Atlantic States Marine Fisheries Commission

Fish Passage Working Group

Upstream Fish Passage Technologies for Managed Species

September 2010

The Atlantic States Marine Fisheries Commission (ASMFC) manages the following diadromous fish species: American shad, hickory shad, alewife, blueback herring, striped bass, Atlantic sturgeon, and American eel. Runs of these species have been decimated over the past 200 years due to the construction of barriers in waterways and the inability of these species to access their historic freshwater habitat. Fishery Management Plans seeking to restore populations of these species must recognize the need to reconnect fish with such habitat by getting the runs past stream barriers. This document summarizes the evaluation by the Fish Passage Working Group of available technologies to accomplish effective passage. Table 1 summarizes the information while the text below provides additional details.

We focus on long-term solutions to fish passage and do not include some approaches to getting fish around barriers that are temporary or unsustainable (e.g. netting fish below a dam and throwing them over the dam). We also do not focus on the *operation* of the various technologies for fish passage, but simply review suitability of various types of fish passage technologies. It must be noted that often a reason fish do not effectively use a fishway is due to problems with attraction into the fishway entrance, i.e. poor location, poor hydraulics, insufficient attraction flow. Poor attraction can plague any kind of fishway. The summaries below are based on our knowledge of how the species perform within a fishway of each type, assuming they have successfully located and entered the fishway. Fishway designs that injure, delay, or stress fish attempting to pass may also be classified as ineffective, regardless of their overall passage performance. These summaries reflect the best professional judgment of which technologies are best for individual species, but scientific data documenting actual efficiencies are scarce. We define efficiency as the number of fish successfully passed divided by the number of fish below the barrier that are attempting to pass.

Brief Description of Common Upstream Fish Passage Technologies

Dam Removal- The most effective means of getting migrating fish above a dam (or other barrier) is to remove the barrier. Total removal will typically bring the stretch of stream back to its natural (pre-development) condition when such fish successfully migrated upstream. Furthermore, removal of the dam restores natural ecological function of the stream, which helps support natural populations of the species that are targeted for restoration. This technique should be investigated for all barrier dams. Many dams are still valued and removal is not a feasible option. At that point, other approaches (listed below) should be considered.

Dam Partial Removal - Sometimes when a dam cannot be removed, a partial removal can be attempted. One common approach is **notching** - cutting a vertical notch in the dam that will pass water and fish. Notches must be carefully considered because they don't always provide effective fish passage due to excessive water velocity and other problems. Another common approach is **breaching** - removing an entire section of a dam, such as a spillway, but leaving the rest of the dam intact. **Lowering** a dam can also be effective for fish that can surmount a barrier with a lower elevation. Such modifications are generally practical only for very low head barriers.

The following sections refer to types of fishways:

Denil- This style is a sloped trough (usually concrete) with v-shaped baffles (usually wooden) inserted at a 45 degree angle to the sloped floor at regular intervals. The slope of the fishway typically ranges from 6 to 16% and these fishways often have flat resting and/or turn pools for taller dams. The typical width of a Denil is often 4 ft although 3 ft and 2 ft wide Denils are built for smaller rivers.

Steeppass - This style is a sloped trough (usually aluminum) with v-shaped vanes welded along the sides and bottom at regular intervals. The slope of the fishway typically ranges from 16 to 25% and these fishways often have flat resting and/or turn pools for taller dams. The width is 22 inches and the depth is generally 27 inches, although deeper models are sometimes used. These fishways are prefabricated in metal shops, typically in 10 foot standardized lengths, and bolted together by a contractor for on-site installation. Due to their relatively small size, they can be self-supporting up to 40 feet in length.

Pool-and-Weirs (Large) - This category includes very large concrete fishways built around tall dams, often at hydroelectric projects. Pool sizes are generally in excess of 6 ft wide and 10 feet long. Weir configurations vary but can include a single notch, double side notches, submerged orifices, vertical slots, or a combination of any of these. The drop per pool varies but can be as great as one foot. Although they contain pools, vertical slots are excluded from this category in this discussion and are listed separately due to the uniqueness of their design. Large pool-and-weir fishways are common on the Pacific Coast for passing large adult salmon and some of this technology has been transferred to the Atlantic Coast for salmon and shad, with varying degrees of success. It appears that the success of this category of design may depend upon size. When the fishway is large, like the size of those on the Columbia River, there may be sufficient energy dissipation, pool volume, and notch dimensions to pass Atlantic Coast species. But when the size is scaled down for smaller Atlantic Coast rivers, these values may become insufficiently small.

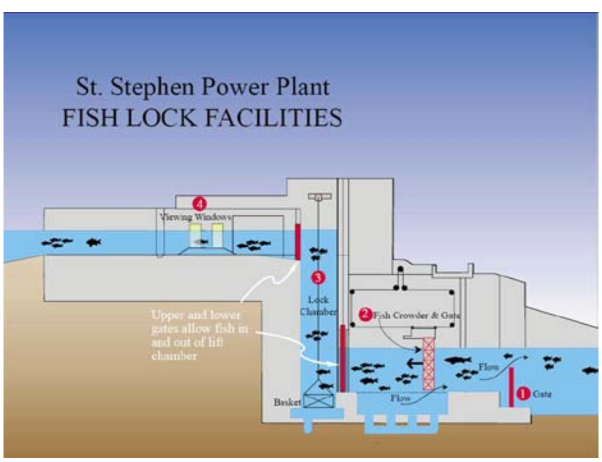
Pool-and-Weirs (small) - These fishways are used at dams generally less than 12 feet in height and have pool sizes smaller than 6 ft x 6 ft. Weir configurations vary but generally are simple, single, full weirs (wall-to-wall), sometimes with a level crest and sometimes with a v-crest. The drop per weir varies but for the species under discussion for this paper that drop is usually between 6 and 9 inches. This style requires relatively stable headpond levels and no draw-downs during the fish passage season.

Vertical Slot- Vertical slot fishways are a specialized type of pool-and-weir fishways. They include a series of pools, each one higher than the previous one, separated by a weir. The opening in the weir is a vertically-oriented slot, open from top to (generally) the bottom. Often, the lower portion of the slot is blocked with a sill block or baffle. The width of the slot depends upon the size of the fishway and the target species. The width of the slot may, in great part, determine the effectiveness of passing Atlantic Coast species. Fishways with narrow slots (< 16 inches) can perform well hydraulically but appear to be less effective at passing targeted species.

Nature-like - This is a broad category that includes fishways of varying appearances. All share characteristics of: a minimal use of concrete, metal and lumber; a reliance on natural materials such as rock and earth; a general natural stream-like appearance; low slopes, and natural landscaping.

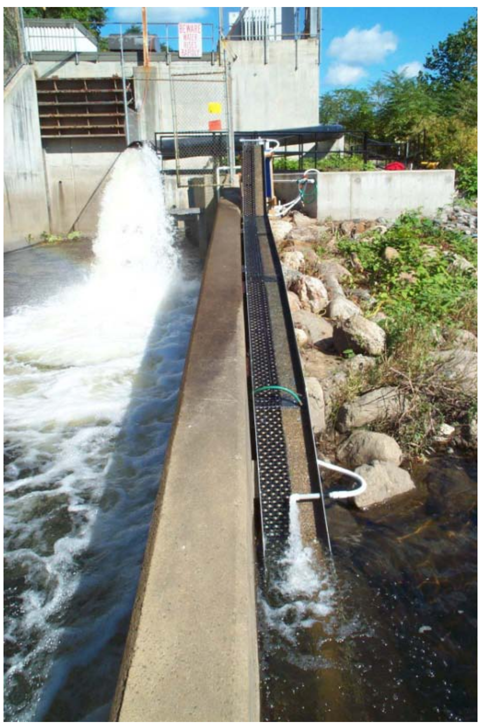
Lift - The most common type of fish lift is an elevator. Fish enter via a structure similar to other technical fishways and are typically crowded mechanically into a hopper, which is set below the floor. When activated, the hopper rises, capturing all accumulated fish and water, and travels vertically to the headpond level, where it discharges its contents into an exit flume that provides fish a pathway to the headpond, usually past a counting window. Initially, lifts were operated manually but now most have been automated to operate at a set interval (e.g. once an hour). This technology has often been favored at very tall dams because the cost of building a superstructure for a lift is less expensive than pouring large quantities of concrete. Lifts also offer the opportunity to sort fish (retain targeted species while returning undesirable species to below the dam) and truck targeted species to targeted portions of the upstream watershed.

Another type of fish lift is a fish lock, which function similar to a navigational lock but is designed and operated specifically for the purpose of passing migrant fish upstream. Some have rising brails that force the fish up to the upper level once the lock has been filled.



Navigational Locks - Navigational locks are designed to pass ships over dams or falls by allowing the ship to enter an enclosed chamber with the water level at tailwater level, closing the lower gates and filling the chamber to headpond level, and then opening the upper gates. In the process of opening gates, fish are attracted to the discharge of water and enter the chamber and have an opportunity to pass upstream along with the ships. Such locks are located for the convenience of shipping not attracting fish and therefore are likely inefficient at attracting fish. In some places, locks have been designed specifically for passing fish but it is not believed any such facilities have been built on the U.S. Atlantic Coast. Experience with fish passage through locks on the Atlantic Coast is very limited, mostly through facilities in South Carolina and North Carolina.

Eel Pass (Climbing Ramps) - There are a number of technologies used to pass American eels over dams but the most common is a sloped climbing ramp. They come in all sizes but typically they are a long open channel about 18 inches wide and four inches deep extending from an appropriate collection spot below the dam up to either the top of the dam or a blind trap at some intermediate level. Channels can be constructed of a variety of materials; sheet aluminum is generally preferred. It is generally recommended that eels not be required to climb more than 25 vertical feet and if the dam is higher, it is more effective to collect them in a trap at the top of a short ramp and hand carry them over the dam. The slope of the ramp should be less than 40 degrees; the floor of the ramp is fitted with some type of rough climbing substrate, often plastic bristles or a layer of plastic knobs laid out like a pegboard. A small amount of water is trickled down the pass substrate but supplemental attraction water is often added at the base of the eel pass. The source of water varies from site to site. In some locations, water is brought over the dam via a siphon in relatively small diameter pipes. In other cases, water is pumped to the top of the eel pass via small portable, submersible pumps located either in the headpond or the tailwater.



<u>Culverts</u> - Much of the preceding text has focused on dams but poorly designed road crossings can create barriers to migration by fishes. A common problem is 'perching'. Over time, high flows passing through the culvert erode soil and stream substrate from below the road crossing and lower the streambed elevation, resulting in a drop that fish cannot surmount. Other problems include culverts set at too steep a slope resulting in excessive water velocities, insufficient capacity to pass water resulting in excessive water velocities and submerged openings that some species (e.g. shad and blueback herring) will not tolerate, and excessive capacity to pass water (multiple box culverts) resulting in water flows that are too shallow to effectively pass fish. The best solution is to avoid culverts altogether and build span bridges.

Full span, bottomless arched culverts that maintain natural substrates are also effective. Setting one box culvert lower than the others in a multiple box installation will provide a minimum flow channel that can effectively pass fish during low flow periods. The installation of baffles inside culverts can be helpful. Perched culverts are usually best addressed by a complete replacement with a culvert that is flat and recessed below streambed level. However, in some cases, the installation of downstream full-width weirs can back-flood a stream up to the elevation of the downstream lip of the culvert.

Example of a perched culvert. In this case, downstream weirs can raise the elevation of the water surface to allow fish to swim over the lip.

Off-set baffles inside a culvert can reduce velocities and deepen flow to make it passable. In this example, there is a second box with a six-inch lip on the upstream end that diverts all low flow into this box, providing enough water during low flow summer months to pass fish.

Brief Summary of the Effectiveness of Common Fishway Designs for Each Managed Species

AMERICAN SHAD

Denils - Shad are known to use 4 ft wide Denils, particularly at slopes between 10% and 16%. Most successes have been with low dams (<25 ft high) and short Denils. Fatigue is a concern within Denils and even with regularly spaced turn and resting pools, there is uncertainty about the species' ability to successfully pass through long Denil. In fact, the inclusion of multiple turn and resting pools may decrease the chances of shad reaching the top. Turn and resting pools can be confusing to shad if the flow patterns are complex and runs can stall within turn pools.

Steeppass - This style is generally not built for shad due to its small size. Shad have been shown to successfully use steeppasses in experimental labs but the design is usually too small (in terms of amount of water passed) to be used in rivers large enough to support American shad. Shad like to travel up fishways in groups and steeppass fishways require single-file migration, which may decrease their effectiveness for shad. Furthermore, if only one or two units were needed to surmount the dam and the shad were able to travel up with a high degree of success (>99%), it might have some potential. However, if any dropback occurred within the steeppass, the narrow passageway with metal vanes could be very damaging to the individual fish dropping back and disruptive for the other fish trying to go up.

Pool-and-weir (large) - This style has been tried in New England for shad with varying degrees of success. The modified Ice Harbor design fishway at Cabot Station (Turners Falls) on the Connecticut River has a very poor track record of passing shad whereas a similarly designed but shorter fishway at the Vernon dam, next dam upstream of Turners Falls, has been relatively successfully at passing whatever passes through Turners Falls. Length of pool-and-weir fishways may affect overall shad passage. Turn pools can be confusing to shad if the flow patterns are complex and runs can stall within turn pools. Submerged orifices in these fishways may have benefit to some species but do not benefit shad.

The key to passing shad through this kind of a fishway may be low slope and/or drop per pool of 9 inches or less, large pools, large weir notches, and an uncomplicated lay-out that minimizes sharp turns. These features increase the cost of this already expensive design and many dam owners may consider less costly options.

Pool-and-weir (small) - This style is inappropriate for shad due to its small size.

Vertical Slot - This has been used at several hydroelectric dams and for most the results have been very poor due to narrow slot width (< 12 inches). This restricts shad movement to single file and may result in excessive scale loss due to impact with the sides of the slot. Some fishways lacked sufficient energy dissipation in the pools. However, some vertical slot fishways (e.g. Boshers Falls, James River and Turners Falls- Gatehouse) seem to pass shad effectively but the slot width is much greater (16 and 18 inches, respectively), the slope is low (1:25), and the pools are much larger and more effective at dissipating energy. Vertical slots may be suitable for American shad if they feature wide slots, low slopes, large pools, and short distances (i.e. low dams).

Nature-like - Performance tests have been conducted at the Conte Anadromous Fish Research Center but there is no field experience with shad using this design in an application as a fishway around a dam. The Conte tests suggest that there is potential for this design if the hydraulics are kept simple, a deeper main channel is maintained, and adequate flows are provided.

Lift - Lifts are very effective at passing American shad and have become the preferred alternative for dams greater than 25 feet in height. Shad tend to have stamina and motivation problems with long 'ladder-like' fishways. Lifting them in a hopper avoids the lengthy stay in a fishway and delivers them to the top of the dam in a very short time. Attraction and retention of shad into a lift is a key component to successful lift performance for this species.

Locks - There has been little experience with shad passing through locks although some have been known to pass through navigational locks.

Eel Pass (Climbing Ramps) - This is inappropriate for use with shad.

Removal - If this species migrated above the site prior to the construction of the dam, it is likely that it will go above the site after the dam is removed. After the Embrey Dam (Rappahannock River), shad were documented as far as 28 miles upstream. Therefore, this is the most effective of all fish passage technologies.

ALEWIFE

Denils - Alewives are known to use both 2 ft wide and 4 ft wide Denils, particularly at slopes between 10 and 16% slopes. Most successes have been with low dams (<25 ft high) but large numbers have passed over the 50 ft high Denil at Woodland, Maine. Fatigue is a concern within Denils and there is a need for regularly spaced resting pools.

Steeppass - Alewives are known to use steeppass fishways very effectively and this is the design of choice for many small coastal dams.

Pool-and-weir (large) - This style has been not been tried much for alewife since this species tends not to move upstream as far as American shad and blueback herring. The exception is the Amoskeag Fishway (modified Ice Harbor, third dam on the Merrimack River) which has passed in excess of 300,000 river herring in one year. It is unclear whether these were both alewife and blueback herring or just one of them. Similar to shad, the key to passing alewives through this kind of a fishway may be low slope, large pools, and large weir notches. These features increase the cost of this already expensive design and many dam owners may consider less costly options.

Pool-and-weir (small) - This style can be highly effective at passing alewife and is the design of choice at many locations in New England, such as Cape Cod. However, many early pool-and-weir designs have limited functionality for alewife due to high slope and/or poor hydraulics.

Key features are targeting drops per weir at six inches and having adequate pool sizes for the dissipation of energy.

Vertical Slot - This has been used at several hydroelectric dams and for most the results have been very poor due to narrow slot width. This restricts alewife movement to single file and may result in excessive scale loss due to impact with the sides of the slot. Some fishways lacked sufficient energy dissipation in the pools. However, some vertical slot fishways (e.g. Turners Falls- Gatehouse) seem to pass shad effectively but the slot width was much greater and the pools were much larger and more effective at dissipating energy. There is less experience with large vertical slot fishways for alewives since these fishways tend to be located further inland where alewives sometimes do not penetrate. One small coastal vertical slot fishway in Connecticut failed to pass alewives where a steeppass subsequently passed them effectively. Vertical slots may be suitable for alewife if they feature wide slots, low slopes, large pools, and short distances (i.e. low dams).

Nature-like - Performance tests have been conducted by the Conte Anadromous Fish Research Center at a constructed fishway in Massachusetts and at a much steeper one in Connecticut. Both passed significant numbers of alewife. The results suggest that this design has applicability for passing alewives but the effectiveness will vary from site to site and will be dependent upon very specific features that may need modifying after post-construction evaluation. Passage performance has been quantified of two existing nature-like fishways in Massachusetts and Connecticut; passage of alewives has been good to excellent in these fishways.

Lifts - Lifts are effective at passing alewives. Unless the dam is very tall, alewives can effectively use less-expensive designs. However, lifts are typically designed for shad and the alewives come with them.

Locks - There has been no experience with alewives passing through locks.

Eel Pass (Climbing Ramps) - This is inappropriate for use with alewife.

Removal - If this species migrated above the site prior to the construction of the dam, it is likely that it will go above the site after the dam is removed. Therefore, this is the most effective of all fish passage technologies.

BLUEBACK HERRING

Denils - Bluebacks are known to use both 2 ft wide and 4 ft wide Denils, particularly at slopes between 10 and 16% slopes. Most successes have been with low dams (<25 ft high) and short Denils. Fatigue is a concern within Denils and there is a need for regularly spaced resting pools.

Steeppass - Bluebacks are known to use steeppass fishways very effectively and this is the design of choice for many small coastal dams.

Pool-and-weir (large) - This style has been tried in New England for blueback herring with varying degrees of success. The modified Ice Harbor design fishway at Cabot Station (Turners Falls) on the Connecticut River has a very poor track record of passing bluebacks whereas a similarly designed fishway at the Vernon dam, next dam upstream of Turners Falls, has been relatively successfully at passing whatever passes through Turners Falls. The key to passing bluebacks through this kind of a fishway may be low slope, large pools, and large weir notches. These features increase the cost of this already expensive design and many dam owners may consider less costly options. Submerged orifices in these fishways may have benefit to some species but do not appear to benefit blueback herring.

Pool-and-weir (small) - This style is highly effective at passing blueback herring and is the design of choice at many locations in New England, such as Cape Cod. Key features are targeting drops per weir at six inches and having adequate pool sizes for the dissipation of energy.

Vertical Slot - This has been used at several hydroelectric dams and for most the results have been very poor due to narrow slot width. This restricts blueback movement to single file and may result in excessive scale loss due to impact with the sides of the slot. Some fishways lacked sufficient energy dissipation in the pools. However, some vertical slot fishways (e.g. Turners Falls- Gatehouse) seem to pass bluebacks effectively but the slot width was much greater and the pools were much larger and more effective at dissipating energy. Vertical slots may be suitable for blueback herring if they feature wide slots, low slopes, large pools, and short distances (i.e. low dams).

Nature-like - Performance tests have been conducted at the Conte Anadromous Fish Research Center but there is no experience with blueback herring using this design in an application as a fishway around a dam. The Conte tests suggest that there is potential for this design if the hydraulics are kept simple, a deeper main channel is maintained, and adequate flows are provided. The evaluation of two constructed fishway for alewives (see above) suggests that this design could be effective for blueback herring as well.

Lifts - Lifts are effective at passing blueback herring. Unless the dam is very tall, blueback herring can effectively use less-expensive designs. However, lifts are typically designed for shad and the bluebacks come with them. However, bluebacks may have stamina and motivation problems at inland locations (at multiple dams from the sea) and the use of a lift may expedite the migration.

Locks - There has been little experience with blueback herring passing through locks although some have been known to pass through navigational locks.

Eel Pass (Climbing Ramps) - This is inappropriate for use with blueback herring.

Removal - If this species migrated above the site prior to the construction of the dam, it is likely that it will go above the site after the dam is removed. Blueback herring was documented 28 miles upstream of the former Embrey Dam (Rappahannock River) after it was removed. Therefore, this is the most effective of all fish passage technologies.

HICKORY SHAD

Denils - Hickory shad are known to use both 2 ft wide and 4 ft wide Denils, particularly at slopes between 10 and 16% slopes. Most successes have been with low dams (<25 ft high) and short Denils. Fatigue is a concern within Denils and there is a need for regularly spaced resting pools.

Steeppass - Hickory shad are known to use steeppass fishways very effectively and this is the design of choice for many small coastal dams.

Pool-and-weir (large) - There is little experience with this style of fishway for hickory shad.

Pool-and-weir (small) - There is little experience with this design for hickory shad.

Vertical Slot - There is little experience with this design for hickory shad.

Nature-like - There is little experience with this design for hickory shad.

Lifts - There has been little experience with this design for hickory shad.

Locks - There has been no experience with hickory shad passing through locks.

Eel Pass (Climbing Ramps) - This is inappropriate for use with hickory shad.

Removal - If this species migrated above the site prior to the construction of the dam, it is likely that it will go above the site after the dam is removed. Hickory shad are regularly collected five miles upstream of the former location of the Embrey Dam (Rappahannock Dam). Therefore, this is the most effective of all fish passage technologies.

STRIPED BASS

Denils - Striped bass are known to use 4 ft wide Denils, particularly at slopes between 10 and 16% slopes. Most successes have been with low dams (<25 ft high) and short Denils. Fatigue is a concern within Denils and there is a need for regularly spaced resting pools. It appears that this style of fishway has been more successful in the Chesapeake Bay region than farther north. It is possible that this style of fishway along with most other types are more successful in passing striped bass that are on a spawning run than passing fish that are moving upstream in a non-natal river on a feeding foray.

Steeppass - There is no evidence of striped bass using steeppass fishways, which may be both too steep and too narrow for the stronger swimming large bass to use.

Pool-and-weir (large) - There is little experience with this style of fishway with striped bass. Striped bass have access to some of these large fishways in New England rivers but very few pass upstream. However, these fishways are generally farther upstream and the stripers are not on spawning runs. The key to passing striped bass through this kind of a fishway may be low slope, large pools, and large weir notches. These features increase the cost of this already expensive design and many dam owners may consider less costly options.

Pool-and-weir (small)- There is little experience with this style of fishway for striped bass but it is assumed that it is too small for mature striped bass on a spawning run.

Vertical Slot- This has been used at several hydroelectric dams but most are located upstream of the normal penetration of striped bass. The Rainbow Dam Fishway in Connecticut has large numbers of large striped bass at its entrance yet only passes <5 striped bass each year and all fish are generally less than 15 inches long. Similar findings have occurred at a similar vertical slot fishway on the Androscoggin River in Brunswick, Maine. The 10 inch wide slots may restrict the movement of larger bass. Vertical slots may be suitable for striped bass if they feature wide slots, low slopes, large pools, and short distances (i.e. low dams).

Nature-like- There is little experience with this design for striped bass.

Lifts- Lifts are known to pass hundreds of striped bass annually. Many of the lifts may have thousands of striped bass below them. Most of these lifts are located in New England where the striped bass are not spawning. Therefore, the efficiency of lifts for striped bass is unknown.

Locks- There has been no experience with striped bass passing through locks.

Eel Pass (Climbing Ramps)- This is inappropriate for use with striped bass.

Removal- If this species migrated above the site prior to the construction of the dam, it is likely that it will go above the site after the dam is removed. Large stripers are routinely captured upstream of the site of the former Embrey Dam (Rappahannock Dam). Therefore, this is the most effective of all fish passage technologies.

ATLANTIC STURGEON

Denils- There is no evidence of sturgeon using a Denil fishway.

Steeppass- There is no evidence of either species using a steeppass fishway.

Pool-and-weir (large)- There is little experience with this style of fishway with sturgeon. A well-established population of shortnose sturgeon (which may have similar swimming abilities of those of Atlantic sturgeon) exists downstream of the modified Ice Harbor design fishway at Cabot Station (Turners Falls) on the Connecticut River but no sturgeon have been documented using it. The value of upstream habitat and the upstream urge of the sturgeon below this fishway is unknown. Pacific species of sturgeon are known to use similar (but larger) designed fishways (e.g. Bonneville Dam fishway) on the Columbia River but the efficiency of such passage is unknown. The key to passing sturgeon through this kind of a fishway may be low slope, large pools, and large weir notches. These features increase the cost of this already expensive design and many dam owners may consider less costly options.

Pool-and-weir (small)- This style is inappropriate for sturgeon due to its small size.

Vertical Slot- This has been used at several hydroelectric dams but most are located upstream of the normal penetration of sturgeon. Shortnose sturgeon have access to the Rainbow Dam Fishway in Connecticut and the Brunswick Dam Fishway in Maine yet neither has ever passed any sturgeon. It is unclear whether sturgeon are present below the dam, wish to proceed upstream, can use the entrance raised off the streambed, or cannot use the vertical slot design. The 10 inch wide slots would likely restrict the movement of mature sturgeon. Vertical slots may be suitable for sturgeon if they feature wide slots, very low slopes, large pools, and short distances (i.e. low dams).

Nature-like- There is no experience with this design for Atlantic sturgeon. The State of Minnesota has successfully passed lake sturgeon through Nature-like fishways (as has the Conte Anadromous Fish Research Center using lab models) so the design may have potential for Atlantic sturgeon.

Lifts- The Holyoke Dam Fish Lift generally lifts fewer than five shortnose sturgeon per year. (Atlantic sturgeon are not believed to be present below Holyoke Dam but the shortnose sturgeon is mentioned here as a proxy for the Atlantic sturgeon.) Most other lifts located in sturgeon habitat experience similar numbers. Theoretically, there is no reason to believe that lifts could not lift most sturgeon effectively, given adequate hopper size. In many cases, the entrance is suspected to be improperly designed (e.g. elevated high above the streambed) to effectively attract sturgeon. Some Columbia River dam had devices that were a cross between a fish lift and fish lock that effectively lifted white sturgeon, so this technology may have potential for Atlantic sturgeon.

Locks- There has been little experience with sturgeon passing through locks although some have been known to pass through navigational locks.

Eel Pass (Climbing Ramps)- This is inappropriate for use with sturgeon.

Removal- If this species migrated above the site prior to the construction of the dam, it is likely that it will go above the site after the dam is removed. Therefore, this is the most effective of all fish passage technologies.

AMERICAN EEL

Denils- Eels are not very strong swimmers and therefore their use of roughened chute style fishways like Denils and steeppasses is not common. However, larger eels have been documented using Denils in low numbers. It is possible that they are able to slowly ascend along the bottom of a Denil and hold themselves in crevices between the baffle and floor to rest. Regardless, this would not be a recommended fishway type for eels.

Steeppass- There is no evidence of eels using a steeppass fishway.

Pool-and-weir (large)- Eels are commonly observed in this style of fishway but the efficiency of this passage is unknown. Observed eels have been mostly large eels and that may be a factor of the upstream location of the fishways or that an eel must be somewhat large to have the strength to swim through the high velocity notches or submerged orifices. The reason that some eels may be able use them is the presence of large, low velocity pools where the eel can rest and even forage. Regardless, this would not be a recommended fishway type for eels.

Pool-and-weir (small)- Eels of all sizes will use this style of fishway to a certain degree. The key may be low water velocities, small drops per weir, and 'leaky' weir boards that allow small eels to wiggle through gaps to pass from pool to pool.

Vertical Slot- Eels of all sizes have been documented using large vertical slot fishways. Passage of eels may be enhanced when the lower portion of the slot is blocked with sill blocks that have gaps around them, allowing small eels to avoid the high velocity flows of the slot. If a vertical slot fishway is planned as the main avenue for upstream migration of eel, some special design features such as submerged orifices through the weirs, stuffed with a porous climbing substrate, may increase the effectiveness of this design.

Nature-like- There is little experience with this design for American eel but based upon the knowledge of eel migratory habitats, there is reason to believe that this design would effectively pass American eel, as long as the entrance was appropriately located.

Lifts- Lifts are known to pass American eel in very small numbers and mostly pass larger yellow eels. It is possible that the attraction water systems for the lifts attract eels away from the hopper more effectively than attracting them into the hopper. All mechanical crowders designed for shad, river herring, and other species are ineffective at crowding eels, which can pass through most crowder screens and lead fences. Once lifted, small eels are probably able to avoid detection at counting windows due to the scale of the counting operation and the raised nature of the bottom of the counting window. Many lifts are outfitted with specific eel passes to address this problem.

Locks- There has been little experience with eels passing through locks although some have been known to pass through navigational locks.

Eel Pass (Climbing Ramps)- This is the preferred design for passing American eel. At sites where glass eels are present, an additional or alternative climbing substrate (e.g. Enkamat) is advised. Larger eels require more coarse climbing substrates. The key to success is selecting an appropriate location for the entrance where eels can find it. Since the number of eels below a dam is typically difficult to quantify, there are no studies that estimate the efficiency of an eel pass in passing migrants. Annual passage numbers can vary from dozens to tens of thousands.

Removal- If this species migrated above the site prior to the construction of the dam, it is likely that it will go above the site after the dam is removed. Therefore, this is the most effective of all fish passage technologies.