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technical BRIEF
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# Ecosystem Services Analysis for Habitat Restoration Alternatives at Mud Lake on the St. Louis River, Minnesota

The purpose of this analysis was to compare the ecosystem services associated with each of the six different alternatives selected by the City of Duluth, Minnesota, for the restoration of habitat at Mud Lake on the St. Louis River. Specifically, the alternatives were analyzed to map indicators related to ecosystem services at Mud Lake (i.e., the service providing areas) and to estimate the area or extent associated with each service. The ecosystem service metrics were either suggested by local stakeholders or were based on metrics described by Angradi et al. (2016; Table 1). The area or extent of each service was then tabulated for each alternative (Table2).

Ecosystem services analyzed for Mud Lake included both supporting and final ecosystem services. Supporting services provide an indirect human benefit such as fish habitat or wetlands; final services are outputs of nature that provide a direct benefit such as fish or wild rice (Boyd and Banzhaf 2007). The final services provided by Mud Lake benefit a variety of people, including recreational, subsistence, and commercial beneficiaries.

**Supporting ecosystem services**

The analysis shows that there are service trade-offs among (Table 2). Alternative 3 (remove causeway) provides the greatest opportunity for increasing deep water habitat and restoring connectivity between the east and west sides of Mud Lake. Deep water habitat that does not freeze to the bottom or become hypoxic during winter is important for fish overwintering in the river. Hydrologic connectivity is important to maintain coastal wetland vegetation communities, and their associated fauna (Albert et al. 2005). Because they increase connectivity, Alternatives 2Av2 and 2Bv2 provide the greatest opportunity for providing coastal wetland sheltered habitat, which is important for a wide diversity of wildlife and fish species (Niemi et al. 2007).

Alternatives 2A and 2B provide slightly more area of dense submerged aquatic vegetation (SAV), though the absolute difference in area among alternatives is small (ca. 11 acres). Areas with dense SAV are favored as nursery habitat for many fish species and provide food and cover for a variety of fish and wildlife (Cvetkovic and Chow-Fraser 2011).

The current condition (i.e., keeping Mud Lake as is) has the least supporting service providing area among the alternative analyzed.

**Final ecosystem services**

As with supporting ecosystem services, trade-off among alternatives was apparent for final ecosystem services (Table2). For both power and human-powered boating, Alternative 3 provided the greatest area because removal of the causeway and the creation of the northern channel allowed for the greatest boatable area. It also provided, along with Alternative 2B and 2Bv2, the most area for shore fishing due to the number of designated shore-based fishing areas included in this alternative.

Alternatives 2A and 2B provided the greatest amount of Northern Pike and Muskellunge (Esocid fishes) spawning habitat owing to the extensive shallow, moderately-vegetated habitat preferred by these fish for spawning, created by these alternatives. However, it should be noted that the absolute difference among alternatives (ca. 10 acres) for this service is small relative to the project area.

Alternative 3 (current conditions) provides the least habitat area for semi-aquatic mammals because removing the causeway decreases the length of riparian shoreline available. Again, it should be noted that the absolute difference in shoreline area (ca. 15 acres) is small relative to the project area.

**Limitations**

A hydrodynamic model of current velocities and wetland water residence time was not available to include in the analysis of the various alternatives. All aquatic vegetation models assumed that current velocity will be like conditions in other sheltered bays in the river, such that establishment of vegetation is likely. Low current velocity could promote aggradation of wetlands, whereas high water velocity could scour existing wetland habitat. Also, upland vegetation plans were not included with the alternatives. Whether the adjacent riparian corridor includes shrubs or mature upland trees will influence availability of habitat for wildlife, waterfowl, and migratory birds. All models were based on a water elevation of 601.1 ft, and therefore habitat values do not reflect high water conditions (ca. 603 ft) or low water conditions (ca. 599 ft).

**Summary**

The largest differences among the Mud Lake restoration alternatives are for overwinter fish habitat (highest for Alternative 3 because it includes the most open water dredging) and boating and fishing (also highest for Alternative 3 because the amount of aquatic habit is increased by causeway removal). On the other hand, the amount of sheltered bay habitat, shoreline, and floating leaved vegetation is lower for Alternative 3 than for the other alternatives.

This analysis is based on area or extent of services and all the services are assumed here to have equal per area benefit quality or "value." The true relative value of the different services (e.g., fishing vs. wetland habitat vs. wildlife) will likely vary among human beneficiaries.

Without reliable estimates of relative valuation for each service, it may be useful to consider the scarcity of the relevant Mud Lake habitats in the context of the entire St. Louis River Estuary ecosystem.

**References**


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Table 1. Ecosystem services analyzed for Mud Lake, including beneficiaries, associated subcategories, and ecosystem service source

| Ecosystem Service (units) | Beneficiary | Subcategories | Description | Source |
|---|---|---|---|---|
| River greater than 6 feet deep (acres) | Indirect (Habitat) | Off-channel deep habitat | Potential for overwintering fish habitat | Suggested by stakeholders |
| Highly-sheltered bay (acres) | Indirect (Habitat) | Back bay habitat | Relative amount of highly-sheltered aquatic habitat relative to reference bays* | Angradi et al. 2016 |
| Moderately-sheltered bay (acres) | Indirect (Habitat) | Back bay habitat | Relative amount of moderately-sheltered aquatic habitat relative to reference bays* | Angradi et al. 2016 |
| Fill in public waters (lineal feet) | Indirect (Habitat) | Loss of connectivity | Distance of artificial structures within project area | Suggested by stakeholders |
| Protected shoreline (feet) | Indirect (Habitat) | Loss of connectivity | Distance of protected (rip rap) within project area | Suggested by stakeholders |
| 75-100 percent probability of vegetation occurrence (acres) | Indirect (Habitat) | Submerged aquatic vegetation (SAV) | Area with dense SAV (e.g., eelgrass, coontail) cover based on predictive models | Angradi et al. 2013 |
| 25-75 percent probability of vegetation occurrence (acres) | Indirect (Habitat) | Submerged aquatic vegetation (SAV) | Area with moderate SAV cover based on predictive models | Angradi et al. 2013 |
| 50-100 percent probability of vegetation occurrence (acres) | Indirect (Habitat) | Floating leaf vegetation (FLV) | Area with moderate to dense FLV vegetation cover based on predictive models | Angradi 2014 |
| Power boating (acres) | Recreational | Boaters, Anglers, Experiencers and Viewers | Area of a suitable depth for power boating (motorized) | Angradi et al. 2016 |
| Human-power boating (acres) | Recreational | Boaters, Anglers, Experiencers and Viewers | Area of a suitable depth for canoes and kayaks | Angradi et al. 2016 |
| Esocid spawning (acres) | Recreational, Subsistence | Anglers | Area of habitat suitable for Northern Pike and Muskellunge spawning | Angradi et al. 2016 |
| Designated shore fishing (acres) | Recreational, Subsistence | Anglers, Food extractors, Food subsisters | Area designated and suitable for shore-fishing | Angradi et al. 2016 |
| Boat/ice fishing (acres) | Recreational, Subsistence | Anglers, Food extractors, Food subsisters | Area of a depth suitable for ice- or boat-based fishing+ | Angradi et al. 2016 |
| Trapping (acres) | Recreational, Commercial | Hunters, Pelt Extractors | Area of habitat suitable for semi-aquatic mammals (e.g., river otters, beavers) | Angradi et al. 2016 |

* Sheltered bay morphology is based on the relative exposure index (REI) and is measured as the number of acres below the mean relative exposure index (Angradi et al. 2016) for reference bays including Duck Hunter Bay, Radio Tower Bay, Stryker Bay, and Rask Bay.

+ Dependent on accessibility of western Mud Lake

Table 2. Ecosystem services providing areas and extent for Mud Lake. The cells are color coded to help indicate relative change from current condition among alternatives: yellow = less than a 30% change from current conditions; blue = at least a 30% increase in area or extent from current conditions; pink = at least a 30% decrease from current conditions. For fill, a decrease in length is a positive change because it increases aquatic habitat connectivity. A decrease in protected shoreline increases connectivity but decreases shoreline habitat.

| Ecosystem Service (units) | Current Condition (Alt 1) | Retain Rail, North Opening (Alt 2A) | Rail to Trail, North Opening (Alt 2B) | Retain Rail, North Opening, Bay Mouth Bar (Alt 2Av2) | Rail to Trail, North Opening, Bay Mouth Bar (Alt 2Bv2) | Remove Causeway, North Opening, Bay Mouth Bar (Alt 3) |
|---|---|---|---|---|---|---|
| River greater than 6 feet deep (acres) | 33.2 | 37.1 | 37.1 | 36.5 | 36.5 | 51.1 |
| Highly-sheltered bay (acres) | 23.4 | 26.5 | 26.5 | 30.9 | 30.9 | 9.8 |
| Moderately-sheltered bay (acres) | 29.8 | 28.2 | 28.2 | 42.6 | 42.6 | 21.0 |
| Fill in public waters (lineal feet) | 4894 | 4782 | 4782 | 4782 | 4782 | 3067 |
| Protected shoreline (lineal feet) | 4379 | 4107 | 4107 | 4107 | 4107 | 1302 |
| 75-100 percent probability of SAV occurrence (acres) | 75.9 | 84.3 | 84.3 | 79.3 | 79.3 | 73.3 |
| 25-75 percent probability of SAV occurrence (acres) | 42.7 | 40.5 | 40.5 | 40.4 | 40.4 | 46.2 |
| 50-100 percent probability (acres) of FLV occurrence (acres) | 42.2 | 51.2 | 51.2 | 57.9 | 57.9 | 2.9 |
| Power boating (acres) | 75.9 | 75.9 | 75.9 | 75.9 | 75.9 | 110.9 |
| Human-power boating (acres) | 129.7 | 129.7 | 173.4 | 129.7 | 173.4 | 184.0 |
| Esocid spawning (acres) | 75.7 | 84.0 | 84.0 | 78.9 | 78.9 | 72.9 |
| Designated shore fishing (acres) | 0.0 | 0.0 | 1.0 | 0.0 | 1.0 | 1.2 |
| Boat/ice fishing (acres) | 144.6 | 153.5 | 153.5 | 149.2 | 149.2 | 160.6 |
| Trapping (acres) | 133.6 | 124.7 | 124.7 | 128.2 | 128.2 | 118.7 |