Modeling fish migration path in a river based on its environmental preference

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Water Quality Model in 1980s

land usage.

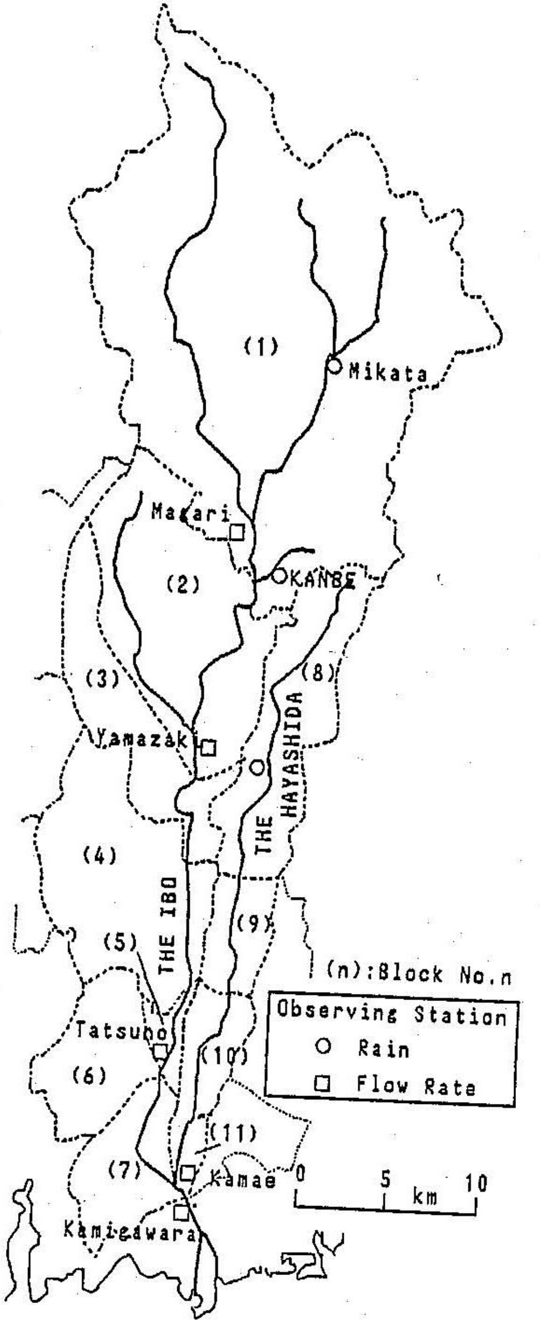


Fig.8. Basin of the Ibo

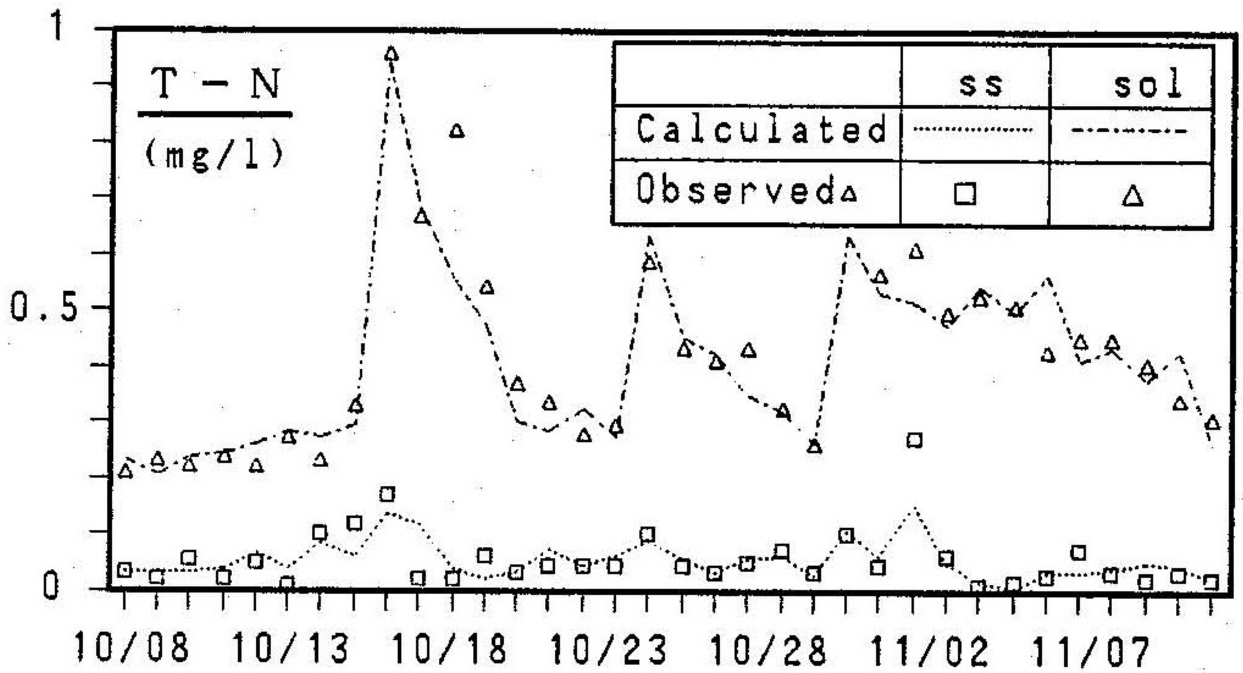
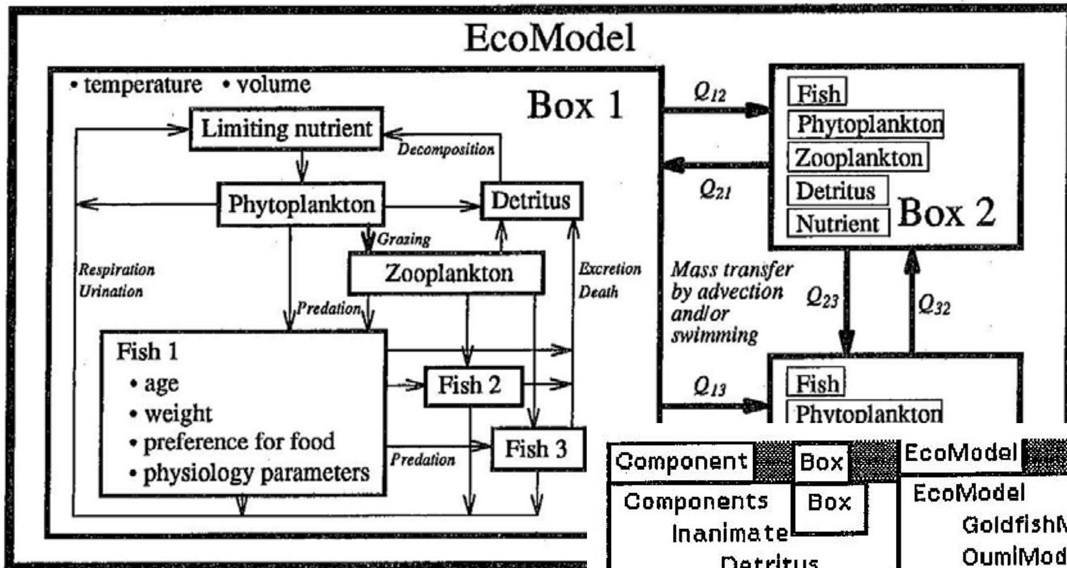


Fig.7. Example of curve-fitting(flow-down stage) (The Abu,T-N)

Sekine et. al, Water Science and Technology, Vol. 23, 1991.



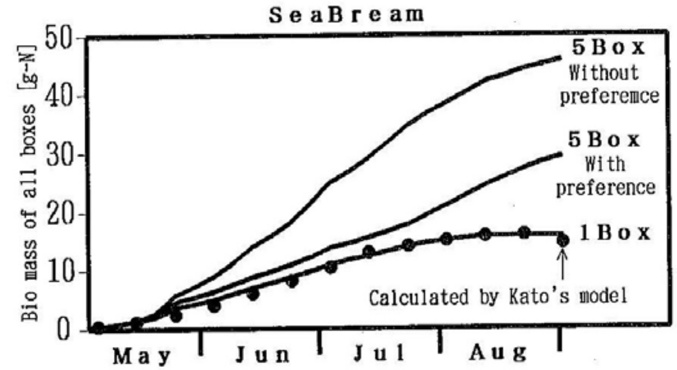
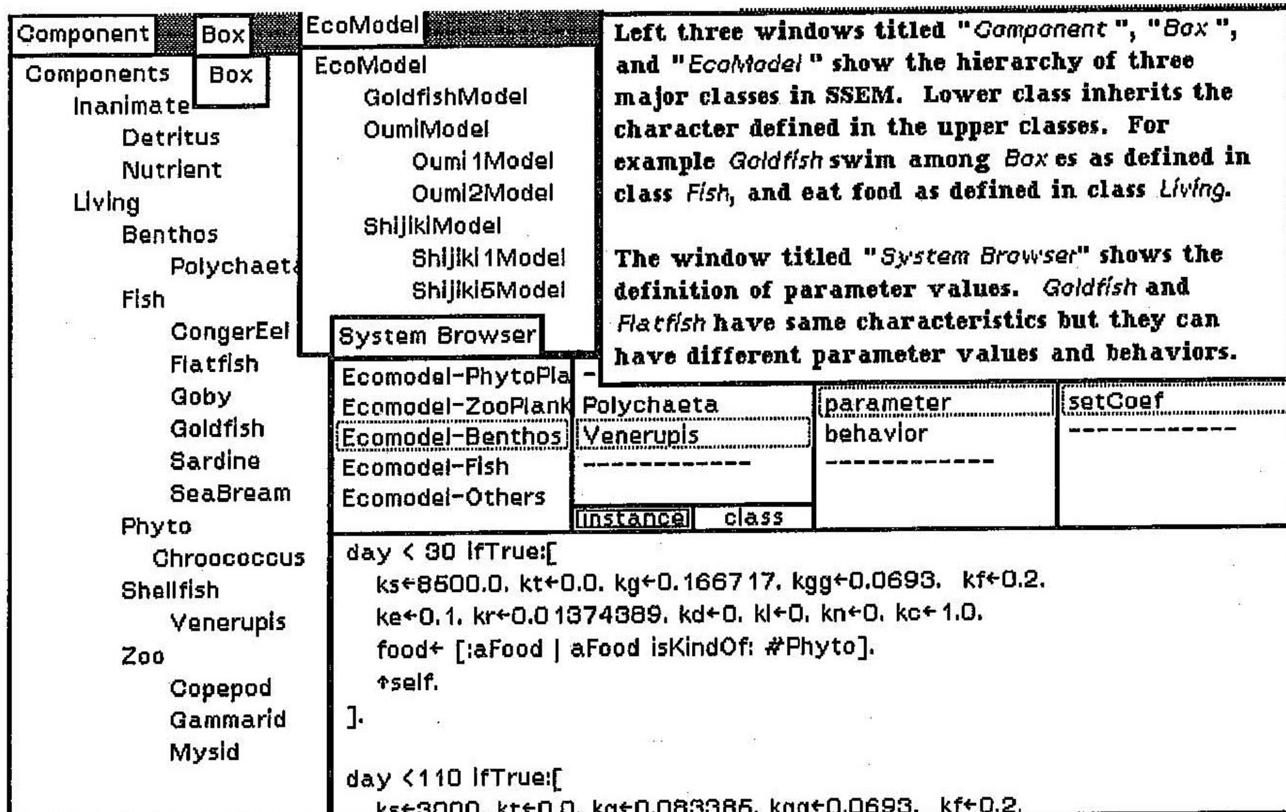


Fig. 7. Results of the Shijiki model.

Sekine et al.

Ecological Modelling,
Vol. 57, October 1991.



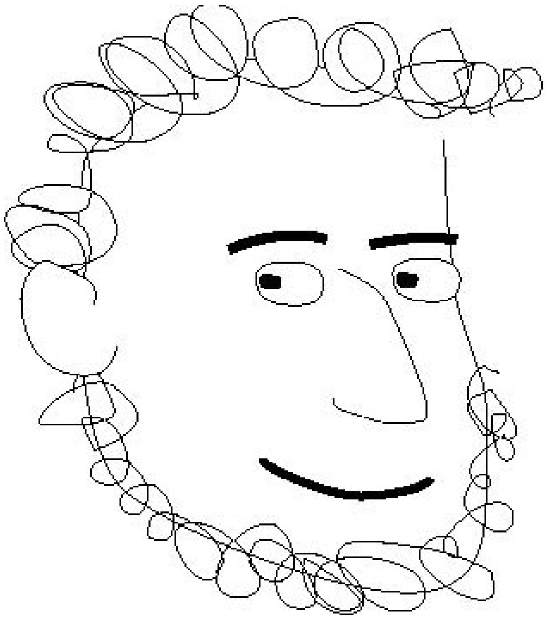
Fish Food Web Model in 1990s

Field and Lab. Work with Simple preference model (current)

for river restoration and channel design

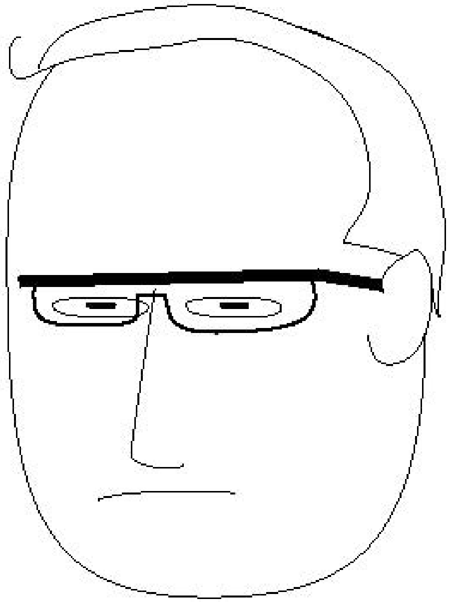
Definition of Dr. Leroy Poff, CSU

Hydro-Ecologist

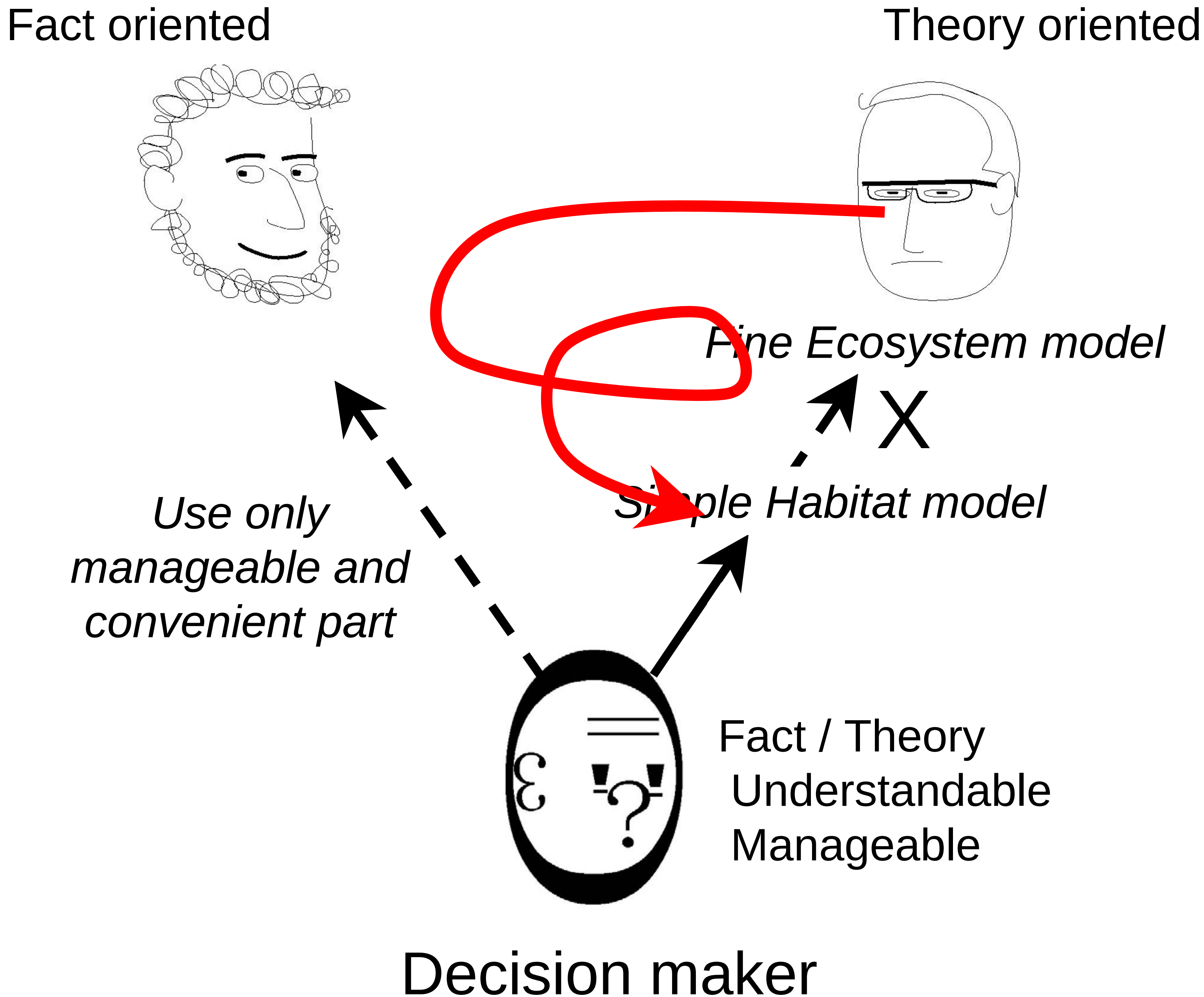


Holist

Eco-Hydrologist

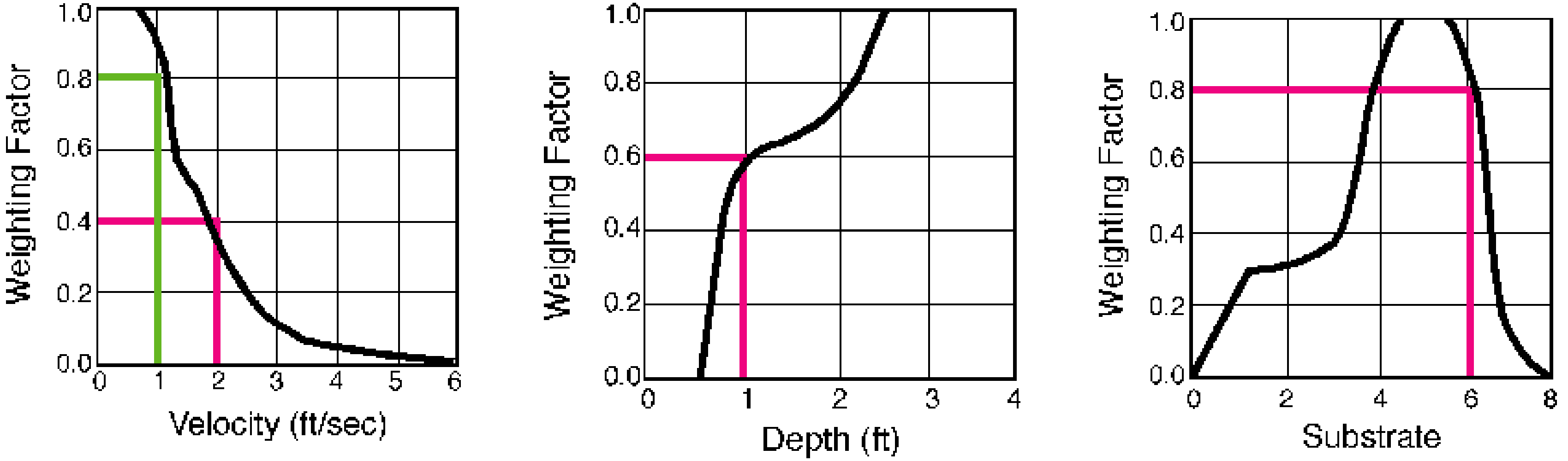


Reductionist

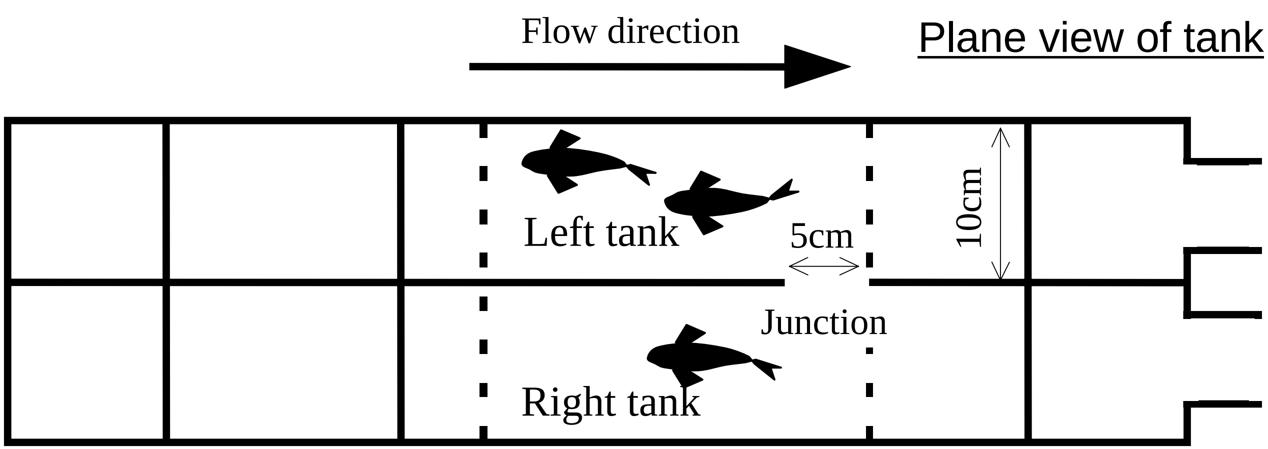


Fact oriented
Theory oriented
Fine Ecosystem model
X
Simple Habitat model
Use only manageable and convenient part
Fact / Theory
Understandable
Manageable
Decision maker

Fish Preference Model for habitat evaluation



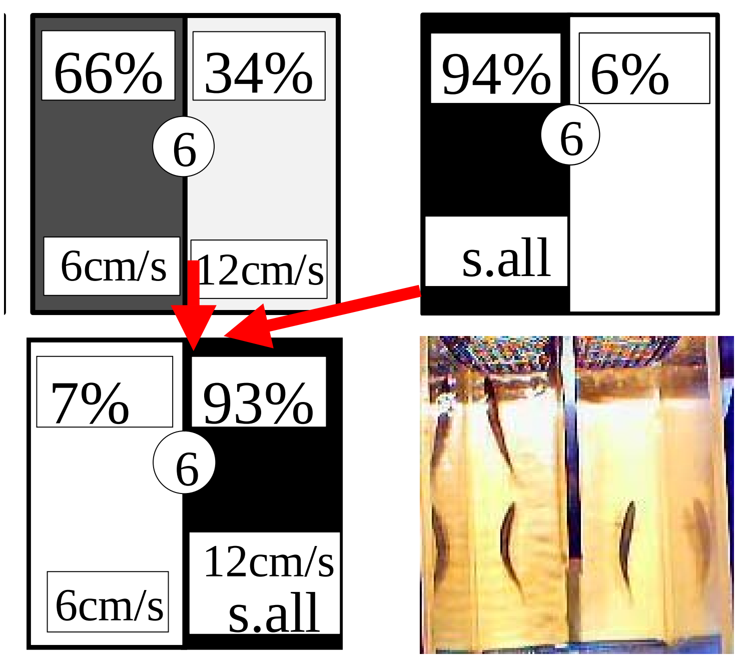
(Above figures are taken from Midcontinent Ecological Science Center Home Page as an example.)



Our former research on fish preference model (1)

Traditional preference model	Our preference model
$P^* = \prod_{j=1}^{J} P_j$	$P^* = \prod_{j=1}^{J} (P_j)^{\frac{W_j}{W_{\max}}}$

Traditional model cannot explain the fish distribution under combined condition.



Additional two strong points of our model

1. The preference curve and weight value for each environmental factor can be determined separately.
2. The environmental factors can be added anytime without affecting other preference curves and weights.

Our former research on fish preference model (2)

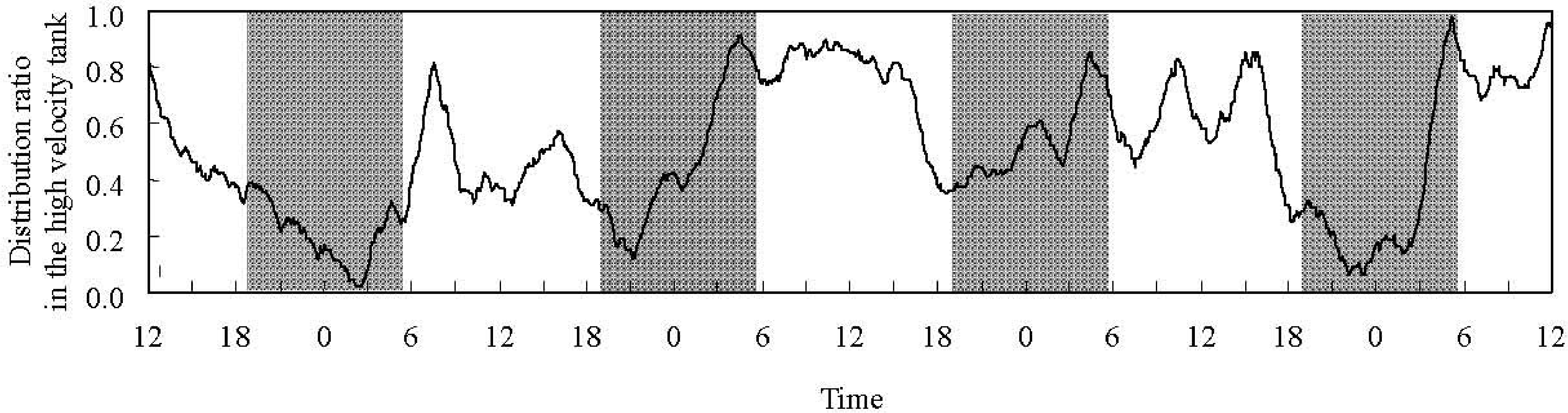


Figure 3. Fluctuation of distribution ratio in the high velocity tank.

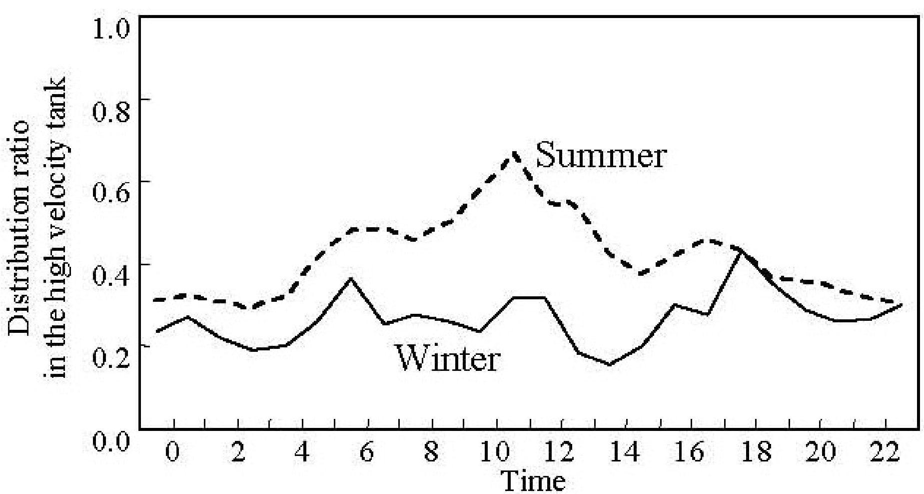


Figure 4. Difference of the distribution ratio during a day in the high velocity tank between summer and winter.

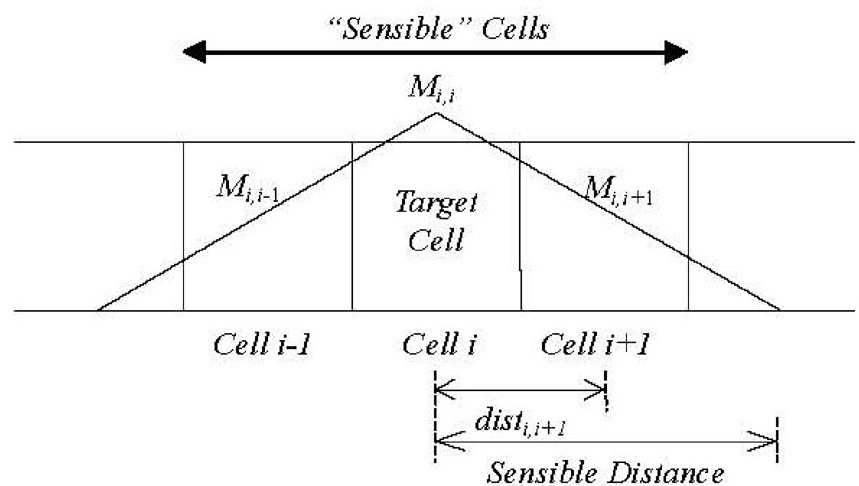
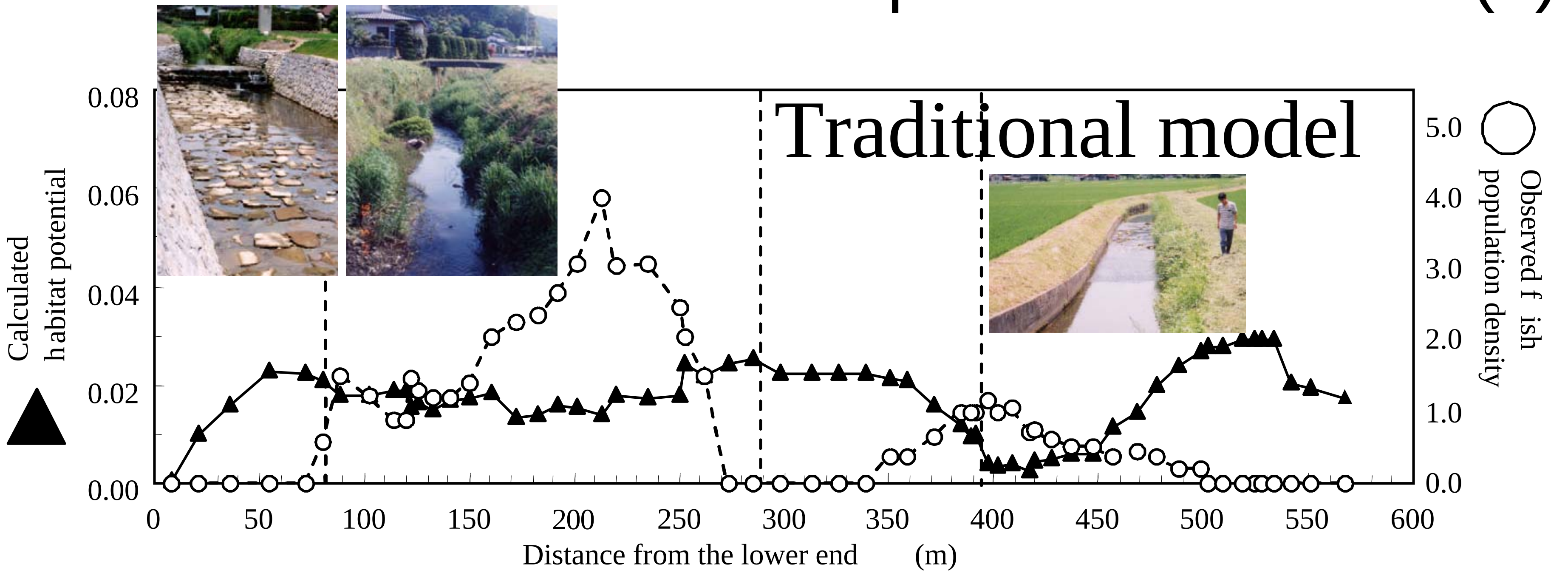
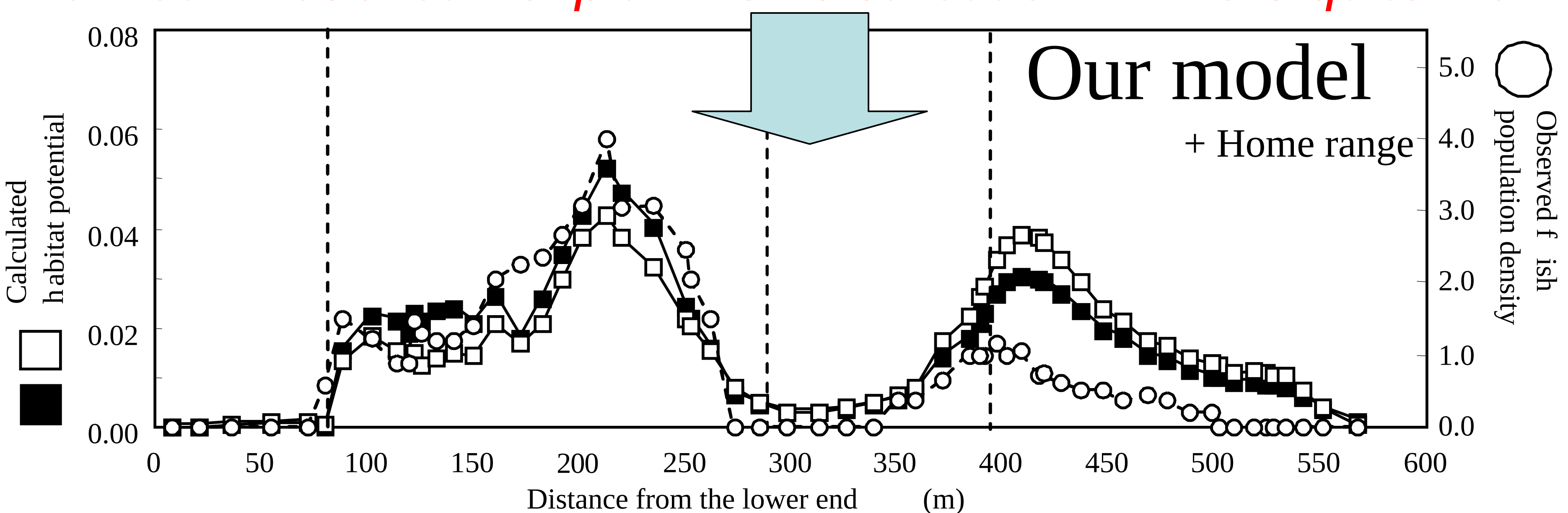


Fig. 5. Sensible Weight and Sensible Distance.

Our former research on fish preference model (3)



Now our model can explain fish distribution in rivers quite well!



PURPOSE

- We have already been able to evaluate fish distribution in "moderate reach" based on its preference.
- The purpose of this research is to evaluate continuity of rivers for migratory fish by constructing a preference model for "barrier reach", which has rapid velocity and/or high gap of water level.

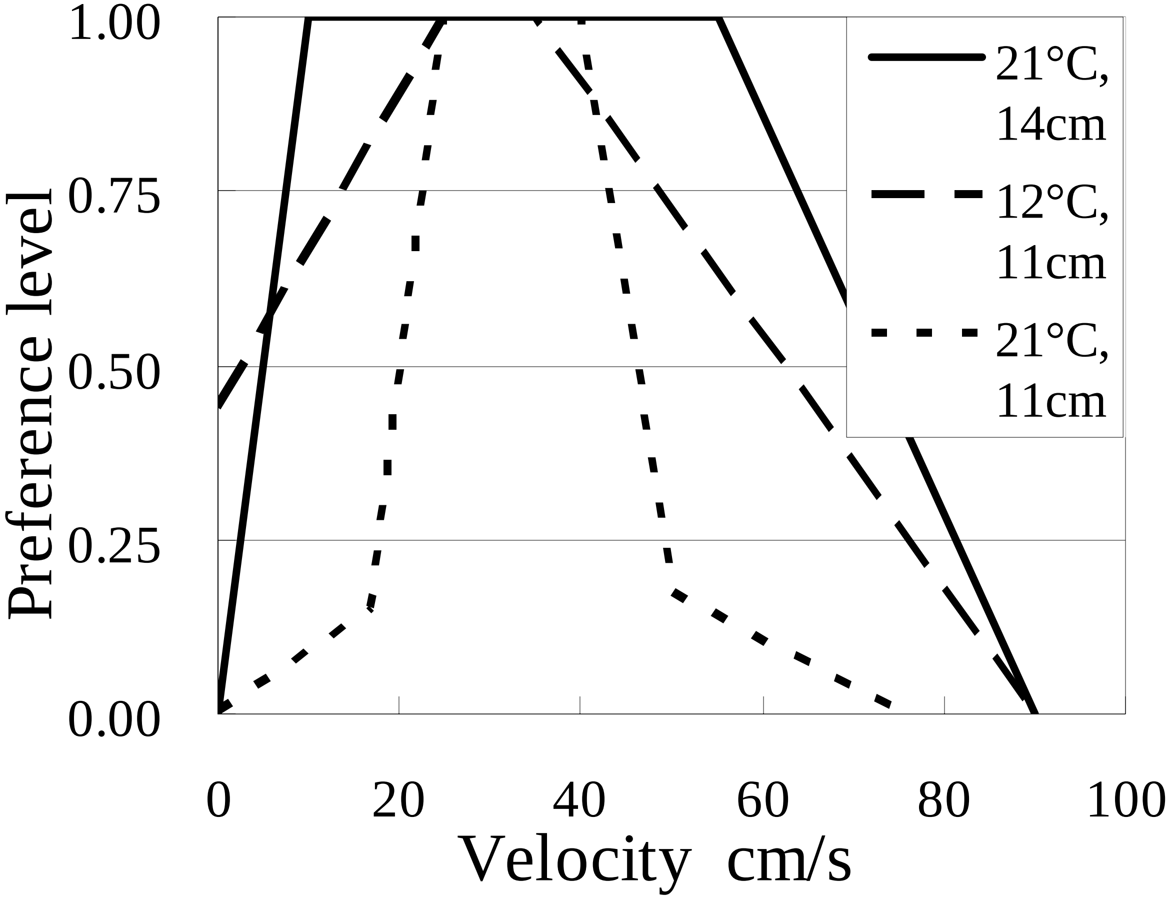
Examples of barrier reach

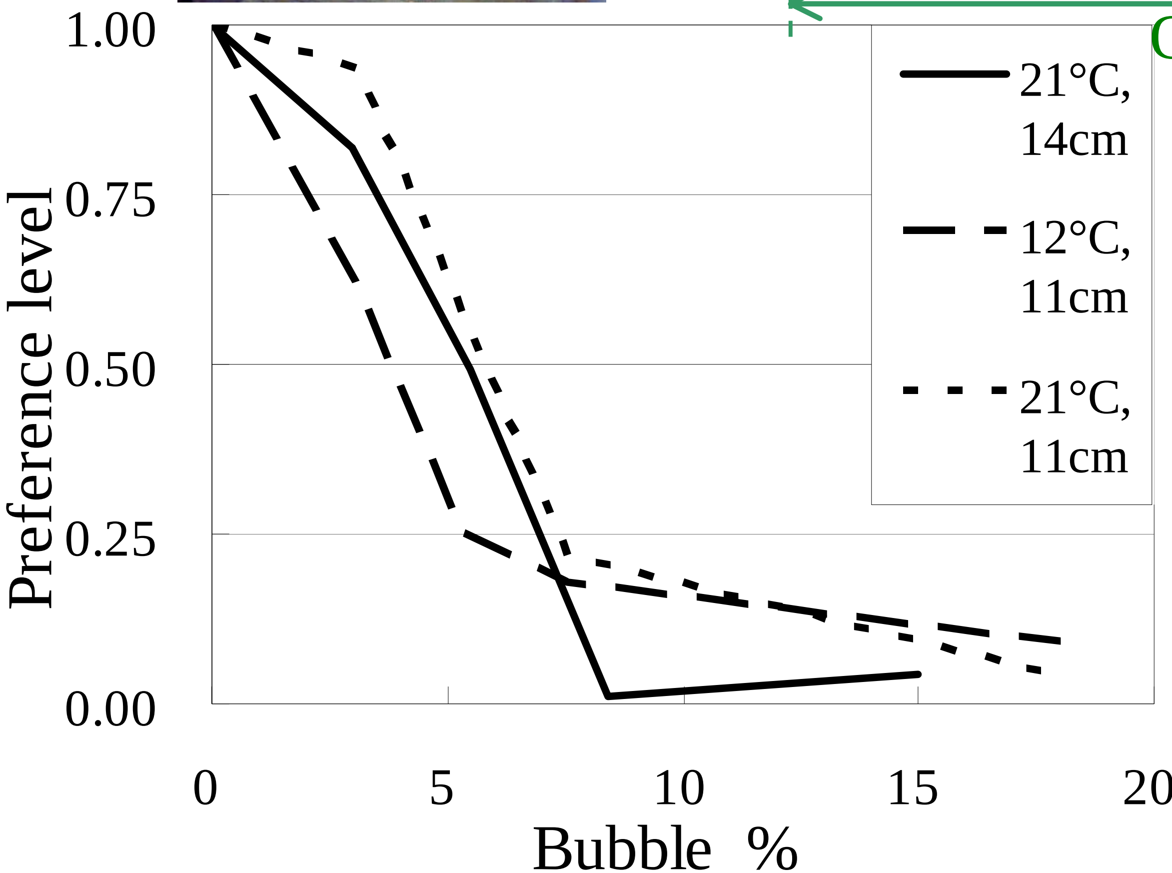
- In barrier reach, turbulence, bubble, and velocity play important roles.
- In sustained swimming section, fish can swim with sustained swimming speed.
- In gap section, fish need to swim with burst swimming speed or even need to jump.

METHOD

1. Decide fish preference models for turbulence, bubble, and velocity based on Lab. tests.
2. Construct model equations for sustained swimming section and gap section.
3. Conduct field surveys to obtain field data of turbulence, bubble and velocity together with counting migratory fish in barrier reaches.
4. Explain fish migratory paths and fish counts by using the model.

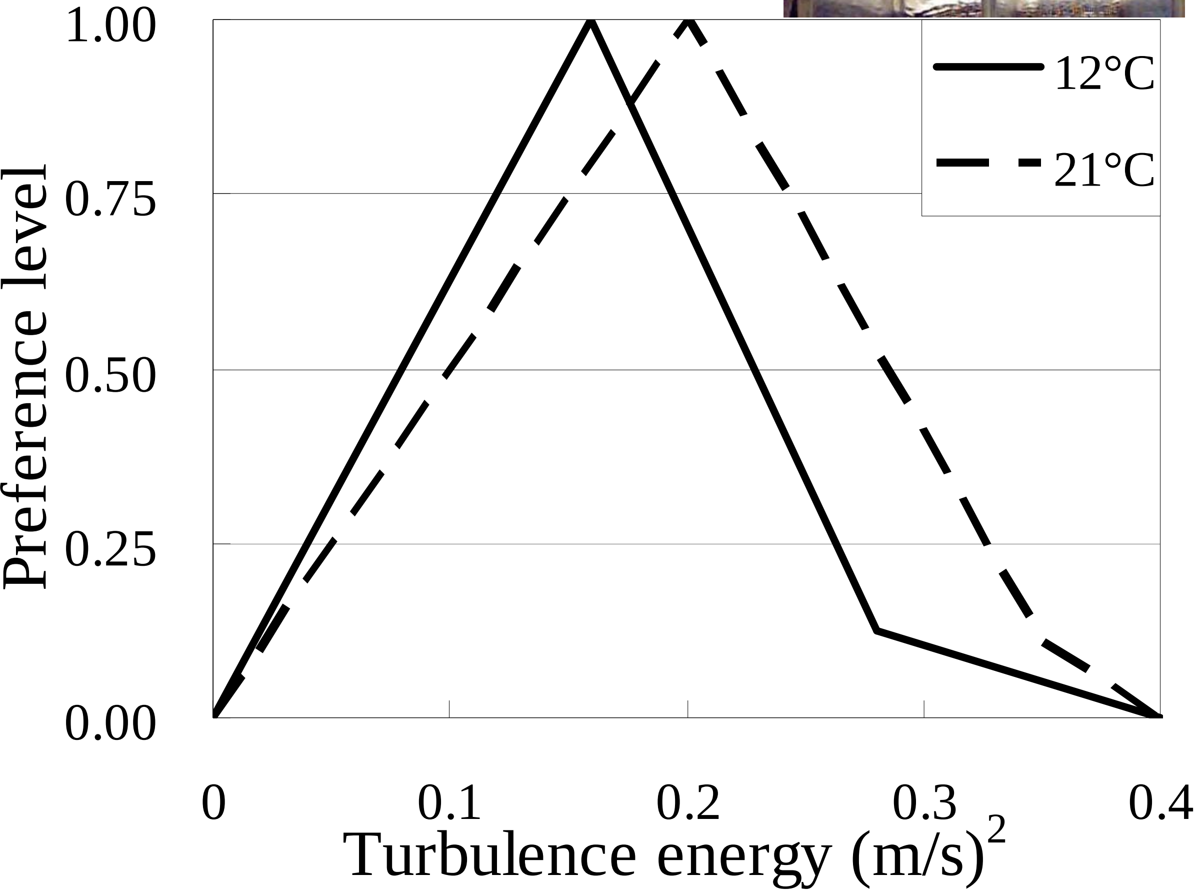
Preference for velocity





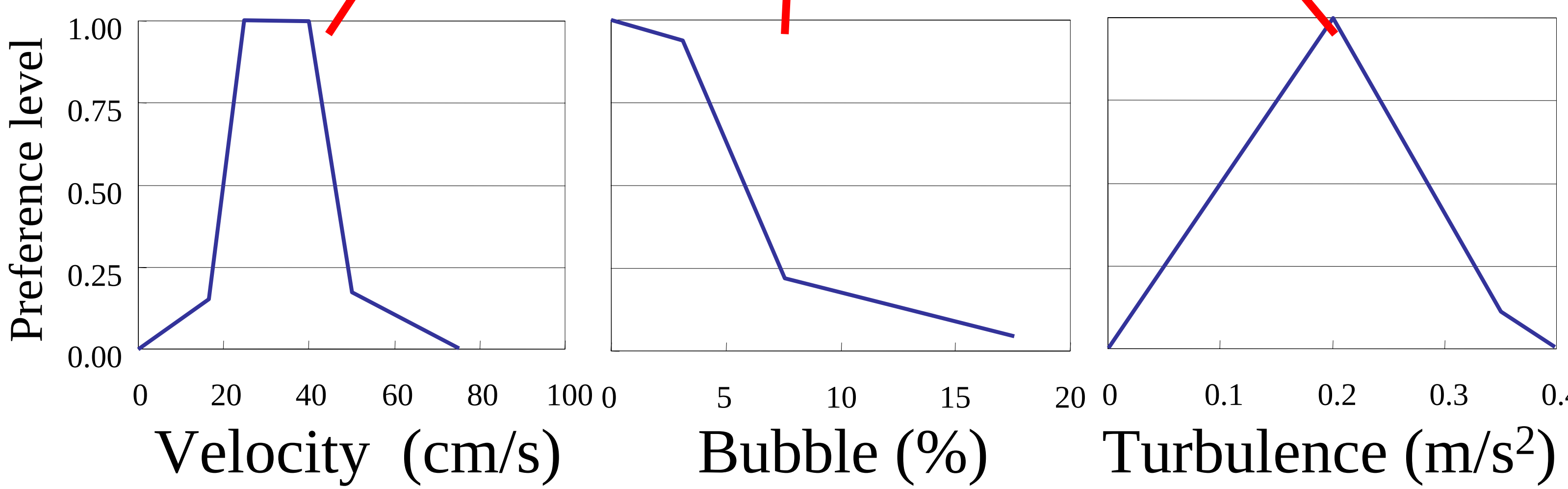
Preference for bubble

Preference for turbulence



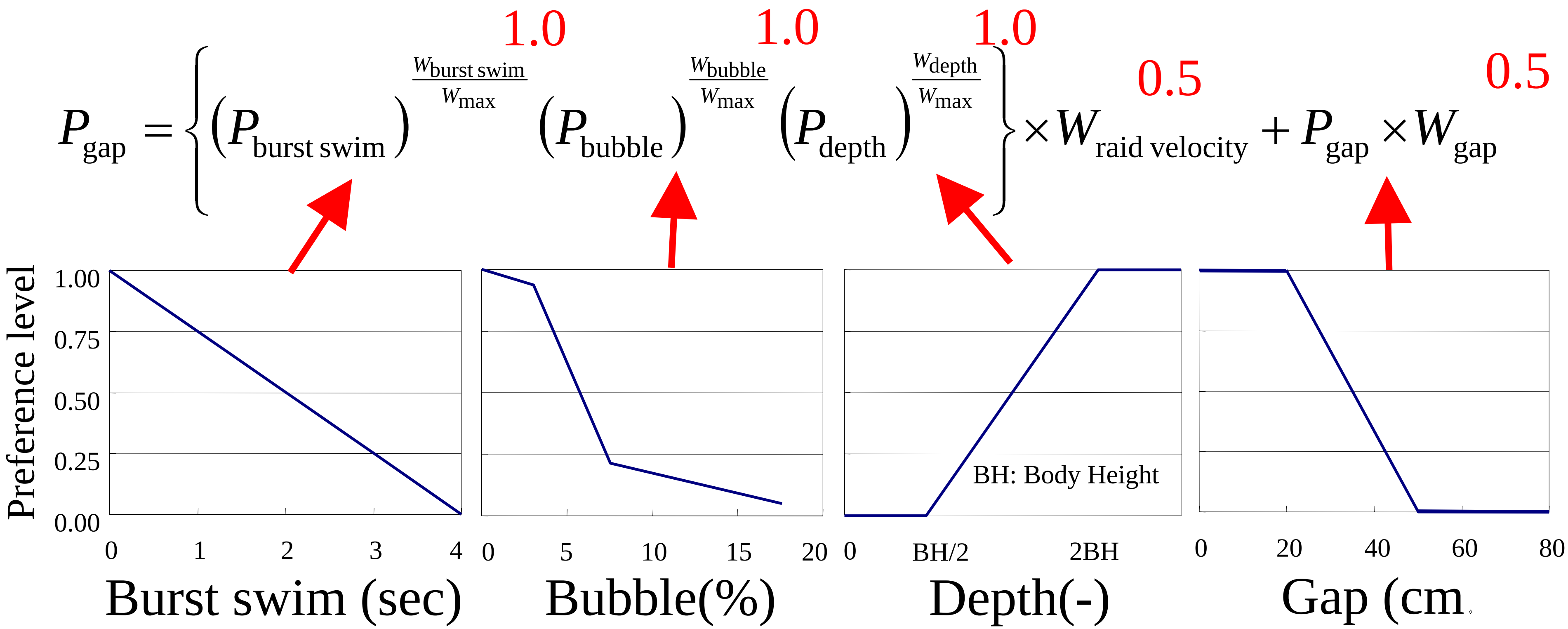
Preference in sustained swimming section

$$P_{\text{sustained swimming}} = P_{\text{velocity}}^{\overset{0.4}{\frac{w_{\text{velocity}}}{w_{\max}}}} \, P_{\text{bubble}}^{\overset{1.0}{\frac{w_{\text{bubble}}}{w_{\max}}}} \, P_{\text{turbulence}}^{\overset{0.6}{\frac{w_{\text{turbulence}}}{w_{\max}}}}$$

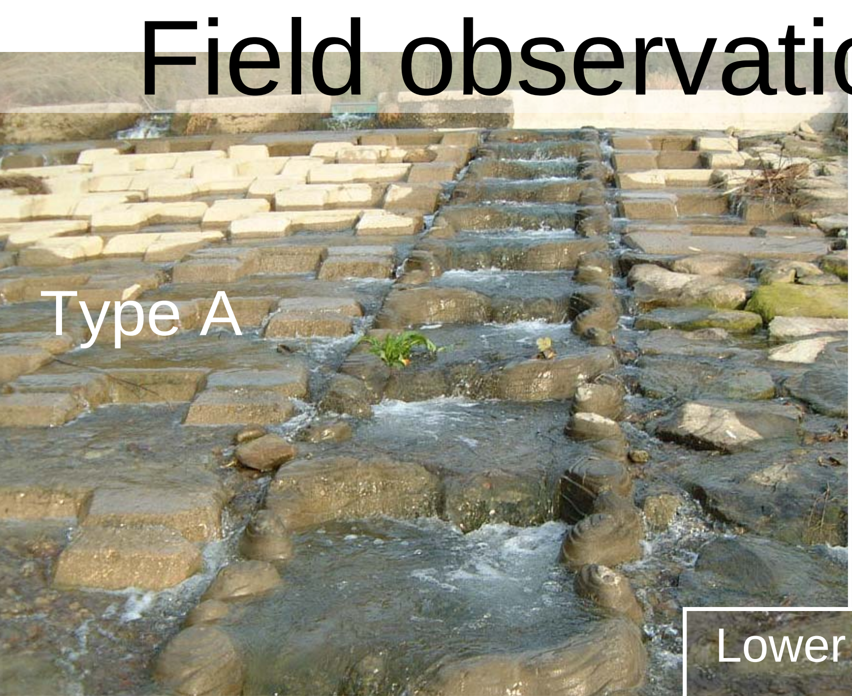


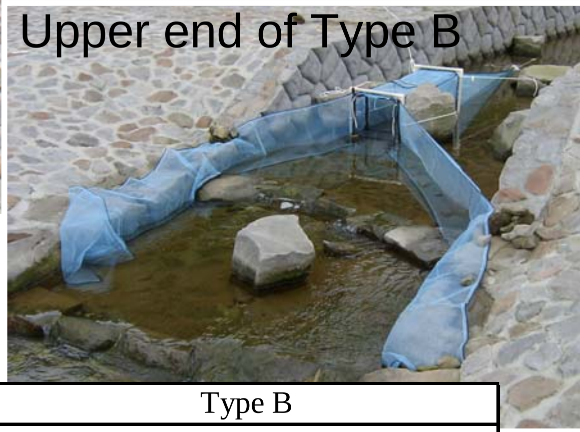
Preference in gap section

$$P_{gap} = \left\{ \left(P_{burst\ swim}\right)^{\frac{W_{burst\ swim}}{W_{max}}} \left(P_{bubble}\right)^{\frac{W_{bubble}}{W_{max}}} \left(P_{depth}\right)^{\frac{W_{depth}}{W_{max}}} \right\} \times W_{raid\ velocity} + P_{gap} \times W_{gap}$$



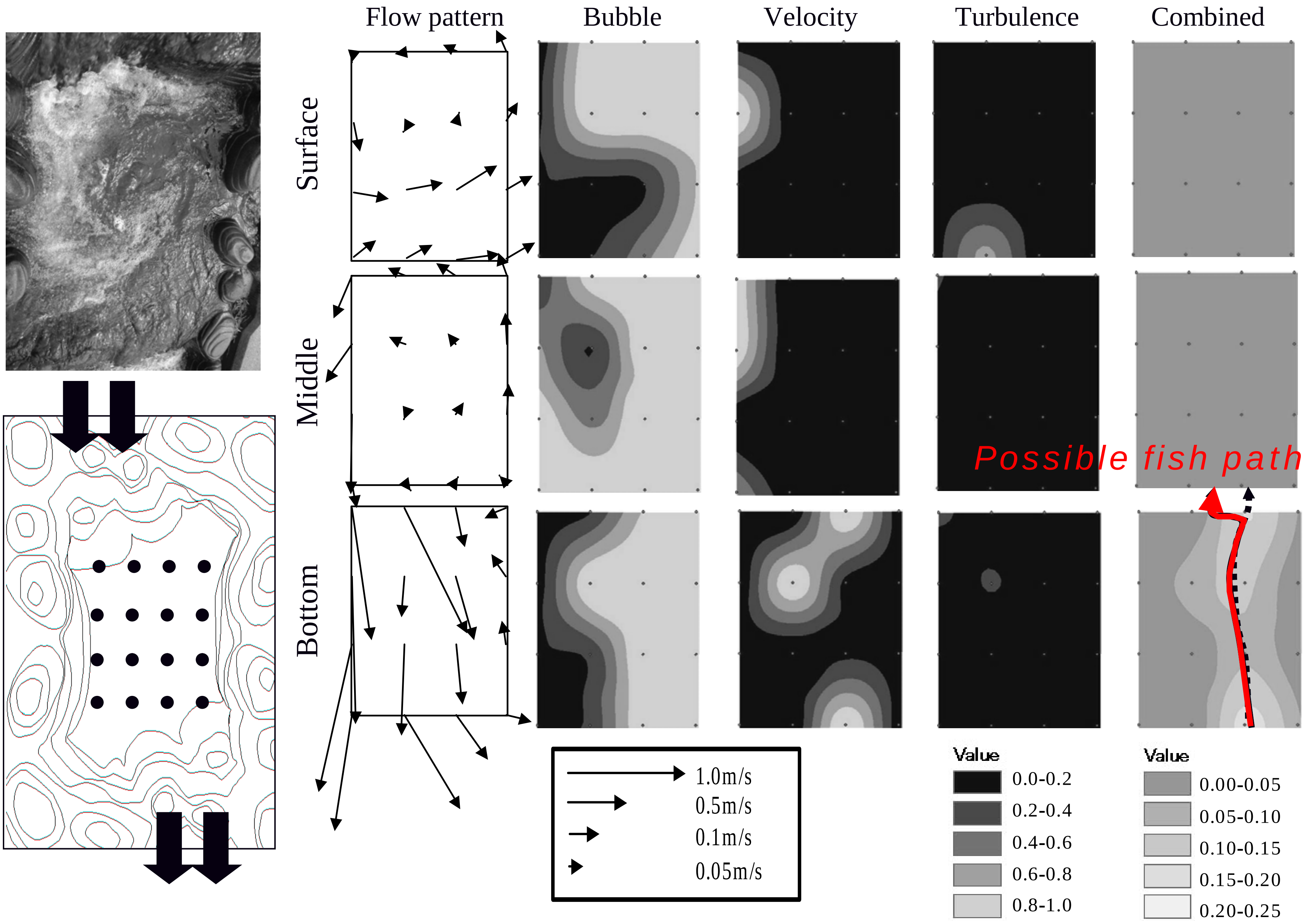
Field observation of ascending fish

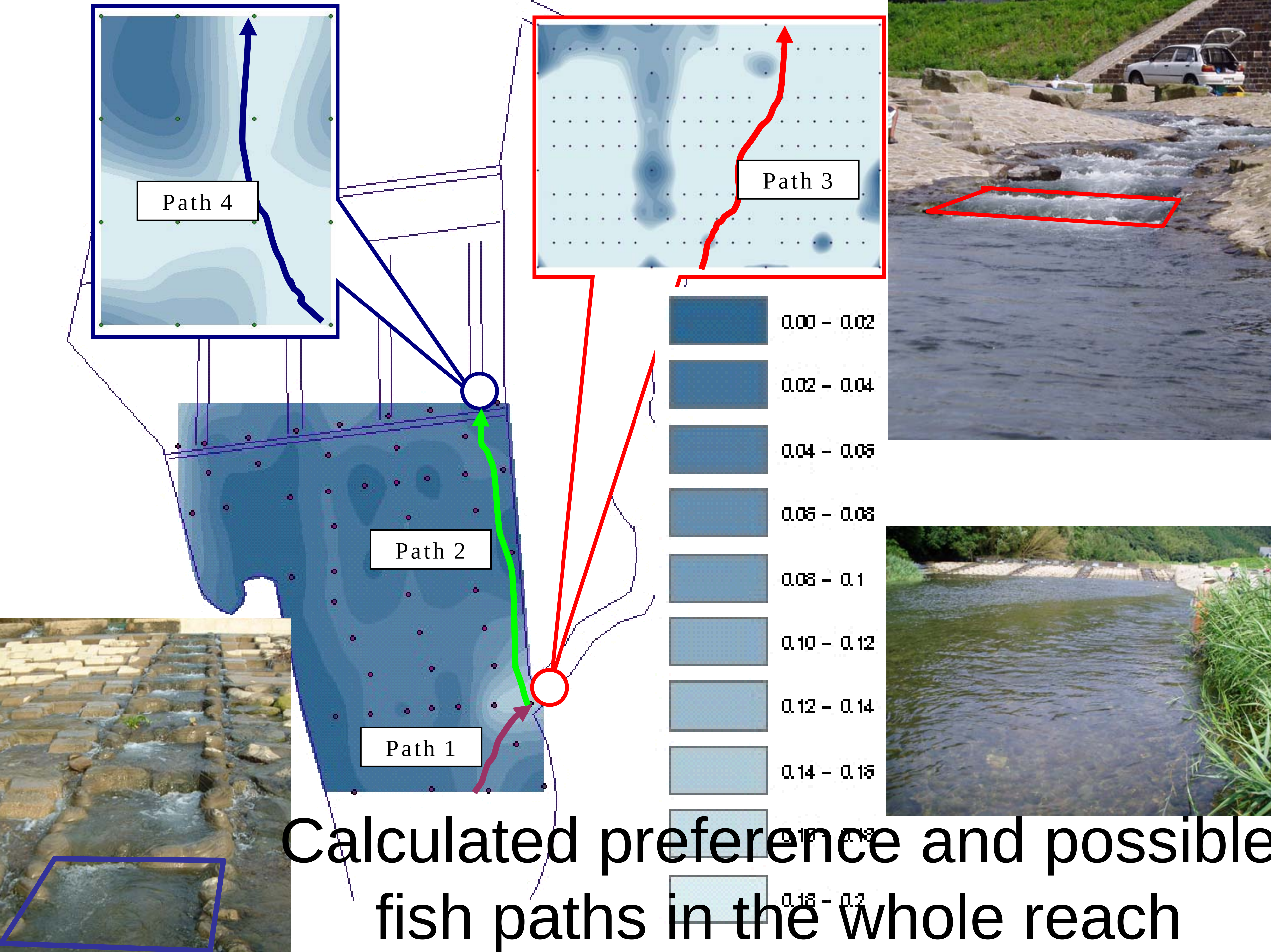




Fishway Type	Type A		Type B	
Water volume of one pool (L)	300		650	
Gap of water level between pools (cm)	17		10	
Pool number (-)	8		19	
Total length of the fishway (m)	12		50	
Slope (-)	~~1/3~~ 1/9		1/33	
Date	7-8 Aug. 2002	12-14 Apr. 2003	7-8 Aug. 2002	12-14 Apr. 2003
Flow rate (m3/sec)	0.018	0.065	0.08	0.009
Water temperature (°C)	27.5	14	27.5	14.3
Captured fish at the upper end (capita per day)	38	30	26	0

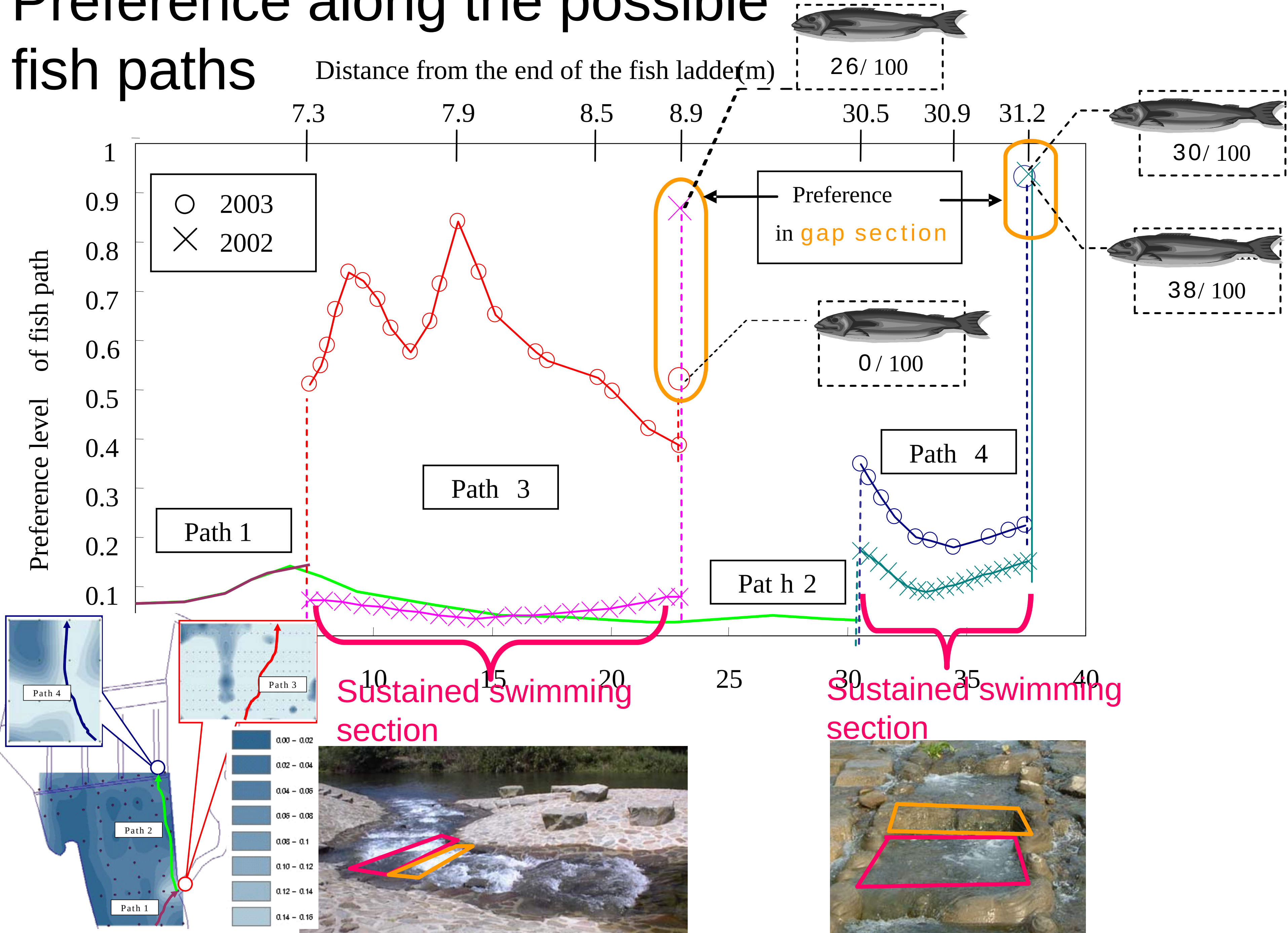
An example of preference pattern in fishway A





Calculated preference and possible fish paths in the whole reach

Preference along the possible fish paths



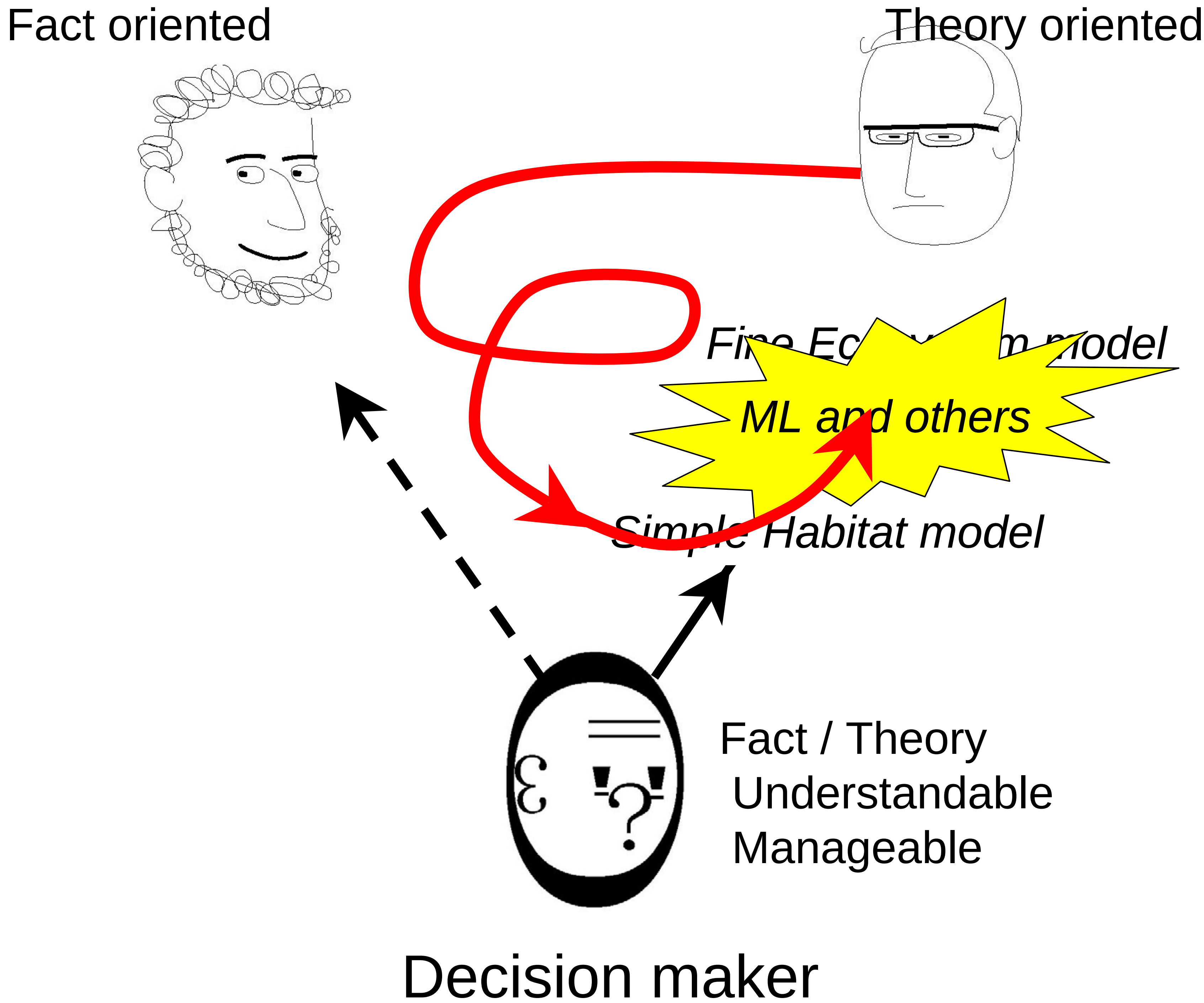
CONCLUSION

- The preference model seems successfully explain the ascending fish number.
- The model could be used to evaluate continuity of rivers.

I could advice our sponsor (concrete block maker) not to construct too comfortable fishway for fish sake.

REMAINING QUESTION

- Preference model in gap section is based on literatures and still not quantitative.
- Preference values of gap section and sustained swimming section are still not comparable.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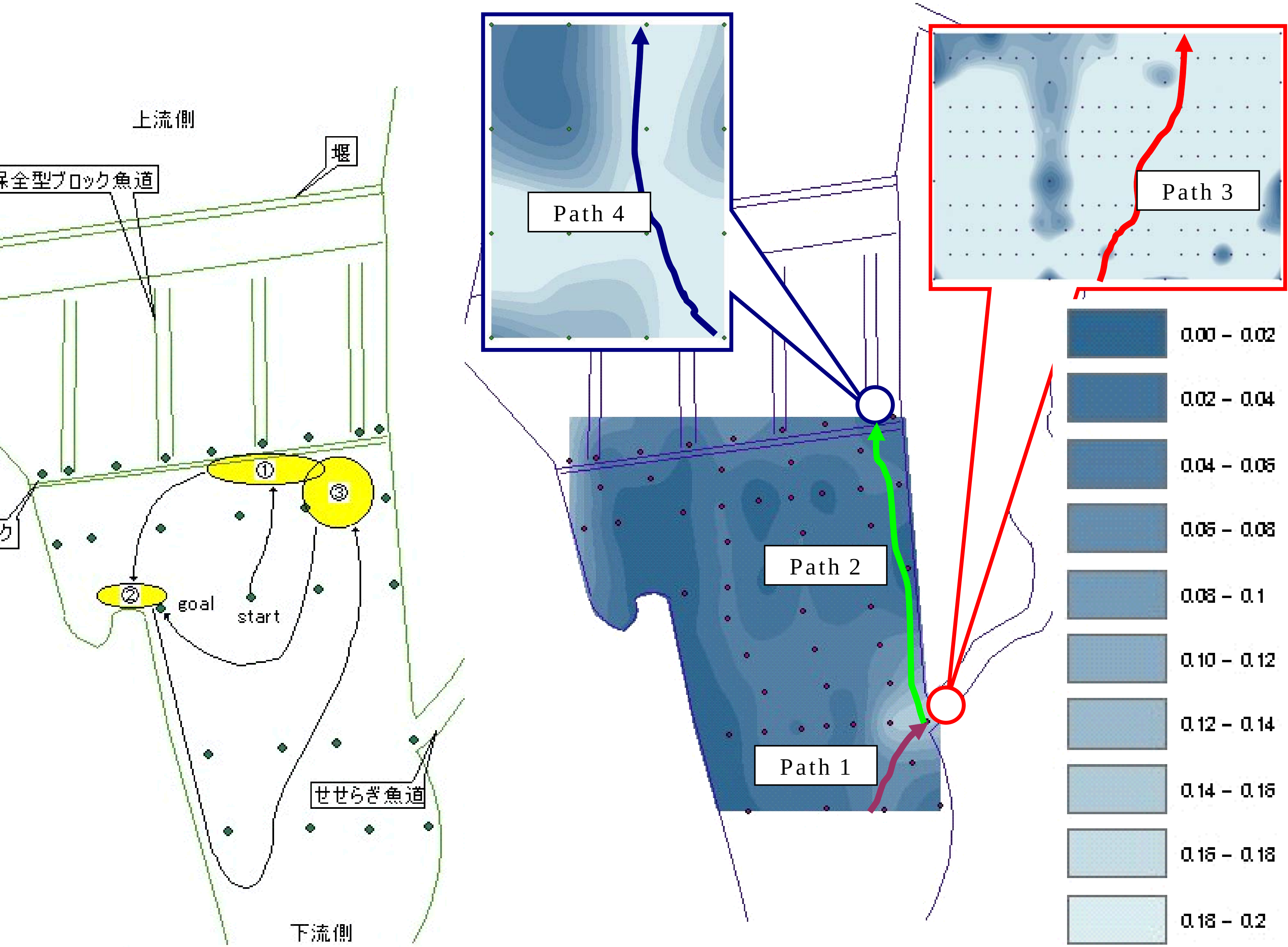
上流側
堰
全型ブロック魚道
①
③
②
goal
start
せせらぎ魚道
下流側
Path 4
Path 3
Path 2
Path 1
0.00 – 0.02
0.02 – 0.04
0.04 – 0.06
0.06 – 0.08
0.08 – 0.1
0.10 – 0.12
0.12 – 0.14
0.14 – 0.16
0.16 – 0.18
0.18 – 0.2