Wing dike morphology and use by bighead and silver carps.

Duane C. Chapman and Joseph E. Deters, U.S. Geological Survey, Columbia Environmental Research Center, 4200 New Haven Road, Columbia, MO 65201

Abstract

The channelized portion of the Missouri River is characterized by a large, swift channel bounded by wing dikes. Telemetry data indicates that low velocity, deep water preferred by the invasive bighead carp (*Hypophthalmichthys nobilis*) and silver carp (*H. molitrix*) in the Missouri River is primarily associated with the plunge pools behind the wing dikes. We used GIS and aerial photography to characterize 15 parameters of wing dikes in a 209 km reach of the Missouri River, and coupled those data with telemetry data from that reach, to determine the characteristics of wing dikes that determine use by bighead and silver carps.

Introduction

Wing dikes are important to bighead and silver carps in the Missouri River because the protected areas behind the wing dikes, often with plunge pools, provide the deep, low velocity water preferred by the carps (Johnson et. al, presented at this symposium). Wing dikes are regularly modified for fish habitat enhancement; some types of modifications can be made with little negative effects on navigation or flood/erosion control aspects of the structures (Fig. 1). If aspects of wing dikes that are important for undesirable invasive carps are known, future mitigation efforts can be focused on accentuating habitat needs of native fish without enhancing habitat for carps. Also, it may be possible to design some wing dikes in a fashion that would make them both very attractive to bighead and silver carps and at the same time very fishable, to enhance the efficiency of commercial fishing or removal efforts. Thirdly, knowledge of habitat requirements of invasive fishes is needed to determine habitat overlaps with native fishes and to evaluate potential competition for habitat.

Fig 1. Notched wing dikes on the Missouri river (Corps of Engineers mitigation sites)

Methods

Telemetry

Data was collected from fall of 2002 to summer of 2004. A total of 51 fish (25 bighead and 26 silver carp) were tagged with combined acoustic-radio tags and provided useful data. Fish were tagged in the Missouri River and in the Lamine River, a tributary of the Missouri. The search area was a 209 km reach of the Missouri River, and navigable sections of tributaries of this reach. This reach was bounded on its upstream end by the mouth of the Grand River and on its lower end by the mouth of the Osage River. Over 500 fish locations were logged, 356 of them on the Missouri River. Only fish locations in the Missouri River were used in this analysis.

GIS

Multiple sources of overlay data were employed at different stages in this project, and include aerial photography from 2000 (USACE 2000) and 2003 (USDA 2003) and a digital representation of wing dike structure (USACE 1994). ESRI ARCMAP was used to overlay carp locations determined by telemetry on these layers. All dikes within the 209 km of river for which we have tracking data were evaluated, a total of 840 wing dikes. Parameters included both non-numeric and numeric variables (Table 1).

Table 1. Measured wing dike parameters.

Non-numeric variables:

- **Navigation structure types (spur, angled spur, unrooted spur , L-head, trailing, and box; see Fig. 2)**
- **Next upstream feature type (navigation structure type or sandbar)**
- **Next downstream feature type (navigation structure type or sandbar)**
- **osition relative to thalweg (thalweg side, side away from thalweg, or crossover)**
- **Presence and location of notches**

Numeric variables:

- **Length of primary arm (arm adjacent to riverbank)**
- **Secondary arm length**
- **Distance to next upstream navigation structure**
- **Distance to next downstream navigation structure**
- **Distance to upstream channel crossover**
- **Primary arm angle to thalweg**
  - **(directly upstream = 0° and directly downstream = 180°)**
- **Secondary arm angle to thalweg**
- **Maximum distance from near shore**
- **River width (line perpendicular to thalweg from root of dike to opposite shore)**
- **Area enclosed**
  - **(area bounded by the dike, the bank, and a line from the most downstream point on a dike to the bank)**

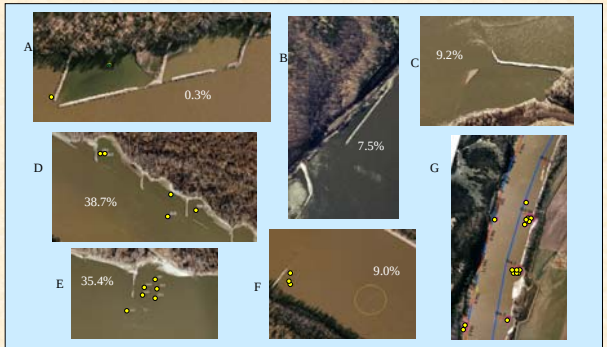

Figure 2. Wing dikes typical of the Missouri river, and their relative frequency in the study reach. A) box dike B) trailing dike C) angled spur D) L-head dikes E) spur dike F) unrooted spur dike (circled) G) series of wing dikes digitized for the purposes of this study. Yellow dots are carp locations determined by telemetry.

Statistical analysis

We first attempted a stepwise discriminate function to evaluate the usefulness of the measured parameters; this proved unsatisfactory because of uneven distribution of data types. We then used a General Linear Model to determine preference (frequency vs. expected) for non-numeric variables, and we used ANOVA to determine wing dike preference based on numeric variables. Fish species were analyzed separately, and coldwater (November-February) periods were analyzed separately from the cool-to-warmwater (March – October) periods. Because of limitations of the statistical methods used, dikes were evaluated on the presence or absence of carp locations, and not weighted by multiple carp locations associated with a single wing dike.

Results

Using a combination of the different GIS layers, we were able to adequately measure all of the parameters except the presence and location of notches. Notch locations were not always visible on the aerial photos (if not inundated) and available maps of notch locations and notch elevation were not sufficiently correct and up-to-date. Some wing dike notches were modified by the Corps of Engineers during the study. Also, while telemetry field notes contain information on whether notches in wing dikes associated with carp locations were inundated, the inundation status of notches in other wing dikes at the time of the carp location are not known. It was thus impossible to interpret notch data in terms of preference.

Many of the parameters measured in this study were interrelated. For example, L-heads were mostly located on the thalweg side of the river (83%), whereas only 11% of spur dikes and no angled dikes were located on the thalweg side. Secondary arm angle to flow was closely related to wing dike type; for L-heads it was usually near 180º, and for angled spur dikes it is usually closer to 90º. Like dike types are often grouped together on the river, which affects the upstream and downstream feature parameter.

Non-numeric parameters significantly preferred by bighead and silver carps are shown in Table 2. The frequency distribution of dike types is found in Figure 2. Telemetered bighead carp and silver carps preferred angled dikes and spur dikes over L-heads and did not use unrooted dikes. Telemetered carps also did not use trailing dikes or box dikes, but the available number of these dike types was very low. Preferred neighboring features were also angled and spur dikes. Bighead and silver carps preferred to use wing dikes that were on the side of the river away from the thalweg, or in crossover sections (Table 2). Dikes on the side of the river away from the thalweg on average extended significantly farther from the bank than those on the thalweg side ($p < 0.0001$). There may be some difference between winter and summer and between species in the preference for crossover or non-thalweg dike positions.

Numeric variables that were associated with use by telemetered bighead and silver carp are given in Table 3. Both species, in both cold and warm-water periods, strongly preferred dikes that extended far from the bank, which presumably have larger amounts of usable low-velocity habitat behind them. A larger distance to the next downstream feature was significantly preferred by bighead carp in the summer and silver carp in both time periods. This parameter was not significantly preferred by bighead carp in winter, but bighead carp in winter did significantly prefer a larger distance to the next upstream feature. Distance to downstream and upstream features was not correlated with dike length in the studied reach ($r = 0.372$ and 0.290, respectively). Both species in both periods preferred wing dikes located in places where the river was narrower. River width was not correlated with dike extension from bank ($r = 0.077$). Carp use did not vary by primary arm length or angle to thalweg, but secondary arm angle to thalweg was negatively associated with carp use, except by silver carp in the summer. Secondary arm length was negatively associated with bighead carp use in the winter and with silver carp use in the summer. Area enclosed by a dike was not significantly associated with carp use except for a negative association with bighead carp in the winter.

	Dike Type	Neighboring features	Position relative to thalweg
Bighead Carp, March – October	Angled spur (strong preference) and Spur	Angled spur and Spur (up or downstream feature)	Side away from thalweg
Bighead Carp, November - February	Angled spur and Spur	Angled spur and Spur (up or downstream)	Side away from thalweg or crossover
Silver Carp, March – October	Spur (Angled and L-head use near expected frequency)	Spur (up or downstream)	Crossover and side away from thalweg
Silver Carp, November - February	Angled spur (strong preference) and Spur	Angled spur (Spurs and L-Head use near expected frequency)	Side away from thalweg or crossover

Table 2. Non-numeric variables significantly preferred by bighead and silver carp in cold and warmwater periods.

Species and period	Parameter	Relationship	p
Bighead carp November - February	Secondary arm length	negative	0.0003
	Distance to upstream feature	positive	0.002
	Max Distance to bank	positive	0.0005
	Sec. arm angle to flow	negative	<0.0001
	River width	negative	0.0003
	Area enclosed	negative	0.0008
Bighead carp March - October	Dist. to downstream feature	positive	0.02
	Secondary arm angle	negative	0.0002
	Max distance to bank	positive	0.0015
	River width	negative	0.0006
Silver Carp November - February	Secondary arm angle	negative	0.0002
	Dist. to downstream feature	positive	0.038
	Max distance to bank	positive	0.0046
	River width	negative	0.0006
Silver carp March - October	Secondary arm length	negative	0.0575
	Dist. to downstream feature	positive	0.039
	Max distance to bank	positive	0.0036
	River width	negative	0.0006

Table 3. Numeric parameters for which a statistically significant affect on use by telemetered bighead and silver carp was found.

Discussion

Dikes in this river reach that extend farther from the bank are preferred over smaller ones, although it is unclear whether that results simply from a larger amount of available habitat behind those dikes or if the relationship is more complex. Angled spur and spur dikes were preferred over other types, and angled spur dikes were sometimes strongly preferred, despite their relative scarcity.

The preference for angled dikes and spur dikes upstream and downstream from the used dike may simply be related to the fact that like wing dike types are grouped together on the river, but these data give no indication that the first or last wing dike in a series, or that those near revetments or sandbars, would be preferred.

The preference for wing dikes in narrower sections of the river seems counter-intuitive at first, because narrower sections of the river should have higher water velocity, which these fishes are thought to avoid. One hypothesis that would explain this relationship is that during high flows the higher energy in narrow sections of the river creates deeper and/or larger plunge pools behind the dikes.

While these data help understand the types of wing dikes used by *Hypophthalmichthys* spp. in the Missouri River, it is difficult to compare wing dike preference with native fishes of concern because of a lack of similar data on those fishes. Ongoing studies on catfishes and paddlefish (*Polyodon spathula*) in the Missouri River should provide data to be compared with these data. Lastly, there remains a strong need to understand how wing dike notches, installed primarily as fisheries mitigation features, affect Asian carps and other fishes.

Citations

USACE (US Army Corps of Engineers) 1994. Missouri River Hydrographic Survey, Rulo Nebraska to the Mouth.

USACE 2000. Orthophotography of the Missouri River.

USDA (US Department of Agriculture) 2003. Aerial photography. National Agriculture Inventory Program.