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ECOLOGY OF
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Letter

Spring home ranges of white bass in irrigation reservoirs of the Republican River Basin, Nebraska

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Abstract – Fishery biologists have documented small home ranges, relative to available habitat, for many littoral freshwater fishes. Home ranges for pelagic species, such as white bass *Morone chrysops*, are generally not well described, yet are thought to be large. We studied white bass movement using acoustic telemetry in two irrigation reservoirs of the Republican River basin in south-western Nebraska. Acoustic transmitters were implanted in fall of the previous year and tracking occurred a minimum of once per week throughout spring (mid-March to May) 2007 and 2008. Linear home ranges were calculated from observed locations of individual fish. Twelve of the twenty-seven tagged fish with at least five locations exhibited localised home ranges throughout the spring whereas the remaining fish exhibited home ranges extending across large portions of each reservoir. Home range size was not correlated with fish size or condition.

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Key words: home range; white bass; acoustic telemetry

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Introduction

Home range is defined as the area that an individual travels through and uses for daily activities during a given period (Burt 1943). Home ranges have been described for many freshwater fish species including bluegill *Lepomis macrochirus* (Paukert et al. 2004), largemouth bass *Micropterus salmoides* (Winter 1977), flathead catfish *Pylodictis olivaris* (Weller & Winter 2001; Vokoun 2003) and walleye *Sander vitreus* (Foust & Haynes 2007). However, most home ranges previously estimated are for littoral-zone species that spend large amounts of time along the shoreline of a water body. Movements defining a home range are specific to individuals and differ from population-directed movements such as seasonal and spawning migrations. Within a single population, some fish may have restricted movements and localised home ranges whereas other fish may have large home ranges (Gerking 1959). However, the source of this variation among individual home-range sizes is often unknown.

Pelagic freshwater fishes, such as striped bass *Morone saxatilis* and white bass *M. chrysops*, are often highly mobile and may roam an entire water body in search of food and other necessary resources. The striped bass has strong site fidelity and localised home ranges in both estuary and reservoir systems (Jackson & Hightower 2001; Ng et al. 2007). Summer home ranges of the striped bass are often limited in southern reservoirs because of low dissolved oxygen and hot water temperatures (Jackson & Hightower 2001). Though no information exists on home ranges of white bass, white bass movements have been assessed in prior studies. Individual white bass move up to 11.1 km·day^{-1} in search of food (Scott & Crossman 1973). Beck & Willis (2000) used biotelemetry to determine that white bass were usually located near-shore during spring and autumn months and offshore during winter and summer months in a South Dakota glacial lake. Multiple regression models quantifying distance of white bass locations from the nearest shore were weakly affected by temperature, cloud cover, precipitation and moon phase (all $R^2 < 0.26$; Beck & Willis 2000). Our objective was to quantify spring home ranges of white bass in two reservoirs within the Republican River basin of south-western Nebraska.

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Study area

Enders Reservoir is an irrigation reservoir constructed along Frenchmen Creek, in Chase County, Nebraska, by the U.S. Bureau of Reclamation in 1951. At conservation pool, Enders Reservoir has a water level of 948.5 m above mean sea level, surface area of 485 ha and maximum depth of 18.3 m. The shoreline is mostly composed of a silt/sand substrate with small cottonwood *Populus deltoides* trees lining the shoreline.

Hugh Butler Lake (Red Willow) is an irrigation reservoir constructed along Red Willow Creek in Frontier County, Nebraska, by the U.S. Bureau of Reclamation in 1962. At conservation pool, Hugh Butler Lake has a water level of 786.9 m above mean sea level, surface area of 660 ha and maximum depth of 15.2 m. Hugh Butler Lake has two inflow sources creating a reservoir with two arms: Spring Creek to the north and Red Willow Creek to the west. The shoreline is mostly composed of a silt substrate with small cottonwood trees lining the shoreline.

Materials and methods

Thirty adult white bass (15 in Enders Reservoir and 15 in Hugh Butler Lake) were implanted using techniques described by Hart & Summerfelt (1975) with Sonotronics ultrasonic tags (model IBT-96-9-1; 42 mm long, 10.5 mm diameter, 3.9 g weight in water) during autumn 2006; an additional 30 white bass (15 in each reservoir) were implanted during autumn 2007 (total tagged fish $N = 60$). Tag weight was <2.0% body weight and had a battery life expectancy of 9 months as reported by the manufacturer. Mean ± standard error (SE) total length for all fish used in further analysis was 306 ± 5 mm, mean weight ± SE was 350 ± 22 g and mean ± SE condition [relative weight (W_r); Wege & Anderson 1978; Brown & Murphy 1991] was 86 ± 2 at the time of tagging (Table 1).

Attempts to locate tagged white bass were made once a week during spring 2007 (17 attempts) and twice a week during spring 2008 (33 attempts). A typical sampling attempt consisted of a period of 12 h with days split into morning (03:00–15:00 h) and evening (15:00–03:00 h) sessions. Tracking attempts began after ice-out on 22 March 2007 and 5 March 2008 and ended on 29 May 2007 and 2 June 2008 due to loss of tag battery life. During each sampling event, we systematically worked around the reservoir stopping approximately every 300 m to scan (i.e. cycling through all frequencies with the directional hydrophone pointed at 0°, 60°, 120°, 180°, 240°, 300° and 360°) for tags. Once a tag was detected, we maintained a constant frequency while moving the boat to pinpoint the location of the fish. After pinpointing a fish's location, we resumed the systematic search. At least three circuits of the reservoir were completed

Table 1. Size and condition of fish (measured during tag implantation during September of previous year), number of spring (mid-March to May) locations and size of linear home ranges for white bass with greater than five locations at Enders and Hugh Butler Lakes, Nebraska, during 2007 and 2008. Condition was assessed using relative weight (Brown & Murphy 1991; Wege & Anderson 1978).

Year	Reservoir	Fish number	Total length (mm)	Weight (g)	Relative weight	Number of locations	Home range (m)
2007	Enders	44	331	439	88	5	1725
		47	342	505	92	11	1186
		51	315			5	86
		53	306	360	92	7	3825
		58	321	409	90	6	1809
		64	259	239	102	6	2460
		67	325	436	93	10	1460
		68	269	253	96	9	1401
		71	331	458	92	5	2560
	Hugh Butler	19	295			5	632
		38	314	320	76	5	1345
		39	300	275	75	6	239
2008	Enders	115	334	434	85	23	397
		125	309	371	92	14	2472
		129	300	357	97	14	231
		140	341	480	88	25	343
		157	349	526	90	14	168
		166	351	568	95	8	239
		171	306	357	91	6	3312
	Hugh Butler	101	262	200	82	17	838
		107	316	343	79	12	8154
		116	310	311	76	15	298
		122	297	230	64	14	605
		127	265	200	80	15	7266
		141	266	189	74	10	69
		151	276	241	85	13	5035
		168	286	257	81	16	5005

during each sampling event; i.e. we attempted to scan a general vicinity every 4 h within a 12-h sampling period.

Geographical coordinates were recorded with a Garmin eTrex GPS unit at each fish location. Coordinates were recorded in NAD83 UTM Zone 14N. Locations were mapped using ArcMap version 9.3 (ESRI 2008) and compared to bathymetric maps of the reservoirs created with data from the Lake Mapping Program of the Nebraska Game and Parks Commission.

Twenty-seven white bass were located a minimum of five times (range 5–25 locations per fish) during spring of 2007 (N = 12) and 2008 (N = 15; Table 1). White bass with less than five locations were not included in analyses because at least five locations are needed to calculate a home range. Multiple locations of individual fish within a sampling period were separated by at least 3 h. Of those 27 white bass, 16 were in Enders Reservoir and 11 were in Hugh Butler Lake.

We calculated home ranges using a linear method in ArcGIS to allow for comparison among individual white bass movements. The linear method defines a home range as the minimum distance between the two most extreme locations (Hayne 1949) and tends to underestimate home-range size by limiting the home range to one dimension. This distance was calculated manually in ArcGIS by measuring the shortest distance required to travel between the two most extreme locations while staying within the reservoir (i.e. not crossing onto shore).

Other home-range methods, such as the adaptive kernel method, tend to overestimate home-range size when the number of locations is less than 25 (Schoener 1981; Worton 1987) and researchers may introduce bias when reducing a kernel-based home range to the actual available home range within a water body. Like the minimum convex polygon estimator, the linear method is prone to effects of sample size (Burgman & Fox 2003). However, the dimension issue is likely minimised in fishery studies because most systems are longer in one dimension (e.g. river channels and dendritic reservoirs) than the other.

Results

Enders Reservoir

Six white bass had small (<1000 m) home ranges in Enders Reservoir during spring 2007 and spring 2008. Fish #51 had the smallest spring home range at Enders Reservoir, which was characterised by a flat, shallow area (Fig. 1). Fish #157 had a small spring home range located along a steep area of natural rock on the west shoreline of the lower reservoir (Fig. 1). Fish #129 and #140 had overlapping spring home ranges restricted to a steep area of natural rock at the northern extent of the riprap dam (Fig. 1). The spring home range of fish #166 was located in the middle reservoir along a shallow, relatively flat area with inundated trees along the shoreline (Fig. 1). Fish #115 also had a small spring home range that was restricted to an area with two riprap jetties along the eastern shore (Fig. 1).

Eight white bass had medium (between 1000 and 3000 m) spring home ranges that extended across larger portions of Enders Reservoir. Fish #47 had a spring home range that extended across the centre of the lower reservoir characterised by a relatively deep basin with steep shorelines (Fig. 1). Fish #58, #67 and #68 had spring home ranges located across the middle portion of the reservoir characterised by a shallow flat area with shorelines dominated by small woody trees with the addition of some sandy beaches along the southern shoreline (Fig. 1). Fish #125 had a spring home range extending across the upper half of the reservoir with locations centred on the sandy point in

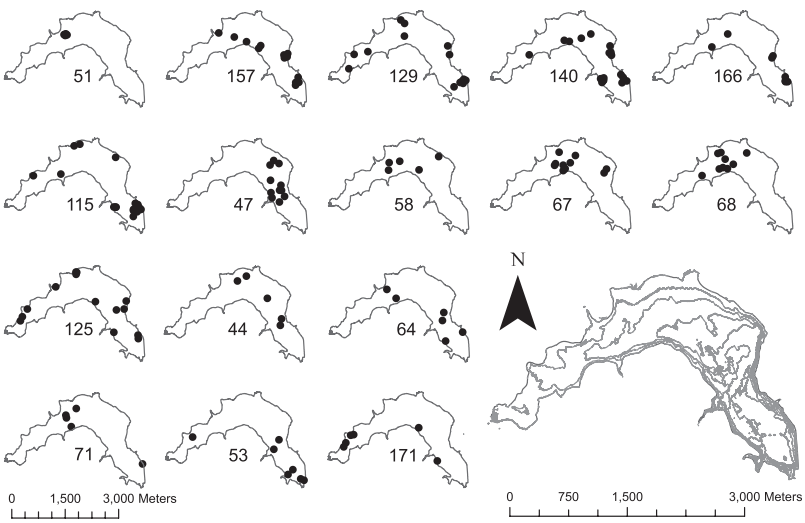

Fig. 1. Locations of tagged white bass with more than five locations in Enders Reservoir, Nebraska, from March to May 2007 (two-digit fish numbers) and March to May 2008 (three-digit fish numbers). Bathymetric map of Enders Reservoir with 2 m contours included.

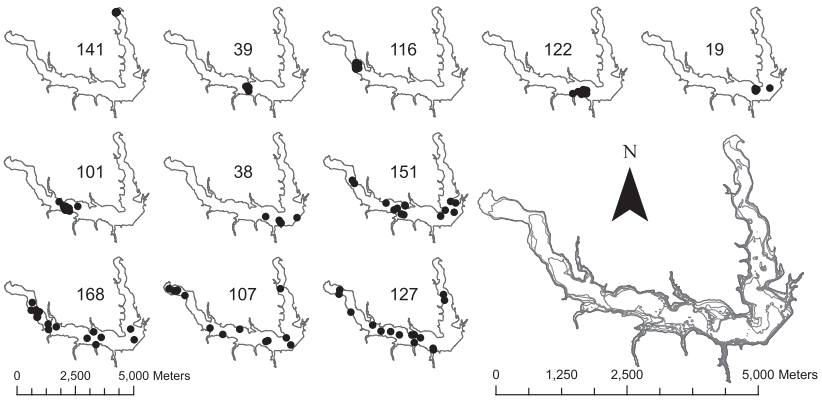

Fig. 2. Locations of tagged white bass with more than five locations in Hugh Butler Lake, Nebraska from March to May 2007 (two-digit fish numbers) and March to May 2008 (three-digit fish numbers). Bathymetric map of Hugh Butler Lake with 2 m contours included.

the middle of the reservoir (Fig. 1), whereas the spring home range of #44 encompassed most of the lower, deeper half of the reservoir (Fig. 1). Fish #64 and #71 had locations and spring home ranges that included shallow water of the upper reservoir.

The remaining two white bass had large (>3000 m) spring home ranges that extended throughout Enders Reservoir. Fish #53 was found throughout the reservoir during spring and had a linear home range encompassing most of the reservoir (Fig. 1). Fish #171 also had a large home range extending across most of the reservoir (Fig. 1).

Hugh Butler Lake

Six white bass had small home ranges in Hugh Butler Lake during spring 2007 and spring 2008. Fish #141 had the smallest spring home range in Hugh Butler Lake, which was characterised by a local structure of dead, standing trees along an old creek channel in the north arm (Fig. 2). Fish #39 had a spring home range restricted to a relatively flat area adjacent to a point extending into the west arm (Fig. 2). Fish #116 had a spring home range located in the upper section of the west arm with most locations occurring along a steep break near shore (Fig. 2). The spring home range of #122 was centred on a large underwater point extending across the middle of the reservoir with some locations nearby along the southern shore (Fig. 2). Fish #19 had a small spring home range characterised by locations on either side of a point extending into the lower reservoir (Fig. 2). Fish #101 had a similar spring home range located along a submerged point further west (Fig. 2).

One white bass had a medium home range in Huge Butler Lake. Fish #38 had a spring home range in the lower reservoir (Fig. 2). Locations of fish #38 were mostly along drop-offs (Fig. 2).

The remaining four white bass had large spring home ranges extending throughout Hugh Butler Lake. Fish #151 and #168 had locations throughout the west arm and their spring home ranges encompassed large areas of this arm (Fig. 2). Fish #107 and #127 both had locations and spring home ranges extending across the entire reservoir (Fig. 2).

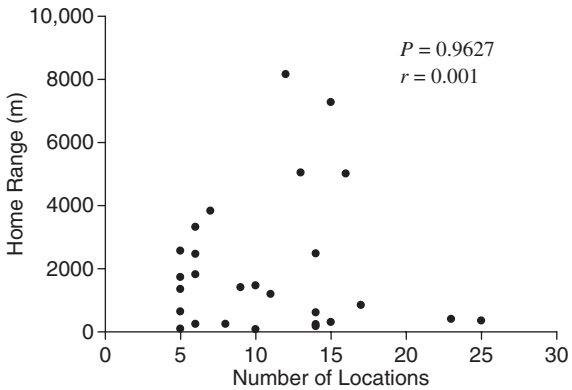

Fig. 3. Correlation of linear home range with the number of locations per individual white bass tracked during spring 2007 and spring 2008 at Enders Reservoir and Hugh Butler Lake, Nebraska.

Home-range analysis

Linear home-range estimates ranged from 69 to 8154 m, with a mean ± SE of 1968 ± 421 m (Table 1). Home-range size did not differ between years (Kruskal–Wallis test, $\chi^2 = 0.18$, $P = 0.67$) or reservoirs ($\chi^2 = 0.10$, $P = 0.75$); thus, observations were pooled for further analysis. Twelve white bass had home ranges restricted to small areas of the reservoir (<25%), nine white bass had home ranges encompassing 25–75% of the reservoir and six white bass had home ranges encompassing almost the entire reservoir. Linear home range was not correlated with number of locations per fish ($r = 0.001$, $P = 0.96$; Fig. 3). Linear home range was also not correlated with fish total length ($r = -0.23$, $P = 0.25$), weight ($r = -0.17$, $P = 0.42$) or condition ($r = 0.10$, $P = 0.65$) at the time of tag implantation (i.e. autumn). No evidence of fish shoaling was observed among

tagged fish during tracking (i.e. no more than one fish was observed in the same location at the same time).

Discussion

The identification of home ranges of white bass during spring (mid-March to May) provides insights into their basic biology. Spawning was limited to approximately 10 days in early May of each year. Thus, linear home ranges described herein encompassed prespawn, spawn and postspawn periods for white bass in these two reservoirs.

Our method of tracking fish using mobile acoustic telemetry should bias the number of encounters towards fish with smaller home ranges. Fish that moved shorter distances were more likely to be encountered during a circuit than fish that moved longer distances. However, no relationship existed between the number of encounters and linear home-range size. Thus, we believe this bias was minimal.

The discontinuity in size of white bass home ranges suggests that two distinct behaviours of white bass occur in these reservoirs during spring. One behaviour produces movement during spring throughout much of the reservoir. The other produces more localised movement – a seemingly counterintuitive result given that white bass is a pelagic species. At least six competing hypotheses for the observed discontinuity in size of spring home ranges can be posed, including: (1) larger fish may require greater home-range areas to obtain sufficient energy for growth and reproduction (Peters 1983; Minns 1995); (2) fish in greater condition (e.g. W_r) may travel less because they are in an area with abundant resources (optimal foraging theory; MacArthur & Pianka 1966); (3) male fish may remain close to potential spawning sites throughout the prespawn and spawning periods; (4) older, reproductively senescent fish may travel little because they lack migratory behaviour that is associated with spawning periods; (5) some fish may spawn in intermittent years, and remain in energetically favourable areas during nonspawning years to promote growth (JØrgensen et al. 2006; Secor 2008); and (6) inter-individual variation in standard metabolic rates may be associated with varying levels of aggressiveness and activity levels (Cutts et al. 2002). Hypotheses 1 and 2 were not supported by our results (body size and W_r were not correlated with linear home-range size), though the sample size was limited ($N = 27$). Although hypothesis 2 was not supported by our data, white bass with small home ranges selected for areas characterised by one of two features: underwater drop-offs or relatively flat areas with small trees. These areas may provide abundant food such that time and energy expenditure is minimised during the search phase of foraging. These areas may also provide habitat necessary for spawning, although results from patch occupancy modelling and acoustic telemetry did not support this contention (Martin 2008). We did not gather age, gender, reproductive status or metabolic data from tagged fish and thus were unable to test hypotheses 3, 4, 5 or 6. Further research is needed to determine the mechanisms responsible for the discontinuity in white bass spring home-range size.

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