14 September 2020

Statement of World Aquatic Scientific Societies on the Need to Take Urgent Action against Human-Caused Climate Change, Based on Scientific Evidence

Water is the most important natural resource on Earth as it is vital for life. Aquatic ecosystems, freshwater or marine, provide multiple benefits to human society, such as provisioning of oxygen, food, drinking water, and genetic resources; regulation of atmospheric composition and climate; water purification; storm buffering; mitigation of floods/droughts; recreation areas, and other purposes. Our existence and well-being depend on the health and well-functioning of aquatic ecosystems. People naturally distribute around water – approximately 40% of the world's population lives within 100 km (62 mi) of a coast (1).

The world’s aquatic resources are now under their greatest threat in human history. Human-caused climate change is accelerating the degradation of aquatic ecosystems and the services they provide. Aquatic ecosystems are among the most affected worldwide (e.g., in the case of freshwater ecosystems, one measure of biodiversity, the freshwater living planet index for species populations, declined 83% from 1970-2014, while up to 90% of coral reefs will disappear by mid-century if the current trends continue) (2).

We, the world’s aquatic scientists, spend our lives studying these systems. We see exceptional and disturbing changes in the world’s aquatic ecosystems due to climate change, and believe that we must continue to share peer-reviewed scientific findings with the public and policymakers to emphasize the seriousness of this threat and the need for immediate action. For the first time, the assessment of global risks conducted by the World Economic Forum, ranked the impact of “climate action failure”, “biodiversity loss”, and “water crisis” among the top five risks over the next decade (3). In recent years, migration has increased and geopolitical tensions have been exacerbated:

between 2008 and 2016, more than 20 million people per year have been forced to move due to extreme weather events, while according to the United Nations, in 2017, water was a major conflict factor in 45 countries (3). These negative effects are expected to increase under current climatic trends. For example, in the United States, the climate-related economic damage is estimated to reach 10% of the gross domestic product by the end of the century (3). In Europe, the minimum cost of not adapting to climate change is estimated at €100 billion per year in 2020 and €250 billion in 2050 (4).

Experts in environmental, social, and economic fields collectively point towards a severe environmental and humanitarian crisis, with repercussions at a global level, unless worldwide concerted climate actions are implemented urgently.

This document summarizes key scientific findings highlighting the effect of climate changes on aquatic ecosystems. These findings provide evidence of what effects are currently happening and why world policymakers and all of humankind need to act jointly and launch concerted actions now if they wish to mitigate these impacts.

The Challenge

- Thousands of peer-reviewed studies by scientists from authoritative institutions worldwide have documented evidence for climate effects on aquatic systems that are already occurring and are extensive (5).
- Many globally respected sources, including the American Geophysical Union (6), National Academies of Science from dozens of countries (7), the Intergovernmental Panel on Climate Change (8), and the Fourth U.S. National Climate Assessment (9) support findings that increased atmospheric concentrations of greenhouse gases from fossil fuels (i.e., emissions) and land use changes such as deforestation are driving current climate change.
- Many of these changes are and will be irreversible. They will continue to worsen if we persist on our current trajectory (10).
- Impacts already occurring range from increased frequency, intensification, and severity of droughts, heat waves, floods, wildfires, and storms; melting glaciers; destabilization of major ice sheets; shifting ocean currents, rising sea level; ocean acidification and deoxygenation; shifts in species ranges, including expansion of alien-invasive species; aquatic plant and wildlife disease outbreaks; mass coral bleaching events; and more, with a mounting toll on vulnerable ecosystems, human societies, and local and global economies (11).
- These events are precursors of even more damages to fisheries, biodiversity, and human society at large (12).
- Delaying action to stop underlying causes of climate change will increase the economic, environmental, and societal consequences (13).
- If humanity wishes to avoid calamitous consequences for our aquatic ecosystems and humans that depend on them, the time to curb greenhouse gas emissions, sequester greenhouse gasses, and adapt to an already changing climate is now

(14). Intelligent, rapid movement toward such goals will provide great benefits to aquatic ecosystems and the humans that depend on them.

- Rapid global response and large-scale actions are possible if public and government commitment exists (15).

The Evidence: Effects on Marine Resources

- Shifts in species composition, behavior, abundance, and biomass production are now occurring (16).
- Lobster (17), cod (18), mackerel (19), coral reef fishes (20) and other species important to fisheries (21) are either moving poleward to deeper waters or declining (22).
- Coastal ecosystems are being transformed, degraded, or lost, either largely (23) or in part due to climate change, including seagrass meadows (24), mangroves (25), coral reefs (26) and kelp forests (27).
- Effects of altered species compositions are affecting entire ecosystems (28).
- Carbon emissions cause global ocean acidification, which is affecting the survival of organisms, especially shellfish, and accelerating coral reef erosion (29).
- Rising frequency and intensity of marine heatwaves has been documented and is projected to continue (30).
- Reductions in global ocean dissolved oxygen concentrations have occurred over the past five decades (31).
- Climate change is interacting with other stressors such as excess nutrient input (32), overharvesting (33), and novel species interactions (34) to further suppress marine ecosystems.
- Climate change is linked to emerging and re-emerging disease outbreaks in marine wildlife and plant species (35).
- Global production of marine animals continues to decrease and shifts in species composition will increase unless greenhouse gas emissions are reduced (36).
- Seabirds are recognized as indicators of long-term environmental change: nearly three out of four of the world's seabirds have disappeared since 1950, and more than half the remaining species face substantial threats (37). In North America alone, two-thirds (389/604) of bird species, which includes waterbirds, are moderately or highly vulnerable to climate change under a 3°C scenario (38).

The Evidence: Effects on Freshwater Resources

- Freshwater ecosystems are among the most threatened on Earth (39).
- Freshwater ecosystems cover less than 1% of the planet's surface but support one-third of vertebrate species and 10% of all species (40).

- The capacity of all freshwater ecosystems to adapt is relatively low given the nature of freshwater systems and the scale of impacts of climate change (41).
- Climate change is altering abundance, predator–prey dynamics, expansion of invasive species, growth, recruitment of species, and novel species interactions, leading to declines in the number and diversity of freshwater aquatic organisms (42).
- Increased frequency, intensity, and length of drought are affecting the amount and quality of freshwater available for both aquatic ecosystems and humans (43).
- Climate change impacts on flow regimes, including both increased droughts and low-flow periods, and increased flooding impact native species with narrow ranges of flow requirements and allow expansion of alien-invasive species that affect recreational and commercial harvest of fishes and clog waterways (44).
- Geographic ranges of many plants and animals have moved poleward and to higher altitudes while alien-invasive species expand with the increasingly warm conditions (45). Unlike marine systems, pathways to other habitats are often blocked, leading to localized extinctions (46).
- Temporal shifts in seasonal cues, such as spring runoff or monsoon seasons, affect spawning success of fish, resulting in poor survival (47).
- Higher incidence of wildfires is affecting aquatic systems by making watersheds more susceptible to flooding and by reducing water quality, especially with post-fire ash and sediment deposition (48).
- Wetlands capacity for carbon storage and mitigation of climate change are being damaged by changes linked to climate shifts and other components of global change, such as increased land development and fires (49).
- Higher temperatures and precipitation runoff have increased harmful algae blooms, which can hurt fish, mammals, birds, and even humans (50).
- Climate change may act synergistically with nutrients to magnify eutrophication and further degrade water quality and ecosystem services, including affecting drinking water (51).
- Organisms dependent on snow melt and glacial streams are declining or shifting their distribution (52).
- Release of heavy metals such as mercury, currently stored in glaciers and the permafrost, is projected to further affect freshwater organisms (53).
- Climate change is linked to emerging and re-emerging disease outbreaks in freshwater wildlife and plant species (54).
- These seemingly diverse and small-scale changes combine to create multiple, cumulatively stressful challenges to aquatic species (55).

The Evidence: Effects on World Society Dependent on Aquatic Resources

- Clean and sufficient water is needed by all life forms.
- Fisheries provide quality protein sources not easily replaced by terrestrial sources. According to the Food and Agriculture Organization of the United Nations, fish accounts for 17% of animal protein consumed globally, fishing and aquaculture directly employ almost 60 million people, and global trade in fish products has reached US$152 billion per year, with 54% originating in developing countries (56).
- In the short term, new fisheries are appearing in some newly formed ice-free areas (57); however, overall fisheries catch is projected to decline related to increasing declines in water quality and primary production as a result of climate change, with corresponding effects on food security (58). Ocean warming and changes in primary productivity are related to changes in many fish stocks. Fish population reestablishment has declined 3% per decade, and maximum catch potential declined 4.1% over the 20th century (59). Water temperature increases due to climate change are projected to exceed the tolerance limits of 10–60% of freshwater and marine species by 2100, depending on the amount of greenhouse gas emissions allowed (60).
- Climate change impacts on aquatic ecosystems are affecting incomes, food security, key cultural dimensions, and livelihoods of resource-dependent communities (61).
- Species shifts are affecting traditional fisheries from the tropics to the polar regions through reduced access to fish stocks, fishing areas, and loss of local knowledge (62).
- Climate change compounds the impact of other practices such as pollution, overfishing, and unsustainable coastal development. These combined impacts are projected to drive many small-scale fisheries and economies out of existence (63).
- Warming of waters affects seafood safety through elevated bioaccumulation of heavy metals and pollutants and an increased prevalence of waterborne pathogens affecting both human and animal health (64).
- Tourism and tourist sites are being affected in many areas that are dependent on local ecosystems. Sustainable diving, snorkeling, angling, marine mammal and bird watching, and other recreational activities and businesses depend on maintenance of healthy aquatic resources (65).
- Climate change degrades coastal ecosystems such as mangroves, sea grasses, marshes, peatlands, and coral reefs that provide services to humans such as protecting coasts from erosion, storms, and flooding, providing key wildlife habitat and sequestering carbon (66).
- Climate change damages riparian ecosystems that provide services to humans, such as protecting streams from flooding, intercepting pollutants, reducing erosion, providing shade and wildlife habitat, sequestering carbon, and storing water during high-flow events (67).

- Climate change contributes to harming wetlands, which provide many of the same services to humans, as stated above. Wetlands play a critical role in carbon storage and sequestration. In particular, peatlands, despite occupying on 3% of the land surface, store twice as much carbon as the world's forests (68).
- The level of impacts will be governed by the level of protective limits our nations place on future emissions combined with riparian and coastal zoning, and changes in fisheries management practices (69).

The Needed Responses

- We assert that rapid action is necessary to drastically curb release of greenhouse gas emissions and to remove and store CO_2 from the atmosphere to prevent the most calamitous consequences of human-caused climate change to marine and freshwater ecosystems on which all humankind depends.
- Global and national targets are necessary to protect and restore carbon dense ecosystems, such as peat, sea grasses, and other wetlands to sequester carbon, prevent greenhouse gas emissions, and reduce the impacts of climate change.
- Governments, the public, industry, academia, and all other sectors of society must prioritize actions and act in a concerted way to halt human-caused climate change if they are to prevent dire consequences.
- A rapid transition towards energy sources and other products and services that do not release greenhouse gases, and research and policies that favor an efficient transition to a low carbon world is required to slow the degradation of aquatic systems, as above. Such a transition could be accomplished by all governments by immediately acting on the advice of specialists in green energy technology, carbon sequestration, marketing, education, socioeconomic principles, and related disciplines.
- Robust adaptation measures; identification and easing of other environmental stressors that act synergistically with climate change; and additional resources for data collection, mapping, and research to better understand potential impacts and to arm natural resources agencies with the tools to mitigate these impacts are essential to better understand and plan for changes in aquatic ecosystems.
- Done intelligently, movement to curtail human-caused climate change can result in advanced, novel technologies; strong economies; healthier aquatic ecosystems; greater food security; and human well-being.

It is time to acknowledge the urgent need to act to address climate change. Delaying action to control greenhouse gas emissions is not an option if humankind wishes to conserve the aquatic resources and environmental safety of the world.

Societies that joined the Statement

American Fisheries Society (AFS)
American Institute of Fishery Research Biologists
American Society of Ichthyologists and Herpetologists
American Water Resources Association
Asian Fisheries Society
Asociación de Oceanólogos de México, A.C.
Asociación Internacional de Hidrogeologos - Mexico Chapter
Asociatia Romana de Limnogeografei (Romanian Limnogeographical Association)
*Association Française de Limnologie / French Limnological Association – EFFS member**
*Associazione Italiana di Oceanologia e Limnologia – EFFS member**
Australian Coral Reef Society
The Australian Freshwater Sciences Society
Australian Marine Sciences Association
Australian Meteorological and Oceanographic Society
Australian Society for Fish Biology
BirdLife Australia
Blue Ventures
The Brazilian Society of Ichthyology
British Phycological Society
Canadian Aquatic Resources Section (CARS) of AFS
Canadian Centre for Evidence-based Conservation
Canadian Conference for Fisheries Research
Canadian Society of Zoologists
Coastal & Estuarine Research Federation
Coastal Research and Education Society of Long Island (CRESLI)
The Coastal Society
Community of Arran Seabed Trust
Conchological Society of Great Britain and Ireland
Croatian Association of Freshwater Ecologists (CAFÉ, HUSEK) – EFFS member
*Czech Limnological Society – EFFS member**
Deep Ocean Stewardship Initiative (Climate and Fisheries WG)
Desert Fishes Council
EFYR European Fresh and Young Scientists – EFFS member
European Federation of Freshwater Sciences (EFFS)
Finnish Limnological Society – EFFS member
Fisheries Society of the British Isles
The Freshwater Biological Association (EFFS member)*
Freshwater Fisheries Society of BC
Freshwater Mollusk Conservation Society
German Ichthyological Society
*German Limnological Society (DGL) – EFFS member**
Gilbert Ichthyological Society
Hungarian Hydrological Society – EFFS member
Hydroecological Society of Ukraine
The Hydrographic Society of America
The Hydrozoan Society

Iberian Association of Limnology – EFFS member
Ichthyological Society of Japan
Ichthyological Society of Ukraine
The Institute of Fisheries Management
International Association for Danube Research
International Association for Great Lakes Research (IAGLR)
International Association of Aquatic and Marine Science Libraries and Information Centers (IAMSLIC)
International Coral Reef Society
International Federation of Hydrographic Societies
International Peatland Society
International Phycological Society
International Seaweed Association
International Society of Limnology
International Water History Association
Irish Freshwater Sciences Association – EFFS member
The Japanese Society of Fisheries Science
Lake Victoria Fisheries Association
The Limnological Society of Turkey (EFS member)
Living Oceans Society
Macrolatinos@ Network
Malacological Society of London
Marine and Oceanographic Technology Network
The Marine Biological Association of India
Marine Biological Association of the United Kingdom
Marine Stewardship Council
National Association of Marine Laboratories (NAML)
Netherlands Malacological Society (Nederlandse Malacologische Vereniging)
The New Zealand Freshwater Sciences Society (NZFSS)
North American Lake Management Society
Oceania Condrichthyan Society
Ocean Conservation Society
Philippine Association of Marine Science
Phycological Society of America
*Polish Limnological Society – EFFS member**
Romanian Ecological Society (EFFS member)
Scientific Committee on Antarctic Research
Serbian Water Pollution Control Society SWPCS – EFFS member
*SIL Austria – EFFS member**
Slovak Ichthyological Society
*Slovak Limnological Society (SLS) – EFFS member**
Sociedad Chilena de Limnología
Sociedad Científica Mexicana de Ecología, A.C.
Sociedad Iberica de Ictiologia
Sociedad Ictiológica Mexicana
Sociedad Mexicana de Planctologia A.C.
Sociedad Mexicana Para El Estudio De Los Florecimientos Algales Nocivos (SOMEFAN) - Mexican Society for the Study of Harmful Algal Blooms
Sociedade Brasileira de Carcinologia

Société Française d'Ichtyologie
Society for Conservation Biology Marine Policy Section
Society for Freshwater Science
The Society for Marine Mammalogy
Society for the Study of Amphibians and Reptiles
Society of Canadian Limnologists/Société canadienne de Limnologie (SC)
Society of Wetland Scientists
Southern African Soc. Aquatic Scientists
Spanish Malacological Society (Sociedad Española de Malacología)
*Swiss Hydrological and Limnological Society – EFFS member**
Vietnam Fisheries Society (VINAFIS)
Western Indian Ocean Marine Science Association
Wild Oceans
World Aquaculture Society
The World Council of Fisheries Societies
World Sturgeon Conservation Society
Zoological Society of Pakistan

* *Denotes both part of EFFS which signed and a society that signed individually*

Notes

(1) Center for International Earth Science Information Network. No date. Percentage of total population living in coastal areas. Center for International Earth Science Information Network, Earth Institute, Columbia University, New York. Available: https://sedac.ciesin.columbia.edu/es/papers/Coastal_Zone_Pop_Method.pdf (July 2020).

(2) Finlayson C. M., G. T. Davies, W. R. Moomaw, G. L. Chmura, S. M. Natali, J. E. Perry, N. Roulet, and A. E. Sutton-Grier. 2019. The second warning to humanity – providing a context for wetland management and policy. Wetlands 39:1–5.

Finlayson C. M., R. D'Cruz, and N. C. Davidson. 2005. Ecosystems and human well-being: wetlands and water, synthesis. World Resources Institute, Washington, D.C. Available: www.millenniumassessment.org/documents/document.358.aspx.pdf (July 2020).

Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. In press. Summary for policymakers. Pages 1–24 */in/* Global warming of 1.5°C: an IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Available: www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf (July 2020).

Ramsar Convention on Wetlands 2018. Global wetland outlook: state of the world's wetlands and their ecosystem services. Ramsar Convention, Gland, Switzerland. Available: www.global-wetland-outlook.ramsar.org (July 2020).

World Wildlife Fund. 2018. Living planet report 2018: aiming higher. World Wildlife Fund, Gland, Switzerland [pages 75 and 54]. Available: https://wwf.panda.org/knowledge_hub/all_publications/living_planet_report_2018/ (July 2020).

(3) World Economic Forum. 2020. The global risks report 2020 [Figure II and page 31]. World Economic Fund, Geneva, Switzerland. Available: www.weforum.org/reports/the-global-risks-report-2020 (July 2020).

(4) European Commission. 2020. The EU strategy on adaptation to climate change [fact sheet]. Available: https://ec.europa.eu/clima/sites/clima/files/docs/eu_strategy_en.pdf (July 2020).

(5) The number of studies that have investigated effects of human-caused climate change on aquatic systems is vast. Most literature compilations combine already observed effects with those projected. In three reports, we counted a total of more than 2,000 studies that reported observed effects on aquatic systems. We did not count projected effects. These reports are as follows:

Barros, V. R., C. B. Field, D. J. Dokken, M. D. Mastrandrea, K. J. Mach, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, and L. L.White, editors. 2014. Climate change 2014 – impacts, adaptation, and vulnerability: Part B: regional aspects. Contribution of Working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.

Field, C. B., V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, and L.L. White, editors. 2014. Climate change 2014 – impacts, adaptation, and vulnerability: part A: global and sectoral aspects. Contribution of Working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.

Krabbenhoft, T. J., B. J. E. Myers, J. P. Wong, C. Chu, R. W. Tingley, J. Falke, T. J. Kwak, C. P. Paukert, and A. J. Lynch. 2020. FiCli, the Fish and Climate Change Database, informs climate adaptation and management for freshwater fishes. Scientific Data 7:124.

Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, and N. M. Weyer, editors. 2019. IPCC special report on the ocean and cryosphere in a changing climate. Available: www.ipcc.ch/srocc/home/ (July 2020).

These are just the beginning of peer-reviewed studies and peer-reviewed compilations of studies that discuss human-caused climate change and the effects of climate change on aquatic ecosystems. Other reports that include both projections and already observed effects on aquatic systems are as follows:

Edenhofer, O., R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, and J.C. Minx, editors. 2014. Climate change 2014: mitigation of climate change. Contribution of Working Group III to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York. [This report gives methods to control greenhouse gas emissions and other ways to “mitigate” or control the factors affecting climate change itself. Cites close to 10,000 studies.]

Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X.

Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. In press. Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Available: www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf (July 2020). [Cites effects on a variety of systems, including both aquatic and terrestrial. The press release accompanying this document states report cites more than 6,000 scientific references and resulted from contribution of thousands of expert and government reviewers worldwide.]

Paukert, G. P., A. J. Lynch, and J. E. Whitney, editors. 2016. Effects of climate change on North American inland fishes. Fisheries 41(7). [Full issue concerning effects of climate change on inland fishes containing more than 90 authors and more than 600 cited references.]

Reidmiller, D. R., C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B.C. Stewart, editors. 2018.//Impacts, risks, and adaptation in the United States: fourth national climate assessment, volume II. U.S. Global Change Research Program, Washington, D.C. [Cites effects on a variety of systems, including both aquatic and terrestrial. More than 5,600 references cited, mostly peer-reviewed, and data sets.]

Stocker, T. F., D. Qin, G.-K Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. M. Midgley, editors. 2013. Climate change 2013: the physical science basis. Contribution of Working Group I to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York. [Discusses the physical scientific evidence for change to both terrestrial and aquatic systems, citing more than 9,200 scientific publications according to the Working Group 1 fact sheet.]

Wuebbles, D. J., D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, and T. K. Maycock, editors. 2017. Climate science special report: fourth national climate assessment, volume I. U.S. Global Change Research Program, Washington, D.C. [Cites effects on a variety of systems, including both aquatic and terrestrial. Number of references not provided, but likely similar to U.S. Global Change Research Program 2018.]

(6) American Geophysical Union (AGU). 2019. Society must address the growing climate crisis now. Position statement. AGU, Washington, D.C.

(7) Statements from various academies of sciences include:

European Academy of Sciences 2015. Statement. Facing critical decisions on climate change in 2015;

The Royal Society and the U.S. National Academy of Sciences. N.D. Climate change evidence & causes. An overview from the Royal Society and the US National Academy of Sciences

Academies of Science for the G8+5 Countries. 2008. Joint science academies' statement: climate change. Adaptation and the transition to a low carbon society;

Academies of Science for the G8+5 Countries. 2007. Joint science academies' statement on growth and responsibility: sustainability, energy efficiency and climate protection;

Network of African Science Academies (NASAC). 2007. Joint statement by the Network of African Science

Academies (NASAC) to the G8 on sustainability, energy efficiency and climate change;

Interacademy Medical Panel (IAMP). N.D. Statement on the health co-benefits of policies to tackle climate change.

(8) See references in 5. References that cite the causes of climate change, including thorough discussions that show overwhelming evidence that emissions are the chief factor, are found in Collins et al. 2013, Edenhofer et al. 2014, and Masson-Delmotte et al. 2018.

(9) See references in 5. Wuebbles et al. 2017 is the primary U.S. report that discusses the physical basis of climate change.

(10) "As a result of the large ocean inertia and the long lifetime of many greenhouse gases, primarily carbon dioxide, much of the warming would persist for centuries after greenhouse gas emissions have stopped." [From Collins, M., R. Knutti, J. Arblaster, J.-L. Dufresne, T. Fichefet, P. Friedlingstein, X. Gao, W. J. Gutowski, T. Johns, G. Krinner, M. Shongwe, C. Tebaldi, A. J. Weaver, and M. Wehner. 2013. Long-term climate change: projections, commitments and irreversibility. Pages 1029–1136 */in/* T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. M. Midgley, editors. Climate change 2013: the physical science basis. Contribution of Working Group I to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge University Press, New York.]

See also Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, E. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, and N. M. Weyer, editors. 2019. Technical summary. Pages 37–69 */in/* IPCC special report on the ocean and cryosphere in a changing climate. Available: www.ipcc.ch/site/assets/uploads/sites/3/2019/11/04_SROCC_TS_FINAL.pdf (July 2020).

Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. In press. Summary for policymakers. Pages 1–24 */in/* Global warming of 1.5°C. An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Available: www.ipcc.ch/site/assets/uploads/sites/2/2019/05/SR15_SPM_version_report_LR.pdf (July 2020).

(11) See citations included in references in 5. Impacts are documented in vast numbers of studies in these citations.

(12) For increasing impacts on the world's oceans, freshwaters, and societies, start with the following:

Bindoff, N. L., W. W. L. Cheung, J. G. Kairo, J. Arístegui, V. A. Guinder, R. Hallberg, N. Hilmi, N. Jiao, M. S. Karim, L. Levin, S. O'Donoghue, S. R. Purca Cuicapusa, B. Rinkevich, T. Suga, A. Tagliabue, and P. Williamson. In press. Changing ocean, marine ecosystems, and dependent communities. Pages 447–587 */in/* H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, and N. M. Weyer, editors. IPCC special report on the ocean and cryosphere in a changing climate. Available: www.ipcc.ch/site/assets/uploads/sites/3/2019/11/09_SROCC_Ch05_FINAL-1.pdf (July 2020).

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