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Erklärung von mehr als 100 Fachgesellschaften für Wasserforschung weltweit zu den Auswirkungen des Klimawandels auf die Wasser-Ökosysteme

„Es ist dringend notwendig, Maßnahmen gegen den vom Menschen verursachten Klimawandel auf der Grundlage wissenschaftlicher Erkenntnisse zu ergreifen!“

Wasser ist die wichtigste natürliche Ressource, denn es ist für das Leben auf der Erde essenziell. Aquatische Ökosysteme, ob Süß- oder Meerwasserökosysteme, bieten der menschlichen Gesellschaft vielfältigen Nutzen. Dazu gehören u.a. die Versorgung mit Sauerstoff, Nahrung, Trinkwasser und genetischen Ressourcen, die Regulierung der Atmosphäre und des Klimas, die Wasserreinigung, das Abschwächen von Stürmen, die Eindämmung von Überschwemmungen und Dürren sowie das Bereitstellen von Erholungsgebieten. Unsere Existenz und unser Wohlbefinden hängen von der Gesundheit und dem guten Funktionieren der aquatischen Ökosysteme ab. Die Menschen siedeln um das Wasser herum – etwa 40 Prozent der Weltbevölkerung lebt innerhalb eines 100 km-Radius von einer Küste entfernt (1).

Die Wasserressourcen der Welt sind derzeit der stärksten Bedrohung in der Geschichte der Menschheit ausgesetzt. Der vom Menschen verursachte Klimawandel beschleunigt die Degradation der aquatischen Ökosysteme und der von ihnen erbrachten Dienstleistungen. Aquatische Ökosysteme gehören weltweit zu den am stärksten betroffenen Ökosystemen. Zum Beispiel wurde bei den Süßwasser-Ökosystemen zwischen 1970 und 2014 ein Rückgang des „freshwater living planet index für species and populations“, einem Maß zur Erfassung der globalen biologischen Vielfalt, um 83 Prozent verzeichnet, während bis zu 90 Prozent der Korallenriffe bis Mitte des Jahrhunderts verschwinden werden, wenn die derzeitigen Trends anhalten (2).

Wir, die Wasserforscher weltweit, verbringen unser Leben damit, diese Systeme zu untersuchen. Wir sehen außergewöhnliche und beunruhigende Veränderungen in den aquatischen Ökosystemen aufgrund des Klimawandels. Wir glauben, dass wir weiterhin wissenschaftliche Erkenntnisse mit der Öffentlichkeit und den politischen Entscheidungsträgern teilen müssen, um die Ernsthaftigkeit dieser Bedrohung und die Notwendigkeit sofortiger Maßnahmen hervorzuheben. Die vom Weltwirtschaftsforum durchgeführte Bewertung globaler Risiken stufte zum ersten Mal die Auswirkungen des "Versagens im Kampf gegen den Klimawandel", des "Verlusts der Biodiversität" und der "Wasserkrise" unter die Top 5-Risiken des nächsten Jahrzehnts ein (3). In den vergangenen Jahren hat die Migration zugenommen und die geopolitischen Spannungen haben sich verschärft: Zwischen 2008 und 2016 waren jährlich über 20 Millionen Menschen aufgrund extremer Wetterereignisse gezwungen, umzuziehen, während laut UNO im Jahr 2017 Wasser in 45 Ländern ein entscheidender Faktor für Konflikte war (3). Diese negativen Auswirkungen dürften unter den gegenwärtigen klimatischen Trends noch zunehmen. In den USA beispielsweise werden die klimabedingten wirtschaftlichen Schäden bis zum Ende des Jahrhunderts schätzungsweise 10 Prozent des Bruttoinlandsprodukts (BIP) erreichen (3). In Europa werden die Mindestkosten für die Nichtanpassung an den Klimawandel auf 100 Milliarden Euro pro Jahr im Jahr 2020 und 250 Milliarden Euro im Jahr 2050 geschätzt (4).

Experten der Umwelt-, Sozial- und Wirtschaftswissenschaften warnen gemeinsam vor einer schweren ökologischen und humanitären Krise mit globalen Auswirkungen, sollten nicht schnellstens weltweit konzertierte Klimaschutzmaßnahmen durchgeführt werden.

Dieses Dokument fasst die wichtigsten wissenschaftlichen Erkenntnisse zusammen, die die Auswirkungen von Klimaveränderungen auf aquatische Ökosysteme beleuchten. Diese Ergebnisse machen deutlich, warum politische Entscheidungsträger weltweit und die gesamte Menschheit jetzt gemeinsam handeln und konzertierte Aktionen einleiten müssen, wenn sie diese Auswirkungen abschwächen wollen.

Die Herausforderungen

- Tausende fachlich geprüfte Studien (peer-reviewed studies) von Wissenschaftlern maßgeblicher Institutionen weltweit haben Beweise für bereits jetzt auftretende, umfängliche Klimaauswirkungen auf aquatische Systeme dokumentiert (5).
- Viele weltweit anerkannte Quellen, einschließlich der American Geophysical Union (6), Nationale Akademien der Wissenschaften aus Dutzenden von Ländern (7), der Weltklimarat IPCC (8) und das vierte nationale Klima-Assessment der USA (9) unterstützen die Feststellung, dass die gestiegenen Treibhausgaskonzentrationen in der Atmosphäre aus fossilen Brennstoffen und der Landnutzungswandel, etwa durch Entwaldung, den derzeitigen Klimawandel vorantreiben.
- Viele dieser Veränderungen sind und werden nicht umkehrbar sein. Sie werden sich weiter verschlechtern, wenn wir an unserem derzeitigen Kurs festhalten. (10).
- Bereits jetzt auftretende Auswirkungen umfassen: die zunehmende Häufigkeit und Schwere von Dürren, Hitzewellen, Überschwemmungen, Waldbränden und Stür-

men; schmelzende Gletscher, die Destabilisierung der großen Eisschilde, die Verschiebung der Meeresströmungen, den Anstieg des Meeresspiegels, die Meeresversauerung und die Reduktion der Sauerstoffverfügbarkeit; Verschiebungen in der Artenzusammensetzung einschließlich der Ausbreitung gebietsfremder invasiver Arten; Ausbrüche von Wasserpflanzen- und Wildtier-Krankheiten; massenhafte Korallenbleiche; eine wachsende Belastung empfindlicher Ökosysteme, menschlicher Gesellschaften sowie der lokalen und globalen Wirtschaft (11).

- Diese Ereignisse sind Vorboten weiterer Schäden für die Fischerei, die Biodiversität und die menschliche Gesellschaft (12).
- Eine verzögerte Umsetzung der Maßnahmen zur Eindämmung der Ursachen des Klimawandels wird die wirtschaftlichen, ökologischen und gesellschaftlichen Folgen verstärken (13).
- Wenn die Menschheit katastrophale Folgen für unsere aquatischen Ökosysteme und für die Menschen, die von ihnen abhängen, vermeiden will, ist es jetzt an der Zeit, den Ausstoß von Treibhausgasen einzudämmen, Treibhausgase aus der Atmosphäre abzuscheiden und sich an das sich bereits verändernde Klima anzupassen (14). Intelligentes und rasches Handeln wird für die aquatischen Ökosysteme und die Menschen, die von ihnen abhängen, von großem Nutzen sein.
- Eine schnelle globale Reaktion und groß angelegtes Handeln sind möglich, wenn Öffentlichkeit und Regierungen sich zu den wissenschaftlichen Fakten bekennen (15).

Die Belege: Auswirkungen auf die marinen Ressourcen

- Bereits jetzt finden Verschiebungen in der Zusammensetzung der Arten, in deren Verhalten, ihrer Häufigkeit und ihrer Biomasse-Produktion statt (16).
- Hummer (17), Kabeljau (18), Makrele (19), Korallenriffische (20) und andere für die Fischerei wichtige Arten (21) bewegen sich entweder polwärts, in tiefere Gewässer oder nehmen in ihrem Bestand ab (22).
- Aufgrund des Klimawandels werden Küstenökosysteme transformiert, degradiert oder gehen verloren (23). Dies schließt Seegras-Wiesen (24), Mangroven (25), Korallenriffe (26) und Algenwälder (27) ein.
- Die Auswirkungen veränderter Artenzusammensetzungen betreffen ganze Ökosysteme (28).
- Kohlenstoffemissionen verursachen die globale Versauerung der Ozeane. Das beeinflusst das Überleben von Organismen, insbesondere von Schalentieren, und beschleunigt die Degradation von Korallenriffen (29).
- Es wurde eine zunehmende Häufigkeit und Intensität mariner Hitzewellen dokumentiert – ein Trend, der sich voraussichtlich fortsetzen wird (30).
- In den vergangenen fünf Jahrzehnten haben sich die globalen Konzentrationen von gelöstem Sauerstoff in den Ozeanen verringert (31).

- Der Klimawandel interagiert mit anderen Stressoren wie einem erhöhten Nährstoffeintrag (32), der Überfischung (33) und Wechselwirkungen mit neuen invasiven Arten (34). Das führt zu einer weiteren Belastung mariner Ökosysteme.
- Der Klimawandel steht im Zusammenhang mit neuen und sich wiederholenden Krankheitsausbrüchen bei Meerestieren und -pflanzen (35).
- Die Abnahme der globalen Biomasse-Produktion von Meerestieren und die Verschiebung in der Artenzusammensetzung verstärken sich, wenn Treibhausgasemissionen nicht reduziert werden (36).
- Seevögel gelten als Indikatoren für langfristige Umweltveränderungen: Fast drei von vier weltweit vorkommenden Seevögeln sind seit 1950 verschwunden, und mehr als die Hälfte der verbliebenen Arten sind erheblich bedroht (37). Allein in Nordamerika wären bei Annahme des 3°C-Szenarios zwei Drittel (389/604) der Vogelarten, zu denen auch Wasservögel gehören, mäßig oder stark durch den Klimawandel gefährdet (38).

Die Belege: Auswirkungen auf Süßwasser-Ressourcen

- Süßwasser-Ökosysteme gehören zu den am stärksten bedrohten Ökosystemen auf der Erde (39).
- Süßwasser-Ökosysteme bedecken weniger als 1 Prozent der Oberfläche des Planeten, stellen aber den Lebensraum für ein Drittel der Wirbeltierarten und 10 Prozent aller Arten (40).
- Die Anpassungsfähigkeit der Süßwasser-Ökosysteme ist angesichts ihrer Beschaffenheit und des Ausmaßes der Auswirkungen des Klimawandels relativ gering (41).
- Der Klimawandel verändert die Häufigkeit von Arten, die Räuber-Beute-Dynamik, die Ausbreitung invasiver Arten, das Wachstum und die Rekrutierung von Arten sowie Interaktionen mit gebietsfremden Arten. Das führt insgesamt zu Rückgängen in der Anzahl und der Vielfalt von Süßwasser-Organismen (42).
- Die zunehmende Häufigkeit, die Intensität und die Dauer von Dürren beeinflussen die Menge und Qualität des sowohl für aquatische Ökosysteme als auch den Menschen zur Verfügung stehenden Süßwassers (43).
- Der Klimawandel wirkt sich auf die Abflussregime der Flüsse aus, einschließlich verstärkter Dürren und Niedrigwasserperioden sowie vermehrter Überschwemmungen. Dies beeinflusst Arten mit spezifischen Strömungsanforderungen und erlaubt eine Ausdehnung von gebietsfremden invasiven Arten, welche z.B. die Fischerträge sowohl von Anglern als auch kommerziellen Fischern beeinflussen und Wasserwege blockieren (44).
- Die geografische Ausbreitung vieler Pflanzen und Tiere hat sich polwärts und in höhere Lagen verlagert, während sich gebietsfremde invasive Arten unter zunehmend warmen Bedingungen ausbreiten (45). Im Gegensatz zu marinen Systemen sind in Süßwasser-Ökosystemen die Wege in andere Lebensräume oft blockiert, was zu lokalem Aussterben führt (46).

- Zeitliche Verschiebungen saisonaler Ereignisse wie Frühjahrhochwässer oder Monsoon beeinflussen den Laicherfolg von Fischen. Das verringert deren Überlebensraten (47).
- Das verstärkte Auftreten von Waldbränden beeinträchtigt aquatische Ökosysteme, indem es die Wassereinzugsgebiete anfälliger für Überschwemmungen macht und die Wasserqualität verringert, insbesondere durch Asche- und Sedimentablagerungen nach Bränden (48).
- Die Kapazität von Feuchtgebieten zur Kohlenstoffspeicherung und zur Eindämmung des Klimawandels wird durch andere Komponenten des globalen Wandels, wie z.B. zunehmende Landerschließung und Brände, herabgesetzt (49).
- Höhere Temperaturen und veränderter Niederschlagsabfluss können zu einer Vermehrung schädlicher Algenblüten führen, die sich negativ auf Fische, Säugetiere, Vögel und sogar Menschen auswirken können (50).
- Die Kombination von Klimawandel und Nährstoffen kann die Eutrophierung verstärken und Wasserqualität und Ökosystemleistungen verschlechtern – mit Auswirkungen auf das Trinkwasser (51).
- Organismen, die von Schneeschmelze und Gletscherbächen abhängen, werden weniger oder verlagern ihre Verbreitung (52).
- Die Freisetzung von Schwermetallen wie Quecksilber, das derzeit in Gletschern und Permafrostböden gebunden ist, wird voraussichtlich zusätzliche Auswirkungen auf Süßwasser-Organismen haben (53).
- Der Klimawandel steht im Zusammenhang mit neuen und sich wiederholenden Krankheitsausbrüchen bei Tieren und Pflanzen des Süßwassers (54).
- Diese scheinbar vielfältigen und kleinräumigen Veränderungen führen insgesamt zu einer multiplen, kumulativen Belastung aquatischer Arten (55).

Die Belege: Auswirkungen auf die von aquatischen Ressourcen abhängige Weltgemeinschaft

- Alle Lebensformen benötigen ausreichend und sauberes Wasser.
- Die Fischerei liefert hochwertiges Protein, das nicht leicht durch terrestrische Quellen ersetzt werden kann. Nach Angaben der Ernährungs- und Landwirtschaftsorganisation der Vereinten Nationen (FAO) macht Fisch 17 Prozent des weltweit verbrauchten tierischen Eiweißes aus. Fischerei und Aquakultur beschäftigen direkt fast 60 Millionen Menschen. Der weltweite Handel mit Fischprodukten erreicht 152 Milliarden USD pro Jahr, wovon 54 Prozent in Entwicklungsländern stattfindet (56).
- Kurzfristig entstehen in neuen eisfreien Gebieten neue Fischfanggebiete (57). Dennoch wird erwartet, dass die Gesamtfangmenge der Fischerei durch die klimabedingte zunehmende Verschlechterung der Wasserqualität und veränderter Primärproduktion zurückgeht – mit entsprechenden Auswirkungen für die Ernährungssicherheit (58). Die Veränderung vieler Fischbestände steht dabei in Bezug zur Erwärmung der Ozeane und den Veränderungen der Primärproduktion. Die Erholung von Fischpopulationen ist um 3 Prozent pro Jahrzehnt zurückgegangen und das

maximale Fangpotenzial war im 20. Jahrhundert um 4,1 Prozent rückläufig (59). Der Anstieg der Wassertemperatur aufgrund des Klimawandels wird voraussichtlich die Toleranzgrenzen von 10-60 Prozent der Süßwasser- und Meeresarten bis zum Jahr 2100 übersteigen – in Abhängigkeit von der Menge der erlaubten Treibhausgasemissionen (60).

- Die Effekte des Klimawandels auf aquatische Ökosysteme wirken sich auf die Einkommen, die Ernährungssicherheit, wichtige kulturelle Bereiche und die Lebensgrundlagen der von Ressourcen abhängigen Bevölkerungsgemeinschaften aus (61).
- Artenverschiebungen beeinträchtigen die traditionelle Fischerei von den Tropen bis zu den Polarregionen durch eingeschränkten Zugang zu Fischbeständen und den Fischerei-Gebieten sowie den Verlust von lokalem Wissen (62).
- Der Klimawandel verstärkt auch andere Prozesse, wie Verschmutzung, Überfischung und nicht nachhaltige Küstenentwicklung. Zusammen mit dem Klimawandel werden sie dazu beitragen, dass viele kleine Fischereibetriebe und Volkswirtschaften ihre Existenz verlieren (63).
- Die Erwärmung der Gewässer beeinträchtigt die Unbedenklichkeit von Meeresfrüchten durch erhöhte Bioakkumulation von Schwermetallen und anderen Schadstoffen. Die Erwärmung trägt zur erhöhten Verbreitung von Krankheitserregern im Wasser bei, die sowohl Menschen als auch Tiere befallen können (64).
- Tourismus und touristische Stätten sind in vielen Bereichen betroffen, die von lokalen Ökosystemen abhängig sind. Nachhaltiges Tauchen, Schnorcheln, Angeln, Meeressäuger- und Vogelbeobachtung sowie andere Freizeitaktivitäten und Geschäfte hängen von der Erhaltung gesunder aquatischer Systeme ab (65).
- Durch den Klimawandel werden Küstenökosysteme wie Mangroven, Seegrasbestände, Sumpfbereiche, Torfmoore und Korallenriffe, die Dienstleistungen für den Menschen erbringen, geschädigt. Zu den Dienstleistungen zählen z.B. der Schutz der Küsten vor Erosion, Stürmen und Überschwemmungen, die Bereitstellung von wichtigem Lebensraum für Tiere und die Bindung von Kohlenstoff (66).
- Der Klimawandel schädigt Uferökosysteme, die Ökosystemleistungen für den Menschen erbringen. Dazu gehört der Schutz vor Überschwemmungen, das Abfangen von Schadstoffen, die Verringerung der Erosion, die Beschattung und Bereitstellung von wichtigen Lebensräumen für Tiere, die Bindung von Kohlenstoff und der Wasserrückhalt bei Hochwasserereignissen (67).
- Der Klimawandel trägt zur Schädigung von Feuchtgebieten bei, die viele der oben genannten Leistungen für den Menschen erbringen. Feuchtgebiete spielen eine entscheidende Rolle bei der Kohlenstoffbindung und -speicherung. Torfgebiete zum Beispiel binden doppelt so viel Kohlenstoff wie die weltweiten Wälder – obwohl sie nur 3 Prozent der Landfläche einnehmen (68).
- Das Ausmaß der Auswirkungen des Klimawandels wird durch die Emissionsgrenzen bestimmt, auf die sich die Weltgemeinschaft künftig festlegt – in Verbindung mit der Ausweisung von zu schützenden Ufer- und Küstengebieten und der Änderungen der Praktiken der Fischereiwirtschaft (69).

Die notwendigen Antworten

- Wir bekräftigen, dass rasches Handeln erforderlich ist, um die Treibhausgasemissionen drastisch einzudämmen sowie CO₂ aus der Atmosphäre zu entfernen und zu speichern. Nur so wird es gelingen, die katastrophalsten Folgen des vom Menschen verursachten Klimawandels für Meeres- und Süßwasser-Ökosysteme, auf die die gesamte Menschheit angewiesen ist, zu verhindern.
- Es sind globale und nationale Zielvorgaben notwendig, um kohlenstoffreiche Ökosysteme, wie Torfmoore, Seegraswiesen und andere Kohlenstoff speichernde Feuchtgebiete zu ertüchtigen und zu schützen, um Treibhausgasemissionen zu verhindern und die Auswirkungen des Klimawandels abzumildern.
- Regierungen, die Öffentlichkeit, die Industrie, die Wissenschaft und alle anderen Bereiche der Gesellschaft müssen Prioritäten setzen und konzertiert handeln, um den vom Menschen verursachten Klimawandel aufzuhalten und schlimme Folgen zu verhindern.
- Um die Degradation aquatischer Systeme wie oben beschrieben zu verlangsamen, ist ein rascher Übergang zu Energiequellen und anderen Produkten und Dienstleistungen, die keine Treibhausgase freisetzen, erforderlich. Außerdem bedarf es Forschung und Politik, die einen effizienten Übergang zu einer kohlenstoffarmen Welt begünstigen – und die auf den Empfehlungen der Spezialisten verschiedener Disziplinen basieren.
- Essenziell für ein besseres Verständnis aquatischer Ökosysteme und das Management von Veränderungen sind: Robuste Anpassungsmaßnahmen; Identifizierung und Entlastung von anderen Umweltstressoren, die synergistisch mit der Klimaänderung wirken; zusätzliche Ressourcen für Datenerfassung, Kartierung und Forschung zum besseren Verständnis potenzieller Auswirkungen des Klimawandels und zur Unterstützung von Umweltbehörden.
- Intelligent gemacht, kann eine Bewegung hin zur Eindämmung des vom Menschen verursachten Klimawandels zu fortschrittlichen und neuartigen Technologien führen, die die Wirtschaft stärken sowie zu gesünderen aquatischen Ökosystemen, größerer Ernährungssicherheit und menschlichem Wohlbefinden beitragen.

Es ist an der Zeit anzuerkennen, dass Maßnahmen gegen den Klimawandel dringend notwendig sind. Ein Aufschub der Maßnahmen zur Kontrolle der Treibhausgasemissionen ist keine Option, wenn die Menschheit die Wasser-Ressourcen und eine sichere Umwelt auf der Erde erhalten möchte.

Der vorliegende Text ist eine Übersetzung der englischsprachigen Erklärung, die durch das Helmholtz-Zentrum für Umweltforschung (UFZ) angefertigt wurde. Im Falle von inhaltlichen Widersprüchen zwischen dem deutschen und dem englischen Text hat der englische Originaltext Priorität.

Fachgesellschaften, die sich der Erklärung angeschlossen haben:

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 Hidrogeólogos - 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 Chondrichthyan 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 Ictiología
 Sociedad Ictiológica Mexicana
 Sociedad Mexicana de Planctología 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

* *Diese Gesellschaften sind als Mitglieder der European Federation for Freshwater Sciences (EFFS) Teil der Unterzeichner und haben das Statement zusätzlich individuell unterzeichnet.*

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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. Alegria, 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).

Brugere C., D. M. Onuigbo, and K. L. Morgan. 2017. People matter in animal disease surveillance: challenges and opportunities for the aquaculture sector. *Aquaculture* 467:158–169.

Fleming, E., J. Payne, W. Sweet, M. Craghan, J. Haines, J. F. Hart, H. Stiller, and A. Sutton-Grier. 2018. Coastal effects. Pages 322–352 /in/ D. R. Reidmiller, C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart, editors. Impacts, risks, and adaptation in the United States: fourth national climate assessment, volume II. U.S. Global Change Research Program, Washington, D.C.

Hoegh-Guldberg, O., D. Jacob, M. Taylor, M. Bindi, S. Brown, I. Camilloni, A. Diedhiou, R. Djalante, K.L. Ebi, F. Engelbrecht, J. Guiot, Y. Hijikata, S. Mehrotra, A. Payne, S.I. Sen-
eviratne, A. Thomas, R. Warren, and G. Zhou. In press. Impacts of 1.5°C global warming on natural and human systems. Pages 175–311 /in/ V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pid-
cock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. May-
cock, M. Tignor, and T. Waterfield, editors. Global warming of 1.5°C. An IPCC special re-
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global greenhouse gas emission pathways, in the context of strengthening the global re-
sponse to the threat of climate change, sustainable development, and efforts to eradicate
poverty. Available: [www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15 Chap-
ter3 Low Res.pdf](http://www.ipcc.ch/site/assets/uploads/sites/2/2019/02/SR15_Chap-
ter3_Low_Res.pdf) (July 2020).

Lipton, D., M. A. Rubenstein, S. R. Weiskopf, S. Carter, J. Peterson, L. Crozier, M. Fogarty, S. Gaichas, K. J. W. Hyde, T. L. Morelli, J. Morissette, H. Moustahfid, R. Muñoz, R. Poudel, M. D. Staudinger, C. Stock, L. Thompson, R. Waples, and J. F. Weltzin. 2018. Ecosystems, ecosystem services, and biodiversity. Pages 268–321 /in/ D. R. Reidmiller, C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart, editors. Impacts, risks, and adaptation in the United States: fourth national climate assessment, volume II. U.S. Global Change Research Program, Washington, D.C.

Pershing, A. J., R. B. Griffis, E. B. Jewett, C. T. Armstrong, J. F. Bruno, D. S. Busch, A. C. Haynie, S. A. Siedlecki, and D. Tommasi. 2018. Oceans and marine resources. Pages 353–390 /in/ D. R. Reidmiller, C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, and B. C. Stewart, editors. Impacts, risks, and adaptation in the United States: fourth national climate assessment, volume II. U.S. Global Change Research Program, Washington, D.C.

Pörtner, H.-O., D. M. Karl, P. W. Boyd, W. W. L. Cheung, S. E. Lluch-Cota, Y. Nojiri, D. N. Schmidt, and P. O. Zavialov. 2014. Ocean systems. Pages 411–484 /in/ C. B. Field, 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. 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.

Settele, J., R. Scholes, R. Betts, S. Bunn, P. Leadley, D. Nepstad, J. T. Overpeck, and M. A. Taboada. 2014. Terrestrial and inland water systems. Pages 271–359 /in/ C. B. Field, 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. 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.

Wong, P. P., I. J. Losada, J.-P. Gattuso, J. Hinkel, A. Khattabi, K. L. McInnes, Y. Saito, and A. Sallenger. 2014. Coastal systems and low-lying areas. Pages 361–409 /in/ C. B. Field, 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. *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.

- (13) 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) [Pages 7–11].

World Bank. 2019. *Climate change and marine fisheries in Africa: assessing vulnerability and strengthening adaptation capacity*. World Bank, Washington, D.C.

- (14) 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) [Page 4].

- (15) Some examples of large-scale, rapid action in response to disease epidemics reported in the following:

Cheng, V. C. C., S. C. Wong, J. H. K. Chen, C. C. Y. Yip, V. W. M. Chuang, O. T. Y. Tsang, S. Sridhar, J. F.W. Chan, P. L. Ho, and K.Y. Yuen. 2020. Escalating infection control response to the rapidly evolving epidemiology of the coronavirus disease 2019 (COVID-19) due to SARS-CoV-2 in Hong Kong. *Infection Control and Hospital Epidemiology* 41:493–498.

Smith, N., and M. Fraser. 2020. Straining the system: novel coronavirus (COVID-19) and preparedness for concomitant disasters. *American Journal of Public Health* 110:648–649.

Sohrabi, C., Z. Alsafi, N. O'Neill, M. Khan, A. Kerwan, A. Al-Jabir, C. Iosifidis, and R. Agha. 2020. World Health Organization declares global emergency: a review of the 2019 novel coronavirus (COVID-19), *International Journal of Surgery* 76:71–76.

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Burrows, M. T., D. S. Schoeman, A. J. Richardson, J. G. Molinos, A. Hoffmann, L. B. Buckley, P. J. Moore, C. J. Brown, J. F. Bruno, C. M. Duarte, B. S. Halpern, O. Hoegh-Guldberg, C. V. Kappel, W. Kiessling, M. I. O'Connor, J. M. Pandolfi, C. Parmesan, W. J.

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