RENEWABLE RESOURCES JOURNAL

VOLUME 37 NUMBER 3

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Water Policy Options as Arizona Adapts to a Drier Colorado River: A Perspective

Sharon B. Megdal

The Colorado Basin Context

On August 16, 2021, the U.S. Bureau of Reclamation announced the first-ever Tier 1 Colorado River shortage. The water delivery cutbacks, which went into effect on January 1, 2022, per the "Colorado River Interim Guidelines for Low Basin Shortages and Coordinate Operations for Lake Powell and Lake Mead" (2007 Interim Guidelines), are most significant for the Central Arizona Project (CAP). Governed by the Central Arizona Water Conservation District, CAP delivers water into Central Arizona for use by tribal, municipal and industrial, and agricultural users. The reason that CAP water users face the most severe cutbacks is because that, in order to secure approval of the 1968 Colorado River Basin Project Act authorizing CAP construction, Arizona had to agree that water delivered through the CAP canal would be junior in priority to California's Colorado River water deliveries. This means that in deep shortage conditions CAP deliveries could be cut in their entirety before California would experience any cutbacks in water deliveries.

To say management of the Colorado River is complex is an understatement. Colorado River water is shared by seven states, 30 Tribal Nations, and Mexico. Within the U.S., the Colorado River Basin is divided into an Upper Division and a Lower Division. Different formulas govern the distribution of water. Upper Basin water is distributed on a percentage basis but each of the Lower Basin states have a set amount of water that is expected to be delivered in non-shortage years. The 1944 Treaty for Utilization of Waters from the Colorado and Tijuana Rivers and of the Rio Grande between the United States and Mexico, which is implemented by the International

Colorado River Basin

Sharon B. Megdal is Director of The University of Arizona Water Resources Research Center (WRRC). She served as a member of the elected Board of Directors for the Central Arizona Project Water Conservation from January 1, 2009, through December 31, 2020.

Boundary and Water Commission, includes a requirement that the U.S. deliver 1.5 million acre feet of water annually.

The 2007 Interim Guidelines were developed because, prior to their development, there had been no framework for sharing shortages of Colorado River water. The Colorado River storage system includes the huge Lake Powell and Lead Mead reservoirs. The low-flow conditions of the early 2000s signaled that it was time to establish a framework for shortage conditions. Though the basin has been experiencing low flows for most of the first 20 years of this century and the 2007 Interim Guidelines have been in place, the Lake Mead water level had not met the criterion for a Tier 1 shortage until this year. This is true despite there being what has been termed a "structural deficit" in the Lower Basin, meaning that more water is allocated to Arizona, California, and Nevada annually than can be expected during average river flow conditions. About 10 years ago, water managers finally acknowledged what many had argued was the case – the Colorado River is overallocated compared to average flow conditions. The Lower Basin was overdrawing its water savings account (the water stored in Lake Mead). Unfortunately, over the past 20-plus years, deposits to storage have not kept up with withdrawals. Despite innovative, sometimes voluntary, approaches to "propping up" Lake Mead, the status of and prognosis for the system indicated that more actions were necessary.

Collaboration among the many water actors led to the Spring 2019 federal enactment of the Drought Contingency Plans (DCPs). The DCP for the Lower Basin called for implementation of Tier 0 cutbacks in water deliveries at Lake Mead elevation level of 1,090 feet above sea level. Tier 0 governed water deliveries for 2020 and 2021. Under Tier 0, CAP experienced cutbacks of 192,000 acre feet. The Tier 1 shortage in 2022 added another 320,000 acre feet, making the total cutback equal to 512,000 acre feet, about one-third of CAP's annual deliveries under normal conditions and about 18 percent of Arizona's annual Colorado River allocation of 2.8 million acre feet. Unfortunately, the health of the Colorado River system is only getting worse; the probabilities of deeper cuts are increasing by the month. Based on Reclamation's monthly modeling, charts like those below are shared each month. The picture is getting worse more quickly than anyone expected. So, while one can hope or pray for the best, doing so will not prepare you for the adverse conditions that are in fact the "new normal."

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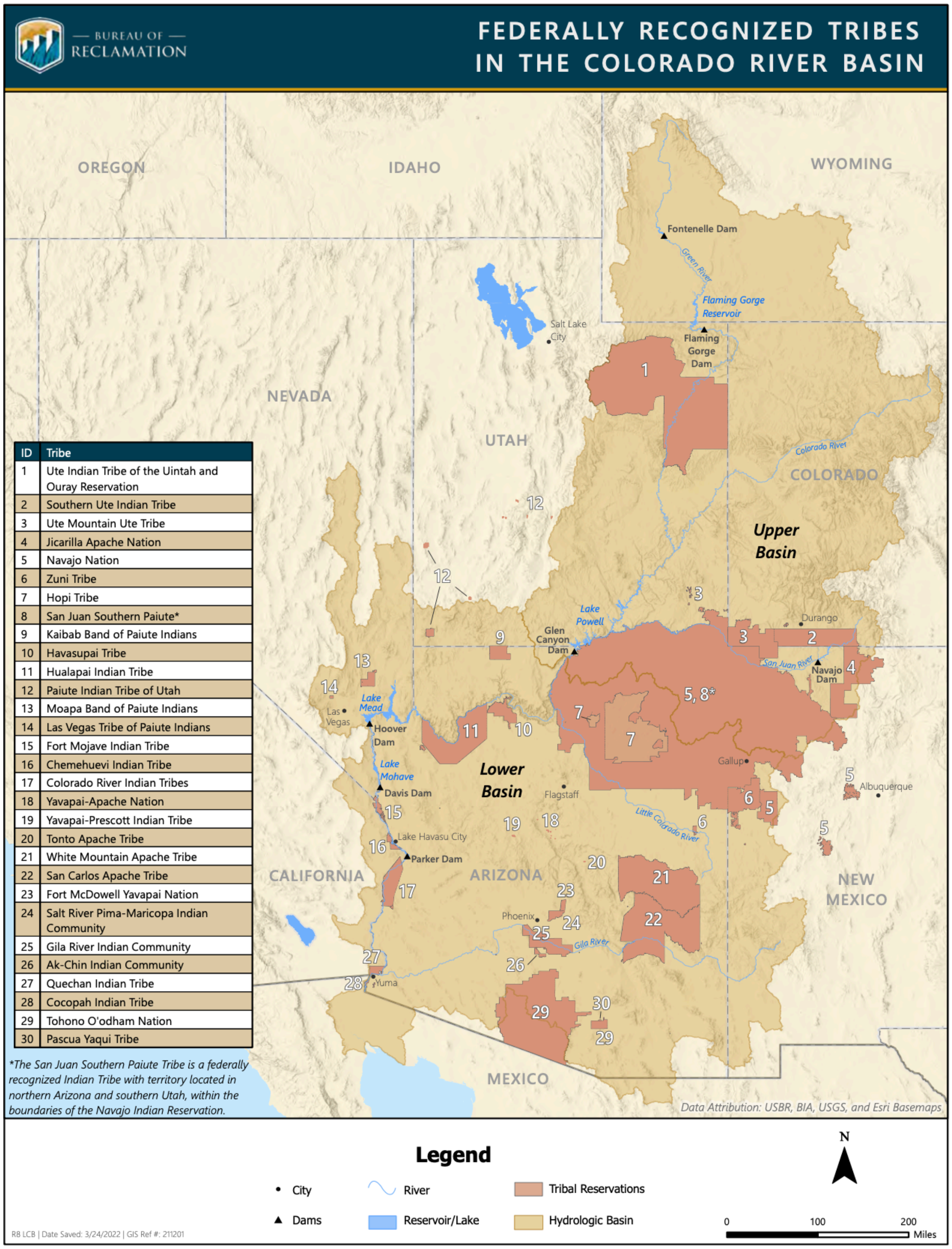
Renewable Resources Journal

Renewable Resources Journal (ISSN 2578-3998) is published quarterly by the Renewable Natural Resources Foundation, 6010 Executive Boulevard, Suite 700, North Bethesda, MD 20852-3809, USA. Tel: +1 301 770 9101 Email: info@rnrf.org Website: https://www.rnrf.org

Editorial Staff: Robert D. Day, editor; Stephen Yaeger, assistant editor.

Implications for Arizona

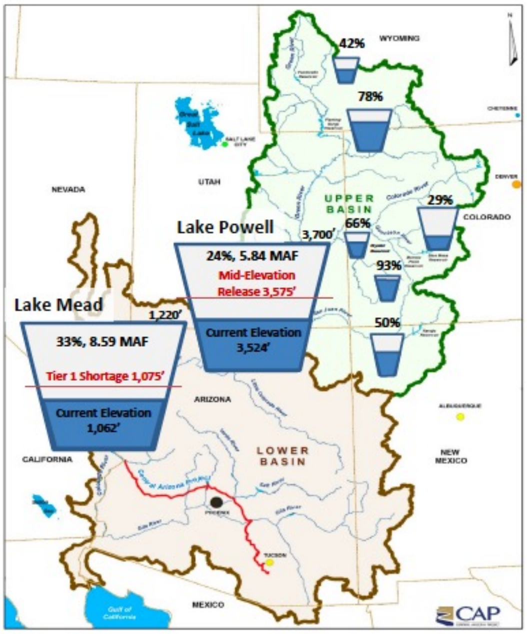
What do these Tier 1 cutbacks mean for Arizona water users? How is Arizona, which continues to grow, positioning itself for a long-term reality of less Colorado River water? The theme of complexity continues as we delve into a look at the Arizona water supply picture. Until the recent cuts in CAP water deliveries, about 40 percent of the 7 million acre feet used across Arizona was Colorado River water, with about an equivalent but growing percentage coming from groundwater. The remaining sources were other surface water supplies, such as Salt River Project waters, and reclaimed or recycled water. Groundwater is regulated pursuant to Arizona's 1980 Groundwater Management Act, as amended, in Active Management Areas (AMAs) only. The Central Arizona AMAs for the most part fall within CAP's service area and encompass Phoenix, the fifth largest city in the U.S., other cities in the Phoenix area, the Tucson region to the southeast, and large agricultural areas.[1] Lands of five Tribal Nations fall within AMA boundaries; however, the water use of sovereign Tribal Nations is not subject to state regulations.



Source: U.S. Bureau of Reclamation

There are different priorities of water deliveries within the CAP system. Historically, the lowest priority water

[1] AMA boundaries are not coincident with county boundaries but rather depend on hydrologic mapping. The three-county CAP service area includes Maricopa, Pinal, and Pima Counties.



Colorado River Water Supply Report

System Contents: 18.71 MAF

As of March 27, 2022

Last Year System Contents: 24.29 MAF

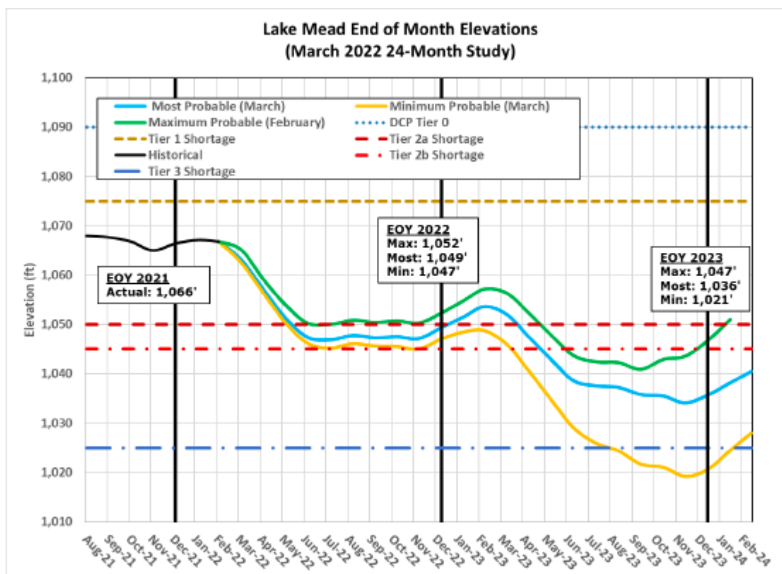
Reservoir Capacities (MAF)			
Reservoir	**Current**	**Change***	**Maximum**
Lake Mead	8.59	- 0.38	25.90
Lake Powell	5.84	- 0.28	24.30
Flaming Gorge Reservoir	2.92	+0.01	3.75
Fontenelle Reservoir	0.15	- 0.02	0.34
Navajo Reservoir	0.85	0.00	1.70
Blue Mesa Reservoir	0.24	0.00	0.83
Morrow Point Reservoir	0.11	+0.01	0.12
Crystal Reservoir	0.02	0.00	0.03

* With respect to previous month's report

CAP CENTRAL ARIZONA PROJECT
YOUR WATER. YOUR FUTURE.

Mead End of Month Elevations – March 24-Month Study

- Projected 2023 Conditions:
  - T1 = Max Probable
  - T2a = Min and Most Probable
- Anticipated 2024 Conditions:
  - T2b = Most Probable
  - T3 = Min Probable

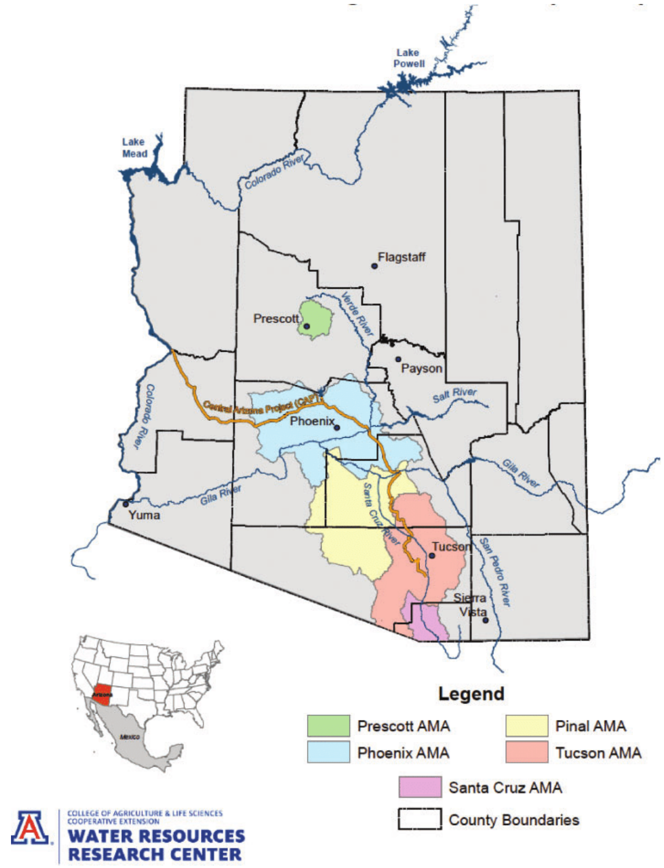


4 | Colorado River Water Supply Report

CAP CENTRAL ARIZONA PROJECT
YOUR WATER. YOUR FUTURE.

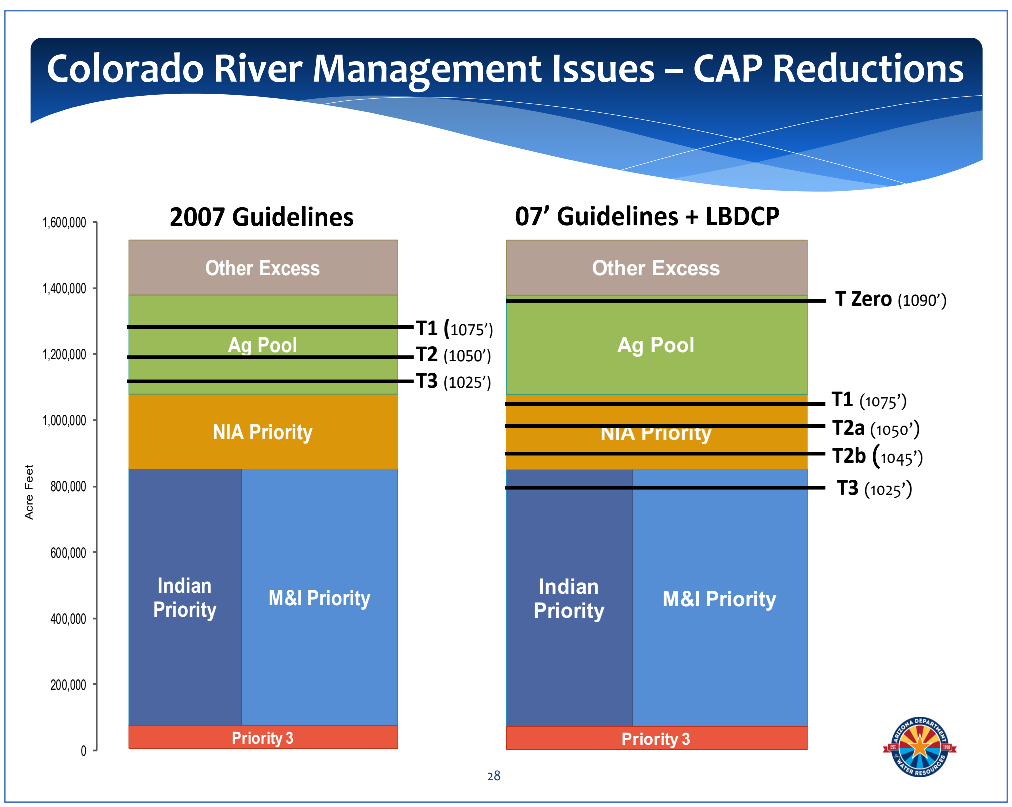
Source: Central Arizona Project, April 2022 Colorado River Water Supply Report to the Central Arizona Water Conservation District

has been what has been called "excess water" or water that was not ordered in a given year but available for use. Recent cutbacks have wiped out the prospects of there being excess water for water banking or other uses. The next lowest priority is water use by agricultural users within the CAP system. The Tier 1 cutback in CAP water deliveries has eliminated all the water known as "ag pool" water. Though there may continue to be some CAP water available to non-Indian agricultural users in the Central Arizona AMAs, the loss of the entire 300,000 acre-foot ag pool is severe and has significant ramifications. It should be noted that on-river agricultural users of Colorado River water, such as those in the Yuma region and Tribes do not experience these cutbacks. These distinctions in priorities are important. All of Arizona Colorado River water use is not junior to California, and not all agricultural water use is of lower priority to non-agricultural water use. CAP water deliveries overall are junior, and, within the CAP, water deliveries to non-Indian agriculture are of low priority. After ag pool water is cut, the category known as non-Indian agricultural (NIA) priority water is next to be cut. This category's name is a remnant of past plans for how agricultural water use of water delivered by the CAP would convert to municipal and industrial water use as agricultural lands were developed. Those holding contracts for NIA water are not agricultural water entities but rather Tribal Nations, cities, and others. The highest priority water categories within the CAP system are Indian and Municipal & Industrial (M&I). Note that some entities hold water contracts for multiple types of CAP water. Even these high priority uses risk being cut should Tier 3 cutbacks be ordered. There is one category of water delivered by the CAP that is of higher priority than other deliveries of water, as shown at the bottom of the block diagram. The diagram shows cutbacks in CAP water deliveries under the 2007 Interim Guidelines on the left compared to cutbacks with the 2019 Lower Basin DCP (LBDCP) overlay.



Map showing Arizona AMAs. *Source: University of Arizona Water Resources Research Center*

Recognizing the low priority of CAP water deliveries, Arizona has not been sitting idly by. In the mid-1990s, when more Colorado River was available than could be used directly, Arizona utilized a strong legislative and regulatory framework for water recharge and established the Arizona Water Banking Authority (AWBA) (Megdal and Seasholes (2014) and Seasholes and Megdal (2021)). The AWBA has stored underground millions of acre feet of Colorado River water for firming the water supplies of M&I and Indian priority water users when shortages hit those sectors. To date, that water remains in storage. Fortunately, some water



Source: Ken Slowinski, Arizona Department of Water Resources suppliers have not had to rely on their current CAP water allocations to meet current demands and have stored water for their future use.

Arizona water users have engaged in innovative partnerships to leave water in Lake Mead and/or ameliorate the burden of delivery cutbacks. Because Arizona's designated negotiator on Colorado River matters – the Director of the Arizona Department of Water Resources – requires legislative approval to sign on to interstate-federal water agreements, Arizona's negotiations on these challenging matters are necessarily inclusive. Arizona is alone among the Basin States in requiring legislative approval. Though intra-Arizona deliberations have at times been turbulent, many have pointed to Arizona's DCP consultative and deliberative process as exemplary. Not all the within-state actions are embraced by all Arizona parties. For example, actions to financially support the irrigation districts as they increase groundwater pumping to partially replace the lost surface water, concern those who see a return to greater groundwater reliance as counter to Arizona's efforts to reduce groundwater overdraft. Yet the irrigators have rights to use groundwater. Not only was their support needed at the Legislature, but there are serious concerns about the economic dislocation to farmers, along with their connected businesses and communities.

It is the Pinal AMA, a largely agricultural AMA in the central part of Central Arizona that is the epicenter of questions about the Colorado River shortage impacts. The Pinal AMA has a groundwater management goal different from the other AMAs, who all aspire to achieve safe-yield or a balance of groundwater withdrawals with natural and artificial recharge. The statutory management goal of the Pinal AMA (PAMA), however, is to allow the development of non-irrigation water uses and to preserve existing agricultural economies in the PAMA for as long as feasible, consistent with the necessity to preserve future water supplies for non-irrigation uses (A.R.S. § 45-562(B)). This region between Phoenix and Tucson continues to attract non-agricultural businesses and their workers. Update to the Arizona Department of Water Resources' groundwater model for the region has brought attention to the imbalance between the expected groundwater demands and groundwater supplies available for use per existing groundwater regulations. Coupled with the focus on the region's agricultural water use have been serious questions about the ability of the non-agricultural development to occur as expected by landowners and developers.

In fact, non-renewable groundwater remains a primary water source for many. Growing populations and economic activity have stressed groundwater resources throughout Arizona, especially in areas outside the AMAs, where there are no groundwater regulations, nor are there water conservation or metering requirements. Groundwater's "invisibility" makes it difficult to know water in storage, and water quality information can be limited. Recognizing these water pressure points, Arizona's Governor Ducey established the Governor's Water Augmentation, Innovation, and Conservation Council to assess the challenges and consider options to address them. In addition, in 2022 Governor Ducey proposed formation of and funding for an Arizona Water Authority, with legislative authorizing language being formulated during the ongoing legislative session. At the same time, some local communities are advocating for formation of new AMAs, something that has not occurred since the Santa Cruz AMA was "carved out of" the Tucson AMA in 1994. In actuality, no new lands have become subject to AMA groundwater regulations since the 1980 adoption of the Groundwater Management Act. In the past and currently, legislative proposals to authorize other regional approaches to water management have stalled due to lack of consensus. Nevertheless, many of the policy options are under discussion. While not all are new, pilot projects, renewed interest, and/or variations in their characterization are generating more robust discussions. Others remain on the back burner. The following discussion summarizes some of these options.

Policy Options and Opportunities

Conservation: No one questions the value of using less water, though there may be questions about what happens to the water conserved. Is it used to support growth? Or more cropping if by the agricultural sector? Though there may be great potential in some places for water savings due to conservation, many water users or suppliers in the AMAs have water conservation programs in place. What could help guide investment in incremental water conservation programs is an approach like that of Southern Nevada Water Authority, where they have calculated the expected impacts of water conservation programs on gallons-per-capita-per-day water consumption. (Pellegrino (2022))

Greater efficiency: Especially in the agricultural sector, conservation is not necessarily the same as more efficiency. (Frisvold et al. (2018)) Installation of novel drip irrigation systems through pilot programs are enabling measurement of the change in water use as well as yields as farmers irrigate fields previously receiving flood irrigation with drip irrigation that relies on gravity-fed rather than highly pressurized water deliveries. Recent legislative activity has considered providing incentives for installation of higher efficiency irrigation technologies. Some of the pilots are being undertaken without incentives; others involve partnerships among water agencies and farmers, including tribal farming entities. Research and pilots related to different crops, such as guayule, which is used for production of rubber products, continue.

Water reuse: In many parts of Arizona, water reuse is a substantial component of water supply portfolios. For years, effluent from metropolitan Phoenix has been used as cooling water for the Palo Verde Generating Station operated by Arizona Public Service. Many communities have ordinance requiring golf courses irrigate with reclaimed water. Some recharge their treated wastewater for meeting non-potable demands for water through storage and recovery. Rules have been adopted in Arizona allowing for direct potable reuse, although no water provider is currently engaged in direct potable reuse. It is recognized that wise reuse is every bit as important as wise "first use" of water. An advantage of water reuse is that the water is locally generated. Included in this category is grey water use at individual households. Increased use of gray water by households means less water flowing into centralized wastewater treatment plans for use by the owners of plant outflows. Also, as water use becomes more efficient, household wastewater flows may decrease.

Desalination: Though Arizona does not abut a sea or an ocean, seawater desalination has been of interest, particularly in collaboration with Mexico. Through the International Boundary and Water Commission, a binational study (**Full Report** and **Executive Summary**) of the potential for large-scale seawater desalination in the Sea of Cortez was completed in 2020. Though this highly collaborative study suggested feasibility, there are many yet-to-be explored questions about such a binational effort in terms of cost, environmental implications, and institutional feasibility. Some talk about it in the context of an exchange: Arizona would help pay for production of water to be used in Mexico in exchange for some of Mexico's Colorado River allocation. Others speak to the possibility of piping the water into the United States. It is clear that working through the many jurisdictional layers and across multiple election cycles at the state and federal levels would be necessary. Possibilities to desalinate in-state brackish groundwater exist, but regulations for disposal of the brine are pending and legal questions regarding the groundwater itself, particularly in the AMAs, have been raised. Though there are some mechanisms for multi-party collaboration within Arizona to fund infrastructure that would be too expensive for a single entity, these opportunities are not active. Questions about the feasibility of restarting or rebuilding the Yuma Desalting Plan also remain.

Moving water: Moving water from one part of Arizona to another comes up in different contexts. One is the transport of Colorado River water from the western boundary of Arizona into Central Arizona. This option, which is unpopular with many along the Colorado River, is seen as an option for meeting growing water needs in Central Arizona. The transfer from landowners in Cibola, Arizona to Queen Creek, Arizona, pending approval by the federal government, is an example. Others have been proposed but not realized for various reasons. Another opportunity is moving groundwater. Though in the late 1980s Arizona enacted legislation limiting movement of groundwater from one basin to another, some exceptions were allowed. One area from which groundwater can be moved is the Harquahala Valley west of Phoenix. Per the CAP's System Use Agreement, the CAP canal could be used for transport of that water, provided that water quality requirements are met. These and related issues are active, including legislation that would enable a private entity to join public entities as eligible to build infrastructure needed for the project. Note that both options discussed here do not augment Arizona water supplies. The first transfers use from agricultural lands in Western Arizona to municipal use in Central Arizona. The second would also transfer water that would/could be used by agriculture in the

Harquahala Valley for municipal use in Central Arizona. A key difference is that the first would be considered renewable water because it is mainstem Colorado River water. In the second instance, the water to be moved is non-renewable groundwater. Some “out-of-the-box” and out-of-region options for moving water include moving water from another region of the United States to Arizona. Multiple ideas have been articulated, including moving floodwater from the Midwest to Arizona via a northern route that could feed into Lake Powell. While some consider such ideas as totally infeasible, others would like to see them investigated, much like the opportunity for binational desalination has been investigated.

Marketing and other mutually agreed-upon transactions: The two examples above can be considered examples of water marketing. In general, market mechanisms involving multiple buyers and sellers interacting through some sort of platform is non-existent in Arizona. Yet, there is a market for the long-term water storage credits that have been accrued pursuant to Arizona’s water storage (recharge) and recovery framework (Bernat and Megdal (2020)). Other opportunities typically involve private negotiations between a buyer and a seller. Private negotiations are allowed of public entities, with only the final vote for the transaction being made public for bodies subject to open meeting laws. A large purchaser of long-term storage credits has been the **Central Arizona Groundwater Replenishment District**, which is required to replenish groundwater use by its Central Arizona members. Efforts to meet required water cutbacks or voluntarily leave water in Lake Mead have involved payment for non-use of water as agricultural lands are fallowed. The contexts for these transactions are many and can be complex.

Rainwater and stormwater capture: Individual household efforts to capture rainwater either actively through cisterns or passively, through swales and directing gutter water to trees, can help augment indirectly the water supplies of a region by substituting rainwater for water delivered through the potable water system. How much of that water would have eventually made its water into the water system relied upon by water suppliers is not quantified, but considerations of whether some of that might have become surface water subject to appropriation by downstream users does not seem to be an obstacle. Arizona law is quite permissive as to individual household installation of rainwater systems, as it is for individual gray water systems. Questions about rainwater harvesting for larger footprints do exist and are indicative of need for study of what water would make it into a stream versus lost to evaporation, for example, and the costs of mechanisms to capture stormwater for recharge.

Designing the built environment: An opportunity for improving the supply-demand imbalance is designing communities and building for lower water use. As a state that continue to grow, with large, planned communities, innovative design could contribute to reduced calculations of water demands. Arizona has the potential to lead in showing how to live in the desert.

Moving Forward

Arizona is a large and diverse state. Population and business growth continues. Agricultural activities are growing in some parts of the State. Colorado River water is an extremely important source of water for Arizona, but it is not the only Arizona water source facing stress. Many parts of Arizona rely almost exclusively on non-renewable groundwater. Some areas are facing the same groundwater overdraft problems that led to the enactment of the 1980 Groundwater Management Act. In addition, water management issues remain for the Active Management Areas. The policy options and opportunities discussed above are not necessarily new. Many, though not all, were discussed in the **2014 Arizona Strategic Vision for Water Supply Sustainability**. However, that document has not been used to guide regional and statewide water planning. While stakeholders have participated productively in meetings of various steering groups, councils, and committees, Arizona does not have a State Water Plan to guide its forward direction. Discussions to form a statewide Arizona Water Authority to pursue options for augmentation include significant funding, funding that has not previously been on the table. There are many questions regarding the scope and governance of the authority. What sorts of projects would it undertake? How would local communities engage? What kinds of partnerships are envisioned? The need for action is recognized statewide, though perhaps not surprisingly, not all agree on the forum or approach.

Robust discussion and debate are welcome – if they lead to action. Bold actions are required so that Arizona can chart its water future. As many note, one can hope or pray for the best, but the necessary course of action is to plan for the worst. Unfortunately, Colorado River conditions are only getting worse. No one holds the crystal ball to know how bad they will go. In April 2022, concerns about the level of Lake Powell resulted in unprecedented actions to keep Lake Powell from falling below the level necessary for electricity generation and for the regular flow of water downstream of the dam. Actions to increase releases into Lake Powell from Flaming Gorge reservoir and decrease releases from Lake Powell to Lake Mead were announced by the Department of the Interior and agreed to by the seven Basin States. Much more is needed, particularly in Central Arizona, which bears so much of the brunt of the expected cutbacks. Collaboration and partnerships are needed so that we can adapt to these drier conditions. Some of the efforts require significant advance planning. A key question is whether we in Arizona will identify the pathways forward proactively or respond reactively to crisis. Perhaps adapting to drier Colorado River conditions will require both proactive and reactive actions as we maneuver these uncharted waters.

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Benefitting from the Common Heritage of Humankind: From Expectation to Reality

Valuing the Deep Sea for the Benefit of Humankind

Aline Jaeckel

Editor's Note: Debate has been ongoing for decades about how best to value and share the biological and mineral resources on the international seabed, identified in the UN Convention on the Law of the Sea as the "Common Heritage of Mankind." The original plan was to gather the necessary scientific data in advance of any exploitation to ensure that biological and mineral resources would be responsibly conserved and managed, and to adopt an administrative process that would ensure that any revenues derived from exploitation would be equitably shared among developed and developing countries. This article describes how the original plans were amended, resulting in incomplete scientific assessment and the "privatizing" of exploitation, leading to today's difficulties and dissatisfaction with the process.

The rationale for mining the seafloor has changed over time, from wealth generation and redistribution, to the active participation of developing States, and supply security. The picture is further complicated by rising concerns about the environmental risks of seabed mining as well as enduring concerns about the negative economic effects for land-based mineral producing States. These changes in benefits and concerns affect our understanding of what actions should flow from the seabed and its resources being the Common Heritage of Mankind (CHM). Indeed, the CHM concept encapsulates these seemingly conflicting developmental, commercial, and ecological imperatives.[1]

With seabed mining edging closer to becoming a reality, there is a need to critically analyse these imperatives and the range of benefits that humankind can (and in some cases already does) derive from the seabed beyond national jurisdiction (the "Area"). As Dr. Surabhi Ranganathan of the University of Cambridge concludes, 'we need more critical inquiry into the idea of the "benefit of mankind" and whether, why and how it may be advanced by seabed mining'.[2]

There are at least six categories of benefits that can be considered. In other words, the CHM concept can be interpreted through different lenses that focus on achieving different, albeit sometimes interrelated, benefits. Identifying these can help to explain divergent views on how to give effect to the CHM. This article critically examines each of these six benefits and assesses them against historical expectations. This reductionistic view of CHM does not take into account the intrinsic value of the Earth's environment, including the deep ocean, and it may not do justice to the grand vision behind the CHM concept. Nonetheless, it is a pragmatic attempt to contribute to a discussion about what the Area regime can achieve today.

This article is an adaptation of an article of the same title, originally published in 2020 in the International Journal of Marine and Coastal Law. Aline Jaeckel was at the time a lecturer on the Faculty of Law at the University of New South Wales. Today, she is an Associate Professor at the University of Wollongong and a Research Associate at the Institute for Advanced Sustainability Studies.

[1] R Collins and D French, 'A Guardian of Universal Interest or Increasingly Out of Its Depth?' (29 July 2019) International Organizations Law Review 1–31, doi: 10.1163/15723747-2019011.

[2] S Ranganathan, 'Ocean Floor Grab: International Law and the Making of an Extractive Imaginary' (2019) 30 European Journal of International Law 573–600, doi: 10.1093/ejil/chz027.

Possible Benefits to Be Derived from the Area

Wealth Generation and Redistribution

In the 1960s and 70s, deep seabed minerals were thought to promise 'immeasurable wealth'[3] capable of generating substantial profits,[4] a prediction that was later described as 'unbridled speculation based on limited data and undeveloped technological capability of the past'.[5] At present, 'there is little consensus on whether [seabed mining] is likely to yield net benefits or costs'.[6] Some studies consider seabed mining to be 'sub-economic at present',[7] although any prediction is complicated by significant uncertainties regarding the size, distribution, and composition of marine mineral deposits.[8] Moreover, it remains extremely difficult to capture the economic value of deep-sea ecosystem services, including carbon absorption, which would be necessary to estimate the overall economic costs and benefits of seabed mining, including any effect on climate change.[9]

Economic profitability of seabed mining depends partially on its environmental footprint. As leading geologists concluded in 2016: 'Whether deep-sea mining will be a viable activity in the future depends largely on its environmental impacts, which have yet to be fully assessed'.[10] Mukhopadhyay et al. find nodule mining in the Indian Ocean to be 'economically feasible assuming that ... an appropriate mining technology is developed and can be used in order to lift the nodules without causing much damage to the ecosystem'.[11] This precondition could prove a major stumbling block as current data suggests that seabed mining 'will have devastating, and potentially irreversible im- pacts on marine life',[12] as discussed below in the section on ecosystem services.

Ranganathan argues that the promise of economic profit, though it already came into question during the early development of the Area regime,[13] was key to keeping developing States engaged in the seabed negotiations.[14]

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[3] UNGA, Summary of Records for 1st to 9th Meetings (Ad Hoc Committee to Study the Peaceful Uses of the Sea-Bed and the Ocean Floor Beyond the Limits of National Jurisdiction), UN Doc A/AC.135/SR.1-9 (10 May 1968), para 69.

[4] United Nations General Assembly (UNGA), Examination of the Question of the Reservation Exclusively for Peaceful Purposes of the Sea-Bed and the Ocean Floor, and the Subsoil Thereof, Underlying the High Seas beyond the Limits of Present National Jurisdiction and the Use of Their Resources in the Interests of Mankind, UN Doc A/C.1./PV.1516 (1 November 1967), para 27; D Bandow, 'Developing the Mineral Resources of the Seabed' (1982) 2 The Cato Journal 793–821; JL Mero, The Mineral Resources of the Sea (Elsevier, Amsterdam, 1965); Ranganathan (n 2); UNGA, Summary of Records for the 13th–26th Sessions (Ad Hoc Committee to Study the Peaceful Uses of the Sea-Bed and the Ocena Floor beyond the Limits of National Jurisdiction) UN Doc A/AC.135/SR.13-16 (1 November 1968).

[5] CL Antrim, 'Deep Seabed Mining the Second Time Around: Supply, Demand and Competitive Opportunities on the Underwater Frontier' (2006) 47 Sea Technology 17–22; see also GP Glasby, 'Lessons Learned from Deep-Sea Mining' (2000) 289 Science 551–553.

[6] MV Folkersen, CM Fleming and S Hasan, 'Depths of Uncertainty for Deep-Sea Policy and Legislation' (2019) 54 Global Environmental Change 1–5, doi: 10.1016/j.gloenvcha.2018.11.002.

[7] GP Glasby, J Li and Z Sun, 'Deep-Sea Nodules and Co-Rich Mn Crusts' (2015) 33 Marine Georesources and Geotechnology 72–78, doi: 10.1080/1064119X.2013.784838.; ECORYS, Study to Investigate the State of Knowledge of Deep-Sea Mining: Final Report to the European Commission under FWC MARE/2012/06 - SC E1/2013/04 (28 August 2014), https:// webgate.ec.europa.eu/maritimeforum/system/files/Annex%203%20Supply%20and%20demand_rev_1.pdf; accessed 27 May 2020.

[8] S Petersen, A Krätschell, N Augustin et al., 'News from the Seabed: Geological Characteristics and Resource Potential of Deep-Sea Mineral Resources' (2016) 70 Marine Policy 175–187, doi: 10.1016/j.marpol.2016.03.012.

[9] MV Folkersen, CM Fleming and S Hasan, 'The Economic Value of the Deep Sea: A Systematic Review and Meta-Analysis' (2018) 94 Marine Policy 71–80, doi: 10.1016/j.marpol.2018.05.003; Folkersen et al. (n 6).

[10] Petersen et al. (n 8).

[11] R Mukhopadhyay, S Naik, S De Souza et al., 'The Economics of Mining Seabed Manganese Nodules: A Case Study of the Indian Ocean Nodule Field' (2019) 37 Marine Georesources & Geotechnology 845–851, doi: 10.1080/1064119X.2018.1504149.

[12] O Heffernan, 'Deep-Sea Dilemma' (2019) 571 Nature 465–468.

[13] PE Sorensen and WJ Mead, 'A Cost-Benefit Analysis of Ocean Mineral Resource Development: The Case of Manganese Nodules' (1968) 50 American Journal of Agricultural Economics 1611–1620, doi: 10.2307/1237364.

[14] Ranganathan (n 2).

The expectation at the time was for seabed mining to become a funding source for international development efforts[15] and, more generally, a way to promote the economic and social advancement of developing States.[16]

Meeting those expectations seems improbable at present, not least because of the uncertain economic potential of seabed mining. Indeed, current discussions about the future payment regime for the Area have generated concern among developing State members of the ISA. Criticising the currently proposed low rate of payments from future mining operations to the ISA, the African Group notes: 'The African Group does not wish to see an exploitation regime that facilitates the loss of common heritage resources in return for minimal or no benefit to the populations of African countries, and other developing States'.[17]

Central to the criticism is the focus on making sure the post-tax profits for contractors are attractive for investors. As the African Group argues, this approach 'implies that the overarching goal of the payment regime is to not inhibit deep-sea mining. We do not agree with that goal or that approach'.[18] Instead, the African Group stressed that it will only support seabed mining 'if it is demonstrably beneficial to mankind'.[19]

Similar concerns were already voiced during the ISA's Preparatory Com- mission in the 1990s in relation to the ISA's power to determine the threshold for environmental degradation caused by seabed mining.

> [I]t was suggested that this could lead to a conflict of interest because the Authority, which would be dependent on revenue from economic activities in the Area, could be biased on [sic] favour of a permissive regulatory regime. Several delegations requested that some provisions be reformulated so that the obligations of the Authority correspond to those of a Sponsoring State.[20]

Determining the economic costs or benefits of seabed mining would require not only an assessment of potential profits but also any costs it generates from impacts to ecosystem services, such as climate regulation.[21] In other words, the natural capital of the seabed would need to be considered.[22] This is particularly important as any profits from seabed mining might be reaped predominantly by private actors while the costs are borne by humankind.[23] In its assessment of a seabed mining application, which led to an ongoing court battle, the New Zealand Environmental Protection Authority used the concept of 'total economic value', which includes 'the direct and indirect values of [natural] resources as used by others or for their intrinsic and ecosystem services

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[15] UNGA (n 3).

[16] UNGA (n 4), paras 114–115; UNCLOS III, Statements on the International Regime and Machinery (Continued), 5th meeting of the First Committee, 16 July 1974, UN Doc A/CONF.62/C.1/SR.5, para 18.

[17] African Group, Request for Consideration by the Council of the African Group's Proposal on the Economic Model/Payment Regime and Other Financial Matters in the Draft Exploitation Regulations under Review (9 July 2018), para 10, available at https://www.isa.org.jm / document/statement-algeria-obo-african-group-2; accessed 27 May 2020.

[18] M Remaoun, Statement on Behalf of the African Group on the Financial Model at the 25th Session of the Council of the ISA (25 January 2019) available at https://ran-s3 .s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/1-algeriaoboag_finmodel .pdf; accessed 27 May 2020.

[19] African Group, African Group Submission of Two Payment Regimes for Consideration by the Council of the International Seabed Authority (15 July 2019) available at https://ran -s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/agpaymentregimes.pdf; accessed 27 May 2020.

[20] Preparatory Commission for the International Seabed Authority (ISA) and for the International Tribunal for the Law of the Sea, Statement to the Plenary by the Chairman of Special Commission 3 on the Progress of Work in that Commission, UN Doc LOS/PCN/L.79 (28 March 1990), para 19.

[21] See e.g., Tonga, Tonga Interventions to Part 1 of the 25th Session of the Council of the ISA (2019) available at https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/7-tg_financial_model.pdf; accessed 27 May 2020.

[22] SE Beaulieu, TE Graedel and MD Hannington, 'Should We Mine the Deep Seafloor?' (2017) 5 Earth's Future 655–658, doi: 10.1002/ eft2.227.

[23] Folkersen et al. (n 6).

values'.[24] Such an approach is supported by scholars arguing for a net-positive benefit to humankind from seabed mining, which is to include 'an assessment of the likely impacts of mining activities on the natural capital of the Area and on other potential uses of the deep sea'.[25] The challenge lies in quantifying the value of ecosystem services provided by the Area, as we currently lack robust evidence.[26] This gap in knowledge would need to be filled before we can estimate the economic costs and benefits of seabed mining in the Area.

The question of wealth generation is further complicated by the fact that any economic profit generated by mining the Area would need to be balanced against potential losses for land-based mineral producing States, many of which are developing States. This key consideration was acknowledged early on,[27] with Algeria noting in 1974 that 'all the documents available suggested that the benefits to be acquired from seabed production would not serve to compensate the land-based producers'.[28] To address these concerns, the legal framework provides for an economic assistance fund for developing States, which, however, is to be financed only from contractors or voluntary contributions and only once the ISA has covered its own administrative costs.[29] Given these constraints, it remains unclear whether this fund can compensate developing States for lost income. In any event, the provision of this fund serves to demonstrate that economic losses to land-based producing developing States are to be expected and rather than seeking to prevent such loss, this fund merely applies 'after an adverse effect has materialized'.[30] In other words, wealth generation on the international level, if it was to occur, may still negatively affect some developing States as well as other States involved in land-based mining.

Realising the economic dimension of the CHM principle would presuppose not only wealth generation through seabed mining but also redistribution of that wealth. In fact, the LOSC specifically provides for the 'equitable sharing of financial and other economic benefits' derived from seabed mining.[31] In the 1970s, developing States expected to receive substantial direct payments from the ISA in the future,[32] an expectation that looks increasingly unlikely given the current discussions around the payment regime.

In any event, it remains unclear how any income of the ISA would be used, after administrative costs of the ISA are covered and some funds are used for the economic assistance fund.[33] The use of funds paid to the ISA as a

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[24] New Zealand Environmental Protection Authority, Trans-Tasman Resources Ltd Marine Consent Decision (June 2014), para 86, available at https://www.epa.govt.nz/assets/File API/proposal/EEZ000004/Boards-Decision/ff4e630f5d/EEZ000004-Trans-Tasman -Resources-decision-17June2014.pdf; accessed 27 May 2020; RE Kim and DK Anton, 'The Application of the Precautionary and Adaptive Management Approaches in the Seabed Mining Context: Trans-Tasman Resources Ltd Marine Consent Decision under New Zealand's Exclusive Economic Zone and Continental Shelf (Environmental Effects) Act 2012' (2015) 30 International Journal of Marine and Coastal Law 175–188, doi: 10.1163/15718085-12341343.

[25] S Christiansen, H Ginzky, P Singh and T Thiele, The International Seabed Authority and the Common Heritage of Mankind (IASS Policy Brief 2/2018) (Institute for Advanced Sustainability Studies, 2018); Folkersen, Fleming and Hasan (n 9).

[26] Folkersen et al. (n 6).

[27] Chile, Working Paper on the Economic Implications for the Developing Countries of the Exploration of the Sea-Bed Beyond the Limits of National Jurisdiction, UNCLOS III, 26 August 1974, UN Doc A/CONF.62/C.1/L.11, para 179.

[28] UNCLOS III (n 16).

[29] Agreement Relating to the Implementation of Part XI of the United Nations Convention on the Law of the Sea (New York, 28 July 1994, in force 28 July 1996) 1836 UNTS 3 [1994 Implementing Agreement], Annex, section 7; United Nations Convention on the Law of the Sea (Montego Bay, 10 December 1982, in force 16 November 1994) 1833 UNTS 3, Arts 151(10), 164(2)(d). [LOSC].

[30] J Siegfried, 'Article 151' in A Proelss (ed), United Nations Convention on the Law of the Sea: A Commentary (C.H. Beck/Hart/Nomos, Munich/Oxford/Baden-Baden, 2017), at p. 1074.

[31] LOSC (n 29), Art 140(2); 1994 Implementing Agreement (n 29), Annex, section 8.

[32] I Feichtner, 'Sharing the Riches of the Sea: The Redistributive and Fiscal Dimension of Deep Seabed Exploitation' (2019) 30 European Journal of International Law 601–633, doi: 10.1093/ejil/chz022, at p. 611; RS Katz, 'Financial Arrangements for Seabed Mining Companies: An NIEO Case Study' (1979) 13 Journal of World Trade 209–222.

[33] LOSC (n 29), Art 173(2); 1994 Implementing Agreement (n 29), Annex, section 1(14).

proxy for humankind might indeed serve to illustrate one of this article's arguments, namely that the vision of the benefits to be derived from the CHM has changed over time. In addition to direct payments to (developing) States, current discussions consider funding the Enterprise (the mining arm of the ISA, the operationalization of which was delayed as a part of the 1994 agreement), as discussed below, or a global sovereign wealth fund that can be used for activities that benefit developing States and/or humankind as a whole, including future generations.[34]

Advancement of Developing States

In addition to generating wealth, seabed mining was to enable developing States to become active participants in collective natural resource management and supporting them in determining their own economic future. As Ranganathan argues:

> [T]hese aspects were perhaps even more meaningful than developed states' commitment to share the profits derived from the exploitation of seabed minerals. For that commitment, although important in itself, could be assimilated within the existing order in which developing states remained passive recipients of aid and consumers of products manufactured elsewhere.[35]

This aim of collective management and solidarity was to be achieved, inter alia, through four key measures: the Enterprise, technology transfer, capacity building, and reserved areas. As is well-known, the 1994 Implementing Agreement undermined these measures and, by extension, the advancement of developing States.[36] However, more recent changes introduced by the ISA have also contributed to shifting away from the notion of collective benefit enshrined in the CHM concept, in favour of supporting individual developing States.

The LOSC foresaw the Enterprise as a public body that would itself conduct deep-seabed mining on behalf of humankind.[37] To allow the Enterprise to keep pace with States and private mining companies, the LOSC provided for funding from States parties, technology transfer to the Enterprise, and capacity-building programmes to ensure the Enterprise has qualified staff.[38] The Implementing Agreement significantly undermined the idea of the Enterprise, not least by eliminating obligatory technology transfers and removing any obligation of States parties to provide funding, leaving the idea of the Enterprise to potentially fail on the basis of insufficient funds.[39] Discussions about setting up the Enterprise have been slow, and its initial functions that were supposed to be performed by the ISA Secretariat have been neglected for some time,[40] causing developing States to repeatedly express dismay at the lack of progress in setting up the Enterprise.[41]

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[34] PEW/RESOLVE, Report of the Workshop 'The Common Heritage of Mankind: Definition and Implementation' at Ocho Rios, Jamaica on 21 July 2018 (PEW Charitable Trusts and RESOLVE, 2018); A Jaeckel, JA Ardron and KM Gjerde, 'Sharing Benefits of the Common Heritage of Mankind: Is the Deep Seabed Mining Regime Ready?' (2016) 70 Marine Policy 198–204, doi:10.1016/j.marpol.2016.03.009.

[35] S Ranganathan, 'The law of the sea and natural resources' in Eyal Benvenisti and Georg Nolte (eds), Community Interests across International Law (Oxford University Press, Oxford, 2018) 121–135, doi: 10.1093/oso/9780198825210.001.0001.

[36] AG Kirton and SC Vasciannie, 'Deep Seabed Mining under the Law of the Sea Convention and the Implementing Agreement: Developing Country Perspectives' (2002) 51 Social and Economic Studies 63–115, at p. 90.

[37] LOSC (n 29), Arts 153, 170.

[38] Final Act of UNCLOS III, Resolution II 'Governing Preparatory Investment in Pioneer Activities Relating to Polymetallic Nodules', UN Doc A/CONF.62/121* (27 October 1982), para 12(a)(ii).

[39] 1994 Implementing Agreement (n 29), Annex, sections 2(3), 5(1)(b).

[40] ISA, Final Report on the Periodic Review of the International Seabed Authority Pursuant to Article 154 of the United Nations Convention on the Law of the Sea, ISBA/23/A/3 (8 February 2017), para 21; 1994 Implementing Agreement (n 29), Annex, section 2(1).

[41] African Group, Request for Consideration by the Council of the African Group's Proposal for the Operationalization of the 'Enterprise' (6 July 2018), para 12, available at https://www .isa.org.jm/document/statement-algeria-obo-african-group-1); accessed 27 May 2020; IISD, 'ISA-24 Part 2 Highlights: Friday 20 July 2018' (2018) 25 Earth Negotiation Bulletin 164, available at http://enb.iisd.org/vol25/ enb25164e.html; accessed 27 May 2020.

In the absence of the Enterprise, capacity building foreseen in the LOSC[42] has been focused on providing individual citizens of developing States with educational opportunities through the ISA's training programmes. These are arguably the most tangible benefits the Area regime currently offers. Between 2013 and 2018, a total of 98 training places were provided, which range from multi-year fellowships and scholarships to at-sea training, internships, and a tendance at workshops.[43] Additionally, the ISA's Endowment Fund for Marine Scientific Research in the Area has provided financial support to individuals from developing States to participate in marine scientific research pro- grammes and activities. While scientific research is undeniably important and training programmes are a valuable measure to support developing States, the Convention's provisions on capacity building can only be realised partially by a focus on individuals rather than the collective longer-term benefit envisioned to arise from upskilled personnel for the Enterprise.

The absence of a functioning Enterprise also affects other measures, such as reserved areas. These are sites with economically valuable mineral deposits that have been studied by contractors from developed States as a condition of them obtaining exploration rights over another site.[44] Reserved areas can be explored and exploited by the Enterprise or a developing State,[45] though the Enterprise has a preferential right of access to reserved areas, which it has not been able to exercise because it does not yet function independently.[46] Instead, reserved areas have only been claimed by individual developing States, most of whom sponsor private companies from developed States, including the ones that originally contributed the reserved area.[47]

Some view this as a pragmatic and successful way for developing States to be actively involved in the Area regime. However, accessing reserved areas as a sponsoring State rather than collectively through the Enterprise increases the risk for developing States as they can be held liable for environmental harm caused by their sponsored entity.[48] In contrast, engaging in mining through the Enterprise alleviates that substantial risk for developing States, although questions remain about the extent of liability of the Enterprise.[49] In addition, it remains unclear whether States accrue significant benefits from sponsoring foreign private mining companies.[50] Moreover, one commentator has speculated about the potential for sponsoring States to also incur financial risks of investment arbitration under international investment law.[51] The role of sponsoring States, as well as the benefits and risks incurred by them, requires further investigation.

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[42] LOSC (n 29), Arts 143(3), 144; Annex III, Art 15; 1994 Implementing Agreement (n 29), Annex, section 1(10), 2(2), 2(5).

[43] ISA, Assembly Report of the Secretary-General of the International Seabed, ISBA/25/A/2 (3 May 2019), para 68, available at https://www.isa.org.jm/document/isba25a2; accessed 27 May 2020.

[44] LOSC (n 29), Annex III, Arts 8, 9.

[45] Ibid., Annex III, Art 9.

[46] Ibid., Annex III, Art 9(4).

[47] Jaeckel et al. (n 49); G Barron, Address to ISA Council (27 February 2019) available at https://www.isa.org.jm/document/nauru-1; accessed 27 May 2020.

[48] LOSC (n 29), Arts 139, 153(4); Annex III, Art 4(4); Seabed Disputes Chamber of the ITLOS, Responsibilities and Obligations of States Sponsoring Persons and Entities with Respect to Activities in the Area, Advisory Opinion, 1 February 2011, ITLOS Reports 2011.

[49] T Davenport, Responsibility and Liability for Damage Arising Out of Activities in the Area: Attribution of Liability (Liability Issues for Deep Seabed Mining Series, Paper No. 4) (Centre for International Governance Innovation, 2019) available at https://www.cigionline.org /sites/default/files/documents/Deep%20Seabed%20Paper%20No.5_0.pdf; accessed 27 May 2020; E Egede, M Pal and E Charles, A Study on Issues Related to the Operational- ization of the Enterprise in Particular on the Legal, Technical and Financial Implications for the International Seabed Authority and for States Parties to the United Nations Convention on the Law of the Sea (ISA, Kingston, 2019), paras 27–30, available at https://ran-s3 .s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/study-enterprise-unedited_advance_text-11jul2019.pdf; accessed 27 May 2020.

[50] Feichtner (n 32), at p. 631.

[51] A Pecoraro, 'Deep Seabed Mining in the Area: Is International Investment Law Relevant?' (2019) EJIL: Talk!, available at https://www.ejiltalk.org/deep-seabed-mining-in-the-area-is-international-investment-law-relevant/; accessed 27 May 2020.

Reserved areas being claimed by sponsoring States also affects the future prospects of the Enterprise, which must conduct its initial operation by joint venture.[52] The incentive for a State or company to propose a joint venture is to gain access to reserved areas. Dwindling numbers of reserved areas arguably make future proposals for joint ventures less likely. Put bluntly, fewer reserved areas equal less incentive to build a joint venture, which in turn reduces the chance of the Enterprise becoming fully operational.

This trend has been exacerbated by a regulatory change introduced in 2010, through which the ISA offers contractors exploring certain types of mineral deposits a choice between contributing a reserved area or offering an equity interest in a joint venture arrangement.[53] Under an equity interest, the Enterprise will receive a share of any profits (at least 20 per cent, and up to 50 per cent if so negotiated), from the contractor's future exploitation of minerals, though the specific terms have yet to be developed. In other words, instead of supporting developing States to directly participate in mining the common heritage, the equity interest option instead rests on financial benefits, the sharing of which is delayed until commercial mining is underway.[54] The equity interest option was introduced because the mineral deposits in question would require substantial upfront exploration work to identify a potential reserved area.[55] However, the decision had follow-on effects for the overall number of reserved areas and thus the future of the Enterprise.

At the same time, the equity interest option offers a potential funding source for the Enterprise. Yet with few reserved areas, and the mineral and environmental data associated with such areas, it becomes less likely that the Enterprise will assume an active role in mining. Indeed it is unclear what role the Enterprise could assume beyond financial redistribution or reinvestment.[56]

As the discussion demonstrates, the original vision of collective benefit and active participation of developing States has largely given way to a focus on privileging individual developing States through access to training programmes and reserved areas. While this shift was initiated by the 1994 Implementing Agreement, it was furthered by the ISA's hesitation to prepare for an independent Enterprise as well as its introduction of an alternative to reserved areas. As Feichtner argues: 'the transformations that the regime is undergoing are promoting a further integration of developing states into an economic order that is characterized by competition and has all but lost its redistributive ambitions'.[57]

Security of Mineral Supply

The availability of metals may be regarded as a benefit in its own right. An increase in living standards across the world's middle class equates to an in- creased demand for metals. As one participant at a July 2018 workshop noted:

> The most significant benefit to bestow on current and future generations is providing them with the minerals that they will need for their economic development. A mature deep-sea mining industry will increase the supply of those minerals and thereby hold down prices.[58]

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[52] 1994 Implementing Agreement (n 29), Annex, section 2(2).

[53] ISA, Regulations on Prospecting and Exploration for Polymetallic Sulphides in the Area, ISBA/16/A/12/Rev.1 (7 May 2010), regulations 16–19, available at https://www.isa.org.jm /documents/isba16a12-rev-1; accessed 27 May 2020; ISA, Regulations on Prospecting and Exploration for Cobalt-Rich Ferromanganese Crusts in the Area, ISBA/18/A/11 (22 October 2012), regulations 16–19, available at https:// www.isa.org.jm/documents/isba18a11; accessed 27 May 2020.

[54] Jaeckel et al. (n 34).

[55] ISA, Considerations Relating to the Regulations for Prospecting and Exploration for Hydrothermal Polymetallic Sulphides and Cobalt-Rich Ferromanganese Crusts in the Area, ISBA/7/C/2 (29 May 2001), para 12.

[56] PEW/RESOLVE (n 34).

[57] Feichtner (n 32).

[58] PEW/RESOLVE (n 34).

There is certainly truth in that, although the extent to which future generations can benefit from an increase in metal supply now depends on metal recycling rates and efforts to move towards a circular economy. Moreover, developing States that engage in land-based mining might in fact be adversely affected by reductions in metal prices, as discussed above. Indeed, the African Group of ISA member States recently noted that they will only support a payment regime that 'results in substantial and fair compensation to mankind' and that either 'constrains production from deep-sea mining to a level that does not result in lower metal prices and a loss of government revenue from land-based mining' or 'results in high enough revenue from deep-sea mining for governments with revenues from land-based mining to be fully compensated'.[59]

In recent years, the benefit of mineral supply has also been framed as necessary for shifting to the green economy and scaling up renewable energy technologies that rely on minerals.[60] In other words, the environmental risks of seabed mining are framed as a necessary cost for achieving another environ- mental goal, namely reducing carbon emissions. This presents a very recent argument in favour of seabed mining and certainly a significant shift from the originally anticipated benefits. While the jury is still out, some regard seabed mining as a necessary compromise,[61] whereas others consider this choice to be a false one, arguing that minerals from the seafloor are not required even to achieve a shift to 100 percent renewable energy supply.[62]

Ecosystem Services

Key benefits which all of humankind derive from the deep oceans are ecosystem services and functions, including oxygen production, carbon dioxide absorption, and climate regulation.[63] These are current rather than future benefits, and the challenge is to ensure that disturbances to the seafloor from mining would not significantly affect these fundamental ecosystem services. Problematically, it remains unclear which ecosystem services are likely to be impacted by seabed mining,[64] though scientists are now predicting potentially 'irreversible loss of some ecosystem functions' from nodule mining[65] and overall biodiversity loss from seabed mining.[66]

This is a significant shift from earlier assumptions. In the 1970s, nodule mining was believed to have far fewer environmental consequences than we know today, with some having argued that 'there are virtually no living organisms' around potential mine sites,[67] which turned out to be entirely incorrect.[68] In the 1990s, as scientific

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[59] African Group, African Group Submission on the ISA Payment Regime for Deep-Sea Mining in the Area (5 July 2019) available at https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/files/documents/agsmitmodelfinal.pdf; accessed 27 May 2020.

[60] D Shukman, 'Renewables' deep-sea mining conundrum' (11 April 2017) BBC, available at https://www.bbc.com/news/science-environment-39347620; accessed 27 May 2020.

[61] J Major, 'Deep sea mining could help develop mass solar energy: Is it worth the risk?' (24 April 2017) The Conversation.

[62] S Teske, N Florin, E Dominish and D Giurco, Renewable Energy and Deep-Sea Mining: Supply, Demand and Scenarios (Report prepared by ISF for JM Kaplan Fund, Oceans 5 and Synchronicity Earth, 2016) available at https://opus.lib.uts.edu.au/handle/10453/67336; accessed 27 May 2020.

[63] Folkersen et al. (n 9); JT Le, LA Levin and RT Carson, 'Incorporating Ecosystem Services into Environmental Management of Deep-Seabed Mining' (2017) 137 Deep-Sea Research Part II: Topical Studies in Oceanography 486–503, doi: 10.1016/j.dsr2.2016.08.007.

[64] Le et al. (n 63).

[65] E Simon-Lledó, BJ Bett, VAI Huvenne et al., 'Biological Effects 26 Years after Simulated Deep-Sea Mining' (2019) 9 Scientific Reports 8040, doi: 10.1038/s41598-019-44492-w.

[66] CL Van Dover, JA Ardron, E Escobar et al., 'Biodiversity Loss from Deep-Sea Mining' (2017) 10 Nature Geoscience 464–465, doi: 10.1038/ngeo2983; HJ Niner, JA Ardron, EG Escobar et al., 'Deep-Sea Mining with No Net Loss of Biodiversity—An Impossible Aim' (2018) 5 Frontiers in Marine Science 53, doi: 10.3389/fmars.2018.00053.

[67] DB Johnson and DE Logue, 'US economic interests in law of the sea issues' in Ryan C Amacher (ed), The Law of the Sea: US Interests and Alternatives (AEI Press, Washington, DC, 1975), at p. 47.

[68] DOB Jones, DJ Amon and ASA Chapman, 'Mining Deep-Ocean Mineral Deposits: What Are the Ecological Risks?' (2018) 14 Elements 325–330, doi:10.2138/gselements.14.5.325.

understanding of the deep ocean improved, significant environmental impacts of seabed mining were highlighted, although considerable uncertainties remained.[69] A 1992 study concluded that disturbance from manganese nodule mining would likely have ‘a large scale severe and disastrous impact on the seabed and the benthic community’.[70] However, the effects of sedimentation at far distances from the mining site were considered to have been overestimated.[71] As scientific knowledge has advanced in the period since the 1990s, these predictions have increased in respect of severity of potential impact,[72] with a 2011 study concluding that due to the environmental conditions of abyssal nodule habitats, ‘the mechanical and burial disturbances resulting from commercial-scale nodule mining are likely to be devastating’.[73] In addition, concerns are being raised about the potential of mining plumes to affect the mid-water column, including through introduction of metal pollution to commercially-fished species such as tuna.[74]

A 2019 study concluded that the ecological footprint of nodule mining ‘may be greater than expected’.[75] The DISCOL site, a scientific experiment involving seafloor disturbances on a small scale carried out in 1989 remains heavily impacted today. As Thiel, the lead scientist on the original experiment concludes: ‘The disturbance is much stronger and lasting much longer than we ever would have thought’.[76] In short, the more scientists learn about deep-ocean ecosystems, the more concerned they become about the magnitude of the environmental impacts of seabed mining.

Environmental considerations have been part of the Area regime from the start and were already reflected in the UN’s 1970 Declaration of Principles.[77] Similarly, the CHM captures the conservation and preservation of natural and biological resources for both present and future generations.[78] The LOSC imposes on the ISA an

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[69] JM Markussen, ‘Deep Seabed Mining and the Environment: Consequences, Perceptions, and Regulations’ (1994) Green Globe Yearbook of International Co-operation on Environment and Development 31–39, at p. 34; CL Morgan, N Allotey Odunton and AT Jones, ‘Synthesis of Environmental Impacts of Deep Seabed Mining’ (1999) 17(4) Marine Georesources and Geotechnology 307–356, doi: 10.1080/106411999273666, at p. 329; H Thiel, ‘Deep-Sea Environmental Disturbance and Recovery Potential’ (1992) 77 Internationale Revue der gesamten Hydrobiologie und Hydrographie 331–339, at p. 335; DD Trueblood, E Ozturgut, M Pilipcuk and IF Gloumov, ‘The Ecological Impacts of the Joint U.S.-Russian Benthic Impact Experiment’ (1997) Proceedings of the ISOPE Ocean Mining Symposium 139–145, at p. 139.

[70] Thiel (n 69), at p. 333.

[71] Trueblood et al. (n 69), at p. 139; H Amann and H Beiersdorf, ‘The Environmental Impact of Deep Sea Mining’ (1993) Proceedings of the 25th Annual Offshore Technology Conference 213–231, at p. 218.

[72] CL Van Dover, ‘Impacts of Anthropogenic Disturbances at Deep-Sea Hydrothermal Vent Ecosystems: A Review’ (2014) 102 Marine Environmental Research 59–72, doi: 10.1016/j .marenvres.2014.03.008; E Ramirez-Llodra, PA Tyler, MC Baker et al., ‘Man and the Last Great Wilderness: Human Impact on the Deep Sea’ (2011) 6 PLoS ONE 1–25, doi: 10.1371 /journal.pone.0022588; Beaulieu et al. (n 22); DOB Jones, S Kaiser, AK Sweetman et al., ‘Biological Responses to Disturbance from Simulated Deep-Sea Polymetallic Nodule Mining’ (2017) 12 PLoS ONE, doi: 10.1371/journal.pone.0171750; Midas Consortium, ‘Managing Impacts of Deep Sea Resource Exploitation: Research Highlights’ (2016) avail- able at https://www.eu-midas.net/sites/default/files/downloads/MIDAS_research_high lights_low_res.pdf; accessed 27 May 2020.

[73] Ramirez-Llodra et al. (n 72).

[74] J Drazen, C Smith, K Gjerde et al., ‘Report of the Workshop Evaluating the Nature of Midwater Mining Plumes and Their Potential Effects on Midwater Ecosystems’ (2019) Research Ideas and Outcomes, e33527, doi: 10.3897/rio.5.e33527.

[75] Simon-Lledó et al. (n 65).

[76] Heffernan (n 12), at p. 468.

[77] K Mickelson, ‘Common Heritage of Mankind as a Limit to Exploitation of the Global Commons’ (2019) 30 European Journal Of International Law 635–663, doi: 10.1093/ejil /chz037; A Jaeckel, KM Gjerde and JA Ardron, ‘Conserving the Common Heritage of Humankind: Options for the Deep-Seabed Mining Regime’ (2017) 78 Marine Policy 150– 157, doi:10.1016/j.marpol.2017.01.019; UNGA, Declaration of Principles Governing the Seabed and the Ocean Floor, and the Subsoil Thereof, beyond the Limits of National Jurisdiction, UN Doc A/RES/2749(XXV) (17 December 1970).

[78] Jaeckel, Gjerde, and Ardron (n 77).

obligation to protect the marine environment from harm caused by seabed mining.[79] As noted above, the ISA must strike a balance between mineral exploitation and its environmental obligations.

The importance of environmental protection was universally accepted and did not form part of renegotiating the controversial aspects of CHM in the early 1990s.[80] Indeed, if anything, the environmental obligations of the ISA have increased in importance over the years, with the 1994 Implementing Agreement specifically acknowledging 'the growing concern for the global environment'.[81] Since then, in line with growing concern in the scientific community about the potential ecological consequences of seabed mining, the ISA has gradually strengthened its environmental standards.[82]

Peter Thompson, Special Envoy of the UN Secretary-General for the Ocean, recently called for a precautionary pause on seabed mining to await the outcome of the UN Decade for Ocean Science from 2021 to 2030 'before we start even thinking about disturbing the seabed of the high seas'.[83] While current discussions at the ISA are a long way off a temporary moratorium, ISA member States have argued for strong environmental standards and a 'precautionary approach to all aspects of the mining code'.[84]

Giving effect to its environmental mandate, and thereby securing environmental benefits for humankind, is one of the ISA's most difficult tasks. The CHM concept, as well as the ISA's far-reaching environmental mandate, offers an opportunity to reassess which benefits can be derived from the Area and which ones are in the interest of humankind as a whole, taking into account that some benefits will be primarily reaped by corporate mining entities rather than humankind. Mickelson speculates about a willingness of States in the years to come 'to again readjust and reduce the emphasis on exploitation based on an enhanced global awareness and appreciation of environmental and ethical concerns' and argues that 'such a shift would in fact be easier to reconcile with CHM's underlying values'.[85]

Scientific Knowledge

Scientific knowledge about the deep ocean is widely considered to be of benefit to humankind as a whole.[86] Marine scientific research has helped to dis- cover the existence of valuable marine genetic resources and brings us closer to searching for life on other planets.[87] As the ISA Secretary-General highlighted: 'The benefits to mankind of deep seabed exploration extend far beyond simply knowledge of the mineral resources but include scientific knowledge of the marine environment that will be critical to realizing all aspects of the Blue Economy'.[88]

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[79] LOSC (n 29), Art 145.

[80] ISA, Secretary-General's Informal Consultations on Outstanding Issues Relating to the Deep Seabed Mining Provisions of the United Nations Convention on the Law of the Sea: Collected Documents (ISA, 2002), at p. 77, para 46, available at http://www.isa.org.jm/files/docu ments/EN/Pubs/SG-InformConsultations-ae.pdf; accessed 27 May 2020; AL Jaeckel, The International Seabed Authority and the Precautionary Principle (Brill Nijhoff, Leiden, 2017), at p. 119–120.

[81] 1994 Implementing Agreement (n 7), preamble, para 3; Annex, section 1(5)(g).

[82] Jaeckel (n 80), chapter 5.

[83] Remaoun (n 18).

[84] Canada, Statement of Canada , Australia and New Zealand to the 25th Assembly Session of the ISA (23 July 2019) available at https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs -public/files/documents/canz_0.pdf; accessed 27 May 2020.

[85] Mickelson (n 77), at p. 646.

[86] PEW/RESOLVE (n 34); MW Lodge, 'The Common Heritage of Mankind' (2012) 27 International Journal of Marine and Coastal Law 733–742, doi: 10.1163/15718085-12341248.

[87] CL Van Dover, S Arnaud-Haond, M Gianni et al., 'Scientific Rationale and International Obligations for Protection of Active Hydrothermal Vent Ecosystems from Deep-Sea Mining' (2018) 90 Marine Policy 20–28, doi: 10.1016/j.marpol.2018.01.020.

[88] M Lodge, Statement at a Side Event on Deep Sea Mining Hosted by H. E. Baron Divavesi Waqa, President of Nauru, during the Forty-Ninth Pacific Island Forum Leaders Meeting, Nauru Island, 3 September 2018, available at https://ran-s3.s3.amazonaws.com/isa.org.jm/s3fs-public/documents/EN/SG-Stats/pif-nauru.pdf; accessed 27 May 2020.

The LOSC requires States to promote cooperative research programmes that benefit developing States and technologically less developed States.[89] Scientific knowledge of the deep ocean is advanced through pure academic research as well as commercial research in the context of exploring for minerals or marine genetic resources. Scientific knowledge holds intrinsic value and enables environmental management of ocean industries. But again, we need to question whether all of humankind has equal access to and benefit from that knowledge.

Other Uses of the Area and Deep Oceans

Lastly, uses of the Area not related to mining can be of great benefit to humankind. For example, submarine cables crossing the Area deliver crucial telecommunication services. Studying ecosystems around hydrothermal vents as well as other marine genetic resources can, and in some cases already does, yield significant benefits for humankind,[90] although the benefits are currently not equitably distributed.[91] Examples of such benefits include improved preservation of organs for transplants using knowledge about oxygen transport gained from vent tubeworms.[92]

Studying marine genetic resources for medical and biotechnological applications can be in direct competition with seabed mining because genetic resources may occur exclusively in some of the habitats that also house high-grade mineral deposits. Researchers have called for a moratorium on mining around active hydrothermal vents, to realise the opportunity of studying vent ecosystems for their scientific, cultural, and commercial value.[93]

When the original legal framework for seabed mining was negotiated, the potential of marine genetic resources was not yet envisioned. It would seem imprudent to ignore such crucial new information about the existence of promising biological resources when evaluating what benefits humankind can derive from the international seabed. As Beaulieu et al. note: '[r]egulations need to be flexible enough to accommodate new knowledge from scientific research that may dramatically change our view of the global ocean resource potential'.[94] Folkersen et al. invite us to adopt a long-term perspective when estimating economic value of the deep ocean. Mineral mining generates one-off revenue as seabed minerals are non-renewable resources, while other uses of the space may generate more long-term, sustainable profit.[95]

Conclusion

The vision of the benefits that can be derived from our common heritage of mankind has significantly changed over time. The promise of future benefits has ranged from wealth generation and redistribution to active involvement of developing States and reduction of inequality. These promises have gradually given way to a narrative of needing to increase mineral supply for a growing population as well as the shift to a green economy, with the latter utilising an environmental narrative to justify a new extractive industry. As Collins and French note, 'the utopian aspects of the underlying principles infused within CHM, conceived on the floor of the UN General Assembly many decades ago, now seem a distant past'.[96]

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[89] LOSC (n 29), Art 143(3).

[90] Van Dover et al. (n 87).

[91] R Blasiak, JB Jouffray, CCC Wabnitz et al., 'Corporate Control and Global Governance of Marine Genetic Resources' (2018) 4 Science Advances, doi: 10.1126/sciadv.aar5237.

[92] J Simoni, 'New Approaches in Commercial Development of Artificial Oxygen Carriers' (2014) 38 Artificial Organs 621–624.

[93] Van Dover et al. (n 87).

[94] Beaulieu et al. (n 22).

[95] Folkersen et al. (n 6).

[96] Collins and French (n 1).

The change in vision was accompanied by an increase in knowledge about the deep ocean over the past four decades. The LOSC was negotiated without knowledge of marine genetic resources around hydrothermal vents and the seriousness of the environmental impacts that seabed mining would cause. Moreover, the negotiations occurred at a time of false promises regarding the economic potential of seabed mining.[97] Indeed, it remains unclear today whether seabed mining can be economically viable, which would be a prerequisite for realising the anticipated benefits of wealth generation and redistribution. In order to determine the full cost and benefits of seabed mining, it will be necessary to include the natural capital and ecosystem services in economic modelling, which remains a challenging task at present.

Knowing what we know today, it is timely to ask what benefits we could, and in some cases already do, reap from our common heritage of humankind. Current benefits include ecosystem services, submarine cables, marine scientific research, training programmes, and early benefits derived from marine genetic resources. Two of these, ecosystem services and increased knowledge from scientific research, are particularly important in the context of climate change, not least because of the deep oceans' natural carbon sequestration mechanisms. The industry building around marine genetic resources serves as a reminder that the Area's resource potential may be broader than originally anticipated, though questions around equitable benefit sharing may be just as applicable as they are in the Area regime.

The aim of advancement of developing States, a key ambition of the Area regime, has been significantly altered, both through the 1994 Implementing Agreement and subsequent actions by the ISA. The original vision of collective benefit and agency gave way to the current expression of the CHM, which focuses on benefiting individual developing States through the sponsorship system. This focus on individual sponsoring States, rather than collectively engaging in seabed mining through the Enterprise, greatly increases financial and legal risks for developing States and reduces the likelihood of the Enterprise becoming operational.

The more recently articulated benefits of increased mineral supply and lower mineral prices could be reaped by some consumers but would negatively affect developing State land-based mineral producers whose interests are recognised by the LOSC. Similarly, it remains unclear whether minerals from the seafloor are indeed required for a transition to a green economy.

In the context of developing the first exploitation regulations, the ISA has the opportunity to re-evaluate which benefits we can draw from the Area. Indeed, the ISA's 2019 draft exploitation regulations include the CHM as a criterion to assess whether an application for an exploitation contract should be approved. They require the ISA to have regard to 'the manner in which the proposed Plan of Work contributes to realizing benefits for mankind as a whole'.[98] In other words, the ISA will need to consider the value of an individual mining operation to all of humankind. That requires clarity on what the relevant benefits are, and how they might be measured. This article seeks to contribute to answering these questions by critically analysing some of the current and future benefits we can derive from our common heritage.

*This article is adapted from an article of the same name, originally published in the International Journal of Marine Coastal Law. The original article can be found **here**.*

*For more background and discussion on issues related to deep seabed mineral mining, read the report of RNRF's 2021 Conference on Deep Seabed Mineral Mining **here**.*

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[97] Johnson and Logue (n 67).

[98] ISA,Draft Regulations on Exploitation of Mineral Resources in the Area (ISBA/C/25/WP.1, 22 March 2019), https://www.isa.org.jm/document/isba25cwp1-0, regulation 12(3).

Climate Change in the Arctic with Biophysical and Economic Impacts

Congressional Research Service

An array of climate changes in the Arctic is now documented by observing systems, with more expected with future greenhouse gas-driven climate change. Observed physical changes in the Arctic include warming ocean, soil, and air temperatures; melting permafrost; shifting vegetation and animal abundances; and altered characteristics of Arctic cyclones. These changes continue to affect traditional livelihoods and cultures in the region, infrastructure, and the economy, as well as the distribution and health of animal populations and vegetation. The changes raise risks of pollution, food supply, safety, cultural losses, and national security. The state government of Alaska concluded that observed climate changes "have resulted in a reduction of subsistence harvests, an increase in flooding and erosion, concerns about water and food safety and major impacts to infrastructure: including damage to buildings, roads and airports."[1]

A monitoring report of the Arctic Council concluded in 2019 that

> the Arctic biophysical system is now clearly trending away from its previous state [in the 20th Century] and into a period of unprecedented change, with implications not only within but also beyond the Arctic.[2]

This article is an excerpt from the Congressional Research Service report "Changes in the Arctic: Background and Issues for Congress." This section was prepared by Jane Leggett, Specialist in Energy and Environmental Policy, Resources, Science, and Industry Division.

A few broad points raise particular concerns about changes in the Arctic:

- Long lag times between cause and full effects: Changes once set in motion prompt further and often slow effects in different components of the Arctic system, such as the influence of rising atmospheric temperatures on ocean and permafrost temperatures. Scientists expect the full effects of near-term climate changes to play out over a period of decades to many centuries.
- Feedbacks that mostly further increase warming: GHG-induced warming leads to positive (enhancing) and some negative (dampening) feedbacks within the Arctic system, which scientists expect in net to amplify warming and pursuant effects. For example, temperature-driven melting sea ice reduces reflection of incoming solar energy, leading to absorption by the Arctic Ocean and further warming of the ocean and the planet.
- Abrupt change risks: The freezing point for water, including permafrost, is one example of thresholds that certain Arctic systems may cross, leading to rapid state changes.
- Risks of irreversibilities: Some Arctic climate impacts, such as loss of sea ice and glaciers, may lead to system changes that scientists expect would be irreversible on a human timescale, even if temperatures stabilize (at a higher level than today).

Understanding remains incomplete regarding future Arctic climate changes and their implications for

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[1] Department of Commerce, Community, and Economic Development, "Climate Change in Alaska." The Great State of Alaska. Accessed February 2, 2022. https://www.commerce.alaska.gov/web/dcra/ClimateChange.aspx.

[2] Jason E Box et al., "Key Indicators of Arctic Climate Change: 1971–2017," Environmental Research Letters 14, no. 4, April 2019.

human and natural systems. With current knowledge, projections point to growing risks, as well as some opportunities.

The Arctic is interconnected to the rest of the globe through circulation of water, energy (e.g., heat), and carbon, including through the atmosphere and oceans. It is also connected through human systems of transport, energy and mineral production, tourism, and security. Consequently, Arctic changes are of import to both Arctic and non-Arctic regions of United States and the rest of the globe.

This section summarizes a variety of observed and projected climate changes in the Arctic and identifies some of their impacts on human and ecological systems.[3] Other sections in this report provide further discussion of implications for, for example, national security and energy production.

Warming Temperatures and a More Intense Water Cycle

The Arctic warmed at approximately three times the global average rate from 1971 to 2019, with the region's surface temperature increasing by more than 3°C (5.5°F).[4] Summers have warmed more than winters. In tandem are trends of fewer cold days, cold nights, frost days, and ice days in the North American Arctic.[5] Researchers found that warming trends as well as climate cycles, including the North Atlantic Oscillation and the Arctic Oscillation, influence observed extreme temperatures, ice distribution, and other facets of the Arctic system.[6] In addition, positive feedbacks from the loss of summer sea ice and spring snow cover on land have amplified warming in the Arctic.[7]

With warming, the water cycle has become more intense. The Arctic has experienced increasing precipitation and an increasing share of precipitation falling as rain. The first recorded rainfall at Greenland's 10,500-foot Summit Station was on August 14, 2021.[8]

Warming and increasing rainfall have led to permafrost thaw, glacier melt, and sea ice decline, leading to greater flows of organic

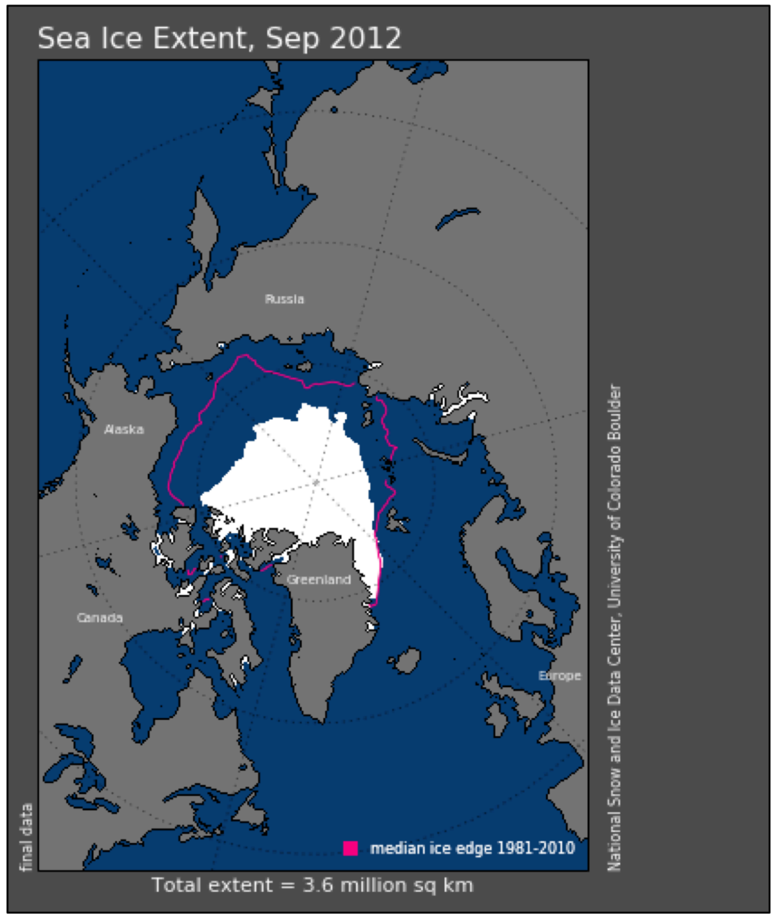

Figure 1. 2012 Record-Low Sea Ice Extent compared with long-term median. *Source: National Snow and Ice Data Center, Sea Ice Index, accessed February 28, 2022.*

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[3] Although much of Greenland is above the Arctic Circle, and many of the changes and implications apply also to Greenland, this section emphasizes other parts of the Arctic and does not attempt to summarize the often large and complex change in Greenland.

[4] T.J. Ballinger et al., "Surface Air Temperature," Arctic Program, Arctic Report Card 2021.

[5] Alvaro Avila-Diaz et al., "Climate Extremes across the North American Arctic in Modern Reanalyses," Journal of Climate 34, no. 7, April 1, 2021.

[6] Ibid.

[7] Intergovernmental Panel on Climate Change, "Summary for Policymakers," Special Report on the Ocean and Cryosphere in a Changing Climate, 2019, https://www.ipcc.ch/srocc/chapter/summary-for-policymakers/. (Hereinafter, SROCC SPM 2019.)

[8] National Snow and Ice Data Center, "Rain at the Summit of Greenland," August 18, 2021.

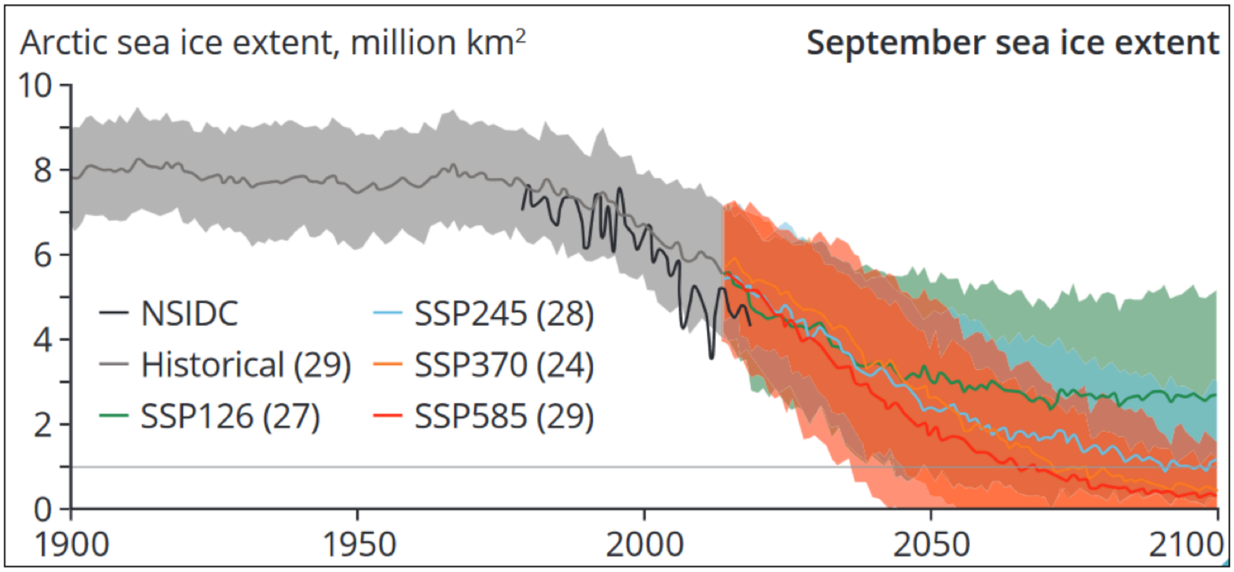

Figure 2. Estimated Historical, Observed, and Projected September Arctic Sea Ice Extent. *Source: Arctic Monitoring and Assessment Programme (AMAP), "Arctic Climate Change Update 2021: Key Trends and Impacts. Summary for Policy-Makers," Arctic Council, May 21, 2021.* **Notes:** NSIDC is the U.S. National Snow and Ice Data Center, the source that synthesized the satellite observation data (the bold black line) in this figure. The "historical" values result from model simulations, showing the modeled mean and the ranges. The projections (in colors) are for a range of greenhouse gas scenarios and associated climate changes, with the means of results represented by lines. SSP means "Shared Socioeconomic Pathway" scenarios produced in support of the International Panel on Climate Change depicting high (SSP585), medium high (SSP30), low (SSP245) and very low (SSP126) scenarios. The shaded areas represent the ranges of numerical model estimates (number), either historical and projected. The horizontal line represents sea-ice areal extent of 1 million square kilometers, below which scientists consider the Arctic to be practically ice-free.

matter and nutrients to Arctic near-coastal zones, with implications for algae, ecosystems, fisheries and other systems.

Sea Ice Decline and Mobility

Arctic sea ice has declined in extent, area, and thickness over recent decades; it has become more mobile and its spatial distribution has shifted. The record low extents of Arctic sea ice in 2012 and 2007 (**Figure 1** and **Figure 2**), as recorded by U.S. National Snow and Ice Data Center, increased scientific and policy attention on climate changes in the high north, and on the implications of projected ice-free[9] seasons in the Arctic Ocean within decades. Recent late summer minima may be unprecedented over the past 1,000 years.[10] (Some implications are discussed in sections of this report on Commercial Sea Transportation; Oil, Gas, and Mineral Exploration; and others.) The 2021 Sixth Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) concluded that "human influence is very likely the main driver of ... the decrease in Arctic sea ice area between 1979–1988 and 2010–2019 (about 40% in September and about 10% in March)."[11]

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[9] In scientific analyses, "ice-free" does not necessarily mean "no ice." The definition of "ice-free" or sea ice "extent" or "area" varies across studies. Sea ice "extent" is one common measure, equal to the sum of the area of grid cells that have ice concentration of less than a set percentage—frequently 15%. For more information, see the National Snow and Ice Data Center, http://nsidc.org/seaice/data/terminology.html.

[10] SROCC SPM 2019.

[11] Intergovernmental Panel on Climate Change, "AR6 Climate Change 2021: The Physical Science Basis - Summary for Policy Makers," August 9, 2021. https://www.ipcc.ch/report/ar6/wg1/.

Simulations under a wide range of future climate change scenarios indicate that the Arctic could be ice-free in late summers in the second half of this century in model simulations of low to very high greenhouse gas scenarios (**Figure 2**).[12] The first instances of an ice-free Arctic in late summers could occur by mid-century in all scenarios, although model simulations provide a wide range of results.[13] The mean results of model simulations reach ice-free seasons in the 2070s in the highest and low warming scenarios, and later in the very low scenarios. In an analysis of the most recent modeling, a selection of those models that "reasonably" simulate historical sea ice extent indicated that practically ice-free conditions may occur at global temperature increases of 1.3°C to 2.9°C above preindustrial levels.[14] Although sea ice would remain variable in extent and distribution, modeling of future sea ice conditions indicate opportunities for transport through the Northwest Passage and the Northern Sea Route, extraction of potential oil and gas resources, and expanded fishing and tourism, though also increasing competition and potential security risks and of oil spills and maritime accidents.

The U.S. Arctic Report Card 2021 noted, in addition, the importance of melting of Arctic land- based ice to experienced sea level rise globally:

> In the 47-year period (1971–2017), the Arctic was the largest global source of sea-level rise contribution, 48% of the global land ice contribution 2003–2010 and 30% of the total sea-level rise since 1992. Temperature effects are dominant in land ice mass balance.

A special report of the IPCC stated that "for Arctic glaciers, different regional studies consistently indicate that in many places glaciers are now smaller than they have been in millennia."[15]

The Arctic Ocean has been undergoing additional changes: It has been acidifying—with some parts acidifying more rapidly than the Atlantic or Pacific Oceans.[16] Some scientists estimate that acidification of the Arctic Ocean may increase enough by the 2030s to significantly influence coastal ecosystems.[17] Primary production in the ocean has increased, due to decreases in sea ice and increases in nutrient supply.

Land-Based changes

Climate changes in the Arctic have important implications for human and natural land-based systems, through permafrost thawing, erosion, instability, and ecosystem shifts.

The U.S. Geological Survey (USGS) concluded that an increase in coastal erosion on the North Slope of Alaska was "likely the result of several changing Arctic conditions, including declining sea-ice extent, increasing summertime sea-surface temperature, rising sea level, and possible increases in storm power and corresponding wave action."[18] The USGS found that erosion has been occurring at an average rate of 1.4 meters annually and

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[12] Arctic Monitoring and Assessment Programme (AMAP), "Arctic Climate Change Update 2021: Key Trends and Impacts. Summary for Policy-Makers," Arctic Council, May 21, 2021; Marika Holland, Cecilia M. Bitz, and Bruno Tremblay, "Future abrupt reductions in the summer Arctic sea ice," Geophysical Research Letters 33, no. L23503 (2006). But see also Julien Boé, Alex Hall, and Xin Qu, "Sources of spread in simulations of Arctic sea ice loss over the twenty-first century," Climatic Change 99, no. 3 (April 1, 2010): 637-645; I. Eisenman and J. S. Wettlaufer, "Nonlinear threshold behavior during the loss of Arctic sea ice," Proceedings of the National Academy of Sciences 106, no. 1 (January 6, 2009): 28-32; Dirk Notz, "The Future of Ice Sheets and Sea Ice: Between Reversible Retreat and Unstoppable Loss," Proceedings of the National Academy of Sciences 106, no. 49 (December 8, 2009): 20590-20595.

[13] Global climate models do not, in general, simulate past sea ice change realistically and tend to produce less decline in sea ice extent than the latest 15-year trend.

[14] The current temperature increase above the 1850-1900 average is about 1.1oC.

[15] SROCC SPM 2019.

[16] Di Qi et al., "Increase in Acidifying Water in the Western Arctic Ocean," Nature Climate Change 7, no. 3, March 2017.

[17] U.S. Global Change Research Program, "Climate Science Special Report," Fourth National Climate Assessment, Volume 1, October 2017, https://science2017.globalchange.gov/.

[18] Pacific Coastal and Marine Science Center, "Climate Impacts to Arctic Coasts," U.S. Geological Survey, October 15, 2021.

that, while some areas are accreting, others are eroding at rates as high as 20 meters per year. Coastal erosion poses risks for native communities, oil and gas infrastructure, and wildlife; adaptations to mitigate and manage adverse impacts can be costly and risky.

Warming temperatures have increased thawing of near-surface permafrost. "The majority of Arctic infrastructure is located in regions where permafrost thaw is projected to intensify by mid- century," according to the IPCC special report on the cryosphere.[19] Existing infrastructure was not generally placed or engineered for the instability, posing risks to human safety and property, and potentially disruption. The IPCC report assessed that "about 20% of Arctic land permafrost is vulnerable to abrupt permafrost thaw and ground subsidence,"[20] increasing risks of sudden failures. According to one study, 30%–50% of critical circumpolar infrastructure may be at high risk by 2050. "Accordingly, permafrost degradation-related infrastructure costs could rise to tens of billions of U.S. dollars by the second half of the century."[21] Other costs could be incurred for relocation of infrastructure and villages, and to manage habitat for subsistence wildlife and endangered and threatened species.

Impacts of climate change on species have been positive and negative. Longer growing seasons have resulted in vegetation growth around the Arctic with overall "greening," though also some "browning" in some regions in some years. Woody shrubs and trees are projected to expand to cover 24%–52% of Arctic tundra by 2050.[22] Vegetation changes can provide amplifying feedbacks that increase temperature and permafrost instability. In particular, scientists have assessed significant methane emissions from some thawing peat bogs.

Potential area burned by wildfire could increase by 25% to 53% by 2100. This could affect, for example, forage for caribou and shifting competition between caribou and moose, with likely detriments to subsistence users of caribou.[23]

The IPCC special report on the cryosphere also found that

> On Arctic land, a loss of globally unique biodiversity is projected as limited refugia exist for some High-Arctic species and hence they are outcompeted by more temperate species (medium confidence).[24]

It identified negative impacts also on food and water security in the Arctic, "disrupt[ing] access to, and food availability within, herding, hunting, fishing, and gathering areas, harming the livelihoods and cultural identity of Arctic residents including Indigenous populations."[25] More broadly, warming and ecosystem shifts have "increased risk of food- and waterborne diseases, malnutrition, injury, and mental health challenges especially among Indigenous peoples."[26]

Few studies have investigated the potential economic effects of the array of physical impacts. A report for the state of Alaska on the economic effects of climate change

> estimated that five relatively certain, large effects that could be readily quantified would impose an annual net cost of $340–$700 million, or 0.6%–1.3% of Alaska's GDP. This significant, but relatively

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[19] SROCC SPM 2019.

[20] SROCC SPM 2019.

[21] Hjort, Jan, Dmitry Streletskiy, Guy Doré, Qingbai Wu, Kevin Bjella, and Miska Luoto, "Impacts of Permafrost Degradation on Infrastructure," Nature Reviews Earth & Environment 3, no. 1 (January 2022): 24–38, https://doi.org/ 10.1038/s43017-021-00247-8.

[22] SROCC SPM 2019.

[23] SROCC SPM 2019.

[24] SROCC SPM 2019.

[25] SROCC SPM 2019.

[26] SROCC SPM 2019.

modest, net economic effect for Alaska as a whole obscures large regional disparities, as rural communities face large projected costs while more southerly urban residents experience net gains.[27]

The research did not consider "nonuse" impacts, such as on culture, subsistence harvests, or other nonmarket values, as well as additional sectors, such as military installations, housing, and others.

Another study estimating the effects of climate change on Alaskan infrastructure found "cumulative estimated expenses from climate-related damage to infrastructure without adaptation measures (hereafter damages) from 2015 to 2099 totaled $5.5 billion (2015 dollars, 3% discount) for RCP8.5 [a high climate scenario] and $4.2 billion for RCP4.5 [a moderate climate scenario], suggesting that reducing greenhouse gas emissions could lessen damages by $1.3 billion this century."[28] Costs were mostly due to road flooding and permafrost instability, and mostly in the interior and southcentral Alaska. It also concluded that adaptation measures could mostly reduce or entirely avoid the estimated economic losses for this land-based infrastructure.

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[27] Berman, Matthew, and Jennifer I. Schmidt, "Economic Effects of Climate Change in Alaska." Weather, Climate, and Society 11, no. 2 (April 1, 2019): 245–58, https://doi.org/10.1175/WCAS-D-18-0056.1. The five effects evaluated were change in value added in Alaska (value of shipments less cost of inputs purchased from outside Alaska) for specific industries; change in household cost of living; change in purchased input costs for businesses and governments; change in nonwage benefit flows to households, including subsistence benefits; and change in value of buildings and infrastructure.

[28] Melvin, April M., Peter Larsen, Brent Boehlert, James E. Neumann, Paul Chinowsky, Xavier Espinet, Jeremy Martinich, et al., "Climate Change Damages to Alaska Public Infrastructure and the Economics of Proactive Adaptation," Proceedings of the National Academy of Sciences 114, no. 2 (January 10, 2017): E122–31, https://doi.org/ 10.1073/pnas.1611056113.

Renewable Natural Resources Foundation
6010 Executive Boulevard, Suite 700
North Bethesda, Maryland 20852 USA