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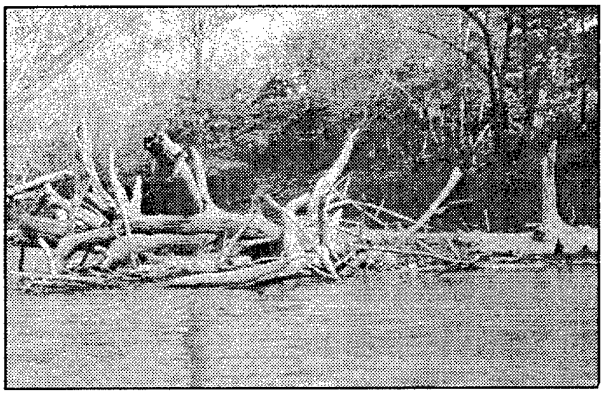
Restoration and enhancement of aquatic habitats

by K. Jack Killgore and Jan Jeffrey Hoover



The Corps of Engineers has a central role in restoring aquatic ecosystems. Under the authority of the 1986 Water Resource Development Act and subsequent amendments, the Corps can modify or construct projects to restore fish and wildlife habitat, as well as assist states and other non-Federal agencies with ecosystem and watershed planning (Table 1). Mitigation of larger water resource projects is required under the National Environmental Policy Act. Thus, the Corps uses a variety of techniques to accomplish restoration and mitigation goals, but the biological merits of each have not been comprehensively evaluated.

Restoration measures, implemented by environmental engineering, change physical habitat and subsequently effect changes in biotic communities. As part of the EMRRP, success criteria for restoration projects are being developed by modeling fish communities. Species within a fish community exhibit broad ranges of sensitivity to environmental disturbance (intolerant to tolerant), reproductive strategies (brooders to explosive breeders), lifespans, (1-10+ years), and trophic position (herbivores to piscivores). Consequently, community indices (percent composition, diversity, biotic integrity) are ideally suited to represent ecosystem function and health because they are not subjectively biased by any single species. Empirical measures of such indices are readily correlated with physical (e.g., water depth, substrate type) and landscape (e.g., percent forested lands) variables. These measures can be used to identify and predict restoration benefits for engineering solutions to habitat degradation.

Current research addresses two spatial scales in restoration ecology:

- **Waterbody-level projects** that restore habitat at specific locations (e.g., within a lake or stream reach).
- **Watershed-level projects** that focus on hydroperiod restoration of river corridors and reservoirs.

Waterbody-level restoration has been the conventional approach and still dominates some kinds of projects (e.g., Section 1135).

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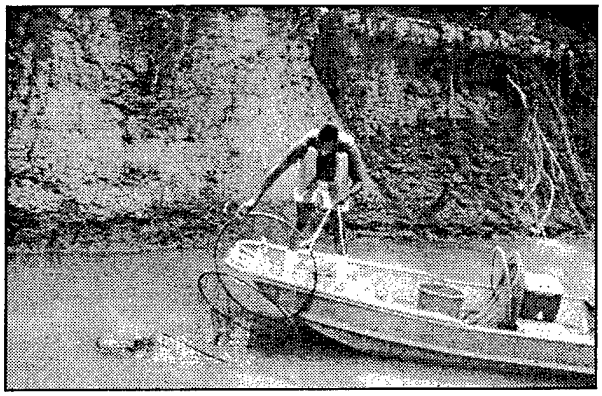
Table 1 Small project authorities that have been used by Districts to restore and mitigate aquatic habitats		
Project	**Legal Authority**	**Cost-Sharing**
Environmental Restoration	Section 1135, WRDA 1986 and amendments	25% non-Federal Federal llimit - $5 million
Planning Assistance to States	Section 22, WRDA 1974 and amendments	50% non-Federal Federal limit - $500,000
Aquatic Ecosystem Restoration	Section 206, WRDA 1986 and amendments	35% non-Federal Federal limit - $5 million
Environmental Management Program (Upper Mississippi River System, Habitat Rehabilitation and Enhancement Projects)	Section 1103, WRDA 1986	25% non-Federal, but 100% Federal on refuge lands
Beneficial Uses of Dredged Material	Section 204, WRDA 1992 and amendments	25% non-Federal Project cost: 100% O&M Federal limit - $15 million

With the advent of geographical information systems and multivariate databases, watershed-level projects are becoming more common. Benefits of restoration projects at these two scales are quantified in terms of habitat gains (e.g., Habitat Evaluation Procedure) and changes in fish communities. All studies are performed in cooperation with local Corps Districts. Waterbody-level studies address environmental engineering features in streams and rivers. Watershed-level studies are multiyear assessments of modifying the operating rule curve for dams that benefit reservoir, riverine, and wetland fish assemblages along stream corridors. Local and state resource agencies were involved in the planning stages of the research, and in some cases, research studies are leveraged with reimbursable funds from Districts.



Waterbody-level restoration

Evaluation of small projects contributes to the growing interest in ecosystem restoration funded under the authority of the 1986 Water Resource Development Act and subsequent amendments, particularly Sections 1135 (Environmental Restoration) and 206 (Aquatic Ecosystem Restoration). Most of these projects have limited budgets (<$5 million) and require cost sharing with local agencies (levee boards, flood control districts). Small restoration projects are also incorporated into individual work item plans as part of "avoid and minimize" alternatives.

The Corps uses various restoration techniques, but criteria for success are often speculative. Environmental assessment of a project is often limited to a single calendar season of sampling. Consequently, existing restoration

projects are being evaluated to describe the effects of temporal and spatial scales on benefit analysis. Data from such studies may be used to incrementally quantify benefits (Figure 1) for cost/benefit analyses. This work unit describes habitat benefits for:

- **Constructed gravel bar** - created to increase substrate complexity for benthic invertebrates and fishes. Initially sampled soon after construction (Wood, Killgore, and Douglas 1989), long-term changes in the fish community will be described and recommendations to improve design will be developed.
- **In-channel weirs** - used to maintain minimum pool elevations, prevent head-cutting, or reroute flows to former channels (Shields and Hoover 1991). Weirs stabilize channels, increase hydraulic complexity, and enhance diversity of local fish assemblages.
- **Backwater weirs** - constructed at the inlet/outlet channels of riverine backwaters to manage water levels of wetlands (Hoover, Killgore, and Konikoff 1995) and oxbow lakes (Hoover, Killgore, and Walker 1998). Weirs maintain minimum pool elevations and enhance reproduction and recruitment of fishes.

These and other techniques have been used under the Section 1135 authority to restore the structural, geomorphic, and/or hydraulic integrity of rivers and wetlands altered for flood control, navigation, or hydroelectric purposes (Table 2), and as part of the Habitat Rehabilitation and Enhancement Projects (HREP) in the Upper Mississippi River (U.S. Army Corps of Engineers 1997).

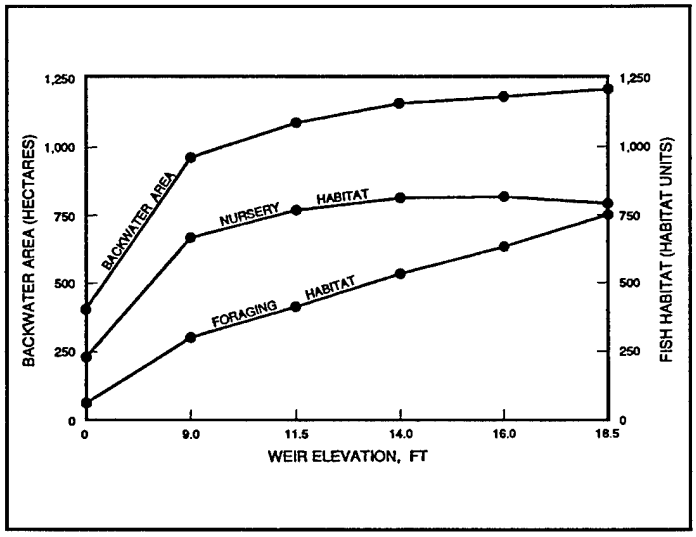


Figure 1. Incremental analysis of restoration benefits of higher water levels in Lake Whittington, an oxbow lake of the Mississippi River, associated with different weir elevations. Lake area and nursery habitat asymptoted at intermediate weir elevations and foraging habitat increased linearly. Cost per habitat unit was subsequently determined and used to select appropriate weir elevaton

Watershed-scale restoration

The Corps increasingly plans and implements projects on watershed scales. Large-scale restoration or mitigation projects funded by General Investigations, Construction General, or Operation and Maintenance funds often involve multiple restoration techniques, land purchases, and are conducted over long periods. Water allocation (e.g., instream flows, reservoir pool elevation) is the primary focus of most watershed-scale projects. Examples include proposed changes in the Missouri River Master Water Control Manual, diversion of fresh water from the Mississippi River to adjacent coastal wetlands in Louisiana, changes in water flow into the Everglades National Park in South Florida, and the Columbia River Fish Mitigation project. Some projects include structural changes

Table 2 Summary of Section 1135 environmental restoration techniques that have been completed or approved for implementation, as of May 1998, listed in order of decreasing frequency within a category*	
Type of Restoration	**Number of Projects**
Reservoirs/Lakes	
Placement of in-lake structure (trees, aquatic vegetation, artificial cover)	2
Sediment removal or abatement	2
Shoreline stabilization (rip-rap/revetment, revegetation, reforestation)	2
Rivers/Streams	
Revegetating riparian zone	9
Providing fish passage	6
Installing instream deflectors	2
Placement of instream structure (artificial and natural)	2
Restoring geomorphology (channel sinuosity, depth, width, substrate)	2
Erosion control (bank vegetation, drop structures)	1
Reaeration of tailwaters	1
Floodplains/Wetlands	
Constructing wetlands	7
Reconnecting backwaters (weirs, dredging)	4
Maintaining minimal pool elevation in oxbow lakes (weir)	1
Revegetating (plants and trees) floodplain corridors and other wetlands	1
Others	
Creating subimpoundments for waterfowl	14
Managing salinity in coastal environments	6
Managing exotic species (sea lamprey barrier)	1
* Summaries provided by Ellen Cummings, CECW-PM.	

(e.g., Missouri River Bank Stabilization Mitigation) as part of a comprehensive plan to restore aquatic habitats while maintaining flood control, navigation, and hydroelectric benefits.

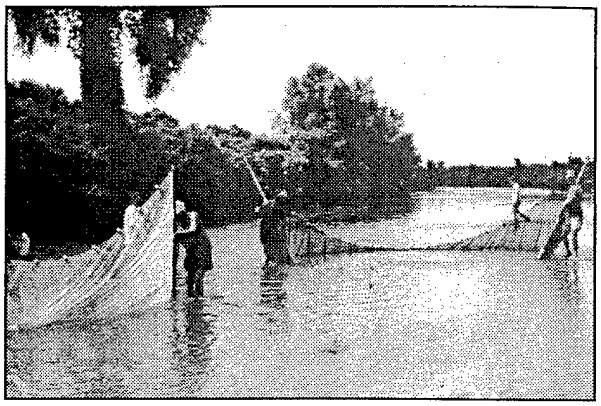
The benefits of hydroperiod management in reservoirs and river corridors are being evaluated. This approach can be used to restore large areas at relatively low cost, and has broad appeal to resource agencies and cost-sharing partners. The reservoir study (Hugo Lake, Oklahoma) was a cooperative effort among private, state, and Federal agencies to improve sportfish populations in Corps reservoirs. Such projects comply with Executive Order 12962 requiring Federal agencies to improve aquatic systems for increased recreational fishing opportunities, and follows the signing of the Memorandum of Understanding (MOU) between the Bass Anglers Sportsman Society and the Corps. The floodplain study (Cypress Bayou, Texas) is being conducted in a regulated river system that includes a wetland of international importance (Navid 1988).

✦ **Reservoir Study** - Reservoir operations affect fisheries system-wide. As water levels decline, terrestrial and aquatic vegetation are dewatered, resulting in reduction of suitable spawning and rearing sites. Rapid increases in water elevation may inundate terrestrial vegetation, but are often associated with erosion and high turbidity. A "rule curve," or set of operational guidelines on water level management, is established to meet project purposes under varying hydrologic regimes. In cooperation with the Tulsa District and Oklahoma Department of Wildlife Conservation, the

possibility of modifying the rule curve at Hugo Lake, a 5,362-ha Corps of Engineers flood control reservoir in southeastern Oklahoma, is being evaluated. The proposed modifications should benefit recruitment of sport fishes and subsequently improve angling success. This reservoir was chosen because of the availability of water that can be dedicated to habitat improvement.

Beneficial reservoir operations manipulate the onset, duration, and extent of reservoir water levels, within authorized project purposes, and generally result in strong year classes of fish, improved water quality, and the maintenance or creation of aquatic habitat. The objective is to measure fish recruitment related to pool elevations that alternate annually or biannually between normal (existing rule curve) and beneficial operations. Beneficial operations substantially increase the littoral area during spring and summer (Figure 2). Larval fish are being sampled in these flooded lands to document nursery benefits. Effects of water level management on trophic patterns are also being evaluated each year including estimates of primary productivity (phytoplankton), primary consumers (zooplankton), forage fish populations (shad), and predatory sportfish populations (largemouth bass, crappie). Economic gains of beneficial operations, measured from periodic creel surveys and increased angler activity, will be evaluated at the completion of the study.

✦ **River Corridor Study** - Junk, Bayley, and Sparks (1989) proposed the "flood pulse" concept: hydrograph peaks coupled with seasonal changes in light and temperature regulate aquatic productivity. Fish production is maximized when the onset of flooding coincides with seasonal warming and decreases gradually after maximum temperatures are obtained. Consequently, variations in flood regime differentially affect fish populations based on individual reproductive chronologies (early vs. late spawners) and habitats (channel vs. floodplain spawners) . A few recent studies have demonstrated flood pulse effects on individual species (Ross and Baker 1983; Raibley et al. 1997) or groups of species (Killgore and Baker 1996), but to date no long-term studies have been conducted in a regulated watershed and effects of hydrographic manipulations on fish communities are undocumented. Affinities for forested wetlands differ substantially among species (Hoover and Killgore 1998), such that in regulated rivers, prescribed water releases can hydrologically restore or enhance riparian and wetland habitats and ultimately determine diversity and composition of fish communities (Figure 3). A three-year study is being conducted to evaluate the feasibility of hydroperiod management in a riverine floodplain of the Cypress Bayou System in Northeast Texas that benefits aquatic species using prescribed releases from a flood control reservoir.



Larval fish are being collected under varying hydrologic regimes in the river and floodplain. Larval fish abundance is a reliable measure of potential adult recruitment. Ichthyofauna of the Cypress Bayou System is diverse (80 species), so anticipated biological benefits are substantial. Although the study is not completed, empirical relationships between larval fish abundance and hydroperiod suggest several different water release strate-

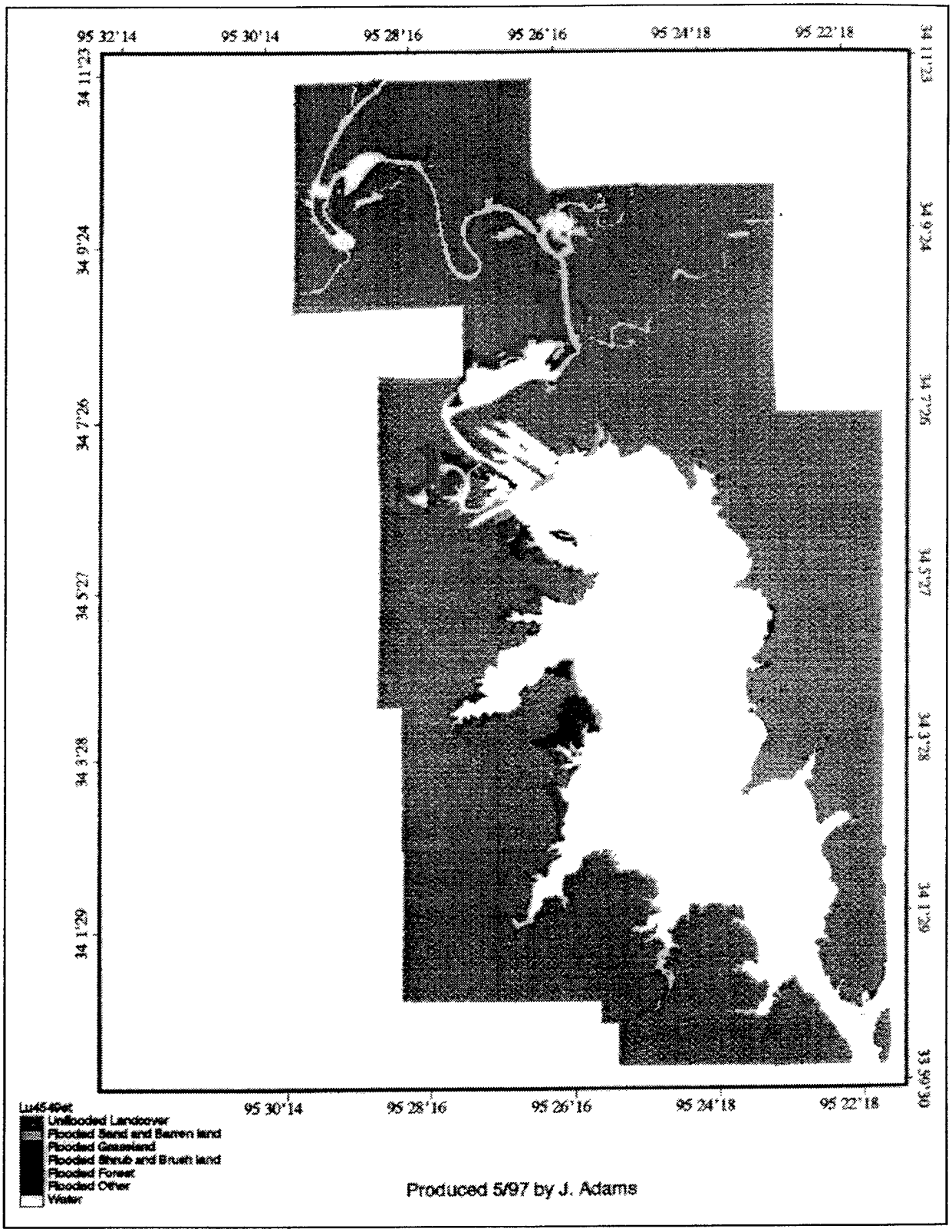


Figure 2. Geographic information system map showing flooded landcover with beneficial operations implemented. Shaded areas correspond to flooded forest, brush, and grassland that provide expanded spawning and rearing habitat

gies. Duration of flooding is important for egg incubation since eggs can be stranded and desiccated if water levels drop before hatching. Therefore, peak discharges should be maintained for the maximum period possible followed by a slow rate of decrease to prevent rapid flushing of fish from protected backwaters. If weather or water demands preclude a protracted flood, spawning chronology data suggest that a bimodal hydrograph would be functionally equivalent: one extreme peak in March-early April for early spawners (e.g., suckers, crappies) and a second reduced peak in late May-early June for late spawners (e.g.,

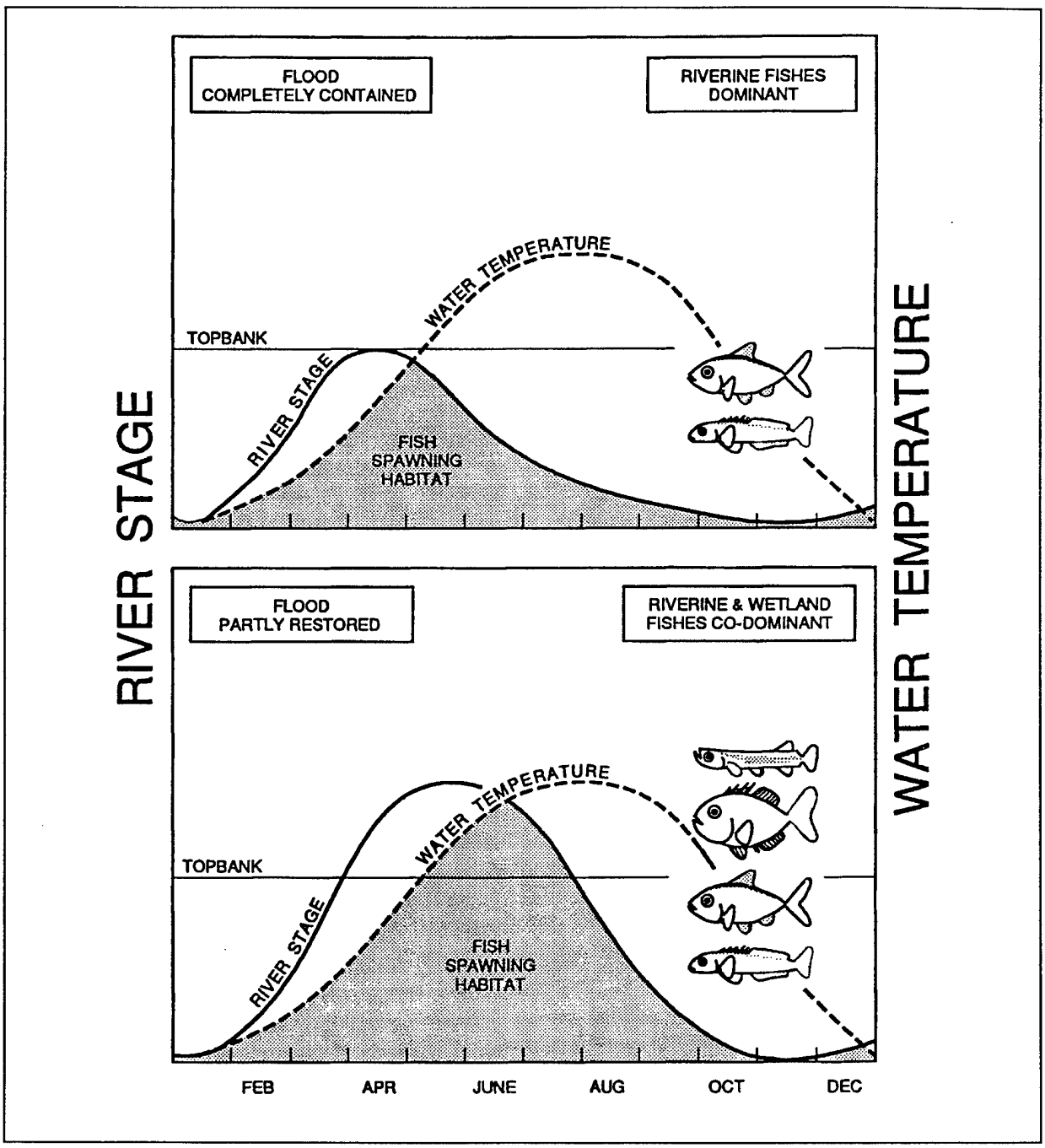


Figure 3. Restoring floods during the spawning and rearing season of fishes can increase species diversity in regulated river systems

minnows, sunfishes). Reservoir releases should also be of sufficient magnitude to connect (i.e., controlling elevation) adjacent backwaters along the river corridor. The controlling elevations of sloughs, tributary mouths, and other backwaters in Cypress Bayou are being surveyed, and major gains in wetland habitat are expected for relatively minor increases in discharge.

Summary

Since passage of WRDA 1986, the Corps of Engineers has become a major participant in restoring aquatic and wetland habitats. As of May 1998, over 125 Section 1135 projects have been proposed, 57 of which have been completed or are near completion. HREP will restore nearly 100,000 acres of river and floodplain habitat once all projects are completed (U. S. Army Corps of Engineers 1997). Habitat benefits of these projects are anticipated, although post-project data are largely unavailable.

Using adaptive management and guidance on ecosystem restoration, the Corps is placing less emphasis on a rigid project design and attempting to link small-scale and site-specific projects to an overall watershed restoration plan (Pastorok et al. 1997; Yozzo, Titre, and Sexton 1996). Water allocation is often the unifying factor, at least in regulated systems, to restore large areas at relatively low cost. Studies on the biotic response of aquatic habitat restoration will contribute to a better understanding of restoration approaches used by the Corps, and strategies to hydrologically restore reservoirs and river corridors will be recommended.

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