AQUATIC CONSERVATION: MARINE AND FRESHWATER ECOSYSTEMS, VOL. 5, 97–108 (1995)

Fate of Lower Mississippi River habitats associated with river training dikes

F. DOUGLAS SHIELDS, JR.
USDA-ARS National Sedimentation Laboratory, PO Box 1157, Oxford, MS 38655-1157, USA

ABSTRACT

1. Regions of reduced velocity adjacent to spur dikes along the Lower Mississippi River are valuable aquatic habitats. Similar zones along other large rivers have been converted to terrestrial habitats by sediment deposition.

2. Repetitive hydrographic surveys of 26 representative groups of dikes are examined to determine the direction and rates of change.

3. Since the dikes were constructed, the aquatic volume and area of associated low-velocity habitats have been reduced by 38% and 17%, respectively. Examination of time series shows that most changes occur shortly after construction, and after initial adjustment, habitat area and volume fluctuate about a condition of dynamic equilibrium.

4. Sedimentation rates were most rapid for dike fields constructed on the inside of bends to prevent chute development. Dike fields built to force or maintain thalweg crossings exhibited erosion rather than deposition.

INTRODUCTION

Human impact on large river morphology has followed a remarkably similar pattern worldwide (Welcomme, 1989). Generally speaking, development of major rivers has tended to decrease spatial and temporal heterogeneity of aquatic habitats by eliminating multiple channels and backwater habitats (Brookes, 1988; Lelek, 1989; Dister *et al.*, 1990). For example, during the past 100 years the lower Missouri river has been converted from a braided channel to a low-sinuosity meandering channel, and water surface has been reduced by 50–70% (Morris *et al.*, 1968; Hallberg *et al.*, 1979). Similar changes have been reported for the Vistula (Babinski, 1992).

Spur dikes, groynes, and similar structures are frequently key components of large river development projects (Derrick *et al.*, 1989). Formerly, river engineers tried to design dike fields so that the low velocity zones around them would rapidly fill with sediments (Anding *et al.*, 1968), potentially enhancing their effect of diverting flow into the navigation channel. More frequently, designers ignored effects of dikes on aquatic areas immediately adjacent to the structures, and most early research on dike performance focused on main channel phenomena. However, low-velocity zones and scour holes adjacent to and between dikes have been shown to provide extremely valuable habitats in large rivers (Pennington and Shields, 1993) and small streams (Bulkley *et al.*, 1976; Knight and Cooper, 1991). A number of techniques for enhancing spur dike habitats have been proposed and tested, although on a limited scale at present (Shields, 1984, 1988; Shields *et al.*, in press). Concern exists over the long-term sustainability of high-quality habitats associated with dike fields. When aquatic areas within dike fields are converted to terrestrial habitat by sedimentation, low-velocity habitats become increasingly scarcer along the river corridor. Lateral migration, and the

CCC 1052–7613/95/020097–12

Received 1 November 1994
Accepted 11 March 1995

concomitant creation of new backwaters and other low-velocity areas, is virtually eliminated by extensive river training (Shields and Milhous, 1992; Shields *et al.*, in press). Thus, the nature and magnitude of sedimentation between and adjacent to spur dikes hold important ecological implications for rivers. Nunnally and Beverly (1986) attempted to quantify the magnitude of sedimentation associated with Lower Mississippi River (LMR) dikes by comparing low-water aerial photographs taken in 1962 and 1976. They reported that total water area changed little between the two dates. However, secondary channel area decreased, and off-channel areas (e.g. sloughs) increased, reflecting the river training strategy of closing the upstream entrances to secondary channels. This paper aims to describe the temporal dynamics of sedimentation in aquatic areas adjacent to LMR dikes. Additionally, sedimentation is related to local channel morphology and dike field location.

STUDY SITE

The LMR is the reach of the Mississippi River from its mouth to the Ohio River confluence. This reach is free of impoundments and has been developed for navigation and flood control using upstream and tributary reservoirs, levees, bend cut-offs, floodways, dredging, and river training structures. During the period of data collection for this study (1958–1987), the channel was free of large-scale instability. Major avulsions and bend migrations were prevented by river training structures and control structures regulating flow into the Atchafalaya distributary. However, many forces were at work on the physical system, including closure of upstream reservoirs, a series of 16 man-made meander cut-offs constructed between 1929 and 1942, and continual dredging to maintain navigation depths at thalweg crossings. Observed responses to these forces include a 48% reduction in annual suspended sediment yield (Keown *et al.*, 1986), slight fining of bed sediments (Queen *et al.*, 1991), and generally wider, shallower flow with more middle bars (Winkley, 1977). Water surface elevations at low flow indicate that the bed has degraded by as much as 3.3 m near the upper end of the reach containing cut-offs and dikes and aggraded up to 1 m near the lower end during the period 1962 to 1988 (Elliot *et al.*, 1991). Fremling *et al.* (1989) and Baker *et al.* (1991) provide detailed descriptions of the LMR, its biota, and their habitats.

River training structures found in the LMR include revetments made of articulated concrete mattresses, which generally occur on concave banks, and about 440 stone dikes located between RK 531 and RK 1527 (Derrick *et al.*, 1989). The total length of dike structures constructed since the early 1960s in the LMR was 330 km (up to 1985) and 475 km have been authorized (Baker *et al.*, 1991); additional dikes are constructed each year. Dikes have been designed and constructed in about 125 groups (dike fields) of 2–12 structures per group to achieve reach-specific objectives (Baker *et al.*, 1991). Dike frequency per unit length of river is inversely related to sinuosity (Winkley, 1982).

DIKE FIELD HABITATS

Regions of reduced velocity between and adjacent to dike fields (hereafter referred to as 'dike field pools' or simply 'pools') are important LMR habitats (Figure 1). Water quality and biotic communities of dike pools resemble main channel communities during high flows, when physical conditions typical to main channel occur, and lentic habitats during lower stages (Beckett and Pennington, 1986). At low to moderate flow, these pools are characterized by relatively great depths (up to several metres), and slow ($< 1\ \mathrm{m\,s^{-1}}$) or no current. Because pools are warmer and less turbid than flowing water habitats, primary productivity often reaches relatively high levels, particularly during late summer and autumn (Baker *et al.*, 1988). Secchi disk depths in the river main channel are normally < 30 cm, but are about twice as great in lentic dike pools (Beckett and Pennington, 1986; Baker *et al.*, 1988). Algal blooms and thermal stratification occur in lentic dike pools during warmer months with attendant changes in water quality: oxygen supersaturation occurs in surface waters with anoxia in deeper regions (Beckett and Pennington, 1986; Baker *et al.*, 1991).

Figure 1. LMR dike fields at low flow, about RK 1133. Flow is from top to bottom of photograph. Note dike field pools at upper right centre and lower left centre. Photo courtesy of US Army Corps of Engineers.

Recent developments in large river ecology have focused attention on the importance of interactions between rivers and floodplains (Junk *et al.*, 1989). Floodplain aquatic habitats along large rivers generally exhibit high primary productivity, while main channels generally exhibit low primary productivity. Production of floodplain habitats is periodically made available to fish living in the river during higher flows (Modde and Schmulbach, 1973; Eckblad *et al.*, 1984; Beckett and Pennington, 1986). Dike field pools may function similarly to floodplain habitats in that they exhibit relatively high primary productivity compared with other mainstream habitats (Baker *et al.*, 1988). This production may be particularly important when levee placement or habitat conversion has reduced seasonally flooded area confluent to the river.

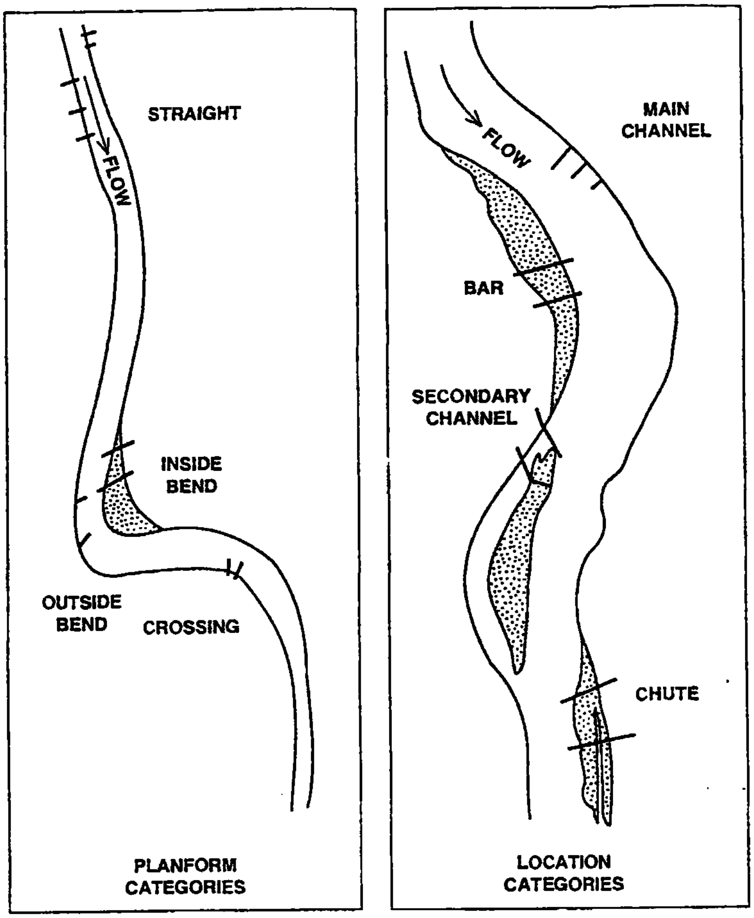

Figure 2. Two-part classification scheme for LMR dike field settings. Each dike field was classified based on the type of reach where it was located, and on the geomorphological feature within the reach upon which the dikes were placed.

Beds of pools are typically covered by fine sediments, although large regions of sand and gravel are found in pools during and immediately after high flows, suggesting seasonal fluctuation (Baker *et al.*, 1988). The spatial and temporal variations in currents within dike pools generate complex mosaics of bed types (Beckett *et al.*, 1983; Baker *et al.*, 1988). These mosaics support diverse invertebrate assemblages (Beckett *et al.*, 1983) that include species typical of both higher-energy habitats (e.g. lotic sandbars) and lower-energy habitats (e.g. sloughs). For example, Beckett and Pennington (1986) reported that *Hexagenia* spp., a large, trophically important organism, was found only in silt substrates in dike pools. Observed *Hexagenia* population densities (50–160 organisms m^{-2}) compared favourably with reported densities for lentic habitats.

The stones comprising the dike structures are inhabited also by large numbers of caddis flies, chironomids, and other epibenthic invertebrates (Beckett and Pennington, 1986; Baker *et al.*, 1988). Some workers have suggested that populations of hydropsychid caddis flies are limited in many large rivers by the availability of suitable substrate (Fremling, 1960; Benke and Wallace, 1980). Because the stone surfaces furnish stable, rocky substrate that is in short supply in the LMR ecosystem, and because the dike

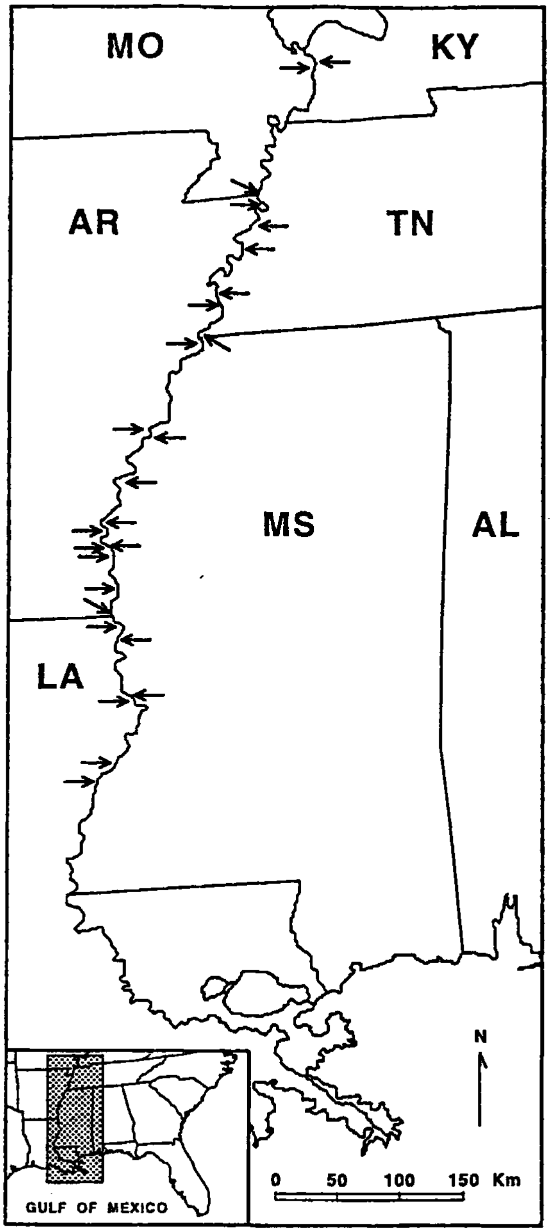

Figure 3. Location of 26 LMR dike fields selected for study.

structures are pervious enough to allow colonization deep below their surfaces, reported macroinvertebrate densities per unit area for the dikes are an order of magnitude greater than for mud substrates in nearby slackwater habitats (Beckett and Pennington, 1986).

A series of studies of LMR ichthyoplankton summarized by Beckett and Pennington (1986) highlight the importance of dike pools to riverine fishes. Species composition of larval fish samples from moving water habitats such as the main channel or lotic side channels was dominated by shad (*Doromosa* spp.), freshwater drum (*Aplodinotus grunniens*), and river carpsucker (*Carpiodes carpio*). Lentic pools within dike

Table 1. Distribution of all LMR dike fields and dike fields selected for study among location categories, %. Study dike fields in parentheses. Row and column sums are not equal to totals due to rounding.

Reach planform	Dike field location				Totals
	Bar	Chute	Main channel	Secondary channel	
Inside bend	7 (4)	12 (8)	1 (0)	16 (24)	35 (35)
Outside bend	0 (0)	0 (0)	2 (0)	4 (4)	6 (4)
Straight	3 (4)	10 (8)	12 (15)	22 (24)	47 (50)
Crossing	0 (0)	1 (0)	7 (4)	5 (7)	12 (12)
Totals	9 (8)	23 (15)	22 (19)	46 (59)	100 (100)

fields had distinctive larval fish assemblages very similar to sloughs and other types of riverine backwaters, supporting high densities of centrarchids and atherinids. Therefore the dike pools serve to replace natural backwater habitats that are slowly being converted to terrestrial habitats by sedimentation. Mouths of flooded tributaries, which serve as alternative nursery habitats in other large rivers like the Ohio, are unavailable along much of the LMR, since confluences are uncommon (Beckett and Pennington, 1986).

Dike pools are also important habitats for adult fish. Studies of LMR dike pools have detected up to 68 species with biomass densities as high as 2000–4000 $\mathrm{kg\,ha^{-1}}$ (Baker *et al.*, 1991). A wide range of fish sizes has been taken from these areas (Baker *et al.*, 1988). These fishery characteristics probably reflect the temporal and spatial heterogeneity of dike pool habitats—a mix containing woody debris, dike structures, lotic and lentic sandbars, eddies, plunge pools, scour holes, etc. (Beckett and Pennington, 1986). Dike pool fish assemblages may be divided into two groups. The first group is composed of species ubiquitous in all LMR habitats, while the composition of the second group varies with river stage from a lotic assemblage at high water to one typical of backwaters at low water (Nailon and Pennington, 1984; Beckett and Pennington, 1986).

Islands and bars within dike fields furnish habitat for birds. Sigrest and Cobb (1987) surveyed 10 dike fields and reported 92 bird species. Migrant swallow and blackbird species comprised 90% of the observed individuals.

In terms of habitat quantity, dike field pools are also significant along the LMR. Baker *et al.* (1991) estimated that pools occupied 8.5% of total LMR aquatic habitat at low river stage, but their definition of pools included low velocity areas downstream of islands and bars as well as regions within dike fields. However, they noted that most of the pool habitat is associated with dike fields. Nunnally and Beverly computed an area for pools and sloughs in diked reaches equivalent to 4.3% of total aquatic habitat at low stage in the reach between RK 515 and RK 1535, while Cobb and Clark (1981) estimated that dike pools comprised 3% of the low-stage aquatic habitat in the reach between RK 772 and RK 853. Since all lentic habitats comprise only about 30% of the total aquatic habitat at low stage (Baker *et al.*, 1991), dike field pools are significant features.

METHODS

A two-part classification system based on reach planform and dike field location was used to classify each of 107 LMR dike fields (Figure 2). The classification system included four reach types and four location types for a total of 16 possible categories. Reach types were straight, inside bend, outside bend, and crossing while locations included bars, secondary channels, main channel, and chutes. Location classification depended on the relationship of the dike field site to river stage: secondary channels carried flow at all stages, chutes carried flow only at higher stages, and bars were entirely terrestrial at low stage. Since river