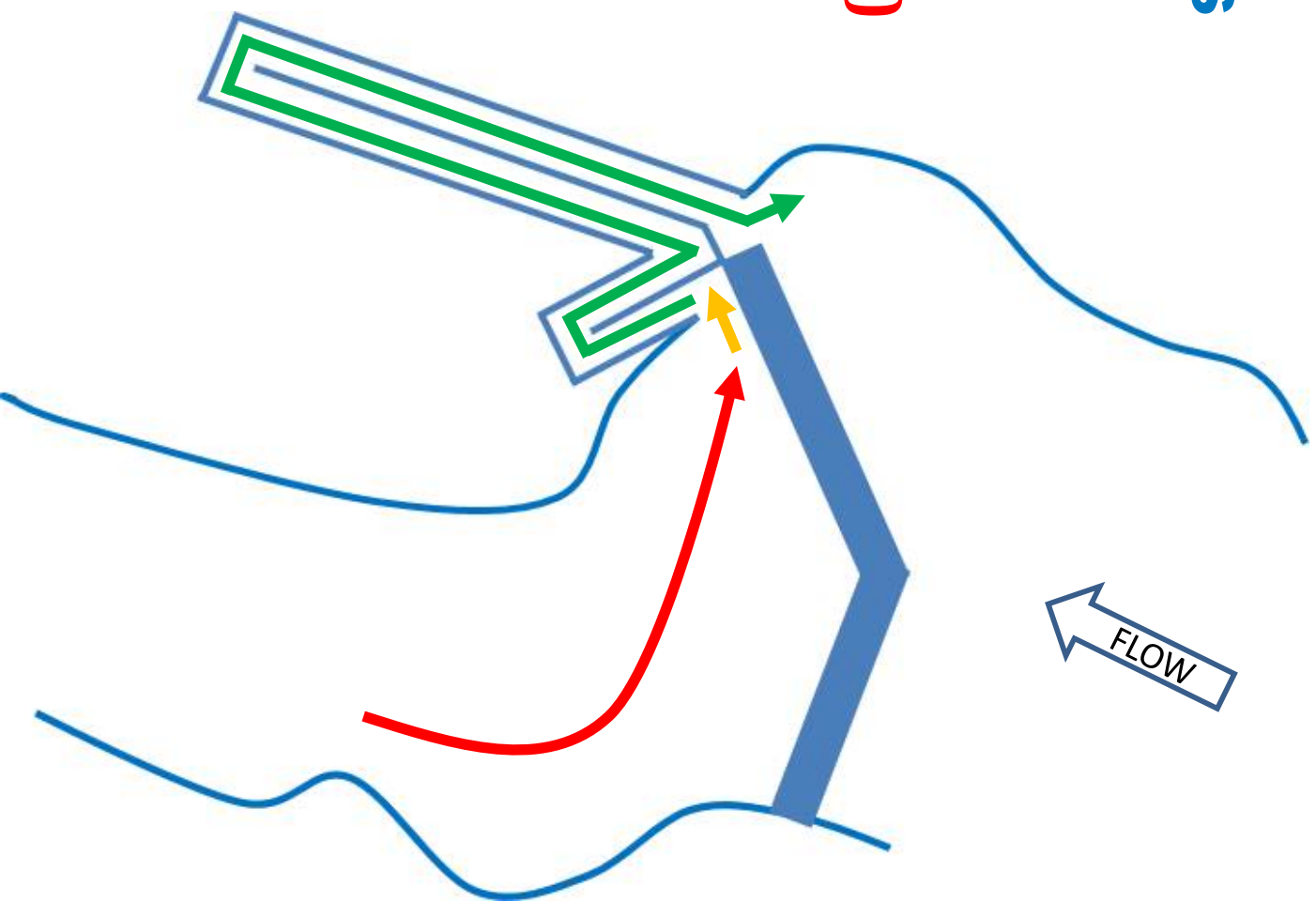


Fishway effectiveness Definitions

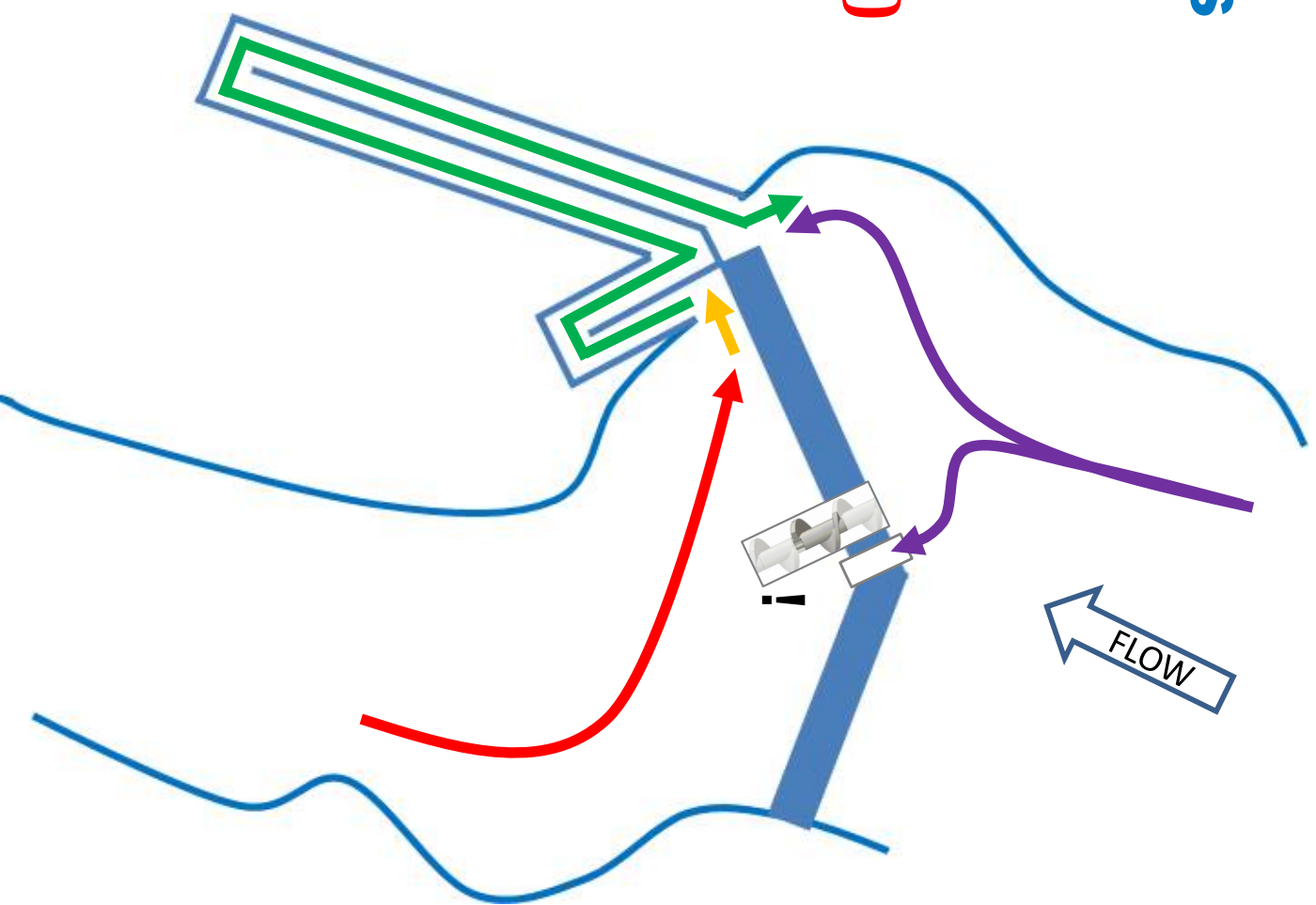
- **Attraction efficiency (%)**
- **Entrance efficiency (%)**
- **Passage efficiency (%)**



Fishway effectiveness

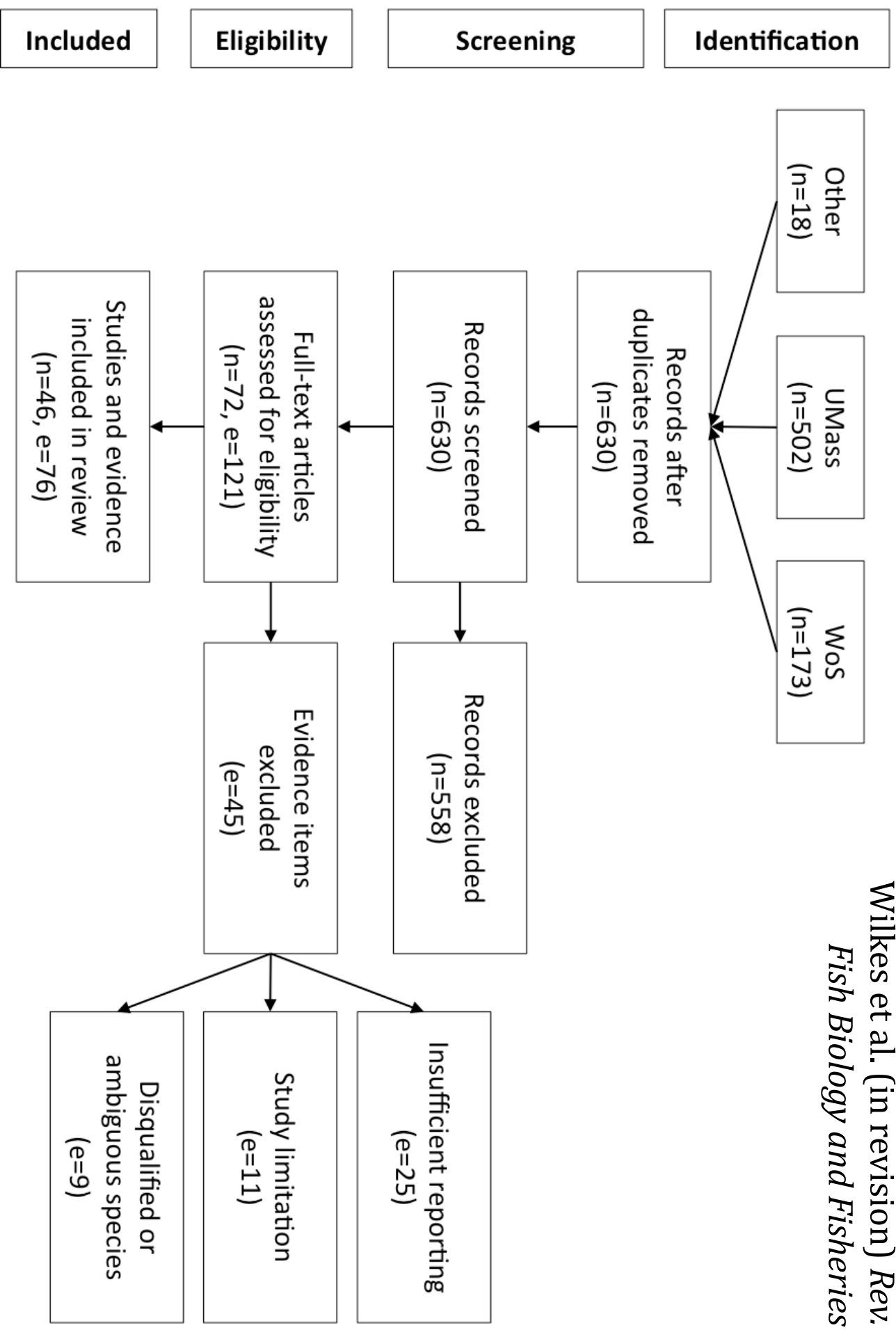
Definitions

- **Attraction efficiency (%)**
- **Entrance efficiency (%)**
- **Passage efficiency (%)**
- **Guidance efficiency (%)**
- **Turbine entrainment (% mortality)**
 - Pressure
 - Fluid shear
 - Blade strike



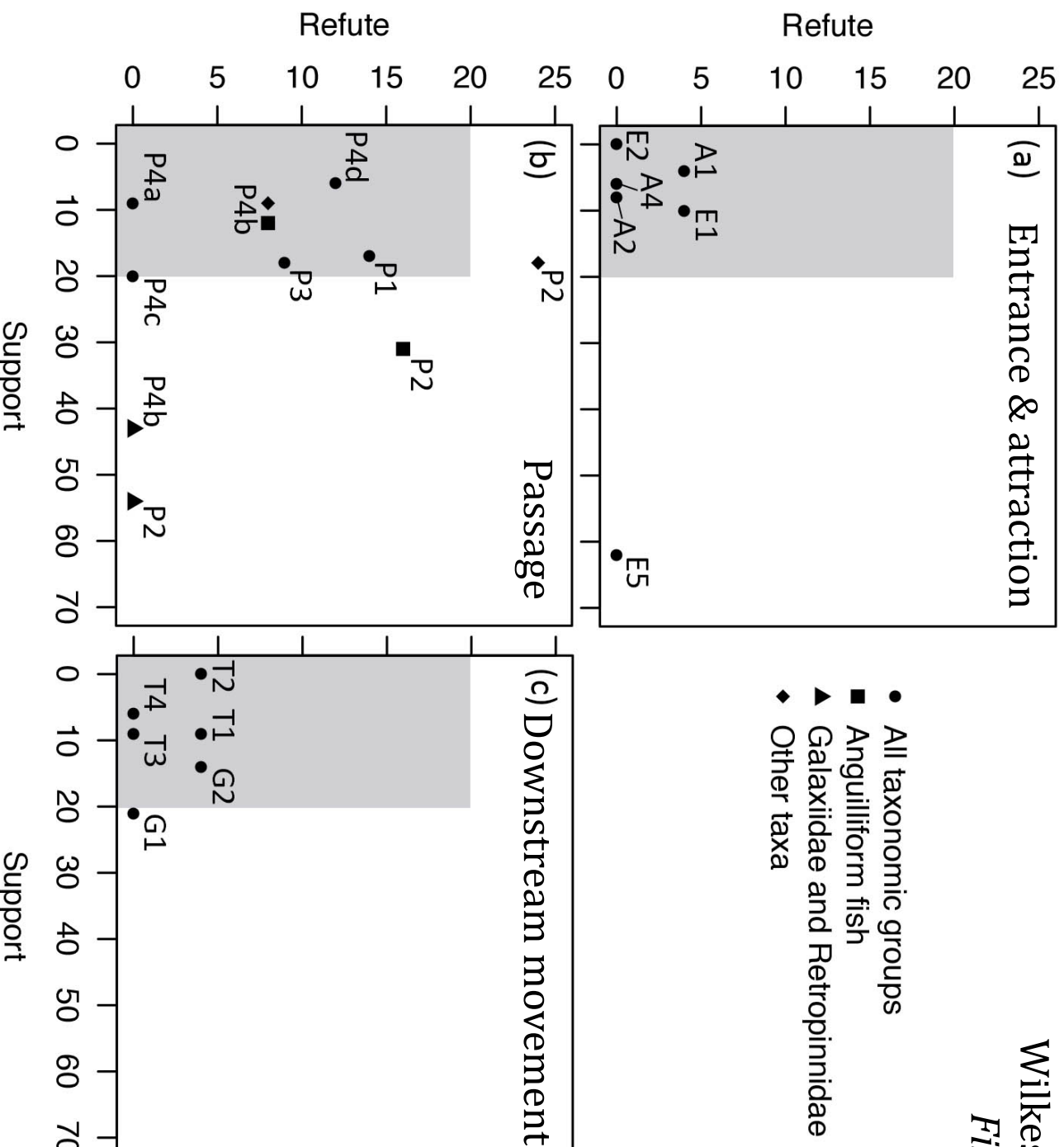
Systematic evidence review

Willkes et al. (in revision) *Rev. Fish Biology and Fisheries*



Systematic evidence review

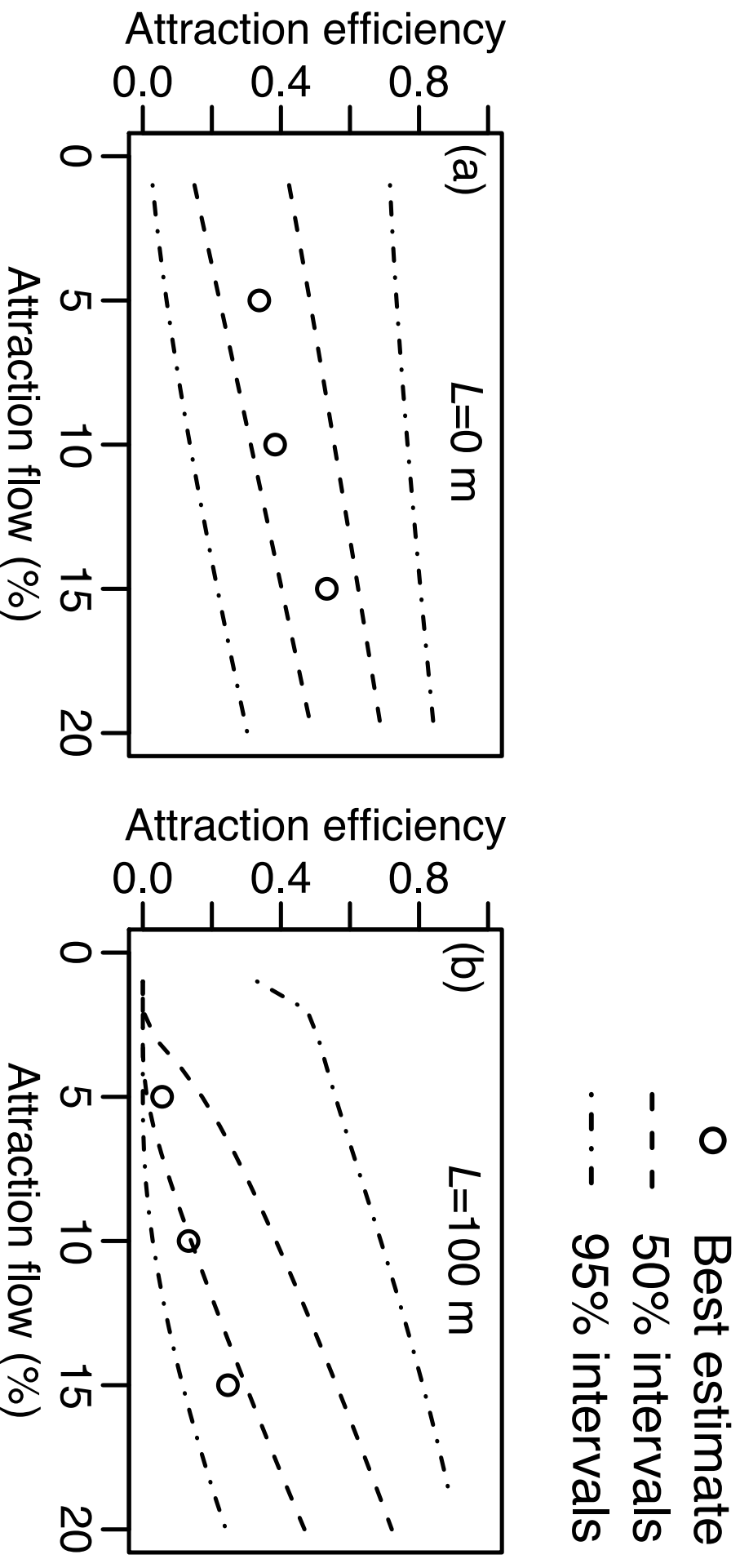
Wilkes et al. (in revision) *Rev. Fish Biology and Fisheries*



Systematic evidence review

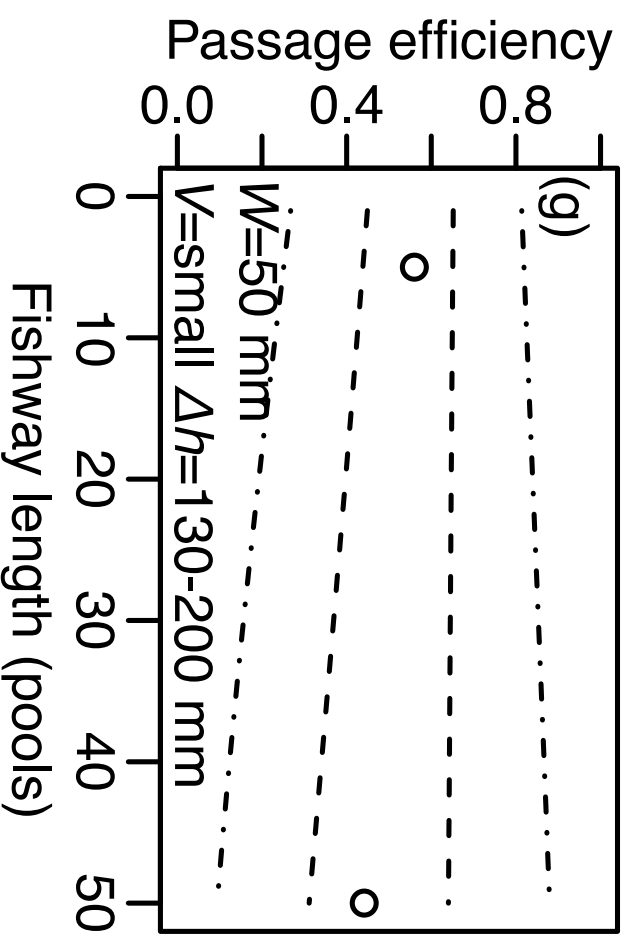
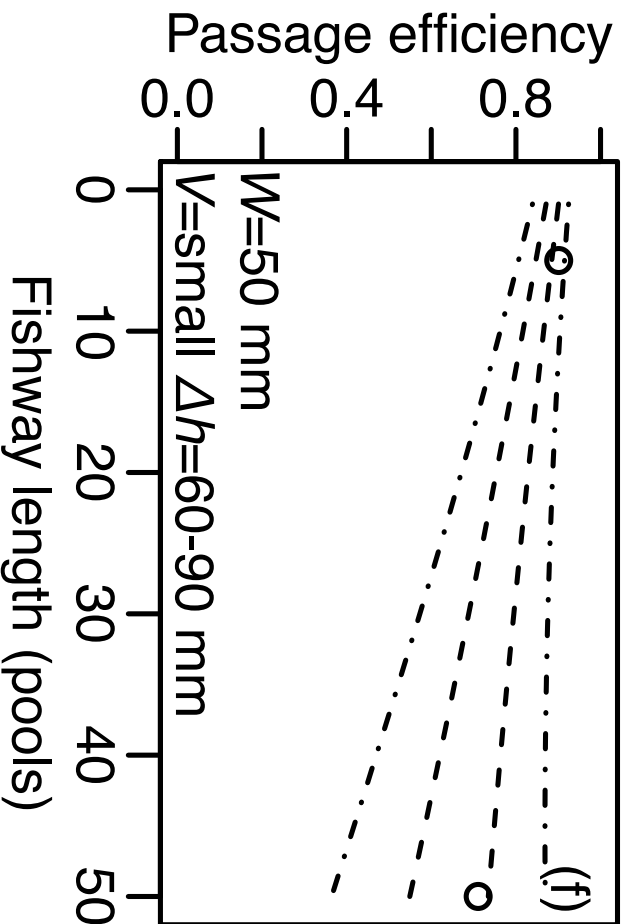
- Key findings:
 - Not enough empirical evidence
 - Attraction of fish and downstream movement neglected
 - Incomplete monitoring data and insufficient reporting
 - Need to combine little evidence with expert knowledge and numerical modelling

Bayesian networks: Upstream passage



Bayesian networks: Upstream passage

- Best estimate
- - - 50% intervals
- · · · 95% intervals

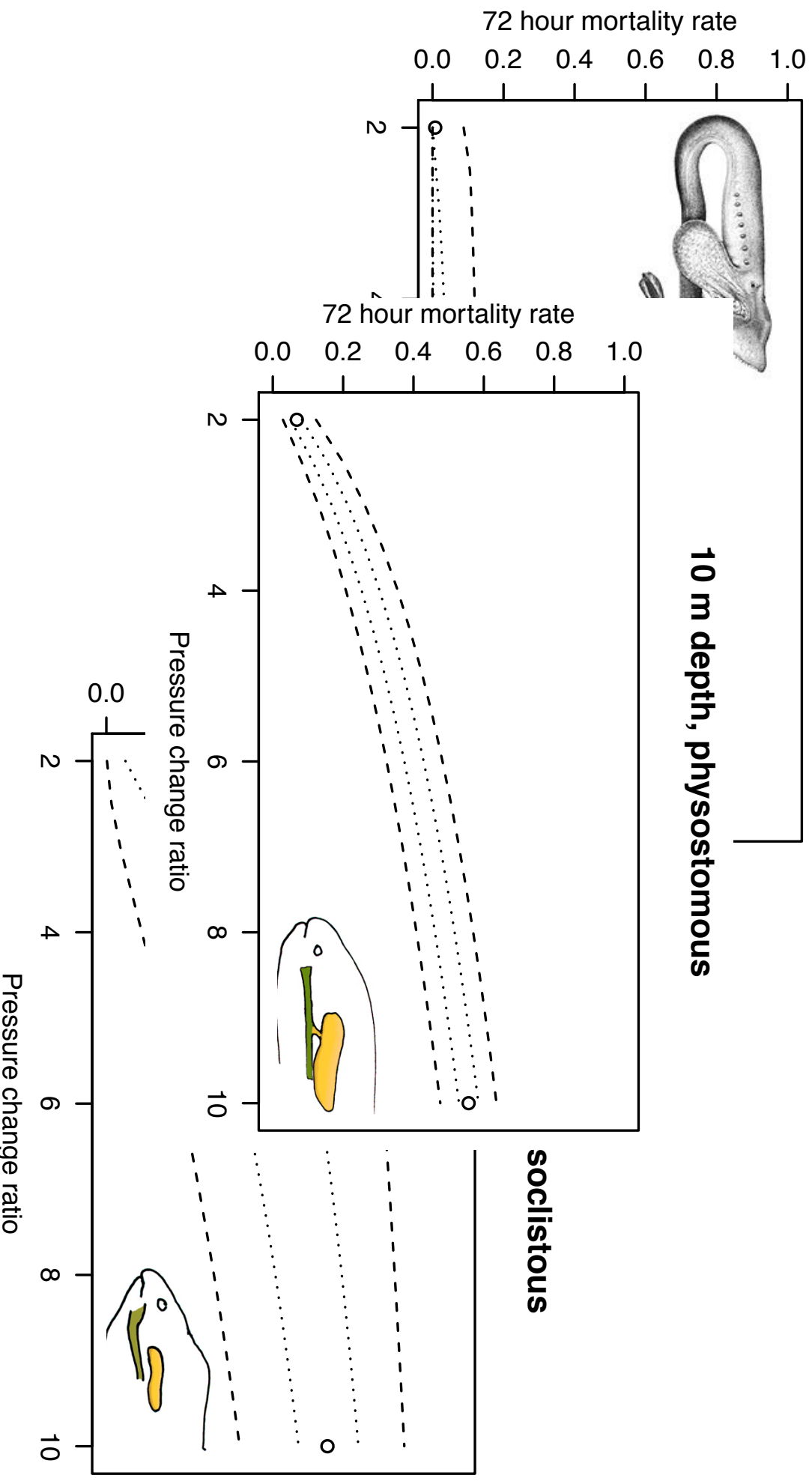


Bayesian networks: Downstream passage

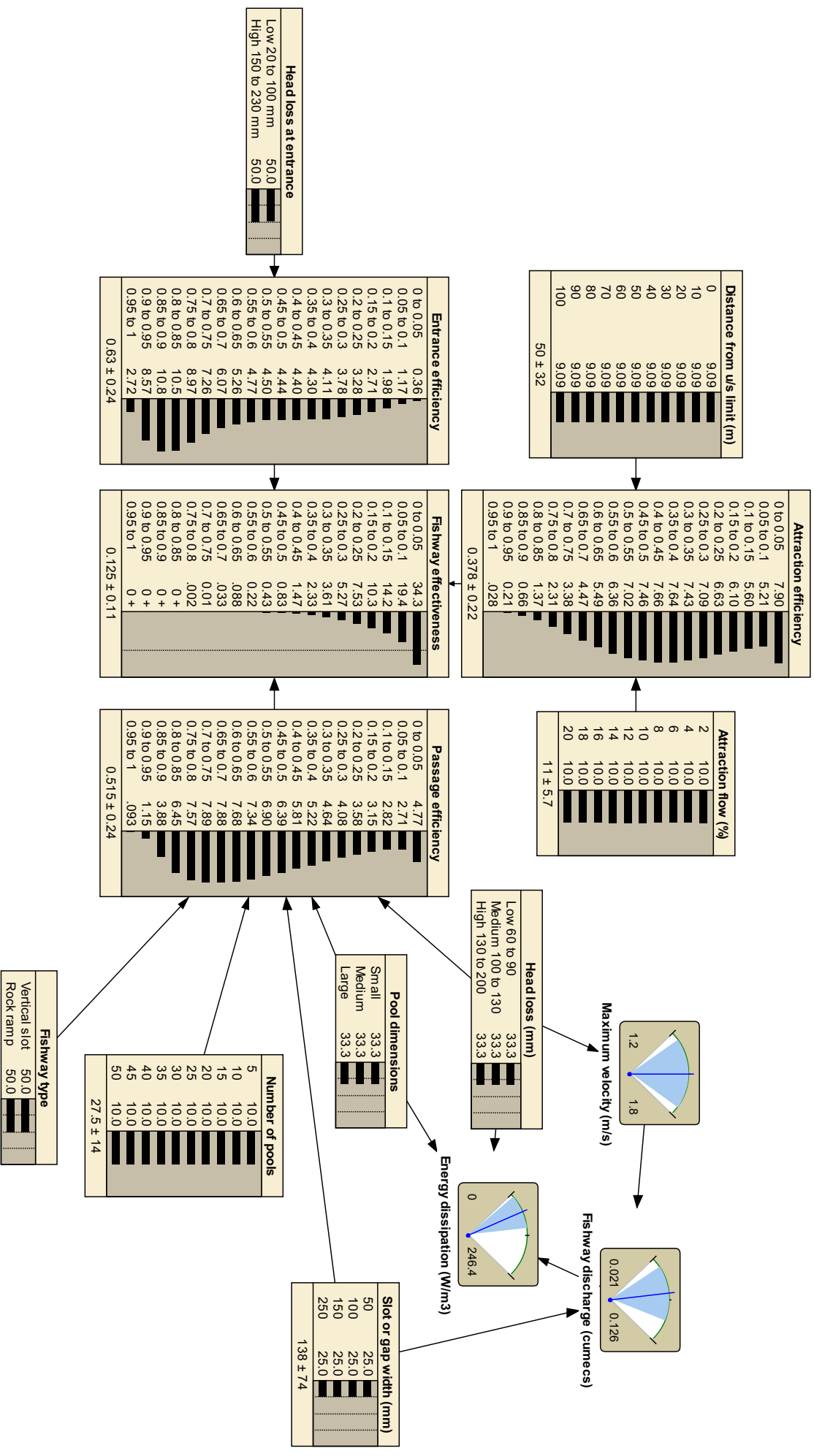
Pressure

1 m depth, no swim bladder

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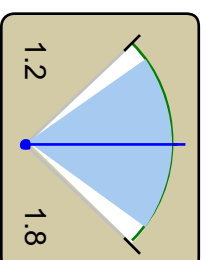


Upstream fishway design

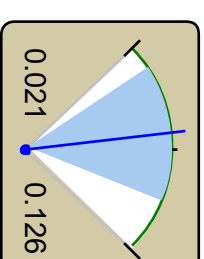


Upstream fishway design

Attraction flow (%)	
2	10.0
4	10.0
6	10.0
8	10.0
10	10.0
12	10.0
14	10.0
16	10.0
18	10.0
20	10.0
11 ± 5.7	



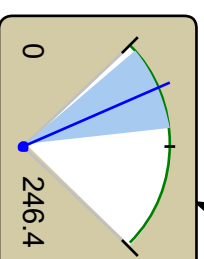
Maximum velocity (m/s)



Fishway discharge (cumecs)

Head loss (mm)	
Low 60 to 90	33.3
Medium 100 to 130	33.3
High 130 to 200	33.3

Head loss (mm)



Energy dissipation (W/m3)

Pool dimensions	
Small	33.3
Medium	33.3
Large	33.3

Pool dimensions

Slot or gap width (mm)	
50	25.0
100	25.0
150	25.0
250	25.0
138 ± 74	

Slot or gap width (mm)

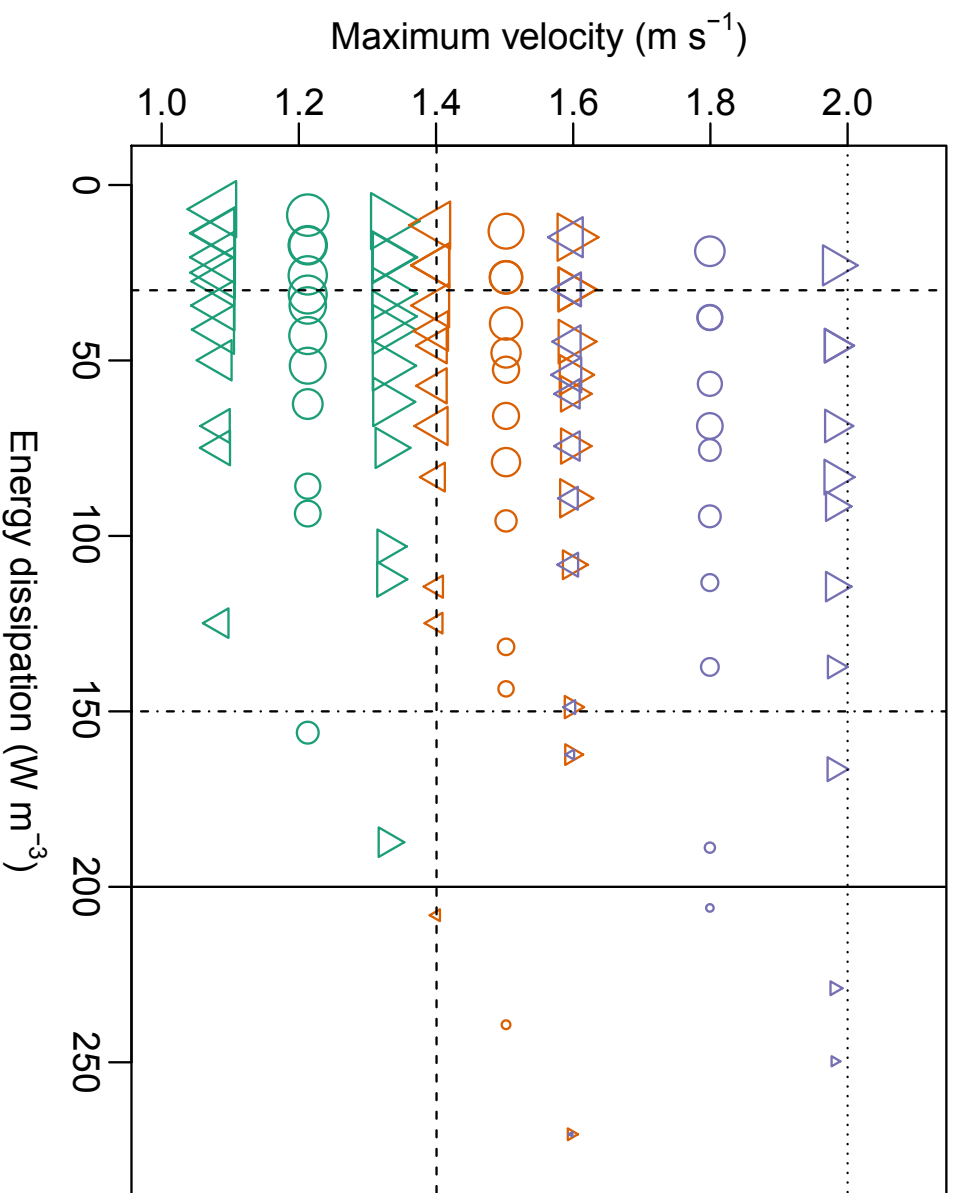
Passage efficiency	
0 to 0.05	4.77
0.05 to 0.1	2.71
0.1 to 0.15	2.82
0.15 to 0.2	3.15
0.2 to 0.25	3.58
0.25 to 0.3	4.08
0.3 to 0.35	4.64
0.35 to 0.4	5.22
0.4 to 0.45	5.81
0.45 to 0.5	6.39
0.5 to 0.55	6.90
0.55 to 0.6	7.34
0.6 to 0.65	7.68
0.65 to 0.7	7.88

Passage efficiency

Number of pools	
5	10.0
10	10.0
15	10.0

Number of pools

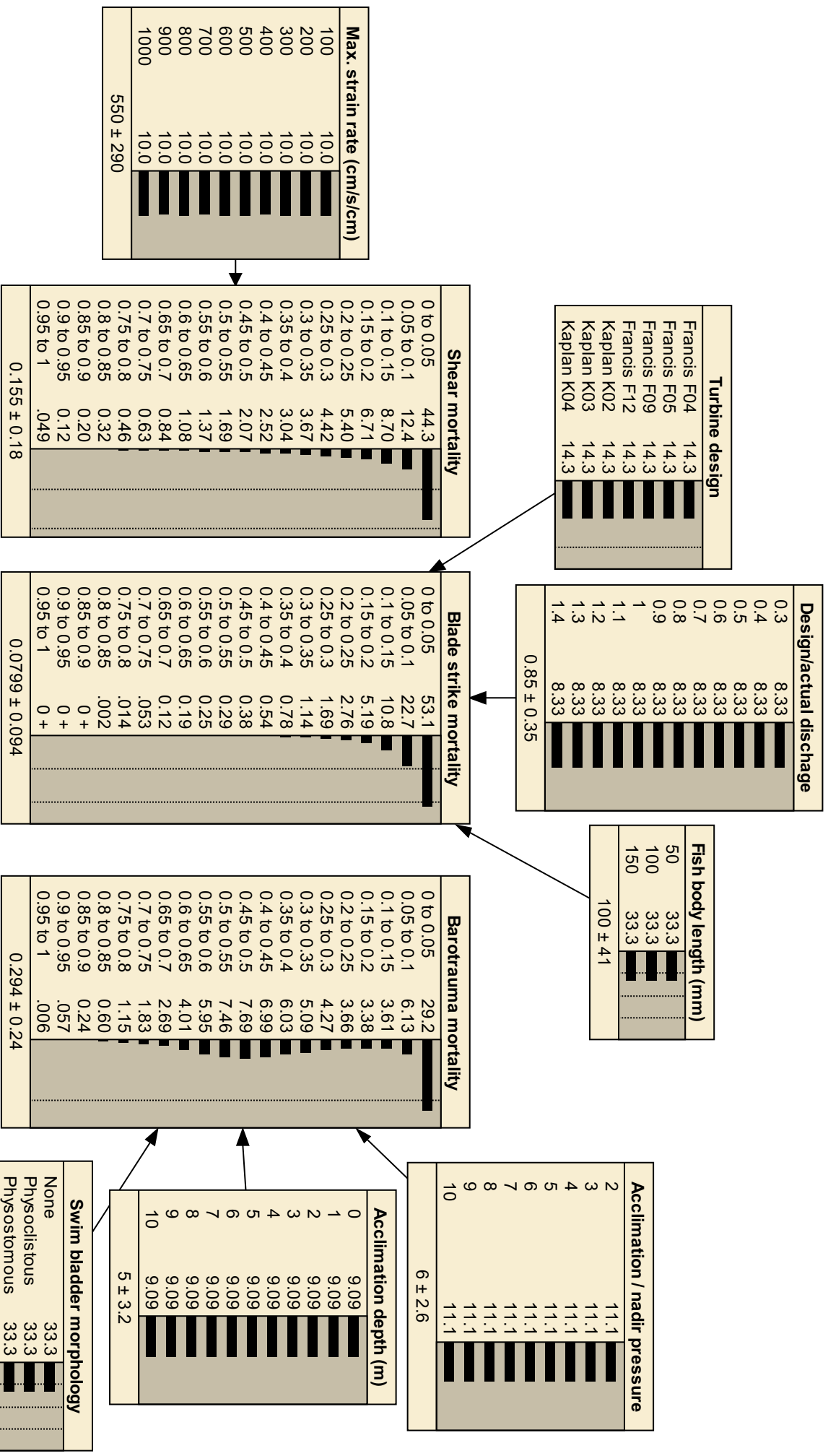
Upstream fishway design criteria



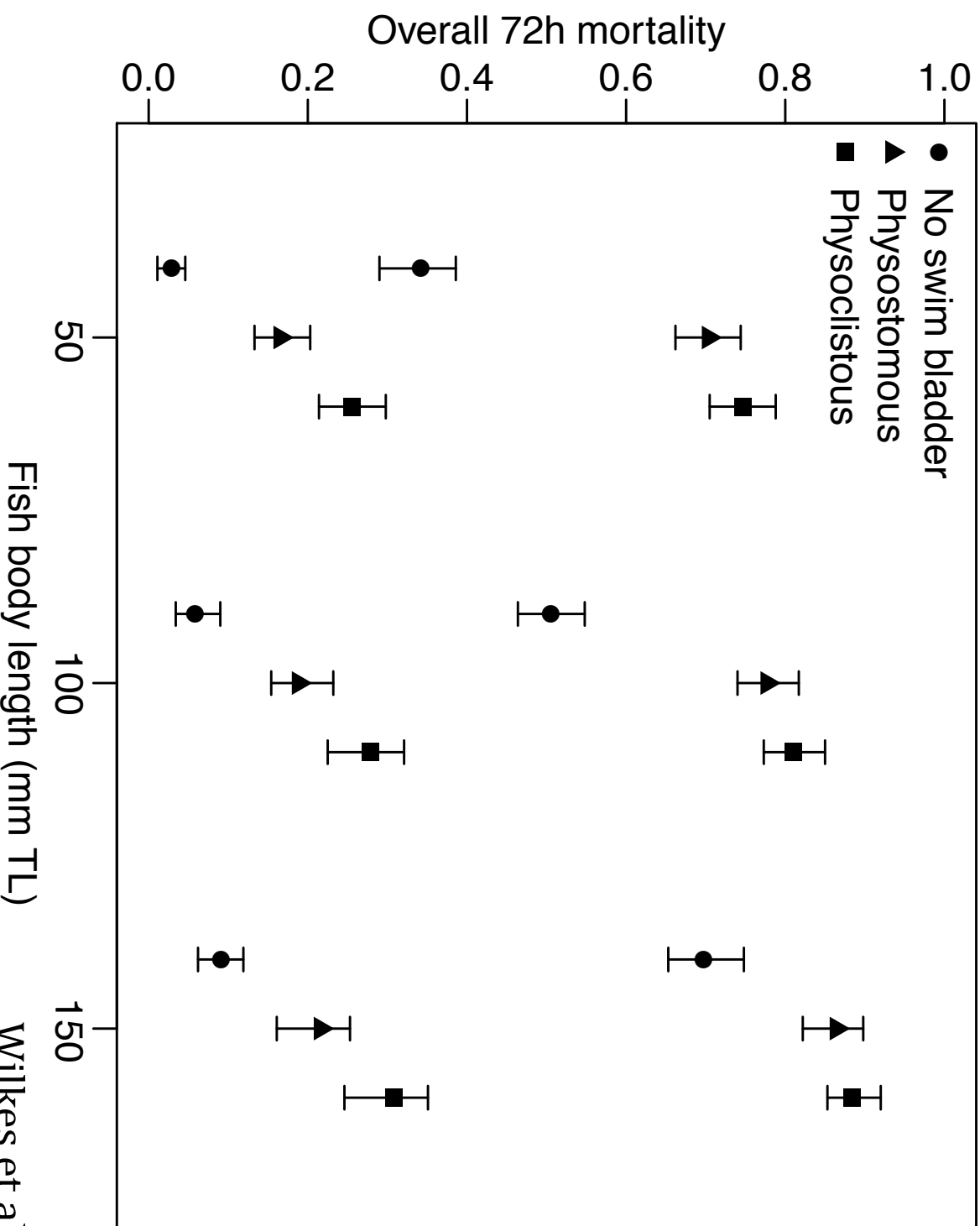
- Head loss 60–90 mm
- Head loss 100–130 mm
- Head loss 130–200 mm
- ▽ Minimum
- Mode
- △ Maximum
- ◊ Passage efficiency 25%
- ◊ Passage efficiency 75%
- ⋯ Larinier (2008), salmonids and cyprinids
- Larinier (2008), salmonids
- - - Larinier (2008), cyprinids
- - - O'Connor et al. (2015)

Willkes et al. (in review)
Fish & Fisheries

Mortality during downstream passage



Mortality during downstream passage



Willkes et al. (in review)

Fish & Fisheries

Bayesian networks

- Key findings:
 - N. Hemisphere criteria an order of magnitude too high
 - Attraction flow, turbine design and pressure most sensitive design parameters
 - Solutions could be near 0% or near 100% effective, depending on design
 - Local extinction, decline in fisheries and ecosystem services expected without sensitive planning and design

Applications to hydropower planning, design and monitoring

Applications

- Predict impact of barrier for planning and EIA
- Design fishways for any target species or group
- Set targets for fish screens and bypasses
- Trade-offs between cost, hydraulic & biological performance
- Prior probabilities for basic fish passage research