

# Fish Habitat Impairment in **U.S. Reservoirs**

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Throughout most of the twentieth century thousands of reservoirs were constructed to address various water-control needs. These reservoirs also provide habitat for fish, plants, and wildlife as well as recreational opportunities such as fishing, boating, and swimming. Additionally, areas surrounding reservoirs realize economic benefits from tourism, enhanced residential property values, and water supply for agricultural and industrial enterprises. Reservoirs are often dismissed as unnatural, ephemeral, and disruptive. Nevertheless, they are a product of public policy and a critical feature in our river basins. As long as society prizes their existence, they cannot be ignored if we are to effectively manage aquatic resources and conserve the biota of river basins.

## Habitat degradation patterns

Reservoirs have distinct habitat characteristics and degradation patterns due to their terrestrial origin and strong linkage to watersheds. Unlike natural lakes, reservoirs tend to have large watersheds and large tributaries because they were engineered to capture as much water as possible to serve flood control, water supply, navigation, or other purposes. This origin is manifested by relatively large inputs of inorganic and organic loads, nutrients, and even contaminants. Depositional filling (Figure 1) has effectively resulted in surface area and volume reductions, habitat fragmentation, loss of depth, and associated changes in water quality. Unnatural water level fluctuations (Figure 2) and wave action degrade shorelines that were once uplands unable to withstand continuous flooding, promoting erosion (Figure 3) and ultimately homogenization



Figure 1. Aerial photograph of the upper end of Sardis Reservoir, Mississippi, showing sediment accumulation over 7 decades (source: ©2013 Google Earth).

of once diverse littoral habitats. Well-established riparian zones and floodplain wetlands that provide key ecological services to natural lakes and the original river are mostly missing in reservoirs. Lack of woody debris deposition in the littoral zone, limited access to adjacent backwaters, and lack of seed banks and stable water levels to promote native aquatic vegetation characterize barren littoral habitats in many reservoirs (although in some cases there is excessive growth of nonnative aquatic vegetation).

As U.S. reservoirs surpass a median age of over 60 years, their fish habitats

are showing various levels of degradation. The intensity of habitat degradation varies among reservoirs due to age, climate, physiography, land-use patterns, and a multiplicity of local conditions. The extent of such problems has not been adequately documented over broad geographical scales such as the entire continental United States. This information could serve to guide research, habitat restoration, and enhancement programs and possibly to better understand the interaction among habitat problems. To this end, we surveyed reservoir managers to identify major factors degrading fish



Figure 2. Low water in Lake Travis, Texas (source: Texas Parks and Wildlife Department).



Figure 3. Erosion along barren shores of Enid Lake, Mississippi.

habitat in reservoirs of the United States, and to examine regional patterns of degradation.

### Surveying habitat degradation

We used an online survey to canvass resource managers about habitat degradation in reservoirs across the

continental United States. The survey was conducted via the host SurveyMonkey between June and December 2010, including a follow-up period during which non-respondents were contacted to encourage participation. The survey included over 50 questions recorded on a six-point Likert-type scale where 0

= no impairment, 1 = low impairment, 2 = low-to-moderate impairment, 3 = moderate impairment, 4 = moderate-to-high impairment, and 5 = high impairment. The respondents were fishery biologists charged with managing fish in a specific reservoir. Biologists ranged in time acquainted with a reservoir from 0 to 40 years (median = 11). The questions inquired about impairment to water quality and clarity, water fluctuations and flow-through, submerged structure and vegetation, littoral and riparian zones, watershed uses, and other habitat features of the reservoir.

Responses to the survey were used to create ten factors that reflected an underlying concept about habitat impairment. Each factor was assumed to be reflected by the responses to a set of questions selected *a priori*. The set of questions representing a factor was selected based on question similarity and factor analyses, and the internal consistency (i.e., inter-correlation) of the set of questions making up a factor was verified with Cronbach's alpha. The factors included connectivity (this factor integrated questions about lack of connection between the reservoir and adjoining backwaters, wetlands, and tributaries); eutrophication (elevated nutrient levels and algae); land use (excessive agriculture and livestock in watershed); degraded littoral areas (excessive shallows, mudflats, disturbed riparian); macrophytes (excessive macrophytes and non-native plants); siltation (excessive accumulation of sediments, shore erosion, substrate homogenization); structural habitat (lack of submerged structures or aquatic plants) (Figure 4); water quality (stratification, turnover, variable dissolved oxygen, pollution, contaminants); and water regime (low retention, mistimed fluctuations, extreme drawdowns). To score a factor we averaged the values assigned by the respondents to the set of questions making up the factor. A reservoir was classified as impaired in regard to a factor if the average score for the factor was 3 or higher.

### And the survey says...

We received 1,599 total responses and retained 1,278 for analyses. The reservoirs excluded were outside of the



Figure 4. Aquatic vegetation plantings in Smithville Lake, Missouri provide needed fish habitat that was lacking previously (source: U.S. Army Corps of Engineers).

study's scope (<100 ha or natural lakes fitted with a dam to control storage) or included too many missing responses. Considering the National Inventory on Dams database ([www.nid.usace.army.mil](http://www.nid.usace.army.mil)) identifies 4,300 regulated water bodies  $\geq 100$  ha, and some of these are probably natural lakes with dams, we estimate that our analyses are based on about 30 percent or more of reservoirs  $\geq 100$  ha in the U.S.

The percentage of impaired reservoirs varied depending on factor. About a third of the sample reservoirs (34 percent) showed no impairment (i.e., mean factor score < 3) on any factor. No reservoir was impaired in all ten factors and over 80 percent of the reservoirs showed impairment on only three or fewer factors (Figure 5). The most common impairments were lack of structural habitat (36 percent of the study reservoirs), siltation (27 percent), land use (23 percent), and eutrophication (20 percent). The least common impairments were water quality (2 percent) and water regime (9 percent). Factors with intermediate levels of impairment included turbidity (17 percent), connectivity (15 percent), degraded littoral area (14 percent), and excessive macrophytes (13 percent). To examine how impairment may change

over the continental United States we analyzed reservoirs according to ecoregions (Figure 6). The ecoregions we used are also used by the U.S. Environmental Protection Agency in

its Wadeable Streams Assessment. We confirmed in a separate analysis that this framework provided the greatest differentiation in impairment among geographical regions when compared to four other spatial frameworks. Overall the least impaired reservoirs were in the Northern Appalachian (NAP), Southern Appalachian (SAP), and Western Mountains (WMT) ecoregions. The most impaired reservoirs occurred in the Temperate Plains (TPL) ecoregion, leading the nation in six out of ten impairment factors (Figure 7). The importance of impairment factors differed among ecoregions. Thus, while excessive siltation was a concern in over a third of TPL and Southern Plains (SPL) reservoirs, this factor afflicted less than two of ten reservoirs in most other ecoregions. Water regime issues were more relevant in western than eastern reservoirs. Water quality exhibited low and similar levels of impairment across ecoregions. Macrophytes and invasive plant species were a concern in about a third of CPL reservoirs, but this factor afflicted less than one of ten reservoirs elsewhere. Structural habitat (Figures 8 and 9) afflicted over 20 percent of reservoirs in all regions, except Upper

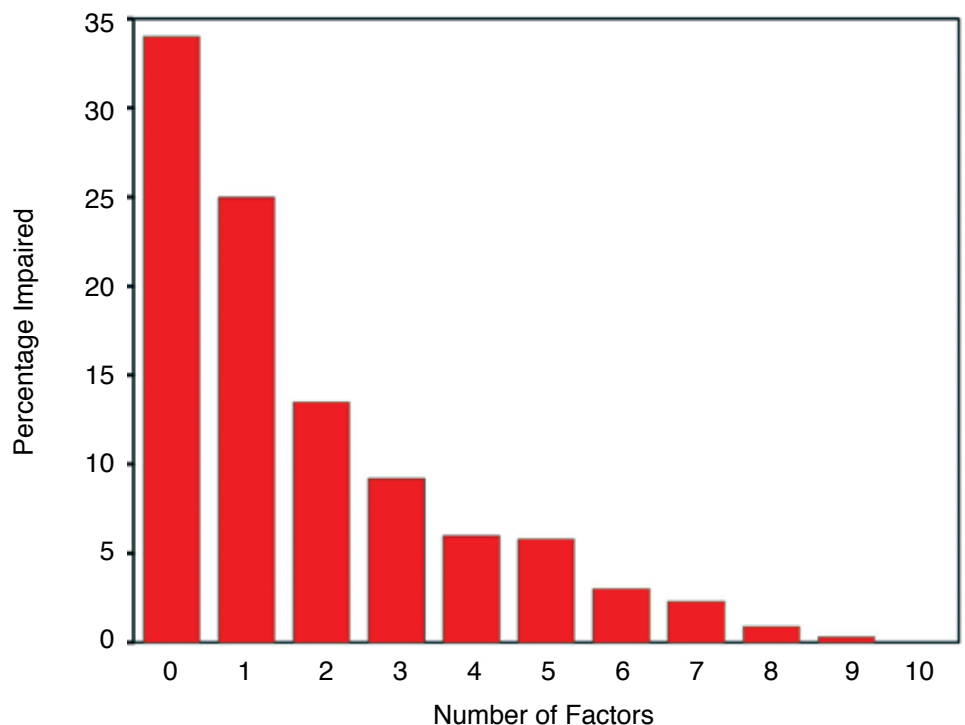


Figure 5. Percentage of impaired reservoirs relative to number of factors. About a third of the sample reservoirs showed no impairment on any factor. No reservoir was impaired in all ten factors, and over 80 percent of the reservoirs showed impairment on only three or fewer factors.

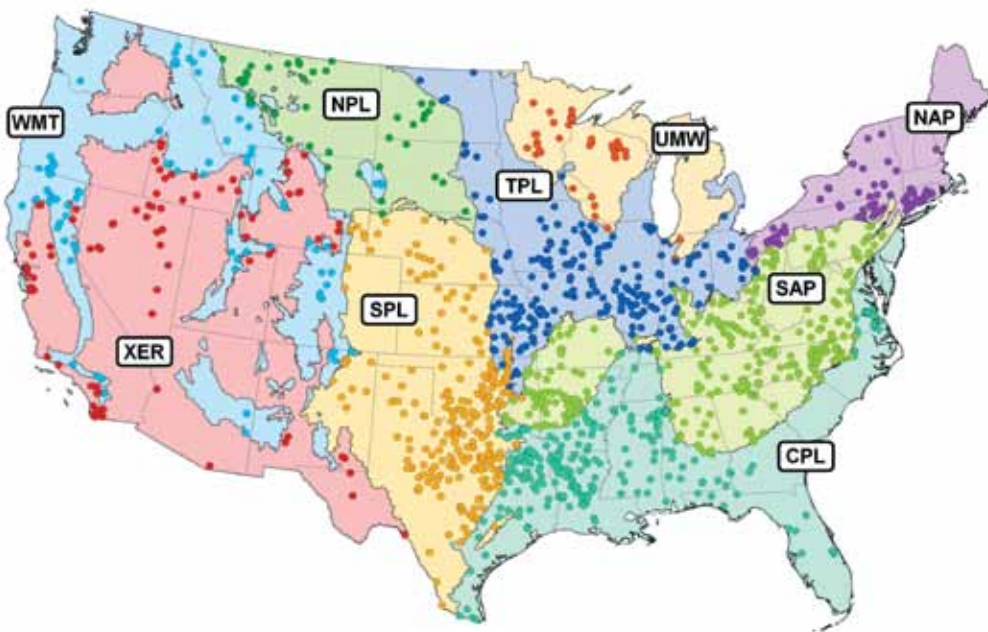


Figure 6 (at left). Wadeable Streams Assessment ecoregions of the conterminous U.S. identifying position of study reservoirs included in this study. Regions include Xeric (XER), Western Mountains (WMT), Northern Plains (NPL), Temperate Plains (TPL), Southern Plains (SPL), Upper Midwest (UMW), Coastal Plains (CPL), Southern Appalachian (SAP), and Northern Appalachian (NAP).

Midwest (UMW). Regional differences and patterns in habitat impairment factors were apparent (Figure 7).

**Survey reliability**

Our results were based on an opinion survey. There are always uncertainties associated with relying on professional judgment, even if the opinions represent those of informed biologists. Small differences in opinion could lead to unequal scoring for reservoirs with essentially equal degradation status. Undoubtedly there were differences in perception about intensity of degradation among respondents. To minimize this perception error and promote consistency we provided, along with each question, expanded descriptions of what we meant by impairment. Upgrading these judgment scores with an objective on-site quantitative survey may increase the exactitude of habitat scoring and improve the capacity to evaluate sources of degradation. However, such gains are likely to come at a substantial rise in cost without corresponding increases in evaluation accuracy.

**Reservoir habitats shaped by internal and external events**

The survey focused on ten major factors representative of fish habitat degradation in reservoirs. Relevance of the factors varied regionally across the United States, reflecting differences in climatic conditions, landscape composition, and watershed disturbances associated with land-use practices. These factors and their geographical

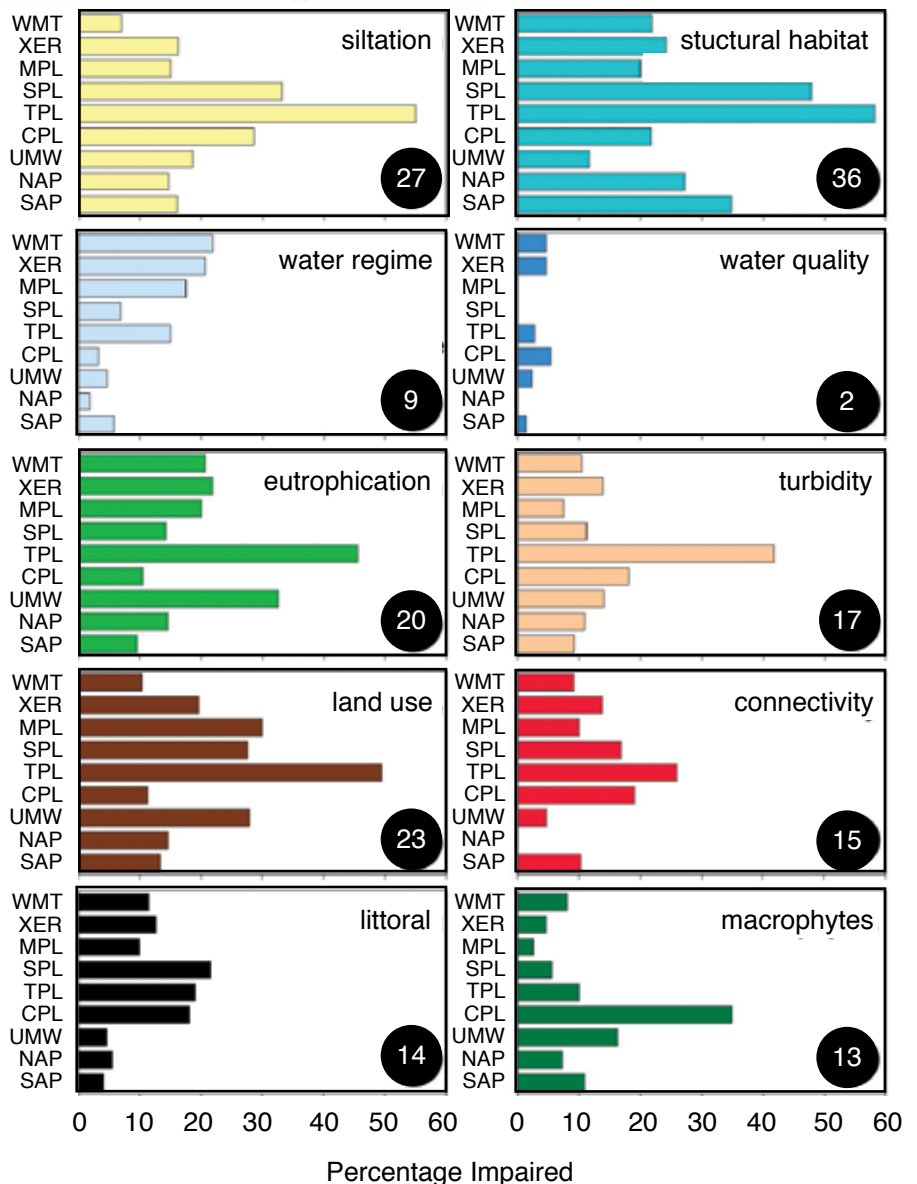


Figure 7. Percentage of impaired reservoirs relative to the ecoregions identified in Figure 6, and relative to the ten impairment factors. The number encircled represents the nationwide percentage of impaired reservoirs relative to a factor.



Figure 8. Installing artificial fish habitat in Pine Creek Lake, Oklahoma (source: Oklahoma Department of Wildlife Conservation).



Figure 9. Barren littoral zones often prompt management agencies to add natural and constructed structures to increase habitat diversity (source: Tennessee Wildlife Resources Agency).

distribution reveal the current state and spread of existing reservoir degradation. The survey pointed to a broad guiding

principle for developing strategy to enhance, maintain, or restore reservoir fish habitats. Specifically, reservoir fish

habitats are degraded by events inside and outside the reservoir. Thus, appropriate management actions would address the causes of habitat degradation throughout a reservoir's watershed, not just within the reservoir. Within this framework, habitat management in reservoirs becomes a collaborative effort among various authorities and interests responsible for the watershed that ends in the reservoir.

Extending the scale of involvement outside the reservoir can enhance the manager's ability to impact reservoir habitats, and can also increase the effectiveness of traditional in-reservoir habitat management measures. Given a potentially overwhelming expansion in management activities, there is a need to also expand the level of human resources involved in reservoir habitat management by partnering with state and federal agencies, local governments, universities, non-government organizations, corporations, and the public. These partnerships can provide the organization needed to plan, fund, and complete habitat restoration work, and may give reservoir managers the influence they may not have outside the reservoir. Over the last two decades watershed management organizations of local and basinwide scopes have shown unprecedented growth across the United States. As partners in these organizations, managers are responsible for demonstrating the linkage between the reservoir and the landscape, and showing how specific watershed actions may affect reservoir habitats. Within this environment, the traditional control exerted by reservoir managers is diminished, but the potential to bring big, long-lasting changes to reservoir environments and biota is increased.

Results from our study also indicate that the reservoir health and management would benefit from new policy aimed at the protection, restoration, and enhancement of reservoir habitats within the context of the ten factors. These factors sum up the bulk of fish habitat problems experienced by reservoirs in the United States. Undeniably there are additional habitat issues that may have small or large effects at local or regional levels (e.g., heated effluents, acid mine drainage). However, our data suggest that national efforts to engage habitat woes by developing policy for assessment

methodology, rating and classification of degradation, and management of habitat degradation in U.S. reservoirs could justifiably focus on these ten factors.

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