



Colloque international sur l'étude, la restauration et la gestion de l'alose  
International symposium on restoration and conservation of shads

## État des connaissances sur les passes migratoires pour l'alose américaine aux États-Unis.

State of the knowledge on fish passes for American shad in the USA.

***François Groux, Jean Therrien (WSP Canada)***

***Matthieu Chanseau, Dominique Courret (ONEMA, France)***

***Stéphane Tétard (EDF, France)***

*Session 2 : État des connaissances / State of science*

**Bergerac**

14-15 octobre 2015



## What ?

Literature review and site visits in North America, Atlantic Coast

## Why ?

*Alosa alosa* and *Alosa sapidissima* have similar migratory behaviors

To obtain a feedback for fishways design criteria after 60 years of monitoring in the US

## Who ?

ONEMA – EDF and WSP as consultant

## Literature review :

More than 100 documents reviewed : studies of fish passes efficiency, restauration plans reports, design reports, monitoring studies, scientific publications, etc.

## Site visits and discussion with local experts :

11 sites on the Atlantic Coast

The 3 most important watersheds regarding the restauration plans since 1960s'





**Alosa alosa – Grande alose ou alose vraie**

**Alosa sapidissima – American Shad**

**Anadromous**

**Body elongate, strongly compressed laterally, deep**

**Migration and spawning behavior vary with water temperature**

- **Average length: 50 to 70 cm**
- **Average weight: 1.5 to 3.5 kg**
- **Migration and spawning:**
  - ✓ **Period varies mainly with water temperature (10 to 15°C)**
  - ✓ **Upstream migration : February to June**
  - ✓ **Spawning : May to August**
  - ✓ **Very low repeat spawning (< 2%)**

- **Average length: 35 to 55 cm**
- **Average weight: 1 to 3 kg**
- **Migration and spawning:**
  - ✓ **Period varies mainly with water temperature (13 to 20°C)**  
*(November in Florida, July in Canada)*
  - ✓ **April to June on the East Coast**
  - ✓ **Repeat spawning increase from the South to the North (between 0% - Florida - and 70% - New Brunswick CA -)**
  - ✓ **Shad may return to spawn up to 6 years**



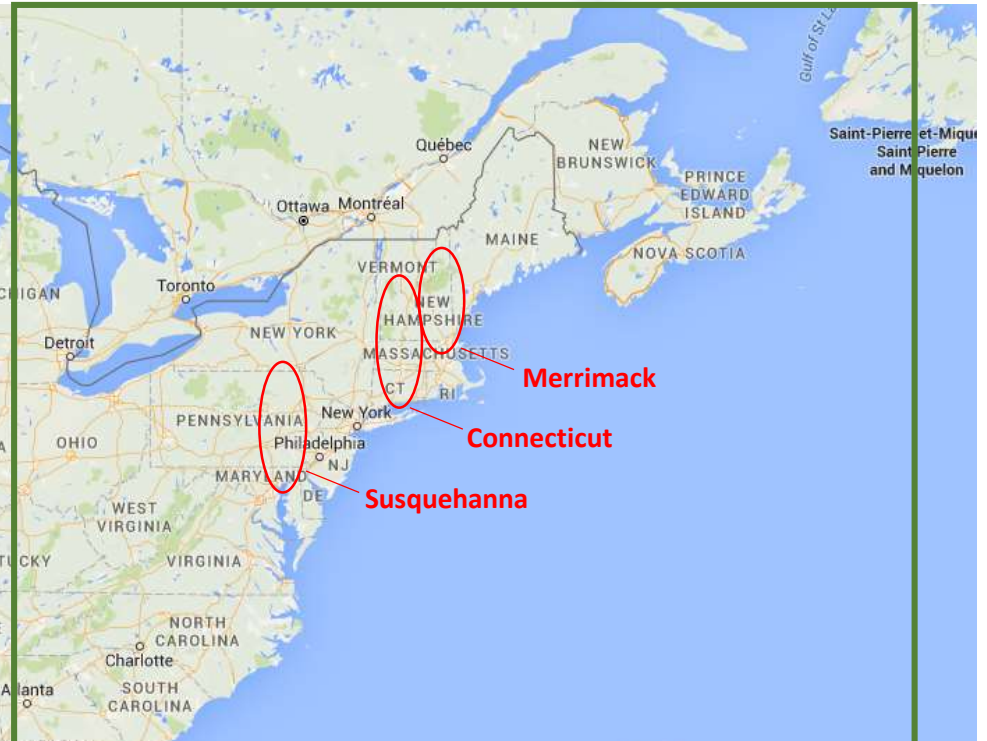




**Cote Ouest West Coast (Pacific)**

L'aloise est une espèce invasive (fin du XIX<sup>ème</sup>).  
 Plusieurs passes d'importance, principalement  
 sur la Columbia, à partir des années 30.

*Shad is an invasive species (introduce at the end  
 of the XIX<sup>th</sup>). Several important fishways, mainly  
 on the Columbia River, since 1930s.*



**Cote Est East Coast (Atlantic)**

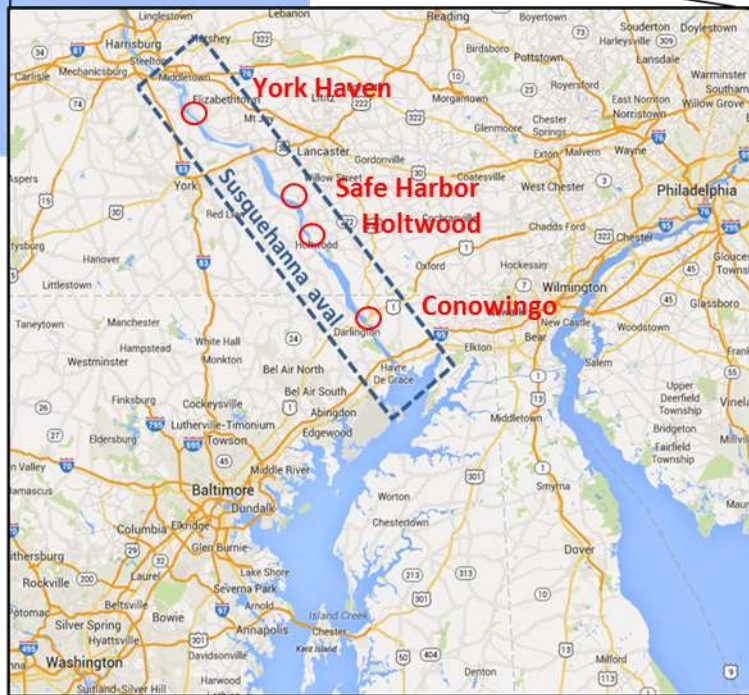
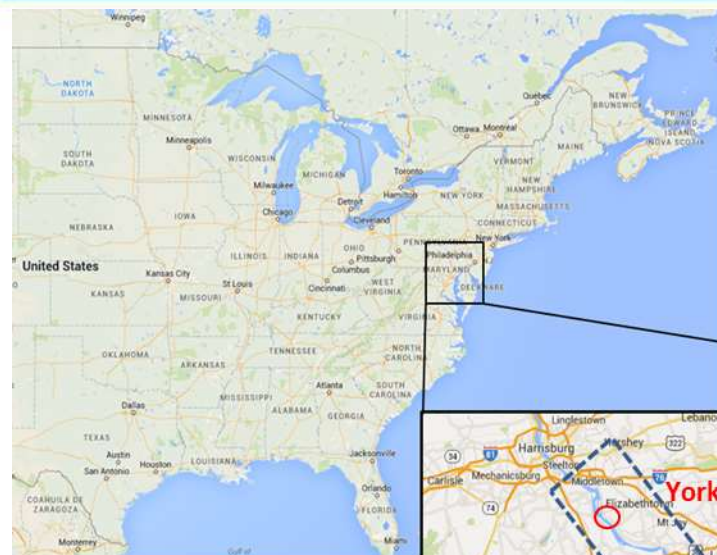
Déclin des populations à la révolution industrielle.  
 Programmes de restauration et construction de passes à partir des  
 années 60 (inspirées de la Côte Ouest où les résultats sont  
 prometteurs).

*Severe decrease of shad populations since the industrial revolution.  
 Restoration plans including fishways construction since 1960s  
 (designed from West Coast example where results seems good).*



Average flow at Conowingo (USGS 01578310) – 1967 / 2014 (m<sup>3</sup>/s)

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANN
1280	1396	2093	2158	1368	971	558	419	595	716	1017	1444	1169

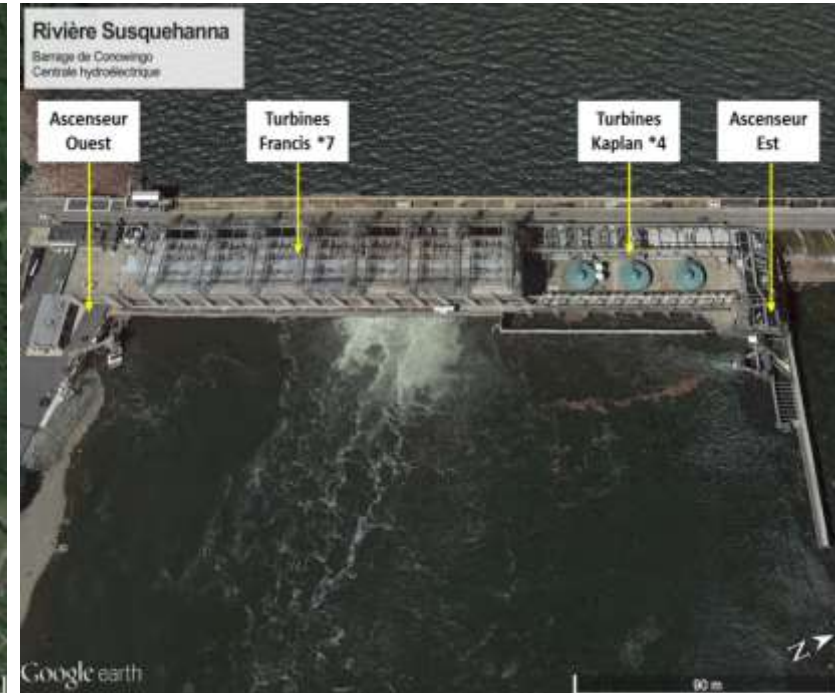
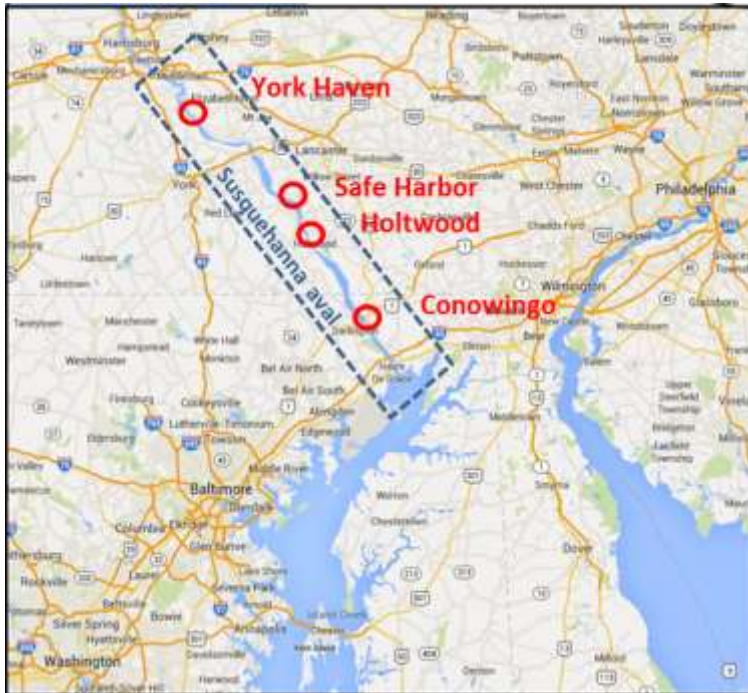






SITE	KM	FISHWAY	DROP (M)	ENTRANCES	ATTRACTIVE FLOW	POWER PLANT CAPACITY	COUNTS AV. 1997-2014	RATE	COUNTS 2014	RATE
CONOWINGO	16	Power Plant Fish lift (*2) <i>Only 1 operated</i>	20	3 <i>2 operated 1 at a time</i>	8.5 m <sup>3</sup> /s 0.3 to 2.7%/PP	2 435 m <sup>3</sup> /s	66 346	?	10 425	≈ 10% <sup>1</sup>

1: Shad population estimated between 80 and 120 000 downstream Conowingo. Information gathered during site visits. Ongoing study financed by the Maryland Department of Natural Resources.

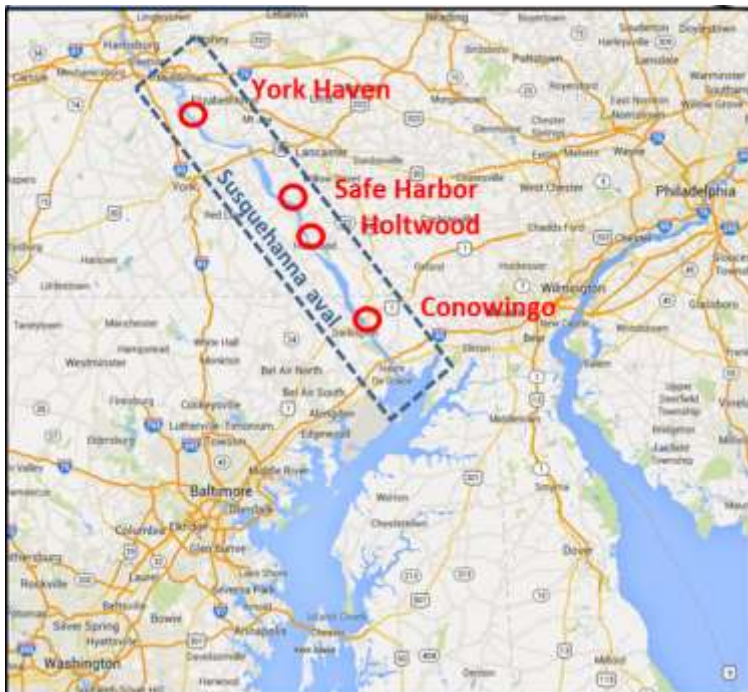






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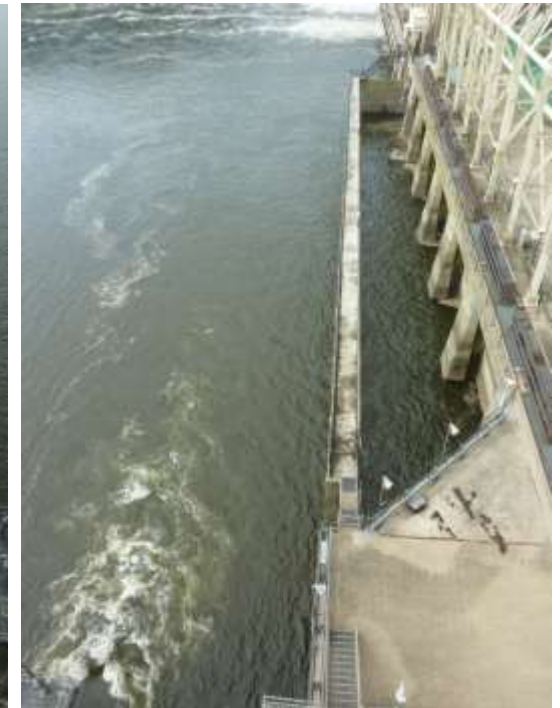
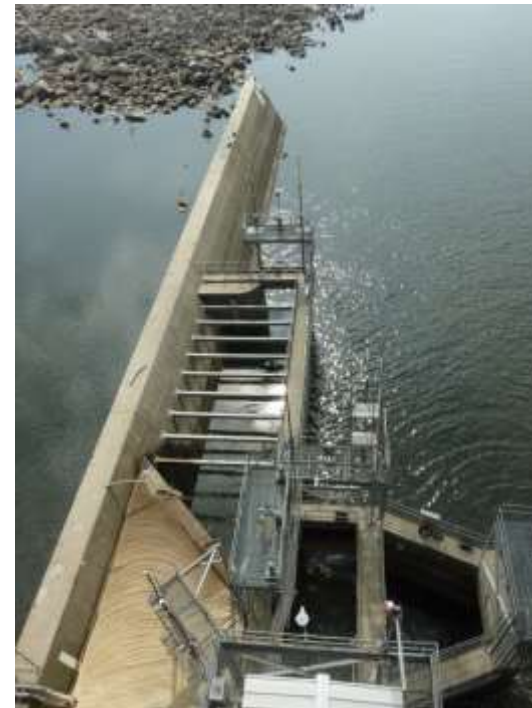
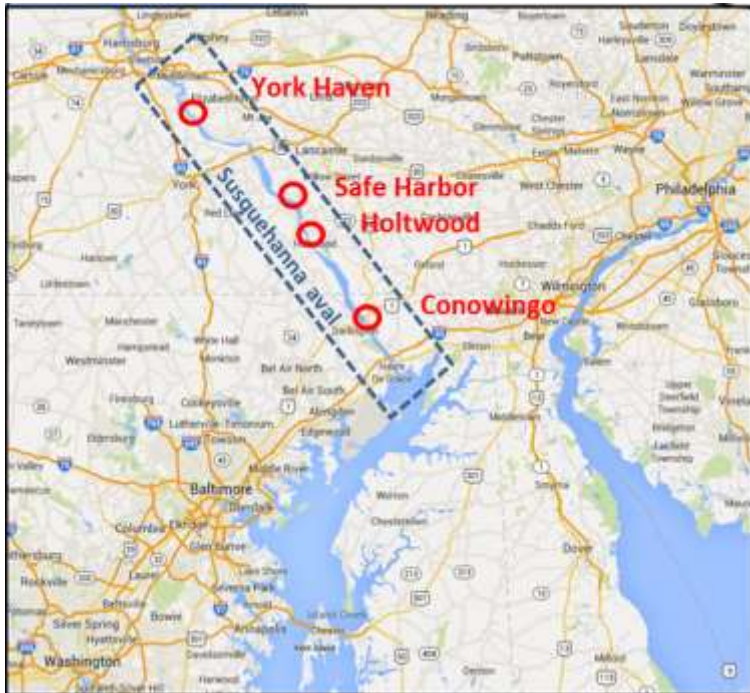
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	Susquehanna	Connecticut	Merrimack	Approach	Entrance	Passage		





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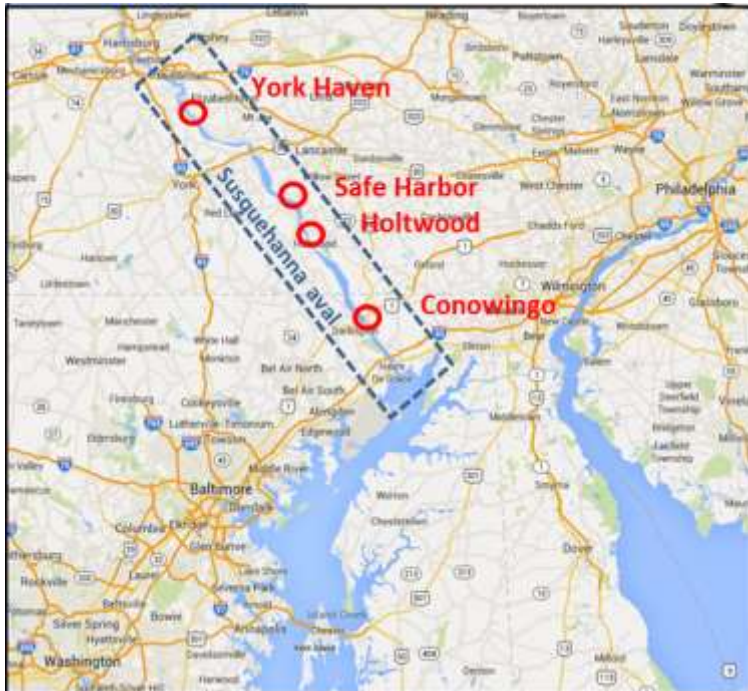


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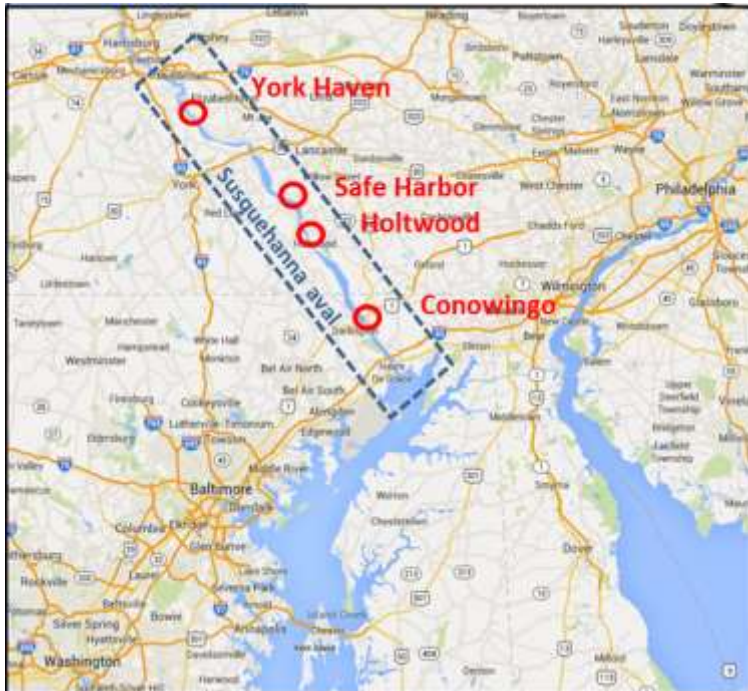
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HOLTWOOD	39	Power House	17	2	8.5 m <sup>3</sup> /s / E 0.9 to 5.2 %/PP	1 730 m <sup>3</sup> /s	20 922	30%	2 528	24%
		Spillway		1						







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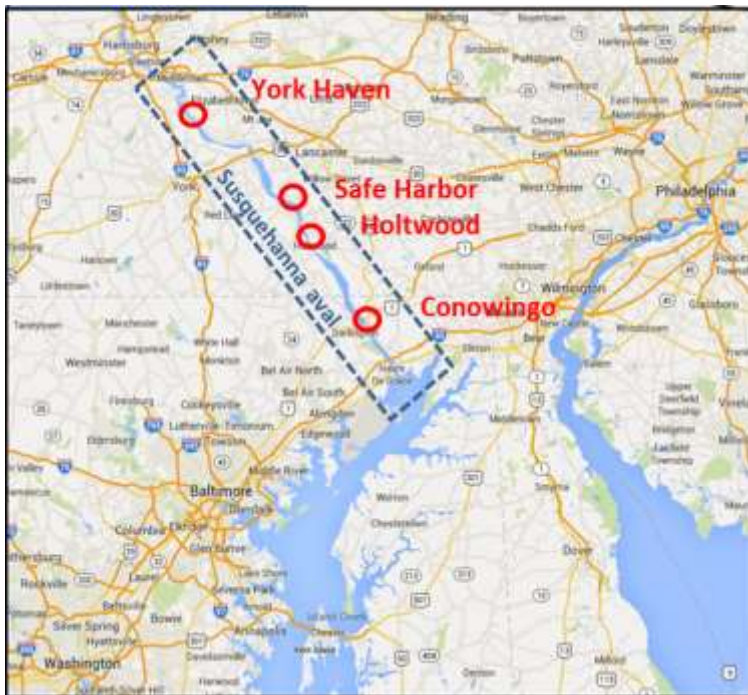


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SAFE HARBOR	50	Power Plant	Fish lift	17	3 2 operated	8.5 / entrance 0.9 to 9% / PP	3 200 m <sup>3</sup> /s	15 959	69%	1 336	53%





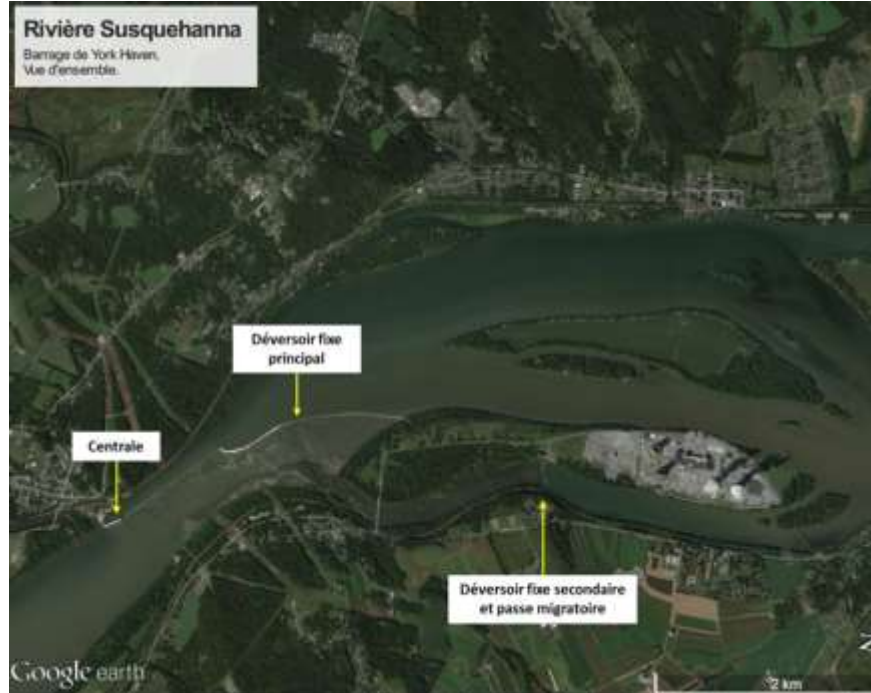
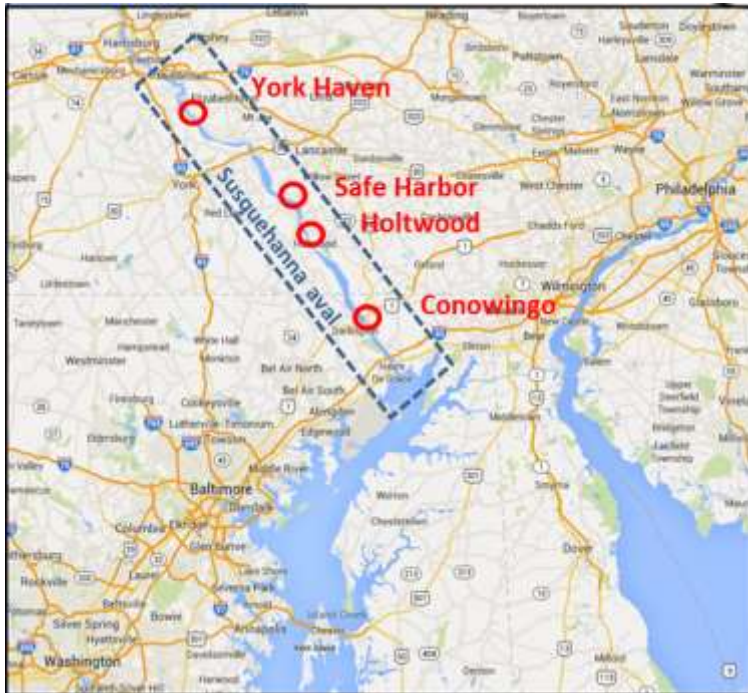
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YORK HAVEN	88	Fish Ladder (vert. slots)	2.7	1	5.7 m <sup>3</sup> /s 10% / Reach 1.1% / PP	481 m <sup>3</sup> /s	2 533	9%	8	1%





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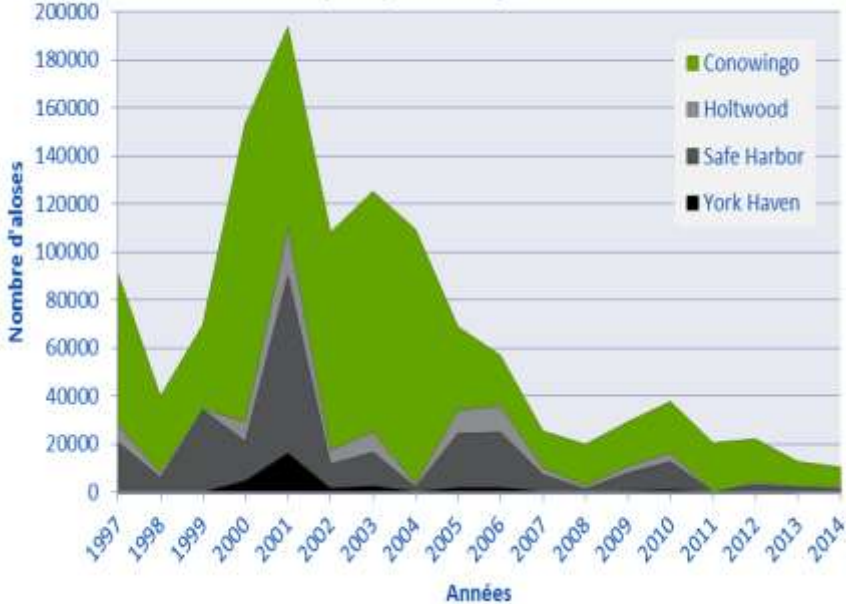


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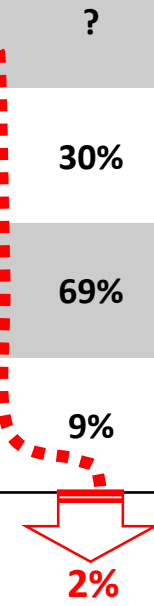




Suivi des migrations d'aloises par comptage ente 1997 et 2014 aux principaux barrages



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**!! Spawning areas between some dams! : Safe Harbor – York Haven**



## Conowingo - Results of telemetry monitoring conducted in 2010 and 2012

YEAR	RELATIVE EFFICIENCY EACH STEP			GLOBAL EFFICIENCY <sup>4</sup>	DURATION <sup>5</sup> (D)
	ENTRANCE ATTRACTIVITY <sup>1</sup>	ENTRANCE COMPETED <sup>2</sup>	INTERNAL EFFICIENCY <sup>3</sup>		
2010	90 %	73 %	61.5% in 2010 (72,5% in one try)	44 %	4
2012	64 %	44 %	58.6% in 2012 (64,7% in one try)	26 %	10

1 : Shad coming close to the entrance (s) / shad present downstream

## Holtwood - Results of telemetry monitoring conducted in 2001

Note: on the 204 marked shad released upstream of Conowingo dam, 136 were later detected in the tailrace (67%).

RELATIVE EFFICIENCY EACH STEP			GLOBAL EFFICIENCY <sup>4</sup>	DURATION <sup>5</sup> (D)
ENTRANCE ATTRACTIVITY <sup>1</sup>	ENTRANCE COMPETED <sup>2</sup>	INTERNAL EFFICIENCY <sup>3</sup>		
84 %	75 %	54%	34 %	5

2 : Shad entering the fishway / shad coming close to the entrance (s)

3 : Shad completing their passage through the fishway / shad entering the fishway

4 : Global efficiency of shad passage

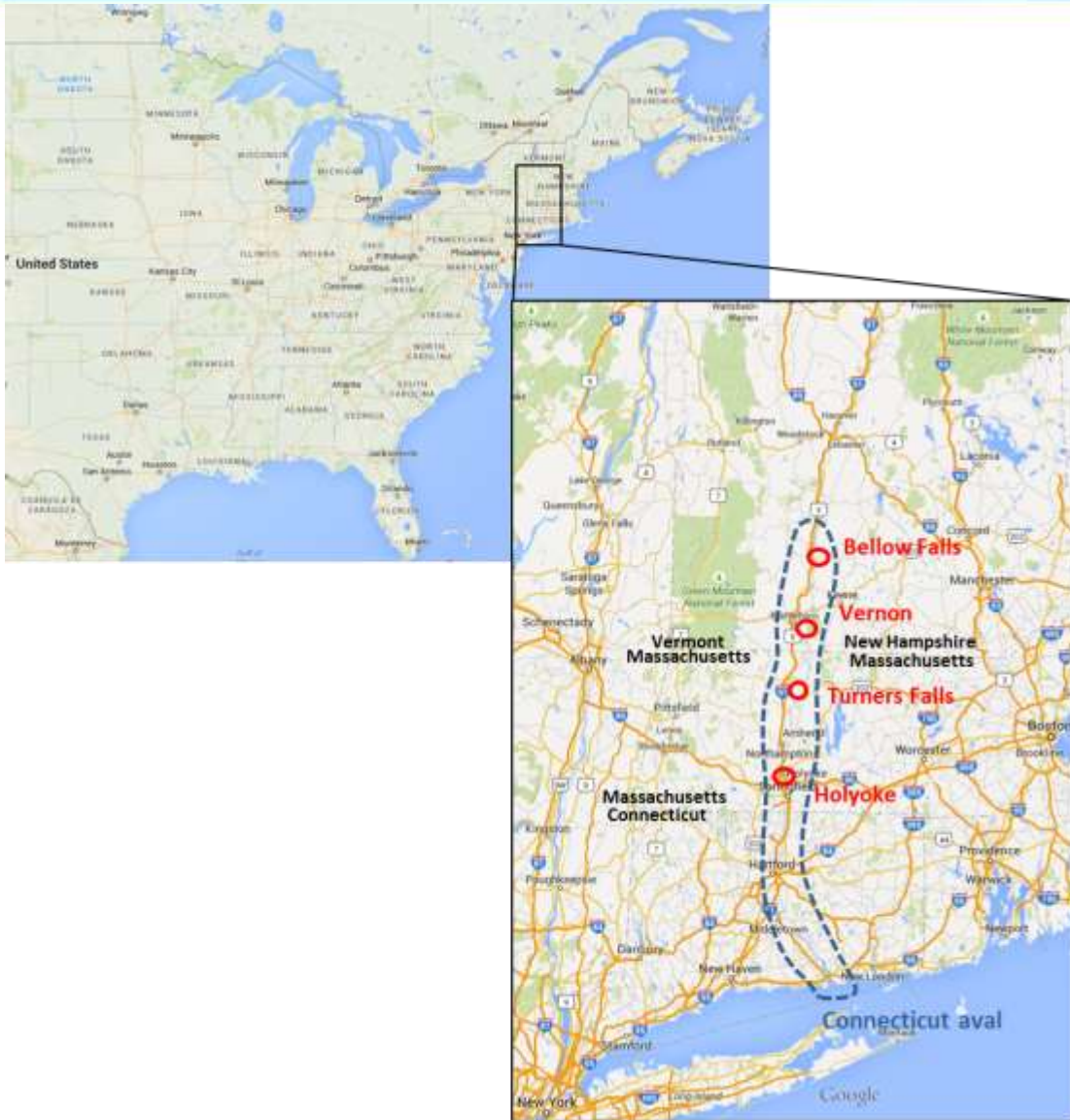
## York Haven – Results of the study done in 2010

Note: attractivity to the East Channel is estimated at 34% in 2010 and 24% of them reached the dam.

RELATIVE EFFICIENCY EACH STEP			GLOBAL EFFICIENCY <sup>4</sup>
ENTRANCE ATTRACTIVITY <sup>1</sup>	ENTRANCE COMPETED <sup>2</sup>	INTERNAL EFFICIENCY <sup>3</sup>	
59 %	53 %	56 %	17 %

5 : Average time of passage from the tailrace to the exit of the fishway (day)





### Average flows for Connecticut River (m<sup>3</sup>/s)

Source : <http://waterdata.usgs.gov>

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANN
Bellow Falls	217	201	385	767	464	241	147	124	113	198	259	259	281
Turners Falls	331	300	589	1 093	654	334	204	172	176	264	365	377	405
Holyoke	359	310	564	1 002	541	352	226	195	175	334	397	420	406

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SITE	KM	FISHWAY	DROP (M)	ENTRANCE	ATTRACTIVE FLOW	POWER PLANT CAPACITY	COUNTS AV. 1967-2014	RATE	COUNTS 2014	RATE
HOLYOKE	139	Power House	Fish lift	16	3	1.7 à 5.6 m <sup>3</sup> /s	313 043 <sup>2</sup>	36% <sup>1</sup>	370 506	?
		Spillway	Fish lift	9	1	1.4 à 4.2 m <sup>3</sup> /s				

1: Average shad population estimated : 770 868

2: 60 % thanks to spillway fish lift (power plant capacity < 25% average flow during April)



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HOLYOKE	139	Power House	16	3	1.7 à 5.6 m <sup>3</sup> /s	230 m <sup>3</sup> /s	313 043 <sup>2</sup>	36% <sup>1</sup>	370 506	?
		Spillway	9	1	1.4 à 4.2 m <sup>3</sup> /s					

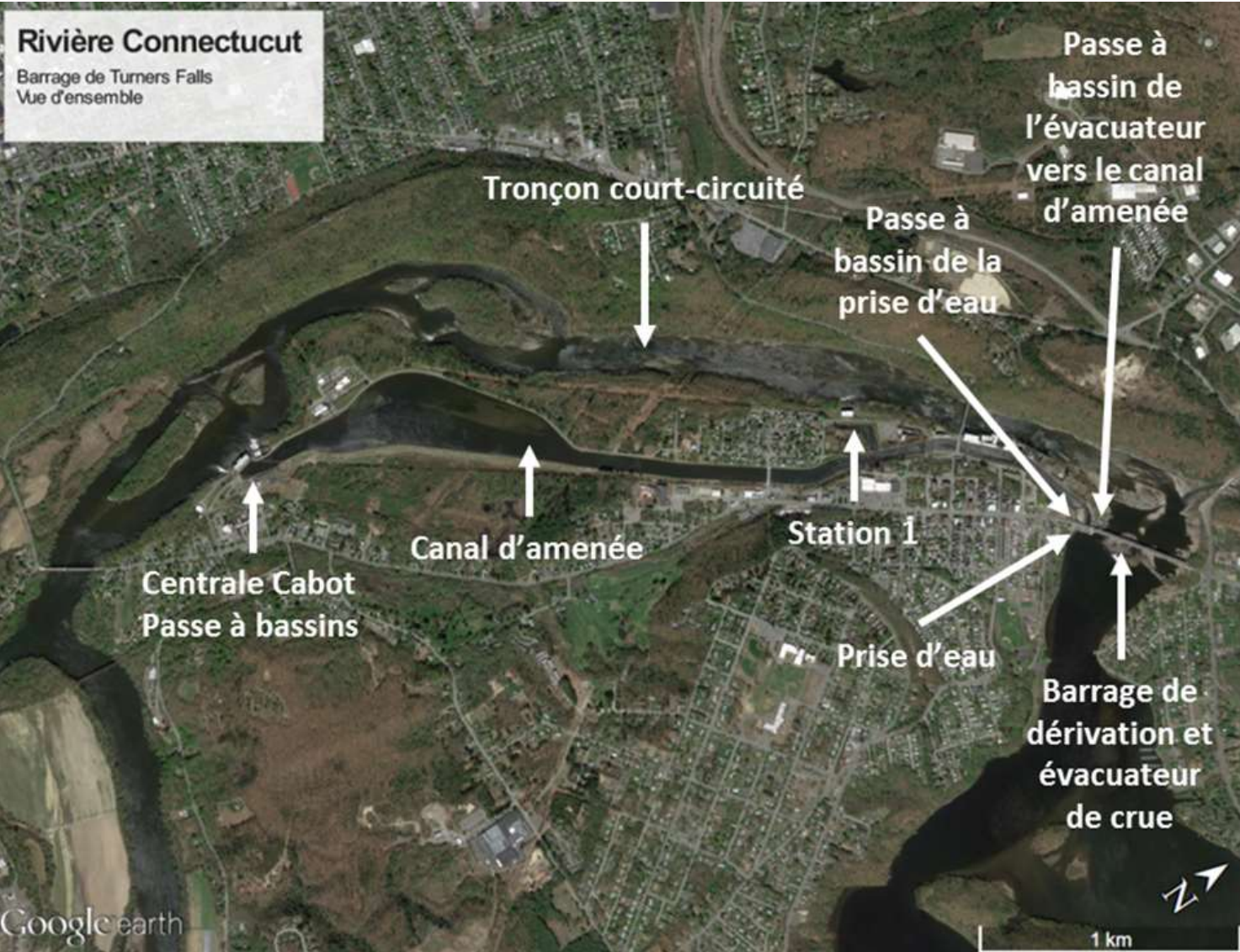
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SITE	KM	FISHWAY	DROP (M)	ENTRANCE	ATTRACTIVE FLOW	POWER PLANT CAPACITY	COUNTS AV. 1967-2014	RATE	COUNTS 2014	RATE	
TURNERS FALLS	198	Cabot (power house)	Fish ladder (Ice Harb. Mod.)	20	5 1 operated	Up to 12.3 m <sup>3</sup> /s 2.7% / PP	451 m <sup>3</sup> /s	13 499	4%	39 914	11% 10% in average since 2010
		Dam	Fish ladder (Ice Harb. Mod.)	11	1	2.8 to 12.3 m <sup>3</sup> /s					
		Gate House (water intake)	Fish ladder (dble vert. slots)	0.6 to 2.4	2	12.3 m <sup>3</sup> /s 2.7% / PP					





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VERNON	228	Power Plant (Ice Harb. Mod. + vert slots)	10	5 1 operated	5.7 m <sup>3</sup> /s 1.5% / PP	370 m <sup>3</sup> /s	6 308	41%	27 700	69%



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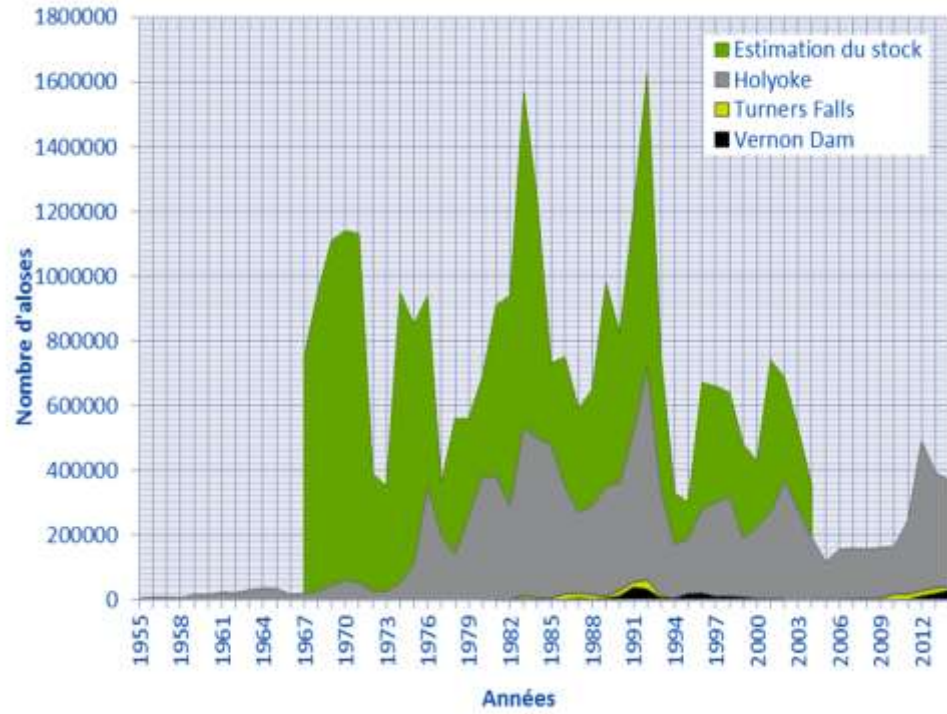


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Suivi des migrations d'aloses par comptage ente 1955 et 2014 aux principaux barrages

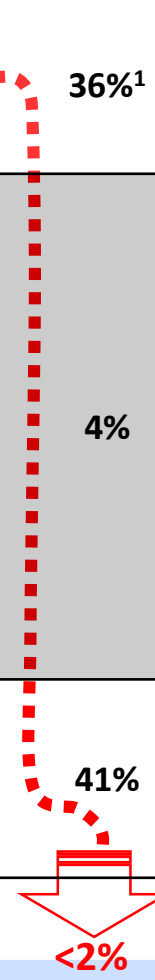


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1: Average shad population estimated : 770 868

2: Increasing since 2010 to 10% on average



<2%



## TURNERS FALLS:

### CABOT STATION

Sullivan (2004) :

- Internal efficiency of the fish ladder from 1999 to 2002 = 13% in average
- Average time to go through the fish ladder is around 10 h : long time could explain the poor efficiency of the ladder, shads going back if the fishway is not completely done at dawn

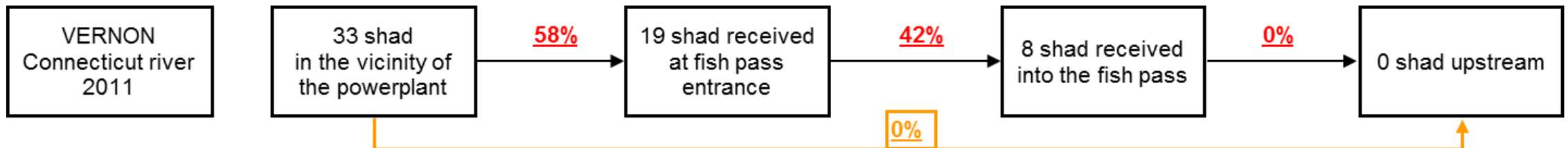
Warner (2003):

- Internal efficiency = 17%
- Entrance efficiency = 34%

Detailed study (2003) : average efficiency in each pool = 80 to 95%

⇒ High number of pools (66) leads to low efficiency

## VERNON:



## SPILLWAY

Sullivan (2004) efficiency 1999-2002 = 16%

## GATE HOUSE

Warner (2003) :

- Internal efficiency = 85%
- Entrance efficiency = 22%

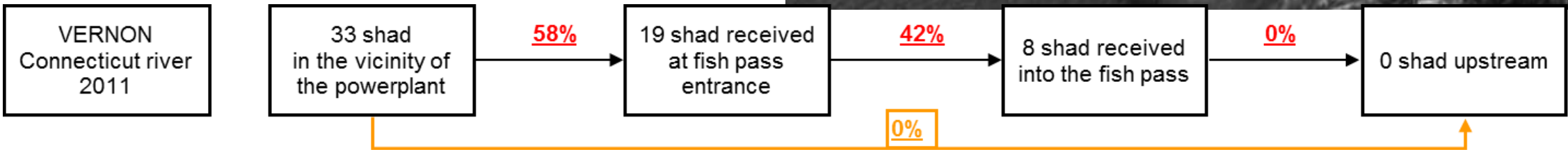
⇒ Improvement of the canal entrance (addition of a downstream entrance on the right side) with good results: efficiency increased to 40-60%.

Average time of transit = 15 min





**VERNON:**



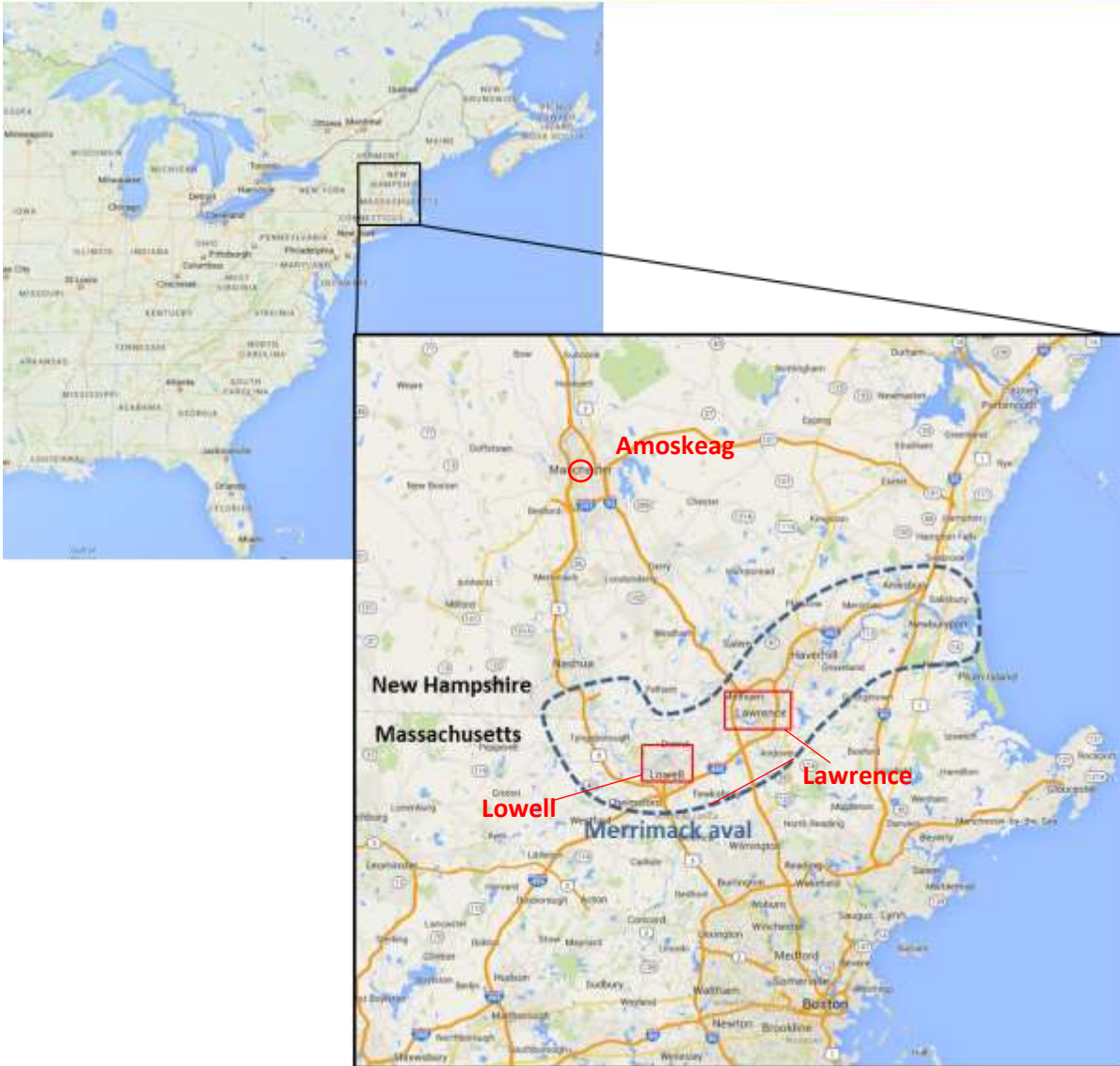
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### Average flows for Merrimack River (m<sup>3</sup>/s)

Source : <http://waterdata.usgs.gov>

Site	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANN
Lawrence	209	213	368	552	334	190	106	87	89	131	198	229	225
Lowell	188	188	332	514	311	174	97	80	82	121	182	208	206



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SITE	KM	FISHWAY	DROP (M)	ENTRANCE	ATTRACTIVE FLOW	POWER PLANT CAPACITY	COUNTS AV. 1967-2014	RATE	COUNTS 2014	RATE
LAWRENCE (ESSEX DAM)	48	Power Plant Fish lift	11	2 1 still operated	4 m <sup>3</sup> /s 1.9 % / PP	210 m <sup>3</sup> /s	23 529	?	34 711	?



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ENTRANCE	ATTRACTIVE FLOW	POWER PLANT CAPACITY	COUNTS AV. 1967-2014	RATE	COUNTS 2014	RATE
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source <http://www.mass.gov/eea/docs/dfg/dmf/publications/tr18-anad-p4-merrimack>







SITE	KM	FISHWAY	DROP (M)	ENTRANCE	ATTRACTIVE FLOW	POWER PLANT CAPACITY	COUNTS AV. 1967-2014	RATE	COUNTS 2014	RATE
LOWELL (PAWTUCKET)	70	Power house Fish lift	11	2 1 still operated	3.4 m <sup>3</sup> /s 1.7 to 4.8 % /PP	195 m <sup>3</sup> /s	4 322	15%	3 396	10%
		Spillway Fish ladder (dble vert. Slots)	4.6	1	6 m <sup>3</sup> /s					



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LOWELL (PAWTUCKET)	70	Power house Fish lift	11	2 1 still operated	3.4 m <sup>3</sup> /s 1.7 to 4.8 % /PP	195 m <sup>3</sup> /s	4 322	15%	3 396	10%
		Spillway Fish ladder (dble vert. Slots)	4.6	1	6 m <sup>3</sup> /s					







SITE	KM	FISHWAY	DROP (M)	ENTRANCE	ATTRACTIVE FLOW	POWER PLANT CAPACITY	COUNTS AV. 1967-2014	RATE	COUNTS 2014	RATE	
AMOSKEAG	110	Power house	Fish ladder (Half Ice Harbor)	15	1	1.4 – 4.2 + Q passe	160	<1 000	<25%	<<	≈ 0%

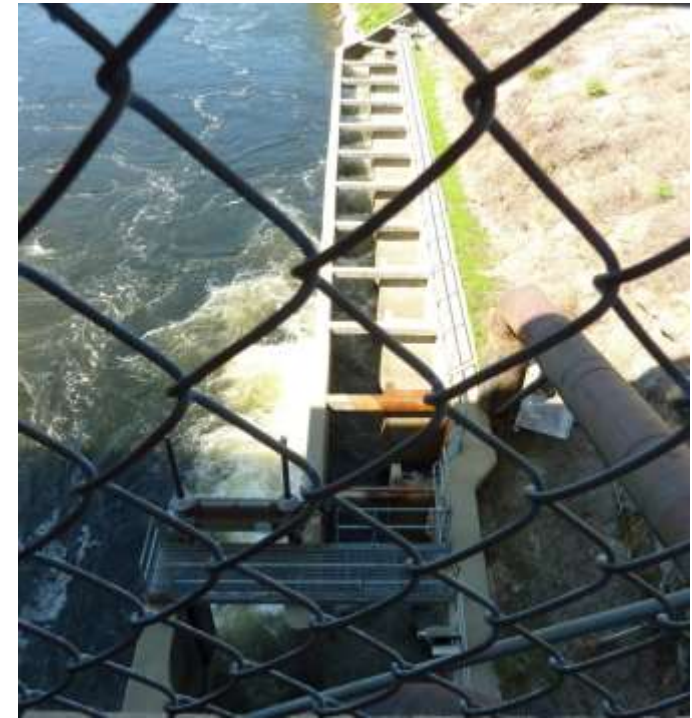


Introduction	Site visits on the East Coast			Issues			Conclusion
	Susquehanna	Connecticut	Merrimack	Approach	Entrance	Passage	





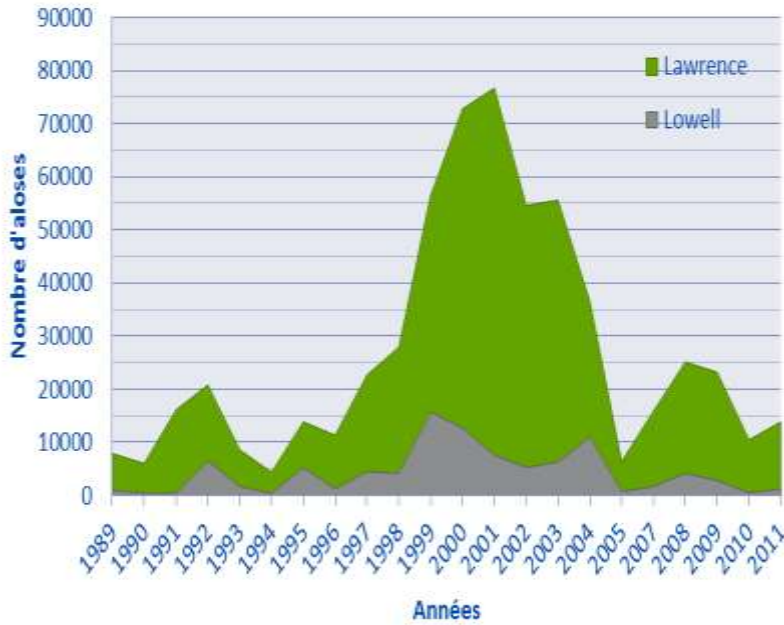
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Suivi des migrations d'aloses par comptage ente 1989 et 2011 sur la Merrimack



SITE	KM	FISHWAY	DROP (M)	ENTRANCE	COUNTS AV. 1983-2014	RATE	COUNTS 2014	RATE
LAWRENCE (ESSEX DAM)	48	Power House Fish lift	11	2 <i>1 still operated</i>	23 529	?	34 711	?
LOWELL (PAWTUCKET)	70	Power house Fish lift	11	2 <i>1 still operated</i>	4 322	15%	3 396	10%
		Spillway Fish ladder (dble vert. Slots)	4.6	1				
AMOSKEAG	110	Power house Fish ladder (Half Ice Harbor)	15	1	<1 000	<25%	<<	≈ 0%

**<4%**

**!! Spawning areas between some dams!**





## Telemetry monitoring results done in 2005 and 2011 at Lowell

- 1 : Shad in the Lowell tailrace / shad upstream of Lawrence.
- 2 : Shad in the entrance / shad in the tailrace.
- 3 : Shad completing their passage through the fishway / shad entering the fishway
- 4 : Global efficiency of shad passage
- 5 : Average time of passage from the tailrace to the exit of the fishway (day)

YEAR	EFFICIENCY EACH STEP			GLOBAL EFFICIENCY <sup>4</sup>	DURATION <sup>5</sup> (J)
	ENTANCE ATTRACTIVITY <sub>1</sub>	ENTRANCE COMPLETED <sup>2</sup>	INTERNAL EFFICIENCY <sup>3</sup>		
2011	57%	11%	65%	7%	9h
2002	55%	-	-	11%	-

**Monitorings show the shad do not use the weir and pool fishway in the shortcut section of the river.**



Lowell Dam – Shad distribution in the tailrace in Spring 2011 – Legend: number of marked shad detected (source : Alden Research Laboratory; Inc., 2011)

Introduction	Site visits on the East Coast			Issues			Conclusion
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Entrance approach efficiency: between 55 and 90%

**Issues :**

- Number / position of entrances
- Influence of turbine operation
- Attractive flows
- Maintain favorable hydraulic conditions close to entrances (rest area and flow perception)

**Observations :**

- Shad avoid areas with high turbulence, aeration and velocities
- Many of the entrances above turbine outflows have been closed because of high turbulence/low efficiency

**Potential improvement:**

- Turbine prioritization and entrances uses depending on turbines operation  
Ex : Conowingo 90% in 2010
- Improve entrance positions  
Ex : Turners Falls, Gate House
- Attractive flow : hard to determine clearly the influence. Generally 0.5 to 2% of total inflow. At Conowingo, experts expect to increase the attractive flow to 4-5% of the total inflow.



Lowell – Merrimack River  
Conowingo – Susquehanna River

Turners Falls Gate House – Connecticut River

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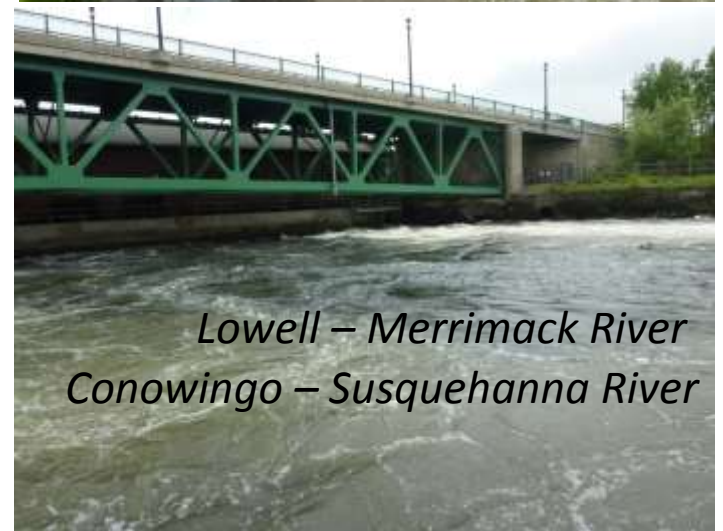
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*Lowell – Merrimack River  
Conowingo – Susquehanna River*

*Turners Falls Gate House – Connecticut River*

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Entrance efficiency : between 10 and 75%

### Issues :

- Ensure entrance of the shad into the fishway

### Observations :

- Difficulties seem come from:
  - ✓ Transition between open environnement and confined area
  - ✓ Hydraulic conditions : particularly turbulences due to attractive flow injection

### Potential improvement:

- Efficient monitoring of the downstream levels
- Adapt hydraulic conditions on downstream levels
- Improve attractive flow injection
- Increase the depth?

### Examples :

#### Vernon :

- In 2012, new instrumentation for downstream water levels monitoring
- Increasing of the efficiency from 0-10% to 40-70% (transfer rates from Turners Falls)

#### Lowell :

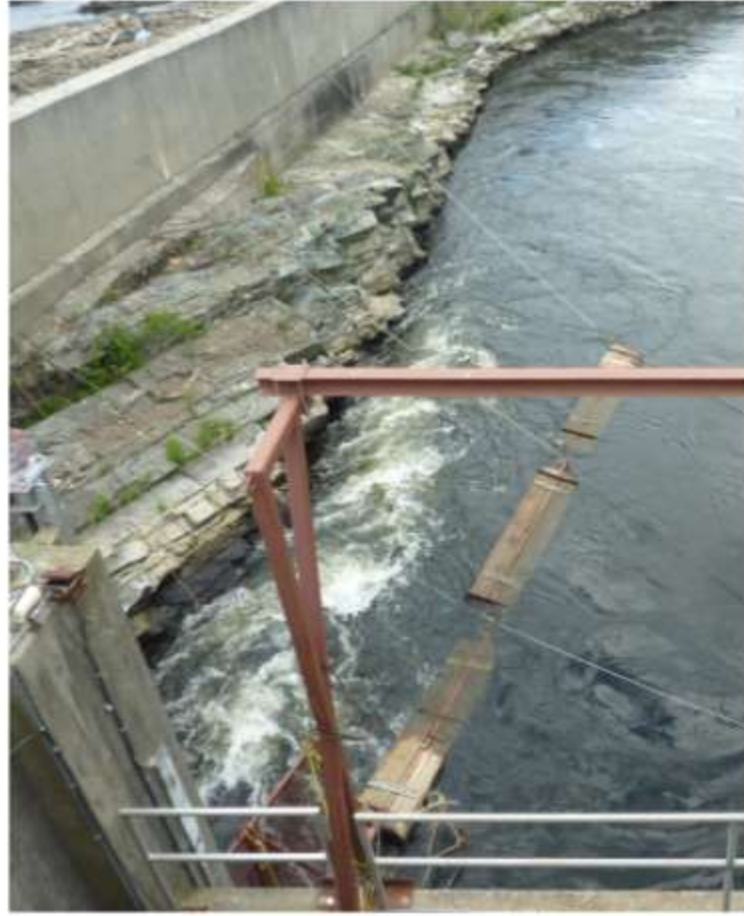
- Monitoring study 2011 : only 11% of the shad enter into the fishway
- In 2015 : regulation of the attractive flow and entrance drop depending on the downstream water levels.

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Entrance efficiency : between 10 and 75%



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**Holtwood – 75 %**

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Introduction	Site visits on the East Coast			Approach	Issues		Conclusion
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**Internal efficiency : 15 to 65% - Most of the time between 50 and 60%**

### Issues :

- Choice of the fishway type
- Length
- Hydraulic conditions

### Observations :

- For fish lifts:
  - ✓ Shad seem to have difficulties to go through the crowder gate
  - ✓ Injection of the attractive flow could be a problem
- For fish ladders :
  - ✓ Most of the time, jets are plunging for Ice Harbor type (half, modified)
  - ✓ U-turn seem to be a problem for shad
  - ✓ Delays could be an issue. Shad have to go through the pass before the sunset

### Potential improvement:

- Design criteria from Larinier – Travade 2002 are still current  
*Gate House (Turners Falls), designed for shad, have internal efficiency between 85 and 100%*
- Have a reflexion on the choice of fish lift VS fish ladders depending on delays to go through the pass

### Examples :

#### Holtwood :

- Approach 84 %, entrance 75 % but passage only 54%
- Injection of the attractive flow seems to be the main problem

#### Conowingo :

- Only 40 shad of 65 go upstream the crowder gate (2010 – 2012)

#### Turners Falls :

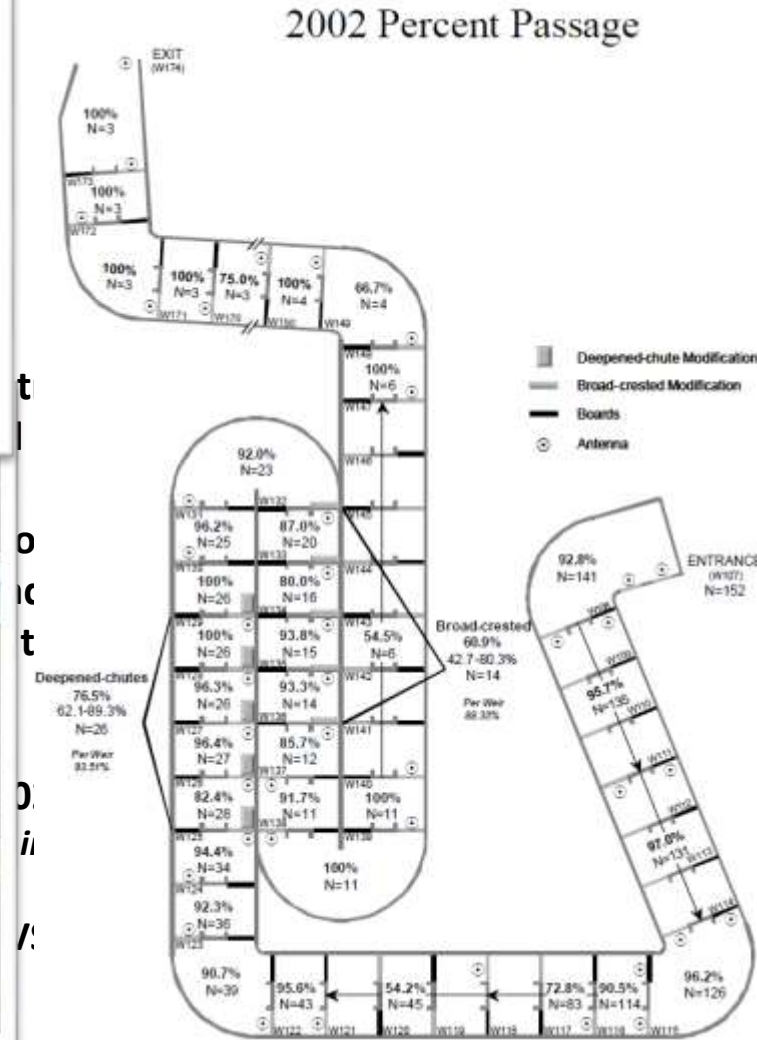
- Internal efficiency around 10-15%
- Delays seem to be too long probably due to many reasons (hydraulic conditions, length, etc.)

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**Best efficiencies observed : approach 90% + entrance 75% + internal 85% → overall maximum of 60%!**

**Improvement – optimization have to be done for each phase**

**To obtain global efficiency of 75%, the minimal efficiency have to be at least 90% at each phase...**

**3 dams equiped with fishways that allow 75% of efficiency => 40% of the stock upstream the third dam**

**5 dams.....=> 25% of the stock upstream the fifth dam**

**10 dams.....=> 5% of the stock upstream the third dam**

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