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SPECIAL SECTION: BACK TO THE FUTURE OF RESERVOIR FISHERIES MANAGEMENT–WHAT HAVE WE LEARNED IN 50 YEARS?

Valuing Angling on Reservoirs Using Benefit Transfer

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Abstract
Economic assessments are rarely applied to inland recreational fisheries for management purposes, especially when compared to fish, habitat, and creel assessments, yet economic assessments can provide critical information for management decisions. We provide a brief overview of economic value, key terminology, and existing economic techniques to address these issues. Benefit transfer, a technique used to measure economic value when an original analysis is not practicable, is conducted by drawing on existing estimates of economic value in similar contexts. We describe an application of benefit transfer to measure the economic value of several recreational fisheries in Nebraska, USA. We examine two approaches to benefit transfer—value transfer and function transfer—which we demonstrate estimate similar economic values for fishing site access but substantially different economic values for catch rate improvements at some reservoirs. We encourage agencies that are responsible for inland recreational fisheries management to consider economic assessment, especially benefit transfer, as a critical tool in the management toolbox.

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"Money talks" is a statement that is often used to describe how money and economic values influence human behavior and decisions. Despite this universally accepted sentiment, economic assessments are rarely applied to inland recreational fisheries management in North America (but see Peirson et al. [2001], Wedekind et al. [2001], and Arlinghaus and Mehner [2003] for European assessments and Bell et al. [1983], Bell [1997], and Lew and Larson [2012] for saltwater assessments) compared to fish, habitat, and creel assessments. One example in which "money could talk" in recreational fisheries management pertains to decisions regarding aging dams and reservoirs (Hansen et al. 2020). Should agencies repair failing infrastructure or decommission dams? How would either scenario affect the economic value of existing recreational fisheries? An economic assessment could provide critical information to assist with this decision. Other examples include understanding the economic value of a specific fishery (e.g., Striped Bass *Morone saxatilis* and hybrid Striped Bass [Striped Bass × White Bass *M. chrysops*]; Whitehead 2013), the economic consequences of low water levels (Ward et al. 1996) or harmful algal blooms (Holland and Leonard 2020), and the effect of new size or length regulations on fishing trip expenditures (Lew and Seung 2010). These assessments can be particularly useful or even required in political or legislative settings (Pawson et al. 2008).

Underutilization of economic assessments in inland recreational fisheries could be related to a lack of awareness or expertise regarding economic valuation methods by fishery scientists, a lack of necessary data, or institutional limitations. To overcome cross-disciplinary challenges between economists and fisheries managers, we provide a brief overview of economic value, key terminology, and existing economic techniques to address these issues. Economic value is the trade-off that a person or group is willing to make to obtain a good or service (Rosenberger and Loomis 2017). It is therefore a relative measure in which the value of one good or service is denominated in terms of another (e.g., the monetary value of a 1-d fishing trip). Economic value is closely related to the concept of willingness to pay (WTP), which is the maximum amount that a person is willing to pay for a good or service given their income. Economic value and WTP are identical when value is expressed in units of money, but they are not equivalent to what one actually pays in terms of price. Price does, however, play a key role in determining two economic measures that decision makers often care about: expenditure value and surplus value. Expenditure value is the amount spent on a good or service, which in turn contributes to the incomes of workers and businesses. Surplus value is what is left over when one subtracts expenditure value from economic value. Surplus value is a key measure in evaluating the social consequences of a policy; in this paper, we focus on measuring the "consumer surplus" value of anglers. Economists may also refer to surplus value as "net economic benefit" or simply "economic benefit." Although value and benefit are imperfect synonyms, for the remainder of the paper when we refer to any economic measure (value, WTP, or benefit), we generally mean anglers' consumer surplus. See Appendix Table A.1.1 for definitions of terms.

Economists have developed several techniques to measure the economic value of environmental goods and services, and recreational fisheries in particular. These techniques are grounded in consumer demand theory (Whitehead 2013), which says that there is an inverse relationship between price and the quantity demanded of a good or service. This relationship helps to identify the economic value of a good, such as a recreational fishing trip. These techniques can also be used to measure the economic value of goods and services that do not require onsite or active consumption, known as nonuse or passive use values. Passive use values are generated by motives such as altruism and bequests to future generations.

Economic valuation techniques come in three varieties based on the source of data used: revealed preference methods, stated preference methods, and benefit transfer. Revealed preference methods use data on actual consumption behavior to estimate demand functions and economic value. Stated preference methods use data from hypothetical questions or scenarios to estimate economic value. Benefit transfer incorporates previously collected data sources from other management scopes (i.e., study site), revealed or stated, and transfers them to the scope of interest (i.e., policy site). Essentially, benefit transfer estimates the economic value of an activity or project at one site by using existing estimates of economic value from other sites (Brookshire and Neill 1992; Wilson and Hoehn 2006; Johnston et al. 2015, 2018).

Economic value can be measured indirectly using the travel cost method (TCM) or directly using the contingent valuation method (CVM). The TCM models the number of recreation trips as a function of travel costs and other relevant site characteristics to measure the economic value of a recreation site or site characteristics (Hotelling 1949; Clawson 1959). The first application of the TCM to reservoir recreation was published over 50 years ago (Burt and Brewer 1971) and estimated the demand for recreation on lakes, reservoirs, and streams in Missouri and Arkansas. That work is notable because it was the first application that used individual data and incorporated substitute prices. Subsequently, researchers developed methods to account for the influence of site characteristics (in addition to travel cost) in trip demand (Vaughan and Russell 1982). The CVM estimates economic value directly by asking about survey respondents' WTP for a good for which access hypothetically depends on agreeing to the payment.

The first CVM study was conducted to estimate the value of recreation in the Maine woods (Davis 1963), and Cameron and James (1987) reported one of the first applications of the CVM for estimating the value of recreational fishing trips and catch. Revealed and stated preference methods both generally rely on surveys to collect data about individual behaviors. These surveys require time and money, which are not always available to researchers.

Despite having many attractive features, benefit transfer has received less attention than revealed preference or stated preference methods in inland recreational fisheries. First, by drawing on existing data, it is often substantially less costly to perform than traditional economic assessments, which typically involve analyzing primary data collected by the investigator, such as through a survey (Rosenberger and Loomis 2003, 2017). This makes the benefit transfer method ideal for analysts and agencies with limited funding (Richardson et al. 2015). Second, because benefit transfer is generally a mathematical rather than statistical exercise, it is computationally more straightforward to implement than traditional economic assessments, which can increase the transparency of the analysis. Third, benefit transfer provides a method by which analysts and agencies can garner new information from past economic assessments. Though estimates may be precise, information about economic value in traditional economic assessments is often constrained by geography, time, and angler types, which can limit their usefulness in decision making (Shrestha and Loomis 2001). When resources are limited and analogous data exist, benefit transfer can be a useful and effective valuation methodology (Allen and Loomis 2008).

There are several types of benefit transfer (Dumas et al. 2005). The most primitive is known as value transfer, which applies an economic value statistic (such as mean WTP) from a study site (i.e., the original research concept) to a policy site (i.e., the context in which one needs information). One of the more widespread uses of benefit transfer is to value an outdoor recreation day. Walsh et al. (1992) provided an early summary of economic values for outdoor recreation suitable for value transfer. This value estimate database has been maintained and updated by the U.S. Forest Service, and as of 2017 the database reported 120 freshwater fishing valuation studies with 913 different value estimates (Rosenberger et al. 2017). The mean estimate is US$82 per day (inflated to 2021 dollars), with a range of $6 to $525. To estimate the aggregate use value of a reservoir, a basic value could be obtained via value transfer by multiplying the number of days of fishing by $82.

Function transfer is an alternative to value transfer that uses the model from a study site to estimate economic value at a policy site. This model might include socioeconomic characteristics and recreation attributes as explanatory variables. One then inserts values for these variables based on the policy context to estimate the economic value of the policy. In general, economists prefer function transfer to value transfer because the former tailors the estimates to conditions at the policy site. However, both methods can return similar values when care is taken to match study and policy contexts in value transfer. Accuracy can be tested by comparing the transferred values with estimates from revealed or stated preference analysis. Loomis et al. (1995) tested the transferability of recreation demand models across reservoirs in Arkansas, California, and Tennessee and Kentucky combined. Although statistical differences in the three demand models were found in pairwise comparisons, estimates of consumer surplus per trip were only slightly different (Loomis et al. 1995). In general, transfer errors across all forms of benefit transfer are expected to decrease as the rigor of the benefit transfer method increases and as the similarity between study and policy contexts increases (Rosenberger and Stanley 2006).

Another form of benefit transfer uses statistical meta-analysis, which involves collecting many valuation studies and then regressing economic value against a set of explanatory variables describing the characteristics of the study sites as well as the studies themselves. For example, Mazzotta et al. (2015) conducted a freshwater fishing meta-analysis to use in a West Virginia surface coal mining policy context. They included 108 estimates of WTP per fish (caught) from 19 studies. Eleven of the studies used stated preference methods, and the remainder used the site choice version of the TCM. Their model estimated the economic value of an additional black bass *Micropterus* sp. caught per trip as ranging from $24 to $29 (inflated to 2021 dollars).

Our goal is to demonstrate how benefit transfer can be used to inform decisions that are often faced by North American inland fisheries managers. We describe specific steps and illustrate the utility of this technique by using a case study from recreational fisheries in Nebraska, USA. Our approach draws on a mix of original studies and creel data; creel surveys are common practice among fishery management agencies and can be used to support economic assessments. We focus our attention on employing and comparing the value transfer and function transfer approaches across three fisheries management scenarios. These approaches were used to estimate economic loss from decreasing angler access (or the benefit of maintaining access) and to estimate the benefit of increasing catch rates at reservoirs. In the context of our case study approach, we conclude by discussing how our demonstration of value transfer and function transfer is useful within reservoir fishery management, overall limitations of benefit transfer, and opportunities for reservoir fisheries managers in developing cooperative and forward-thinking economic data collection to inform methods like benefit transfer, ultimately providing substantial cross-boundary benefits for effective management. Hopefully, this will encourage agencies that are responsible for inland recreational fisheries management to consider economic valuation as a critical tool in the management toolbox and to place it alongside standardized fish, habitat, and creel assessments.

CASE STUDY

Study areas.— Our case study is primarily centered on four Nebraska reservoirs: Gracie Creek Reservoir, Merritt Reservoir, Lake Wanahoo, and Lake McConaughy. We also included 10 secondary Nebraska reservoirs as part of a broader assessment (see Kaemingk et al. 2018, 2019 and Kane et al. 2020 for general descriptions of reservoirs in Nebraska). We deliberately chose these reservoirs to reflect the diversity of fishing locations in the state. Gracie Creek Reservoir is a pond with low catch rates that receives few visits compared with larger reservoirs. Merritt Reservoir and Lake Wanahoo are mid-sized reservoirs with high catch rates, but accessing Merritt Reservoir is relatively difficult because it is located far from population centers. Lake McConaughy is one of the largest and most popular reservoirs for fishing in Nebraska. Mean driving distance and size and catch rates for various species from creel surveys for the four primary reservoirs (Table 1) were key variables used in our application of function transfer.

Policy context.— The first step in benefit transfer is to define the policy context (Rosenberger and Loomis 2003), which in our case refers to the aforementioned Nebraska recreational fisheries. To assess the economic value of these Nebraska reservoirs and the economic value of higher catch rates, we examined three policy scenarios: (1) closing each reservoir, which is a loss from an angler's perspective, to measure the economic value of keeping each reservoir open; (2) a 50% increase in Largemouth Bass *Micropterus salmoides* catch rates to measure the economic value of more Largemouth Bass at each reservoir; and (3) a 50% increase in Walleye *Sander vitreus* catch rates to measure the economic value of more Walleye. Largemouth Bass and Walleye are popular sport fish in the region (Hurley and Duppong-Hurley 2005). After estimating the economic value of these policies at the four individual reservoirs separately, we estimated the economic value when the policies were applied to all four reservoirs simultaneously and then to all four focal reservoirs plus the 10 additional reservoirs. We selected these scenarios because they demonstrate how potential management actions (e.g., stocking of fish and removal of dams) at local and landscape scales influence the economic value of recreational fisheries. Reservoir closures could become more frequent due to emergency drawdowns to repair aging infrastructure (Hansen et al. 2020) and harmful algal blooms (Chapra et al. 2017). Inland reservoir management plan objectives often aim to increase catch rates or other catch-related metrics. Although large swings in catch rates or reservoir closures may seem unlikely to some managers, using extreme scenarios is a common practice for economists to gather data on peoples' values.

Reservoir and lake valuation literature.— The second step in benefit transfer is to review the literature for studies with potentially relevant information. Finding a study site that shared the conditions of the policy site is crucial to minimizing transfer error. For example, the value of trout fishing at a river trip might differ substantially from the value of black bass fishing at a lake (Whitehead and Aiken 2007). To identify studies on reservoir and lake fishing values, we examined several existing literature reviews (Wilson and Carpenter 1999; Grantham and Rudd 2015; Hunt et al. 2019), searched scholarly databases, and queried the listserv of the Association of Environmental and Resource Economists (https://www.aere.org/resecon). We do not claim to have conducted an exhaustive, systematic search, but to our knowledge this is the largest bibliography of reservoir and lake economic valuation studies yet assembled (see Appendix A.2).

The bibliography contains 77 entries, with 58 articles published in peer-reviewed journals or books and 19 articles in the gray literature (e.g., unpublished government reports, dissertations, books, and working papers). We

TABLE 1. Nebraska reservoirs and policy site variables used in function transfer for recreational fishing.

Reservoir	Travel cost (mean $US per trip)	Largemouth Bass catch rate (fish/h)	Walleye catch rate (fish/h)	Crappie *Pomoxis* spp. catch rate (fish/h)	Surface area (ha)
Gracie Creek	168	0.000	0.001	0.000	1
Merritt	256	0.041	0.335	0.070	1,176
Wanahoo	115	0.396	0.021	0.829	258
McConaughy	235	0.006	0.342	0.000	12,141

reviewed each of the 58 journal articles and categorized them according to their main valuation purpose. The largest category of studies ($n = 30$) estimated the value of a recreational fishing day or trip. Nine studies valued water quality at reservoirs and lakes, and six studies valued changes in water levels. Five studies focused on estimating fishing trip expenditures and the economic impacts of management activities at reservoirs. The remaining eight studies valued catch rates for specific species and were the studies that we used in our benefit transfer effort.

We identified eight studies as potentially suitable for benefit transfer (Table 2). The literature is recent, with the earliest study published in 1999 and five of the eight studies published in the past 5 years. Two of the studies examined anglers from Ontario, and the rest focused on U.S. anglers; two studies examined Great Lakes anglers (one study of Ontario anglers and one study of Michigan anglers). All studies used mail surveys to contact anglers; one study also used telephones, whereas another used both telephones and the Internet. Four of the studies used revealed preference methods, three used stated preference methods, and one used both. Six studies had sample sizes from 300 to 800, and the other two studies had sample sizes greater than 2,000.

Four studies valued single-species fisheries for Paddlefish *Polyodon spathula*, Walleye, Channel Catfish *Ictalurus punctatus*, and Largemouth Bass. Four studies valued multi-species fisheries for two to four species (Table 2). Three studies valued black bass and catfish catch; two studies valued Walleye, salmon, trout, and sunfish catch; one study valued crappie catch; and one study valued Paddlefish catch. The unit values (Table 2) were taken from tables in each article. We report the range from the minimum to the maximum value presented by the authors. The values are inflated to 2021 dollars using the consumer price index, with the year in which the data were collected from each study as the base year. The benefit estimates from the two Canadian studies are converted to U.S. dollars using the yearly average foreign exchange rate at the time of the study.

Scenarios that were used to develop each estimate were not consistent across the studies, so the value estimates

TABLE 2. Nonmarket valuation studies for recreational angling on reservoirs. See the notes for descriptions of the valuation scenarios provided by the authors of each article.

Reference	Study area	Survey mode	Data type	Sample size	Fish species	Range of value (2021 US$)
Cha and Melstrom (2018)	Oklahoma lakes and rivers	Mail	Actual, hypothetical	539	Paddlefish	\$12–17[a]
Hunt et al. (2007)	Ontario lakes and rivers	Telephone and mail	Actual	347	Walleye	<\$1–2[b]
Hunt et al. (2021)	Ontario Great Lakes	Mail	Hypothetical	2,090	Black bass, Walleye, salmon, trout	\$4–54[c]
Hutt et al. (2013)	Texas reservoirs and rivers	Mail	Hypothetical	462	Catfish	\$30–75[d]
Jones and Lupi (1999)	Great Lakes	Mail	Actual	2,873	Salmon, trout	<\$1–2[e]
Melstrom et al. (2017)	Oklahoma reservoirs	Mail, telephone, or internet	Actual	536	Black bass	\$2–9[f]
Melstrom and Kaefer (2020)	Oklahoma lakes	Mail	Hypothetical	479	Catfish, sunfish	<\$1–5[g]
Melstrom and Welniak (2020)	Oklahoma reservoirs	Mail	Actual	791	Catfish, crappie, sunfish, black bass	<\$1[h]

[a] Willingness to pay (WTP) to increase daily catch by three fish statewide (2015 dollars); $n = 3$ WTP estimates; Canadian dollars converted to U.S. dollars according to the yearly average exchange rate at ofx.com.

[b] Value of avoiding a 50% decline in Walleye catch rates per trip (2004 dollars); $n = 8$ estimates; Canadian dollars converted to U.S. dollars according to the yearly average exchange rate at ofx.com.

[c] Median per-trip value of a one-fish increase for active anglers (2017 dollars); $n = 15$ estimates for active anglers; another $n = 15$ for inactive anglers.

[d] WTP for double harvest of same-sized fish (2011 dollars); $n = 5$ over several types of anglers; $n = 25$ over various angler and catch scenarios.

[e] Mean per-trip welfare measures (1984 dollars); $n = 6$ catch rate × lake combinations; $n = 36$ total WTP estimates.

[f] WTP for a 50% increase (2014 dollars); $n = 6$ WTP estimates varying by lake scenario.

[g] WTP for a one-fish increase (2016 dollars); $n = 8$ estimates.

[h] WTP for a 50% increase in black bass catch rates (2016 dollars); $n = 2$; also presents (1) WTP to avoid a 50% decrease in black bass catch rates at all sites and (2) WTP to avoid a decrease of one fish per trip ("\$21.86 for catfish, \$10.58 for crappie, \$7.51 for sunfish, \$26.38 for White Bass, and \$19.39 for black bass" from Melstrom and Welniak [2020]).

should not be compared across studies—for example, ranking economic values of water bodies or fish species (Table 2; scenarios are reported in the table notes). We only report the values to illustrate the range of values reported in the literature, which ranged from less than \$1 to \$75 across the eight studies. At the low end of the range is the value for a 50% change in catch or a one-fish increase per trip, and the higher values are associated with greater catch increments (e.g., an increase in the daily catch of three fish and a doubling of current harvest).

The eight studies assembled here (Table 2) were not enough to support a formal meta-analysis. In comparison, Johnston et al. (2006) conducted a meta-analysis using 391 WTP estimates from 48 studies. The studies we summarize reported 133 valuation estimates, which is enough for regression analysis but the redundancy in target species and the small spatial scales of the published studies make this data set insufficient to support a meta-analysis. Therefore, we estimated economic value using the value transfer and function transfer approaches.

Value transfer.— The value transfer approach was applied to the data set in this study using the steps described by Rosenberger and Loomis (2003). After screening the relevant studies for estimates of economic value, the next step in value transfer is to adjust an estimate into units relevant to the policy context and multiply it by the number of affected units at the policy site. In our application to reservoir fishing in Nebraska, the relevant unit was a fishing trip, with the total number of fishing trips to the policy site being $trips_{\mathrm{PS}}$. Let $\mathrm{WTP}_{\mathrm{SS}}$ refer to the economic value estimate from the study site. We then estimated the annual economic benefit of the policy using the formula

$$\mathrm{WTP}_{\mathrm{PS}} = trips_{\mathrm{PS}} \times \phi_{\mathrm{PS}} \times \mathrm{WTP}_{\mathrm{SS}}, \tag{1}$$

where ϕ_{PS} is the fraction of trips affected by the policy. We calculated the number of trips using data from annual creel surveys, which recorded fishing effort in hours. In estimating the value of a reservoir, we fixed ϕ_{PS} equal to 1 (because closing or opening a reservoir would affect every trip to it). From our literature review (Table 2), we selected a $\mathrm{WTP}_{\mathrm{SS}}$ of \$53 based on the midpoint of the range in Hutt et al. (2013), who reported per-trip values of \$30–76 for anglers targeting catfish at Texas reservoirs. Although most Nebraska anglers do not target catfish, the estimate from Hutt et al. (2013) approximates other conditions at our policy sites, including reservoir fishing and locations in the central USA. To estimate the benefit of catching 50% more Largemouth Bass, we used a $\mathrm{WTP}_{\mathrm{SS}}$ of \$1.92 per trip based on Melstrom et al. (2017). To estimate the benefit of 50% more Walleye, we used a $\mathrm{WTP}_{\mathrm{SS}}$ of \$1.24 per trip based on Melstrom and Jayasekera (2017). Because the values from these study sites are denominated per trip regardless of species preference, rather than per trip targeting black bass or Walleye, we continued to use ϕ_{PS} equal to 1.[1] We then constructed 95% confidence intervals using the upper and lower bounds of the confidence intervals from the above studies, if they were available (confidence intervals supporting the estimates in the closure scenarios were not available from Hutt et al. 2013).

Function transfer.— When conducting function transfer, the steps after screening the literature include selecting a demand function provided by a study, gathering data on the policy site that are relevant to the variables in the demand function, and finally using the demand variables and parameters to estimate economic value. The information in these variables and parameters allows the analyst to control differences between the study and policy sites, thus increasing the accuracy of function transfer.

We conducted function transfer using a site choice model and partial site aggregation. A site choice model describes the decision of an angler to fish at site j out of J possible sites. Partial site aggregation includes in J the individual policy sites of interest and distinct groups of substitute sites (Lupi and Feather 1998). With function transfer, the number of fishing trips ($trips_{\mathrm{PS}}$) depends on the conditions at the policy sites and anglers' own characteristics. These conditions include catch rates of Largemouth Bass, Walleye, and crappie (derived for the policy sites from creel surveys) and reservoir size. Angler characteristics include travel costs, which we estimated using information about travel distances between reservoirs and populated areas in Nebraska, and targeting preferences. Formally, we can say that anglers must travel from n out of N possible residential locations and will target fish f (for example, Largemouth Bass or Walleye) out of F possible species. We can then differentiate anglers based on the combination of their residential location and fishing preference (nf). On a given trip occasion, an angler nf visits the most desirable site j to them, which can be expressed as

$$U_{nfj} > U_{nfk} \forall j \neq k, \tag{2}$$

where U_{nfj} is a utility function that relates the angler's own value of the fishing trip to the characteristics of the angler and the fishing site. We used the following utility function for Nebraska fishing trips:

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[1] If the values from the study sites were denominated per trip specifically for bass or Walleye, then we would set ϕ_{PS} equal to the percentage of anglers targeting bass or Walleye, respectively. For example, in Nebraska about 35% of anglers target bass and 20% target any species, based on the 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation state report for Nebraska (USFWS and U.S. Census Bureau 2011); if we had an estimate for 50% more bass catch in terms of value per trip for bass, then we would use $\phi_{\mathrm{PS}} = 0.35 + 0.20 = 0.55$.

$$U_{nfj} = \beta_{tc} tc_{nj} + \beta^{f}_{lmb} lmb_j + \beta^{f}_{wae} wae_j + \beta^{f}_{crp} crp_j + \beta_{size} \ln\left(shore_j\right) + \ln\left(m_j\right) + \delta_j + \varepsilon_{nfj}, \quad (3)$$

where tc_{nj} is the travel cost to site j from residential location n; lmb_j is the Largemouth Bass catch rate at site j; wae_j is the Walleye catch rate; crp_j is the crappie catch rate; $\ln\left(shore_j\right)$ is the natural logarithm of shoreline distance; $\ln\left(m_j\right)$ is the natural logarithm of the number of sites in the grouped alternatives; δ_j is an alternative-specific constant for each policy site; and ε_{nfj} is an error component. The β parameters measure the importance of each site attribute to anglers. We assumed that the error component ε_{nfj} is an independent and identically distributed extreme value (Haab and McConnell 2002) so that the probability that angler nf chooses site j can be written as

$$prob_{nf}(j) = \frac{e^{V_{nfj}}}{\sum_{k=1}^{J} e^{V_{nfk}}}, \quad (4)$$

where $V_{nfj} = \beta_{tc} tc_{nj} + \beta^{f}_{lmb} lmb_j + \beta^{f}_{wae} wae_j + \beta^{f}_{crp} crp_j + \beta_{size} \ln\left(shore_j\right) + \ln\left(m_j\right) + \delta_j$. Equation (4) says that the attractiveness of a fishing site depends on the site attributes and the importance of these attributes to anglers. We then estimated the number of trips to the policy site using the formula

$$trips_{\mathrm{PS}} = \sum_{f=1}^{F} \sum_{n=1}^{N} prob_{nf}(\mathrm{PS}) \times trips_{nf}, \quad (5)$$

where $trips_{nf}$ is the number of trips taken by angler type f living in location n.

With a site choice model, the economic benefit of a policy is

$$\mathrm{WTP}_{nf} = \frac{\ln\left(\sum_{j=1}^{J} e^{V_{nfj}}\right) - \ln\left(\sum_{j=1}^{J} e^{V^{*}_{nfj}}\right)}{-\beta_{tc}}, \quad (6)$$

where V^{*}_{nfj} is the utility function with the policy in place. Equation (6) is the economic benefit per trip for angler nf. To measure the annual economic benefit of the policy, we summed across all trips and angler types:

$$\mathrm{WTP} = \sum_{f=1}^{F} \sum_{n=1}^{N} \mathrm{WTP}_{nf} \times trips_{nf}. \quad (7)$$

We used equation (7) to estimate the economic benefits of the same policy scenarios used for value transfer: closure of, increasing Largemouth Bass catch at, and increasing Walleye catch at Gracie Creek Reservoir, Merritt Reservoir, Lake Wanahoo, and Lake McConaughy individually; all four reservoirs simultaneously; and the same 4 reservoirs plus 10 additional reservoirs.

A site choice model is just one of several possible demand models that are suitable for function transfer. Although widely used to measure economic values in recreation demand contexts, a site choice model is limited in that it cannot estimate how policies can affect total effort in a system. Rather, it assumes that total effort is fixed and that any changes in effort at one site will redistribute to other sites; this can lead to upwardly biased benefit estimates. Changes in total effort are likely to scale with the scope of the policy, so this assumption may only be reasonable when the policy effect is small. Models that allow total effort to change with policies include the repeated nested logit, which includes “no fish” as a choice alternative; the linked participation–site choice model; and the Kuhn–Tucker model (Herriges et al. 1999).

Conducting function transfer with a site choice model requires information about the choice set and site conditions. The choice set in our application includes the 4 reservoirs described above, 10 additional reservoirs with creel data, and 404 other fishable reservoirs in Nebraska that we aggregated into six grouped alternatives based on geography (i.e., northeast reservoirs, south-central reservoirs, etc.). We therefore modeled the policy sites as individual reservoirs and all other reservoirs as aggregated choice alternatives. Bias due to site aggregation should be low because the individual sites (reservoirs) include the most popular reservoirs in the state (Lupi and Feather 1998). We calculated travel costs to each reservoir from the 300 most populated zip codes in Nebraska (which cover more than 90% of residents), assuming a per-kilometer driving cost of 17 cents (per-mile driving cost of 28 cents), an opportunity cost of travel time of \$8.08 per hour (half the value of the state average income divided by 2,000 working hours[2]), and a driving speed of 72 km/h (45 mi/h). We used creel surveys to calculate Largemouth Bass, Walleye, and crappie catch rates.[3]

We used information from our literature review (Table 2) to parameterize the site choice model. Based on Melstrom and Jayasekera (2017), we set the travel cost parameter to −0.019 and the shoreline length parameter to 0.985. Although Melstrom and Jayasekera (2017) measured the importance of black bass and Walleye fishing, the catch parameters in their model were based on electrofishing

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[2] Lupi et al. (2020) described research on the value of travel time. One-third of the hourly wage rate is most commonly used, but some studies have found that up to 100% of the wage is consistent with travel behavior. We use one-half of the hourly wage rate, as recommended in U.S. Department of Transportation (2016) guidelines.

[3] Due to a lack of creel data, catch rates at grouped alternatives are set to zero.

surveys that are unsuitable for our model, which relies on catch rates from creel surveys at the policy sites. We therefore used catch rate parameters from Melstrom and Lupi (2013), who estimated a site choice model of recreational fishing in Michigan using catch rates from creel data. We set β^{f}_{lmb} equal to 2.550 for anglers who target Largemouth Bass or all species, $\beta^{f}_{wae}=2.550$ for those who target Walleye or all species, and $\beta^{f}_{crp}=0.254$ for those who target crappie or all species; otherwise, for other anglers, we set these parameters to zero. We controlled for scale differences between the Melstrom and Jayasekera (2017) and Melstrom and Lupi (2013) parameters by multiplying the catch rate parameters by the ratio of the travel cost parameters (0.019/0.028). We constructed 95% confidence intervals using 1,000 draws of the parameters with means and SDs based on the study sites and assuming normality.

The final piece of information needed is $trips_{nf}$. Although we can estimate $trips_{nf}$ for the policy sites using creel data, we do not know $trips_{nf}$ at any of the potential substitute sites. This is potentially important because policies that improve fishing quality at one site can attract trips going to substitute sites. We therefore estimated $trips_{nf}$ using population-level statistics and data on fishing avidity. Let pop_n indicate the number of residents living in location n, and let σ indicate the share of the population that fishes. Furthermore, let $\hat{trip}$ indicate the average number of fishing trips in a year and let ϕ_f represent the share targeting f among those that fish. In our application, n is a zip code and f includes anglers targeting Largemouth Bass, Walleye, crappie, and any species. We estimated $trips_{nf}$ (using)

$$trips_{nf}=pop_n\times\sigma\times\hat{trip}\times\phi_f. \tag{8}$$

We used the American Community Survey 5-year estimates published in 2019 by the U.S. Census Bureau (https://www.census.gov/programs-surveys/acs) to determine pop_n. To reduce the computational burden of the transfer, we restricted n to the 300 most populated zip codes in Nebraska (which cover more than 90% of residents). We then used the 2011 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation state report for Nebraska (USFWS and U.S. Census Bureau 2011) to determine that σ is equal to 0.10 (10% of the population fished) and $\hat{trip}$ is equal to 11 (Nebraska angler average of 11 trips annually).[4] Based on the 2011 survey estimates of the percentage of Nebraska anglers targeting various species, we set ϕ_f equal to 0.25 for Largemouth Bass anglers, 0.30 for Walleye anglers, 0.15 for crappie anglers, and 0.20 for anglers targeting any species. Once we could predict trips to each site, we then parameterized the alternative-specific constants, δ_j, to guarantee that the predicted number of trips to each policy site equaled the trip estimate from the creel data.

RESULTS

Value Transfer

Estimates of the value transfer approach are provided in Table 3. The most popular reservoir of our subset was Lake McConaughy, and the least popular was Gracie Creek Reservoir. Based on the individual reservoir closure scenarios, the annual economic benefits of keeping each reservoir open were $36,997 for Gracie Creek Reservoir, $1,180,539 for Merritt Reservoir, $1,524,969 for Lake Wanahoo, and $2,632,963 for Lake McConaughy (all values reported hereafter are annual). The economic benefits of all four reservoirs combined were $5,375,467. Applying value transfer to the catch rate scenarios, the economic values of a 50% increase in Largemouth Bass catch rates at these four reservoirs varied from $737 to $52,461. Similarly, the economic values of a 50% increase in Walleye catch rates at these same reservoirs varied from $433 to $30,801. These economic values are an exact multiple of the number of trips to each reservoir; thus, value transfer always implied that the highest economic values were associated with Lake McConaughy, which was the most visited site based on creel data.

Function Transfer

Estimates of the function transfer results are provided in Table 4. By design, the effort estimates were identical to those from the creel data used in value transfer. Based on the effort estimates, the most and least popular reservoirs were Lake McConaughy and Gracie Creek Reservoir, respectively. As one would therefore expect, Lake McConaughy was the most valuable lake ($2,975,588), whereas Gracie Creek Reservoir was the least valuable lake ($36,737) among the individual reservoirs subjected to the closure scenarios. The economic values of a 50% increase in Largemouth Bass catch rates at a single reservoir varied from $0 to $36,967. The economic values of a 50% increase in Walleye catch rates varied from $1 to $46,865.

Using function transfer, the economic value of a reservoir appeared to be disproportionately related to its popularity. This pattern was seen by calculating the per-trip value of reservoirs in each closure scenario, which was the estimated economic value divided by the number of affected trips. The per-trip value of the least popular

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[4] These estimates of fishing effort could be biased upward due to recall and avidity bias in responses to the National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (USFWS and U.S. Census Bureau 2011). The effect of this bias on benefit estimates should be small in our application, though, because we used alternative-specific constants to match predicted trips with the number of trips estimated from creel data. The effect of the bias would certainly be much greater if we attempted to apply benefit transfer to one of the aggregated sites.

TABLE 3. Value transfer estimates (with 95% confidence intervals in parentheses) of changes in willingness to pay for simulated closures of individual and combined Nebraska fisheries and for simulated 50% increases in catch rates of Largemouth Bass and Walleye for individual and grouped fisheries.

Reservoir	Effort (trips)	Closure ($US)	50% more Largemouth Bass ($US)	50% more Walleye ($US)
Gracie Creek	698	36,997	737 (42–1,774)	433 (−2 to 1,188)
Merritt	22,274	1,180,539	23,522 (1,348–56,599)	13,810 (−72 to 379,06)
Wanahoo	28,773	1,524,969	30,384 (1,741–73,112)	17,839 (−93 to 48,965)
McConaughy	49,679	2,632,963	52,461 (3,006–126,233)	30,801 (−160 to 84,542)
All four lakes[a]	101,424	5,375,467	107,104 (6,136–257,718)	62,883 (−328 to 172,600)
All 4 lakes +10 more[b]	213,780	11,330,359	225,752 (12,934–543,216)	132,544 (−690 to 363,805)

[a] Grouped the following reservoirs: Gracie Creek Reservoir, Merritt Reservoir, Lake Wanahoo, and Lake McConaughy.

[b] Grouped the following reservoirs: Gracie Creek Reservoir, Merritt Reservoir, Lake Wanahoo, Lake McConaughy, Harlan County Reservoir, Calamus Reservoir, Southerland Reservoir, Sherman Reservoir, Branched Oak Lake, Pawnee Lake, Standing Bear Reservoir, Prairie Queen Reservoir, Halleck Reservoir, and Schwer Park Lake.

reservoir, Gracie Creek Reservoir, was $52.66, whereas the per-trip value of the most popular reservoir, Lake McConaughy, was $59.90. Furthermore, the per-trip value of the four reservoirs as a whole was $59.02. The economic losses from site closures tend to accrue at an increasing rate with the number of affected trips.

Comparing Value Transfer and Function Transfer

The WTP estimate for the closure scenario was $53 per trip using value transfer (Table 3) compared to $53–60 per trip using function transfer (Table 4). This resulted in lake-specific ratio differences that ranged from only 0.99 for Gracie Creek Reservoir to 1.13 for Lake McConaughy. In this scenario, the confidence intervals provided by the value transfer and function transfer methods overlapped and contained "central" estimates for each approach, providing evidence for similar estimates (did not statistically differ). For the catch rate scenario, the benefit of a 50% increase in Largemouth Bass catch rate at Merritt Reservoir was $23,522 using value transfer but only $2,214 using function transfer—a difference of 90%. The benefit of a 50% increase in Walleye catch rate at Lake Wanahoo was $17,839 using value transfer, but only $1,282 using function transfer—a difference of 92%. As such, most estimates did not differ (overlap of confidence intervals), whereas some estimates differed (no overlap of confidence intervals).

DISCUSSION

We provided guidance on valuing recreational fisheries and policy decisions using benefit transfer. Benefit transfer

TABLE 4. Function transfer estimates (with 95% confidence intervals in parentheses) of changes in willingness to pay for simulated closures of individual and combined Nebraska fisheries and for simulated 50% increases in catch rates of Largemouth Bass and Walleye for individual and grouped fisheries.

Reservoir	Effort (trips)	Closure ($US)	50% more Largemouth Bass ($US)	50% more Walleye ($US)
Gracie Creek	698 (438–957)	36,737 (21,203–52,271)	0 (0–0)	1 (0–1)
Merritt	22,274 (18,179–26,369)	1,259,443 (937,318–1,581,569)	2,214 (2,086–2,341)	20,571 (19,348–21,794)
Wanahoo	28,773 (23,751–33,795)	1,530,326 (1,315,758–1,744,894)	36,967 (17,986–55,947)	1,282 (665–1,900)
McConaughy	49,679 (35,806–63,552)	2,975,588 (2,002,029–3,949,147)	750 (576–925)	46,865 (35,689–58,041)
All four lakes[a]	101,423 (81,889–120,958)	5,986,261 (4,530,410–7,442,112)	39,928 (20,725–59,131)	68,649 (55,832–81,466)
All 4 lakes +10 more[b]	213,580 (177,763–249,396)	12,468,529 (9,843,197–15,093,861)	66,093 (34,239–97,947)	144,241 (80,980–207,502)

[a] Grouped the following reservoirs: Gracie Creek Reservoir, Merritt Reservoir, Lake Wanahoo, and Lake McConaughy.

[b] Grouped the following reservoirs: Gracie Creek Reservoir, Merritt Reservoir, Lake Wanahoo, Lake McConaughy, Harlan County Reservoir, Calamus Reservoir, Southerland Reservoir, Sherman Reservoir, Branched Oak Lake, Pawnee Lake, Standing Bear Reservoir, Prairie Queen Reservoir, Halleck Reservoir, and Schwer Park Lake.

is a powerful tool to inform policy decision making. It can be done rapidly relative to primary valuation studies because it does not require additional field data collection. Despite the efficiency of benefit transfer, the lack of published studies in North American inland fisheries indicates that the tool may be underused in practice. We hope that this paper has addressed potential cross-disciplinary issues, ultimately leading to greater use of benefit transfer in North American inland fisheries. We found that a more standardized approach in primary WTP study scenarios could make benefit transfer more practicable overall. Our literature review revealed a variety of methods that researchers have used to develop models, measure attributes, and report WTP in recreational fisheries. Some researchers reported WTP for catch rate improvements for all sites, whereas others reported this WTP in terms of just one site; some did not report WTP at all or they reported WTP in terms of kilometers (miles) driven rather than dollars. Based on our experience, estimates of economic value are most readily employed in benefit transfer to recreational fisheries when a study (1) reports WTP for a specific percentage increase in catch for a given species and location, (2) reports WTP for access to that location, (3) measures WTP in dollars per trip or per angler-day to the location in question, and (4) provides descriptive statistics (e.g., catch rates, size, and effort) about the location. We believe that there is a critical need for reporting economic research at study sites using approaches that are forward thinking and systematic, with the intention of facilitating wider use of benefit transfer.

In our case study, we applied benefit transfer to reservoir fishing in Nebraska and estimated the economic value of different policy scenarios. These scenarios—controlling effort and increasing catch rates—were selected because they represent novel strategies that have been suggested as potentially useful for overcoming challenging management issues, like catch rate hyperstability (Cahill et al. 2018; Feiner et al. 2020) or maintaining high satisfaction without impairing stock density (Camp et al. 2015; van Poorten and Camp 2019). As managers shift from reservoir-scale to landscape-scale approaches that recognize the heterogeneity inherent among angler preferences and reservoir dynamics, interdisciplinary approaches like benefit transfer can provide necessary tools for monitoring and evaluation. We provided estimates using a simpler approach (value transfer) and a more precise approach (function transfer) to demonstrate their effectiveness in evaluating novel management strategies and to show the importance of using appropriate study site data for the policy site being investigated, as the results of a benefit transfer depend entirely on the data inputs incorporated.

We demonstrated that both benefit transfer methods can yield comparable estimates of economic value when study site data are appropriately collected and match the characteristics of the policy site. For the reservoirs in the closure scenario, value transfer and function transfer produced effectively equivalent benefit estimates. By construction, the two methods have the same number of trips going to the policy sites, so any differences in WTP reflect differences in the estimates of per-trip value, which were relatively modest in our scenarios. For the catch rate scenarios, all of the function transfer estimates fell within the 95% confidence intervals of the value transfer estimates except Lake McConaughy Largemouth Bass, suggesting that the two sets of estimates are similar and do not differ due to the included parameters. Rather, differences appear to be due to conditions for which function transfer controls but value transfer does not. The situation at Lake McConaughy demonstrates this clearly. Largemouth Bass catch is low at Lake McConaughy—0.006 fish/h—so a 50% increase in Largemouth Bass catch rates is barely an improvement. Function transfer thus reasonably predicts that a 50% increase in Largemouth Bass catch rates at Lake McConaughy has a small economic value. Value transfer, in contrast, assumes that catch rates at Lake McConaughy are identical to those at the study site, where Largemouth Bass catch rates were high, resulting in a much larger economic value. This does not imply that value transfer is less reliable than function transfer in general, but it does imply that analysts should consider how closely the characteristics of a study site match those of the policy site before transferring values.

Anglers' WTP (and consumer surplus) is an important concept in describing angler behavior (e.g., participation, site choice, and involvement) within a fishery landscape, and inland fisheries managers can apply this concept to assist in making informed management decisions that are easily communicated to politicians, regulatory organizations, and the public (Johnston et al. 2010; Fenichel et al. 2013; Hunt et al. 2019). Anglers' behaviors will have direct and consequential effects on the travel costs that they are willing to incur, decisions for overnight or out-of-state trips, and the many other costs related to a fishing trip (Hunt et al. 2013). Further, angler behaviors also incorporate their perceptions of opportunities to achieve a successful outcome, as determined by their individual motivations (Beardmore et al. 2013). Anglers make decisions based on their fishing preferences, the accessibility of potential fishing sites, and the site characteristics that they expect to experience on a trip (Hunt et al. 2019). As we demonstrate here, benefit transfer can allow inland fisheries managers to understand these important aspects of angler behavior while working within budgetary constraints and competing priorities.

Little investment has been made in understanding how management decisions impact angling costs, but economic assessments provide an opportunity to better understand the impacts of management on angler behavioral changes.

In this paper, we demonstrated ways in which benefit transfer might be applied to investigate the effect of management decisions. We encourage both practitioners and researchers to consider these types of investigations within long-term plans to build capacity through systematic application of economic assessments that rely on primary valuation studies and complementary benefit transfer studies.

As the limitations of benefit transfer are based on the availability of appropriate primary valuation studies that are similar to study sites of interest, we encourage scientists and decision makers to consider developing a spatiotemporal sampling protocol within fisheries landscapes to overcome these limitations and ensure optimal use of resources over the long term. If inland fishery managing organizations consider each additional economic assessment as a long-term investment toward a broader data repository, benefit transfer will become more widely applicable and more accurate. For example, in Nebraska, it may be beneficial to establish economic values for fishing in two to three reservoirs in each size category (extra small, small, medium, and large; see Kaemingk et al. 2019) rather than establishing economic values for fishing in 8–12 reservoirs representing a single category (e.g., large). Doing so would allow more reliable estimation, via benefit transfer, of the economic values of fishing in all public reservoirs throughout Nebraska. Similarly, it may be beneficial to establish economic values for fishing in these reservoirs across multiple years rather than a single year to incorporate temporal variation in local and national economies.

One advantage of economic valuation is the ability to quantify benefits in equivalent units that are transferable between other units (i.e., time- and place-specific money). What we have referred to in this paper is based on an instrumental definition of value that limits the welfare benefits considered to those that directly benefit humans (Gómez-Baggethun et al. 2010). This approach gives weight in policy decision making to economic trade-offs that may not always be deemed appropriate in relation to ecosystem services or cultural implications (Baard 2019). Given current societal concerns for environmental justice (McClanahan et al. 2015), potential misrepresentation of the importance of ecosystem services via monetization (Chan et al. 2016; Liu et al. 2019), and questions of fairness over use and management of fisheries (Le Goffe and Salanié 2005), focusing on trade-offs in this manner may not be ideal.

There are other forms of value that look beyond direct benefits to people and measure other benefits associated with natural resources like inland fisheries. Intrinsic value suggests that nature has inherent value independent of the social benefits people derive from it (Baard 2019), and this value is not based on the personal trade-offs fundamental to economic valuation (O'Connor 1994; Rea and Munns 2017). Relational value incorporates aspects of the complete instrumental–intrinsic value dichotomy and highlights the interactions between humans and nature and the person-to-person interactions that involve nature. The benefits that are being measured within relational value are tied directly to the complex interactions people have with nature while consuming, protecting, and interacting with natural resources. Quantification of relational values monetarily is possible, unlike with intrinsic value, but has only been operationalized in a few limited studies (Arias-Arévalo et al. 2017; Klain et al. 2017). Relational value better incorporates more diverse views of natural resource benefits than instrumental value. Further, relational value may provide a more inclusive representation of how nature and natural resources are valued, though there is evidence that they may be equivalent measures in practice (See et al. 2020); however, further investigation is needed.

Ultimately, benefit transfer is an underutilized but powerful tool available to inland fisheries managers. We have demonstrated how benefit transfer can be used to investigate the potential effects of different management actions on recreational anglers within a fisheries landscape. However, benefit transfer is only as effective as the primary valuation data available. We urge inland fisheries managers to continue implementing primary valuation studies and to do so in an efficient manner using effective data integration guidelines so that benefit transfer may be applied more widely and precisely at diverse scales. Doing so will increase the applicability of primary valuation studies beyond their individual sampling scope and create sources of data that can be applied widely to investigate landscape-scale fisheries management problems. With long-term planning and forethought, inland fisheries managers can use benefit transfer to carry out inexpensive and accurate economic assessments of policy decisions.

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Appendix A.1: Definitions of Terms

TABLE A.1.1. Definitions of common economic terms.

Category	Term	Definition
General	Utility	Total satisfaction received from consuming a good or service.
	Benefit	An advantage or positive effect that can be measured in monetary terms.
	Economic valuation	Methods that use both stated and realized preferences to measure willingness to pay (WTP) or ability to pay for a particular good, service, or experience.
	Consumer surplus	Difference between the maximum WTP or ability to pay for a particular good, service, or experience and the actual costs incurred.
	Producer surplus	Difference between the actual costs incurred for a particular good, service, or experience and the minimum amount a producer is willing to accept for them.
Value	Instrumental value	The worth of natural resources based on the role in satisfying human needs or wants.
	Relational value	The worth of the relationships that exist between natural resources and human society, including the person-to-person relationships that are associated with those natural resources.
	Intrinsic value	The inherent worth that exists in living and non-living entities in nature, independent of human needs or wants.
	Use value	The ability of a particular natural resource to directly fulfill the needs or wants of a consumer.
	Nonuse value	The ability of a particular natural resource to indirectly fulfill the needs or wants of a consumer, independent of consumption in the present or the future.
Benefit transfer	Unit value transfer	The transfer of a WTP value from a study site or a series of sites to a particular policy site of interest.
	Benefit function transfer	The transfer of a benefit function from a study site to a particular policy site of interest.
	Meta-analysis transfer	Using statistical regression techniques to pool the data and resulting benefit functions from a series of study sites to transfer a more precise benefit function that incorporates the results of multiple studies.
	Study site	The study area where a primary economic valuation study was conducted to quantify a benefit function and WTP estimate.
	Policy site	The study area to which a benefit function or WTP value is being transferred for use in estimating a plausible WTP value at that site.

Appendix A.2: Bibliography of Reservoir and Lake Economic Valuation Studies

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