Table 2.S.1. Attribution and Assessment of uncertainties associated with key statements on Observed Impacts. Lines of evidence for confidence statements

Key statement	Geographic region	Period	Evidence for non-climate/CO2 drivers		LINES OF EVIDENCE for climate change (including increased atmospheric CO2 as 1° driver of observed change)								Agreement for climate change attribution	Confidence level	References
			Non-climate/CO2 Driver Land Use Change: Evidence for changes in land use as driver of observed change	Non-climate/CO2 Driver: Other: Evidence for changes in other drivers as driver of observed change	TYPE = Paleo data	TYPE = Experiments	TYPE = Long-term Observations	TYPE = a Fingerprint of climate change response	TYPE = Model outputs of expected current CC response match observed trends; OR models w/ & w/o CC - which match observed best?; Model outputs project future impacts consistent w/ observed changes	TYPE = Change in climate variable at relevant scale has been linked to GHG forcing	TYPE = multivariate statistical analysis	TYPE = Meta-analyses			
About half of all species where land use change has been a minimal driver and with longterm (>20 years) of records have shifted their ranges, with 80-90% of movements being in the direction expected from regional warming trends - i.e. poleward and upward. Conclusions from prior ARs are further supported with new literature for butterflies, birds, xxx. New studies document that other taxa are also exhibiting consistent reponses, including for freshwater fish, xxxxx	Global	Varies by study. Range = 20 - 250 years, mean = xx years	Minimized by study designs (1)		Polewards and upward ranges shifts have been common responses to past major climatic shifts (2)	Translocation of temperature-limited species outside the historic range boundaries has been unsuccessful in the absence of warming and successful during warming periods (3)	Yearly variability in polewards range boundaries for mobile birds and butterflies highly significantly correlated with annual temperature variability (4)	Very long-term records (>50 years) demonstrate "sign-switching" (5) in which a species poleward boundary shifts polewards during warming periods and towards the equator during cooling periods (6)	species distribution models, Phenological models, and other process-based models driven by climate parameters have high predictive power in back-casting observed distributional changes (7)	Yes. Warming seasonal and annual temperatures have been linked to GHG forcing at both regional and global scales (8)		multiple global meta-analyses of xx-xx species show from 40% to 60% of species in a given region or taxonomic group having shifted their poleward range boundary further poleward over the past 20-120 years (9)	high level of evidence, high agreement,	*very high confidence*	(1) {Parmesn, 2003}; (2) {Coope, xx}; (3){refs}; (4){refs}; (5){ }, (6) {Parmesan, 2003}, (7) {Hill, xx}, {Chuine, xx}, (8) {WGI}; (9) {Parmesan, 2003}, {Root, 2003}, {Rosenzweig, 2008}, + refs in section {2.2.4}
Where precipitation has been shown to be the principle driver of a range boundary, regional increases in precipitation have been associated with downward shifts and east-west shifts (shown for trees and birds)	USA, other?														refs in section {2.4.2.1}
About 2/3 of all species with long-term (>20 years) of records have shifted the timing of spring events in directions expected from regional winter and spring warming.	Global	Varies by study. Range = 20 - 400 years, mean = xx years	NA	Photoperiod is an important cue for some species, which would show up as either no change in phenology over time, or where both photoperiod and temperature are drivers, photoperiod cues may tend to	NA	Controlled experiments demonstrate that temperature has large effects on timing of spring events for many species (2)	Yearly variability in appearance times of birds and butterflies highly significantly correlated with spring temp variability (3)	Very long-term records (>50 years) demonstrate "sign-switching" (4) in which a species shifts to earlier spring events during warming periods and later spring events during cooler periods (5)	Phenological models based on temperature have high predictive power in back-casting observed phenological change (6)	Yes. Warming spring temperatures have been linked to GHG forcing at both regional and global scales (7)		multiple global meta-analyses all show from xx% to xx% of species in a given region or taxonomic group having shifted towards earlier spring timing in recent decades (8)	high level of evidence, high agreement,	*very high confidence*	(1){refs}; (2) {refs}; (3) {Sparks}, (4) {Parmesan, 2003}, (5)Crefs}; (6) {refs}; (7) {WGI}; (8) { cohen, 2018}, {Parmesan, 2003}, {Root, 2003}, {Rosenzweig, 2008}, Freshwater: {Blenckner et al, 2007}, {Adrian et al, 2006}, {Adrian et al, 2009} + refs in section {2.4.2.2}
New studies that were not designed for CC attribution are consistent with earlier studies on attribution in demonstrating general poleward and upward shifts of species' ranges and earlier spring events in regions with significant warming. These changes have been documented in both plants and animals, in terrestrial, lake and rivers systems	Global	Varies by study. Range = xx - xx years, mean = xx years	Not assessed									yes (1)			(1) {Chen, 2011}, {Thackeray, 2012},
For species that require winter chilling, winter warming has countered spring warming, resulting in either delayed spring events or no change. When these species are taken into account, it is estimated that 92% of species in these studies have responded to regional warming trends	Northern Europe and USA	Varies by study. Range = xx-xxx years.	NA	Photoperiod and vernalization requirements interact add details) (1)	NA	orange tip, vernalization of plants (UEA group) - demonstrate high heritability (strong genetic basis). Metabolic pathways understood for some species (2)	Yearly variability in break of diapause and dormancy highly significantly correlated with variability of fall and winter temperatures (3)		Models based on seasonal temperature sensitivties of individual species have high predictive power in back-casting observed phenological change (4)	Yes. Fall and winter warming has been linked to GHG forcing at both regional and global scales (5)		none to date	medium evidence, high agreement	*high confidence*	(1) {Gill, 2015}; (2) {Stohlhanski, }, {UEA group}; (3) {Gotthard, }, {Cook, 2012}, {Cook, 2013}; (4) {Cook 2012}, {Cook, 2013}; (5) {WGI} + refs in section {2.4.2.3}
Wildfire has burned increasingly extensive areas, increasing nine-fold in 32 years, driven more by the increased heat and aridity of anthropogenic climate change than by non-climate factors	western North America	1984-2017	Population density, roads, built area, analyzed but less important				Field and remote sensing measurements of burned area: Western USA burned area increased >900%, 1984-2015; Alaska burned area in 2015 was the second highest in the 1940-2015 record; British Columbia, Canada, burned area in 2017 was the highest in the 1950-2017 record. Weather station measurements of climate: Western USA temperature increased 1.5ºC, 1920-2018, summer precipitation decreased 12%, 1984-2016		Numerical models of wildfire as a function of climate and non-cliimate variables, calibrated by historical data, run for actual observed values and compared to model runs in which temperature remains unchanged. Western USA: anthopogenic climate channge doubled burned area over natural burning, accounting for 49% (32-76%, 95% confidence interval) of cumulative burned area, 1984-2016; Alaska: Anthropogenic climate change accounted for 34-60% of 2015 burned area; British Columbia: Anthropogenic climate change increased 2017 burned area 7 to 11 times over the area of natural burning	Increased temperature and decreased summer precipitation detected and attributed to anthropogenic greenhouse gas forcing. Anthropogenic climate change accounts for half the magnitude of a regional drought, 2000-2020, reducing soil moisture to its lowest levels since the 1500s.	Correlation of burned area to climate variables (temperature, precipitation, relative humidity, evapotranspiration) outweighed local human factors (population density, roads, and built-area)		high evidence, high agreement	*high confidence*	Abatzoglou and Williams 2016, Holden et al. 2018, Kirchmeier-Young et al. 2019, Mansuy et al. 2019, Partain et al. 2016, Williams et al. 2020 + refs in section {2.4.4.2}
Tree mortality has increased substantially, as much as doubling in 52 years, driven more by the increased heat and aridity of anthropogenic climate change than by non-climate factors	North America, Africa	ca. 1945-2007	Multivariate and bivariate statistical analyses of population density, roads, timber harvesting, livestock grazing, increased tree density, fire supression, toppling of large trees, analyzed but less important				Field surveys of trees: western U.S. tree mortality doubled, 1955-2007; African Sahel tree mortality 18%, 1954-2002; southwest Morocco tree mortality 44%, 1970-2007; weather station measurements show significant increases in temperature and decreases in precipitation			Increases in temperature and changes in precipitation detected and attributed to anthropogenic greenhouse gas forcing	Canonical correlation analyses of climate and non-climate factors found climate change outweighed other factors; other cases correlation analyses of climate factors significant, non-climate factors non-significant		medium evidence, high agreement	*medium confidence*	van Mantgem et al. 2009, Gonzalez 2001, Gonzalez et al. 2012, le Polain de Waroux and Lambin 2012 [many other cases detected (Allen et al. 2010, Allen et al. 2015, Bennett et al. 2015, Martínez-Vilalta and Lloret 2016, Greenwood et al. 2017, Hartmann et al. 2018) but not formally attributed + refs in section {2.4.4.3}
Vegetation biomes have shifted significantly towards the poles or the Equator or upslope at 19 sites in boreal, temperate, and tropical ecosystems, caused more by increased temperatures and changes in precipitation of anthropogenic climate change than by non-climate factors	Global	1500-2008	Research in some areas conducted multivariate statistical analyses of climate and other factors, population density, roads, other non-climate factors analyzed but less important; research at other areas selected sites with no substantial human land use change				Field surveys show significant changes of vegetation species locations and densities, boreal forest shifting into tundra, subalpine forest shifting into alpine grassland, broadleaf forest shifting into coniferous forest, grassland shifting into woodland; Weather station measurements show significant increases in temperature and changes in precipitation			Increases in temperature and changes in precipitation detected and attributed to anthropogenic greenhouse gas forcing	Canonical correlation analyses of climate and non-climate factors in some areas; correlation analyses of climate factors significant, non-climate factors non-significant in some areas; no substantial local human land use change in some areas		high evidence, high agreement	*high confidence*	Beckage et al. 2008, Brink 1959, Danby and Hik 2007, Devi et al. 2008, Dial et al. 2007, Gonzalez 2001, Gonzalez et al. 2010, Gonzalez et al. 2012, Kirdyanov et al. 2012, Kullman and Öberg 2009, Leonelli et al. 2011, Lloyd and Fastie 2003, Luckman and Kavanagh 2000, Millar et al. 2004, Payette and Filion 1985, Payette 2007, Peñuelas and Boada 2003, Settele et al. 2014, Suarez et al. 1999, Walther et al. 2005, Wardle and Coleman 1992 + refs in section {2.4.3.2}; {2.4.3.3}; {2.4.3.4}
Beetles & moths shifting poleward and upward has brought new pest species into some forests	North America, *other?*	Varies by study. Range = xx=xx years.	Not directly assessed, but occuring in both areas of high LUC and protected areas												refs in section {2.4.3.3}
Shift in forest composition has occurred due to species-specific differences in response to increasing drought															{Anderegg, 2016}

Increased tree mortality has occurred globally, in boreal, temperate and tropical systems, in response to increased drought, wildfire and insect pest outbreaks	Global	Varies by study. Range = xx=xx years.	For many studies, land use change is an important driver. For some studies, LUC is minimal (1)	pest outbreaks are important drivers, but impacts have been exacerbated by heat/drought induced tree stress (2)	tree-rings show xxx (3)	controlled temperature experiments link warming winters to lower insect mortality, and increased growing season length to increased number of generations per year, which leads to large increases in insect abudances in late growing season (4)	yes - add detail (5)	??? can this been deduced from records > 50 years? Eg. evidence for tree mortality being higher than past 100 years? (6)	yes - add detail (7)	true for some studies, not others? Ie probably true for large regional studies, but not very local ones (8)		????	high evidence, high agreement	*high confidence*	refs in section {2.4.4.3}
exotic species are responding differently from native species in both abundance changes and phenological changes, but not in a consistent fashion													low/medium evidence, low agreement		{Primack, },
The most-cold-adapted species have shown the large range contractions and population declines (Sea-ice dependent, mountain-top restricted, upper headwaters, coldest lakes)															
Body size changes															
Diseases wildlife/humans															
Newly emerging vector-borne diseases (dengue, chikungunya, Japanese encephalitis, malaria, visceral leishmaniasis) and their vectors (*An.spp., Aedes albopictus, Ae. aegypti, Culex quinquefasciatus, C. tritaeniorhynchus*) are appearing in higher elevation and non-endemic regions of Nepal. Climate change will intensify VBD epidemics in mountain regions of Nepal.	South Asia (Nepal)	Dengue (2004-present) / Chikungunya (2013-present) / Japanese Encephalitis (1995-present) / Visceral Leishmaniasis (2009-present)	JE has + association with irrigated land, agriculture, land use	Malaria: incidence decreased in lowlands with free distribution of long-lasting insecticidal nets (LLINs)			Dengue: 1st reported case in Nepal in 2004, outbreak in 2006, then expansion to new areas in 2008, spread to highlands in 2010 || Chikungunya: 1st local transmission in 2013|| Japanese Encephalitis: introduced in 1970s to S. Nepal but 1st epidemic in 1995 in Kathmandu valley, shifted to mountain districts after 2005 || Visceral Leishmaniasis: 1st case in hilly non-endemic region in 2011, now found in hill & mountain regions previously considered non-endemic || Malaria: reported in 1969 at 1800+ m., and An. maculatus recorded up to 3100 m.; most malaria cases below 1200 m. in 1978-80 (originally confined to forest areas of lowlands); now in hills and mountains 2000+m			Higher warming rates in high-elevation areas compared to lowlands -- warming rate of Nepal is higher than global average / decreasing trends of cool days & increasing trends of warm days in higher elev. / increasing trends of max temps & more warming in winter compared to other seasons /statistically sig. warmind trend of max temps / sig increase in annual mean temp highly influenced by max temp / increasing trends in heavy prec. events				*medium-high confidence*	{Dahal, 2008; Dhimal et al., 2015; Pandey et al., 2015; Pandey et al., 2017; Pun et al., 2014; Srestha, 2018; Srestha, 2019; Tuladhar et al., 2019a; Tuladhar et al., 2019b}
Fasciolosis risk caused by F. hepatica (exposure, prevalence, outbreaks, geographic emergence) significantly increased or appeared in new areas over time. There are broad trends towards increased risk.	Northeastern Europe (UK, Scotland)		Increased irrigation, slope, altitude, agricultural region, lake density	Antihelminthic drug resistance may be contributing to disease increases in some areas; however, drug resistance would not be expected to alter the seasonality by extending the fall grazing/transmission season						temperature, rainfall, humidity, or number of rainy days with these variables explaining the majority of variability					{van Dijk, 2009, climate change and; Martínez-Valladares et al., 2013; Bosco et al., 2015; Caminade et al., 2015}
The geographic range of schistosomiasis is likely to shift poleward into more temperate regions as opposed to expanding as long as snail hosts and parasite can move. Tropical areas expected to become hotter may become less suitable for the parasite and snail hosts.	East Asia (China)		Irrigation				Historical isotherm (freezing line/northern limit) of S. japonicum shifted from 33°15' to 33°41' N in E Asia expanding potential transmission area by 41,335 km2 and risk to 20.7 million more people.		Annual Growing Degree Days (GDD) would increase (parasite generation numbers would increase by speeding up development in longer growing seasons and extending current area of proliferation)						{Yang, 2006, a growing degree-days; Stensgaard, 2019, schistosomes snails and; Zhou, 2008, potential impact of; Pederson, 2017}
Tick-borne diseases and vectors northward expansion and increased disease (Lyme, Rocky Mountain Spotted Fever, Ticke-borne encephalitis)	North America, Europe, Asia														{Huber, 2020, symposium report: emerging; Ogden, 2016, effects of climate; Raghaven, 2016, hierarchical bayesian spatio-temporal; Semenza, 2018, vector-borne diseases and}
Malaria shifting to highland areas in Tropics and moving poleward in birds	Alaska (birds) / Tropical highlands - Africa, South America														{Caminade, 2014, impact of climate}
West Nile disease incidence increased due to temperature and has moved further north in Eurasia.	(eastern Europe) Russia	1999-2012		Decreased incidence was observed in the year following an outbreak.		Temp increases shorten gonotrophic period (GP), and increases reproduction of Culex spp., and decreases extrinsic incubation period (EIP) of the virus.	WND first reported in Russia in 1999. Outbreaks were associated with higher summer temperatures and mild winters.			Mean temp in winter (Dec-March) (R=0.59), mean temp in summer (July-Sep) (R=0.67), hours temp above 25°C (R=0.70), mean humidity in 2nd and 3rd quarters (R= -0.51), mean atm. pressure in 3rd quarter (R= -0.71)				Limited evidence, med/high agreement?	{Mihailović, 2020, impact of climate; Platonov, 2014, the incidence of; Platonov, 2008, epidemiology of west}
Taxonomic-specific statements															
Climate change induced warming leads to shifts in thermal regime of lakes	Boreal	past >40 years	eutrophication	Trophic state of lakes(1)			In situ monitoring in real time; decadal observations >40 years	Polymictic lakes (regularly mixed throughout summer) may become dimictic more frequently; dimictic lakes (regularly stratify throughout summer) may have a greater tendency to become monomictic; and monomictic lakes (differ to dimictic lakes in that they do not freeze over in winter) may tend to become oligomictic (thermally almost stable, mixing only rarely; mostly tropical lakes) (2)	yes, observed changes based on long-term empirical data match model projections; Kirillin 2010, Kirillin & Shatwell, 2016		One dimensional lake model, statistical analysis, numerical models		High evidence that CC is one of the primary driver. Planktonic events can contribute to polymictic-dimictic regime shifts in temperate lakes	high	(1) {Shatwell,2016, planktonic events may}; 2 {Kirillin, 2010, modeling the impact; Shatwell, 2019, future projections of; Kirillin, 2016 #1903}{Wood, 2016, simulation of deep; Ficker, 2017, From dimictic to; Woolway, 2019, Worldwide alterations of}

Climate change causes gains and losses in freshwater water level	Global	1984-2015	Water abstraction, dams	Recent (2002-2016) changes in terrestrial water storage in Australia and Sub-Saharan Africa have been attributed to the passage of natural drought and precipitation cycles, not climate change {Rodell, 2018, Emerging trends in}. The complexities of lake water storage responses to climate change and the challenges associated with its detection and attribution are reflected in the ongoing debate about the influence of climate change effects on lake water storage {Muller, 2018, Cape Town's drought}.			Water storage increases in the Tibetian Plateau can be more confidently attributed to climate change, since they are corroborated by half-century old ground survey data {Ma, 2010, A half-century of}, and recent observations from the GRACE satellite mission {Rodell, 2018, Emerging trends in}, and because there are minimal irrigated agriculture operations or water diversions which may confound the trend {Rodell, 2018, Emerging trends in}.	Global surface water extents have been mapped using Landsat, which showed that from 1984 to 2015, 90,000 km2 of permanent surface water has disappeared globally, while 184,000 km2 of lake surface area has formed elsewhere (Figure ##a). Most of these changes are thought to be attributable to background climate variability, water extractions, and reservoir filling, rather than climate change per se {Pekel, 2016, High-resolution mapping}.					Until the influence of climate change on all water fluxes (precipitation, ET, runoff) relevant to specific lake water budgets can be adequately resolved, the magnitude of climate change effects on global lake water storage will remain highly uncertain, particularly in the presence of	low	1 {Pekel, 2016, High-resolution mapping}2{Ma, 2010, a half-century of} 3{Rodell, 2018, Emerging trends in}
Warming may amplify the trophic state lakes are allready in. Eutrophic lakes have been shown to become more productive while nutrient limitation may increase in oligotrophic lakes.	Global	Varies by study. Range 20-50 years	Land-use changes, agriculture				Long-term observations past>40 years, remote sensing data	In nutrient poor lakes prolongation of thermal startification limits nutrient entrainments via vertical mixing which leads to a reduction in algal biomass (2), while global warming reinforces eutrophication of already eutrophic lakes via oxygen depletion in the sediment near water layers which triggers release of nutrients previously bound in the sediment (3,4).	yes, ecosystem model PCLake (1)		multivariate statitical analysis, maschine learning tools		Aggreement is high for amplifycation of eutrophication in eutrophic lakes. Limited evidence for CC driven enhanced nutrient limitation in deep oligotrophic lakes	high / medium confidence level	1{Mooij et al. 2007}; 2 {Kraemer et al. 2017}, 3{Adrian et al. 2009}, 4{De Somerpond Domis et al. 2013}
In lakes weather extremes in wind, temperature, precipitation and loss of ice foremost affect the thermal regime with repercussions on water temperature, transparancy, oxygen and nutrient dynamics, affecting ecosystem functionality	Global	past >40 years	Antecedent conditions				In situ monitoring in real time; decadal observations >40 years	Depending on lake type, the severity and timing of the extreme event, and the nature of entrainment from run-off (e.g. DOM) and internal nutrient loads, algal biomass and biodiversity has either declined or increased (1). A once in 250-year flood event in 2009 caused the water column of Lough Feeagh, a large nutrient poor lake in Ireland, to destabilise, followed by reduced primary production (2). The dominant CH4 emission pathway in a shallow productive lake, shifted from gas ebullition to diffusion following high CH4 release from sediments that was driven by colder deep water temperatures during a heatwave (3). Oxygen depletion in the cold deep water body of lakes during heat extremes has forced fish to move upwards into the warm upper water layers where thermal stress and metabolic costs increase. Summer fish kills have been related to summer temperature extremes and near-bottom oxygen depletion (4).					Aggreement is high that the increase in the number and severity of extreme events can be attributed to CC	medium / low	{1}{Havens, 2016, extreme weather events} {Kuha, 2016, response of boreal} {Kasprzak, 2017, extreme weather event} {Bergkemper, 2018, moderate weather extremes} {Stockwell, 2020, Storm Impacts on}; {2}{de Eyto, 2016, response of a}; {3}{Bartosiewicz, 2016, Heat-wave effects on}; {4}{Kangur, 2016, changes in water}
Severe floods and droughts are major threads for river	Global		Antecedent conditions	(1) urban development, farming				Duration of droughts in			mathematical modeling,		Aggreement is	medium /high	(1) {Colls Lozano, 2019, Effects of Duration}(2)
In boreal, coniferous areas changes in forestry practices and climate change have caused an increase in terrestrial derived dissolved organic matter (DOM) transport into rivers and lakes leading to their browning.	Boreal	past decades	Forestry practice, planting of spruce (2); Land-use changes (2).	Non climate related proposed drivers of browning are the strong decline in atmospheric sulfur deposition since the 1980ties, reducing acidification and by that increasing the solubility and transport of DOC from soils (1,2).		Mesocosm experiments (3)	Long-term observations during past decades (1,4), for review see (2)	Browning has been shown to drive a shift from auto- to heterotrophic/mixotrophic-based production (2,5) with a subsequent decline in energy transfer efficiency and a reduction of biomass at higher trophic levels (6). Mild browning may accelerate primary production and favour fish production (2014) through input of nutrients associated with DOM in nutrient poor lakes(6,8,9) and increase cyanobacteria growth (cyanobacteria better cope with low light intensities(10) and toxin levels (11,12).	An increase in browning by factor 1.3 based on a worst case climate scenario was predicted for 6347 lakes and rivers in the boreal region of Sweden until 2030, which match observed trends in the past decades (13).				Agreement is high that climate change induced hydrological intensification and greening of the northern hemisphere are major drivers of browning {Solomon, 2015, ecosystem consequences of} {de Wit, 2016, current browning of} {Finstad, 2016 #1713} {Catalán, 2016, Organic carbon	high	(1){de Wit, 2016, current browning of}, (2){Kritzberg, 2020, browning of freshwaters}, (3){Urrutia-Cordero, 2017, Phytoplankton diversity loss}, (4) {Creed, 2018 #1621}, (5) {Zwart, 2016, Metabolic and physiochemical}, (6){Ellison, 2017 #1687}, (7) {Finstad, 2014, unimodal response of}, (8){Thrane, 2014 #2343}, (9) {Seekell, 2015 #2255, (10){Huismann; 2018, Cyanobacteria blooms},(11){Hansson, 2013, food-chain length; (12) {Urrutia-Cordero, 2016, local food web management}, (13) {Weyhenmeyer, 2016, Sensitivity of freshwaters}

Greenhouse gas emissions from freshwater ecosystems are equivalent to around 20% of global burning fossil fuel CO2 emission	global	past decades	eutrophication, agriculture			Fine sediment fraction and organic carbon content were important drivers of methane production and potential methane oxidation in rivers-based on field/laboratory studies (1); CH4 ebullition due to temperature induced increase in sediment CH4 production will increase in freshwater ecosystem; literature data combined with mesocosm experiments (2).		CO2 and CH4 emissions from freshwater ecosystems are likely to increase due to the imbalance between losses and gains of CO2 by photosynthsis and respiration, enhanced emissions from exposed sediments during droughts (3,4), enhanced CH4 ebulition of seasonally hypoxic lakes (2,5,6,7,8), increased matter transport from land to water (particularly permafrost thaw) (6) are key mechanisms which contribute to rising GHG emissions from freshwater ecosystems to the atmosphere.					Uncertainty primarily stems from the large site specific heterogeneity of CO2 and CH4 dynamics (6), seasonality of their sediment-water–air fluxes (6,9), the exclusion of ponds and the winter season in global carbon flux estimates (6,9), procedures of upscaling (6) and	medium to low	(1){Bodmer, 2020, sediment properties drive}, (2){Aben, 2017 #1405}, (3) {Marcé, 2019 #1996}; (4) Keller, 2020, global CO2 emissions}; (5) {Sanches, 2019 #2228}; (6){DelSontro, 2018 #1650}; (7){Beaulieu, 2019 #1490}; (8){Bartosiewicz, 2019 #1478}, (9) Denfeld, 2018, A synthesis of}
Climate change induced warming leads to shifts in thermal regime of rivers and streams; lowland rivers show a stronger thermal response than high-altitude, cold-water receiving streams	North America, Europe	past decades	Antecedent conditions				Lowland rivers have been observed to be extremely sensitive to heatwaves while high-altitude snow-fed rivers and regulated rivers receiving cold water from higher altitude showed a damped thermal response (1); small mountain streams do not warm linearly with increasing air temperature because of strong local temperature gradients associated with topographic controls (2)						high evidence	high confidence	(1) {Piccolroaz, 2018, Exploring and quantifying, (2) {Isaak, 2016, Slow climate velocities}
Loss of biodiversity in streams can be directly attributed to climate change through increased water temperatures, hydrological changes such as increased peak discharges, flow alteration and droughts	global	past decades	Antecedent conditions				Observed long-term trends in stream macroinvertebrates have shown that changes in species composition and community structure can be attributed to climate change triggered by hydroclimatic changes (1,2). In the Mediterranean climate change may increase the occurrence of droughts and reduce small floods needed to guarantee habitat diversity (3) particularly threatening fish species of small body size, small range size and low dispersal abilities (4). Heat waves have shown to alter the density, species richness and structure of mollusc communities, favouring more resilient species with a slow pace of recovery (5).						high agreement	very high confidence	(1){Daufresne, 2007, Impacts of global}, (2){Chessman, 2009, Climatic changes and}, (3){Death, 2015, resetting the river}, (4){Jaric, 2019, susceptibility of european}, (5){Mouthon, 2015, Resilience of mollusc}.
Climate change is causing range shifts of freshwater fish	North America	past decades	Antecedent conditions				Systematic shifts towards higher elevation and upstream were found for 32 stream fish species in France following geographic variation in climate change (1). Stream fish are currently responding to recent climate warming at a greater rate than many terrestrial organisms, although not as much as needed to cope with future climate						high agreement	high confidence	(1) {Comte, 2013, Do stream fish}, (2) {Isaak, 2010, Effects of climate}, (3) {Eby, 2014, Evidence of climate}.
Whole biome shifts have occurred. Boreal forests have shifted into arctic tundra, treeline has shifted upward into alpine tundra, temperate deciduous shrubs and forests upwards into conifer forest, xx	Global		Mixed. add detail												
Woody encroachment into open (grassland, desert) systems has occurred globally, with climate change as one of the primary drivers	Global		yes - loss of browsing herbivores; fire suppression. Reviews of long term experiments demonstrate impacts (1)	yes - (2)	yes - emergence of grasslands after CO2 came down below ~500ppm (3)	Experiments manipulating CO2 benefit woody plants (4)	yes -Long-term fire and grazing trials show woody encroachment occurs even when land use is held constant or accounted for indicating a global driver. (5)		yes - indicating co2 driven increase in woody cover (6)	yes - add detail (7)		yes - consistent encroachment across all savannas (8)	*In development: high evidence that CC is one of the primary drivers, but LUC also primary driver. High amount of evidence (lots of studies) but medium agreement on CC attribution because of complex drivers*	medium	(1){Bakker et al 2016} {Bond and Midgley 2012}{Smit et al 2010} (3) { Ehleringer and Ceerling 2002}{Beerling and Osborne 2008}(4) {Kgope et al 2010}{Bond and Midgley 2000}{Polley et al 1997}{Hoffmann et al 2000}{Quirk et al 2019}(5){Buitenwerf et al 2012}{Zhang et al 2019}{Venter et al 2018} (6){Scheiter et al 2018}{Moncrieff et al 2014}{Higgins and Scheiter et al 2009} (8){Stevens et al 2017}
High arctic and high mountain tundra systems have generally experienced greater warming than adjacent regions - *statement on impacts in development*															
Widespread greening and shrubbification of tundra	High artic and mountain tundra	1900-				yes - network of warming experiments link warming to increases in shrub, grass and sedge species (4)	yes - satellite and long term repeat photos (5)			yes - IPCC		yes - widespread shrubbification (8)	high	high	(4) {Elmendorf et al. 2012a, 2012b, 2015}{Bjorkman et al. 2018, 2019} {Myers-Smith et al 2019}(5) {Tape et al. 2006}{ Phoenix and Bjerke 2016} (8) {Myers-Smith et al 2011}
Tropical forests	Tropical region														

Drought and warming induced diversity shifts in Meditterean type ecosystems	Mediterranean ecosystems		insect outbreaks assoicated with drought (1); loss of fsh species {Jaric, 2019, susceptibility of european} (9)				yes - Field surveys of long term monitoring show reduced diversity or shift in functional due to increasing prevalence of extreme hot and dry weather often the post-fire regeneration phase(5)				yes - increase in extreme droughts in regions (8)			medium evidence changes are mediated by an increase in extreme droughts. Changes are not always direct but interact through altering the fire		(1) {Fettig et al. 2019}{ McIntyre et al. 2015}(5) {Fettig et al. 2019}{ McIntyre et al. 2015}{Stephenson et al. 2018} {Slingsby et al 2017}{{Harrison, LaForgia, and Latimer 2018}. {Smithers et al 2018} (8) {F. E. Otto et al. 2018}{Sousa et al. 2018} {AghaKouchak et al. 2014} {Robeson 2015}, (9) {Jaric, 2019, susceptibility of european}
Deserts															
Med shrublands shifting to grasslands	Med ecosystems, arid shrublands		Human driven fragmentation and nitrogen deposition benefits grasses (1)				Long-term								(1) {Lambrinos 2006}{ Fenn et al. 2010}
Terrestrial carbon stocks							Long term monitoring and remote sensing show grass invasions (5)								(5) {Young et al. 2019; Syphard, Brennan, and Keeley 2019, Jacobsen et al 2018}
Droughts associated with El Nino lead to an increase of anthropogenic fire in drained tropical peatlands	Southeast Asia	past decades												high	{Herawati and Santoso, 2011}, [Page and Hooijer, 2016}