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D 5.8: A scenario study for assessing responses of water quality in catchment-reservoir system to the anticipated climate change

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PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

CONTENTS

1. Introduction

Water quality in water bodies reflects numerous processes that occur in the catchment and within the water body itself. Catchment geomorphology and climate conditions, land cover, hydrogeological pathways of water from precipitation over the land surface or through the soils and ground water aquifers to streams, transport and/or retention of particles and solutes within the river network, anthropogenic sources of pollution etc. create a complex of factors that form water composition in the stream runoff from catchment (Webb, Walling 1992). In-lake processes can further significantly modify water quality for example by sedimentation, biochemical and/or photochemical decomposition reactions, biomass production of phytoplankton and littoral aquatic plants, and cycling of substances between the water column and sediments (Straškraba 2005).

The anticipated climate change with its increase in temperature and impacts to the runoff can affect water quality in water bodies especially due to three groups of factors: (i) changes in the structure of runoff paths through the soil, i.e., proportion of surface, subsurface, and shallow/deep groundwater runoffs that carry significantly different composition of solutes and particulates, (ii) changes in the hydrologic conditions that may affect the extent of water level fluctuation in water resources with storage function and consequently exert more stress to the aquatic ecosystem, for example by damaging littoral zone and/or by increasing area loads of nutrients with eutrophication impacts, (iii) modifications of hydrodynamics and seasonal mixing and stratification pattern that can influence a complicated bunch of often antagonistic relations among production and decomposition of organic matter and utilisation, cycling, and retention of nutrients.

The aim of this work was to explore water quality responses in a temperate, stratified reservoir to climate change scenarios that were modelled with the atmosphere-catchment-reservoir simulation system developed and described within previous deliverables (i.e., D5.2 and D5.4). The scenarios of climate change were developed using pattern scaling techniques from the outputs of 3 global and 2 regional climate models, representative scenarios for the development of emissions of greenhouse gases and aerosols, and a range of climatic sensitivity to emissions. The scenarios were constructed in a future time span from 2011 to 2115.

2. Methods

2.1 Locality

Římov Reservoir (volume, 34 mil. m^3; surface area, 2.1 km^2; max. depth, 43 m; mean flow, 4.1 m^3/s; mean water residence time, 0.25 yr) is situated in the Czech Republic, on the Malše River in the upper part of the Vltava River basin. This reservoir was built in 1978 with the main purpose to supply drinking water for the region of South Bohemia (~200 thousand inhabitants). Other purposes include the maintenance of flow downstream from the dam and hydropower production. The reservoir is replenished during the next winter or early spring. The reservoir design guarantee withdrawal of raw water (average 1.48 m^3/s) plus minimum flow downstream from the dam (0.65 m^3/s). The storage pool (volume 30 mil. m^3) is operated with a one-year cycle. In most years, the pool is full in the spring a then, during the summer and autumn months, water level gradually decreases as the sum of outflow and withdrawal usually exceeds the inflow.

The morphology of basin is deep and relatively narrow, with surface area partly protected against mixing by wind. The reservoir is moderately eutrophic with occasional water blooming with cyanobacteria in the summer and autumn and almost regular, every-year anoxic conditions in the hypolimnion at the dam part of reservoir from July to October.

The catchment above the dam profile of Římov Reservoir has an area of 489 km^2 and mean/maximum/minimum altitudes of 705/1072/428 m above sea level. The bedrock is formed by weathered paragneiss, diorite and granite. Most soils are dystric cambisols and mountainous podsols of acidic character (pH<4.5). About 23% of the catchment is used as arable land, 21% as meadows, 53 % for forestry, and 2 % are urban areas. Approximately 18 thousand inhabitants live in the catchment (i.e., population density is 35 inhabitants per square kilometre).

Two key factors of water quality in Římov Reservoir that deteriorate good water quality and treatability to drinking water include occasional increases of dissolved organic matter (DOM) concentration and eutrophication of the reservoir. The DOM is largely allochthonous and its high concentrations originate from washing out topsoil during interflow runoff events in summer and autumn months (Hejzlar et al. 2003). The high trophic state results from excessive P-loads, mainly from point source discharges, that lead to high concentrations of phytoplankton at the reservoir surface and anoxic condition in the hypolimnion and deterioration of water quality in the withdrawal by increased concentrations of dissolved manganese and iron. More detailed information about the reservoir and its catchment in Deliverable D5.4.

2.2 Modelling system

The model system that has been developed for the description of effects of climate change on hydrology and water quality in Římov Reservoir is described in detail in the previous deliverable (D5.4). It consists of two major model compartments, i.e., HSPF and CE-QUAL-W2 for simulations of the precipitation-runoff process in the catchment and the reservoir hydrodynamics plus water quality, respectively, and several supplementary submodels that couple these two models and provide data on inflow water quality (PHOSP, DOM, STEMP) and on reservoir hydrological operation (RESMNG). The HSPF model (Bicknell et al. 2001) is a conceptual precipitation-runoff model with a modular structure that enables simulations of transport of multiple substances from the catchment and their transformations in the river network. Simulations are accomplished in user-defined separate parts of the catchment and of the river network that have similar soil, water ecosystem, and climate conditions. The separation of the Římov Reservoir catchment was done into five subcatchments. Each subcatchment was composed of 4 segments that represented farmland, low-slope (<8°) areas, high-slope (>8°) areas, and impervious areas. The two-dimensional, laterally averaged numerical reservoir model CE-QUAL-W2 v. 3.5 (Cole and Wells, 2006) was used for the Římov Reservoir with a finite-difference grid that consisted of 24 segments long 300 m to 1 km long and thick 1 m. Water quality simulations included the following quantities: temperature, ice cover thickness, dissolved oxygen, biomass of 3 phytoplankton groups, labile and refractory dissolved and particulate organic matter (LDOM, RDOM, LPOM, RPOM), orthophosphate P (PO4-P), NO3-N, and NH4-N. The modelling system was calibrated with the period 1999–2003, validated for the period 1991–1998, and evaluated by sensitivity and uncertainty analyses (Deliverable D5.4).

2.3 Scenarios

The site-specific scenarios of climate change were prepared using the pattern scaling techniques from the outputs of 3 global and 2 regional climate models with different spatial resolution.

The method of data downscaling from global circulation models used the procedure described in Dubrovsky et al. (2005). In this method, the standardised scenario that relates the climate variable responses to a 1 °C rise in global mean temperature (T_G) is multiplied by the predicted change (ΔT_G). The standardised scenarios were determined from CGM runs and ΔT_G values that were calculated by the simple climate model MAGICC (Harvey et al. 1997, Hulme et al. 2000) for 3 combinations of conditions that were selected from representative emission scenarios and climatic sensitivities. The climate change scenarios were based on the transient simulations with three GCMs, i.e., ECHAM4/OPYC3 (ECHAM), HadCM2 (HadCM), and NCAR DOE-PCM (NCAR), available from the IPCC-DDC (http://ipcc-ddc.cru.uea.ac.uk) at the beginning of 2001. The following variables were used from the GCM outputs in a daily step: daily mean temperature (*TAVG*), minimum and maximum daily temperatures, precipitation (*PREC*), solar radiation (*SRAD*), vapour pressure (*VAPO*), and wind speed (*WIND*). Since *SRAD* was not available from HadCM, cloudiness was used as a surrogate for determining changes in solar radiation. The data from the GCM runs were geographically interpolated to the central point of the basin areas. The emission scenarios SRES A1, A2, B1, and B2 from the IPCC Third Assessment Report (IPCC 2001) were used in the estimation of future global temperature increase together with the most likely range of the values for the climate sensitivity factor, *i.e.* an increase of global temperature by 1.5-4.5 °C per a doubling of the atmospheric CO_2 concentration (IPCC 2001). To reduce the number of scenarios for the hydrology modelling, the values of global temperature increase for the used emission scenarios were compared for the low, middle, and high estimates of the climate sensitivity factor and 3 scenarios, i.e. the most optimistic, middle, and most pessimistic, were selected for the requested time instants (i.e., 2011–2040, 2036–2065, and 2086–2115) resulting in a total of 27 scenarios (for details see Deliverable D5.4).

Data from the RegCM3 140-year transient run (1961–2100) in 25 × 25 km resolution were downloaded from the ICTP ftpserver. This regional model uses the ECHAM5 run3 with the A1B emission scenario as the boundary condition. Four nearest grid points were selected to represent climatic conditions in the Římov catchments. Data from these grid points were averaged for TAVG, PREC, SRAD, WIND and Mixing Ratio that was recalculated to VAPO; potential evapotranspiration was calculated according to FAO Penmann-Monteith equation. Then we identified differences in TAVG and other climatic quantities for average monthly values between the control period 1971–2000 and time slices for near (2021–2050) and far (2071–2100) future from this transient run. The input data for the modelling system were modified accordingly (i.e., by additive factor with temperature or by multiplicative factor with all other quantities) for each scenario run.

ALADIN data in 10 × 10 km resolution were downloaded from the CHMI ftpserver. ALADIN RCM uses the ARPEGE–CLIMATE GCM with the A1B emission scenario as the boundary condition. Daily data for the nearest 9 grid points to the Římov catchment were selected. From the control run 1961–2000 we used the last 30 years and from the future predictions the periods of 2021–2050 and 2071–2100. The input data for the modelling systems were modified by additive or multiplicative factors as described above.

The climate change scenarios were run in the Římov Reservoir modelling system with a fixed catchment land use and a constant value of P export into surface waters from point sources corresponding to the state in the recent period of 2006–2007 (i.e., arable land, 23 %; grassland, 21%; forest, 53%; urban, 2%; P-load from point sources, 3.5 t/yr). The scenarios were run for 10-year periods differently for the outputs of GCM and high-resolution regional climatic models. The GCM based scenarios included the periods of 2031–2040 (near future), 2056–2065 (medium future), and 2106–2115 (far future). The RegCM3 and ALADIN scenarios included the periods of 2041–2050 (near-to-medium future) and 2091–2100 (far future). All these scenario runs were compared against a base run with measured climatic and hydrologic conditions in the period of 1991–2000.

3. Results and discussion

The simulation results on the development of hydrological conditions at Římov Reservoir during the 21st century according to the climate change scenarios are given in Tab. 1 and 2. The model runs indicated significant changes in reservoir hydrology, water temperature, stratification patterns, and water quality.

3.1 Hydrology and water supply

The scenarios of future development of climate conditions indicated a significant decrease in the runoff from catchment into Římov Reservoir during the century (Fig. 1). The mean inflow into the reservoir dropped by 5–24 % in the near-future period (2031–2050) and by 13–87 % in the far-future period (2091–2115). The growth of scatter and uncertainty in modelling results with time sprang mostly from the increasing uncertainty in predictions of greenhouse gases development and different values of climate sensitivity factor that are included in the climatic

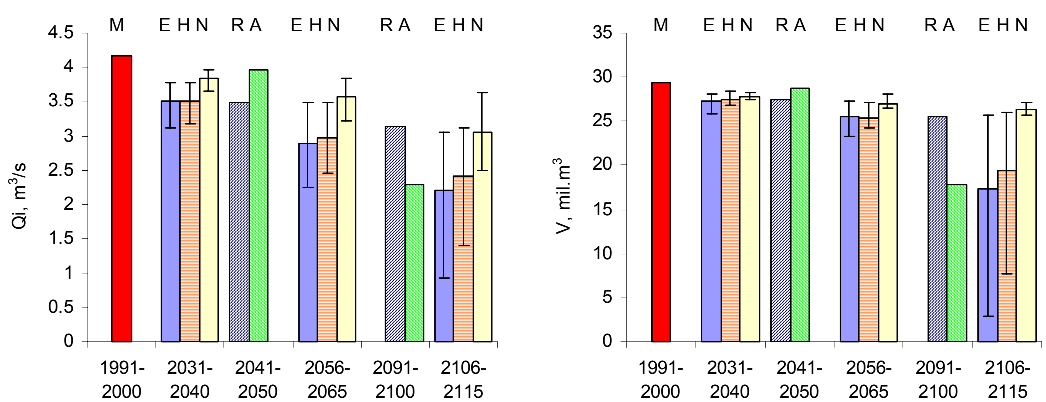

Fig. 1. Mean reservoir inflow (left) and mean total reservoir volume (right) in modelled climate change scenarios. Columns denote mean values for each model and time period and vertical bars give ranges between high and low sensitivities of models to global temperature change: M − model base run on monitored input data 1991–2000, E − ECHAM, H − HadCM, N − NCAR; R − RegCM3, A − ALADIN

Table 1. Mean inflow (Qi), mean volume (V), temporal breaks in water supply (BWS), mean hydraulic residence time (HRT), mean air temperature (Ta), mean water temperature of the inflow (Tw-in), mean water temperature in different depths of reservoir near the reservoir dam (Tw-0m to Tw-bottom), and mean ice cover duration (Ice) in Římov Reservoir in model scenarios of climate change

Period	Model / sensitivity		Qi, m3/s	V, mil. m^3	BWS, %	HRT, d	Ta, °C	Tw-in, °C	Tw-0m, °C	Tw-10m, °C	Tw-20m, °C	Tw-30m, °C	Tw-bot., °C	Ice, d/yr
1991-2000	BASE		4.18	29.3	0	89	8.2	8.4	10.9	7.1	4.7	4.1	4.1	47
2031-2040	E	high	3.12	25.8	0	105	9.7	9.1	12.0	7.4	4.9	4.0	4.0	38
		low	3.77	28.1	0	95	8.8	8.7	11.3	7.2	4.8	4.1	4.1	43
		middle	3.50	27.2	0	99	9.2	8.9	11.6	7.3	4.8	4.0	4.0	40
	H	high	3.17	26.7	0	107	9.6	9.1	11.9	7.5	4.9	4.0	4.0	38
		low	3.77	28.4	0	96	8.7	8.7	11.3	7.3	4.9	4.1	4.1	43
		middle	3.50	27.4	0	100	9.1	8.8	11.5	7.3	4.8	4.0	4.0	41
	N	high	3.66	27.4	0	95	9.2	8.9	11.6	7.6	5.0	4.0	4.0	39
		low	3.97	28.3	0	91	8.6	8.6	11.2	7.2	4.9	4.1	4.1	45
		middle	3.85	27.7	0	92	8.9	8.7	11.3	7.3	4.9	4.0	4.1	43
2041-2050	RegCM3		3.48	27.5	0	100	9.1	8.8	11.2	7.1	4.9	4.2	4.1	36
	ALADIN		3.97	28.8	0	92	9.3	8.9	11.7	7.7	5.1	4.2	4.1	40
2056-2065	E	high	2.05	17.7	4.4	100	11.1	9.8	12.8	8.2	4.9	4.2	4.4	33
		low	3.49	27.2	0	99	9.2	8.9	11.6	7.3	4.9	4.1	4.0	40
		middle	2.90	25.5	0	112	10.0	9.3	12.2	7.6	5.0	4.2	4.1	36
	H	high	2.45	24.2	2	126	10.9	9.7	13.0	8.4	5.4	4.6	4.2	35
		low	3.49	27.1	0	99	9.1	7.7	11.3	6.9	4.7	4.3	4.1	41
		middle	2.98	25.3	0	108	9.9	9.2	12.1	7.4	4.9	4.4	4.1	37
	N	high	3.21	26.5	0	105	10.2	9.3	12.4	8.2	5.3	4.2	4.1	36
		low	3.85	28.1	0	93	8.9	8.7	11.4	7.4	4.9	4.1	4.1	42
		middle	3.57	26.9	0	96	9.5	9.1	11.8	7.7	5.1	4.1	4.0	38
2091-2100	RegCM3		3.14	25.5	0	103	11.0	9.7	12.8	7.9	5.2	4.4	4.3	31
	ALADIN		2.30	17.9	3.7	99	10.9	9.7	12.6	8.1	4.5	4.4	4.4	34
2106-2115	E	high	0.93	2.9	63	40	14.4	11.4	14.6	6.4	5.7	4.3	8.5	23
		low	3.05	25.6	0	107	9.8	9.2	12.0	7.5	4.9	4.3	4.1	37
		middle	2.21	17.4	4.7	100	11.1	9.8	12.8	8.2	4.9	4.3	4.4	33
	H	high	1.40	7.7	31	70	13.9	11.2	14.4	7.8	5.6	4.4	5.6	24
		low	3.11	26.0	0	106	9.7	9.1	12.0	7.4	4.8	4.4	4.0	38
		middle	2.42	19.4	2.9	102	10.9	9.7	12.7	7.8	4.9	4.4	4.2	34
	N	high	2.49	25.7	2	131	12.5	10.5	14.2	10.3	6.8	5.0	4.6	21
		low	3.63	27.2	0	95	9.3	8.9	11.7	7.6	5.1	4.4	4.2	38
		middle	3.05	26.3	0	110	10.2	9.4	12.4	8.3	5.4	4.6	4.3	35

Table 2. Mean durations of summer stratification (SStr), winter stratification (WStr), and mixing period (MIX), mean orthophosphate P, total P, and dissolved organic carbon concentrations in the inflow (PO4-P-in, TP-in, and DOC-in, respectively), mean orthophosphate P, mean total P, maximum total P, mean DOC, mean chlorophyll-a, and maximum chlorophyll-a concentrations in the surface layer of reservoir near the dam (PO4-P-r, TP-r, TP-r max, DOC-r, Chla, Chla max, respectively), and duration of anoxia (DO < 1 mg/l) in the he depths of 10 and 20 m below the surface and 3 m above the bottom (AN-10 m, AN-20 m, and N-bot, respectively) in Římov Reservoir in model scenarios of climate change

Period	Model / sensitivity		SStr, d/yr	WStr, d/yr	MIX, d/yr	PO4-P-in, µg/l	TP-in, µg/l	DOC-in, mg/l	PO4-P-r, µg/l	TP-r, µg/l	TP-r max., µg/l	DOC-r, mg/l	Chla, µg/l	Chla max., µg/l	AN-10 m, d/yr	AN-20 m, d/yr	AN-bot., d/yr
1991-2000	BASE		225	64	76	26	46	4.6	11	24	33	4.7	6.3	23	47	31	59
2031-2040	E	high	238	53	75	28	48	4.7	11	23	34	4.7	6.2	18	54	32	61
		low	232	59	74	27	46	4.7	11	24	34	4.7	6.2	23	47	28	72
		middle	236	58	72	27	47	4.7	11	23	34	4.7	6.2	21	50	29	67
	H	high	237	53	75	28	48	4.7	11	23	34	4.7	6.1	23	56	33	80
		low	230	58	77	27	47	4.7	11	24	35	4.7	6.2	24	49	34	67
		middle	234	57	75	27	47	4.7	11	23	34	4.7	6.2	23	52	33	78
	N	high	239	54	72	27	47	4.7	11	24	35	4.7	6.4	24	53	40	80
		low	230	61	75	26	46	4.7	11	24	38	4.7	6.3	25	47	30	71
		middle	233	59	74	27	47	4.7	11	24	35	4.7	6.4	24	49	32	77
2041-2050	RegCM3		236	55	75	27	47	4.7	11	23	33	4.7	6.2	21	42	26	64
	ALADIN		237	58	70	26	46	4.7	11	24	34	4.8	6.2	23	51	34	81
2056-2065	E	high	236	41	88	32	52	4.8	12	24	42	4.8	6.5	22	70	97	91
		low	236	57	73	27	47	4.7	11	23	34	4.7	6.2	22	50	29	69
		middle	239	49	77	28	48	4.8	11	23	35	4.7	6.1	19	56	37	65
	H	high	240	41	85	32	52	4.8	10	22	35	4.7	5.6	20	67	45	71
		low	230	52	83	27	47	4.7	11	23	34	4.7	6.0	23	51	32	73
		middle	238	51	77	28	48	4.7	11	23	35	4.7	6.1	24	61	33	73
	N	high	245	44	76	27	47	4.8	10	23	38	4.8	6.4	24	61	49	82
		low	233	57	75	27	47	4.7	11	24	36	4.7	6.4	24	49	32	73
		middle	240	53	71	27	47	4.7	11	24	35	4.7	6.4	24	56	44	86
2091-2100	RegCM3		246	42	78	28	48	4.8	11	23	37	4.8	5.8	21	59	48	80
	ALADIN		234	49	81	38	58	4.8	12	24	39	4.8	6.3	23	77	94	98
2106-2115	E	high	202	19	144	90	110	5.0	24	46	249	5.1	15	76	194	29	156
		low	239	52	74	28	48	4.7	11	23	34	4.7	6.2	19	54	34	61
		middle	235	40	90	33	53	4.8	12	24	47	4.8	6.6	21	69	62	94
	H	high	225	24	116	97	117	5.0	16	30	119	4.9	8.2	42	132	48	138
		low	237	51	77	28	48	4.7	11	23	34	4.7	6.1	22	59	34	77
		middle	236	44	85	33	53	4.8	11	23	40	4.8	6.1	24	72	52	91
	N	high	262	28	75	34	54	4.9	9	22	36	4.9	6.1	19	72	65	118
		low	239	54	72	27	47	4.7	11	24	35	4.7	6.4	24	53	40	79
		middle	246	43	76	28	48	4.8	10	23	38	4.8	6.3	22	60	45	80

models which predictions were used in this study. The mean reservoir pool volume reduced in parallel with the decrease in the inflow (Fig 1). The reduction in reservoir volume was non-linearly related to the drop of inflow. It was relatively moderate (<17 %) until the inflow decreased up to ~40 % of its 1991–2000 value but then increased rapidly.

At the decrease of mean flow by ~45 % (to less than ~2,5 m^3/s) the reservoir storage pool started to become entirely depleted during low flow periods (i.e., the first four years of the modelled period) and breaks in water supply appeared (Tab. 1, Fig. 2).

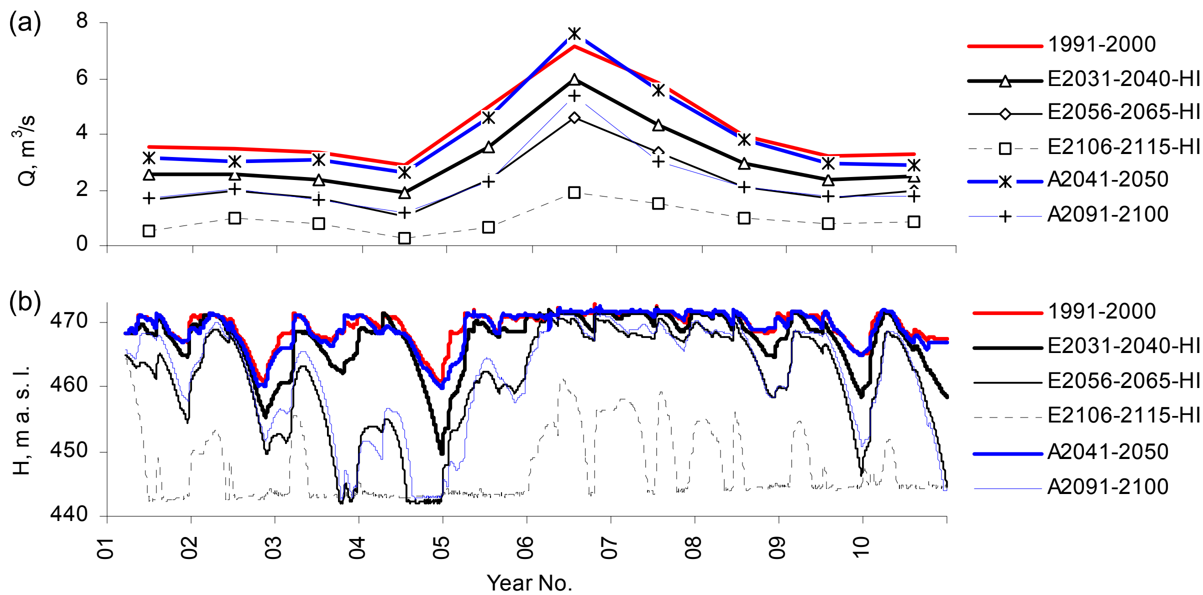

Fig. 2. (a) Mean annual inflow of Římov Reservoir and (b) development of water surface level in a selected range of model scenarios (ECHAM at high sensitivity and ALADIN)

Hydraulic residence time (HRT) as a very important factor in reservoir limnology (Straškraba 2005) that controls for example seasonal stratification patterns and retention of nutrients in water bodies was affected relatively little in climate change scenarios because the drops in runoff from catchment were partly compensated with the parallel decrease in reservoir volume. It grew from ~90 d in 1991–2000 to ~95–130 d in the far future period except for two cases of the intense drops in the inflow together with simultaneous depletion of reservoir pool (i.e., ECHAM and HadCM scenarios for high sensitivities) when HRT shortened to 40 and 70 days.

3.2 Temperature and seasonal stratification patterns

Water temperature increased in the model scenarios both in the reservoir inflow and the reservoir itself but the rate of increase was less than for the increase in air temperature (Tab. 1, Fig. 3). While the mean air temperature for the middle sensitivity of models increased by ~3 °C in the far future period, the mean water temperature of the inflow and reservoir surface layer raised for the same models and period by ~1–1.5 °C. This lower temperature increase can be explained by naturally smaller seasonal amplitude of temperature variations in surface waters (because water

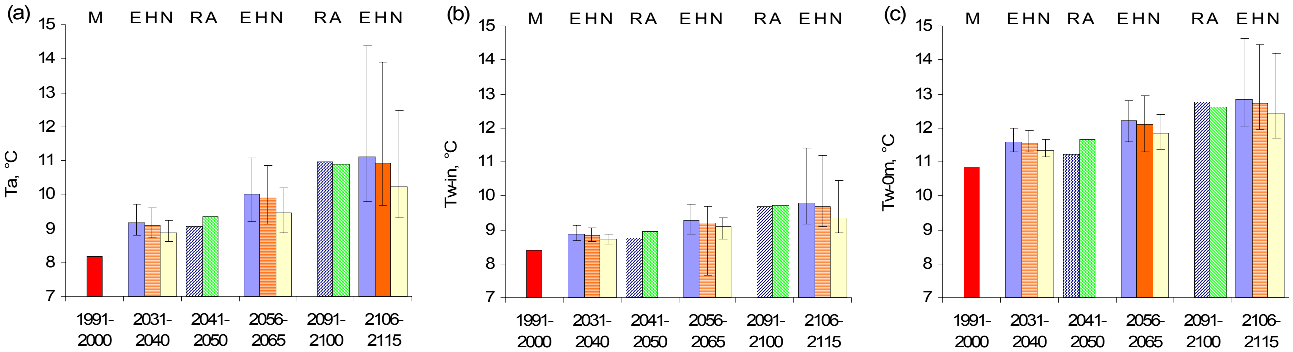

Fig. 3. (a) Mean air temperature, (b) mean inflow water temperature, and (c) mean surface water temperature at the dam of Římov Reservoir in model scenarios of climate change

temperature in streams and water bodies does not drop below 0 °C and the high heat capacity of water smoothes rapid temperature changes). In the reservoir the temperature change was largest in the surface layer and diminished with increasing depth. In the depth of 20 m the mean temperature increase was less than ~0.7 °C in the far future period except for two scenarios with the models ECHAM and HadCM at high sensitivity when water level dropped for a large part of the modelled period to minimum operation value.

The increase in temperature and decrease in flow in the climate change scenarios influenced the length of stratification and mixing periods of the dimictic seasonal cycle in Římov Reservoir. The summer stratification period prolonged in the near future and far future periods by ~10 and 15 d, respectivelzy, for the models at middle sensitivity, respectively (Tab. 2, Fig. 4). The winter stratification period shortened by ~15 d (Tab. 2, Fig. 4) and also the mean duration of ice cover shortened (Tab. 1). The duration of mixing periods prolonged slightly, except for two scenarios of ECHAM and HadCM models at high sensitivity that showed significant prolongation due to decreased reservoir volume and shortened HRT.

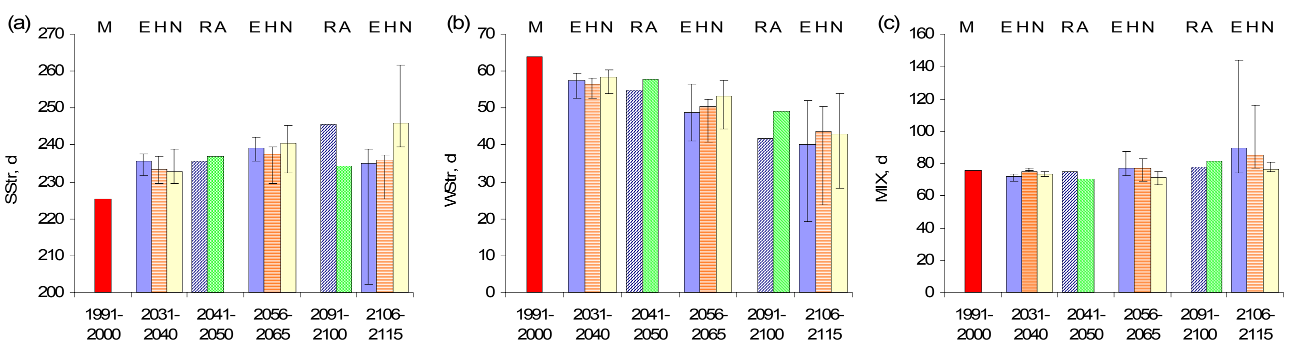

Fig. 4. Mean duration of stratification and mixing periods at the dam of Římov Reservoir in model scenarios of climate change: (a) summer stratification (SStr; temperature difference between surface and bottom layers >1 °C), (b) winter stratification (WStr; temperature difference between surface and bottom layer >–2 °C), (c) spring and autumn mixing (MIX)

3.3 Water quality

Two major factors controlling water quality in Římov Reservoir are: (i) the inflow concentration of phosphorus as the limiting nutrient for phytoplankton growth and therefore determining trophic status of this water body and (ii) the inflow concentration of dissolved organic carbon (DOC) that determines treatability of water withdrawn by the waterworks.

The mean inflow PO4-P and TP concentrations in the modelled base run (1991−2000) were 26 and 46 μg/l, respectively (Tab. 2, Fig. 5). The modelling system predicted only a moderate increase in mean P concentrations (i.e., by ~10−20 % or ~8−15 μg/l) in the scenarios of future climate development in spite of significant decrease in flow (i.e., by up to more that 50 %). This corresponded with an increase in retention of P in the catchment with the decrease of flow. P retention in the reservoir was ~55−70 % and ~50−60 % for PO4-P and TP, respectively, with the lower values of these ranges corresponding to HRT ~90 d and the upper values to HRT ~130 d. These results indicate that both the catchment and reservoir feature a buffering mechanism that actually stabilizes P concentrations and trophic conditions. The modelled mean and maximum chlorophyll-a concentrations corresponded to P concentrations (Fig. 5, Tab. 2).

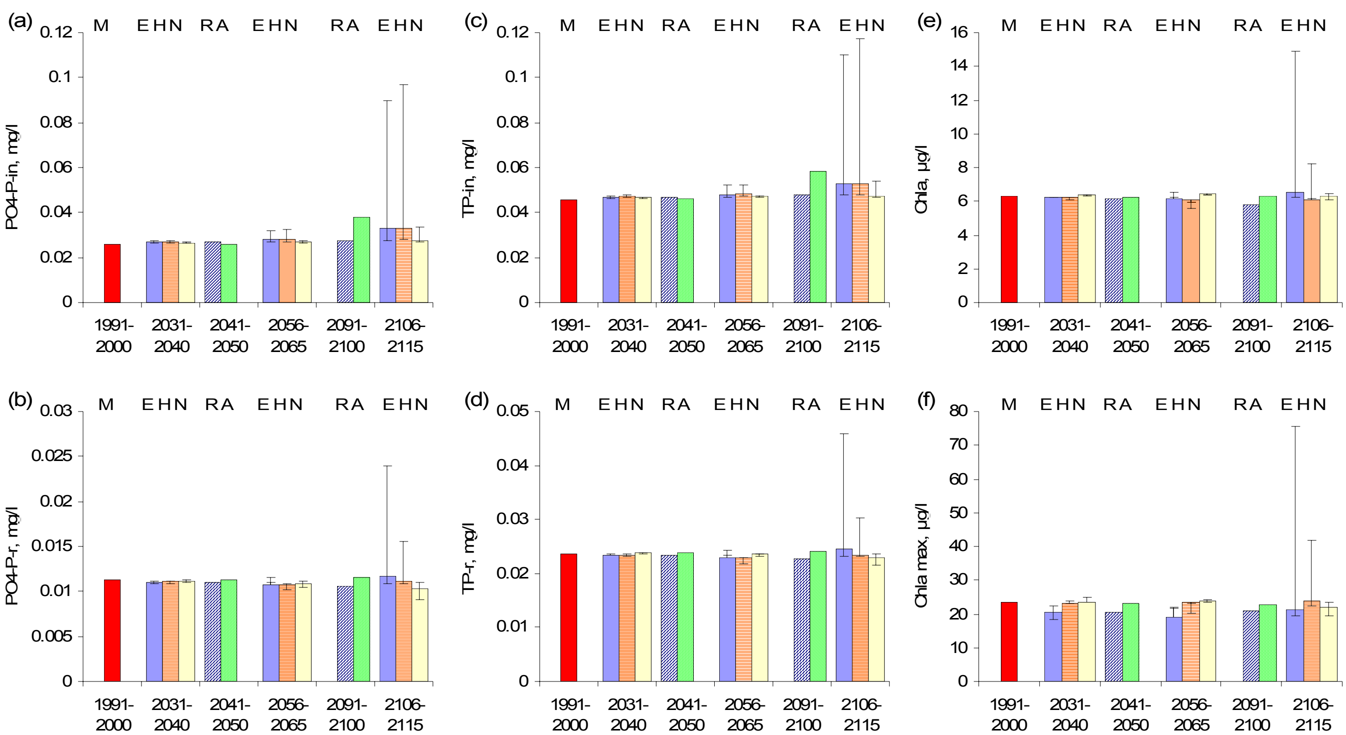

Fig. 5. Mean PO4-P and TP concentrations in the inflow (PO4-P-in, TP-in) and in the surface layer at the dam of Římov Reservoir (PO4-P-r, TP-r) and mean and maximum chlorophyll-a concentrations in the surface layer at the dam of Římov Reservoir (Chla, Chla max, respectively) in model scenarios of climate change

The duration of anoxic conditions in the water column of Římov Reservoir increased in the modelled scenarios in the far future period by ~20 d (Tab. 2). This can be perceived as a surprising result because the trophic conditions apparently did not change. However, the reasons were (i) in the decrease of reservoir volume which means also an increase in the ratio of volumes of production a decomposition zones of the water column leading to a faster depletion of oxygen in the hypolimnion and (ii) in the prolongation of summer stratification period and the increase in water temperature that promotes microbial respiration and increases the rate of oxygen consumption.

Mean DOC concentrations showed a moderate increase both in the inflow and reservoir (Tab. 2, Fig. 6), which reflects the increase in temperature and change in seasonal distribution of precipitation (Hejzlar et al. 2003).

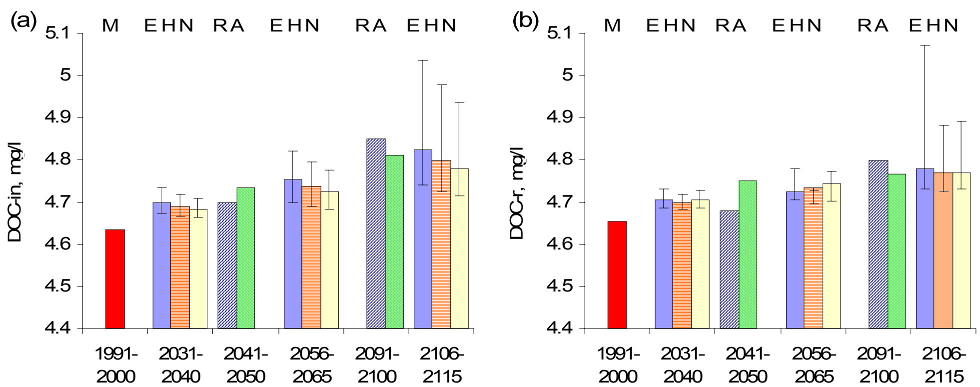

Fig. 6. Mean DOC concentrations in the inflow (DOC-in) and the surface layer at the dam of Římov Reservoir (DOC-r) in model scenarios of climate change

4. Conclusions

The analysis of water availability and water quality responses in the temperate, stratified Římov Reservoir to climate change scenarios that were modelled with the atmosphere-catchment-reservoir simulation system showed that in the far future period around 2100:

- catchment runoff and reservoir water yield will significantly decrease by up to ~50±30 %

- water level fluctuation in the reservoir will significantly increase

- water quality in the inflow will decrease due to increased concentrations of DOC (originating mainly from natural sources) and P (mainly from point sources)

- despite the increased inflow P concentrations, the reservoir trophic status will not significantly deteriorate because the increased P load will be compensated by an increased P retention under longer water residence times and higher temperature

- anoxic conditions in water column will worsen due to smaller hypolimnion volume and higher sedimentation rates

- altogether this means a higher stress on the aquatic ecosystem

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