

Supplementary Material

Table 2.5.2 Summary of fish response to dam removal. The reasons for dam removal have been abbreviated to allow inter-study comparisons: safety concerns (SC), economic costs for continued maintenance (EM), fish restoration (FR) or public demand (PD). The metrics used differed among studies and have been abbreviated as follows: Species Composition (SC) or alternatively Assemblage Shift (AS), Species Richness (SR), Species Abundance (SA1), Recolonization (RC) Fish Density (FD), Fish Biomass (FB), Nesting Success (NS), Spawning Activity (SA2), Movement Patterns (MP) (described here but largely quantified in terms of SA2), Species Diversity (SD), Changes in Fish Size Structure (SS), Recruitment (R), Migration Timing (MT). General Terminology has largely been abbreviated as follows: Dam Removal (DR) in reference to Upstream (US) or Downstream (DS) waters, Pre-removal (PRR) or Post Removal (PR) along with Species Type: Tolerant (T) and Intolerant (IT), Riverine (R), Lotic (LO) or Lentic (LE). Fish response to barrier removal was assessed relative to baseline conditions or reference sites (if available) and were assigned (=) if no change occurred, if decreased (<), if increased (>). A few of the findings from these studies have also been abbreviated as follows: Direct Evidence of Passage Success (PS), Recolonization Success: (RS).

| Report Type | Location | Number of Dams Removed | Reason for Dam Removal | Dam height | BACI? | Number of Species | Years of Pre-Removal | Years of Dam Drawdown | Years of Post-Removal | Metrics Used | Upstream Response | Downstream Response | Citation |
|-----------------------|-------------------------------|------------------------|------------------------|---------------|-----------------------|--|----------------------|-----------------------|-----------------------|-----------------|--|--|-----------------------------|
| Thesis | North Carolina, North America | 1 | FR | Not specified | No, PRR not available | American Shad and Stripped Bass | 0 | Not applicable | 2 | SA2, MP | SA2 for American Shad found in similar habitat US that was available DS prior to removal, For MP US PS was seen for 55% American Shad and 65% Stripped Bass, US migrations had a mean maximum of 226, 251 rkm for American Shad and 218, 250 rkm for Stripped Bass | Not applicable | (Bowman, 2001) |
| Peer-reviewed, Thesis | North Carolina, North America | 1 | EM | Not specified | No, PRR not available | American Shad, Hickory Shad, Stripped Bass | 0 | Not applicable | 2 | MP, SA2, SS, NS | SA2 observed for all anadromous species, SS with egg & larvae presence, MP seen for PS US, >NS | SA2 primarily in DS reaches for Hickory Shad, SS egg & larvae presence, >NS | (Burdick & Hightower, 2006) |
| Peer-Reviewed, Thesis | Michigan, North America | 1 | EM | 5.18 | No, PRR not available | Community | 0 | 7 | 4 | RS, SA1, SS | RS of 8 species previously excluded US, SS for white suckers, >SA for 18 of 25 species | SS changes for white suckers towards smaller size classes (100mm to 500mm) to (100mm-200mm), >SA for | (Burroughs et al., 2010) |

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| | | | | | | | | | | | | 18 of 25 species was evaluated for the full river rather than DS alone and so was not used in our DS synthesis to avoid potential DS only effects that were not accounted for | |
| Peer-Review ed | Pennsylvania, North America | 1 | SC | 2 | Yes | Community | 1 | Not applicable | 2 | SC, SA1 | SC transition from LE to LO | <SA, then >SA within a year after removal | (Bushaw-Newton et al., 2002) |
| Peer-Review ed | Wisconsin, North America | 4 | SC, EM | 1.5-2.4 | No, lack of pre-removal replicates and paired reference samples | Community | D1=3 D2= 1 D3= 1 D4= 2 Range from 1 to 3 years *based on impoundment monitoring | Not applicable | D1=2 D2=5 D3= 4 D4= 3 Range from 2 to 5 years *based on impoundment monitoring | SR, AS, RC | For AS < %T, > %IT for 3 dams, >%IT with NC in %T for 1 dam, 2 dams saw >SR, and two dams saw =SR, RS for 10 of 11 species never or rarely found US PRR | <SR, then >SR for 2 of 3 sites within 2 years, For AS tolerant species remained stable except for one instance that <T and >T, no clear trend for intolerant species, except for one instance <IT | (Catalano et al., 2007) |
| Technical Report | North Carolina, North America | 1 | FR | Not specified | No | Community | 1 | Not applicable | 2 | SR, SA1, AS | >SR, >SA, AS did not transition fish assemblage at reference sites | Not applicable, only looked at impounded vs. reference stations | (Chatham, 2007) |
| Thesis | Taiwan, Asia | 1 | FR | Not specified | No | Taiwan Salmon | 0.08 (approx. 30 d period) | 0.13 (approx. 40 d period) | 0.08 (approx. 30 d period) | MP, RC | For MP, US PS limited by dam before removal, following removal >daily movements and >total stream distance covered | For MP, during dam draw-down fish moved little, >long distance movements after removal to US habitat | (Chen, 2012) |
| Technical Report | New York, North America | 1 | SC, EM | 2.7 | Yes, used Little Salmon River as a | Community | 2 | Not applicable | 3 | AS | AS =natives, >invasives | AS =natives | (Cooper, 2013) |

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| Technical Report | Oregon, North America | 1 | FR, EM | Not specified | No | Shortnose Suckers, Lost River Suckers | 2 | Not applicable | 1 | MP | For MP, >PS US following removal | Not applicable | (Ellsworth et al., 2009) |
| Technical Report | Washington, North America | 1 | EM, FR | 38 | No | Chinook Salmon | 1 | Not applicable | 1 | SA2, NS | SA2 observed US, >NS, with presence of redds | SA2 observed DS, >NS, with presence of redds | (Engle et al., 2013) |
| Peer-Reviewed | Norway, Europe | 2 | FR | Both 2.5 | Yes, provided control sites | Atlantic Salmon and overall Community | 5 | Not applicable | 2 | SS, NS, SC, MP | For SS >R of juveniles, >egg survival, >NS, MP and MT 1 month earlier for PR when compared to PRR for Atlantic Salmon, SC from LN to LO | Not applicable, focused on upstream spawning success and community shift (above weirs) | (Fjeldstad et al., 2012) |
| Peer-Reviewed | Maine, North America | 1 | FR | 3 | Yes, Modified Before-After-Control-Impact-Design | Community | 2 | Not applicable | 1 | SA1, SR, FD, SD | >SA1, >FD, >SD | <SA1, <SR, <FD | (Gardner et al., 2013) |
| Technical Report | Ohio, North America | 1 | FR, PD | 2.5 | Yes, Unreplicated Before-After-Control-Impact-Design | Community | 2 | Not applicable | 2 | AS, SR, FD, FB, SA1, SD | For AS <non-native, >invasives, >IT, =T, >SR, >FD, >FB, >SA, =SD | For AS =non-natives, <IT, >T, =SR, <FD, <FB, =SA, =SD | (Gottgens, 2009) |
| Technical Report | Maryland, North America | 2 | EM, SC, FR | 3 and 7.3 | No | Eel, Community | 2 | Not applicable | 2 | SC, SA1, SS | For SC, US/DS assemblages become more similar | For SC, US/DS assemblages become more similar, for SS, <relative size of eels, <SA1 of YOY smallmouth bass, AS with <IT | (Harbold et al., 2013) |
| Peer-Reviewed | Alabama, North America | 6 partially removed, 5 relict dams | Not specified | Not specified | No | Community | Unknown | Not Applicable | 1 | SR, SA2, AS | For breached dams <SR when compared to DS, for SA2 >generalist spawners, SC >species with preference for cobble substrate, found 1 indicator species for relict dams US | For breached dams >SR, when compared to US | (Helms et al., 2011) |

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| Peer-Review ed | Florida, North America | 1 | PD | Not specified | No | Community with focus on Largemouth Bass and Stripped Bass for recreational fisheries | 1 | Not applicable | 3 | SS, SR, RC | >SR, SS with strong year classes for Largemouth Bass, RS of Stripped Bass | Not applicable | (Hill et al., 1994) |
| Technical Report | Wisconsin, North America | 1 | EM, FR | Not specified | No | Community | 1 | Not applicable | 5 | SD, AS, SS | >SD, for AS > natives, SS with >R for Smallmouth Bass with multiple year classes | Not applicable | (Hirethota et al., 2005) |
| Peer-Review ed | Virginia, North America | 1 | FR | 6.7 | Yes, but not explicitly identified as such | Eel | 8 | Not applicable | 4 | SA1, FB, SS | >SA1, <FB, SS associated with decreasing eel length, dam likely impeded smaller individuals | Not applicable | (Hitt et al., 2012) |
| Peer-Review ed, Thesis | Maine, North America | 1 | FR | 1.3 | No, control was not used | Sea Lamprey | 1 | Not applicable | 2 | SA1, SA2 NS, MP, RC | >SA1, SA1 with >NS, for MP PS took 6 d for initial recolonization, 3 d during spawning run, could be linked to conspecific pheromone cues with MT | >SA1, SA with >NS primarily occurred DS | (Hogg et al., 2013) |
| Peer-Review ed, Thesis | Maine, North America | 1 | FR | Not specified | Yes, Modified Before-After-Control-Impact-Design | Alewife, Atlantic Salmon and Sea Lamprey | 2 | Not applicable | 3 | Peer-Review ed: FD, FB, SD, SR, SS, RC Thesis: NS, MT | >FD, >FB, >SD, RS of and SS increase in 0-age size class for all anadromous species | <FB, <SR initially and then >SR a year later | (Hogg et al., 2015) |
| Thesis | Pennsylvania, North America | 3 | FR | Not specified | No | Community | 1 | Not applicable | 4 | SC, RC | SC was similar, changes could only be attributed to yearly differences in environmental variables (i.e., precipitation), RS of several species only found DS in PRR | SC was similar, changes could only be attributed to yearly differences in environmental variables (i.e., precipitation) | (Hutchison, 2008) |
| Technical Report | Washington, North America | 1 | FR | 38 | No | Pacific Lamprey | 1 | Not applicable | 1 | SS | For SS presence of larvae | For SS presence of larvae | (Jolley et al., 2013) |
| Peer-reviewed | Wisconsin, North America | 1 | SC, EM | 4.3 | No, lack of pre-removal replicates | Smallmouth Bass, Common Carp | 1 | Not applicable | 5 | SA1, FB, SS | >SA1, >FB for Smallmouth Bass, <SA1, <FB for Common | No clear trend in SA1 or FB for Smallmouth Bass, | (Kanehl et al., 1997) |

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| | | | | | | | | | | | Carp, SS shows strong 1-year classes of Smallmouth Bass | gradual <SA1, <FB for Common Carp | |
| Peer-Review ed | Minnesota, North America | 2 | SC, FR, EM | Not specified | No | Sandstone Dam: Lake Sturgeon Appleton Dam: Community | Two Separate Case Studies: Sandstone Dam: 1 Appleton Dam: 1 | Not applicable | Two Separate Case Studies: Sandstone Dam: 3 Appleton Dam: 1 | MP, AS | Sandstone Dam: For MP >PS for Lake Sturgeon Appleton Dam: for AS > natives | Not applicable | (Katapodis & Aadland, 2006) |
| Peer-Review ed | Wisconsin, North America | 1 | Not specified | 3.4 | No, control was not used | Community | 3 | Not applicable | 3 | FD, FB, SC, RC | <FD, >FB, RS of previously excluded species: largemouth bass, white sucker and yellow perch, SC similar to DS | <FB, fish density for predator/prey was inversely correlated | (Kornis et al., 2015) |
| Peer-Review ed | France, Europe | 1 | EM | 3 | No, control was not used | Sea Lamprey | 6 | Not applicable | 5 | MP, NS | For MP >PS, for NS there was >nesting sites US | Following removal, for NS the nesting sites were more uniform throughout river system (after > nesting sites US occurred) | (Lasne et al., 2014) |
| Peer-Review ed | Massachusetts, North America | 1 | SC | 6 | No, control was not used | Community | 1 | Not applicable | 0.5 | SA2, SR, RC, SA1 | <SA1, <SR, RS of 4 previously excluded species | <SA, <SR, SA2 of sea lamprey below the dam | (Magilligan et al., 2016) |
| Peer-Review ed | Illinois, North America | 1 partially removed, 10m breach in 105m dam width | EM, FR | 1.7 | Yes, Modified Before-After-Control-Impact Design | Community | 3 | Not Applicable | 3 | SC, AS, FD, SR | SC became similar to DS where LN to LO only slightly | <FD, <SR AS with >invasive species the common carp | (Maloney et al., 2008) |
| Thesis | South Carolina, North America | 2 | Not specified | 2.4 and 9.4 | Yes, Modified Before-After-Control-Impact-Design | Community | 5 | Not applicable | 2 | SC, FD | SC from LE to LO within 6-months for upper DR and within 1.5 yrs for lower DR | >non-native FD following lower DR | (Marion, 2014) |
| Peer-Review ed | Connecticut, North America | 1 | Not specified | 1.5 | No | Community | 1 | 2 | 3 | SC, SA1 | SA1 followed species specific trends, SC did not transition to similar reference sites 3 years post-removal | SA1 followed species specific trends, SC did not transition from LN to LO within 3 | (Poulos et al., 2014) |

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| | | | | | | | | | | | | years post-removal | |
| Peer-Review ed, Thesis | North Carolina, North America | 3 complete, 1 partially removed | Not Specified | ≤4 | No, PRR not available | American Shad | 0 | Not applicable | 3 | SA1, SA2, MP | >SA1 then <SA1, for MT males immigrated earlier and used US habitat at a higher percentage than females, weight loss for females was greater than males (50%, 30% respectively), post-spawning survival rates were low | >SA1 then <SA1 | (Raabe & Hightower, 2014a) |
| Peer-reviewed, Thesis | North Carolina, North America | 3 complete, 1 partially removed | EM | 0.9-4 | No, PRR not available | American Shad, Gizzard Shad and Flathead Catfish | 0 | Not applicable | 3 | MP, RC | PS varied by species and by the extent of dam removal (complete vs. partial) (e.g., PS was 40-49% Gizzard Shad compared to PS of 4-11% for Flathead Catfish) | 17-28% species did not pass the partially removed dam, 20-39% that passed remained DS for more than 24 hrs before moving US | (Raabe & Hightower, 2014b) |
| Peer-Reviewed | Wisconsin, North America | 2 | FR | 1 and 2.5 | Yes | Brook Trout and Overall Community | 2 | Not Applicable | 2 | AS, SS | AS did not occur, no new species invaded US waters. For SS, <adult Brook Trout, and R >YOY Brook Trout | AS did not occur. For SS, <adult Brook Trout, and R >YOY Brook Trout | (Stanley et al., 2007) |
| Thesis | Colorado, North America | 1 | SC, FR | 2.5 | No | Community | 1 | Not Applicable | 1 | SA1 | =SA, further monitoring is needed | =SA1, further monitoring is needed | (Straub, 2007) |
| Technical Report | Oregon, North America | 2 | Not specified | 2.2 | No | Community | 1 | Not Applicable | 1 | AS, SC | For AS =% natives, =SC | For AS =% natives, =SC | (Tullos et al., 2013) |
| Technical Report | Ohio, North America | 2 | Not specified | Not specified | No | Community | 1 | Not applicable | 1 | SR, AS | For AS >IT, >SR | Not applicable for the metrics used in this review | (US Environmental Protection Agency, 2010) |
| Peer-Reviewed | Maine, North America | 1 | FR | Not specified | No, PRR not available | Shortnose Sturgeon | 0 | Not applicable | 6 | MP, SS | For MP, PS to historic spawning grounds, SS from recruitment of larvae | Not applicable | (Wippelhauser et al., 2015) |

