Comments on the July 2013 Draft Environmental Impact Statement for the St. Johns Bayou and New Madrid Floodway Project
Fisheries Impacts and Mitigation

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1. Introduction

I recently retired as Research Director of the National Great Rivers Research and Education Center in East Alton, Illinois. Currently, I am a Research Affiliate of the Illinois Natural History Survey, a unit of the University of Illinois at Urbana. My research specialty is big river ecosystems and the freshwater fish that use them. I have published 58 peer-reviewed articles related to these subjects, including 36 articles related to the Mississippi River and its tributaries. I previously directed the Large River Research Program of the Illinois Natural History Survey and the Water Resources Center at the University of Illinois at Urbana-Champaign. A major focus of my research has been the function of floodplains for Mississippi River system fish populations. I have served on three panels established by the National Research Council of the National Academy of Sciences. One panel focused on the Restoration of Aquatic Ecosystems, which included the Mississippi River and other large floodplain-river ecosystems. Its report discussed the importance of floodplains, and the potential value of floodplain restoration, and is directly relevant to the project at issue here. A second panel evaluated water resource planning policies and procedures of the U.S. Army Corps of Engineers. A third panel evaluated the potential for establishing a peer-review system for the U.S. Army Corps of Engineers. Because of these other panels, I am familiar with much of the Corps of Engineer's evaluation techniques and processes. A copy of my curriculum vitae is attached as Exhibit A.

I have reviewed substantial portions of the new draft Environmental Impact Statement. Previously I had reviewed substantial sections of earlier draft environmental impact statements and final environmental impact statements for this project. I have reviewed various Fish & Wildlife Service Fish & Wildlife Coordination Act reports, different variations of the fisheries analysis, mitigation analyses and other documents provided by the Corps. I have also reviewed two reports commenting on this project by Dr. Robert Sheehan filed with comments of Environmental Defense, as well as the report prepared by Dr. Sheehan under contract to the Corps of Engineers dated July 1998 entitled: St. Johns Basin and New Madrid Floodway Fisheries Survey: Final Report ("Sheehan 1998 Report"). I have also toured the project site and discussed the project with Dr. Paul Wills, who worked with Dr. Robert Sheehan, a fish biologist who was originally hired by the Corps of Engineers to analyze fisheries impacts of the project.

I have provided comments on early drafts and the previous final Environmental Impact Statement for this project. These comments go into substantial detail about why this project will have irremediable and harsh impacts on Mississippi River fisheries. The project is substantially unchanged since these earlier comments, with the main changes being that gates will not be closed and pumps activated until water levels reach very slightly higher elevations. These modest changes do not fundamentally alter my conclusions.

In fact, most of the proposed mitigation would now rely on forms of mitigation that earlier version of the DEIS recognized were problematic. Together, nearly all the fish mitigation (e.g., 90% during the mid-season), would be provided by Big Oak Tree State Park, batture land reforestation (land between the levies), and construction of artificial "floodplain lakes" (e.g., "ecologically designed borrow pits"). These forms of mitigation were considered in the earlier versions of the EIS but either rejected or greatly limited, and there is no new analysis to justify the changes in position. I summarize here:

New Mitigation	Previous Position	Comments below
Big Oak Tree State Park and Surrounding Reforestation	Earlier versions recognized that fish access to Big Oak and surrounding area was sufficiently problematic that it should not be counted for fish mitigation	Discussion below indicates that Big Oak and surrounding areas are at elevations at which gates must be closed before they are inundated, blocking fish access
Batture Lands	Although previous versions reserved the possibility of some use of batture lands, they recognized that mitigation in these lands had shortcomings.	Likely high velocities and low temperatures during flooding, as well as limited complexity of habitat mosaics, preclude uses of such sites for equivalent spawning and rearing habitat
Borrow pits and floodplain lakes	Corps agreed with interagency science committee that these habitats should only be used to offset impacts on other floodplain lakes.	New evaluation system accords even small areas of restored lakes inappropriately vast habitat value and habitat will be used to offset lost seasonal flooding of forests, agricultural land and other habitats

The new draft EIS continues to claim that these impacts on fish will be fully mitigated. In this statement, I explain why that is not the case: first, because the detrimental impacts of the project are underestimated; and second, the effects of mitigation are overestimated. There are several reasons for the problematic estimates, which I discuss below: (1) the closure of the New Madrid Floodway (hereafter, Floodway) will impede fish access to the floodplain to a degree not fully accounted for in the analyses of impacts and mitigation; (2) the impact analyses have additional problems; (3) the proposed mitigation is overvalued and often invalid; and (4) there are broader scientific flaws with the use of the fish model to analyze impacts and mitigation.

2. Fish Access

2.1 Importance of fish access to spawning and rearing sites on the floodplain.

A principal driving force for Mississippi River ecology was the annual flooding of a massive floodplain, which provided Mississippi River fish access to spawning and rearing grounds. According to estimates, 93% of this floodplain on the lower Mississippi River has been lost. That makes remaining habitats of this type extremely valuable. The combination of large contiguous areas, rapidly warming areas, diverse areas, productive areas, areas with slack water, and areas that meet all these conditions even in the largest

floods give the remaining open floodplain extraordinary value. The Floodway is one of the few large open floodplains that remain, and the only one remaining in Missouri.

For fish to take advantage of the Floodway for annual rearing and spawning, they must have access. One of the values of the New Madrid Floodway is that it provides an open quarter-mile gap for fish to access the Floodway. The project would greatly reduce that access by building a levee closure and gate. The impacts on access can be divided into two categories. First, even when the gates are open, fewer fish will move through the long dark, and narrow culverts than would move into the Floodway through an open river and floodplain. Second, the gates will often be *closed*, and they will be closed particularly during periods of expansive flooding. No fish will then move between the river and the floodplain. That is particularly important because most of the fish that access the Floodway only do so during their specific portions of the overall spawning and rearing periods; they seek to access the Floodway only at specific times when they need this function cued by such actions as certain water temperatures and rising water levels, and if the gates are closed at these times they cannot use the Floodway. In addition, not all fish will be prepared to move into the Floodway at the same time, and so closed gates during much of the spawning and rearing period will block fish access even if a few fish can gain entry at other times.

2.2 Fish access analysis ignores impact of closing the gates whenever extensive habitat would otherwise be available.

First, assuming no other problems with data or methodology, the fish access factor is calculated in a way that assumes the gates are open 100% of the time. In other words, it purports at best to calculate the impacts on fish access of replacing a quarter-mile-wide gap with four culverts. It does not address the issue that access will be blocked much of the time by closed gates.

The fish access factor calculation starts with a study for a single year that tagged a total of 85 fish, placed them below the St. Johns Bayou culverts, and determined how many of them moved through the culverts to the floodplain in the Bayou. Of all the tagged fish, 34% accessed the Bayou. In contrast, *all* (100%) tagged fish for the New Madrid Floodway entered that Floodway. Rather than using 34%, the Corps then determined that the floodplain gates were closed roughly one third of the time, and so adjusted the figure to 52%, on the theory that this percentage of the fish would have accessed the floodplain if the gates had been open the entire time. This point is critical. It means that the methodology is designed to estimate fish access assuming the gates are open all the time. This fish access figure does not account for the impacts on fish access of closing the gates. As a consequence, the impacts of the project on fish are underestimated, and the value of mitigation is overestimated, as described next.

The fish access factor is further increased to 73% based on an averaging of impacts on individuals and species. I discuss below why that incorrectly analyzes the fish access impacts even when gates are open.

2.3 Failure to account for lack of access results in underestimation of impacts.

For example, 1951 had flooding at 289 feet or above for nearly all of April, making it an excellent flood year for fish that spawn in mid-season, with access to more than 17,000 acres nearly that entire month. However, flood levels were above 286 feet on April 1st, so if the the preferred alternative (3.1) had been in effect in 1951, the gates would have been closed the first day of the mid-spawning season, and those gates would have to have remain closed the entire month and until the middle of the first week of May. That means that for the bulk of the mid-season, there would have been no fish access. For the remaining ten days of the mid-season, the gates would have been open but water levels would have remained at 282 and 283 feet, flooding at most 1,764 acres. Thus, for a short term, fish might have had at least have some chance of access but could use little habitat. Moreover, floodplain spawners usually move onto the floodplain with rising water levels, so with water levels receding rapidly during the relatively brief period when gates were open, there would probably be little movement into the floodplain. Overall, 1951 is a year that gate closure would have barred nearly all spawning or rearing use of the floodway during the middle of the spawning season although the Corps methodology would recognize the floodway as providing abundant habitat.

The year 1951 is not an anomaly. In many years in which there was flooding in the middle of the spawning season (1 April to 15 May), the gates would have been closed even before the mid-season started.

- For example, there was persistent flooding in 1952, but the gates would have been closed until the last few days of the mid-season, and only opened when water would be rapidly rushing from the Floodway.
- In a year like 1944, the gates would only be open for roughly half a week. Although flood levels in 1944 were high enough to have created large areas of habitat throughout the entire mid-season, the gates would have been closed most of the time.
- In a year like 1945, the gates would have been closed from April 1st until roughly May 10th and therefore only open for a few days in the mid-season and only when flood levels would be low.
- In a year like 1948, the gates would have been closed during an otherwise extensive habitat year from before the mid-season until nearly the end of the first week of May, virtually the entire fish spawning season. While the gates would have been open the final week, there would have been almost no habitat because the water would have receded.
- In a year like 1973 with extensive flooding throughout the entire mid-season, the gates would have been closed 100% of that mid-season.

These problems of fish access are at least as pronounced in the late season as for the mid season. The late season is a six-week period that extends from May 16th through June 30th. According to the gate closure rules, the gates must be closed above 284 feet in the last two weeks of May and at 278.5 feet in June (DEIS:Table 2.10, p48). At 278.5 feet, there could be no more than a few hundred acres of flooded habitat. Late season flooding is generally less extensive than during the mid-season. This rule means that throughout two thirds of the late season, the gates will never be open when there is more

than a trivial area of fish habitat, and they will rarely be open when there is extensive habitat even in the first two weeks. A year like 1974 would be an example where there was extensive flooded habitat throughout the entire late season without the project, but with the proposed project in place the gates would have been closed 100% of that year. Yet none of these impacts of gate closure are accounted for.

In summary, the impacts of the project are underestimated and the central issue remains just as Judge Robertson pronounced in his opinion: "[T]he need to keep the gates closed when water levels reach certain heights essentially guarantees that in years with habitat, there will be little or no fish access to the sump area during the mid-season; and in years with access, there will be little or no habitat.". Opinion in Environmental Defense et al. v. U.S. Army Corps of Engineers et al., Civil Action No. 04-1575 (D.D.C. September 13, 2007), p. 14.

2.4 Overestimation of fish access score even when the gates are open:

In addition to ignoring gate closure, the DEIS also overestimates the fish access when the gates are open. From its analysis of 85 individual fish, the Corps determined that 52% of the fish would access the floodplain if the gates were open year round. That 52% should therefore be the maximum fish access score for this period. However, the Corps also determined that for twelve of thirteen fish species examined, at least one individual accessed the floodplain. That implied to the Corps that 93% of fish species would access the floodplain (Appendix G Fisheries P. 37) The DEIS then uses that figure to increase the fish access score to 73% by taking the average of 93% and 52%.[1]

This analysis makes no biological sense. If, as the Corps concludes, some species of fish will not make it into the Floodway if the project is built, that is a reason for further decreasing, not increasing the individual fish access score. I believe the loss of habitat for individual species entirely should count for a great deal, for reasons I discuss more below. But even if that only counted proportionately, the appropriate mathematical adjustment would be to reduce the fish access score by the percentage of species that would not make it into the Floodway, here 7%.That would make the fish access score when the gates are open 48%. Even this adjustment understates the significance of the fact that some species may not be able to access the floodplain at all through gates and culverts as operated according to the project plan.

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[1] The access score of 52% was itself increased by averaging the actual ingress value of 34% (29 of 85 individual fish succeeded in moving through the culverts into the Bayou) with the egress value of 100% (all 11 fish placed upstream of the structure in the Bayou succeeded in exiting the Bayou through the culverts, according to page 37 of the Fisheries Appendix G). Ingress and egress should be separated because in the year the study was done, the direction of water flow through the culverts at the time the fish entered or left could have assisted some species. Also, it is important to know whether man-altered habitats are population sources or sinks. If more individuals of a species exit the habitat than entered, then the habitat is a population source. If more enter than exit, then the habitat is a population sink. My comments assume that the Corps used the 73% figure.

To see why it is invalid to average the percent species and the percent of individuals that accessed the floodplain to determine an access factor, I use a simple analysis. Imagine that only 1% of all individual fish were able to move through the gates when open, but that included 100% of all species. Under the approach now in the DEIS, the fish access score would be 50.5% even through the presence of the culverts would block 99% of all individual fish.

This failure to account properly for fish access problems leads to an underestimation of project impacts.

2.5. Failure to account for lack of access results in inadequate estimation of project impacts

According to the DEIS, even after the project is built, the Floodway will continue to provide 2082 annual aquatic habitat units (AAHU) in the early spawning season, compared to 3249 today, maintaining two thirds of its early season habitat value. For the mid spawning season, the comparable figures are 1668 AAHU compared to 3,279 under existing conditions, essentially half the present habitat value, and for the late spawning season, 884 of the 1811 present AAHU in the late season, also essentially half of its present habitat (49%). (These figures are all from Table III-3 of the Fisheries Appendix G, pp. 39-40.) If for no reason other than the enormous reductions in fish access, these figures are great underestimates of the reduction in fish habitat, as discussed next.

I here provide one alternative numerical estimate of the fish access problem. Dr. Amy Lerner, a geographer at Princeton University, used Corps-generated water level data (the data shown graphically in the hydraulics appendix), to calculate the percentage of days in each fish spawning and rearing season when (1) inundation would occur at or above 280 feet and (2) river gates would be open. For river gates to be open, inundation levels would have to be below 286 feet in March (the early season); below 286 feet from April 1st to April 15th and below 284 feet from April 16 through May 15th (the mid-season); below 284 feet from May 16th through May 30th and below 278.5 feet from June 1 through June 30th (the late season). We used 280 feet because only minimum habitat would be flooded below 280 feet, that is the lowest elevation for which the Corps provides data on habitat in the New Madrid Floodway, and even if fish could access areas below 280 feet, they would find minimal habitat. It is important to recognize that once the gates are closed, fish lack access not only to areas above these elevation levels (e.g., 286, 284 and 287.5 feet, depending on the spawning season) but to habitat below these elevation levels as the gates are located and closed far below 280 feet. Lerner's analysis using the R statistical program is that the gates would be open when water levels are above 280 feet only 45.5% of the early season; 32% of the mid-season and 14% of the late season. Over the entire three seasons, the gates would be open 32% of the days that water levels are above 280 feet.

The figure of 32% still significantly and generously overstates fish access for two reasons. First, it treats a day of fish access when water levels are merely at 280 feet, when only 519 acres would be flooded, as equivalent to a day of fish access when water levels are at or above 286 feet, when at least 5,282 acres would be flooded. Many of the

days when gates would be open and water levels are above 280 feet are days when elevations are much closer to 280 feet. Second, many of the days gates are open with water levels above 280 feet occur at the end of each fish spawning or rearing season when levels are receding from higher elevations. Fish could only then access the floodplain if they fought against the currents and if so, only for a handful of days while the habitat remained flooded. The assumption of potential fish access in these open gate days is therefore generous.

A composite fish access factor would therefore be the percentage of days with gates open (32%) multiplied by the fish access factor for when gates are open, which we indicate above should be 48% if one relied on the Corps data, for a composite fish access factor of 15% (32% multiplied by 48%).

If one applies this more accurate, but still generous, fish access factor to the habitat the DEIS claims will remain in the New Madrid Floodway, the additional loss of habitat is as follows

Fish Spawning and Rearing Season	Claimed AAHU With 73% Fish Access Factor (Table III-3 Appendix G	AAHU With Adjusted 15% Fish Access Factor	Additional Losses
Early	2081.54	437	1645
Mid	1668.04	350	1318
Late	883.65	186	698

I wish to emphasize again that the use of the 15% access factor is generous for the reasons noted above.

2.6 Failure to account for lack of access results in large overestimates of project mitigation.

The lack of fish access also leads to gross overestimates of the value of fish mitigation. I address different components of that mitigation below.

Big Oak Tree State Park. Efforts to regenerate roughly 1,800 acres of forest and to maintain water levels higher in Big Oak Tree State Park by building levees around it have been part of the mitigation plan for at a least the last two final and draft versions of the DEIS. In all these versions, the Corps neglected to claim fish mitigation credit for the Park because it recognized the difficulty of fish access. In this DEIS, there is no explanation of how these technical problems would be overcome, but the DEIS claims the same fish access as for the remainder of the New Madrid Floodway. As shown in Table 23 of the Fisheries Appendix G reproduced below, when combined with the claimed increase in flooding, Big Oak Tree would provide 914 AAHU in the early season out of 1729.5 needed; 889.5 out of 2061.1 needed in the mid-season, and 577.3 out of 1,165.8 needed in the late season. Big Oak Tree Park therefore provides a majority of needed mitigation in the early and late seasons and 43% of mid-season mitigation.

Table 23. Fisheries compensatory mitigation benefits (AAHU) in the St. Johns Bayou Basin.

Mitigation	Acres	Early	Mid	Late
Impacts		-386.6	-441.3	-245.3
BLH Restoration < 285'	400	40.7	41.9	15.4
BLH Restoration < 5-year	1,816	124.2	127.9	50.1
Riparian Buffer Strips	47	5.9	5.6	1.8
Ecologically Designed Borrow Pits	387	268.4	268.4	268.4
Net Gain		52.6	2.5	90.4

Table 24. Fisheries compensatory mitigation benefits (AAHU) in the New Madrid Floodway.

Mitigation	Acres	Early	Mid	Late
Impacts		-1,729.5	-2,061.1	-1,165.8
Big Oak Tree State Park and Surrounding Area	2,800	914.0	889.5	577.3
BLH Restoration < 285'	387	61.7	70.5	0.0
BLH Restoration < 5-year	1,970	179.3	84.7	0.0
Batture Land Reforestation	3,050	692.4	692.4	310.2
Ecologically Designed Borrow Pits	60	41.6	41.6	41.6
Floodplain Lake	432	326.8	326.8	326.8
Net Gain		486.2	44.4	90.1

The above Tables are from Mitigation Technical Appendix R, p. 40.

The proposed mitigation includes an additional gate and canal to get water directly to Big Oak Tree State Park from the Mississippi River to the south. However, it does not propose to build large levees to line that canal. As a result, to prevent water from overflowing into the surrounding lands, the gates to that canal will also have to be closed according to the same flooding elevation schedule as the principal gates to the New Madrid Floodway.

According to information in the Big Oak Tree State Park Natural Resource Management plan provided by the U.S. Fish & Wildlife Service, land in the Park is between elevation 290 and 292. These elevations are above those at which the New Madrid gates must be closed throughout the entire fish spawning season, which are 288 feet in March, 286 feet in the first two weeks of April, 284 feet from April 16th through June 1st, and 278.5 feet in June. These elevations mean that the gates will be closed 100% of the time that water levels are high enough to reach Big Oak Tree State Park.

In addition to Big Oak Tree itself, the mitigation plans 1,800 acres of reforestation around the Park. But according to the DEIS, these potential lands range in elevation from 285 to 295 feet. In other words, nearly all of this land is above the 286 gate closure level that is the highest level in both the early and mid-season, and all is above the 284 foot level that is the highest gate closure level for the last four weeks of the mid-season and all of the late-season. The only time in the mid-season that the gates would be open and flooding could occur in the absolute lowest of these lands are the few days when water levels are at or above 285 feet, but below 286 feet. Even if fish accessed these restoration lands at that time, once the gates were closed at 286 feet, no more water could enter the Park and the only habitat available would be only that small portion of the restoration sites roughly at 286 feet. The land in the Park is above 290 feet and would be unavailable to fish at a water elevation below 286 feet.

There would be even further problems in getting fish to Big Oak Tree State Park. At a very minimum, no water could be allowed into the Park from the river during the fish spawning and rearing seasons without flooding adjacent lands. However, the plan somewhat vaguely calls for maintaining water levels longer in the Park than at present. To do so, a set of secondary gates to the Park would have to be closed to keep the water in. That would prevent a further impediment to fish access even if the gates to the Floodway were open.

More broadly, I cannot understand how the Corps expects ever to get water to the Park from the river. According to the DEIS, gate closure is supposed to occur even outside the fish spawning and rearing season at 288.5. That would only allow water to enter the Park from the river up to that elevation. Higher water levels in the Park would have to result from interior rainfall. That may occur, and in fact, the primary "benefit" for extended flooding of the water control system is likely to be from this interior rainfall (or possibly if the Corps later decides to add pumps). But that source of water would not permit fish access.

The DEIS claims that there would be fish access because "water would be flowing into the basin during many open-gate periods," p. 176, but those periods would be outside of the fish spawning and rearing seasons. It is not plausible to conclude from this overview that Big Oak Tree will provide anything more than negligible spawning and rearing habitat if any.

Five-year Forest Restoration Lands . The DEIS also proposes to reforest 1,970 acres of forest below the five-year flood elevation line post-project. According to page C-6 of the hydraulics appendix, that would be 288.7 feet in the New Madrid Floodway. That is distinguished from the two-year flood elevation line of 287.6 feet and other lands that the DEIS proposes to reforest at 285 feet. Presumably therefore, these lands will be all or at least predominantly above 285 feet and up to 288.7 feet. Again, according to the DEIS, the gates will never be open when any lands above 286 feet will be flooded during any part of the spawning and rearing season. Even if some lands are between 285 and 286 feet, they will never be flooded for two thirds of the mid-season and all of the late season;

and they would only have fish access in those extremely few days when flood levels were over 285 feet but below 286 feet. In short, these lands will have little to no fish access.

285 Foot Elevation Forest. The mitigation would include 387 acres of forest restoration at 285 foot elevation. Again, fish would face closed gates whenever habitat enhanced at this elevation would be flooded during two thirds of the mid-season and all of the late season, and would only be able to access this habitat during the early season and first third of the mid-season during the few days when inundation levels are between 285 feet and 286 feet.

In short, the DEIS relies heavily for mitigation on reforestation and other changes within the New Madrid Floodway, but these sites will be located at 285 feet at the lowest elevation and generally higher. Although project areas below 285 feet might have some reduced fish access if the project is built, these mitigation sites would have almost no fish access when flooding is actually occurring during the spawning and rearing seasons. The only mitigation sites that would not have these fish access barriers are those in the batture lands. I explain later why those mitigation sites are inappropriate for separate reasons.

2.7 **Scientific limitations of fish access analysis even in open-gate periods**

All of the above discussion takes at face value the adequacy of the scientific analysis of the extent to which fish will move through open culverts. In fact, for several reasons, these analyses do not meaningfully establish the claims that 52% of fish will make it through open culverts.

- First, nearly all the fish studied were mid-season fish. No early season fish were studied, and only one late-season fish was studied during the late season (channel catfish, Table II-1 p. 20 Fisheries Appendix).
- Second, the tracking of individual fish occurred only one year, with a small number of fish, and a restricted number of species. There were 32 smallmouth buffalo, 14 bigmouth buffalo and 18 white bass tagged, but only 1 to 7 individuals of 11 other species were tagged. (Table II-1 p 20 Fisheries Appendix).

The limited number of species analyzed is particularly concerning because fish behaviors are very different and all of the species analyzed were large-bodied fishes, presumably because of the problems of putting transmitters on small fishes. The extremely limited sampling simply cannot establish the degree of fish access claimed.

In addition, data gathered by Robert Sheehan suggests that the 7% reduction in species access is too low. In sampling done in both basins by Dr. Sheehan for the Corps, he found young-of-the- year fish from only 11 species in the St. Johns basin compared to 24 different fish species in the New Madrid basin. The fact that St. Johns also has local stream fishes implies that even that figure probably underestimates the number of species coming through the river gates.

This insufficient understanding of how many fish will enter the Floodway when gates are open has important implications. First, assuming that authorization of the project

requires an affirmative judgment that mitigation fully offsets project impacts, insufficient evidence makes such a judgment unjustified. Second and more fundamentally, the science of analyzing impacts and mitigation is based on the understanding that much remains poorly understood of the complex combination of attributes of aquatic ecosystems that fish and other species rely upon. As a result, the science has recognized the importance of maintaining natural hydrological processes and complexity, and an obviously important hydrologic factor is open fish access. The scientific principles that have emerged therefore emphasize the maintenance of these factors.[2]

2.8 A Possible Major Conceptual Error

If this project is not built, the habitat available in the New Madrid Floodway will continue to be accessible to river fish during floods. The impact of the project, under the logic of the fish model, would therefore start with total fish habitat units under existing hydrologic conditions. It would then subtract the habitat under proposed Alternative 3.1, which would be calculated as the inundated habitat available (average annual habitat units for each season) multiplied by the fish access factor (73%). The difference is the loss of accessible fish habitat attributable to the project, which should be mitigated.

On page 32 of the Appendix G Fisheries, the Corps states that project impacts were calculated assuming that "future without project" conditions were also reduced through multiplication of the "fish access reduction." [3] That would be an obvious mistake. Taking this language at face value indicates that the Corps improperly reduced its estimation of the project fish habitat available without the project by 27%. That would in turn mean that fish impacts were underestimated as follows: early season (877 AAHU); mid-season 885 AAHU, and late season by 489 AAHU.[4] These underestimates would add roughly 50% to the estimation of project impacts through correction of this error

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[2] There may be another problem with the fish analysis if, as the DEIS fish appendix states, the Corps applied the fish reduction factor not just to the proposed project alternative but also to the evaluation of habitat in existing conditions. On page 32 of the Appendix G Fisheries, the Corps states that project impacts were calculated assuming that "future without project" conditions were also reduced through multiplication of the "fish access reduction." That would be an obvious mistake. Taking this language at face value indicates that the Corps improperly reduced its estimation of the project fish habitat available without the project by 27%. That would in turn mean that fish impacts were underestimated as follows: early season (877 AAHU); mid-season 885 AAHU, and late season by 489 AAHU. These underestimates would add roughly 50% to the estimation of project impacts through correction of this error alone. My hope is that the Corps did not make this obvious error, but that instead, it was an error in the description of the methodology on page 32.

[3] The following is a cut and paste from the document:

Project impacts were calculated by the following formula:

Project Impacts = (AAHU Future Without Project x Fish Access Reduction)
– (AAHU Future With Project x Fish Access Reduction)

alone. My hope is that the Corps did not make this obvious error, but that instead, it was an error in the description of the methodology on page 32.

3. Additional Problems with Impact Analysis

The DEIS understates the project impacts on habitat area and value because it excludes important habitat areas for invalid reasons and undervalues flooded agricultural land. It also underestimates impacts on floodplain lakes.

3.1 Exclusions of habitat areas

The fish habitat evaluation technique uses a variety of exclusions to ignore and to diminish valuable habitats. First, the technique excludes 100% of flooded agricultural land above the two-year floodplain. This exclusion ignores tens of thousands of acres of flooded habitat. Second, even for agricultural lands below the two-year floodplain, the habitat is ignored if they are flooded for less than a depth of one foot and for less than eight consecutive days. (The DEIS is somewhat ambiguous, but some of the language suggests that these hydrologic criteria were also applied to flooded forests and marshes.) Third, all areas above the five-year floodplain are ignored completely. These exclusions are inappropriate and the exclusions of agricultural land are illogical even under the terms of the rationale expressed in the DEIS.

I first address the exclusion of agricultural lands below the two-year floodplain unless they are flooded eight consecutive days and to a depth of one foot . That exclusion is essentially justified by spawning criteria. The theory is that eggs laid in shallower, less frequently flooded water will dry up. Even if true, these criteria do not define rearing habitat. Fish can and do move into and out of flooded areas as floodwaters move up and down regardless of whether they are flooded for eight consecutive days. Shallow water areas are also used by rearing fish. The DEIS even acknowledges that, stating: "Once hatched, rearing fish . . . can potentially use any area of the inundated floodplain <u>regardless of flood depth and duration."</u> Fisheries Appendix p. 34 (emphasis added). For that reason, the DEIS accepts that forested habitat will be counted if it is flooded on any day it is flooded to a depth even of one tenth of a foot. Flooded agricultural lands also provide rearing habitat. There is no justification for the differential treatment of flooded agricultural lands and flooded forest for rearing purposes.

The value of shallow water habitat was emphasized by Dr. Sheehan based on his sampling. In comments on this project, he wrote:

> "*Our evidence, collected using an active sampling gear (seining) . . . shows that small fish prefer habitats less than one foot in depth (probably to avoid predation by larger fish) as opposed to deeper depths, even when cover type stays the same. Using seining, we collected a total of 2,572 fish in seine samples from the shallowest water along the shore in Mississippi River waters of 1 foot or less, whereas we captured only totals of 407 and 206 fish in comparable sampling done at progressively deeper depths. We have found 39 Missisippi River species use waters of one (or less) foot*

depth. Much of our sampling was done in the spring. We find elevated water temperatures in the shallow, near shore area, perhaps explaining why they are used as much as they are by small fish."

Another justification for excluding more temporarily flooded lands is that they may dry up and leave fish stranded. Again that theory would apply equally to forest and agricultural lands and not justify differential treatment. More fundamentally, strandings of small fish have ecological value. Rearing fish are valued not merely because they contribute to the fish population but also because they provide food for migrating birds and other wildlife, which they can provide when stranded. This rationale is an example of how the focus on individual wildlife categories leads to flaws in evaluating impacts on the broader ecology.

The justification for excluding lands above the two-year floodplain is that they are on higher ground than the 1-to-2-year elevations and therefore farther from the downstream access point to the river. The assumption is that the farther the habitat is from the access point, the less likely that migrants from the river are to use it (Fisheries Appendix p 34). There are two problems with this claim. Again, even if true, that would not provide a justification for ignoring agricultural lands but counting forested lands, as both would be too far removed. More fundamentally, it is not true. Figures 1.4 and 1.5 indicate that land elevations are patchy, not neatly zoned by distance from the downstream access. Patches of 5-year floodplain occur adjacent to 2-yr floodplain at equivalent distances from the access. The DEIS provides no evidence for the claim that fish do not access these areas. Again, Dr. Sheehan, who actually sampled the fish habitat in these areas for the Corps, strongly disagreed with this exclusion.

Put simply, any reduced value for agricultural habitat can logically at most justify the lower habitat score for each acre when flooded. It cannot justify different hydrologic criteria. Rearing fish will move into and out of shallow waters that are only flooded for a day and only flooded to a few inches.

Finally, I can see no justification for exclusion of habitat above the five-year floodplain. Many fish that use the project area live for ten years or more, even decades. They can take advantage of even occasional floods to boost their populations—a boost that may last for years. Even fish that live shorter periods of time gain boosts in their populations. And those small fish are in turn consumed by long-lived larger fish and by birds and other species that have long life spans. The greater food supply boosts the nutrition and reproductive capability of the adult consumers and the growth and survival of their young. Also important, these areas provide increased habitat during high flood periods when any spawning and rearing available in the batture land will be even more reduced because of the high velocities. In other words in high flow years they not only supplement habitat available at lower elevations, they may be needed to substitute for those lower elevation habitats, which become less available. The hydrologic criteria used by the Corps inherently values habitat based on its frequency and duration of flooding, and the hydrologic model provides the means of doing so. There is no justification for

excluding categories of habitat within the project area up to the maximum area of backwater flooding.

3.2 Undervaluation of agricultural land

Flooded agricultural lands can have high values even for spawning. Species such as the sunfishes and basses can find firm substrates on fallow and farm ground on which to construct their nests. Elsewhere, in the permanent water bodies and channels, particularly those in the Floodway, there are accumulated soft sediments that are poor nesting substrate, according to the DEIS. A similar situation exists along the Illinois River, where I have observed basses and sunfishes nesting on gravel roads and fallow and farmed land during floods. Floods, including the 3-to-5-year floods, provide access to these firmer substrates.

When any floodplain lands are flooded, even agricultural lands, plankton blooms appear following release of nutrients from the flooded soil. Those food supplies attract small fish as Dr. Sheehan found, and do so whether lands are agricultural or not. The plankton can be carried by floodwaters into other habitats, providing important food supplies.

There is no real evidence provided by the DEIS for the extremely low habitat value assigned to flooded agricultural land. It may be lower in general, but will vary for different fish and all fish should be considered important. Greater true evidence should be necessary before so dramatically underestimating the value of habitat we know to be used and to supply food supplies to adjacent areas.

3.3 Underestimation of impacts on floodplain lakes

Floodplain lakes can have high fish values, but their value for river fish is largely based on their value as refugia for young fish otherwise bred in the floodplain that allows them to grow and that gives them increased chance of survival if they exit during a subsequent flood. For floodplain lakes to have this value, they need to be embedded in a larger flooded floodplain and there needs to be abundant opportunity for ingress and egress by river fish. (Floodplain lakes closer to the river may also have values even if not embedded in a larger floodplain, but less for spawning and rearing of floodplain-dependent fish.)

In prior analyses, the project estimated impacts on floodplain lakes by estimating the reduction in the period flooded by the river. The value of the lakes was based on how often they were flooded within each fish spawning season. As a result, if river flooding declined from 30% to 10%, lake value declined by 20%. That was an imperfect system (and of course ignored fish access problems) but it had at least focused on the importance of flooding between the river and the lakes to establish value for spawning and rearing habitat.

The new evaluation technique overvalues floodplain lakes relative to other floodplain habitats and at the same time greatly underestimate the impacts on floodplain lake habitat.

The new technique overvalues floodplain lake habitat by assigning it a value that is the equivalent to flooding of a bottomland hardwood for 100% of the days in all years and in all seasons. It does so by giving these lakes the same habitat unit score as flooded forest, but then assigning it the equivalent value of 100% ADFAs (average daily flooded acres), i.e., by assuming these habitats are available every single day of every single year. The permanent lakes are indeed wet all year round but they are not "flooded" by the river for that period.

The implications can be seen in Tables III-1 and III-3 of the Fisheries Appendix. As noted above, the spawning and rearing value of 640 acres of floodplain lakes in the New Madrid Floodway are considered equivalent to the value of roughly 7,995 acres of flooded forest within the five-year floodplain for the late season and more or less half the value of those forests during the early and mid-seasons.[5] They are always considered of more value than all the area's tens of thousands of acres of flooded agricultural lands. The overvaluation in the St. John's basin is similar.

On the other hand, the impacts on this habitat are heavily underestimated because the assumption is that any floodplain lakes flooded once every five years at any time of the year, for any duration retain their full value spawning and rearing habitats. The result is that floodplain lakes in the New Madrid Floodway only decline from 728 AAHU (average annual habitat units) in each season to 653 AAHU in each season for Alternative 3.1. Table III-3.

I can use the late season to show the error of this view. According to Table 21 of the Mitigation Appendix, under the proposed project (Alternative 3.1), water levels during the late season will never reach an elevation of 285 or higher (and areas at 284 feet will be flooded by the river less than 1% of the time). That means that 576 acres of floodplain lakes counted by the project as continuing to provide 100% ADFA habitat for a huge habitat score will never actually be flooded from the river in the late season and therefore could not provide fish spawning and rearing habitat for late season fish.[6]

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[5] According to Table 3.2 of the DEIS, there are 689 acres of permanent water bodies in the New Madrid Floodway up to 297 feet (rounded from 296.6), the 5-year floodplain. According to Table III-3 of the Fish Appendix, they are treated as providing 728.47 average daily flooded acres, and therefore 728.47 average annual habitat units for each spawning season: early, middle, and late. (That may be because assumptions of additional WRP lands bring water bodies up from 689 to 728.47.) According to Table III-3, bottomland hardwoods provide 733.53 average annual habitat units, roughly the same. They are based on lands flooded up to the five-year floodplain, which is 297 feet of elevation, and according to Table 3.2 of the DEIS, these habitat units are created by 7,995 acres of forest. Table III-3 also indicates that this same acreage of flooded forest (bottomland hardwoods) provide 1,629 average annual habitat units during the mid-season, which is more than twice the 728 units provided by permanent water bodies.

[6] According to Table 3.2 of the DEIS, there are 727 acres of floodplain lakes at or under 294 feet, the five-year floodplain. There are only 151.5 acres of such lakes at the 284 foot flood elevation, a difference of 488.5 acres. The Corps found a decline of floodplain lake habitat of 75 acres.

This approach leads to only an extremely small estimation of impacts on open water habitat and a very high estimation of potential benefits from a small area of open water mitigation.

The proper way to evaluate impacts on floodplain lakes is to treat them as an important habitat but one that is fundamentally distinct from other floodplain habitats. That was implicit in previous versions of the EIS where the Corps concurred with the Fish & Wildlife Service that lake habitat would be mitigated separately by other lake habitat.

Instead of assuming that these lakes retain their value for spawning and rearing habitat if they are flooded at any time during the five-year floodplain, their value should be tied to their frequency of flooding and to their associations with broader floodplain habitat. Different arguments could be made about how to do so. At a minimum, these 576 acres of floodplain lakes above 284 feet should be recognized as losing their fish spawning and rearing habitat.

More generally, the combination of substantially reduced flooding on the lakes, plus the restrictions on fish access, plus the loss of broader floodplain habitat should lead to the general judgment that the value for spawning and rearing of these lakes in the New Madrid Floodway are lost. Appropriate mitigation for the lakes alone could, in theory, occur by restoring lakes in the context of a broader restoration of inundation to a comparable backwater habitat.

4. Proposed Mitigation is Overvalued and Often Invalid

Much of the mitigation proposed would be behind levees in the floodplain, including Big Oak Tree State Park work, which would be behind two sets of levees, and is overvalued because of the limitations of fish access.

The second principal source of mitigation is supposed to occur through reforestation of batture lands, i.e., lands between the main channel of the Mississippi River and the main levee. These lands would not have fish access problems but would rarely provide equivalent rearing and spawning habitat for two principal reasons: First, the great bulk of batture lands, and perhaps all, will have substantially colder water than backwaters because of their continual replenishment with water from the river that is, on average, deeper and comes from the north. As both Robert Sheehan and I have previously written in comments on this project, temperature is an important component of the value of floodplain habitat and warmer temperatures are essential to successful spawning and rearing.

Second, batture lands will all or nearly all have more rapidly flowing water, particularly during high floods. Most batture lands closely hug the river. The Corps has indicated previously that

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Deducting the 75 from the 488.5 still leaves more than 400 acres considered to provide 100% habitat in the late season although never flooded in the late season.

even wider floodplain areas in the batture, such as Donaldson Point, experience rapidly flowing water during high flood years.

There is a mathematical error in the estimation of fish mitigation for reforesting 387 acres below 285 feet in elevation on page 31 of the Mitigation Appendix.[7] According to the equations and logic presented, the habitat provided by the reforested land should be based on the Mid-season AAHU of 60.1. That figure should be multiplied by the fish access factor of .73, to generate a mitigation figure of 43.9 rather than 81. With the subtraction of existing habitat value of 10.5, the net gain is 32.4. The error was the substitution of the figure 110.9 in the parentheses of the fish access coefficient rather than 60.1 on the line above. The result is an overstatement of mitigation benefits by 38.1 AAHU.

The Corps proposed to achieve much of its mitigation through the creation of open water bodies. This mitigation would compensate not merely for loss of other open water body habitat but floodplain forests and agricultural lands. For the reasons I explained above, this type of habitat is greatly overvalued.

One of the sites the Corps would "restore" as a lake is Riley Lake. This area already floods frequently, contains 180 acres of trees, and is valuable habitat. The Corps claims that it would generate roughly 327 AAHU in every season by building a levee around Riley Lake up to an elevation of around 287 feet, turning it into a pond. Not only would that overvalue the habitat value for reasons discussed above, but the levee would actually significantly reduce fish access to areas that can now be accessed far more frequently and extensively.

More broadly, the ecologically designed borrow pits and the modified water bodies are likely to fill more rapidly with sediment in the batture than in many of the backwater areas within the Floodway and the Bayou. The main current of the Mississippi carries high sediment loads, especially during floods, and the closer the water bodies are to the channel, the more quickly they will accumulate sediment, unless they have high current velocities that keep sediments in suspension. By contrast, as the name "backwater" indicates, the water backs relatively slowly into the lower portion of the New Madrid Floodway during seasonal floods, allowing river sediments to drop out in areas nearest the river. Although sedimentation occurs and some habitat maintenance is therefore required in the backwater areas, the rates of sedimentation and costs of maintenance are likely to be less than in the batture adjacent to the main channel, except in areas

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[7] The calculation is at page 31 of the mitigation appendix.

> The following steps were used to determine compensatory mitigation benefits in the New Madrid Floodway from reforesting 387 acres[13] (approximately 25 percent of available farmlands) of agricultural lands below an elevation of 285 feet in the mid-season period:
>
> BLH Transition: 859.2 HU = (20 years) * (71.6) * [(0.2+1.0)/2]
> BLH for remainder of project life: = 2,148 HU (30 years) * (71.6) * [1.0]
> Cumulative HU: 3,007.2 (859.2 HU + 2,148 HU)
> Mid-Season AAHU: 60.1 (3,007.2 cumulative HU/50 years)
> Fish Access Coefficient: 81.0 (110.9 * 0.73)
> **Mitigation Benefit = 70.5 AAHU** (81.0 with mitigation AAHU – 10.5 without mitigation AAHU)

where scouring velocities occur during advance and recession of floods. Scouring velocities would preclude spawning and rearing by fishes that access the floodplain to reproduce and rear their young.

This review indicates that all of the proposed mitigation sites offer limited potential mitigation for fish. Reforestation of areas within the floodplain will provide areas with extremely limited access by fish. Reforestation of batture lands is unlikely to provide habitat of equivalent value for spawning and rearing because of the high velocities and low temperatures. Digging of open water areas in the batture lands is likely to create habitat that will be rapidly silted in, and the changes to Riley Lake proposed are adverse: reducing fish access to already existing habitat.

5. Scientific Shortcomings of the Impact and Mitigation Analysis

In all of the above comments, I have largely taken the concept behind the fish model at face value, focusing on its detail. For reasons I, Dr. Sheehan, the Fish & Wildlife Service and others have consistently emphasized, this whole type of analysis is fundamentally unscientific because it treats each acre as though its value is independent of its relationship to other acres, and as though it depends entirely on only two factors: flooding and basic vegetation cover. It is well-known instead that the value of aquatic habitat depends on many more physical characteristics including flow and temperature and rates of change, and just as importantly on its landscape position. Landscape factors include whether the acre is part of a mix of other habitat types on which its value depends; whether it is part of a large contiguous area of habitat; and whether it is rare.

The project area's value is based on the fact that even though manipulated it provides a large, relatively naturally flooded, contiguous, complex and connected form of habitat to the Mississippi River. This type of habitat is extremely rare. It simply cannot be replaced by the piecemeal manipulation of other small areas, particularly in different landscape locations, with different connectivity and without the same mosaic of habitat types. It certainly cannot be replaced by a much smaller area simply because of these manipulations.

Robert Sheehan made this point in an earlier report: "[T]he Mississippi River used to have access to an extensive floodplain characterized by a range of backwater ponds and wetlands, stream networks, and combinations of cover type. Different fish prefer different kinds of habitats, and the same fish prefer different habitats at different stages of their life cycle and even during different times of the day. As floodwaters recede, an extensive stream (or even ditch) network provides a valuable resource for fish to recede through. It is the mosaic of habitat types provided in the project area that is ecologically valuable."

As I have previously noted, the Corps fishery biologist Dr. Kilgore admitted many of these important characteristics for fish habitat in a deposition that are not incorporated into the fish model. These characteristics he agrees include slack water; water that

warms relatively early; and a mosaic of flooded lands and permanently wet streams and ponds. These are all important characteristics of the project site, but the mitigation plan does not require or even contemplate that they be reproduced in the mitigation sites let alone as a mosaic.

It is also important to recognize that even to the extent the fish model represents the best scientific judgments of some about such things as preferred habitat values, it is based on little evidence. There are dozens of fish species in the Mississippi, and as Dr. Sheehan noted, they have different needs at different stages of their lives and rely on areas to provide food (such as plankton) that they may not reach themselves. With the possible exception of sport fishes, relatively little documentation exists on the requirements of many of these species. For example, one habitat score, e.g. 0.2 for agricultural land, is inappropriately provided for *all* fish, and that score is based largely on guesswork.

Recognizing these limitations and complexities, ecologists have instead focused on what they do know: which is that certain characteristics are important: including spatial extent, natural hydrologic patterns, contiguity, complexity and connectivity. The fishery analysis mostly ignores these factors that are important, and the mitigation plan pays them no attention at all. Instead, fish habitat is based entirely on the vegetation cover of the land and on the average duration of flooding during three seasons.

I conclude by quoting the accepted understanding expressed in 1992 in a report by the National Academy of Sciences: “Restoration of the flow regime is one of the most neglected aspects of stream and river restoration … Preservation of a river channel is not sufficient to ensure survival of fish that spawn on floodplains—both the floodplain and the flood cycle must be maintained (NRC 1992:180). It further states (page 175): “Immediate attention should be given to the remnants of large river-floodplain systems that still exist, because there are so few (e.g., there is only one twelfth-order river in the conterminous United States, the Mississippi River).

Richard E. Sparks

Richard E. Sparks, Ph.D.

Appendix A. Short Resume Dr. RICHARD E. SPARKS
(updated 24 November 2013)

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Dr. Richard Sparks is an aquatic ecologist currently affiliated with the Illinois State Natural History Survey, a unit of the University of Illinois at Urbana-Champaign. He formerly directed the Illinois Water Resources Center at the University of Illinois. In 2002 he helped found the National Great Rivers Research and Education Center on the Mississippi River at Alton, Illinois. The Great Rivers Center is a partnership between the University of Illinois and Lewis and Clark Community College. For 26 years he directed the Large River Research Program of the Illinois Natural Survey from field stations located on the Illinois and Mississippi rivers. He has authored or co-authored 211 articles, book chapters, reviews and reports, including The Flood Pulse Concept in River-Floodplain Systems, a much-cited paper which describes the role of seasonal flood cycles in maintaining the ecological structure and function of large floodplain-river ecosystems. He has served on several committees of the National Research Council, most recently the Committee on Improving Principles and Guidelines for Federal Water Resources Planning, which advised the Obama Administration's Council on Environmental Quality. From 1995 to 1997 he served on the Illinois River Strategy Team and the Hydrology and Hydraulics Action Team for the Integrated Management Plan for the Illinois River Watershed. In Argentina, Brazil, India, and China he provided advice on management of floodplain ecosystems and large rivers. He served on the Illinois Long-Term Flood Recovery Council, which was funded by the U.S. Economic Development Administration to help Illinois develop a flood recovery strategy, following the floods of 2008.

EDUCATION:

Post-doctoral Research Associate 1972, Center for Environmental Studies, Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Research: Rapid assessment of water quality, using aquatic organisms as sensors (funded by U.S. Environmental Protection Agency).

Ph.D. Biology 1971, Virginia Polytechnic Institute and State University, Blacksburg, Virginia
Doctoral dissertation: Using the respiratory responses of bluegill sunfish (*Lepomis macrochirus* Rafinesque) to monitor zinc concentrations in water. (funded by U.S. Environmental Protection Agency)

M.S. Zoology 1968, University of Kansas, Lawrence, Kansas
M.S. thesis: Effects of treated effluent from the Sunflower Army Ammunition Plant on fish. (funded by the Kansas Biological Survey)

B.A. Biology 1964, Amherst College, Amherst, Massachusetts

PEACE CORPS SERVICE: Nigeria, 1964-1966

CURRENT POSITION:

Research Affiliate, Illinois Natural History Survey, a division of the Prairie Institute at the University of Illinois at Urbana-Champaign

PROFESSIONAL ACTIVITIES (selected from last 5 years)**:**

Current: Science advisory committees: American Rivers; the following units of The Nature Conservancy ─Illinois Chapter; the Great Rivers Partnership; the Emiquon Floodplain Restoration Project.

2010-2011 Member of National Research Council Committee (U.S. National Academy of Sciences and National Academy of Engineering) to review the Principles & Guidelines for Planning Water Projects. P&G establishes objectives and procedures for planning water resources projects undertaken by several federal agencies, including the Corps of Engineers, Bureau of Reclamation, Department of Agriculture, and others.

2008-2009 The Illinois Long-Term Flood Recovery Council.

CONTRIBUTIONS TO SCIENCE EDUCATION: Firth, Penny, Richard E. Sparks, and Milton Muldrow, Jr. Units on River and Water Science for elementary school teachers and students: see http://www.sciencenetlinks.com/lessons.php?BenchmarkID=11&DocID=523

SELECTED PUBLICATIONS (From a total of 211 papers, including refereed journal articles, book chapters, symposium proceedings, and reports. Publications are arranged by subject category and in order from most recent to oldest.) Some publications are listed in more than one subject category.

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Sparks, R.E. 1993. Making predictions that change the future: forecasts and alternative visions for the Illinois River. Keynote Speech at the Third Biennial Governor's Conference on the Management of the Illinois River System. Illinois Natural History Survey, Center for Aquatic Ecology Technical Report 93/18. 23 p.

National Research Council 1992. Restoration of Aquatic Ecosystems: Science, Technology, and Public Policy. National Research Council, Commission on Geosciences, Environment and Resources. National Academy Press. Washington, D.C. As chairman of the Subcommittee on Rivers and Streams, **R.E. Sparks** prepared most of Chapter 5, Rivers and Streams, (Pages 149-242), as well as the following case studies: The Upper Mississippi River (Pages 377-381); The Illinois River-Floodplain Ecosystem (Pages 382-399); and The Atchafalaya Basin (Pages 370-376).

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