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Estimating the number of recreational anglers for a given waterbody

Kevin L. Pope[a,*], Larkin A. Powell[b], Brian S. Harmon[c], Mark A. Pegg[b], Christopher J. Chizinski[b]

[a] U.S. Geological Survey–Nebraska Cooperative Fish and Wildlife Research Unit, School of Natural Resources, University of Nebraska, Lincoln, NE 68583, USA
[b] School of Natural Resources, University of Nebraska, Lincoln, NE 68583, USA
[c] Nebraska Cooperative Fish and Wildlife Research Unit, School of Natural Resources, University of Nebraska, Lincoln, NE 68583, USA

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ABSTRACT

Knowing how many anglers use a given body of water is paramount for understanding components of a fishery related to angling pressure and harvest, yet no study has attempted to provide an estimate of the population size of anglers for a given waterbody. Here, we use information from creel surveys in a removal-sampling framework to estimate total numbers of anglers using six reservoirs in Nebraska, USA, and we examine the influence of the duration of sampling period on those estimates. Population estimates (N ± SE) of unique anglers were 2050 ± 45 for Branched Oak Lake, 1992 ± 29 for Calamus Reservoir, 929 ± 10 for Harlan County Reservoir, 985 ± 24 for Lake McConaughy, 1277 ± 24 for Merritt Reservoir, and 916 ± 18 for Pawnee Lake during April–October 2015. Shortening the sampling period by one or more months generally resulted in a greater effect on estimates of precision than on estimates of overall abundance. No relationship existed between abundances of unique anglers and angling pressures across reservoirs and sampling duration, indicative of a decoupling of angler abundance and angling pressure. The approach outlined herein has potential to provide defendable answers to "how many are there?", questions we ask when subjects cannot be marked, which should provide new insights about angler populations and subpopulations.

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1. Introduction

"How many are there?" is an age-old sociological question as well as an age-old ecological question. The need to know population size has spawned numerous analytical techniques that have been used over two centuries to estimate the size of populations as diverse as the 1802 human population of France (Cochran, 1978), the number of illicit drug users in Los Angeles County, California, USA (Hser, 1993), and the number of invasive Chinese mystery snail (*Bellamya chinensis*) in Wild Plum Lake, Nebraska, USA (Chaine et al., 2012). The volume of literature pertaining to this question is immense. Even so, abundance estimation remains an active area of research, particularly because estimating the abundance or density of people within geographic boundaries or animals in wild populations is not a trivial matter. Virtually all techniques for estimation of abundance involve the basic problem of estimating the size of the population from a sample, or subset, of encountered individuals. Many methods have been developed to estimate the probability of detection associated with various kinds of survey count statistics (Powell and Gale, 2015). Techniques include multiple observers (Manly et al., 1996; Nichols et al., 2000), removal methods (Moran, 1951 Zippin, 1958), capture-recapture (Amstrup et al., 2010; Bailey et al., 2004; Nichols, 1992) and repeated counts (Dail and Madsen, 2011; Dodd and Dorazio, 2004; Royle, 2004; Royle et al., 2007).

Recreational fishing (the attempt to capture aquatic animals—mainly fish—that do not constitute the angler's primary resource to meet basic nutritional needs and are not generally sold or otherwise traded on export, domestic or black markets [FAO, 2012]), is a multi-billion-dollar industry (Cowx, 2002). During 2011, 33.1 million U.S. residents 16 years old and older participated in recreational fishing (USFWS and USCB, 2011). Understanding fishing pressure and angler composition at the region or waterbody level is important if fishery managers are to serve and satisfy their constituents. Gaining such understanding is complicated because anglers seek different kinds of experiences (Hunt, 2005), which results in potential differences in their spatial and temporal distributions and hence susceptibility to being counted—all of this makes it difficult to estimate the number of anglers for a given waterbody.

* Corresponding author at: 424 Hardin Hall, Lincoln, NE 68583-0984, USA.
E-mail address: kpope2@unl.edu (K.L. Pope).

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Fishing pressure is important, yet so is fidelity (or frequency of participation). For example, there were 705,236 ± 32,765 h of recreational angling from shore along 250 km of the south and south-west coast of Portugal during August 2006-July 2007, which corresponded to 166,430 ± 9792 trips (Veiga et al., 2010). Even so, it is unknown whether 166,430 unique anglers each fished one day along this coastal stretch during that year, 457 unique anglers each fished every day along this coastal stretch during that year, or likely some combination therein. The implications as to which scenario accurately represents angler behavior have far-reaching effects from a fishery-management perspective in terms of allocating financial, human, and other resources. For example, there might be a priority placed on providing supporting amenities (e.g., shoreline fishing access and ablution facilities) to facilitate a large number of anglers at any one point in time if the former scenario were representative of angler abundance. So the question becomes – how do we estimate angler abundance to ensure sound management of a given system?

One feasible approach to estimate abundance of anglers is to use existing techniques with which managers and policy makers are relatively familiar. We often estimate the number of fish in a waterbody using direct observation, mark-recapture, and removal methods (Hayes et al., 2007). For example, Hankin and Reeves (1988) used direct observation of juvenile Coho salmon (*Oncorhynchus kisutch*) by divers to estimate that there were 4106 ± 886 (95% confidence interval) fish in the pools and riffles of the lower 9.6 km of Cummins Creek, Oregon during 1985. Steffensen et al. (2012) used mark and recapture to estimate annual density of wild pallid sturgeon (*Scaphirhynchus albus*) in an 80.5-rkm of the lower Missouri River varied from 5 to 9 fish/rkm during 2008–2010, while the annual density of hatchery-reared fish varied from 29 to 32 fish/rkm. Milewski and Willis (1989) used removal to estimate that there were 38 ± 13 (90% confidence interval) brown trout (*Salmo trutta*) in a 90-m stretch of Gary Creek, South Dakota during 1988. The same techniques used to estimate the number of fish in a waterbody could potentially be used to estimate the number of anglers fishing that same waterbody. Although people in many countries are provided unique identification numbers (e.g., social security number in the USA, social insurance number in Canada, and personal identity number in Sweden), we cannot typically mark or tag an angler. Thus, the techniques used for estimation of anglers are constrained. However, we do 'capture' anglers in an unmarked fashion by conducting creel surveys. Therefore, we propose that removal methods can be used on anglers, just like removal methods can be used on captured fish that do not receive individual marks.

Biologically, we believe that effort-based estimates are the appropriate measure, especially when considering the influence of recreational activities on the fishery resource. Politically, we believe that population estimates are the appropriate measure, especially when considering needs for educational programs or preparing for potentially contentious management actions. Generally, participation estimates at recreational sites or waterbodies are effort-based, such as the number of angler-trips or number of visitor-days. To that end, our goal was to estimate the number of recreational anglers for a reservoir with a simple, non-intrusive process of removal (via a capture-recapture approach) during on-site, in-person interviews that were part of routine (i.e., standard monitoring procedures for management agencies of recreational fisheries) creel surveys. To our knowledge, this is the first reported attempt to estimate the number of recreational participants on this scale—that is, attempt to estimate the population size of unique anglers for a given waterbody and compare estimates of overall abundance to angling effort.

2. Material and methods

We estimated the population sizes of anglers and angling effort during April-October 2015 for six reservoirs located throughout Nebraska, USA (Table 1). Clerks used automobiles to move (rove with the intent of gathering a representative sample proportional to use) among parking areas around the reservoirs, and moved on foot along the shore and in parking lots to contact angler parties. Thus, we interviewed boat anglers at boat ramps (generally completed fishing for the day) and bank anglers at parking areas (generally completed fishing) or on the shoreline (active in fishing) to estimate the reservoir-specific population size of unique anglers. Anglers that fished multiples of these reservoirs were included in the respective multiple population estimates. We used a stratified multi-stage probability-sampling regime (Malvestuto, 1996) to determine days of interviews. We had a target of 16 or 18 interview days each month, stratified into 10 week-days, 6 weekend-days, and 2 holiday-days (holidays occurred during May, July, and September). Each interview day was further stratified into morning (sunrise to 1330) and afternoon (1330 to sunset) periods.

A clerk contacted an angler party (i.e., a group of individuals travelling together for fishing) onsite at the reservoir and interviewed one individual that was designated the party-appointed spokesperson. The spokesperson was asked, "Have you been interviewed at this waterbody, [*reservoir name*], this year?" A binary (i.e., "yes" or "no") answer was recorded, and that answer was replicated by the number of individuals within that party. We summed within each month for each reservoir the number of responses in which anglers stated that they had not been interviewed at that reservoir during the current year. We modeled our datasets as mark-removal studies in closed systems and analyzed our reservoir-specific data with a full likelihood capture (p) and recapture (c) model in program MARK. We evaluated four capture-probability (given presence and not previously removed) schemes across months and selected the best model using an information-theoretic approach (Anderson, 2008) for each reservoir. The four schemes were (1) capture probability constant across months, (2) capture probability constant across months except for April, (3) capture probability constant across months except for April and May, and (4) capture probability different across all months. During preliminary analysis, we suspected that utilization of each reservoir by most anglers did not occur until either May or June, which is why we included Schemes 2 and 3. We set the probability of recapture (c) at 0, and treated the

Table 1
Characteristics of reservoirs.

Reservoir	Latitude (N)	Longitude (W)	Surface area (ha)	Number of access areas for: Boat anglers	Bank anglers
Branched Oak Lake	40.972539°	−96.863604°	728	4	16
Calamus Reservoir	41.847826°	−99.220834°	2075	5	10
Harlan County Reservoir	40.057313°	−99.272493°	5463	3	9
Lake McConaughy	41.248224°	−101.683402°	12,141	14	21
Merritt Reservoir	42.627675°	−100.871769°	1176	5	19
Pawnee Lake	40.842609°	−96.869964°	299	2	10

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