

Appendix 2: Climate Change Impacts on Rivers and Species

Source: Le Quesne et al. (2010). "Flowing Forward: Freshwater Ecosystem Adaptation to Climate Change in Water Resources Management and Biodiversity Conservation," Water Working Notes 28, World Bank Group, p. 18.

IMPACTS OF CLIMATE CHANGE	ECO-HYDROLOGICAL IMPACTS	IMPACTS ON ECOSYSTEMS AND SPECIES
<ul style="list-style-type: none"> ■ Changes in volume and timing of precipitation ■ Increased evapotranspiration ■ Shift from snow to rain, and/or earlier snowpack melt ■ Reduced groundwater recharge ■ Increase in variability and timing of monsoon ■ Increased demand for water in response to higher temperatures and climate mitigation responses 	Increased low-flow episodes and water stress	<ul style="list-style-type: none"> ■ Reduced habitat availability ■ Increased temperature and pollution levels ■ Impacts on flow-dependent species ■ Impacts on estuarine ecosystems
<ul style="list-style-type: none"> ■ Shift from snow to rain, and/or earlier snowpack melt ■ Changes in precipitation timing ■ Increase in the variability and timing of annual monsoon 	Shifts in timing of floods and freshwater pulses	<ul style="list-style-type: none"> ■ Impacts on spawning and emergence cues for critical behaviors ■ Impacts on key hydrology-based life-cycle stages (e.g., migration, wetland and lake flooding)
<ul style="list-style-type: none"> ■ Increased temperatures ■ Reduced precipitation and runoff 	Increased evaporative losses from shallower water bodies	<ul style="list-style-type: none"> ■ Permanent water bodies become temporary/ephemeral, changing mix of species (e.g., from fish-dominated to fairy shrimp–dominated)
<ul style="list-style-type: none"> ■ Increased precipitation and runoff ■ More intense rainfall events 	Higher and more frequent storm flows	<ul style="list-style-type: none"> ■ Floods remove riparian and bottom-dwelling organisms ■ Changes in structure of available habitat cause range shifts and wider floodplains ■ Less shading from near-channel vegetation leads to extreme shallow water temperatures
<ul style="list-style-type: none"> ■ Changes in air temperature and seasonality ■ Changes in the ice breakup dates of lakes 	Shifts in the seasonality and frequency of thermal stratification (i.e., normal seasonal mixing of cold and warm layers) in lakes and wetlands	<ul style="list-style-type: none"> ■ Species requiring cold-water layers lose habitat ■ Thermal refuges disappear ■ More frequent algal-dominated eutrophic periods from disturbances of sediment; warmer water ■ Species acclimated to historical hydroperiod and stratification cycle are disrupted, may need to shift ranges in response
<ul style="list-style-type: none"> ■ Reduced precipitation and runoff ■ Higher storm surges from tropical storms ■ Sea-level rise 	Saltwater encroachment in coastal, deltaic, and low-lying ecosystems	<ul style="list-style-type: none"> ■ Increased mortality of saline-intolerant species and ecosystems ■ Salinity levels will alter coastal habitats for many species in estuaries and up to 100 km inland
<ul style="list-style-type: none"> ■ Increase in intensity and frequency of extreme precipitation events 	More intense runoff, leading to increased sediment and pollution loads	<ul style="list-style-type: none"> ■ Increase of algal-dominated eutrophic periods during droughts ■ Raised physiological and genetic threats from old industrial pollutants such as dioxins
<ul style="list-style-type: none"> ■ Changes in air temperature ■ Increased variability in temperature 	Hot or coldwater conditions and shifts in concentration of dissolved oxygen	<ul style="list-style-type: none"> ■ Direct physiological thermal stress on species ■ More frequent eutrophic periods during warm seasons ■ Oxygen starvation for gill-breathing organisms ■ Miscues for critical behaviors such as migration and breeding