



Beurteilung von 1D und 2D Modell- Fähigkeiten zur Schwall und Sunk Analyse (MSc Projektarbeit)

BASEMENT Anwendertreffen 2018

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Übersicht

- **Einführung**
 - Hintergründe, Ziele der Studie
- **Methodik**
 - Geometrien, Schwall-Sunk Ganglinie, Biotische Indikatoren
- **Resultate und Diskussion**
 - Stranden von Fischen, Habitateignung
- **Fazit**

Hintergrund

- Gewässerschutzgesetz (GSchG) Art.39a Abs.I:
 - Wesentliche Beeinträchtigungen auf einheimische Tiere und Pflanzen durch Schwall und Sunk müssen bis Ende 2030 durch Kraftwerksinhaber verhindert/beseitigt werden.
- Die Vollzugshilfe «Renaturierung der Gewässer» - Modul «Schwall-Sunk – Massnahmen» (Tonolla et. al, 2017) schlägt mehrere Indikatoren zur Quantifizierung von Schwall-Sunk-Auswirkungen vor.

Hintergrund

- Problem:

Benötigte Modell Komplexität (1D/2D) und erforderliche räumliche Auflösung für die Analyse ist oft unklar.

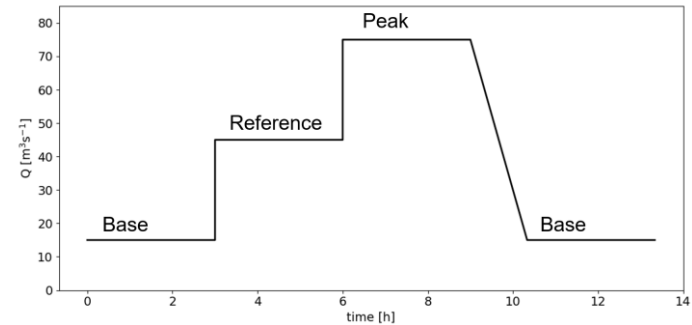
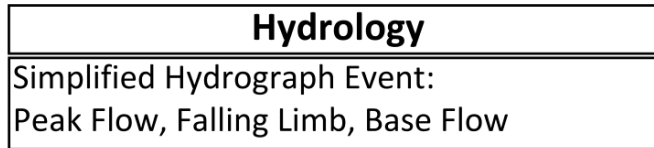
Ziele des Projektes

- Vergleich von 1D und 2D Modellen für Schwall-Sunk Analysen

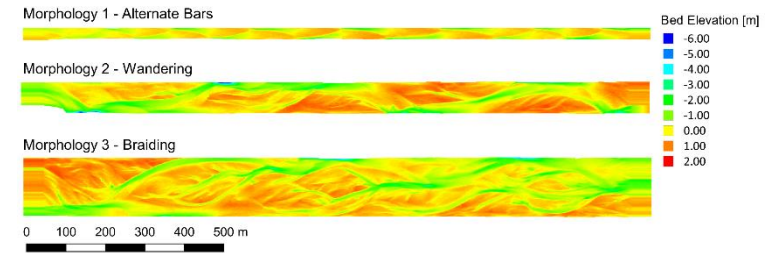
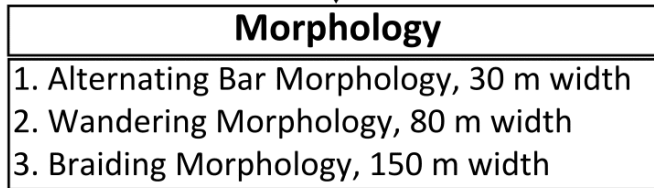
- Untersuchung des Effekts der räumlichen Auflösung

Methodik

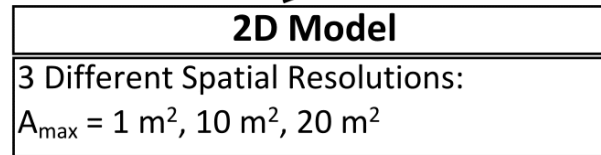
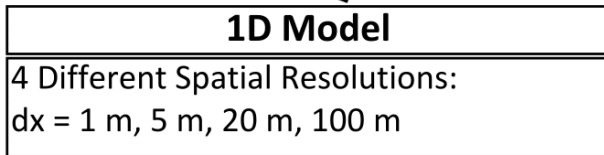
Arbeitsablauf



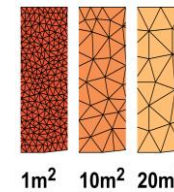
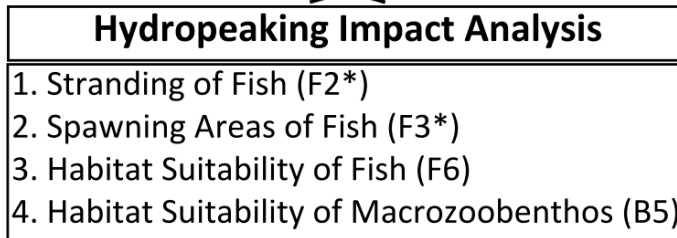
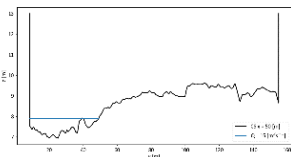
QGIS
(Crayfish,
BASEmesh)



Garcia Lugo et al., 2015



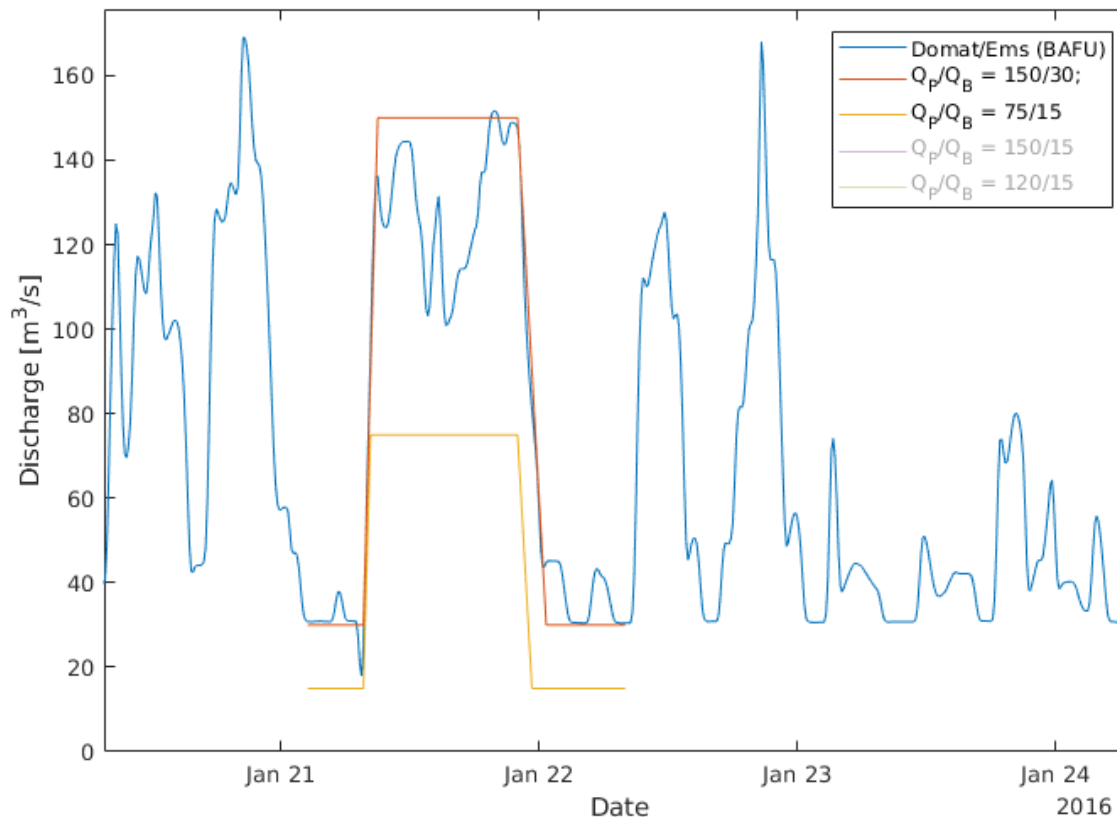
BASEMENT
(BASEchain, BASEplane)



Post-Processing mit
Python

Schwall-Sunk Ganglinie

- $Q_{\text{Schwall}}/Q_{\text{Sunk}} = 5$ (aus Abflussdaten am Alpenrhein bei Domat/Ems)
- $Q_{\text{Sunk}} = 15 \text{ m}^3\text{s}^{-1}$ $Q_{\text{Schwall}} = 75 \text{ m}^3\text{s}^{-1} (5 \cdot Q_{\text{base}})$
- Abflussrückgang = $0.75 \text{ m}^3 \text{ s}^{-1} \text{ min}^{-1}$



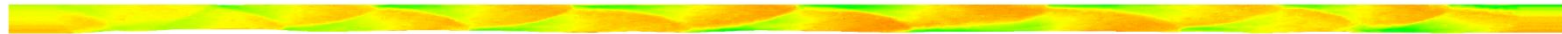
Betrachtete Flussmorphologien

- Hochskalierung (x100) von 3 vermessenen Laborgerinnen von der Universität Trient
- → Original DHM: 5 m x 0.5 m Auflösung

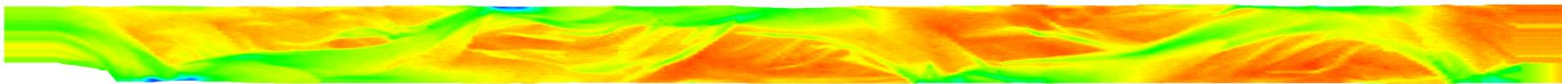
Betrachtete Flussmorphologien

- Alternierende Bänke (30 m breit, 1495 m lang)
- Wandernde Morphologie (80 m breit, 1495 m lang)
- Verzweigte Morphologie (150 m breit, 1495 m lang)

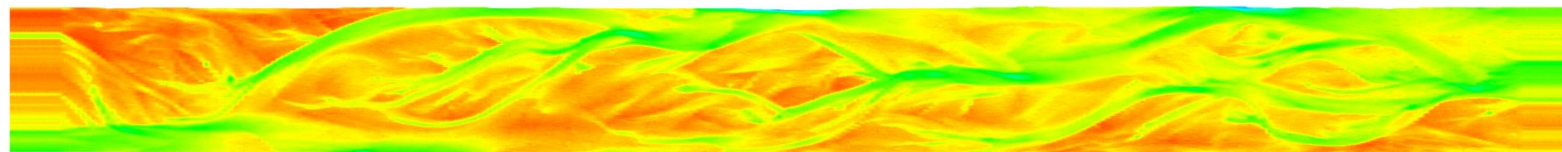
Morphology 1 - Alternate Bars



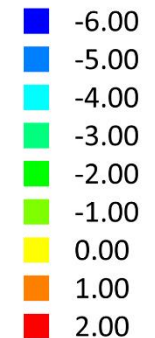
Morphology 2 - Wandering



Morphology 3 - Braiding



Bed Elevation [m]



0 100 200 300 400 500 m



Erstellung 2D Geometrien

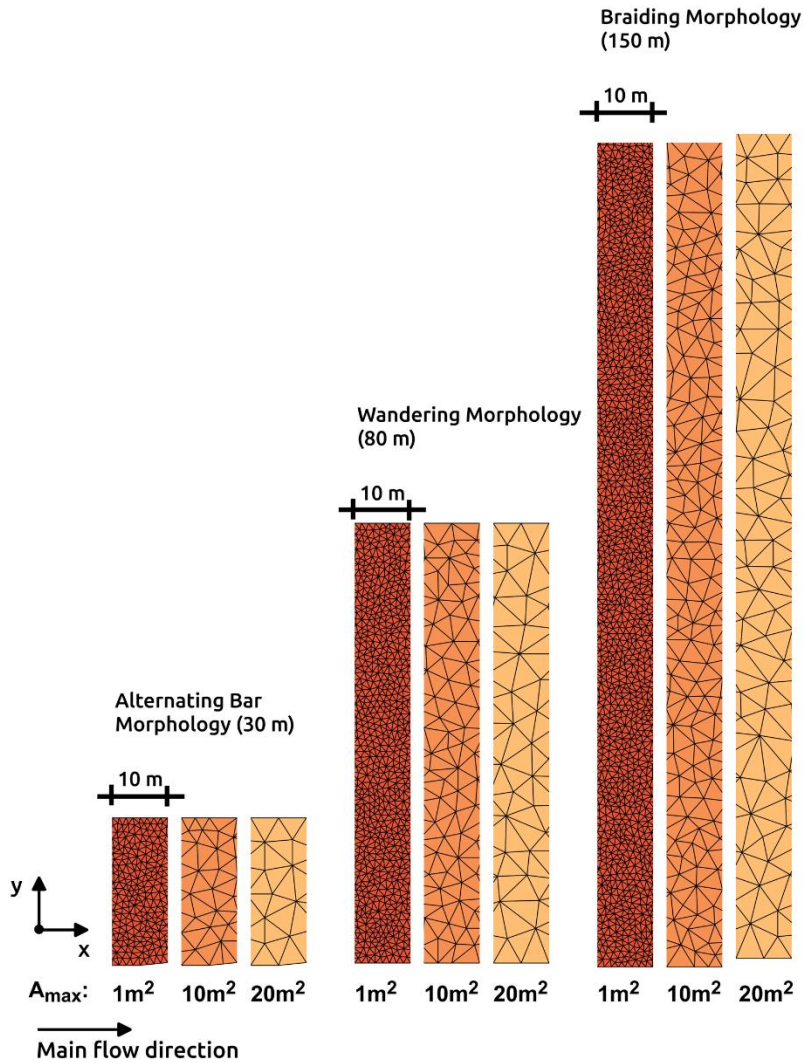
Mit MATLAB:

- Änderung des mittleren Gefälles von 1 % auf 0.3 %
- Entfernung der seitlichen Böschungen vom Grid
- Verlängerung und Abflachung der Inflow und Outflow Boundaries

Mit BASEmesh Plugin in QGIS:

- Generieren der “Elevation meshes” und “Quality meshes”
($A_{\max} = 1\text{m}^2$, $A_{\max} = 10\text{m}^2$, $A_{\max} = 20\text{m}^2$)
- Interpolation der Höhendaten von den “Elevation meshes” auf die “Quality meshes”
- Exportieren als .2dm Files

2D Geometry



Elementgrößen

A_{\max}	A_{\min}	A_{average}
[m ²]	[m ²]	[m ²]
1	0.3	0.6
10	2.5	6.0
20	6.5	12.5

Erstellung der 1D Geometrien

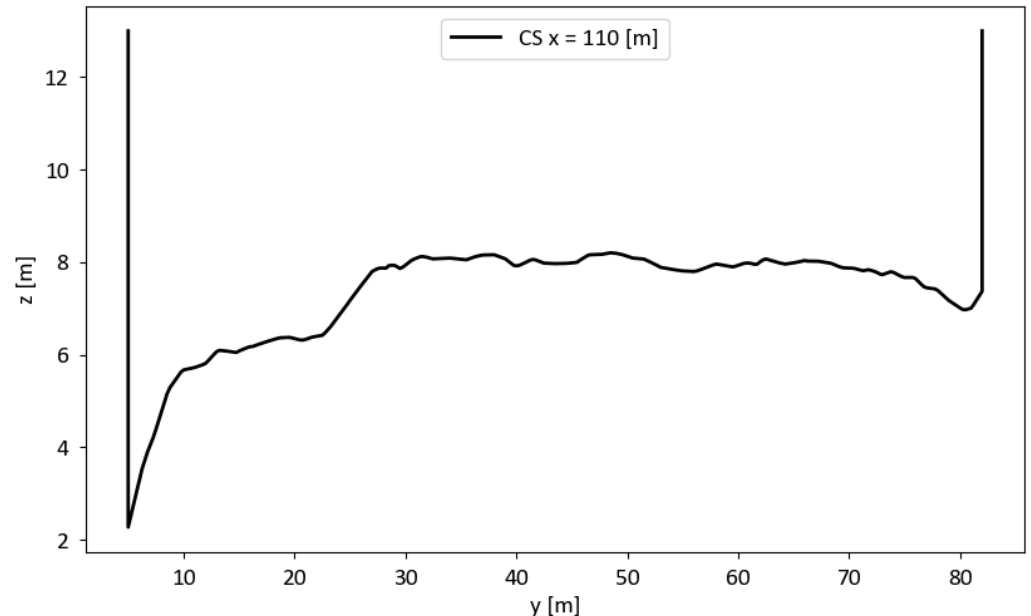
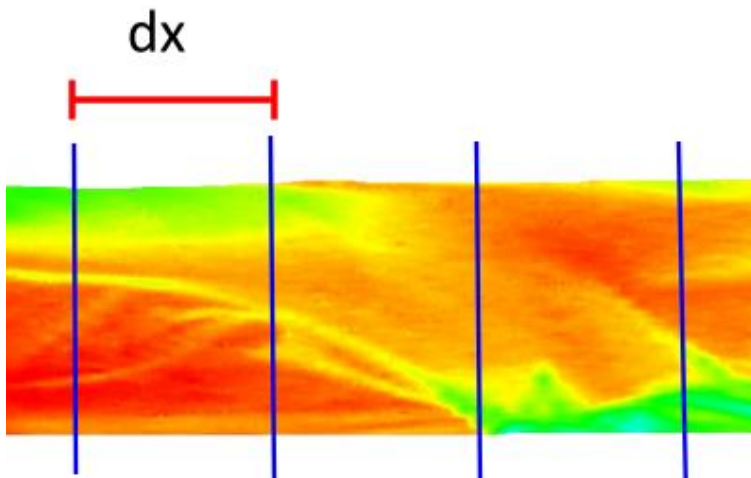
1D Geometrien basieren auf 2D Geometrien mit $A_{\max} = 1\text{m}^2$

Mit Crayfish Plugin in QGIS:

→ Exportieren der .2dm Files als 0.25m x 0.25m DEM (TIF)

Mit Python:

→ Skript welches Querschnitte für beliebige Abstände “dx” extrahiert und als .bmg Files speichert



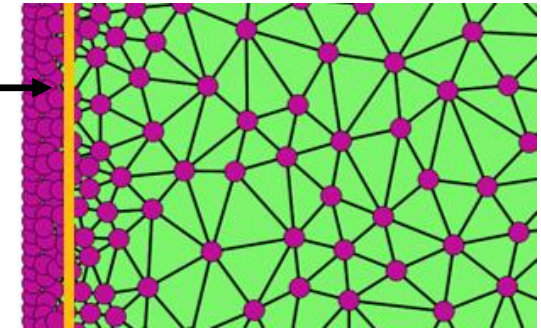
Simulationen mit BASEMENT



■ Aufgetretene Probleme

- Probleme beim Erstellen der Grids falls steile Böschungen, aufgrund der definierten Breaklines. Kleine, unregelmässige Dreiecke führten zu Fehlermeldungen in Basement. Zudem vergrössern Sie die Rechenzeit enorm.

Breakline



→ Lösung:

- Entfernung der steilen seitlichen Ufern (nur noch Sohlentopographie)

Simulationen mit BASEMENT



■ Aufgetretene Probleme

- Fehlermeldungen ($v > 200\text{m/s}$) bei zu grossen Höhenunterschieden zwischen Elementen an Inflow und Outflow Boundaries

→ Lösung:

- Verlängerung und Abflachung der Inflow und Outflow Boundaries
- Reduzieren der Inflow und Outflow Stringdefs auf flachen Bereich

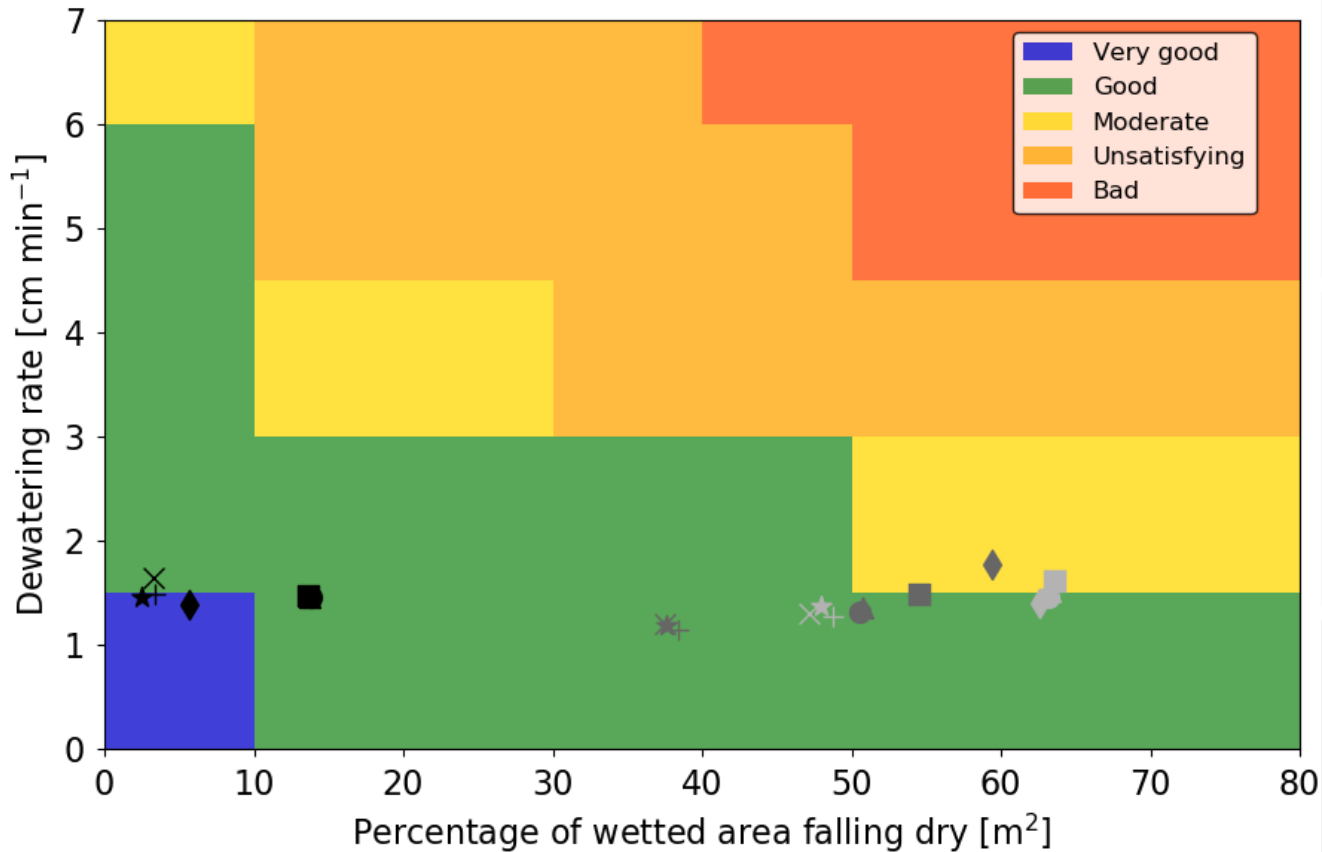
Indikatoren für Wirkungsanalyse (BAFU 2017)

- **Stranden von Fischen (F2*)**
 - Basiert auf Pegelabsenkungsrate und Variation der benetzten Fläche zwischen Schwall und Sunk
- **Laichareale der Fische (F3*)**
- **Habitateneignung Fische (F6)**
- **Habitateneignung Makrozoobenthos (B5)**
 - F3*, F6 und B5 basieren auf Habitatmodellierung mittels Präferenzkurven

→ Berechnung mit Python (Numpy, Pandas, Matplotlib...)

Resultate and Diskussion

Indikator Stranden von Fischen (F2*)



Indikator Habitataignung Fische (F6)

Habitataignungskarte Adulte Bachforellen

2D Alternating Bar Morphology: Base Flow ($Q = 15 \text{ m}^3\text{s}^{-1}$)



1D Alternating Bar Morphology: Base Flow ($Q = 15 \text{ m}^3\text{s}^{-1}$)



2D Braiding Morphology: Base Flow ($Q = 15 \text{ m}^3\text{s}^{-1}$)

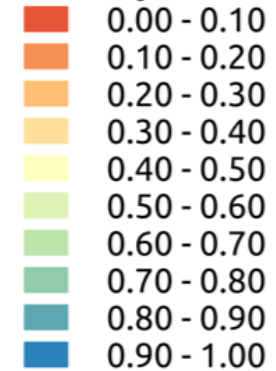


1D Braiding Morphology: Base Flow ($Q = 15 \text{ m}^3\text{s}^{-1}$)

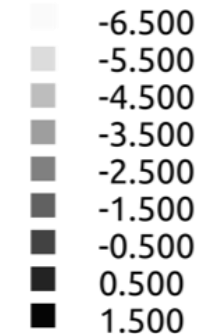


Habitat Suitability Index [-]

Dry



DEM [m]



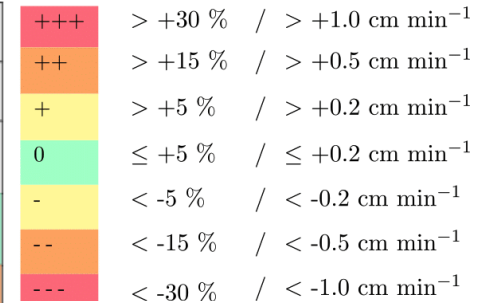
0 50 100 150 200 250 300 m



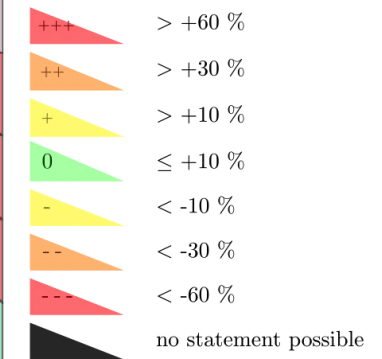
Evaluation für Morphologie 3 (verzweigt)

Legend

Deviation in wetted area and dewatering rate compared to 2D,1m²



Deviation in habitat area (F3*, F6, B5) compared to 2D,1m²



Base Peak
base and peak flow conditions

Morphology 3		Modelling Scenarios						
		2D			1D			
		1m ²	10m ²	20m ²	1m	5m	20m	100m
Fish Stranding	Dewatering Rate	0	0	0	0	+	+	0
	Wetted Area	0	0	0	++	++	++	++
	Fish Stranding (F2*)	0	0	0	+	++	++	+
Habitat Area	Spawning Areas of Fish (F3*)	0/0	0/0	+/0	0/---	0/---	-/---	0/---
	Habitat Suit. Of Fish (F6) Juv.	0/0	-/0	0/0	---	---	---	---
	Habitat Suit. Of Fish (F6) Ad.	0/0	0/0	0/+	---	---	---	---
	Habitat Suit. Of Macroz. (B5)	0/0	-/0	-/0	---	---	---	---
Computing Time		v. h.	low	low	mod.	low	low	low

v.h. very high (>8h) high high (>2h) mod. moderate (>0.5h) low low (≤0.5h)

Fazit (1)

Fähigkeiten des 1D Modells:

- Stranden von Fischen (F2*) für simple Morphologien

Limitationen des 1D Modells:

- Stranden von Fischen (F2*) für komplexe Morphologien
- Habitateignung (F3*, F6, B5)

Fazit (2)

Effekt der räumlichen Auflösung

- Gröber aufgelöste Modelle können die Rechenzeit der Simulationen stark reduzieren aber immer noch zufriedenstellende Resultate liefern.
- Kompromiss zwischen Genauigkeit und Rechenzeit.

Referenzen

- Garcia Lugo, G., Bertoldi, W., Henshaw, A., and Gurnell, A. (2015). The effect of lateral confinement on gravel bed river morphology. *Water Resources Research*.
- Hauer, C., Unfer, G., Holzapfel, P., Haimann, M., and Habersack, H. (2014). Impact of channel bar form and grain size variability on estimated stranding risk of juvenile brown trout during hydropeaking. *Earth Surface Processes and Landforms*
- Person, E. (2013). Impact of hydropeaking on fish and their habitat. Technical report, EPFL
- Schmedtje, U. (1995). Ökologische Grundlagen für die Beurteilung von Ausleitungsstrecken. Schriftenreihe des Bayerischen Landesamtes für Wasserwirtschaft Heft 15, 154 S.
- Tonolla, D., Chaix, O., Meile, T., Zurwerra, A., Büsser, P., Oppliger, S., and Essyad, K. (2017). Schwall Sunk Massnahmen. Ein Modul der Vollzugshilfe Renaturierung der Gewässer. Bundesamt für Umwelt, Bern. *Umwelt-Vollzug*, 1701:133.s

Fragen

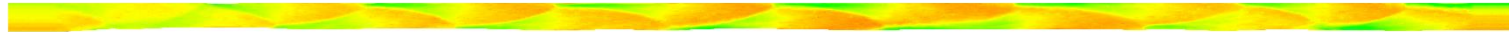
Simulation Scenarios

Runs	Hydrograph	Morphology	Model (1D/2D)	Resolution
1	A	1 (Alternating Bars)	1D	$Dx = 1 \text{ m}$
2	A	2 (Wandering)	1D	$Dx = 1 \text{ m}$
3	A	3 (Braiding)	1D	$Dx = 1 \text{ m}$
4	A	1	1D	$Dx = 5 \text{ m}$
5	A	2	1D	$Dx = 5 \text{ m}$
6	A	3	1D	$Dx = 5 \text{ m}$
7	A	1	1D	$Dx = 20 \text{ m}$
8	A	2	1D	$Dx = 20 \text{ m}$
9	A	3	1D	$Dx = 20 \text{ m}$
10	A	1	1D	$Dx = 100 \text{ m}$
11	A	2	1D	$Dx = 100 \text{ m}$
12	A	3	1D	$Dx = 100 \text{ m}$
13	A	1	2D	$A_{\max} = 1 \text{ m}^2$
14	A	2	2D	$A_{\max} = 1 \text{ m}^2$
15	A	3	2D	$A_{\max} = 1 \text{ m}^2$
16	A	1	2D	$A_{\max} = 10 \text{ m}^2$
17	A	2	2D	$A_{\max} = 10 \text{ m}^2$
18	A	3	2D	$A_{\max} = 10 \text{ m}^2$
19	A	1	2D	$A_{\max} = 20 \text{ m}^2$
20	A	2	2D	$A_{\max} = 20 \text{ m}^2$
21	A	3	2D	$A_{\max} = 20 \text{ m}^2$

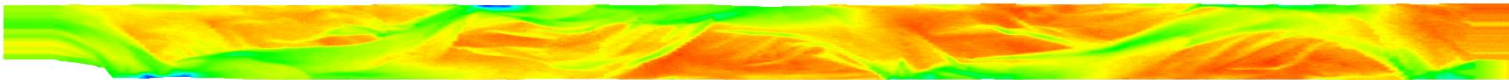
Morphological Bed Forms

- 3 upscaled laboratory flumes (Garcia Lugo et al., 2015)
- 2D geometries: $A_{\max} = 1 \text{ m}^2, 10 \text{ m}^2, 20 \text{ m}^2$
- 1D geometries: $dx = 1 \text{ m}, 5 \text{ m}, 20 \text{ m}, 100 \text{ m}$

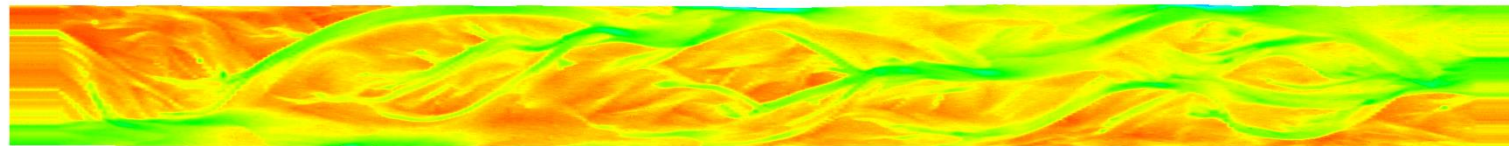
Morphology 1 - Alternate Bars



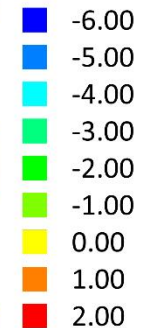
Morphology 2 - Wandering



Morphology 3 - Braiding



Bed Elevation [m]

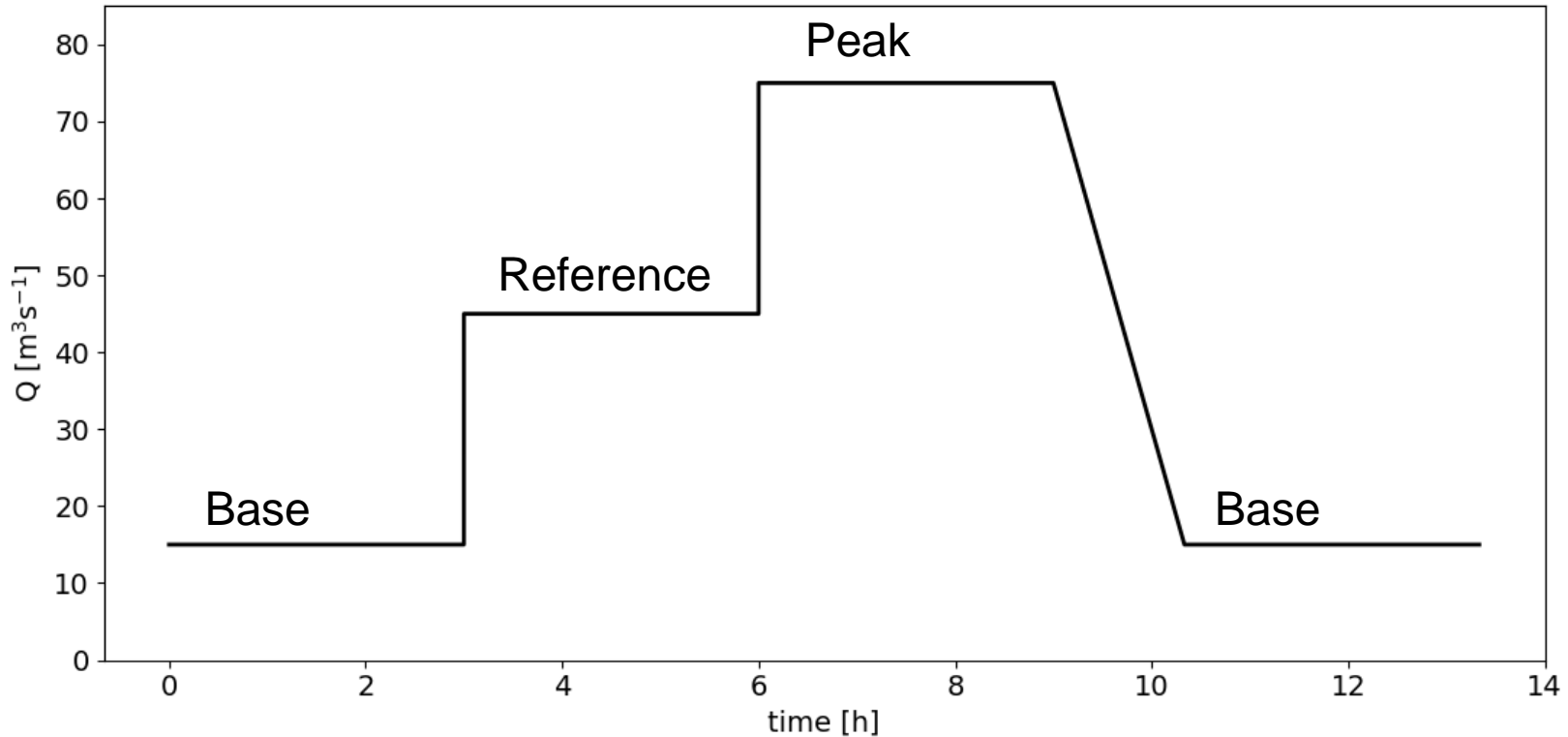


0 100 200 300 400 500 m



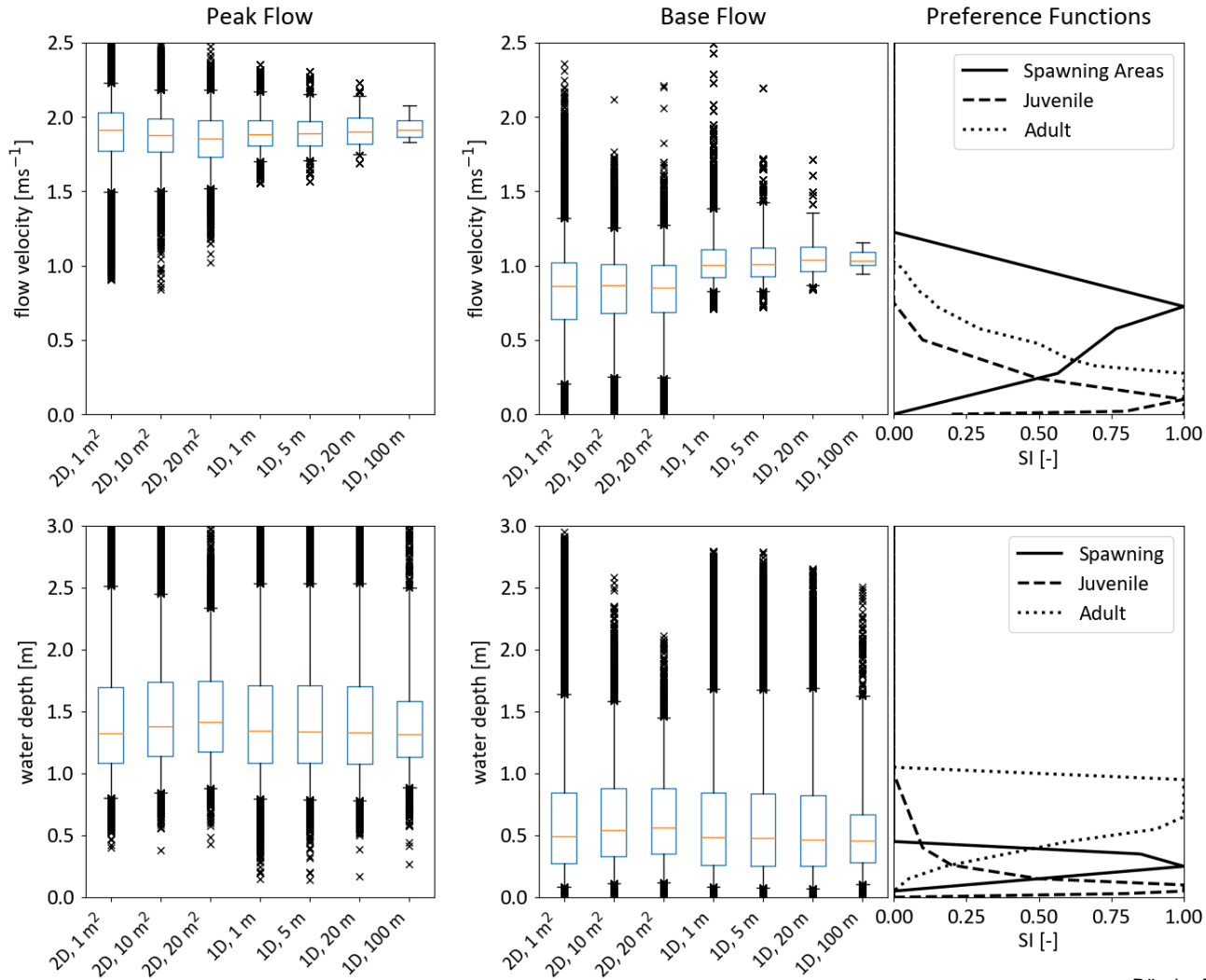
Hydrograph

- $Q_{\text{peak}}/Q_{\text{base}} = 5$, Recession = $0.75 \text{ m}^3 \text{ s}^{-1} \text{ min}^{-1}$

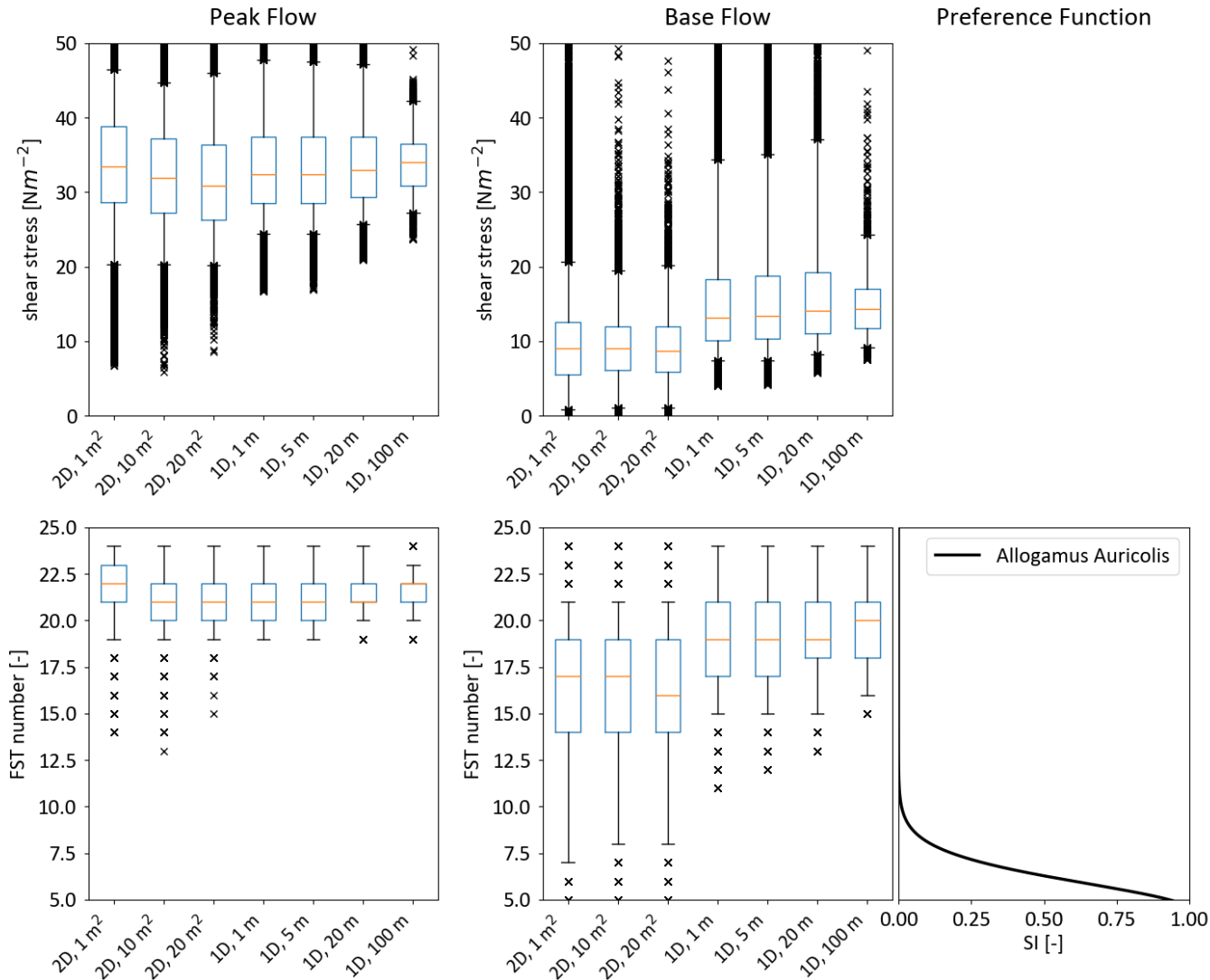


Distribution of water depth and flow velocity

Alternating Bar (30 m)



Distribution of shear stress and FST number

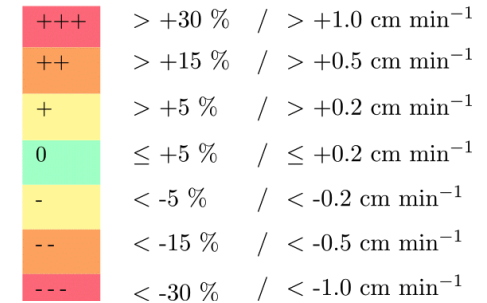


Evaluation for Morphology 1 (Altern. Bars)

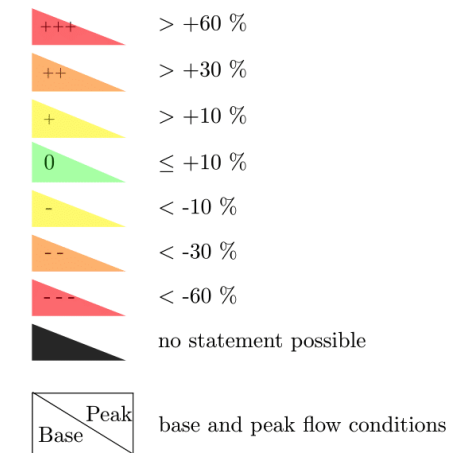
		Modelling Scenarios						
		2D			1D			
		1m ²	10m ²	20m ²	1m	5m	20m	100m
Morphology 1								
Fish Stranding	Dewatering Rate	0	0	0	0	0	0	-
	Wetted Area	0	0	0	+	+	+	0
	Fish Stranding (F2*)	0	0	0	+	+	+	-
Habitat Area	Spawning Areas of Fish (F3*)	0	0	-	---	---	---	---
	Habitat Suit. Of Fish (F6) Juv.	0	-	-	---	---	---	---
	Habitat Suit. Of Fish (F6) Ad.	0	-	++	---	---	---	---
	Habitat Suit. Of Macroz. (B5)	0	-	0	---	---	---	---
Computing Time		high	low	low	low	low	low	low

Legend

Deviation in wetted area and dewatering rate compared to 2D,1m²



Deviation in habitat area (F3*, F6, B5) compared to 2D,1m²



Computing time

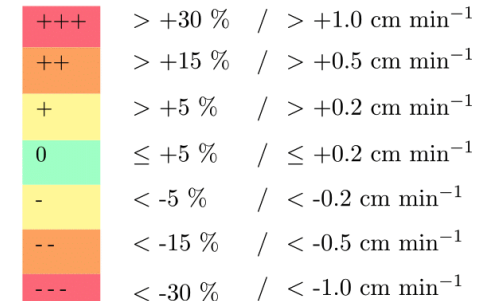
v.h. very high (>8h) high high (>2h) mod. moderate (>0.5h) low low (≤0.5h)

Evaluation for Morphology 2 (Wandering)

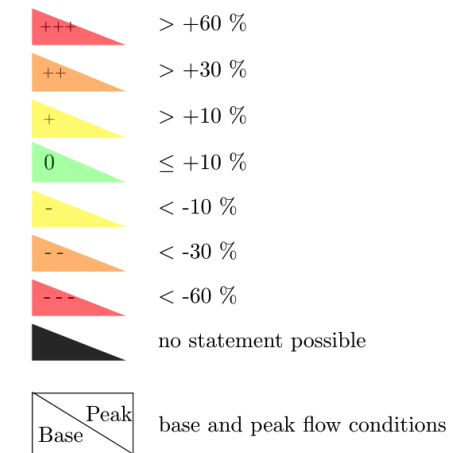
Morphology 2		Modelling Scenarios						
		2D			1D			
		1m ²	10m ²	20m ²	1m	5m	20m	100m
Fish Stranding	Dewatering Rate	0	0	0	0	0	+	++
	Wetted Area	0	0	0	+	+	++	++
	Fish Stranding (F2*)	0	0	0	+	+	++	++
Habitat Area	Spawning Areas of Fish (F3*)	0	+	+	---	---	---	---
	Habitat Suit. Of Fish (F6) Juv.	0	0	0	---	---	---	---
	Habitat Suit. Of Fish (F6) Ad.	0	0	0	---	---	---	---
	Habitat Suit. Of Macroz. (B5)	0	0	+	---	---	---	---
Computing Time		high	low	low	mod.	low	low	low

Legend

Deviation in wetted area and dewatering rate compared to 2D,1m²



Deviation in habitat area (F3*, F6, B5) compared to 2D,1m²



Computing time



Evaluation for Morphology 3 (Braiding)

		Modelling Scenarios						
		2D			1D			
		1m ²	10m ²	20m ²	1m	5m	20m	100m
Morphology 3								
Fish Stranding	Dewatering Rate	0	0	0	0	+	+	0
	Wetted Area	0	0	0	++	++	++	++
	Fish Stranding (F2*)	0	0	0	+	++	++	+
Habitat Area	Spawning Areas of Fish (F3*)	0 / 0	0 / 0	+ / 0	0 / ---	0 / ---	- / ---	--- / ---
	Habitat Suit. Of Fish (F6) Juv.	0 / 0	- / 0	0 / 0	--- / ---	--- / ---	--- / ---	--- / ---
	Habitat Suit. Of Fish (F6) Ad.	0 / 0	0 / 0	0 / +	--- / ---	--- / ---	--- / ---	--- / ---
	Habitat Suit. Of Macroz. (B5)	0 / 0	- / 0	- / 0	--- / ---	--- / ---	--- / ---	--- / ---
Computing Time		v. h.	low	low	mod.	low	low	low

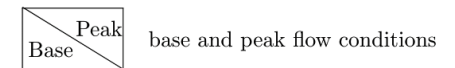
Legend

Deviation in wetted area and dewatering rate compared to 2D,1m²

+++	> +30 % / > +1.0 cm min ⁻¹
++	> +15 % / > +0.5 cm min ⁻¹
+	> +5 % / > +0.2 cm min ⁻¹
0	≤ +5 % / ≤ +0.2 cm min ⁻¹
-	< -5 % / < -0.2 cm min ⁻¹
--	< -15 % / < -0.5 cm min ⁻¹
---	< -30 % / < -1.0 cm min ⁻¹

Deviation in habitat area (F3*, F6, B5) compared to 2D,1m²

+++	> +60 %
++	> +30 %
+	> +10 %
0	≤ +10 %
-	< -10 %
--	< -30 %
---	< -60 %
■	no statement possible



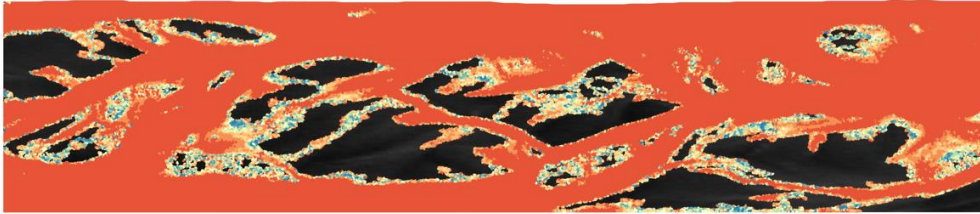
Computing time

v.h.	very high (>8h)	high	high (>2h)	mod.	moderate (>0.5h)	low	low (≤0.5h)
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Indicator Habitat Suitability of Fish (F6)

Habitateignungskarte Juvenile Bachforellen

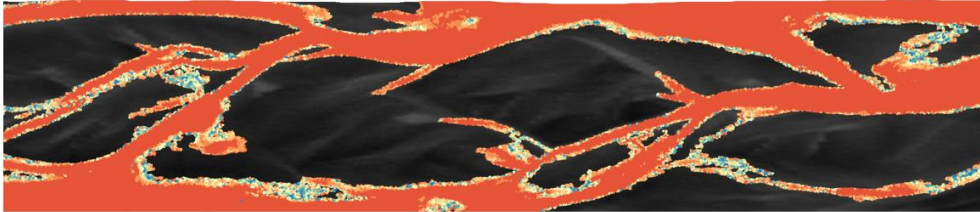
2D Braiding Morphology: Peak Flow ($Q = 75 \text{ m}^3\text{s}^{-1}$)



1D Braiding Morphology: Peak Flow ($Q = 75 \text{ m}^3\text{s}^{-1}$)



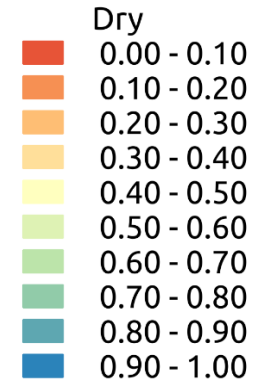
2D Braiding Morphology: Base Flow ($Q = 15 \text{ m}^3\text{s}^{-1}$)



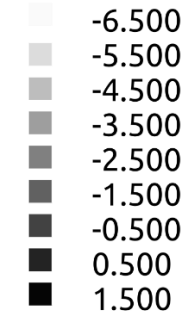
1D Braiding Morphology: Base Flow ($Q = 15 \text{ m}^3\text{s}^{-1}$)



Habitat Suitability Index [-]



DEM [m]

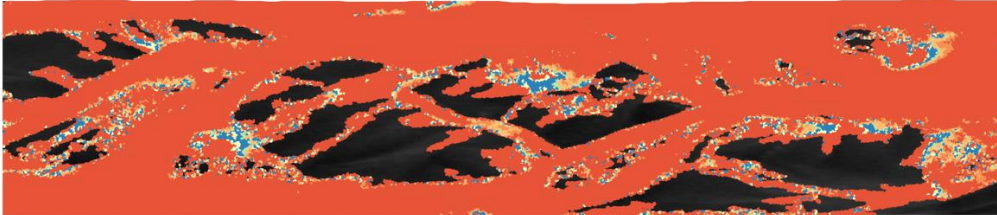


0 50 100 150 200 250 300 m



Indicator Habitat Suitability of Macrozoobenthos (B5)

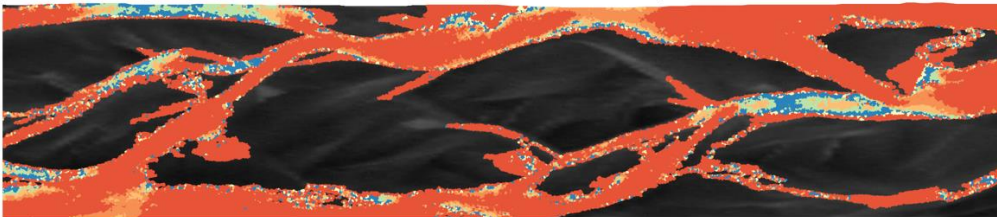
2D Braiding Morphology: Peak Flow ($Q = 75 \text{ m}^3\text{s}^{-1}$)



1D Braiding Morphology: Peak Flow ($Q = 75 \text{ m}^3\text{s}^{-1}$)



2D Braiding Morphology: Base Flow ($Q = 15 \text{ m}^3\text{s}^{-1}$)

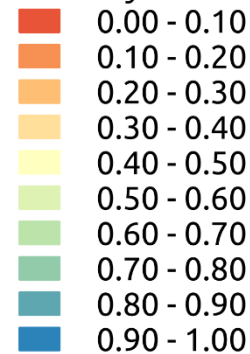


1D Braiding Morphology: Base Flow ($Q = 15 \text{ m}^3\text{s}^{-1}$)

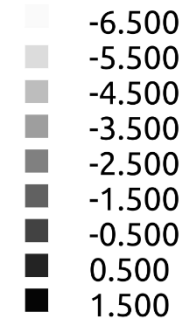


Habitat Suitability Index [-]

Dry



DEM [m]



0 50 100 150 200 250 300 m



Indicator Spawning Areas of Fish (F3*)

Habitat Maps Spawning Areas

2D Alternating Bar Morphology: Peak Flow ($Q = 75 \text{ m}^3\text{s}^{-1}$)



1D Alternating Bar Morphology: Peak Flow ($Q = 75 \text{ m}^3\text{s}^{-1}$)



2D Alternating Bar Morphology: Base Flow ($Q = 15 \text{ m}^3\text{s}^{-1}$)

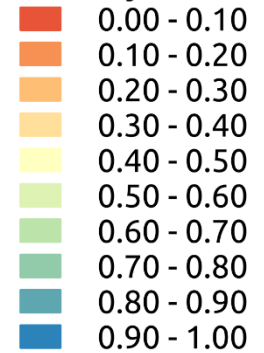


1D Alternating Bar Morphology: Base Flow ($Q = 15 \text{ m}^3\text{s}^{-1}$)

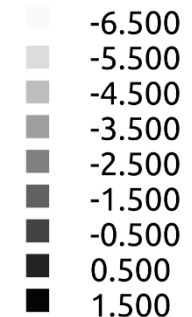


Habitat Suitability Index [-]

Dry



DEM [m]

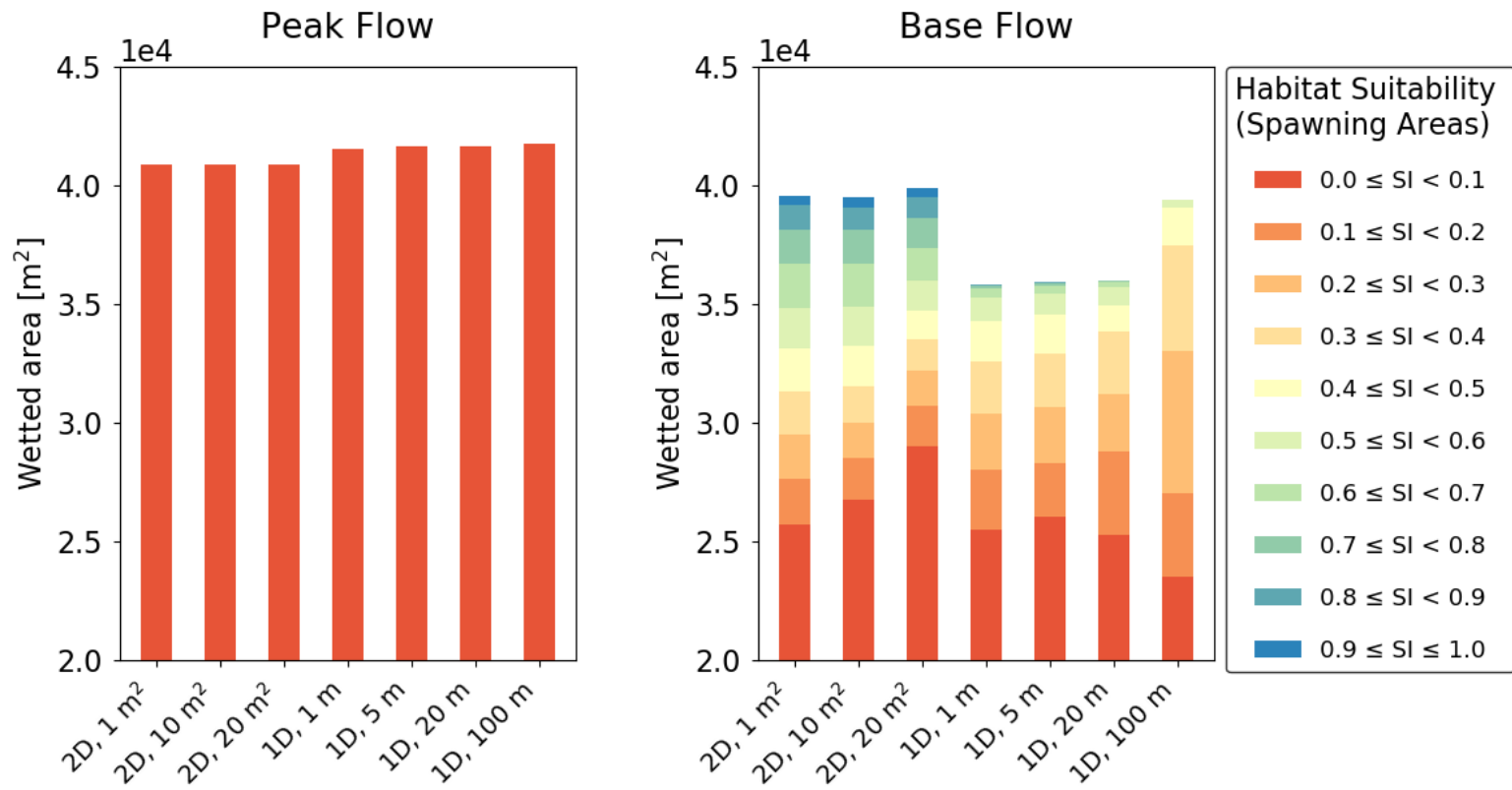


0 50 100 150 200 250 300 m



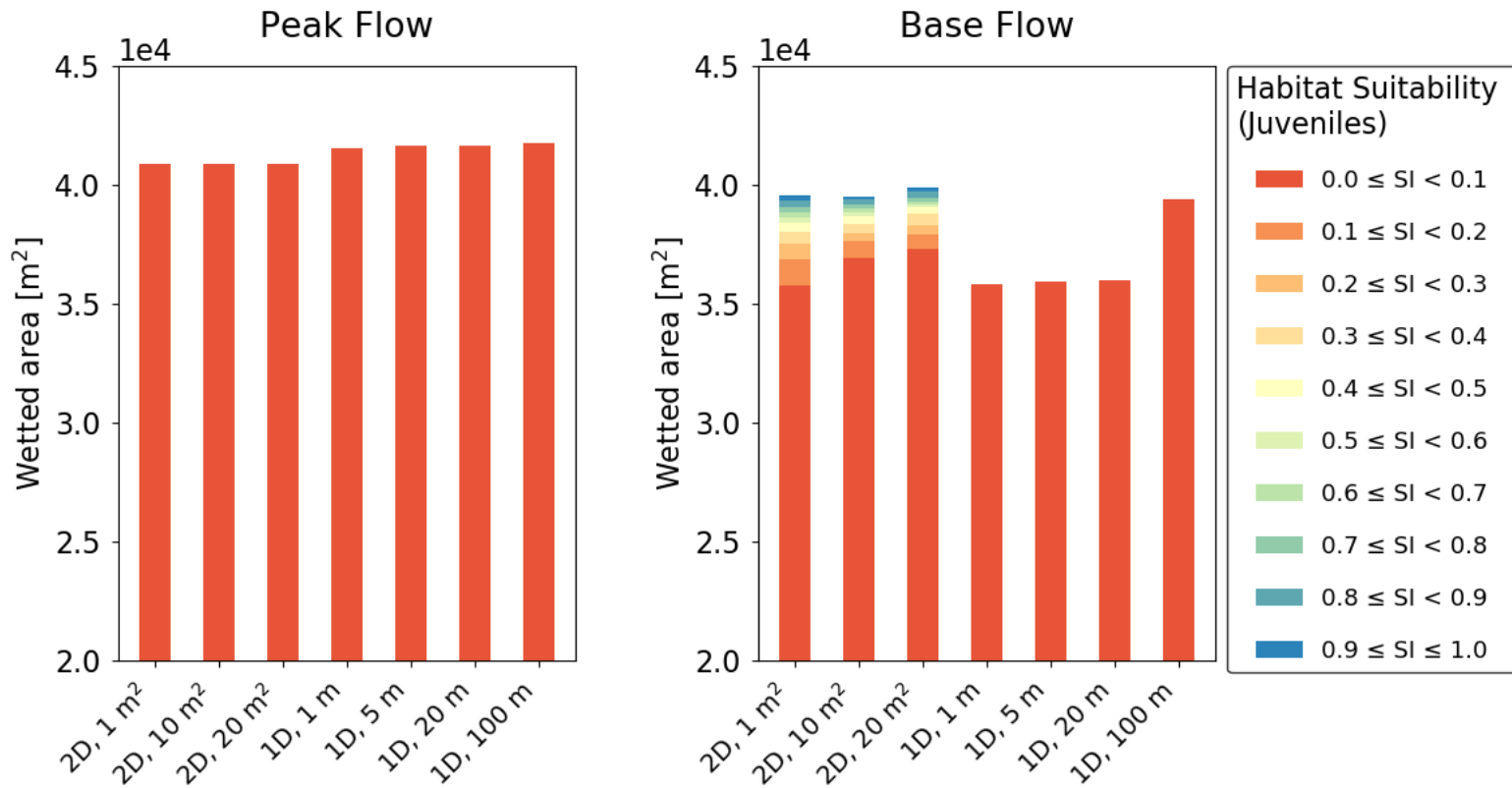
Indicator Spawning Areas of Fish (F3*)

Morphology 1 (Alternating Bars)



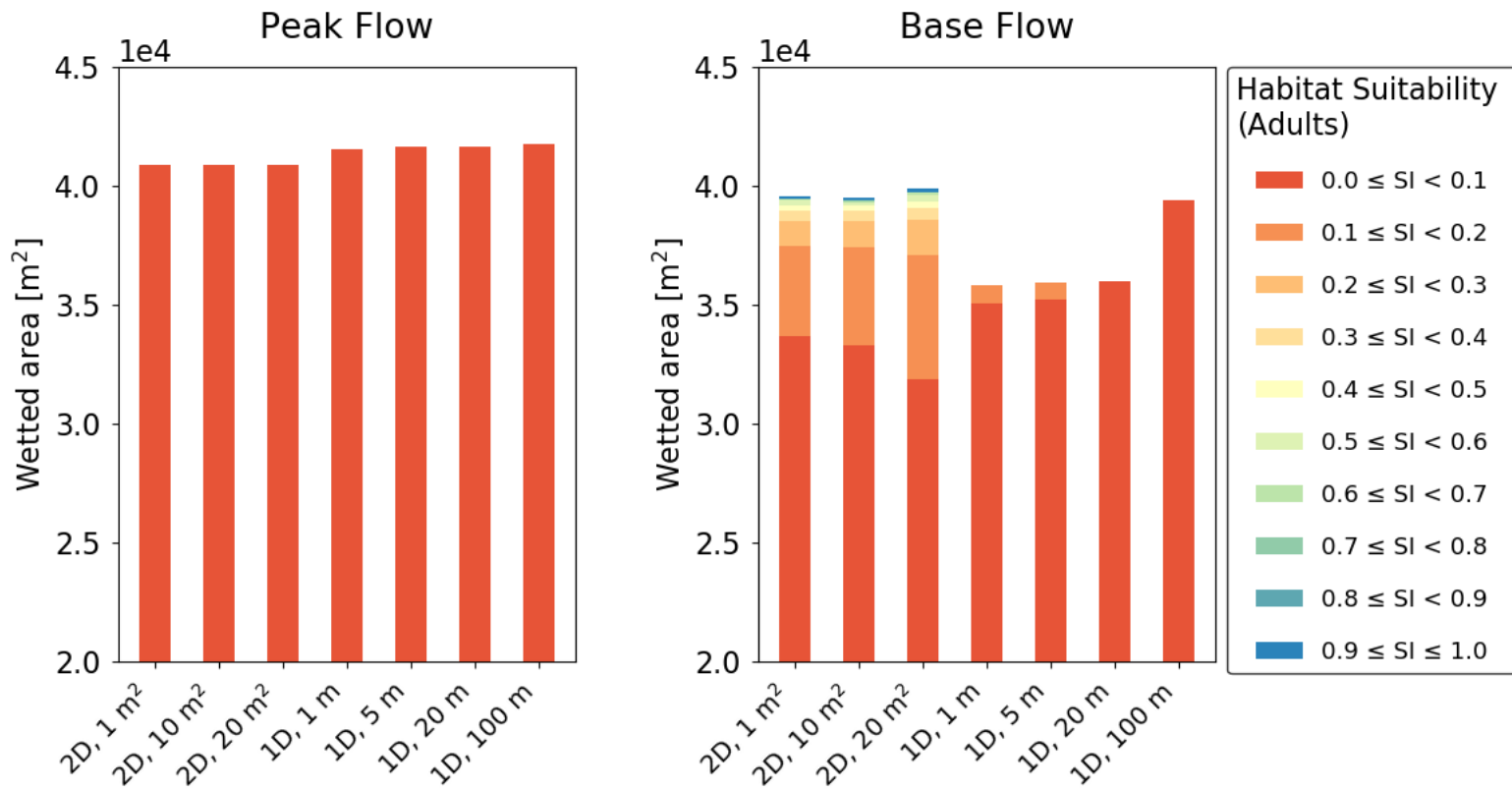
Indicator Spawning Areas of Fish (F3*)

Morphology 1 (Alternating Bars)



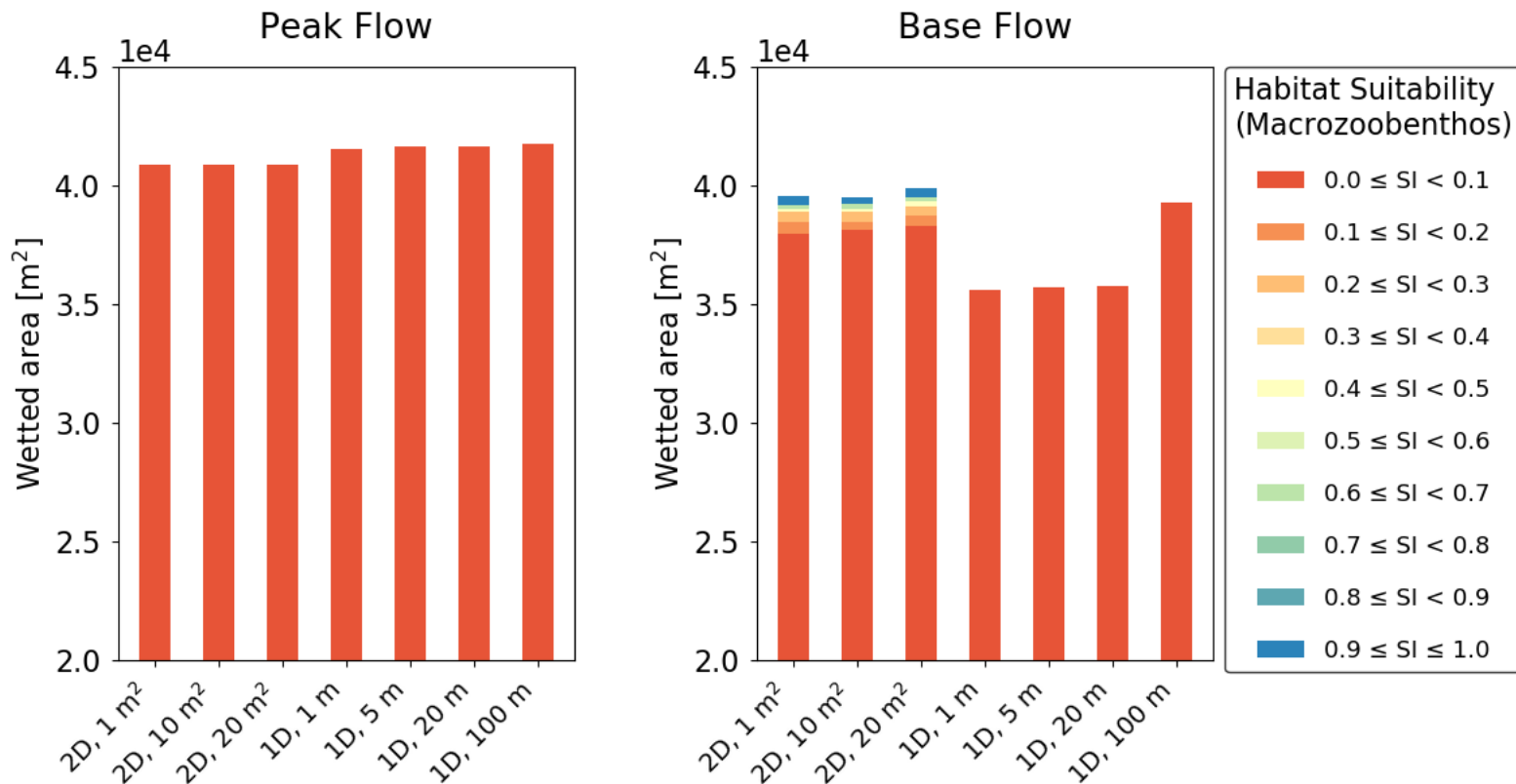
Indicator Spawning Areas of Fish (F3*)

Morphology 1 (Alternating Bars)



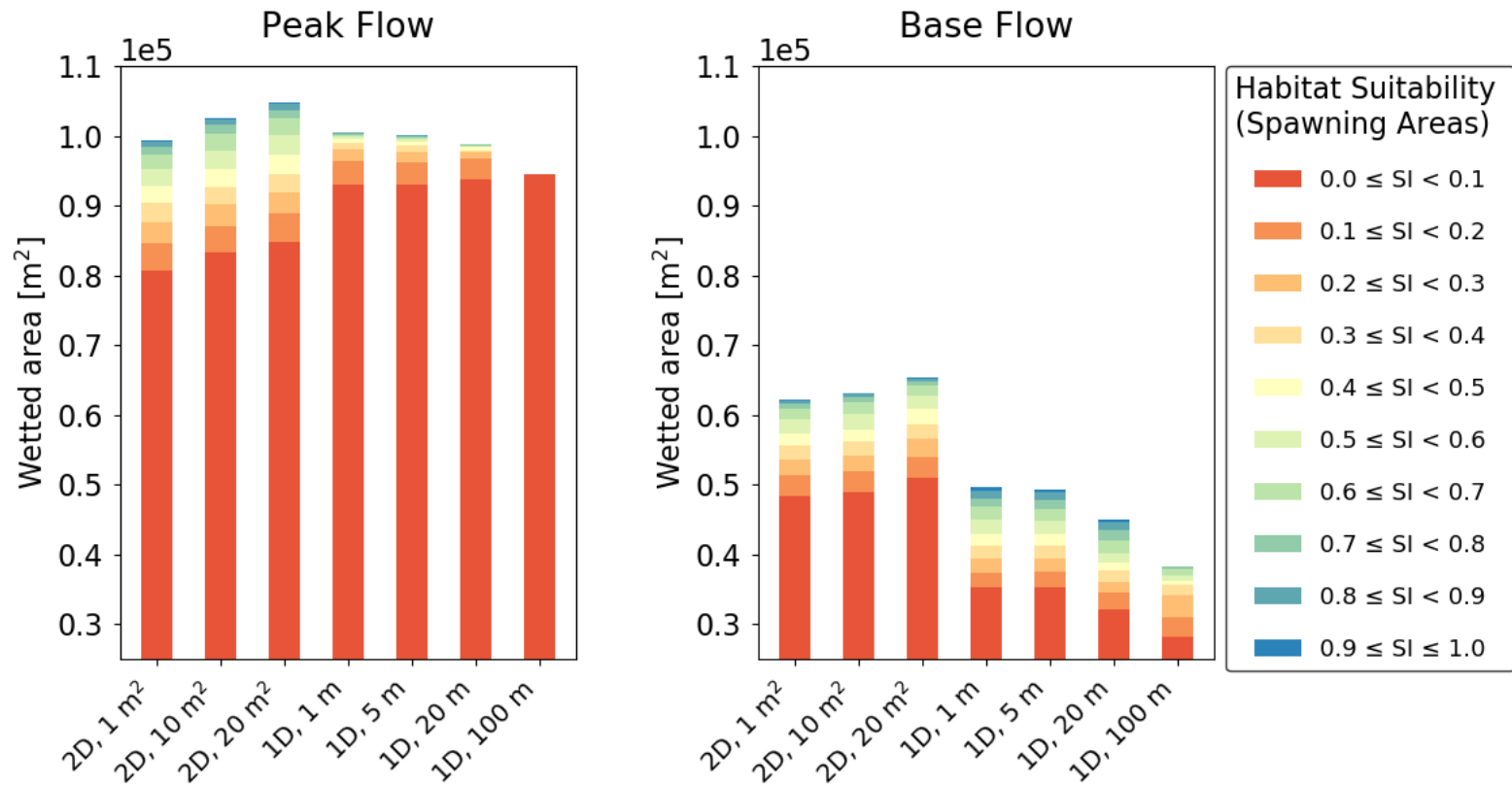
Indicator Spawning Areas of Fish (F3*)

Morphology 1 (Alternating Bars)



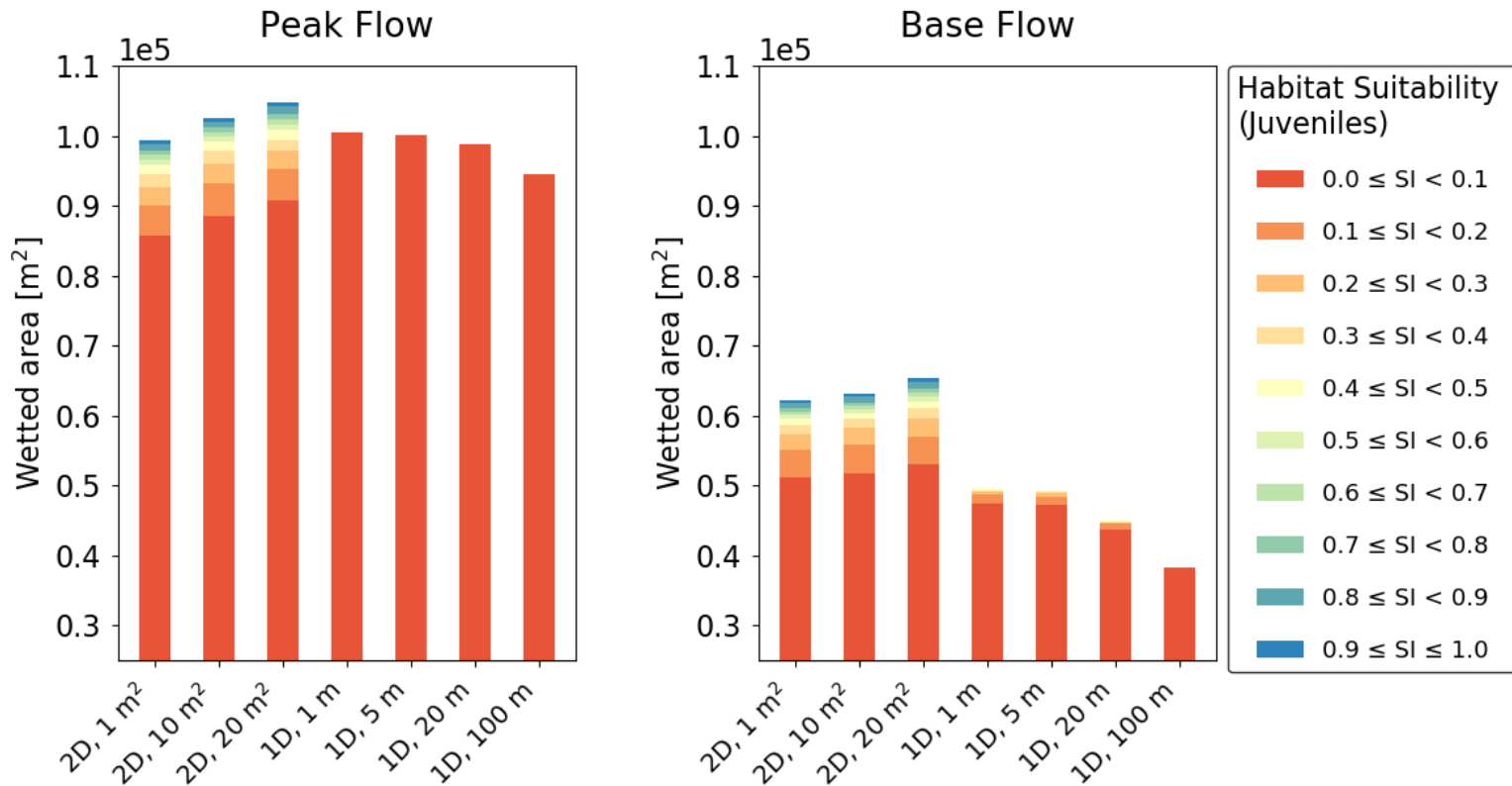
Indicator Spawning Areas of Fish (F3*)

Morphology 2 (Braiding)



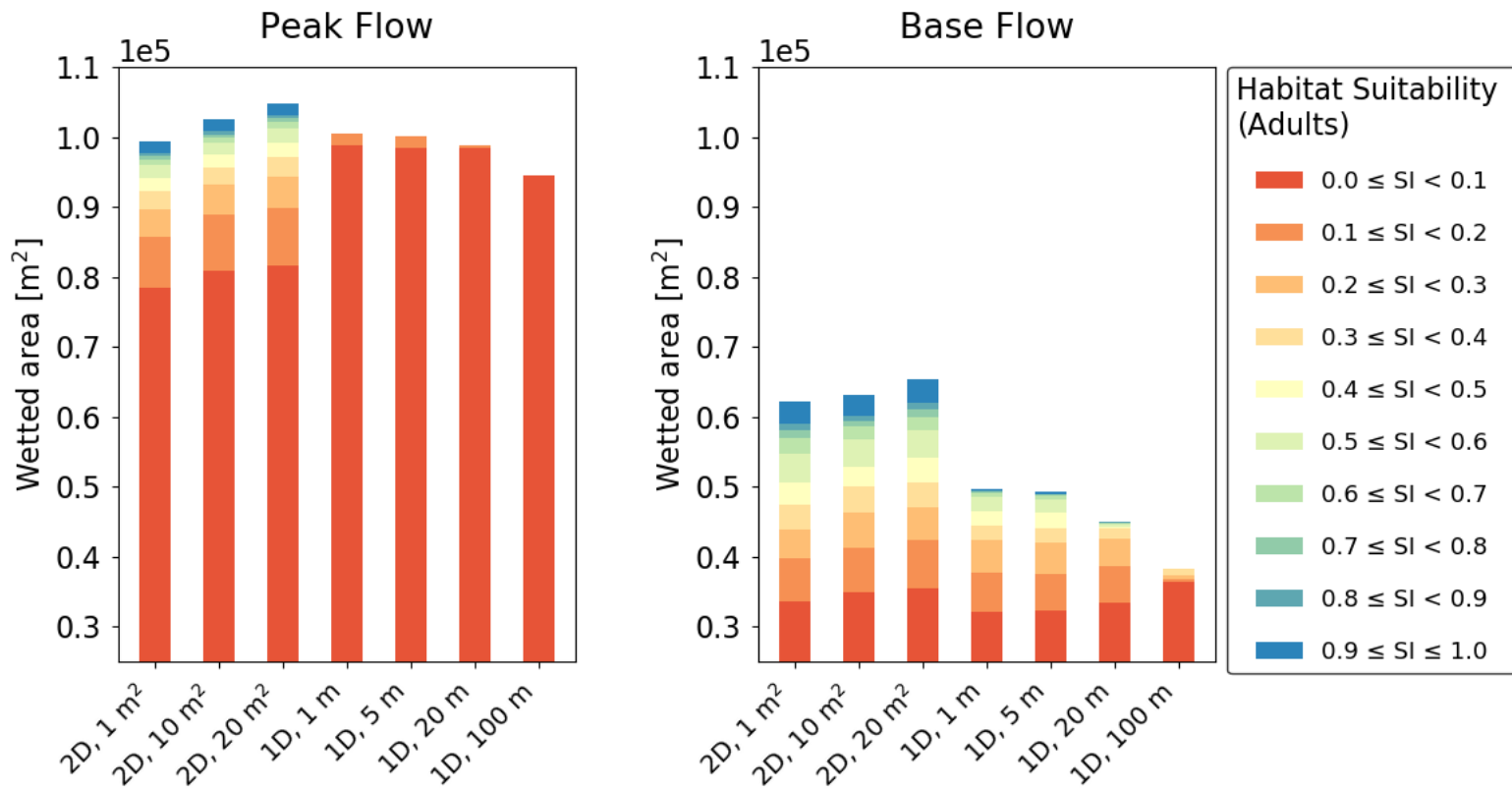
Indicator Spawning Areas of Fish (F3*)

Morphology 2 (Braiding)



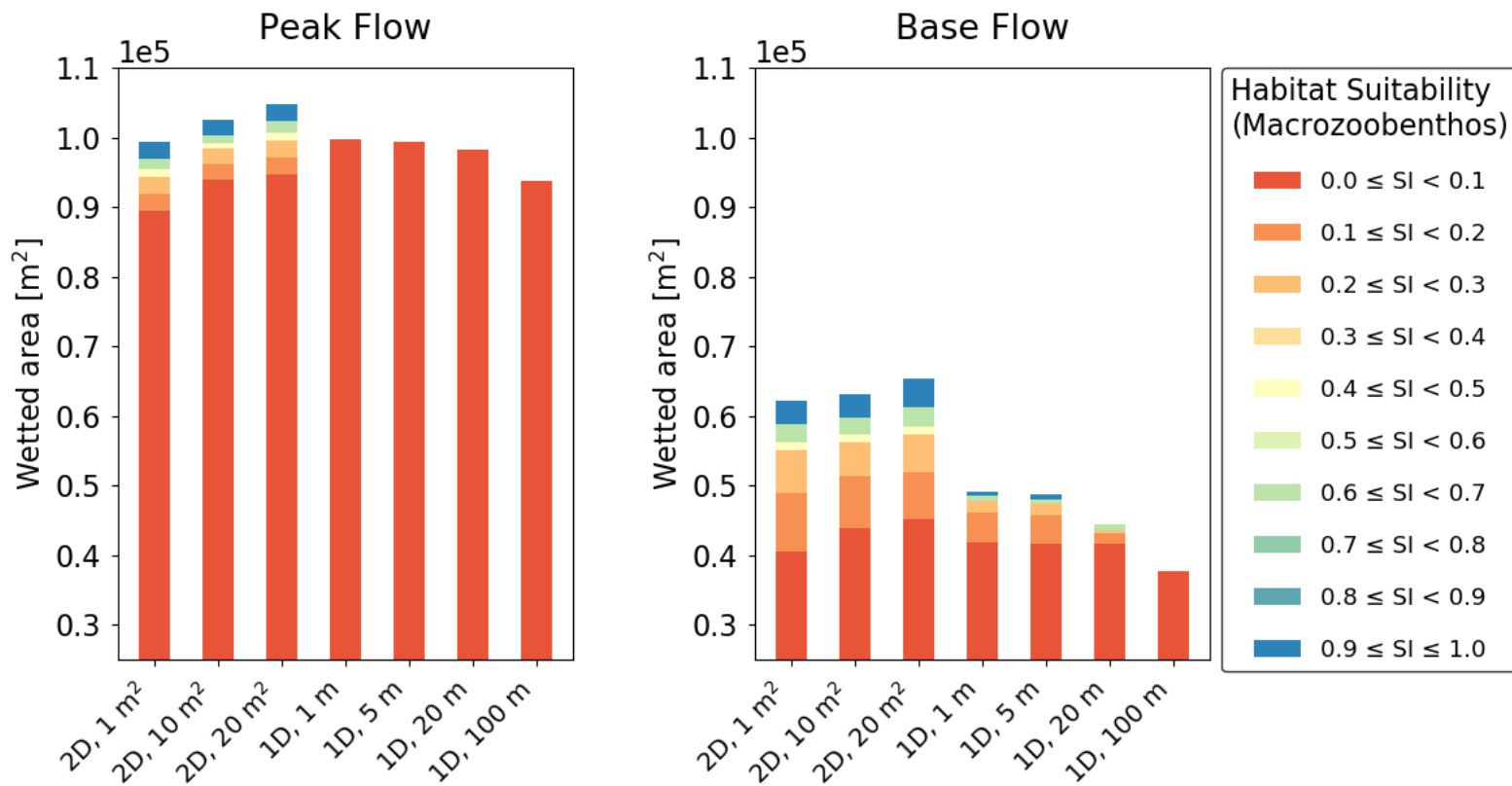
Indicator Spawning Areas of Fish (F3*)

Morphology 2 (Braiding)



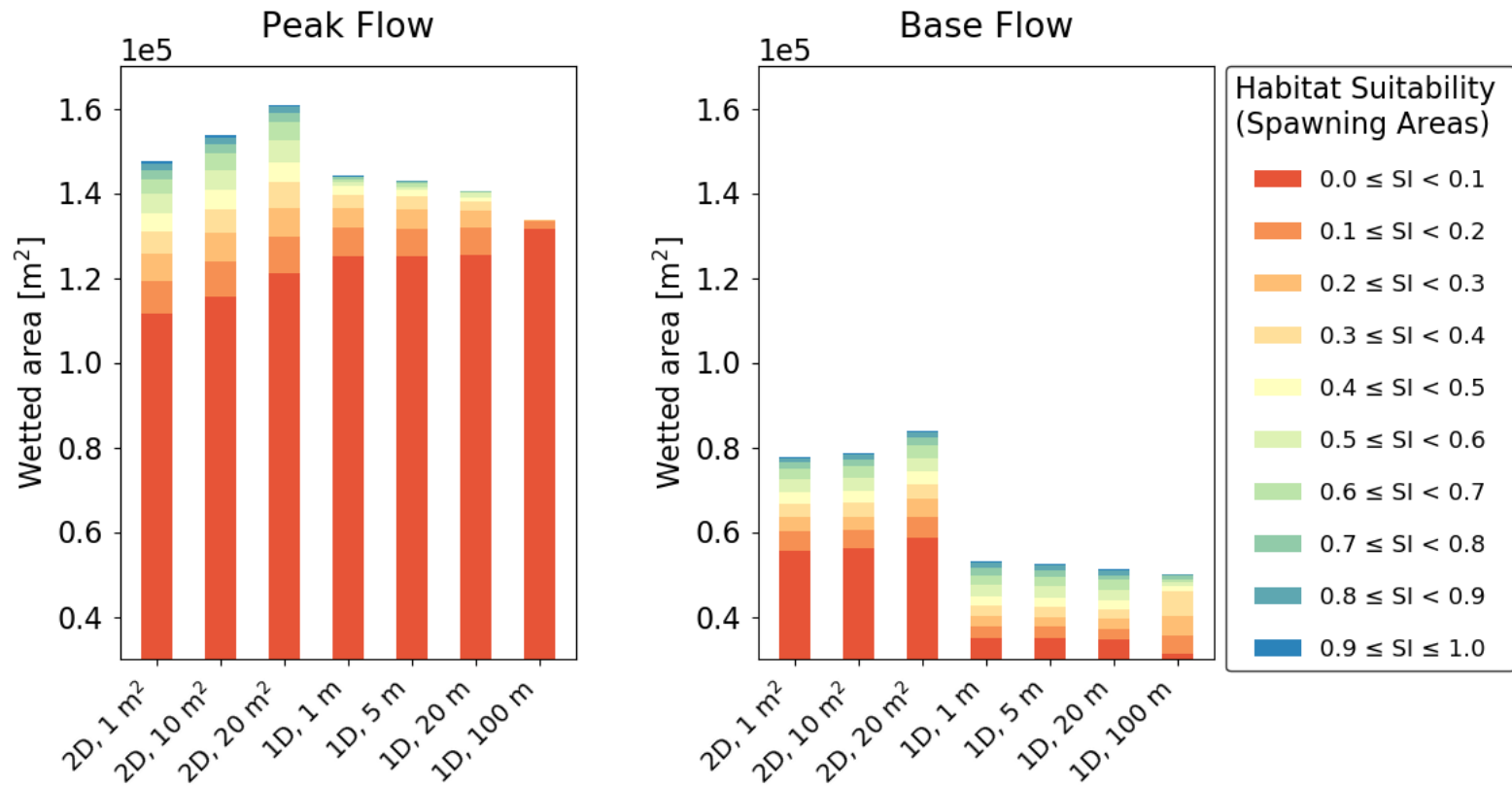
Indicator Spawning Areas of Fish (F3*)

Morphology 2 (Braiding)



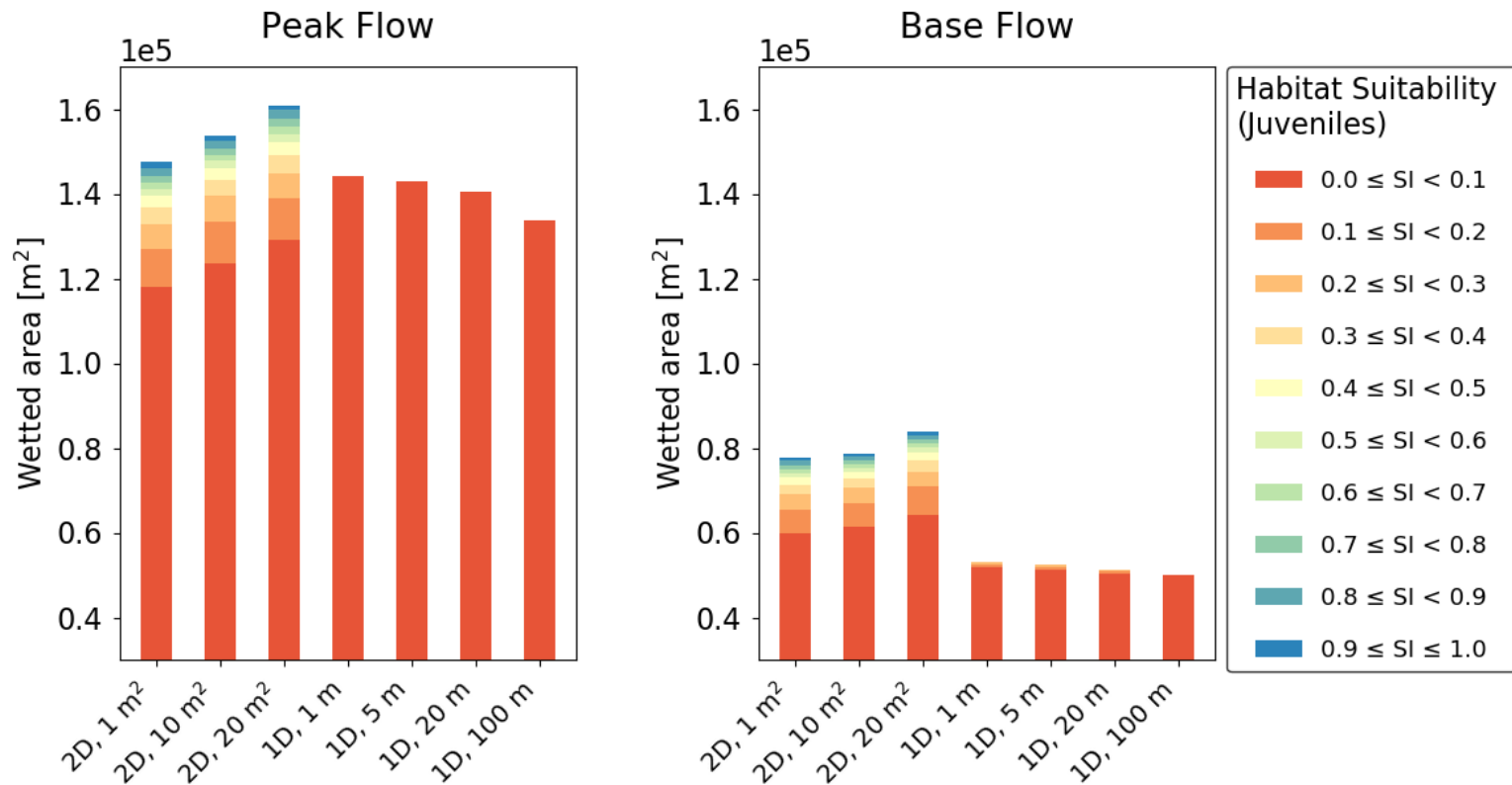
Indicator Spawning Areas of Fish (F3*)

Morphology 3 (Wandering)



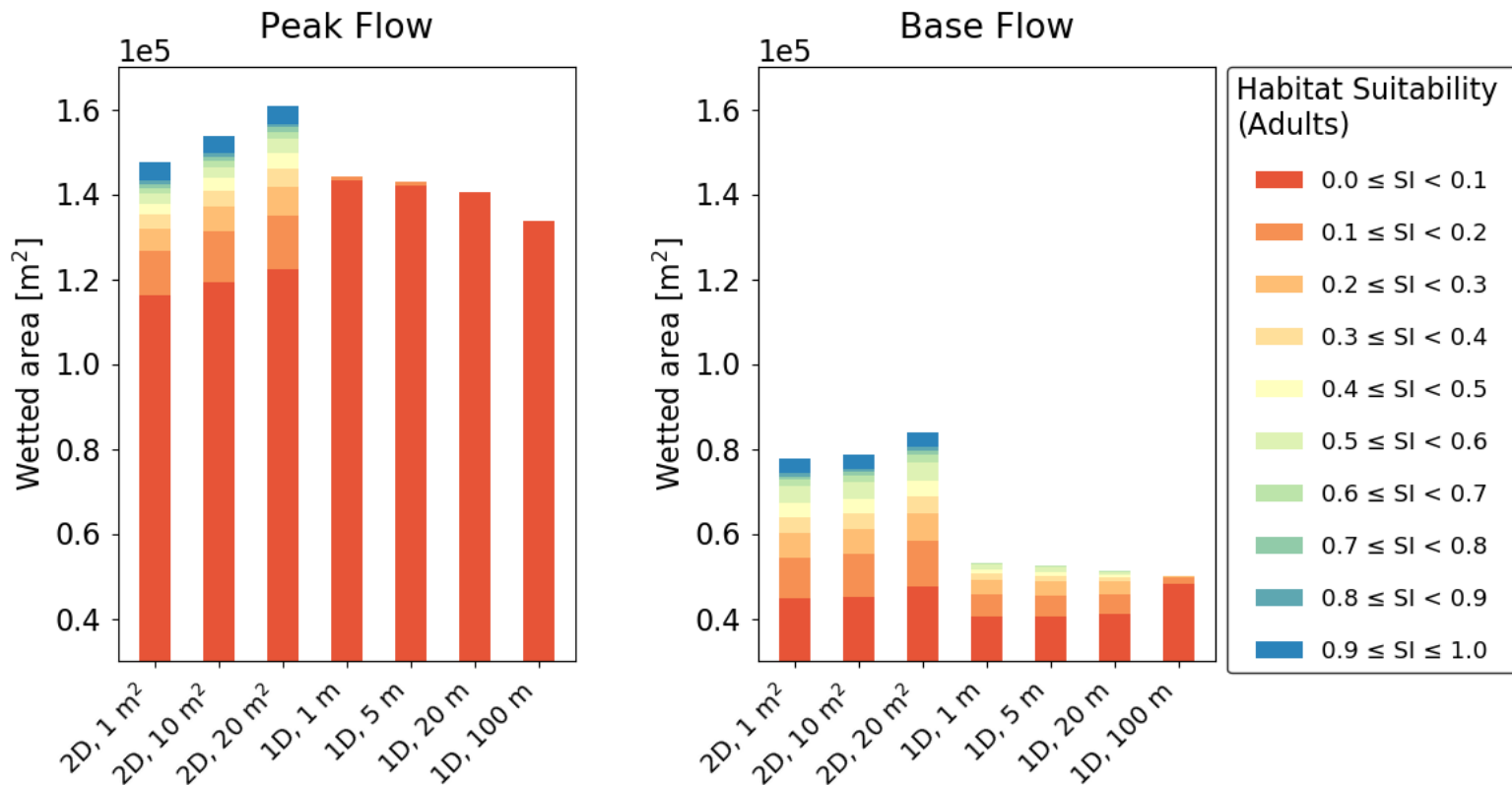
Indicator Spawning Areas of Fish (F3*)

Morphology 3 (Wandering)



Indicator Spawning Areas of Fish (F3*)

Morphology 3 (Wandering)



Indicator Spawning Areas of Fish (F3*)

Morphology 3 (Wandering)

