effort estimates from an access point creel survey of the number of boats returning daily to three different ramps on New Zealand's North Island. Stahr and Knudson (2018) documented a high correlation between camera counts of boats exiting a boat ramp and in-person counts at an Arizona Reservoir. The tighter association found by Stahr and Knudson (2018) likely relates to their ability to identify individual fishing boats entering and exiting the water, which required a large amount of time to review images.

Seasonal and day type (weekend versus weekday) effects appear to be important when predicting angler effort from time-lapse trailer counts. These covariates were found to be statistically significant in all of the models, except that the day type effects were omitted from models that predicted access creel effort, because these were only conducted on weekends. Similarly, van Poorten and Brydle (2018) reported significant seasonal and day type effects on the proportion of boaters fishing in their models that related vehicle counts from traffic counters with angler effort at Kawkawa Lake in British Columbia. These effects were likely important because the proportion of trailers associated with boats that are fishing varies according to weekly and seasonal cycles, with more non-fishing recreational activity occurring during summer and on weekends. One of the most important shortcomings of using time-lapse boat trailer counts to predict fishing effort is the inability to differentiate the type of recreational activity being performed from trailers observed with digital cameras (Steffe et al. 2017). The improved prediction of fishing effort when including these variables in our analysis suggests that perhaps reasonable predictions of fishing effort could be made with time-lapse trailer counts without being able to identify fishing boat trailers. We speculate that effort predictions could be improved further if fishing boat trailers could be identified on time-lapse photos; however, this is often unfeasible due to substantial overlap in trailer style among different types of boats.

Time-of-day and reservoir effects were not significant covariates for predicting angler effort from time-lapse trailer counts in our analysis. The absence of reservoir effects may allow for generalizations to other systems, if our findings hold up to additional site-specific evaluations. The similarity of these relationships across reservoirs suggests that the proportion of trailers at boat ramps associated with fishing boats and the proportion of anglers accessing the reservoirs via public boat ramps are similar across these reservoirs. Additional research will be needed to better understand the generality of these findings across a wider set of reservoirs.

Weak reservoir effects in these relationships may have been related to the fact that we were able to place cameras at all paved public boat ramps at each reservoir. This approach may have minimized additive reservoir effects by essentially capturing most of the trailer effort at each reservoir, and thus presented a best-case scenario for the performance of trailer counts as an index of fishing effort. Extending this approach to larger reservoirs, with many public and private boat ramps, will require sampling from the pool of available ramps for camera placement. It is anticipated that without complete coverage of all ramps on the water body, variance in the effort estimates would increase. Overflow parking is another complication, and trailers in these areas were only partially sampled at each ramp in the study. This would present a problem during large fishing tournaments or holidays, when parking extends down entry roads or parking occurs in nontraditional locations. If trailers are unable to be enumerated during high-flow events, cameras would underestimate effort on these days. Therefore, a great deal of planning should be used for the number of cameras and their locations when designing coverage from digital cameras frame of view.

Trailer counts from time-lapse cameras serve as an index of fishing effort rather than a census; therefore, they must be trained to estimate total angler effort. The inclusion of an intercept creel survey method allows for validation in estimating angler effort (van Poorten et al. 2015; Hartill et al. 2016; Taylor et al. 2018) and was essential in our study to calibrate camera-based trailer counts. Our simulation revealed that conducting a roving creel survey four times per reservoir per 28-d period over a 1-year training period was sufficient to maintain CVs of less than 30% in a quarterly hybrid effort estimator that use time-lapse cameras. This amount of effort is substantial, but we speculate that the frequency of roving creels could be reduced if the training period were extended beyond 1 year. Including an intercept creel survey method additionally provides information about harvest, species targeting, and catch rate, which offers value to fisheries managers and stock assessment scientists that is unobtainable from camera surveys alone. With the large temporal coverage from the time-lapse digital cameras, it is expected that accuracy will be higher due to the larger sampling size (Steffe et al. 2008).

Management Implications

Estimating recreational fishing effort at large reservoirs requires the commitment of substantial personnel time and funding for fisheries management agencies. The utilization of a time-lapse trailer count effort index into creel surveys may reduce uncertainty in effort estimates by supplementing traditional angler intercept methods, such as roving creels. However, surveys that incorporate trailer count indices will need to be carefully designed to ensure that the index is properly calibrated to observations of lake-wide fishing effort. This can be accomplished by running camera counts concurrently with traditional angler intercept methods, but a substantial number of paired observations may be needed for adequate calibration. We demonstrated such an approach in a system of three Alabama reservoirs, but more research will likely be needed on a wider range of systems to evaluate the utility of the approach more generally.

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