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Eels I: European Eel Passage Survival and Injury through Three Propeller Type Turbines in France

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CONTENTS

- Describe how the HI-Z tag recapture technique was utilized on adult European eels to assess their condition after turbine passage.
- Present survival/injury rate of adult eels passing hydro power stations in France with vertical and horizontal (bulb) turbines.
- Assess effect of the number of turbine blades on condition of passed eels.

Map of France

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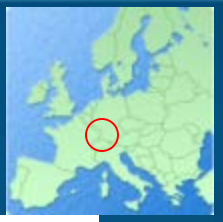
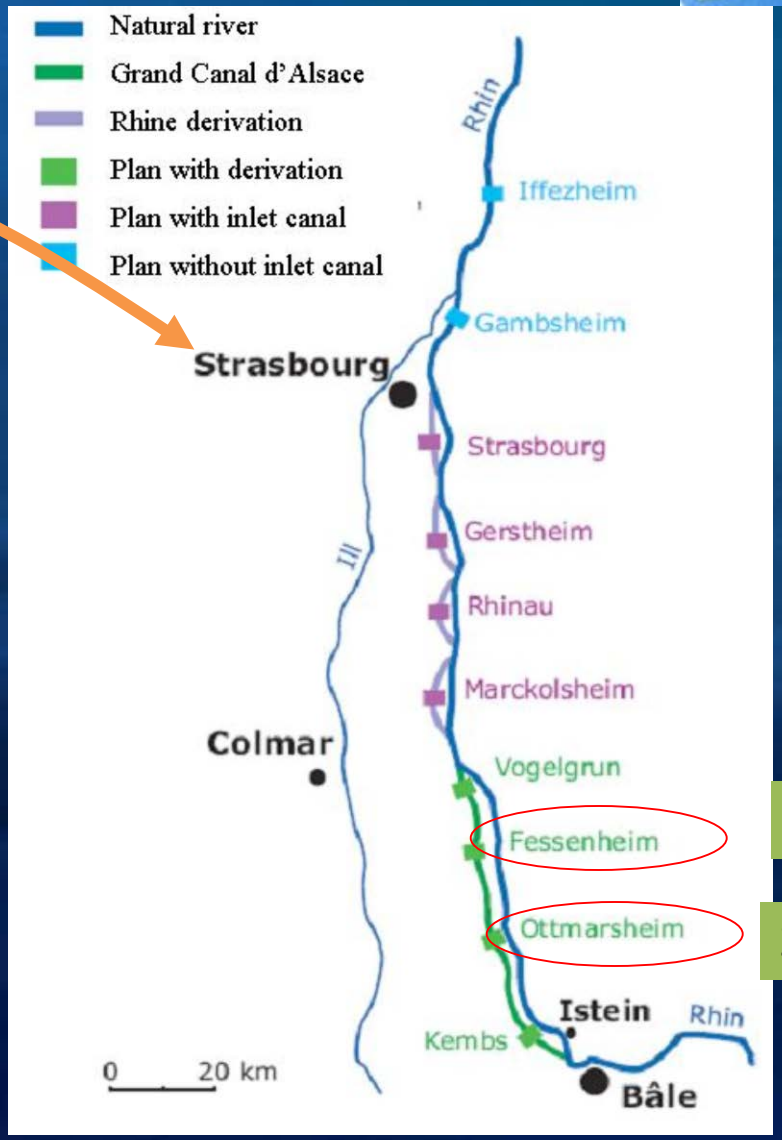
Site Study: Rhine River





2009

2010

10 Hydropower Plants:

≈ 120 km or about 100 river miles

- 4 in the "Grand Canal d'Alsace"
- 4 with inlet canal
- 2 without inlet canal

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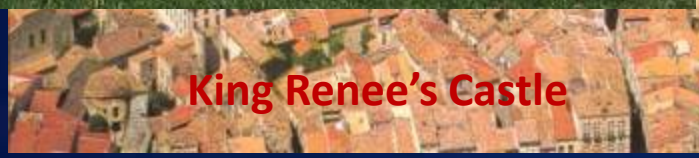
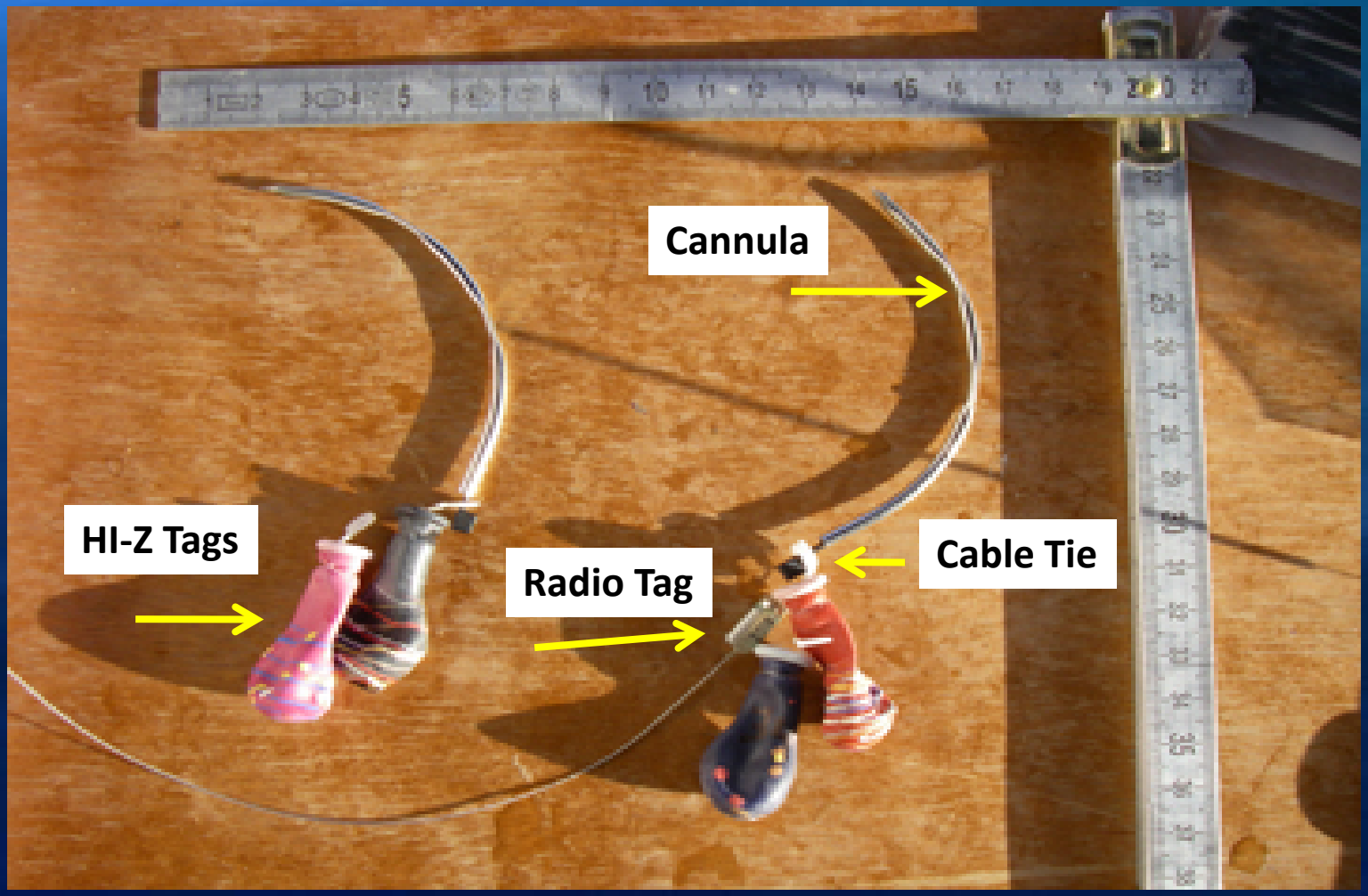
Bea
Stud



METHODS

Tag Attachment Equipment- Cannula Needle with HI-Z and Radio Tags



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Positioning Eel in Restraining Tagging Tube

Tag attachment with Cannula Needle and Cable Tie

Attached HI-Z Tags

Hi-Z Tag Activation Just Prior to Release

Releasing Tagged Eel

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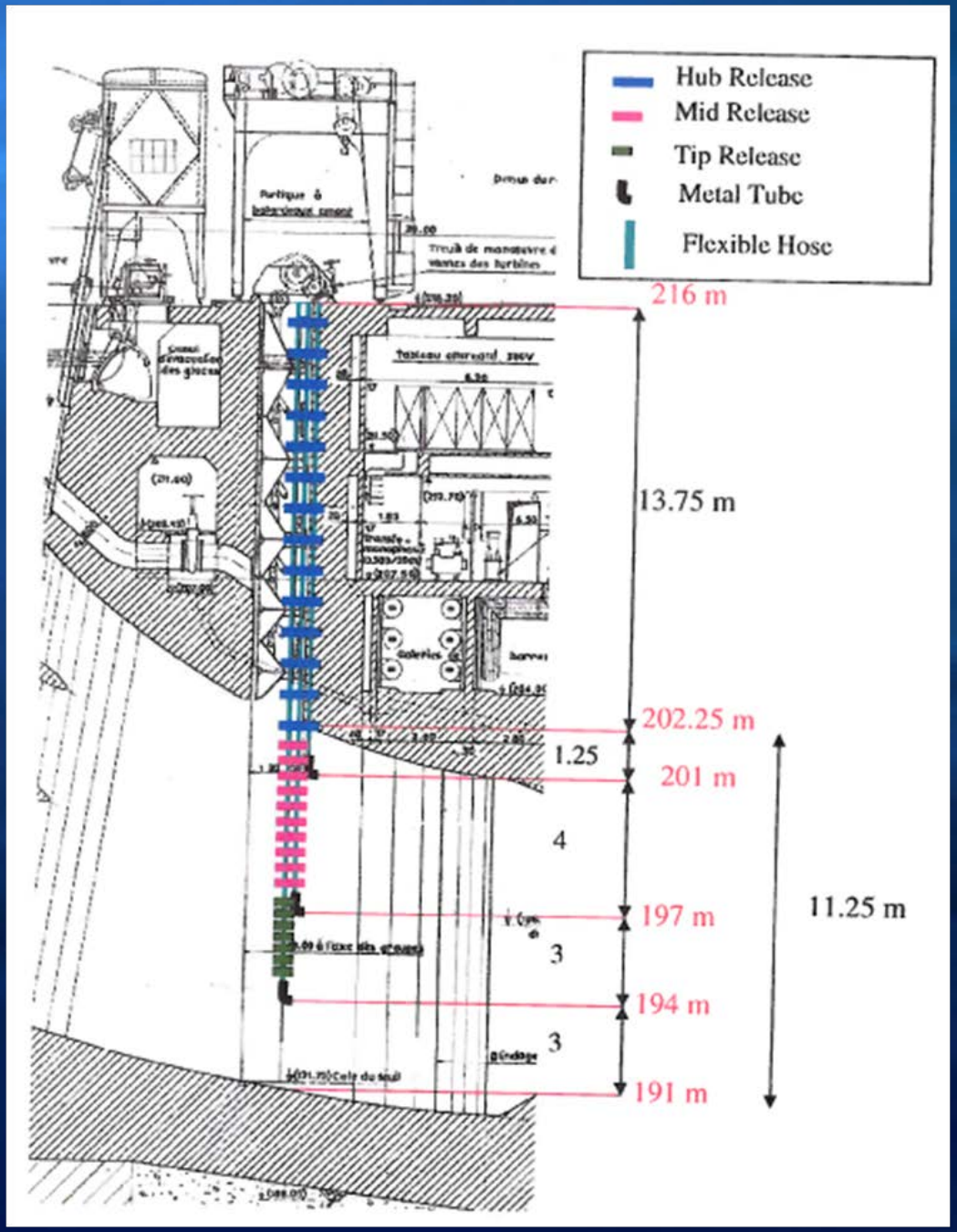
Eel Release Tank and Hoses

Release Pipe Configuration -Vertical Kaplan Turbine



Positioned so eels projected path should be near:

- Shallow=Hub
- Mid=Mid
- Tip=Deep

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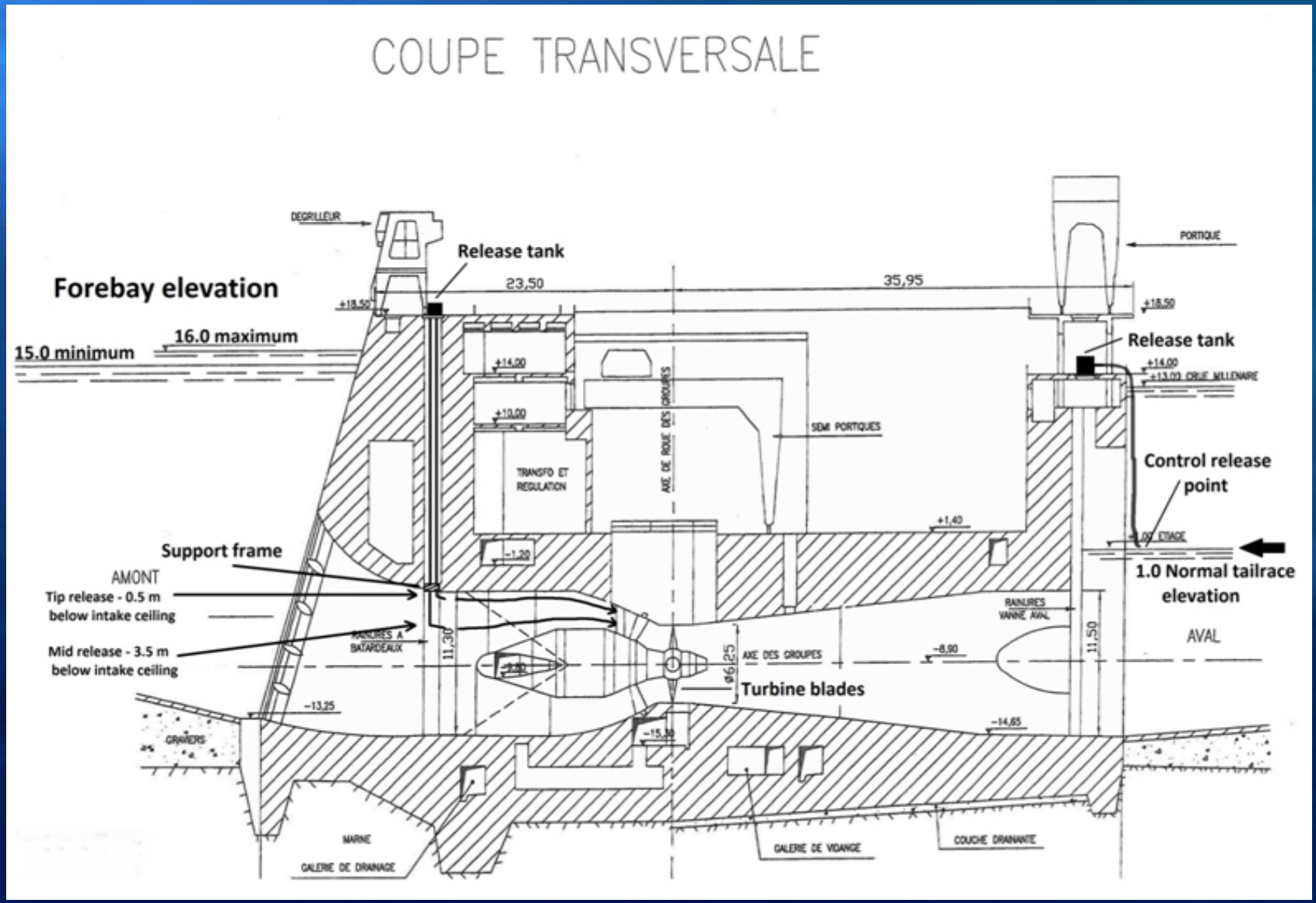
Release Pipe Conjunction – Bulb Horizontal Turbine



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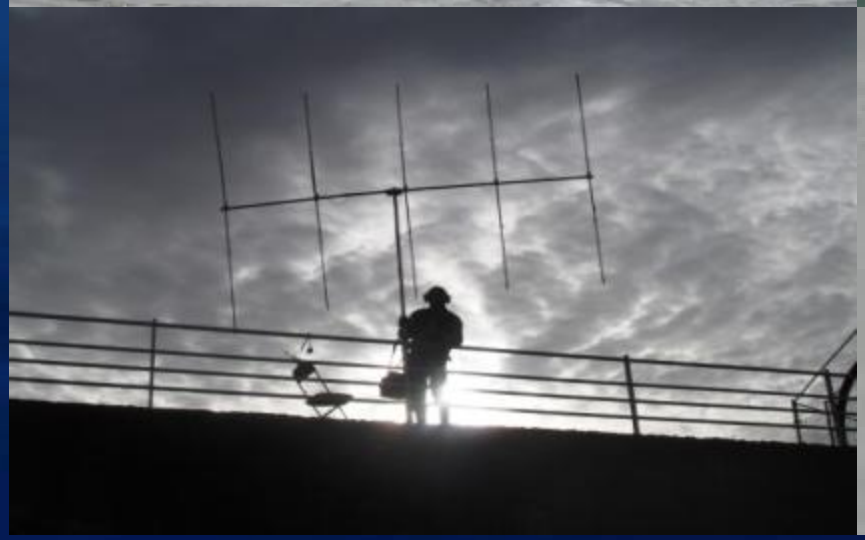
Buoyed Eels



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Eel Recapture

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Recaptured Eel

- Tags removed, except Floy Tag
- Examined for Injuries
- Transported to Holding Pools

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Characteristics of Propeller Tested Turbines

	Kaplan Conventional	Kaplan Bulb	Kaplan Conventional
Number of Blades	4	4	5
RPM	88	94	94
Runner Diameter (m)	6.7	6.2	6.2
Operating Head (m)	15	14	14.5
Output (mw)	45	35	~ 45

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Study Conditions

	4 Blade Kaplan	4 Blade Bulb	5 Blade Kaplan
Projected Passage Locations	Hub/Mid Blade/Tip	Mid Blade/Tip	Hub/Mid Blade/Tip
Length Range (cm.)	60 – 90	57 – 104	62 – 100
Mean Length (cm.)	70	69	75
Number of Treatment Fish Released	281	275	300
Physical Recapture Rate*	96%	96%	98%
Number of Controls Released	71	50	55
Recapture rate	96%	100%	100%

* Tags only recaptured on most of remaining fish (assigned dead).

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RESULTS

Direct Survival (48 h)

	4 Blade Kaplan	4 Blade Bulb	5 Blade Kaplan
Range	88.1 – 93.6%*	91.4 – 93.7%*	76.0 – 81.8%*
Mean	92.4%	92.3%	78.6%
90% CI±	3.6%	2.6%	3.9%
Highest Survival	Hub (Shallow)	Tip (Deep)	Hub (Shallow)
Lowest Survival	Mid	Mid	Mid

* Individual estimates not significantly different P>0.10.

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Malady – Free Rates
Free of Visible Injuries and Loss of Equilibrium

	4 Blade Kaplan	4 Blade Bulb	5 Blade Kaplan
Number Examined	270	263	294
Malady - Free Range	88.3 – 95.6*	90.7 – 92.3*	69.1 – 75.0*
Mean	92.6%	91.6%	72.5%
90% CI±	5.2%	2.8%	4.3%
Best Location	Hub (Shallow)	Mid	Tip (Deep)
Worst Location	Tip	Tip	Mid

*Individual estimates not significantly different P>0.10.

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Primary Injury Types

4 Blade Kaplan - Bruised, Scraped Body 6%; Severed or Nearly Severed 5%; Internal/Broken Backbone 2%

4 Blade Bulb - Bruised Body 6%; Hemorrhaged gills 2%; Severed or Nearly Severed 1%

5 Blade Kaplan - **Severed or nearly Severed 14%; Bruised, Scraped Body 11%; Internal/Broken Backbone 6%**

Typical Severance Injury

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Broken Backbone – Attributed to Pinching

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Crushed Head – Direct Strike

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Body Bruising Near Tail

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Body Bruising - Mid Body

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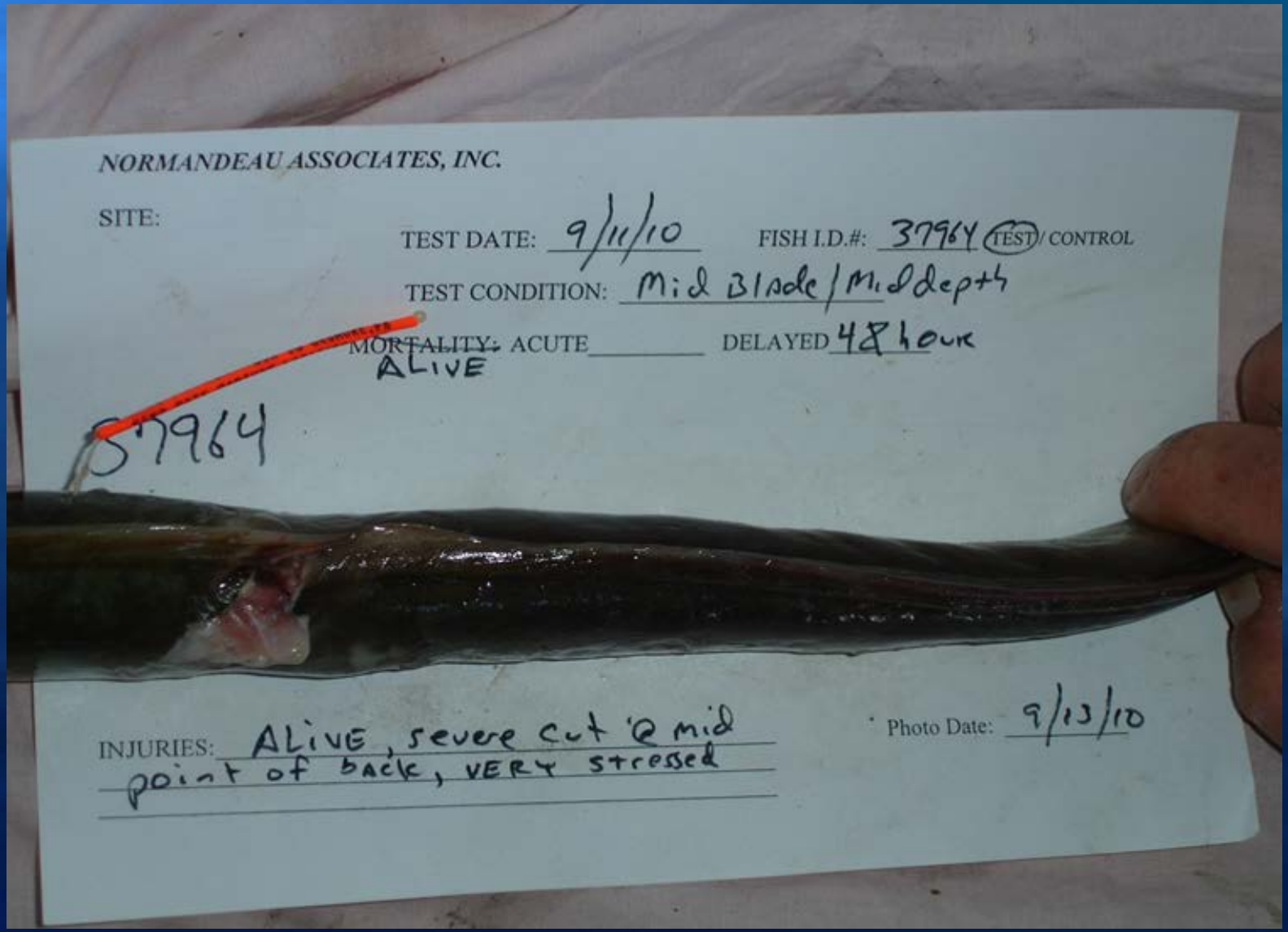
Severe Laceration



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SUMMARY/CONCLUSIONS

- The HI-Z Tag recapture technique provided high recapture rates and precision.
- Direct survival and injury estimates attributed to turbine passage attained with relatively few specimens.
- Turbine passage survival at three different projects ranged from 78.6 to 92.4%.
- Malady-free ranged from 72.5 to 92.6%.
- The number of blades affected survival/injury rates, the lower the number of blades the higher the survival and lower the injury rates.
- Four bladed turbines were the most benign.
- The role of shape and thickness of the leading edge of the turbine blades on eel survival and injury needs to be further evaluated.

- Direct survival and injury estimates for the present study at Wilder, Bellows Falls, and Vernon indicate that the eels fared better passing through the larger and slower speed Francis turbines than through the Kaplan (propeller type) turbines.

- Higher survival through these Kaplan turbines is consistent with other direct survival/injury studies

- Survival relative to other Francis turbines has not been conducted (other than the similar FirstLight study conducted in 2015, not yet filed) so comparisons of this turbine type are not available at this time.

- Emigrating eels should incur high survival and few injuries passing the two larger Francis Units 9 and 10.

- Turbine passage should also be relatively high for eels passing the smaller Francis Units 1-4.

- Kaplan Units 5-8 effects on eel passage survival and severity of injuries appears to be partially dependent upon discharge rates with better passage conditions at lower discharges.

Turbine Comparison Example

2006 6 Bladed Turbine

2008 5 Bladed Turbine

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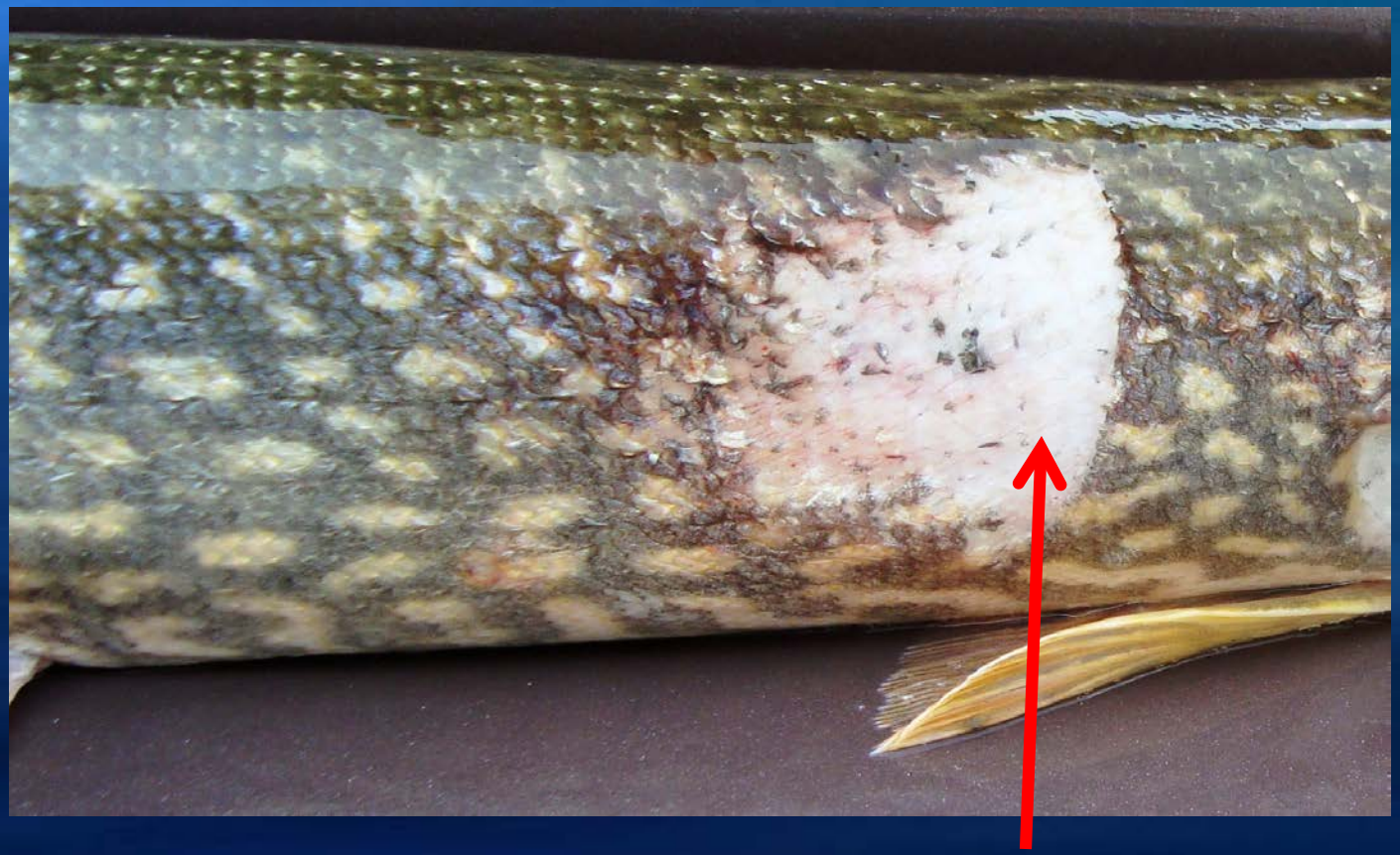
Size and Thickness of Leading and Trailing Edge of Turbine Blade



The thinner and sharper an object is the greater the chance that it can cut something that contacts.

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Future Studies

- Twelve studies indicate survival is related to number of blades, diameter, and rotation rate.
- Francis Units have generally higher survival than propeller units.

Questions and or Comments

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