INDEX-BASED ANALYSIS OF CLIMATE CHANGE IMPACTS ON ECOLOGICALLY RELEVANT FLOW REGIME

Joanna O'Keeffe[1], Mikołaj Piniewski[1,2], Mateusz Szcześniak[1], Paweł Oglęcki[1], Tomasz Okruszko[1]

1. Warsaw University of Life Sciences
2. Potsdam Institute for Climate Impact Research

Objective

To assess climate change impacts on flow regime and environmental conditions for fish with the use of a dynamic watershed model and indexes in the Vistula and Odra basins.

Environmental flow

Environmental flow is the water regime provided within a river, wetland or coastal zone to maintain ecosystems and their benefits where there are competing water uses and where flows are regulated (IUCN 2003).

Climate change will have a strong impact on fish as it will affect the flow regime and cause loss of habitat, changes in community composition and behavioral habits, species losses (local extinctions) and reduced biodiversity (EPA 2008).

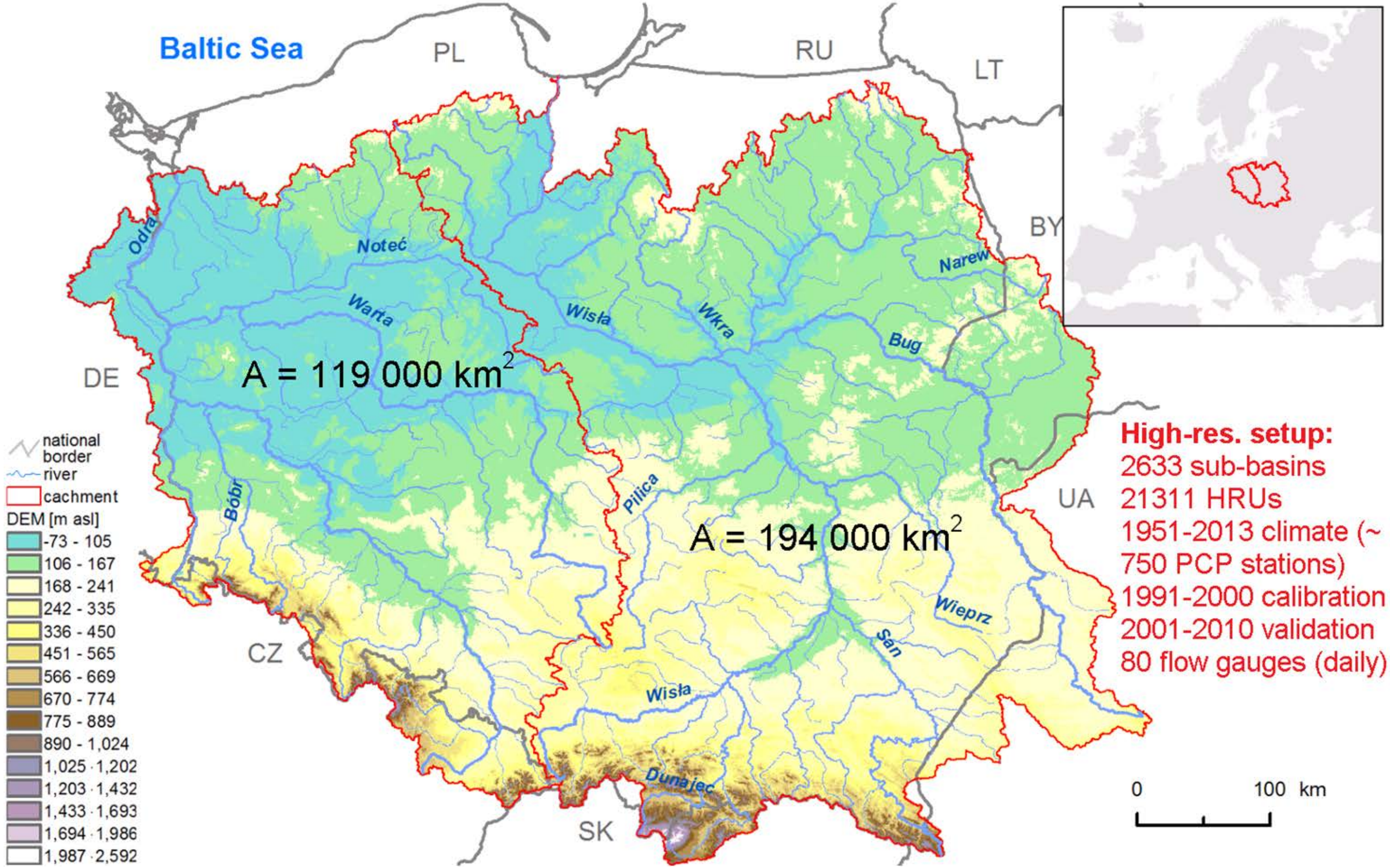
Modelling with SWAT

The input data on streamflow (average daily streamflow out of reach m^3/s) was obtained from the **SWAT** (Soil & Water Assessment Tool) model **calibrated and validated** for the Vistula and Odra basins (Piniewski et al. 2017).

SWAT model was selected because of its suitability to model large river basins and wide-spread application.

The model simulates "natural" flows.

Study area: a high-resolution SWAT model setup



High-res. setup:
2633 sub-basins
21311 HRUs
1951-2013 climate (~750 PCP stations)
1991-2000 calibration
2001-2010 validation
80 flow gauges (daily)

Piniewski *et al.*, HSJ, submitted

Scenarios

9 bias corrected EUROCORDEX GCM-run-RCM combinations composing the multi-model ensemble (MME) for the historical period and two future periods (with 3 years of warm-up period) :

- Historical period - 1971-2000
- Near future - 2021-2050
- Far future - 2071-2100

Under two RCPs: 4.5 and 8.5 (Representative Concentration Pathways **-** greenhouse gas concentration trajectories adopted by the IPCC)

Modelling results

The multi-model ensemble (MME) median change in mean annual:

Temperature | **Precipitation** | **Runoff**

RCP 4.5 | RCP 8.5 | RCP 4.5 | RCP 8.5 | RCP 4.5 | RCP 8.5

NF (2024 – 2050)

FF (2074 – 2100)

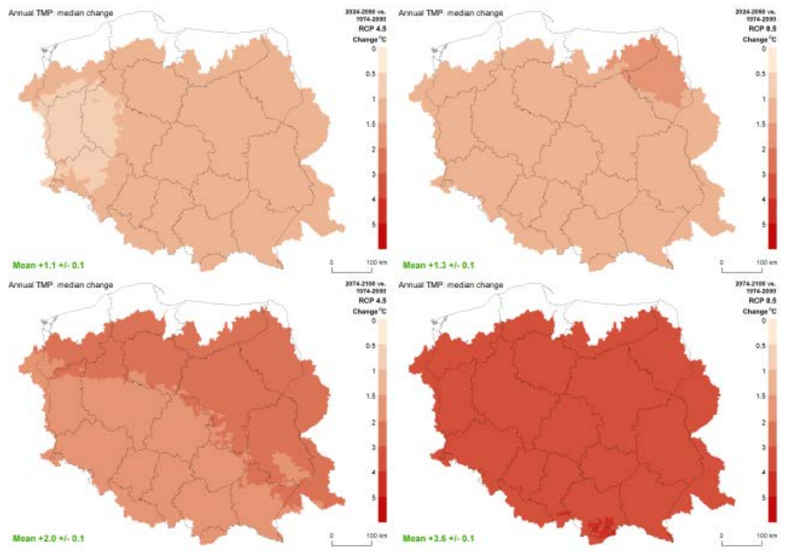


Figure 2: The MME median change in mean temperature for the near and far future under RCPs 4.5 and 8.5.

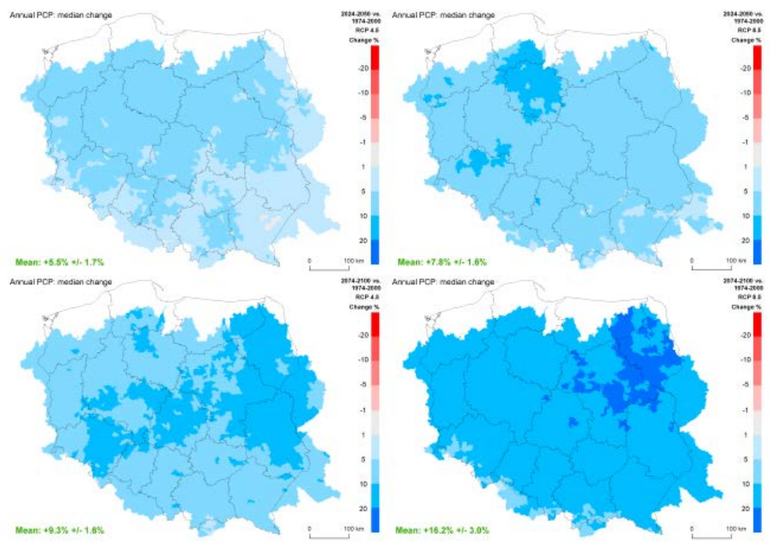


Figure 5: The MME median change in mean annual precipitation for the near and far future under RCPs 4.5 and 8.5.

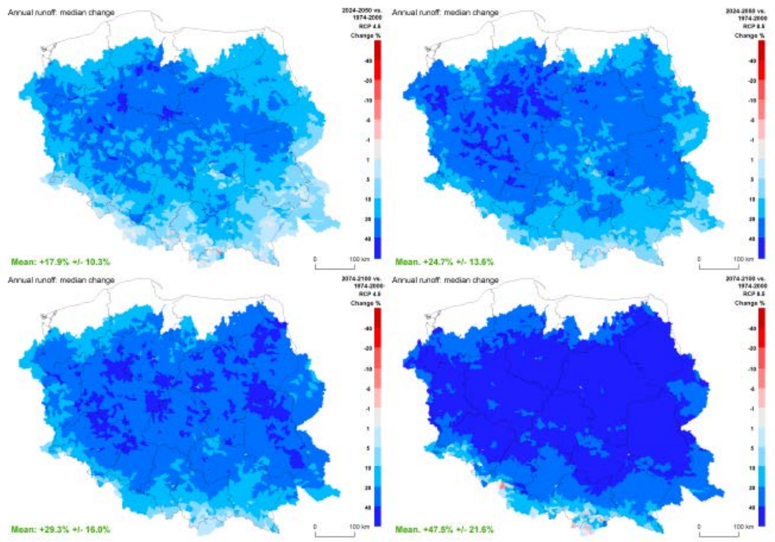


Figure 11: The MME median change in mean annual runoff for the near and far future under RCPs 4.5 and 8.5.

IHA parameters

Indicators of Hydrological Alteration (IHA) are a desk-top technique for defining environmental flow requirements introduced by Richter *et al*. (1996, 1997). This approach recognizes that all characteristics of the flow regime are ecologically relevant.

The IHA method contains a subset of **33 parameters** of flow regime providing information about hydrological alteration in five classifications: magnitude, timing, frequency, duration and rate of change.

On the basis of literature review we assessed which IHA parameters are ecologically relevant and significant for fish in Polish conditions.

Alignment of fish into 3 groups

According to literature managing flows for multiple species is difficult and it is advised to develop a fish community typology that can represent the hydrological needs of those communities (Cowx et al. 2004).

Fish species can be grouped according to preference of: water temperature, river substrate, flow velocity, vegetation, river depth, migration distance etc.

Fish group	Characteristic	Species
1	Sedentary species that migrate in special situations, usually to the nearest suitable habitats. They don't carry out long spawning migration.	bleak (*Alburnus alburnus*), gudgeon *(Gobio gobio)*, **pike** (Esox luscious), perch (*Perca fluviatilis)*, zander (*Sander lucioperca),* wels catfish (*Silurus glanis*), asp (*Aspius aspius*), Eurasian ruffe (*Gymnocephalus cernuus*), grayling (*Thymallus thymallus*).
2	Species migrating up to approx. 50 km with higher spawning requirements, more adjusted to migration.	roach (*Rutilus rutilus*), common bream (*Abramis bram),* white bream *(Blicca bjoerkna)*, brown trout (*Salmo trutta* m. *fario),* **chub** (*Squalius cephalus*), ide (or orfe) (*Leuciscus idus*).
3	Migratory species travelling long distance mostly to reach the spawning grounds (and possibly returning from them).	european eel (*Anguilla anguilla*), **sea trout** (*Salmo trutta* m. *trutta),* Atlantic salmon (*Salmo salar*), vimba bream (*Vimba vimba*).

Flow requirements of the 3 groups of fish

Literature review on environmental flow requirements (in relation to IHA).

Fish group 1 PIKE

Spring spawner, steady streamflow above bankfull for 20 days – uses flooded natural grassland for spawning (Piniewski et al. 2011), low flows negatively influence the spawning success (Boët et al. 1999), prefers flows with little variability and steady fluctuation between high and low flow (Cowx et al. 2004).

Fish group 2 CHUB

Spawning season occurs from May to June (Pusłowska – Tyszewska et al. 2015), peak flows are important for habitat maintenance and probably as spawning cues (Bunn and Arthington 2002, Nunn et al. 2003), Inhabits rivers with very high flows and with relatively high low flows (Cowx et al. 2004).

Fish group 3 SEA TROUT

Autumn spawner (Brylińska 1986), sensitive to changes in low flows, influenced by the rate of flow, the rate of change of flow, duration of high and low flow events and their seasonal timing (Cowx et al.2004).

12 indicators chosen in total.

Each of the 3 groups of fish can be assessed with a set of 7 indicators.

Fish group	IHA parameter
1	March mean flows
1,2	April mean flows
1,2	May mean flows
2	June mean flows
3	October mean flow
3	November mean flows
2, 3	7 day minimum flow
1	30 day maximum flow,
2, 3	Mean duration of low pulses
1, 3	Mean duration of high pulses
1, 2, 3	Number of high pulses
1, 2, 3	Number of low pulses

Setting thresholds of changes with no impact (% change between the baseline and future scenario)

IHA Parameter	1 group of fish	2 group of fish	3 group of fish
March mean flows	-30% do + 30%	-	-
April mean flows	-30% do + 30%	-30% do + 30%	-
May mean flows	-30% do + 30%	-30% do + 30%	
June mean flows	-	-30% do + 30%	-
October mean flow	-	-	-30% do + 30%
November mean flows	-	-	-30% do + 30%
7 day minimum flow	-	-20% do +20%	-20% do +50%
30 day maximum flow,	-50% do +20%	-	-
Mean duration of low pulses	-	-50% do +20%	-50% do +20%
Mean duration of high pulses	-50% do +20%	-	-20% do +50%
Number of high pulses	-50% do +20%	-30% do + 30%	-30% do + 30%
Number of low pulses	-30% do + 30%	-30% do + 30%	-30% do + 30%

Setting thresholds and classes

Data: The multi-model ensemble (MME) **median change in mean annual streamflow**.

Presentation: **reach** level (2633 reaches).

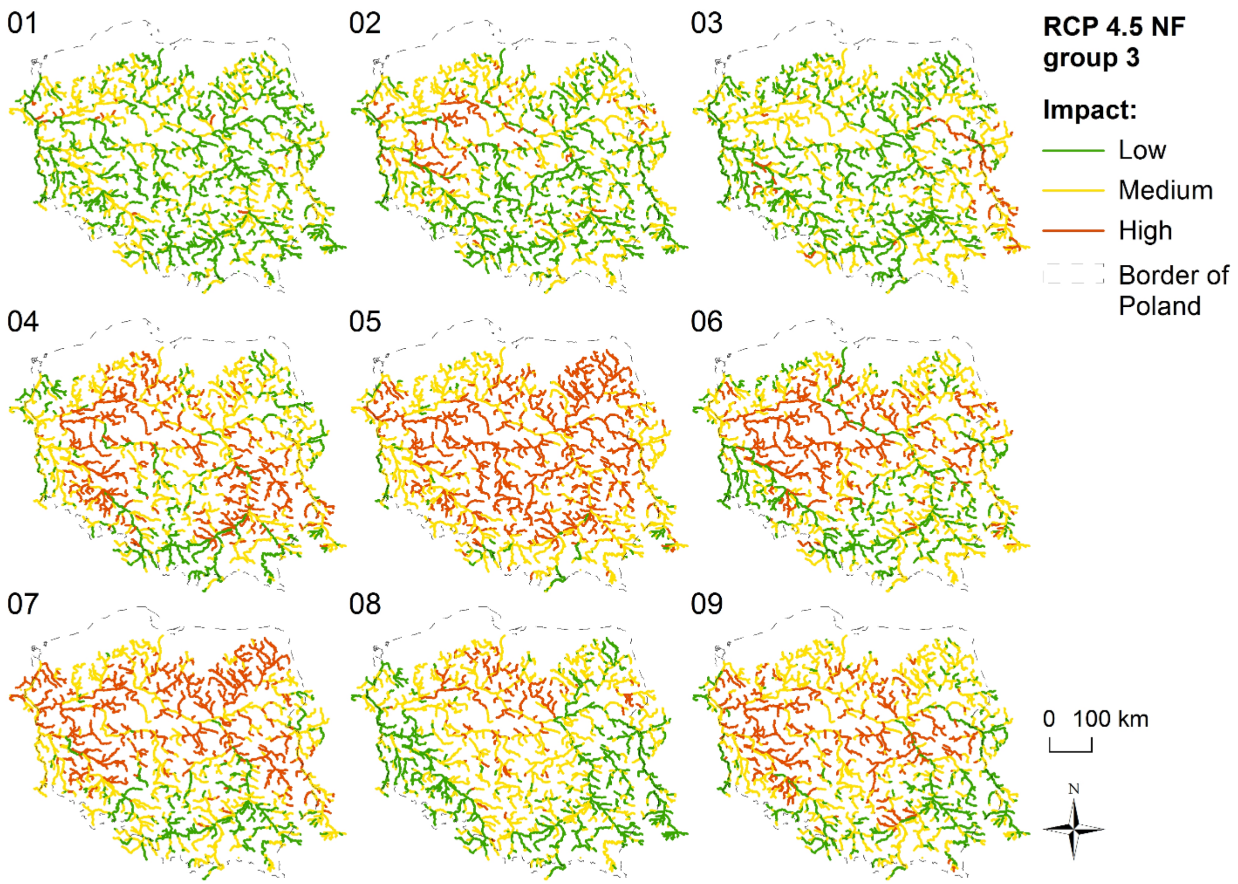
Step 1: If the difference from the baseline scenario exceeds **the %** threshold than the difference is considered to be significant.

Step 2: An indicator was assigned the **value of 1** if the threshold criterion was exceeded (impact) or **0** if this threshold was not surpassed (no impact).

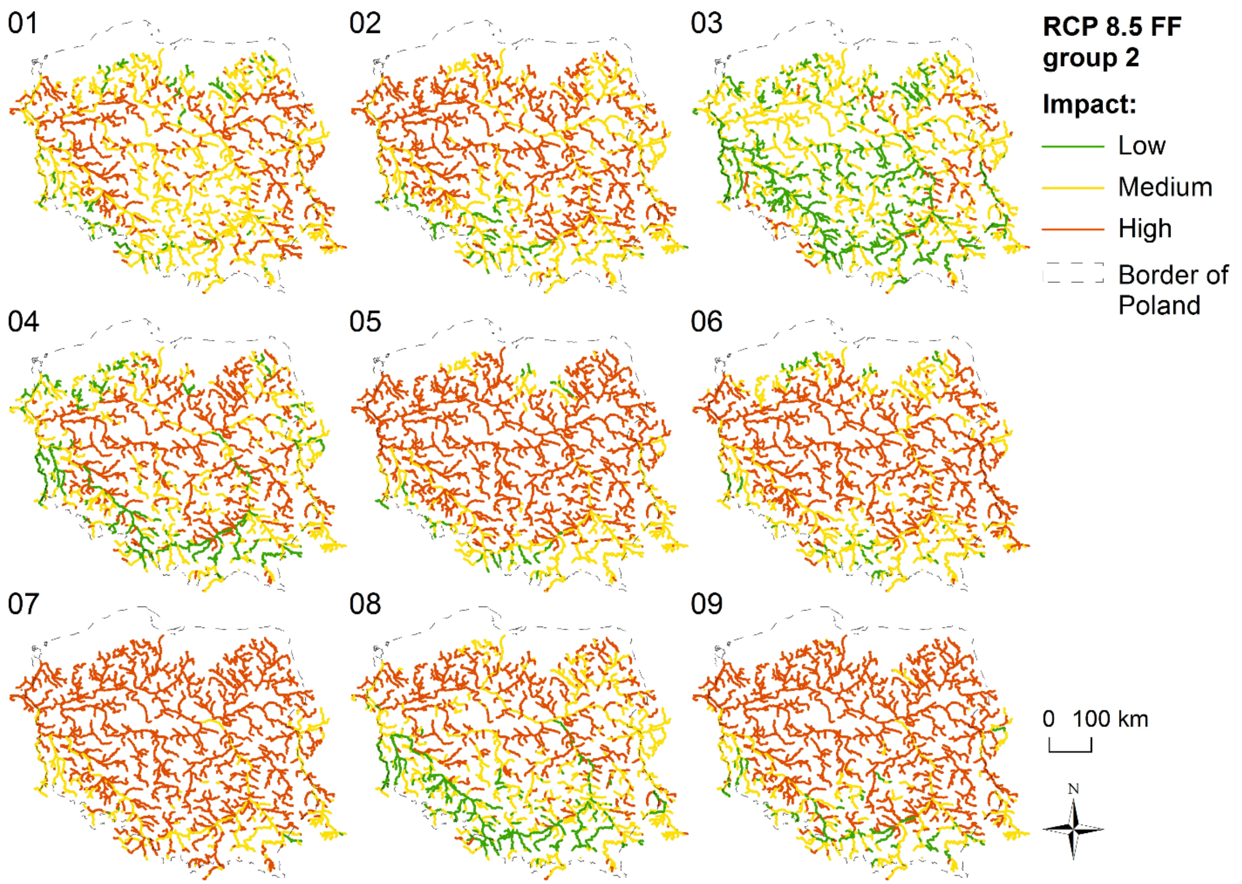
Step 3: Each group of fish is influenced by 7 indicators, so each reach can obtain a **grade from 0 to 7**.

Colour code	Score	Impact
Classification of results based on a single climate model		
green	0-1	Low
orange	2-4	Medium
red	5-7	High

Models disagreement:



Models agreement:

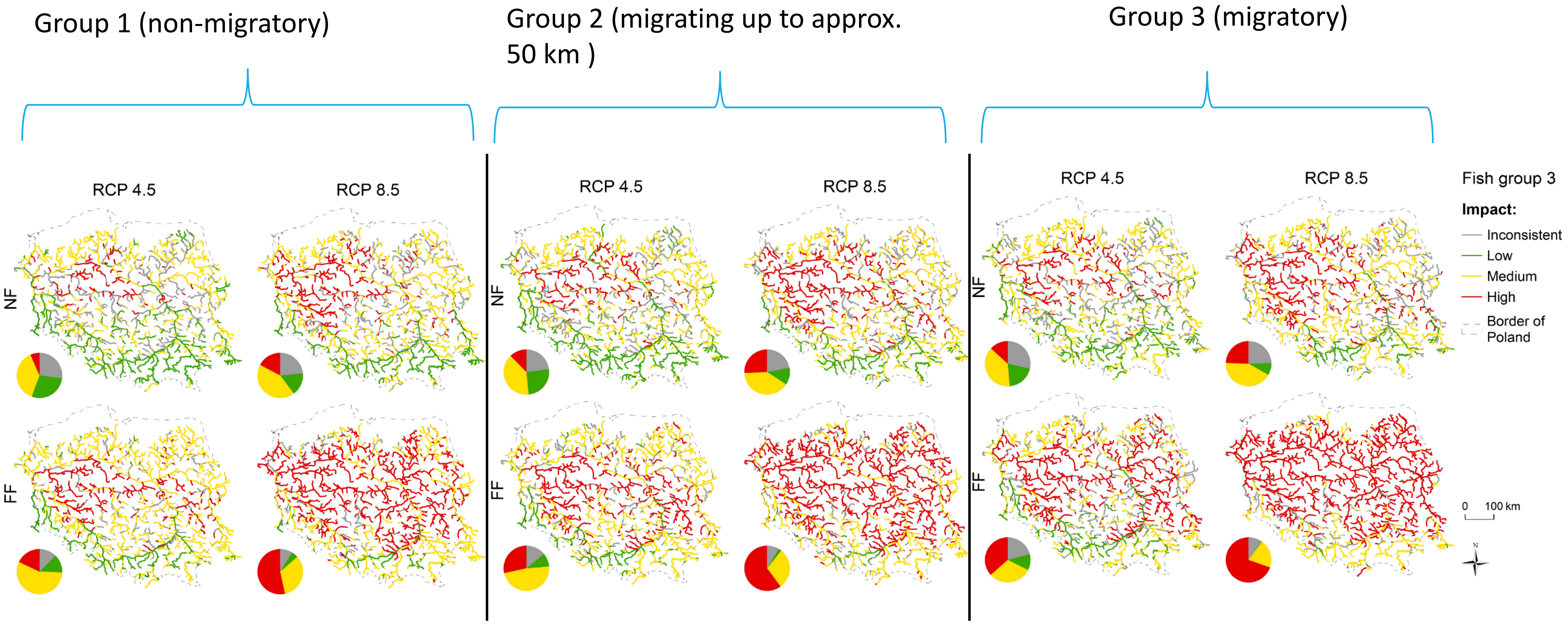


Model uncertainty assessment

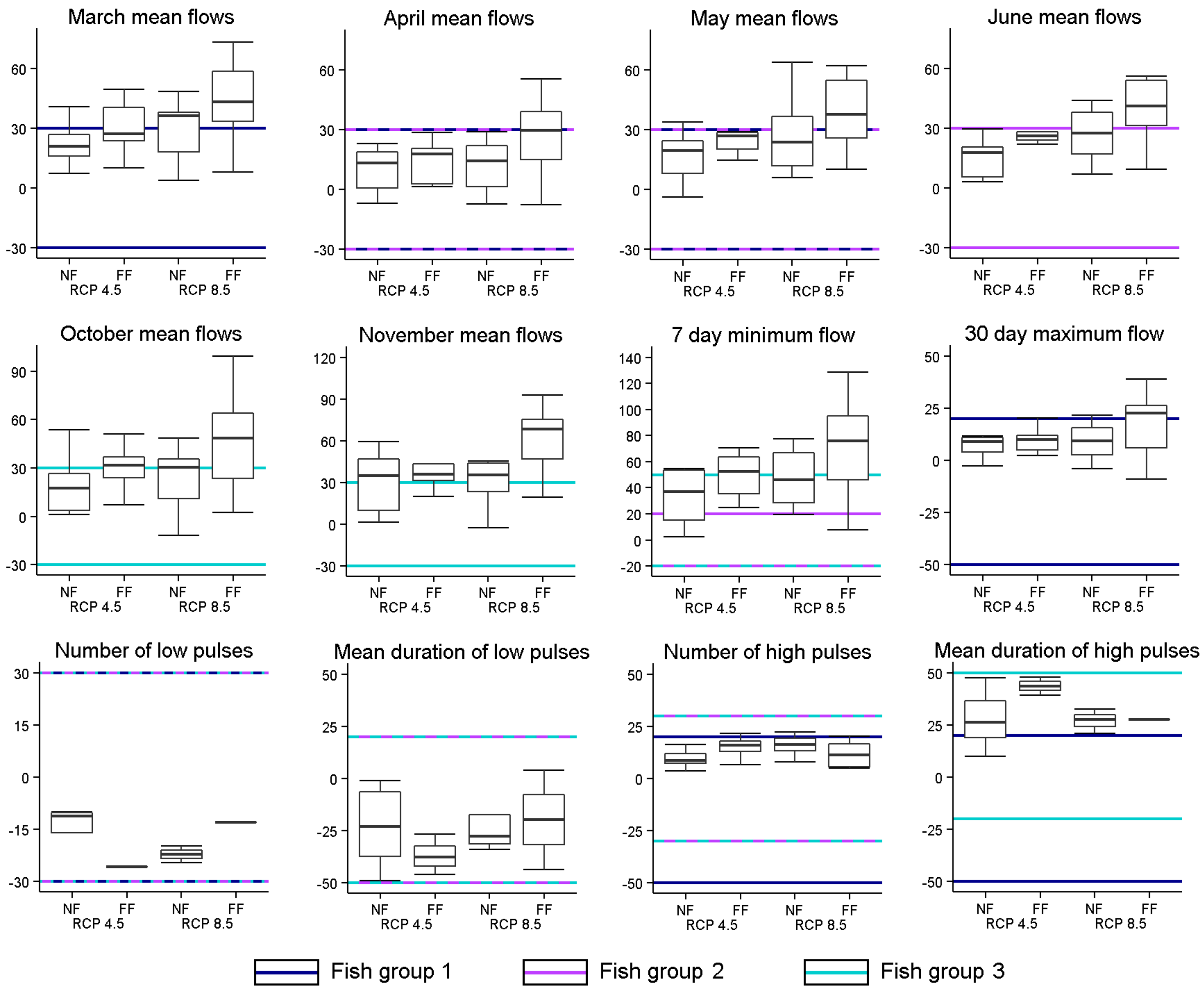
Color	Assessment	Impact
Classification for results based on the climate model (CM) ensemble		
grey	None of the impact classes assigned for at least 5 CMs	inconsistent between 9 models
green	Low impact class assigned for at least 5 CMs	Low
orange	Medium impact class assigned for at least 5 CMs	Medium
red	High impact class assigned for at least 5 CMs	High

If at least 5 out of 9 models agree on the impact class then a given reach was assigned with that impact class (low, medium, high).

Results: Projected impact of climate change on fish



Impact of changes of IHA parameters on the results



Conclusions

- The results show similar spatial patterns as the climate model results (precipitation, runoff, temperature) with respect to the direction of changes (larger impact in the lowlands).
- Hydroclimatic projections show an increase in precipitation which influences the increase in streamflow.
- Fish species from group 1 are the least impacted and fish from group 3 are under highest impact.
- This suggests that climate change will have a impact on in-stream ecosystems in the Vistula and Odra basins and that habitats for fish may be degraded or lost.
- Changes in streamflow might favor invasive species or species with good adaptation capabilities.
- The methodology does not include dams and other man-made obstacles influencing the streamflow and focuses on natural streamflow.

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Thank you for your attention!