

Declaração das Sociedades Científicas de Ciências Aquáticas sobre a necessidade de tomar medidas urgentes contra as alterações climáticas causadas pelo homem, com base em evidências científicas

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A água é o recurso natural mais importante da Terra, pois é vital para a vida. Os ecossistemas aquáticos, marinhos ou de águas doces, fornecem vários benefícios para a sociedade humana, como o fornecimento de oxigênio, alimentos, água potável e recursos genéticos; regulação da composição atmosférica e do clima; purificação da água; proteção contra tempestades; mitigação de inundações / secas; áreas de recreação; e outros fins. A nossa existência e bem-estar dependem da saúde e do bom funcionamento dos ecossistemas aquáticos. As pessoas distribuem-se naturalmente em torno da água - aproximadamente 40% da população mundial vive num raio de 100 km de uma costa¹.

Os recursos aquáticos do mundo estão agora sob sua maior ameaça na história da humanidade. As alterações climáticas causadas pelos humanos estão a acelerar a degradação dos ecossistemas aquáticos e dos serviços que eles fornecem. Os ecossistemas aquáticos estão entre os mais afetados em todo o mundo (por exemplo, no caso dos ecossistemas de água doce, uma medida da biodiversidade, o “índice do planeta vivo de água doce para populações de espécies”, diminuiu 83% de 1970 a 2014, enquanto até 90% dos recifes de coral desaparecerão em meados do século se as tendências atuais continuarem)².

Nós, cientistas aquáticos do mundo, passamos as nossas vidas a estudar estes sistemas. Estamos a ver alterações excecionais e perturbadoras nos ecossistemas aquáticos do mundo devido às alterações climáticas e acreditamos que temos o dever de partilhar as descobertas científicas validadas por pares com o público e legisladores para enfatizar a gravidade desta ameaça e a necessidade de ação imediata. Pela primeira vez, a avaliação de riscos globais conduzidos pelo Fórum Económico Mundial classificou o impacto de "falha da ação climática", “perda de biodiversidade” e “crise hídrica” entre os cinco principais riscos na próxima década³. Nos últimos anos, a migração aumentou e as tensões geopolíticas foram exacerbadas: entre 2008 e 2016, anualmente mais de 20 milhões de pessoas foram forçadas a se deslocar devido a eventos climáticos extremos, enquanto, de acordo com as Nações Unidas, em 2017, a água foi um importante fator de conflito em 45 países³. Estes efeitos negativos deverão aumentar com as tendências climáticas atuais. Por exemplo, nos Estados Unidos, o dano económico relacionado com clima é estimado em 10% do produto interno bruto até o final do século³. Na Europa, o custo mínimo da não adaptação às alterações climáticas é estimado em € 100 bilhões por ano em 2020 e € 250 bilhões em 2050⁴.

Especialistas nas áreas ambiental, social e económica apontam coletivamente para uma crise ambiental e humanitária severa, com repercussões a nível global, a menos que ações climáticas mundialmente concertadas sejam implementadas com urgência.

Este documento resume as principais descobertas científicas, destacando o efeito das mudanças climáticas sobre os ecossistemas aquáticos. As descobertas fornecem evidências dos efeitos que estão a acontecer atualmente e por que razão os legisladores mundiais e toda a humanidade precisam agir em conjunto e lançar ações concertadas agora, se se quiser mitigar esses impactos.

O Desafio

- Milhares de estudos escrutinados por cientistas de instituições de elevada reputação mundial têm documentado evidências dos efeitos do clima nos sistemas aquáticos que estão em curso e são extensivos⁵.

- Muitas fontes mundialmente respeitadas, incluindo a American Geophysical Union⁶, Academias Nacionais de Ciências de dezenas de países⁷, o Painel Intergovernamental sobre Mudanças Climáticas⁸, e a Quarta Avaliação Nacional do Clima dos EUA⁹ validam a descoberta que um aumento das concentrações atmosféricas de gases de efeito estufa provenientes da queima de combustíveis fósseis (ou seja, emissões) e as alterações no uso da terra, como a desflorestação, estão a impulsionar as mudanças climáticas atuais.
- Muitas dessas mudanças são e serão irreversíveis. Elas vão continuar a piorar se persistirmos na nossa trajetória atual¹⁰.
- Os impactos que já ocorrem incluem aumento na frequência, intensificação e severidade das secas, ondas de calor, inundações, incêndios florestais e tempestades; derretimento de glaciares; desestabilização de grandes mantos de gelo; mudança nas correntes oceânicas, aumento do nível do mar; acidificação e desoxigenação do oceano; alterações na área de distribuição de espécies, incluindo a expansão de espécies exóticas invasoras; surtos de doenças em plantas aquáticas e animais selvagens; eventos de branqueamento massivo de corais; e mais, com um pedágio crescente em ecossistemas vulneráveis, sociedades humanas, e economias locais e globais¹¹.
- Estes eventos são precursores de danos ainda maiores à pesca, à biodiversidade e à sociedade humana¹².
- Atrasar ações para impedir as causas subjacentes da mudança climática agravará as consequências económicas, ambientais e sociais¹³.
- Se a humanidade deseja evitar as consequências calamitosas para os nossos ecossistemas aquáticos e humanos que deles dependem, agora é o tempo para reduzir as emissões de gases de efeito estufa, sequestrar gases de efeito estufa e nos adaptarmos a um clima em mudança¹⁴. Um movimento rápido e inteligente em direção a esses objetivos proporcionará grandes benefícios aos ecossistemas aquáticos e aos humanos que deles dependem.
- Uma resposta global rápida e ações em larga escala são possíveis se existir um compromisso público e governamental¹⁵.

A Evidência: Efeitos nos Recursos Marinhos

- Estão em curso alterações na composição das espécies, comportamento, abundância e produção de biomassa¹⁶.
- As lagostas¹⁷, o bacalhau¹⁸, a cavala¹⁹, os peixes de recifes de coral²⁰, e outras espécies importantes para a pesca²¹ estão-se a movimentar em direção aos polos, para águas mais profundas ou em declínio²².
- Os ecossistemas costeiros estão a ser transformados, degradados ou perdidos, maioritariamente²³ ou em parte devido às alterações climáticas. As alterações incluem os prados marinhos²⁴, mangais²⁵, recifes de coral²⁶, e florestas de algas²⁷.
- Os efeitos das alterações na composição de espécies estão a afetar todo o ecossistema²⁸.
- As emissões de carbono causam a acidificação global dos oceanos, o que está a afetar a sobrevivência dos organismos, especialmente crustáceos, e a acelerar a erosão dos recifes de coral²⁹.

- Tem sido documentado um aumento da frequência e intensidade das ondas de calor marinhas; prevê-se que estas ondas de calor continuem³⁰.
- Têm sido documentadas reduções nas concentrações globais de oxigénio dissolvido nos oceanos nas últimas cinco décadas³¹.
- A alteração climática está a interagir com outros fatores de stress, como o excesso de entrada de nutrientes³², pesca excessiva³³, e novas interações entre espécies³⁴ que suprimem ainda mais os ecossistemas marinhos.
- A alteração climática está ligada a surtos de doenças emergentes e re-emergentes na vida selvagem marinha e em espécies de plantas³⁵.
- A produção global de animais marinhos continua a diminuir e as alterações na composição das espécies irão aumentar, a menos que as emissões de gases de efeito estufa sejam reduzidas³⁶.
- As aves marinhas são reconhecidas como indicadores de alterações ambientais de longo prazo: quase três em cada quatro aves marinhas do mundo desapareceram desde 1950, e mais da metade das espécies restantes enfrentam ameaças substanciais³⁷. Só na América do Norte, dois terços (389/604) das espécies de aves, o que inclui aves aquáticas, são moderadamente ou altamente vulneráveis às alterações climáticas num cenário de aumento da temperatura em 3°C³⁸.

A Evidência: Efeitos nos Recursos de Água Doce

- Os ecossistemas de água doce estão entre os mais ameaçados da Terra³⁹.
- Os ecossistemas de água doce cobrem menos de 1% da superfície do planeta, mas sustentam um terço das espécies de vertebrados e 10% de todas as espécies⁴⁰.
- A capacidade de adaptação de todos os ecossistemas de água doce é relativamente baixa, dada a natureza dos sistemas e a escala dos impactos das alterações climáticas⁴¹.
- As alterações climáticas estão a alterar a abundância, a dinâmica predador-presa, a expansão de espécies invasoras, o crescimento, o recrutamento de espécies e novas interações entre espécies, levando ao declínio no número e diversidade de organismos aquáticos de água doce⁴².
- O aumento da frequência, intensidade e duração da seca estão a afetar a quantidade e a qualidade da água doce disponível para os ecossistemas aquáticos e os seres humanos⁴³.
- As alterações climáticas afetam os regimes de caudal dos rios, incluindo tanto aumento de secas quanto os períodos de baixos caudais e ainda cheias. Estas alterações impactam principalmente espécies nativas que vivem em faixas estreitas de caudais e permitem a expansão de espécies exóticas invasoras, afetando assim a pesca recreativa e comercial de peixes e ainda as hidrovias⁴⁴.
- As variações geográficas de muitas plantas e animais mudaram em direção aos polos e para altitudes mais elevadas, enquanto espécies exóticas-invasoras se expandem com as condições cada vez mais quentes⁴⁵. Ao contrário dos sistemas marinhos, a deslocação para outros habitats está frequentemente bloqueada, levando a extinções localizadas⁴⁶.
- Alterações temporais em sinais sazonais, como escoamento de primavera ou estações de monções, afetam o sucesso da desova de peixes, resultando em baixa sobrevivência⁴⁷.

- Uma incidência elevada de incêndios florestais está a afetar os sistemas aquáticos, tornando as bacias hidrográficas mais suscetíveis às inundações e reduzindo a qualidade da água, especialmente com cinzas pós-incêndio e deposição de sedimentos⁴⁸.
- A capacidade das zonas húmidas para armazenamento de carbono e mitigação das alterações climáticas está a ser deteriorada por mudanças ligadas a alterações no clima e outros componentes da mudança global, tais como alterações no uso do solo e incêndios⁴⁹.
- As temperaturas elevadas e o escoamento da precipitação promovem a proliferação de algas prejudiciais, que podem prejudicar peixes, mamíferos, aves e até mesmo os humanos⁵⁰.
- As mudanças climáticas podem agir sinergicamente com o incremento em nutrientes para aumentar a eutrofização e degradar ainda mais a qualidade da água e os serviços ecossistémicos, incluindo a disponibilidade de água potável⁵¹.
- Os organismos dependentes de água proveniente do derretimento da neve e riachos glaciais estão a diminuir ou a alterar a sua distribuição⁵².
- Projeta-se que a liberação de metais pesados como o mercúrio, atualmente armazenado nos glaciares e no permafrost vá afetar ainda mais os organismos de água doce⁵³.
- A mudança climática está ligada a surtos de doenças emergentes e re-emergentes na vida selvagem de água doce e em espécies de plantas⁵⁴.
- Estas alterações aparentemente diversas e de pequena escala combinam-se para criar stresses múltiplos e, cumulativamente que são um desafio para as espécies aquáticas⁵⁵.

A Evidência: Efeitos Sobre a Sociedade Mundial Dependente dos Recursos Aquáticos

- Água limpa e em quantidade suficiente é necessária para todas as formas de vida.
- A pesca fornece fontes de proteína de qualidade que não são facilmente substituídas por fontes terrestres. De acordo com a Organização para Alimentos e Agricultura das Nações Unidas, o peixe é responsável por 17% da proteína animal que consumidos globalmente. A pesca e a aquicultura empregam diretamente quase 60 milhões de pessoas, e globalmente o comércio de produtos da pesca chega aos US \$ 152 bilhões ao ano, sendo 54% originários de países em desenvolvimento⁵⁶.
- No curto prazo de tempo, novas pescarias aparecerão em algumas áreas livres de gelo recém-formadas⁵⁷. Contudo, prevê-se que a captura global de peixes diminua em consequência do declínio crescente na qualidade da água e na produção primária como resultado das alterações climáticas, com efeitos correspondentes na segurança alimentar⁵⁸. O aquecimento dos oceanos e as mudanças na produtividade primária estão relacionados com as mudanças na quantidade de peixes. O restabelecimento de populações de peixes diminuiu 3% por década, e o potencial máximo de captura diminuiu 4,1% ao longo do século 20⁵⁹. Aumentos na temperatura da água devido às mudanças climáticas são projetados para exceder os limites de tolerância de 10-60% das espécies de água doce e marinhas até 2100, dependendo da quantidade de emissões de gases de efeito estufa permitidas⁶⁰.

- Os impactos das alterações climáticas nos ecossistemas aquáticos estão a afetar o rendimento, a segurança alimentar, aspetos culturais importantes e meios de subsistência de comunidades dependentes de recursos⁶¹.
- Alterações na distribuição de espécies estão a afetar a pesca tradicional dos trópicos às regiões polares por meio da redução do acesso aos estoques de peixes, áreas de pesca e perda de conhecimento local⁶².
- As alterações climáticas aumentam o impacto de outras práticas, como poluição, pesca excessiva e desenvolvimento costeiro insustentável. É esperado que esses impactos combinados conduzam ao fim de muitas atividades pesqueiras de pequena escala e da sua importância económica⁶³.
- O aquecimento das águas afeta a segurança dos recursos alimentares do mar por meio da elevada bioacumulação de metais pesados e poluentes e uma maior prevalência de organismos patogénicos transmitidos pela água e que afetam a saúde de humanos e animais⁶⁴.
- O turismo e os locais turísticos estão a ser afetados em muitas áreas que dependem dos ecossistemas locais. O mergulho sustentável, *snorkeling*, pesca, observação de mamíferos marinhos e aves e outras atividades recreativas e económicas dependem da manutenção de recursos aquáticos saudáveis⁶⁵.
- As alterações climáticas degradam os ecossistemas costeiros, como mangais, pradarias marinhas, pântanos, turfeiras e recifes de coral que prestam serviços aos humanos, como a proteção das costas contra a erosão, tempestades e inundações, fornecendo habitat essencial para a vida selvagem e sequestrando carbono⁶⁶.
- As alterações climáticas danificam os ecossistemas ribeirinhos que prestam serviços aos humanos, como protegendo os rios das cheias, interceptando poluentes, reduzindo a erosão, proporcionando sombra e habitat à vida selvagem, sequestrando carbono e armazenando água durante eventos de alto caudal⁶⁷.
- As alterações climáticas contribuem para prejudicar as zonas húmidas, que fornecem muitos dos mesmos serviços para humanos, como afirmado acima. As zonas húmidas desempenham um papel crítico no armazenamento e sequestro de carbono. Em particular, as turfeiras, apesar de ocuparem 3% da superfície terrestre, armazenam duas vezes mais carbono do que as florestas do mundo⁶⁸.
- O nível de impactos será governado pelo nível da proteção que nossas nações coloquem nas emissões futuras, combinadas com a zonação ripícola e costeira e as alterações nas práticas de gestão da pesca⁶⁹.

A Necessidade de Respostas

- Afirmamos que uma ação rápida é necessária para reduzir drasticamente a emissões de gases de efeito estufa e para remover e armazenar dióxido de carbono da atmosfera para evitar as consequências mais calamitosas das alterações climáticas causadas pela humanidade nos ecossistemas marinhos e de água doce, dos quais toda a humanidade depende.
- São necessárias metas globais e nacionais para proteger e restaurar ecossistemas densos em carbono, como turfeiras, pradarias marinhas e outras zonas húmidas para sequestrar carbono, prevenir as emissões de gases de efeito estufa e reduzir os impactos das alterações climáticas.

- Os governos, o público, a indústria, a academia e todos os restantes setores da sociedade devem priorizar ações e agir de forma concertada para travar as alterações climáticas causadas pela humanidade, se quiserem prevenir consequências indesejáveis.
- É necessária uma rápida transição para fontes de energia e outros produtos e serviços que não lancem gases de efeito estufa, investigações e políticas que favoreçam uma transição eficiente para um mundo de baixo carbono de forma a diminuir a degradação dos sistemas aquáticos, como acima indicado. Essa transição poderia ser realizada por todos os governos, agindo imediatamente sob o conselho de especialistas em tecnologia de energia verde, sequestro de carbono, marketing, educação, princípios socioeconómicos e disciplinas afins.
- É essencial tomar medidas de adaptação robustas, proceder à identificação e atenuação de outros agentes de stress ambiental que atuam sinergicamente com as alterações climáticas; e colocar recursos adicionais para recolha de dados, mapeamento e investigação para entender melhor os impactos potenciais e munir as agências de recursos naturais com ferramentas para mitigar esses impactos de forma a melhor compreender e planear para as alterações nos ecossistemas aquáticos.
- Feito de forma inteligente, o movimento para reduzir as alterações climáticas causadas pelo homem pode resultar em avanços, novas tecnologias; economias fortes; ecossistemas aquáticos mais saudáveis; maior segurança alimentar; e melhoria do bem-estar humano.

É hora de reconhecer a necessidade urgente de agir para enfrentar as alterações climáticas. Atrasando ações para controlar as emissões de gases de efeito estufa não é uma opção se a humanidade deseja conservar o meio aquático e segurança ambiental do mundo.

Notas

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. Moufou-ma-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. 2018. 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. 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. Moufou-ma-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. 2018. 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. (September 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 the following:
 - European Academy of Sciences. 2015. Statement. Facing critical decisions on climate change in 2015. Available: <https://easac.eu/publications/details/facing-critical-decisions-on-climate-change-in-2015/>. (September 2020).
 - The Royal Society and the U.S. National Academy of Sciences. 2020. Climate change evidence & causes: update 2020. An overview from the Royal Society and the US National Academy of Sciences. Available: https://royalsociety.org/-/media/Royal_Society_Content/policy/projects/climate-evidence-causes/climate-change-evidence-causes.pdf. (September 2020).
 - Academies of Science for the G8+5 Countries. 2008. Joint science academies' statement: climate change: adaptation and the transition to a low carbon society. Available: http://insaindia.res.in/pdf/Climate_05.08_W.pdf. (September 2020).
 - Academies of Science for the G8+5 Countries. 2007. Joint science academies' statement on growth and responsibility: sustainability, energy efficiency and climate protection. Available: www.scj.go.jp/ja/info/kohyo/pdf/kohyo-20-s4.pdf (September 2020).
 - 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. Available: www.interacademies.org/sites/default/files/publication/nasac_g8_statement_07_-_low_res.pdf. (September 2020).
 - Interacademy Medical Panel (IAMP). 2010. Statement on the health co-benefits of policies to tackle climate change. Available: www.interacademies.org/statement/iamp-statement-health-co-benefits-policies-tackle-climate-change. (September 2020).
 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. Fichet, 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 the following:
- Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufou-ma-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. 2018. 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_HR.pdf. (September 2020).
 - Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, E. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegria, 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 (September 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. 2019. 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. Alegria, 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. (September 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. Seneviratne, A. Thomas, R. Warren, and G. Zhou. 2018. 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. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. *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/2/2019/02/SR15_Chapter3_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. 2018. 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. 2018. 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.
16. Bindoff, N. L., W. W. L. Cheung, J. G. Kairo, J. Aristegui, 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. 2019. 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. Alegria, 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. (September 2020). [Pages 450–451, 478– 481.]
- 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. Sydeman, S. Ferrier, K. J. Williams, and E. S. Poloczanska. 2014. Geographical limits to species-range shifts are suggested by climate velocity. *Nature* 507:492–495.
- Chambers, L. E., P. Dann, B. Cannell, and E. J. Woehler. 2014. Climate as a driver of phenological change in southern seabirds. *International Journal of Biometeorology* 58:603–612.
- Chambers, L. E., C. A. Devney, B. C. Congdon, N. Dunlop, E. J. Woehler, and P. Dann. 2011. Observed and predicted impacts of climate on Australian seabirds. *Emu* 111:235–251.
- 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. Seneviratne, A. Thomas, R. Warren, and G. Zhou. 2018. 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. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. *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/2/2019/02/SR15_Chapter3_Low_Res.pdf. (July 2020). [Pages 218, 222.]
- Nagelkerken, I., and S. D. Connell, 2015: Global alteration of ocean ecosystem functioning due to increasing human CO₂ emissions. *Proceedings of the National Academy of Sciences of the United States of America* 112:13272–13277.
- Poloczanska, E. S., C. J. Brown, W. J. Sydeman, W. Kiessling, D. S. Schoeman, P. J. Moore, K. Brander, J. F. Bruno, L. B. Buckley, M. T. Burrows, C. M. Duarte, B. S. Halpern, J. Holding, C. V. Kappel, M. I. O’Connor, J. M. Pandolfi, C. Parmesan, F. Schwing, S. A. Thompson, and A. J. Richardson. 2013. Global imprint of climate change on marine life. *Nature Climate Change* 3:919–925.

- Price C. A., K. Hartmann, T. J. Emery, E. J. Woehler, C. R. McMahon, M. A. Hindell. 2020. Climate variability and breeding parameters of a trans-hemispheric migratory seabird over seven decades. *Marine Ecology Progress Series* 642:191–205.
- Vergés, A., P. D. Steinberg, M. E. Hay, A. G. B. Poore, A. H. Campbell, E. Ballesteros, K. L. Heck, D. J. Booth, M. A. Coleman, D. A. Feary, W. Figueira, T. Langlois, E. M. Marzinelli, T. Mizerek, P. J. Mumby, Y. Nakamura, M. Roughan, E. van Sebille, A. S. Gupta, D. A. Smale, F. Tomas, T. Wernberg, and S. K. Wilson, 2014. The tropicalization of temperate marine ecosystems: climate-mediated changes in herbivory and community phase shifts. *Proceedings of the Royal Society B* 281(1789):20140846.
17. Caputi, N., R. Melville-Smith, S. de Lestang, A. Pearce, and M. Feng. 2010. The effect of climate change on the western rock lobster (*Panulirus cygnus*) fishery of Western Australia. *Canadian Journal of Fisheries and Aquatic Sciences* 67:85–96.
- Gould, W. A., E. L. Díaz, (co-leads), N. L. Álvarez-Berrios, F. Aponte-González, W. Archibald, J. H. Bowden, L. Carrubba, W. Crespo, S. J. Fain, G. González, A. Goulbourne, E. Harmsen, E. Holup-chinski, A. H. Khalyani, J. Kossin, A. J. Leinberger, V. I. Marrero-Santiago, O. Martínez-Sánchez, K. McGinley, P. Méndez-Lázaro, J. Morell, M. M. Oyola, I. K. Parés-Ramos, R. Pulwarty, W. V. Sweet, A. Terando, and S. Torres-González, 2018: U.S. Caribbean. Pages 809–871 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.
- Le Bris, A., K. E. Mills, R. A. Wahle, Y. Chen, M. A. Alexander, A. J. Allyn, J. G. Schuetz, J. D. Scott, and A. J. Pershing. 2018. Climate vulnerability and resilience in the most valuable North American fishery. *Proceedings of the National Academy of Sciences of the United States of America*. 115:1831–1836.
18. Barbeaux, S., K. Aydin, B. Fissel, K. Holsman, W. Palsson, K. Shotwell, Q. Yang, and S. Zador. 2017. Assessment of the Pacific Cod stock in the Gulf of Alaska. Pages 189–332 in *North Pacific Fisheries Management Council Gulf of Alaska SAFE (Stock Assessment and Fishery Evaluation) [council draft]*. Available: www.city.kodiak.ak.us/sites/default/files/fileattachments/fisheries_workgroup/meeting/10388/2017_goa_pcod_stock_assessment.pdf. (July 2020).
19. Meredith, M., M. Sommerkorn, S. Cassotta, C. Derksen, A. Ekaykin, A. Hollowed, G. Kofinas, A. Mackintosh, J. Melbourne-Thomas, M. M. C. Muelbert, G. Ottersen, H. Pritchard, and E. A. G. Schuur. 2019. Polar regions. Pages 203–320 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/3/2019/11/07_SROCC_Ch03_FINAL.pdf. (July 2020).
20. Nicholas A. J. Graham, N. A. J., S. K. Wilson, S. Jennings, N. V. C. Polunin, J. P. Bijoux, J. Robinson. 2006. Dynamic fragility of oceanic coral reef ecosystems. *Proceedings of the National Academy of Sciences* 103:8425–8429.
21. Poloczanska, E. S., C. J. Brown, W. J. Sydeman, W. Kiessling, D. S. Schoeman, P. J. Moore, K. Brander, J. F. Bruno, L. B. Buckley, M. T. Burrows, C. M. Duarte, B. S. Halpern, J. Holding, C. V. Kappel, M. I. O'Connor, J. M. Pandolfi, C. Parmesan, F. Schwing, S. A. Thompson, and A. J. Richardson. 2013. Global imprint of climate change on marine life. *Nature Climate Change* 3:919–925.
22. Dulvy, N. K., S. I. Rogers, S. Jennings, V. Stelzenmüller, S. R. Dye, and H. R. Skjoldal. 2008. Climate change and deepening of the North Sea fish assemblage: a biotic indicator of warming seas. *Journal of Applied Ecology* 45:1029–1039.
- Hastings, R. A., L. A. Rutterford, J. J. Freer, R. A. Collins, S. D. Simpson, and M. J. Genner. 2020. Climate change drives poleward increases and equatorward declines in marine species. *Current Biology* 30:1572–1577.
- 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. [Pages 358, 362.]
23. Babcock, R. C., R. H. Bustamante, E. A. Fulton, D. J. Fulton, M. D. E. Haywood, A. J. Hobday, R. Kenyon, R. J. Matear, E. Plaganyi, A. J. Richardson, and M. Vanderklift. 2019. Severe continental-scale impacts of climate change are happening now: extreme climate events impact marine habitat forming communities along 45% of the Australian coast. *Frontiers in Marine Science* 6:411.

24. 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. [Page 331.]
- Kaladharan, P., and A. Koya. 2019. Shrinking seagrass meadows observations from four lagoons of Lakshadweep archipelago. *Journal of the Marine Biological Association of India* 61:47–51.
- 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. [Page 377.]
25. 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. [Page 331.]
- Friess, D. A., K. Rogers, C. E. Lovelock, K. W. Krauss, S. E. Hamilton, S. Y. Lee, R. Lucas, J. Primavera, A. Rajkaran, and S. Shi. 2019. The state of the world's mangrove forests: past, present and future. *Annual Review of Environment and Resources* 44:16.1–16.27.
- Jennerjahn, T. C., E. Gillman, K. W. Krauss, L. D. Lacerda, I. Nordhaus, and E. Wolanski. 2017. Mangrove ecosystems under climate change. Pages 211–244 in V. H. Rivera-Monroy, S. Y. Lee, E. Kristensen, and R. R. Twilley, editors. *Mangrove ecosystems: a global biogeographic perspective*. Springer International Publishing, New York.
- Oppenheimer, M., B. C. Glavovic, J. Hinkel, R. van de Wal, A. K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes-Jara, R. M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari. 2019. Sea level rise and implications for low-lying islands, coasts and communities. Pages 321–445 in H.-O. Pörtner, 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. *IPCC special report on the ocean and cryosphere in a changing climate*. Available: www.ipcc.ch/site/assets/uploads/sites/3/2019/11/08_SROCC_Ch04_FINAL.pdf. (July 2020).
- Saintilan, N., N. S. Khan, E. Ashe, J. J. Kelleway, K. Rogers, C. D. Woodroffe, and B. P. Horton. 2020. Thresholds of mangrove survival under rapid sea level rise. *Science* 368:1118–1121.
26. 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. Seneviratne, A. Thomas, R. Warren, and G. Zhou. 2018. 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. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. *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/2/2019/02/SR15_Chapter3_Low_Res.pdf. (July 2020). [Pages 229–230.]
- Gattuso, J.-P., A. Magnan, R. Billé, W. W. L. Cheung, E. L. Howes, F. Joos, D. Allemand, L. Bopp, S. R. Cooley, C. M. Eakin, O. Hoegh-Guldberg, R. P. Kelly, H.-O. Pörtner, A. D. Rogers, J. M. Baxter, D. Laffoley, D. Osborn, A. Rankovic, J. Rochette, U. R. Sumaila, S. Treyer, and C. Turley. 2015. Contrasting futures for ocean and society from different anthropogenic CO₂ emissions scenarios. *Science* 349(6243):aac4722.
- Gould, W. A., E. L. Díaz, (co-leads), N. L. Álvarez-Berrios, F. Aponte-González, W. Archibald, J. H. Bowden, L. Carrubba, W. Crespo, S. J. Fain, G. González, A. Goulbourne, E. Harmsen, E. Holup-chinski, A. H. Khalyani, J. Kossin, A. J. Leinberger, V. I. Marrero-Santiago, O. Martínez-Sánchez, K. McGinley, P. Méndez-Lázaro, J. Morell, M. M. Oyola, I. K. Parés-Ramos, R. Pulwarty, W. V. Sweet, A. Terando, and S. Torres-González. 2018. U.S. Caribbean. Pages 809–871 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. [Pages 827–831.]

- Hughes, T. P., K. D. Anderson, S. R. Connolly, S. F. Heron, J. T. Kerry, J. M. Lough, A. H. Baird, J. K. Baum, M. L. Berumen, T. C. Bridge, D. C. Claar, C. M. Eakin, J. P. Gilmour, N. A. J. Graham, H. Harrison, J. P. A. Hobbs, A. S. Hoey, M. Hoogenboom, R. J. Lowe, M. T. McCulloch, J. M. Pandolfi, M. Pratchett, V. Schoepf, G. Torda, and S. K. Wilson. 2018. Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. *Science* 359:80–83.
- 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. [Page 359.]
- 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. [Pages 378–379.]
27. Bindoff, N. L., W. W. L. Cheung, J. G. Kairo, J. Aristegui, 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. 2019. 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. (September 2020). [Pages 499–500.]
- Krumhansl, K. A., D. K. Okamoto, A. Rassweiler, M. Novak, J. J. Bolton, K. C. Cavanaugh, S. D. Connell, C. R. Johnson, B. Konar, S. D. Ling, F. Micheli, K. M. Norderhaug, A. Pérez-Matus, I. Sousa-Pinto, D. C. Reed, A. K. Salomon, N. T. Shears, T. Wernberg, R. J. Anderson, N. S. Barrett, A. H. Buschmann, M. H. Carr, J. E. Caselle, S. Derrien-Courtel, G. J. Edgar, M. Edwards, J. A. Estes, C. Goodwin, M. C. Kenner, D. J. Kushner, F. E. Moy, J. Nunn, R. S. Steneck, J. Vásquez, J. Watson, J. D. Witman, and J. E. K. Byrnes. 2016. Global patterns of kelp forest change over the past half-century. *Proceedings of the National Academy of Science of the United States of America* 113:13785–13790.
- Voerman, S. E., E. Llera, and J. M. Rico. 2013. Climate driven changes in subtidal kelp forest communities in NW Spain. *Marine Environmental Research* 90:119–127.
- Wernberg, T., K. Krumhansl, K. Filbee-Dexter, and M. F. Pedersen. 2019. Status and trends for the world’s kelp forests. Pages 57–78 in C. Sheppard, editor. *World seas: an environmental evaluation*. Elsevier, 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. [Pages 377–378.]
28. Babcock, R. C., R. H. Bustamante, E. A. Fulton, D. J. Fulton, M. D. E. Haywood, A. J. Hobday, R. Kenyon, R. J. Matear, E. Plaganyi, A. J. Richardson, and M. Vanderklift. 2019. Severe continental-scale impacts of climate change are happening now: extreme climate events impact marine habitat forming communities along 45% of the Australian coast. *Frontiers in Marine Science* 6:411.
- Gattuso, J.-P., A. Magnan, R. Billé, W. W. L. Cheung, E. L. Howes, F. Joos, D. Allemand, L. Bopp, S. R. Cooley, C. M. Eakin, O. Hoegh-Guldberg, R. P. Kelly, H.-O. Pörtner, A. D. Rogers, J. M. Baxter, D. Laffoley, D. Osborn, A. Rankovic, J. Rochette, U. R. Sumaila, S. Treyer, and C. Turley. 2015. Contrasting futures for ocean and society from different anthropogenic CO₂ emissions scenarios. *Science* 349(6243):aac4722.
- Gould, W. A., E. L. Díaz, (co-leads), N. L. Álvarez-Berrios, F. Aponte-González, W. Archibald, J. H. Bowden, L. Carrubba, W. Crespo, S. J. Fain, G. González, A. Goulbourne, E. Harmsen, E. Holup-chinski, A. H. Khalyani, J. Kossin, A. J. Leinberger, V. I. Marrero-Santiago, O. Martínez-Sánchez, K. McGinley, P. Méndez-Lázaro, J. Morell, M. M. Oyola, I. K. Parés-Ramos, R. Pulwarty, W. V. Sweet, A. Terando, and S. Torres-González.

2018. U.S. Caribbean. Pages 809–871 in D. R. Reidmiller, 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.
- Hughes, T. P., K. D. Anderson, S. R. Connolly, S. F. Heron, J. T. Kerry, J. M. Lough, A. H. Baird, J. K. Baum, M. L. Berumen, T. C. Bridge, D. C. Claar, C. M. Eakin, J. P. Gilmour, N. A. J. Graham, H. Harrison, J. P. A. Hobbs, A. S. Hoey, M. Hoogenboom, R. J. Lowe, M. T. McCulloch, J. M. Pandolfi, M. Pratchett, V. Schoepf, G. Torda, and S. K. Wilson. 2018. Spatial and temporal patterns of mass bleaching of corals in the Anthropocene. *Science* 359:80–83.
- Levin, L., M. Baker and A. Thompson, editors. 2019. Deep-ocean climate change impacts on habitat, fish and fisheries. FAO Fisheries and Aquaculture Technical Paper No. 638, Rome.
- Pörtner, H.-O., D. C. Roberts, V. Masson-Delmotte, P. Zhai, E. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegria, 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). [Page 61.]
29. Bednaršek, N., R. A. Feely, M. W. Beck, S. R. Alin, S. A. Siedlecki, P. Calosi, E. L. Norton, C. Saenger, J. Štrus, D. Greeley, N. P. Nezlin, M. Roethler, and J. I. Spicer. 2020. Exoskeleton dissolution with mechanoreceptor damage in larval *Dungeness* crab related to severity of present-day ocean acidification vertical gradients. *Science of The Total Environment* 716:136610.
- 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. [Page 357.]
- Rhein, M., S. R. Rintoul, S. Aoki, E. Campos, D. Chambers, R. A. Feely, S. Gulev, G. C. Johnson, S. A. Josey, A. Kostianoy, C. Mauritzen, D. Roemmich, L. D. Talley, and F. Wang. 2013. Observations: ocean. Pages 255–267 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.
- Wisshak M., C. H. L. Schönberg, A. Form, and A. Freiwald. 2012. Ocean acidification accelerates reef bioerosion. *PLOS (Public Library of Science) ONE* 7(9):e45124.
30. Hobday, A. J., E. C. J. Oliver, A. S. Gupta, J. A. Benthuyzen, M. T. Burrows, M. G. Donat, N. J. Holbrook, P. J. Moore, M. S. Thomsen, T. Wernberg, and D. A. Smale. 2018. Categorizing and naming marine heatwaves. *Oceanography* 31:162–173.
- Holbrook, N. J., H. A. Scannell, A. S. Gupta, J. A. Benthuyzen, M. Feng, E. C. J. Oliver, L. V. Alexander, M. T. Burrows, M. G. Donat, A. J. Hobday, P. J. Moore, S. E. Perkins-Kirkpatrick, D. A. Smale, S. C. Straub, and T. Wernberg. 2019. A global assessment of marine heatwaves and their drivers. *Nature Communications* 10:2624.
- Oliver, E. C. J., M. T. Burrows, M. G. Donat, A. S. Gupta, L. V. Alexander, S. E. Perkins-Kirkpatrick, J. A. Benthuyzen, A. J. Hobday, N. J. Holbrook, P. J. Moore, M. S. Thomsen, and T. W. D. A. Smale. 2019. Projected marine heatwaves in the 21st century and the potential for ecological impact. *Frontiers in Marine Science* 6:734.
- Oliver, E. C. J., M. G. Donat, M. T. Burrows, P. J. Moore, D. A. Smale, L. V. Alexander, J. A. Benthuyzen, M. Feng, A. Sen Gupta, A. J. Hobday, N. J. Holbrook, S. E. Perkins-Kirkpatrick, H. A. Scannell, S. C. Straub, and T. Wernberg. 2018. Ocean warming brings longer and more frequent marine heatwaves. *Nature Communications* 9:1324.
31. 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. [Pages 355, 357.]
- Rhein, M., S. R. Rintoul, S. Aoki, E. Campos, D. Chambers, R. A. Feely, S. Gulev, G. C. Johnson, S. A. Josey, A. Kostianoy, C. Mauritzen, D. Roemmich, L. D. Talley, and F. Wang. 2013. Observations: ocean. Pages 255–267 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. [Pages 294–296.]
- Schmidtko, S., L. Stramma, and M. Visbeck. 2017. Decline in global oceanic oxygen content during the past five decades. *Nature* 542:336–339.
32. Bindoff, N. L., W. W. L. Cheung, J. G. Kairo, J. Aristegui, 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. 2019. 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. (September 2020). [Pages 451, 494– 498.]
- Wiedenmann, J., C. D’Angelo, E. G. Smith, A. N. Hunt, F. E. Legiret, A. D. Postle and E. P. Achterberg. 2013. Nutrient enrichment can increase the susceptibility of reef corals to bleaching. *Nature Climate Change* 3:160–164.
33. Bindoff, N. L., W. W. L. Cheung, J. G. Kairo, J. Aristegui, 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. 2019. 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. (September 2020). [Pages 512–513.]
- Free, C. M., J. T. Thorson, M. L. Pinsky, K. L. Oken, J. Wiedenmann, and O. P. Jensen. 2019. Impacts of historical warming on marine fisheries production. *Science* 363:979–983.
34. Bindoff, N. L., W. W. L. Cheung, J. G. Kairo, J. Aristegui, 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. 2019. 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. (September 2020). [Pages 450–451, 478– 502.]
- Lurgi, M., B. C. Lopez, and J. M. Montoya. 2012. Novel communities from climate change. *Philosophical Transactions of the Royal Society B* 367:2913–2922.
35. Burge, C. A., and P. K. Hershberger. 2020. Climate change can drive marine diseases. Pages 83–94 in D. C. Behringer, B. R. Silliman, and K. D. Lafferty, editors. *Marine disease ecology*. Oxford University Press, Oxford, UK.
- Harvell, C. D., and J. B. Lamb. 2020. Disease outbreaks can threaten marine biodiversity. Pages 141–158 in D. C. Behringer, B. R. Silliman, and K. D. Lafferty, editors. *Marine disease ecology*. Oxford University Press, Oxford, UK.
- Lamb, J. B., J. A. J. M. Van de Water, D. G. Bourne, C. Altier, M. Y. Hein, E. A. Fiorenza, N. Abu, J. Jomba, and C. D. Harvell. 2017. Seagrass ecosystems reduce exposure to bacterial pathogens of humans, fishes, and invertebrates. *Science* 355:731–733.
- Sokolow, S. 2009. Effects of a changing climate on the dynamics of coral infectious disease: a review of the evidence. *Diseases of Aquatic Organisms* 87:5–18.
36. Bindoff, N. L., W. W. L. Cheung, J. G. Kairo, J. Aristegui, 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. 2019. 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. (September 2020). [Pages 450–454, 478– 502.]
- 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. Hijjoka, S. Mehrotra, A. Payne, S.I. Seneviratne, A. Thomas, R. Warren, and G.

- Zhou. 2018. 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. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. *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/2/2019/02/SR15_Chapter3_Low_Res.pdf. (July 2020). [Pages 226–230.]
- 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. 2018. 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. (September 2020). [Pages 12, 22.]
- 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. [Pages 358–361.]
- Porter, J. R., L. Xie, A. J. Challinor, K. Cochran, S. M. Howden, M. M. Iqbal, D. B. Lobell, and M. I. Travasso. 2014. Food security and food production systems. Pages 485–533 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.
- 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. [Pages 456–459.]
- 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. Summary for policymakers. Pages 1–35 in *IPCC special report on the ocean and cryosphere in a changing climate*. Available: www.ipcc.ch/site/assets/uploads/sites/3/2019/11/03_SROCC_SPM_FINAL.pdf. (July 2020).
37. North American Bird Conservation Initiative. 2016. *The state of North America's birds 2016*. Environment and Climate Change Canada, Ottawa.
- Paleczny, M., E. Hammill, V. Karpouzi, and D. Pauly. 2015. Population trend of the world's monitored seabirds, 1950–2010. *PLOS (Public Library of Science) ONE* 10(6):e0129342.
38. Bateman, B. L., C. Wilsey, L. Taylor, J. Wu, G. S. LeBaron, and G. Langham. 2020. North American birds require mitigation and adaptation to reduce vulnerability to climate change. *Conservation Science and Practice*, <https://doi.org/10.1111/csp2.242>.
39. Of the 29,500 freshwater dependent species so far assessed for the IUCN Red List, 27% are threatened with extinction. See the following:
- Dudgeon, D., A. H. Arthington, M. O. Gessner, Z. I. Kawabata, D. J. Knowler, C. Leveque, R. J. Naiman, A. H. Prieur-Richard, D. Soto, M. L. J. Stiassny, and C. A. Sullivan. 2006. Freshwater biodiversity: importance, threats, status and conservation challenges. *Biological Reviews* 81:163–182.
- 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. [Page 312.]
- Tickner, D., J. J. Opperman, R. Abell, M. Acreman, A. H. Arthington, S. E. Bunn, S. J. Cooke, J. Dalton, W. Darwall, G. Edwards, I. Harrison, K. Hughes, T. Jones, D. Leclère, A. J. Lynch, P. Leonard, M. E. McClaine, D. Muruven, J. D. Olden, S. J. Ormerod, J. Robinson, R. E. Tharme, M. Thieme, K. Tockner, M. Wright, and L. Young. 2020. Bending the curve of global freshwater biodiversity loss: an emergency recovery plan. *BioScience* 70:330–342.S
- Vörösmarty, C. J., P. B. McIntyre, M. O. Gessner, D. Dudgeon, A. Prusevich, P. Green, S. Glidden, S. E. Bunn, C. A. Sullivan, C. R. Liermann, and P. M. Davies, 2010. Global threats to human water security and river biodiversity. *Nature* 467:555–561.
40. Strayer, D. L., and D. Dudgeon. 2010. Freshwater biodiversity conservation: recent progress and future challenges. *Journal of the North American Benthological Society* 29:344–358.
41. Bloesch, J., C. Sandu, and J. Janning. 2012. Challenges of an integrative water protection and river basin management policy: the Danube case. *River Systems* 20:129–144.
- Harrod, C., A. Ramírez, J. Valbo-Jørgensen and S. Funge-Smith. 2018. How climate change impacts inland fisheries. Pages 375–391 in M. Barange, T. Bahri, M. C. M. Beveridge, K. L. Cochrane, S. Funge-Smith, and F. Poulain, editors. *Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options*. Food and Agricultural Organization of the United Nations, Fisheries and Aquaculture Technical Paper 627, Rome.
42. Alexander, J. E., Jr., and K. C. Wagoner. 2016. Respiratory response to temperature variability in the river snail *Lithasia obovata* and its relevance to the potential impacts of climate change on freshwater gastropods. *American Malacological Bulletin* 34:1–14.
- Bănăduc D., M. Joy, H. Olosutean, S. Afanasyev, and A. Curtean-Bănăduc. 2020. Natural and anthropogenic driving forces as key elements in the Lower Danube basin—south-eastern Carpathians—north-western Black Sea coast area lakes: a broken stepping stones for fish in a climatic change scenario? *Environmental Science Europe* 32: article 7.
- Ferreira-Rodríguez, N. 2019. Spatial aggregation of native with non-native freshwater bivalves and activity depletion under summer heat waves: ‘dangerous liaisons’ in a climate change context. *Hydrobiologia* 834:75–85.
- Ganser, A. M., T. J. Newton, and R. J. Haro. 2013. The effects of elevated water temperature on native juvenile mussels: implications for climate change. *Freshwater Science* 32:1168–1177.
- 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. [Pages 273– 279.]
- Lynch, A. J., B. J. E. Myers, C. Chu, L. A. Eby, J. A. Falke, R. P. Kovach, T. J. Krabbenhoft, T. J. Kwak, J. Lyons, C. P. Paukert, and J. E. Whitney. 2016. Climate change effects on North American inland fish populations and assemblages. *Fisheries* 41:346–361.
- Markovic, D., S. Carrizo, J. Freyhof, N. Cid, S. Lengyel, M. Scholz, H. Kasperdius, and W. Darwall. 2014. Europe’s freshwater biodiversity under climate change: distribution shifts and conservation needs. *Diversity and Distributions* 20:1097–1107.
- 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. [Pages 312–314.]
43. Dai, A. 2013. Increasing drought under global warming in observations and models. *Nature Climate Change* 3:52–58.
- Gonzalez, P., G. M. Garfin, D. D. Breshears, K. M. Brooks, H. E. Brown, E. H. Elias, A. Gunasekara, N. Huntly, J. K. Maldonado, N. J. Mantua, H. G. Margolis, S. McAfee, B. R. Middleton, and B. H. Udall. 2018. Southwest. Pages 1101–1184 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.
- Jiménez Cisneros, B. E., T. Oki, N. W. Arnell, G. Benito, J. G. Cogley, P. Döll, T. Jiang, and S. S. Mwakalila. 2014. Freshwater resources. Pages 229–269 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.
- Vertessy, R., D. Barma, L. Baumgartner, S. Mitrovic, F. Sheldon, and N. Bond. 2019. Independent assessment of the 2018–19 fish deaths in the lower Darling. Final Report. Available: www.mdba.gov.au/sites/default/files/pubs/Final-Report-Independent-Panel-fish-deaths-lower%20Darling_4.pdf. (July 2020).
44. Center, T. D., and N. R. Spencer. 1981. The phenology and growth of water hyacinth (*Eichhornia crassipes* (Mart.) Solms) in a eutrophic north-central Florida lake. *Aquatic Botany* 10:1–32.
- Döll, P., and S. E. Bunn. 2014. Cross-chapter box on the impact of climate change on freshwater ecosystems due to altered river flow regimes. Pages 143–146 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.
- Rahel, F. J., and J. D. Olden. 2008. Assessing the effects of climate change on aquatic invasive species. *Conservation Biology* 22:521–533.
- Rehage, J. S., and J. R. Blanchard. 2016. What can we expect from climate change for species invasions? *Fisheries* 405–407.
- Oliver, J. D. 1993. A review of the biology of giant salvinia (*Salvinia molesta* Mitchell). *Journal of Aquatic Plant Management* 31:227–231.
- Pimentel, D., R. Zuniga, and D. Morrison. 2005. Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52:273–288.
45. Alahuhta, J., J. Heino, and M. Luoto, 2011: Climate change and the future distributions of aquatic macrophytes across boreal catchments. *Journal of Biogeography* 38:383–393.
- Comte, L., and G. Grenouillet, 2013. Do stream fish track climate change? Assessing distribution shifts in recent decades. *Ecography* 36:1236–1246.
- Galego de Oliveira, A., D. Bailly, F. A. S. Cassemiro, E. V. d. Couto, N. Bond, D. Gilligan, T. F. Rangel, A. A. Agostinho, and M. J. Kennard. 2019. Coupling environment and physiology to predict effects of climate change on the taxonomic and functional diversity of fish assemblages in the Murray–Darling basin, Australia. *PLOS (Public Library of Science) ONE* 14(11):e0225128.
- 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. [Pages 275, 276–277, 281.]
- Rahel, F. J., and J. D. Olden. 2008. Assessing the effects of climate change on aquatic invasive species. *Conservation Biology* 22:521–533.
- Rehage, J. S., and J. R. Blanchard. 2016. What can we expect from climate change for species invasions? *Fisheries* 405–407.
- 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. [Pages 295, 312–314, 295.]

- Sorte, C. J. B., I. Ibáñez, D. M. Blumenthal, N. A. Molinari, L. P. Miller, E. D. Grosholz, J. M. Diez, C. M. D'Antonio, J. D. Olden, S. J. Jones, and J. S. Dukes. 2013. Poised to prosper? A cross-system comparison of climate change effects on native and non-native species performance. *Ecology Letters* 16:261–270.
46. 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. [Pages 295, 312–314.]
47. 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. Morisette, 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. [Page 285.]
- Lynch, A. J., B. J. E. Myers, C. Chu, L. A. Eby, J. A. Falke, R. P. Kovach, T. J. Krabbenhoft, T. J. Kwak, J. Lyons, C. P. Paukert, and J. E. Whitney. 2016. Climate change effects on North American inland fish populations and assemblages. *Fisheries* 41:346–361.
- Whitney, J. E., R. Al-Chokhachy, D. B. Bunnell, C. A. Caldwell, S. J. Cooke, E. J. Ellason, M. Rogers, A. J. Lynch, and C. P. Paukert. 2016. Physiological basis of climate change impacts on North American inland fishes. *Fisheries* 41:332–345.
48. Goode, J. R., C. H. Luce, and J. M. Buffington. 2012. Enhanced sediment delivery in a changing climate in semi-arid mountain basins: implications for water resource management and aquatic habitat in the northern Rocky Mountains. *Geomorphology* 139–140:1–15.
- Lall, U., T. Johnson, P. Colohan, A. Aghakouchak, C. Brown, G. McCabe, R. Pulwarty, and A. Sankarabramanian. 2018. Water. Pages 145–173 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.
- Lyon, J. P., and J. P. O'Connor. 2008. Smoke on the water: can riverine fish populations recover following a catastrophic fire-related sediment slug? *Austral Ecology* 33:794–806.
- Vose, J. M., D. L. Peterson, G. M. Domke, C. J. Fetting, L. A. Joyce, R. E. Keane, C. H. Luce, J. P. Prestemon, L. E. Band, J. S. Clark, N. E. Cooley, A. D'Amato, and J. E. Halofsky. 2018. Forests. Pages 232–267 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.
49. Morant, D., A. Picazo, C. Rochera, A. C. Santamans, J. Miralles-Lorenzo, A. Camacho-Santamans, C. Ibañez, M. Martínez-Eixarch, and A. Camacho. 2020. The role of ecological features and conservation status on the carbon cycle and methane emissions in the Ebro Delta wetlands. *PLOS (Public Library of Science) ONE* 15(4):e0231713.
- Hooijer, A., S. Page, J. Jauhiainen, W. A. Lee, X. X. Lu, A. Idris, and G. Anshari. 2011. Subsidence and carbon loss in drained tropical peatland: reducing uncertainty and implications for CO₂ emission reduction options. *Biogeosciences Discussions* 8:931–935.
- Page, S. E., and A. Hooijer. 2016. In the line of fire: the peatlands of Southeast Asia. *Philosophical Transactions of the Royal Society B* 371:20150176.
- Turetsky, M. R., B. Benscoter, S. Page, G. Rein, G. R. van der Werf, and A. Watts. 2014. Global vulnerability of peatlands to fire and carbon loss. *Nature Geoscience* 8:11–14.
50. Chapra, S. C., B. Boehlert, C. Fant, V. J. Bierman, J. Henderson, D. Mills, D. M. L. Mas, L. Rennels, L. Jantarasami, J. Martinich, K. M. Strzepek, and H. W. Paerl. 2017. Climate change impacts on harmful algal blooms in U.S. freshwaters: a screening-level assessment. *Environmental Science and Technology* 51:8933–8943.
- Jöhnk, K. D., J. Huisman, J. Sharples, B. Sommeijer, P. M. Visser, and J. M. Stroom. 2008. Summer heatwaves promote blooms of harmful cyanobacteria. *Global Change Biology* 14:495–512.
- Michalak, A. M., E. J. Anderson, D. Beletsky, S. Boland, N. S. Bosch, T. B. Bridgeman, J. D. Chaffin, K. Cho, R. Confesor, I. Daloglu, J. V. DePinto, M. A. Evans, G. L. Fahnenstiel, L. He, J. C. Ho, L. Jenkins, T. H. Johengen, K. C. Kuo, E. LaPorte, X. Liu, M. R. McWilliams, M. R. Moore, D. J. Posselt, R. P. Richards, D.

- Scavia, A. L. Steiner, E. Verhamme, D. M. Wright, and M. A. Zagorski. 2013. Record-setting algal bloom in Lake Erie caused by agricultural and meteorological trends consistent with expected future conditions. *Proceedings of the National Academy of Sciences of the United States of America* 110:6448–6452.
- 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. [Page 291.]
51. Gordon, L., C. M. Finlayson, and M. Falkenmark. 2010. Managing water in agriculture to deal with trade-offs and find synergies among food production and other ecosystem services. *Agricultural Water Management* 97:512–519.
- Jenny, J.-P., O. Anneville, F. Arnaud, Y. Baulaz, D. Bouffard, I. Domaizon, S. A. Bocaniov, N. Chèvre, M. Dittrich, J.-M. Dorioz, E. S. Dunlop, G. Dur, J. Guillard, T. Guinaldo, S. Jacquet, A. Jamoneau, Z. Jawed, E. Jeppesen, G. Krantzberg, J. Lenters, B. Leoni, M. Meybeck, V. Nava, T. Nöges, P. Nöges, M. Patelli, V. Pebbles, M.-E. Perga, S. Rasconi, C. R. Ruetz III, L. Rudstam, N. Salmaso, S. Sapna, D. Straile, O. Tammeorg, M. R. Twiss, D. G. Uzarski, A.-M. Ventelä, W. F. Vincent, S. W. Wilhelm, S.-Å. Wängberg, and G. A. Weyhenmeyer. 2020. Scientists' warning to humanity: rapid degradation of the world's large lakes. *Journal of Great Lakes Research* 46:686–702.
52. Heim, K. C., M. S. Wipfli, M. S. Whitman, C. D. Arp, J. Adams, and J. A. Falke. 2016. Seasonal cues of Arctic Grayling movement in a small Arctic stream: the importance of surface water connectivity. *Environmental Biology of Fishes* 99:49–65.
- Meredith, M., M. Sommerkorn, S. Cassotta, C. Derksen, A. Ekaykin, A. Hollowed, G. Kofinas, A. Mackintosh, J. Melbourne-Thomas, M. M. C. Muelbert, G. Ottersen, H. Pritchard, and E. A. G. Schuur. 2019. Polar regions. Pages 203–320 in H.-O. Pörtner, 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. *IPCC special report on the ocean and cryosphere in a changing climate*. Available: www.ipcc.ch/site/assets/uploads/sites/3/2019/11/07_SROCC_Ch03_FINAL.pdf. (July 2020). [Page 256.]
- Poesch, M. S., L. Chavarie, C. Chu, S. N. Pandit, and W. Tonn. 2016. Climate change impacts on freshwater fishes: a Canadian perspective. *Fisheries* 41:385–391.
53. Hock, R., G. Rasul, C. Adler, B. Cáceres, S. Gruber, Y. Hirabayashi, M. Jackson, A. Käb, S. Kang, S. Kutuzov, A. Milner, U. Molau, S. Morin, B. Orlove, and H. Steltzer. 2019. High mountain areas. Pages 131–202 in H.-O. Pörtner, D. C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegria, M. Nicolai, A. Okem, J. Petzold, B. Rama, N. M. Weyer, editors. *IPCC special report on the ocean and cryosphere in a changing climate*. Available: www.ipcc.ch/site/assets/uploads/sites/3/2019/11/06_SROCC_Ch02_FINAL.pdf. (July 2020).
- Zhang, Q., J. Huang, F. Wang, L. Mark, J. Xu, D. Armstrong, C. Li, Y. Zhang, and S. Kang. 2012. Mercury distribution and deposition in glacier snow over western China. *Environmental Science and Technology* 46:5404–5413.
54. Marcos-López, M., P. Gale, B. C. Oidtmann, and E. J. Peeler. 2010. Assessing the impact of climate change on disease emergence in freshwater fish in the United Kingdom. *Transboundary and Emerging Diseases* 57:293–304.
- Olusanya, H. O., and M. van Zyll de Jong. 2018. Assessing the vulnerability of freshwater fishes to climate change in Newfoundland and Labrador. *PLOS (Public Library of Science) ONE* 13(12):e0208182.
- Viana, D. S. 2017. Can aquatic plants keep pace with climate change? *Frontiers in Plant Science* 8:1906.
55. 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. [Pages 282– 283.]
- Ormerod, S. J., M. Dobson, A. G. Hildrew, and C. R. Townsend. 2010. Multiple stressors in freshwater ecosystems. *Freshwater Biology* 55(s1).
- Tockner, K., M. Pusch, D. Borchardt, and M. S. Lorang. 2010. Multiple stressors in coupled river–floodplain ecosystems. *Freshwater Biology* 55(s1):135–151.

56. Food and Agriculture Organization of the United Nations (FAO). 2018. The state of world fisheries and aquaculture 2018: meeting the sustainable development goals. FAO, Rome.
57. Meredith, M., M. Sommerkorn, S. Cassotta, C. Derksen, A. Ekaykin, A. Hollowed, G. Kofinas, A. Mackintosh, J. Melbourne-Thomas, M. M. C. Muelbert, G. Ottersen, H. Pritchard, and E. A. G. Schuur. 2019. Polar regions. Pages 203–320 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/3/2019/11/07_SROCC_Ch03_FINAL.pdf. (July 2020). [Pages 256–257, 261–262.]
- 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. Seneviratne, A. Thomas, R. Warren, and G. Zhou. 2018. 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. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. 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/2/2019/02/SR15_Chapter3_Low_Res.pdf. (July 2020). [Pages 222, 239.]
58. 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. 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). [Pages 61, 65.]
59. Magnan, A. K., M. Garschagen, J.-P. Gattuso, J. E. Hay, N. Hilmi, E. Holland, F. Isla, G. Kofinas, I. J. Losada, J. Petzold, B. Ratter, T. Schuur, T. Tabe, and R. van de Wal. 2019. Cross-chapter box 9: integrative cross-chapter box on low-lying islands and coasts. Pages 657–674 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/3/2019/11/11_SROCC_CCB9-LLIC_FINAL.pdf. (2020).
- 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. 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. (September 2020). [Page 61.]
60. Dahlke, F. T., S. Wohlrab, M. Butzin, and H.-O. Pörtner. 2020. Thermal bottlenecks in the life cycle define climate vulnerability of fish. *Science* 369:65–70.
61. 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. 2019. 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. (September 2020). [Pages 451, 502–503.]
- 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. Seneviratne, A. Thomas, R. Warren, and G. Zhou. 2018. 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. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. 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/2/2019/02/SR15_Chapter3_Low_Res.pdf. (July 2020). [Pages 180, 212, 230, 237–238.]

- Junk, W. J., S. An, C. M. Finlayson, B. Gopal, J. Květ, S. A. Mitchell, W. J. Mitsch, and R. D. Robarts. 2013. Current state of knowledge regarding the world's wetlands and their future under global climate change: a synthesis. *Aquatic Sciences* 75:151–167.
- Magnan, A. K., M. Garschagen, J.-P. Gattuso, J. E. Hay, N. Hilmi, E. Holland, F. Isla, G. Kofinas, I. J. Losada, J. Petzold, B. Ratter, T. Schuur, T. Tabe, and R. van de Wal. 2019. Cross-chapter box 9: integrative cross-chapter box on low-lying islands and coasts. Pages 657–674 in H.-O. Pörtner, 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. IPCC special report on the ocean and cryosphere in a changing climate. Available: www.ipcc.ch/site/assets/uploads/sites/3/2019/11/11_SROCC_CCB9-LLIC_FINAL.pdf. (2020). [Page 664.]
- Markon, C., S. Gray, M. Berman, L. Eerkes-Medrano, T. Hennessy, H. Huntington, J. Littell, M. Mc Cammon, R. Thoman, and S. Trainor. 2018. Alaska. Pages 1185–1241 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.
- Meredith, M., M. Sommerkorn, S. Cassotta, C. Derksen, A. Ekaykin, A. Hollowed, G. Kofinas, A. Mackintosh, J. Melbourne-Thomas, M. M. C. Muelbert, G. Ottersen, H. Pritchard, and E. A. G. Schuur. 2019. Polar regions. Pages 203–320 in H.-O. Pörtner, 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. IPCC special report on the ocean and cryosphere in a changing climate. Available: www.ipcc.ch/site/assets/uploads/sites/3/2019/11/07_SROCC_Ch03_FINAL.pdf. (July 2020). [Pages 260, 262–263.]
- Pendleton, L., A. Comte, C. Langdon, J. A. Ekstrom, S. R. Cooley, L. Suatoni, M. W. Beck, L. M. Brander, L. Burke, J. E. Cinner, C. Doherty, P. E. T. Edwards, D. Gledhill, L.-Q. Jiang, R. J. van Hooijdonk, L. The, G. G. Waldbusser, and J. Ritter. 2016. Coral reefs and people in a high-CO₂ world: where can science make a difference to people? *PLOS (Public Library of Science) ONE* 11(11):e0164699.
- Pershing, A. J., M. A. Alexander, C. M. Hernandez, L. A. Kerr, A. Le Bris, K. E. Mills, J. A. Nye, N. R. Record, H. A. Scannell, J. D. Scott, G. D. Sherwood, and A. C. Thomas. 2015. Slow adaptation in the face of rapid warming leads to collapse of the Gulf of Maine cod fishery. *Science* 350:809–812.
- 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. [Pages 361–362, 365–366.]
62. Barange, M., T. Bahri, M. C. M. Beveridge, K. L. Cochrane, S. Funge-Smith, and F. Poulain, editors. 2018. Impacts of climate change on fisheries and aquaculture: synthesis of current knowledge, adaptation and mitigation options. Food and Agriculture Organization of the United Nations, Fisheries and Aquaculture Technical Paper 627, Rome.
- Markon, C., S. Gray, M. Berman, L. Eerkes-Medrano, T. Hennessy, H. Huntington, J. Littell, M. Mc-Cammon, R. Thoman, and S. Trainor. 2018. Alaska. Pages 1185–1241 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. [Pages 1204–1206.]
- 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). [Pages 15–16.]
63. Cheung, W. W. L., V. W. Y. Lam, J. L. Sarmiento, K. Kearney, R. Watson, Z. Zeller, and D. Pauly. 2010. Large-scale redistribution of maximum fisheries catch potential in the global ocean under climate change. *Global Change Biology* 16:24–35.
- 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. Seneviratne, A. Thomas, R. Warren, and G. Zhou. 2018. 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. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield, editors. 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/2/2019/02/SR15_Chapter3_Low_Res.pdf. (July 2020). [Pages 230, 237.]
- McClanahan, T. R., E. H. Allison, and J. E. Cinner. 2015. Managing fisheries for human and food security. *Fish and Fisheries* 16:78–103.
64. Alava, J. J., W. W. L. Cheung, P. S. Ross, and U. Rashid Sumaila. 2017. Climate change–contaminant interactions in marine food webs: toward a conceptual framework. *Global Change Biology* 23:3984–4001.
- 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. 2019. 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. Alegria, 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. (September 2020). [Pages 509–512.]
- Vezzulli, L., C. Grande, P. C. Reid, P. Hélaouët, M. Edwards, M. G. Höfle, I. Brettar, R. R. Colwell, and C. Pruzzo. 2016. Climate influence on *Vibrio* and associated human diseases during the past half-century in the coastal North Atlantic. *Proceedings of the National Academy of Sciences of the United States of America* 113:E5062–E5071.
65. 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. 2019. 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. Alegria, 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. (September 2020). [Pages 516–517.]
- Chen, P.-Y., C.-C. Chen, L. Chu, and B. McCarl. 2015. Evaluating the economic damage of climate change on global coral reefs. *Global Environmental Change* 30:12–20.
- Cisneros-Montemayor, A. M., and U. R. Sumaila, 2010: A global estimate of benefits from ecosystem-based marine recreation: potential impacts and implications for management. *Journal of Bioeconomics* 12:245– 268.
- Gattuso, J.-P., O. Hoegh-Guldberg, and H.-O. Pörtner. 2014. Cross-chapter box on coral reefs. Pages 97–100 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.
- Markham, A., E. Osipova, K. Lafrenz Samuels, and A. Caldas. 2016. *World heritage and tourism in a changing climate*. United Nations Environment Programme, Nairobi, Kenya and United Nations Educational, Scientific and Cultural Organization, Paris, France.
66. Alexandrov, G. A., V. A. Brovkin, T. Kleinen, and Z. Yu. 2020. The capacity of northern peatlands for long-term carbon sequestration. *Biogeosciences* 17:47–54.
- Alongi, D. M. 2008. Mangrove forests: resilience, protection from tsunamis, and responses to global climate change. *Estuarine, Coastal and Shelf Science* 76:1–13.
- Kaladharan, P., A. M. Amalu, and S. Revathy, 2019. Role of seaweeds in neutralizing the impact of seawater acidification: a laboratory study with beached shells of certain bivalves and spines of a sea urchin. *Journal of the Marine Biological Association of India* 61:94–99.
- Nahlik A. M., and M. S. Fennessy. 2016. Carbon storage in US wetlands. *Nature Communications*. 7:1–9.
- Oppenheimer, M., B. C. Glavovic, J. Hinkel, R. van de Wal, A. K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes-Jara, R. M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari. 2019. Sea level rise and implications for low-lying islands, coasts and communities. Pages 321–445 in H.-O. Pörtner, 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. IPCC special report on the ocean and

- cryosphere in a changing climate. Available: www.ipcc.ch/srocc/chapter/chapter-4-sea-level-rise-and-implications-for-low-lying-islands-coasts-and-communities/ (September 2020). [Pages 380, 411.]
- Orth, R. J., T. J. B. Carruthers, W. C. Dennison, C. M. Duarte, J. W. Fourqurean, K. L. Heck, Jr., A. R. Hughes, G. A. Kendrick, W. J. Kenworthy, S. Olyarnik, F. T. Short, M. Waycott, and S. L. Williams. 2006. A global crisis for seagrass ecosystems. *BioScience* 56:987–996.
- Pendleton, L., D. C. Donato, B. C. Murray, S. Crooks, W. A. Jenkins, S. Sifleet, C. Craft, J. W. Fourqurean, J. B. Kauffman, N. Marbá, P. Megonigal, E. Pidgeon, D. Herr, D. Gordon, and A. Baldera. 2012. Estimating global “blue carbon” emissions from conversion and degradation of vegetated coastal ecosystems. *PLOS (Public Library of Science) ONE* 7(9):e43542.
- Reguero, B. G., M. W. Beck, V. N. Agostini, P. Kramer, and B. Hancock. 2018. Coral reefs for coastal protection: a new methodological approach and engineering case study in Grenada. *Journal of Environmental Management* 210:146–161.
- Waycott M., C. M. Duarte, T. J. B. Carruthers, R. J. Orth, W. C. Dennison, S. Olyarnike, A. Calladinea, J. W. Fourqurean, K. L. Heck, Jr., A. R. Hughese, G. A. Kendrick, W. J. Kenworthy, F. T. Short, and S. L. Williams. 2009. Accelerating loss of seagrasses across the globe threatens coastal ecosystems. *Proceedings of the National Academy of Sciences of the United States of America* 106:12377–12381.
- 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. [Pages 386–388.]
67. Dargie, G. C. 2017. Age, extent and carbon storage of the central Congo Basin peatland complex. *Nature* 542:86–90.
- Davies, P. M. 2010. Climate change implications for river restoration in global biodiversity hotspots. *Restoration Ecology* 18:261–268.
- Feld, C. K., M. R. Fernandes, M. T. Ferreira, D. Hering, S. J. Ormerod, M. Venohr, and C. Gutiérrez- Cánovas. 2018. Evaluating riparian solutions to multiple stressor problems in river ecosystems—a conceptual study. *Water Research* 139:381–394.
- Gundersen, P., A. Laurén, L. Finér, E. Ring, H. Koivusalo, M. Sætersdal, J. O. Weslien, B. D. Sigurdsson, L. Högbom, J. Laine, and K. Hansen. 2010. Environmental services provided from riparian forests in the Nordic countries. *Ambio* 39:555–566.
- Baker, J. P., and S. A. Bonar. 2019. Using a mechanistic model to develop management strategies to cool Apache Trout streams under the threat of climate change. *North American Journal of Fisheries Management* 39:849–867.
- Vose, J. M., D. L. Peterson, G. M. Domke, C. J. Fettig, L. A. Joyce, R. E. Keane, C. H. Luce, J. P. Prestemon, L. E. Band, J. S. Clark, N. E. Cooley, A. D’Amato, and J. E. Halofsky. 2018. Forests. Pages 232–267 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. [Page 246.]
68. Alexandrov, G. A., V. A. Brovkin, T. Kleinen, and Z. Yu. 2020. The capacity of northern peatlands for long-term carbon sequestration. *Biogeosciences* 17:47–54.
- Camacho, A., A. Picazo, C. Rochera, A. C. Santamans, D. Morant, J. Miralles-Lorenzo, and A. Castillo-Escriva. 2017. Methane emissions in Spanish saline lakes: current rates, temperature and salinity responses, and evolution under different climate change scenarios. *Water* 9:659.
- Crump, J., editor. 2017. *Smoke on water: countering global threats from peatland loss and degradation—a rapid response assessment*. United Nations Environment Programme, Nairobi, Kenya and GRID-Arendal, Arendal, Norway.
- Leifeld, J., and L. Menichetti. 2018. The underappreciated potential of peatlands in global climate change mitigation strategies. *Nature Communications* 9:article 1071.
- Ramsar Convention on Wetlands. 2018. *Global wetland outlook: state of the world’s wetlands and their services to people*. Ramsar Convention Secretariat, Gland, Switzerland.
69. Masson-Delmotte, V., P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufou-ma-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. 2018. 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. (September 2020). [Pages 7–11.]

- 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. [Pages 362, 364.]
- Porter, J. R., L. Xie, A. J. Challinor, K. Cochrane, S. M. Howden, M. M. Iqbal, D. B. Lobell, and M. I. Travasso. 2014. Food security and food production systems. Pages 485–533 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. [Pages 516–517.]
- 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). [Pages 17–28, 31–33.]