ongoing mCDR projects and protocols in PICES region

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Objective

*Catch up present status of mCDR programs implementing / planning in PICES countries
*Also catch up present status of ***regulation*** of mCDR programs by gathering international protocols / manuals

Information source

*Information form S-CC members and WS presenters
*web portals (Oceanvision etc.)
*carbon credit services (ISOMETRIC etc.)

Range of collection: projects/researches

*led by members from PICES countries
*implementing within North Pacific
*ongoing in 2025

Range of collection: protocols/manuals

*all protocols/manuals collected

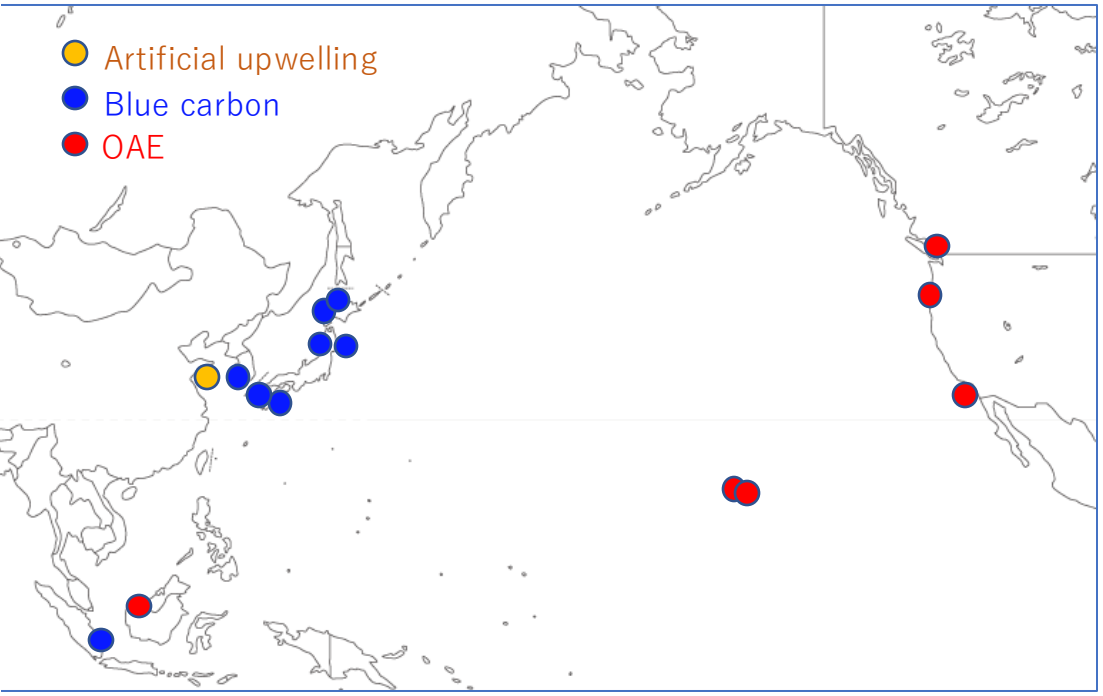
Projects now implementing

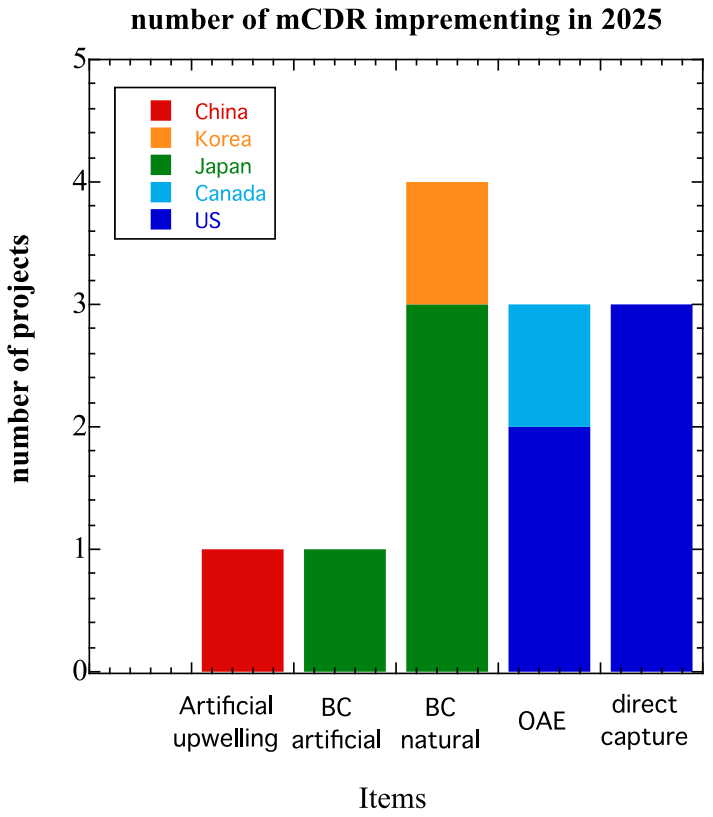
List of ongoing / planning mCDR projects

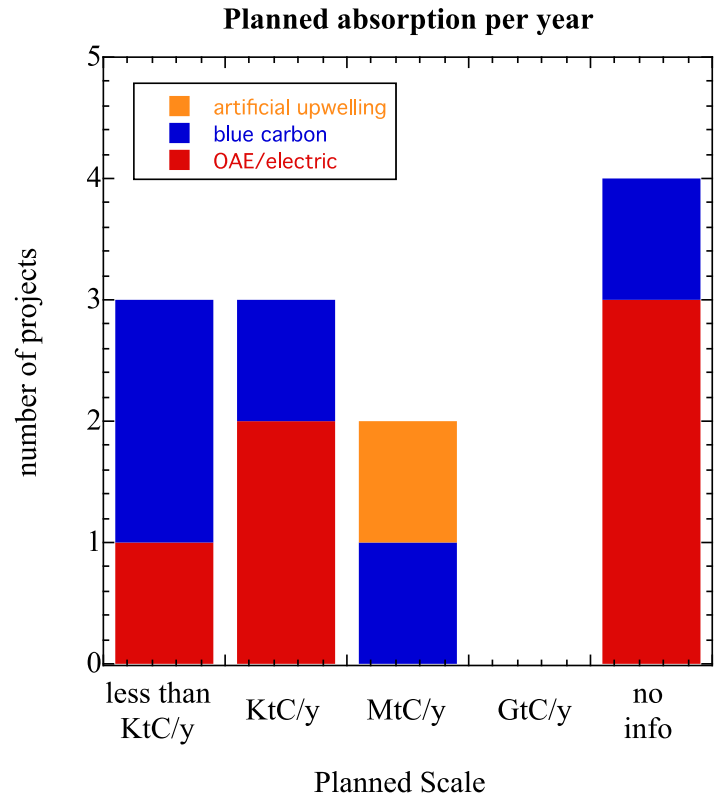
classification	Project name	Country	investor	PI		Carbon chemist	biologist	Impremenation period		carbonBudget		summary of project / URL
				name	affiriation			start year	end year	total	per year	
Nutrient Fertilization (includng iron)												
Artificial upwelling and downwelling	Demonstration field of artificial upwelling in Aoshan Bay	china	Ocean Negative Carbon Emissions program (ONCE)	Chen Ying	Zhejiang University	yes	yes	2015	ongoing	4.9MtC		https://www.global-once.org/#/detail?title=RESEARCH&name=Geo-Engineering&code=36261a89badc4e0dbac011fcd18a6864%2F15_49268305844822018
Artificial blue carbon (Seaweed cultivation)	Fish port development including bule carbon cultivation fi	Japan	New Energy and Inductrial Technology Development Organization (NEDO)	Toshiro Ito	Sansho Suiko Co. LTD	no	yes	2022	2030		399tC/y	This project aims to product over 1,435 MtCO2 of new carbon adsorption by implementing fish ports those attache blue carbon cultivation systems. Project itself contains no carbon scientist, while estimation of carbon adsorption is made based on the methodoligy of the "Blue carbon study group for mitigatipon of global warming." https://research-er.jp/projects/view/1201518
Natural blue carbon (Recovely of marine ecocyctem)	Blue carbon study group for mitigatipon of global warmin	Japan	Ministry of Land, Infrastructure, Transport and Tourism	Tomohiro Kuwae	Port and Airport Research Institute (PARI)	yes	yes	2023	no limit		35ktC/y	By using FREA's evaluation method of CO2 inventory per area for several types of Japanese coastal seaseed meadow, this study group estimated national carbon inventory of Japanese coastal
	Creation of sea forests	Japan	Nippon Steel Co. Ltd	Nippon Steel Co. Ltd		no	yes	2004	ongoing		50tC/y	This project aims to regenerate seaweed/seagrass beds along Japanese coast through field monitoring and solution developments including addition of steel slag for nutrient and iron supply. Part of this project has certified as new carbon sinks by Japan Blue Credit system. https://www.nipponsteel.com/en/csr/env/circulation/sea.html
	Mangrove Restoration & Conservation Project	Japan	Mitsui O.S.K Lines	Mitsui O.S.K Lines		no	yes	2022	ongoing	11MtC		This project aims to product 11MtCO2 of CO2 sinks through restration and conservation of mangrove forests in Indnesia. https://www.mol.co.jp/en/bam/003/
	Marine forest reforestation project	Korea	Korea Fisheries Resources Angency (FIRA)/ Pohang U. of Science and Technology (POSTECH) /	Jin-Woo Kang	FIRA	yes	yes			no info		https://iss2023.net/2023/01/16/marine-forest-reforestation-project-of-korea-fisheries-resources-agency-fira/
Ocean Alkalinity Enhancement	Project Macoma	USA	Ebb Carbon /UW/PNNL/NOAA	Ben Tarbell	Ebb Carbon	yes	no	2025		no info		https://www.ebbcarbon.com/post/project-macoma-launches-in-port-angeles
	coastal ocean alkalinization project in Burrard Inlet, BC	Canada	Pranetary Technologies / Prepurchase organized through Frontier	Mike Kelland	Pranetary Technologies	yes	yes	2025			116,148 tons contracted, 937 tons delivered	https://vancouversun.com/news/local-news/metro-vancouver-plans-2025-trial-to-remove-co2-in-ocean
	Coastal enhanced weathering using olivine, Duck, North Carolina	USA	Vestra	Doug Edwards	Vestra	yes	no	2024	2027	no info		https://www.projectvesta.org/science#Introduction
Electrochemical Engineering	Third Direct Ocean Capture plant at Kona, Hawaii	USA	Captura Corp.	Steve Oldham	Captura Corp.	yes	no	2025		1000tC/y		https://capturacorp.com/captura-opens-new-direct-ocean-capture-pilot-plant-in-hawaii/
	Ocean-assisted carbon removal plant at Hawaii	USA	HEIMDAL			yes	no	2024		no info		https://www.heimdalccu.com/news/meet-the-worlds-first-ocean-assisted-carbon-removal-plant
	Seawater-based carbon removal project in Sarawak	USA	Equatic	Edward Sanders	Equatic	yes	no	2026		365tC/y		https://www.equatic.tech/articles/collaboration-to-develop-seawater-based-carbon-removal-project-in-sarawak

Total 12 projects
For 5 mCDR technologies

Statistic _ area & country



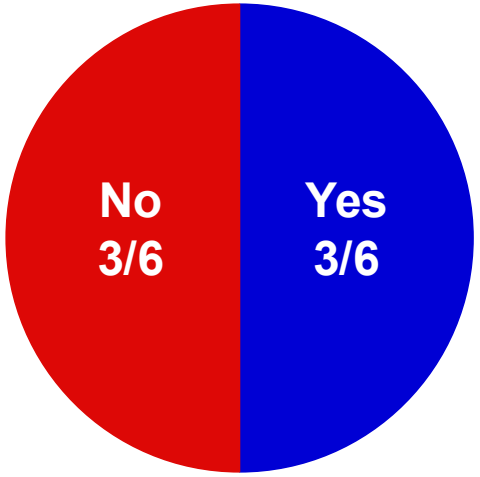




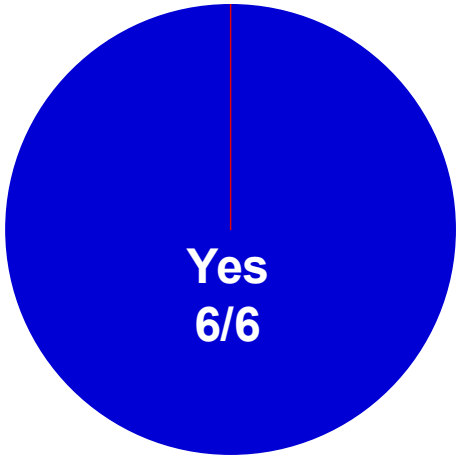
- clear east-west dependence (East: OAE, West:Blue carbon)
- current scales are ~KtC/y both for Blue carbon and OAE/direct capture

Statistic _ involvement of scientist

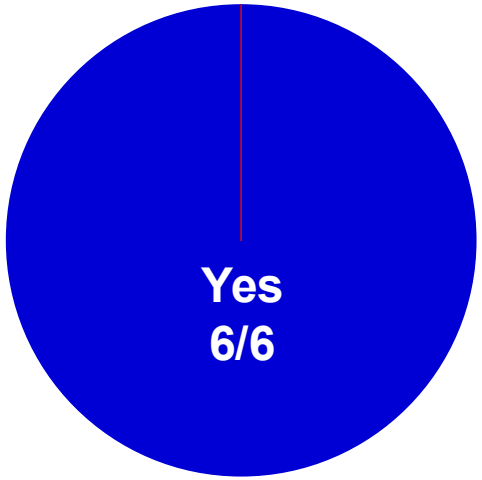
carbon biogeochemistry scientist in blue carbon project



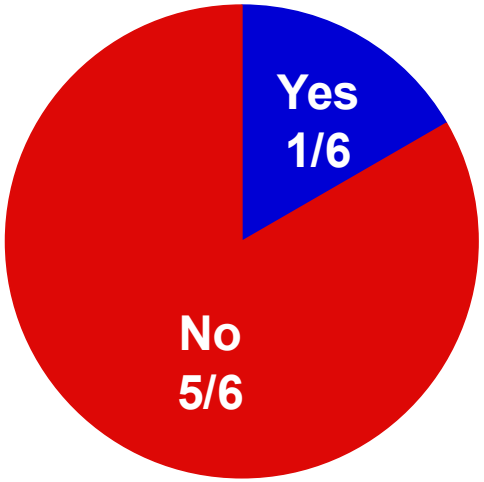
carbon biogeochem. scientist in OAE & direct caputure



biology scientist in blue carbon project



carbon biogeochem. scientist in OAE & direct caputure



- Blue carbon projects **sometimes** do not include carbon biogeochemical scientist within their official project member.
  In such case, they use “fixed protocol” made by biogeochemical scientists in their MRV

- Currently implementing OAE & direct carbon capture projects **often** do not include biological scientist within their official project member.
  Most protocols for OAE & direct carbon capture projects contain specific measures to minimize environmental risk.

Researches now ongoing

classification	Project name	Country	investor	PI		Impremention period		summary of project / URL
				name	affiriation	start year	end year	
Nutrient Fertilization (includng iron)	Exploring Ocean Iron Solutions (ExOIS)	USA	Various philantrophies	Ken Buesseler	WHOI	2024	?	Group trying to organize a larger scale Iron fertilziation experiment with the aimt o quantify the efficacy and safety of OIF (ocean iron fertilziation) in context of mCDR activities. https://oceaniron.org/
Artificial upwelling and downwelling	Ocean Negative Carbon Emissions program (ONCE)	China	UN	Nianzhi Jiao	Xiamen Univ.			https://www.global-once.org/
Artificial blue carbon (Seaweed cultivation)	Redesign of Macroalgae for Highly Efficient CO2 Fixation by Functional Modifications and Their Product Generation	Japan	New Energy and Inductrial Technology Development Organization (NEDO)	Mitsuyoshi Ueda	Kyoto Univ.	2022	2024	This projecte aimed to improve the CO2 fixation rate of macroalgae and treat them as unused resources, converting them to bioethanol for fuel and for other uses. https://www.nedo.go.jp/english/news/ZZCA_100007.html
	Precise evaluation of biomass and carbon adsorption efficiency of seaweed acuaculture	Japan	Japan Science and Technology Agency	Naoki Gregory Nishihara	nagasaki Univ.	2024	2029	This procect develops methods for precise evaluation of biomass and carbon adsorption efficiency of seaweed acuaculture, with special attention to fucoidan productivity of seawweds. No English URL
	Quantifying the Potential and Risks of Large-scale Macroalgae Cultivation and Purposeful Sequestration as a Viable CO2 Reduction (CDR) Strategy	USA	UCSB	David Siegel	UCSB	2018	ongoing	https://seaweedcdr.eri.ucsb.edu
	Deep Ocean Biomass Sinking – Benthic Lander Experiment	Canada	Ocean Network Canada			2023	2025	https://www.oceannetworks.ca/news-and-stories/stories/oncs-deep-sea-observatory-supporting-ocean-based-carbon-dioxide-removal-research/
	Ocean Negative Carbon Emissions program (ONCE)	China	UN	Nianzhi Jiao	Xiamen Univ.			https://www.global-once.org/
		USA	NSF	Ann Pearson, and many	NSF			
Natural blue carbon	Development of stable coastal blue carbon distribution survey methods using satellites, observations, models, and AI	Japan	Japan Society for the promotion of Science	Yuji Sakuno	Hiroshima U	2023	2025	This study improves estimation methods of seaweed and seagrass areas by conbination of satellites, numerical models and deep-learning. No English URL
	Observation and verification of CO2 uptake using innovative methods in blue carbon ecosystems	Japan	Japan Society for the promotion of Science	Tomohiro Kuwae	Port and Airport Research Institute (PARI)	2024	2025	This study develops remote sensing methods for simultaneous estimation of seaweed area and its air-sea CO2 flux by using dorones. No English URL
	Unrecognized oceanic capture of carbon degradated from coastal sediments	Japan	Japan Society for the promotion of Science	Kenta watanabe	Port and Airport Research Institute (PARI)	2022	2026	This study estimates transport of additional DIC originated from the degradation of coastal sediments into deep ocean. No English URL

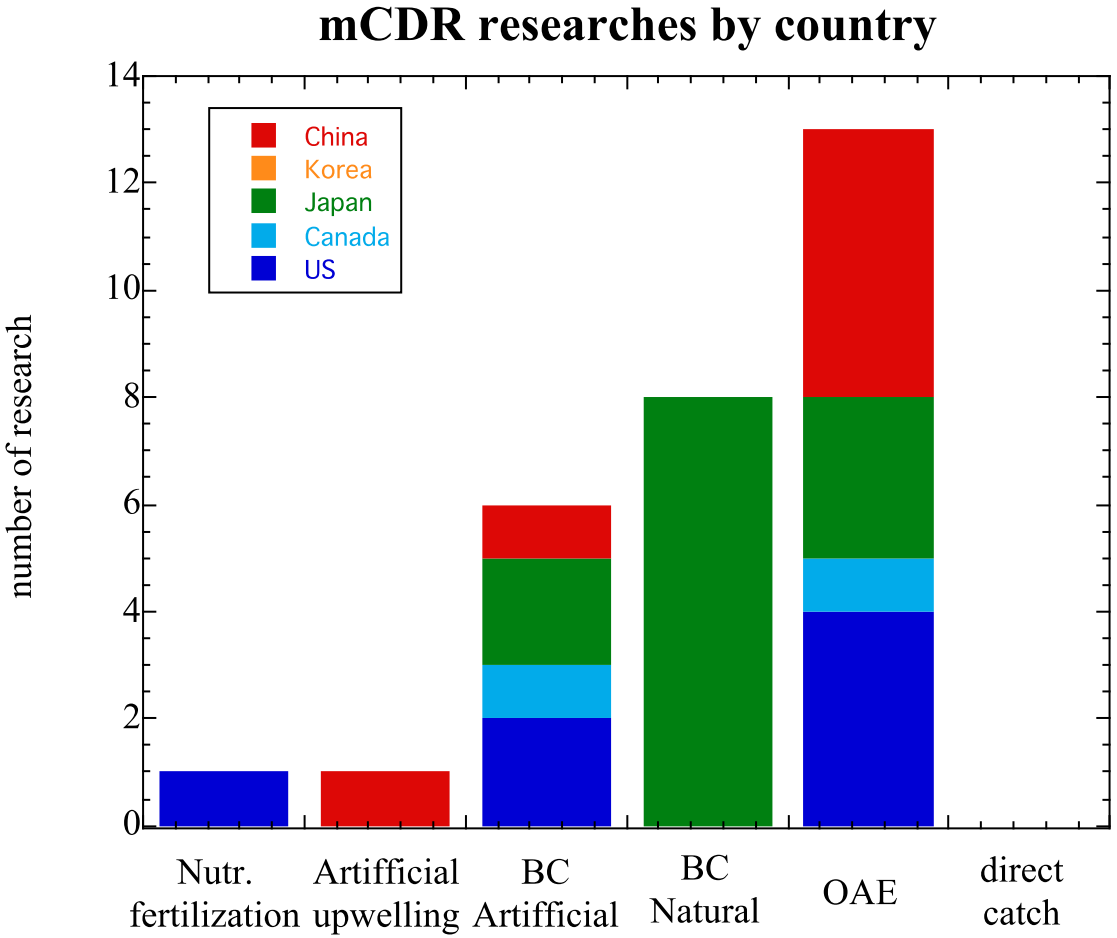
- Total 29 researches are found so far.

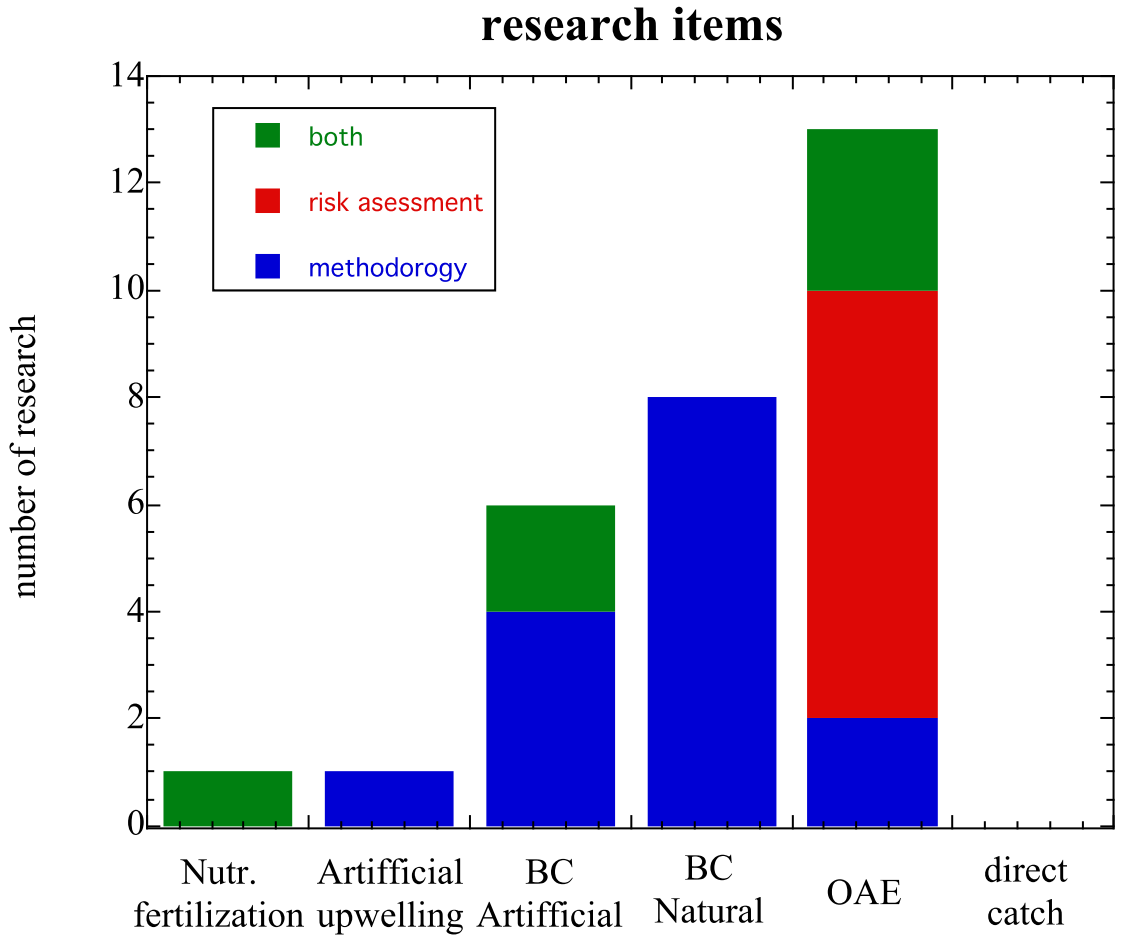
#Many other researches should be ongoing

Researches now ongoing (continued)

(Recovely of marine ecocyctem)	Evaluation of carbon outwelling from shallow coastal systems	Japan	Japan Society for the promotion of Science	Tomonori Isada	Hokkaido Univ.	2024	2028	This study estimates carbon flow from subarctic coastal ecosystems to deep ocean. No English URL
	Complehensive understanding of carbon sequestation and atmospheric CO2 adsorption in coastal ecosystems	Japan	Japan Science and Technology Agency	Kenta watanabe	Port and Airport Research Institute (PARI)	2024	2027	This study investigates how oceanic DIC decrease captured by coastal blue carbon systems is recovered by air-sea CO2 flux. Necessary time and spacial scales for DIC recoverly will be estimated. No English URL
	Investigation on chemical mechanisms responsible for long-term carbon sequestration in sediment of shallow coastal vegetated habitats	Japan	Japan Society for the promotion of Science	Toshihiro Miyajim	Tokyo Univ.	2022	2026	This study investigates chemical mechanisms that are responsible for long-term carbon sequestration in sediment of shallow coastal vegetated habitats. No English URL
	Contributuion of bacterium activities to carbon sequestation capacity of mangrove ecosystems	Japan	Japan Science and Technology Agency	Masumi Hasegaw	Japan Agency for Marine Science and Technology (JAMSTEC)	2023	2026	This study investigates contributuion of bacterium activities for maintenance of carbon sequestation capacity of mangrove ecosystems. No English URL
	Relationship of species diversity of detritus-eating organisms and carbon sequestation efficiensy in Mangrove systems	Japan	Japan Society for the promotion of Science	Kusuto Nanjo	Fisheries Research and Education Agency (FREA)	2024	2027	This study Investigates relationship of species diversity of detritus-eating organisms and carbon sequestation efficiensy in Mangrove systems. No English URL
Ocean Alkalibity Enhancement	Rearing experiment of ocean calcifiers in alkalinazed seawater	Japan	Fisheries Research and Education Agency (FREA)	Tsuneo Ono	Fisheries Research and Education Agency (FREA)	2024	2025	This project investigates physiological changes of ocean calcifires (shellfish and urchines) against increase of ocean alkalinity. No english URL
	Ocean Alkalinity Enhancement Pelagic Impact Intercomparison Project(OAEPIIP)	Japan	Hokkaido Univ	Koji Suzuki	Hokkaido Univ	2025	2025	These experiments consist an international rearing experiment called OAEPIIP, which is lead by Univ. Tasmania. Experiments are carried out using same apparatus and protocols established within this program. https://appliedbgc.imas.utas.edu.au/ocean-alkalinity-enhancement-pelagic-impact-intercomparison-project/
				Tomonori Isada	Hokkaido Univ	2025	2029	
		China	Southern University of Science and Research Centre for Ocean Negative Carbon Emissions, Xiamen	Mark Hopwood Xuechao Wang	Southern University of Research Centre for Ocean Negative Carbon Emissions.	2024	2025	
				Jihua Liu		2024	2025	
		Canada	Dalhousie Univ	Julie LaRoche	Dalhousie Univ	2024	2024	
		USA	Univ. Southern Californ	Will Berelson	Univ. Southern C	2024	2025	
	Ocean Alkalinity Enhancement Mesocosms in Shenzhen	China	SUSTech Southern University of Science and Technology			2023	2025	https://www.sustech.edu.cn/en/colleges/ocean-science-and-engineering.html
	Developing a Community-Driven OAE Field Data Management Protocol	USA	Submarine Scientific	Jacki Long	Submarine Scientific	2024	ongoing	https://www.carbontosea.org/oae-data-protocol/1-0-0/
	Integrating OAE into Sustainable Marine Ecosystem Management	USA	UCSB	Debora Rodriguez-Iglesias	UCSB	2024	ongoing	
	Ocean Negative Carbon Emissions program (ONCE)	China	UN	Nianzhi Jiao	Xiamen Univ.			
		USA	NSF	Feng Chen, others	NSF			https://www.global-once.org/
Electrochemical Engineering								

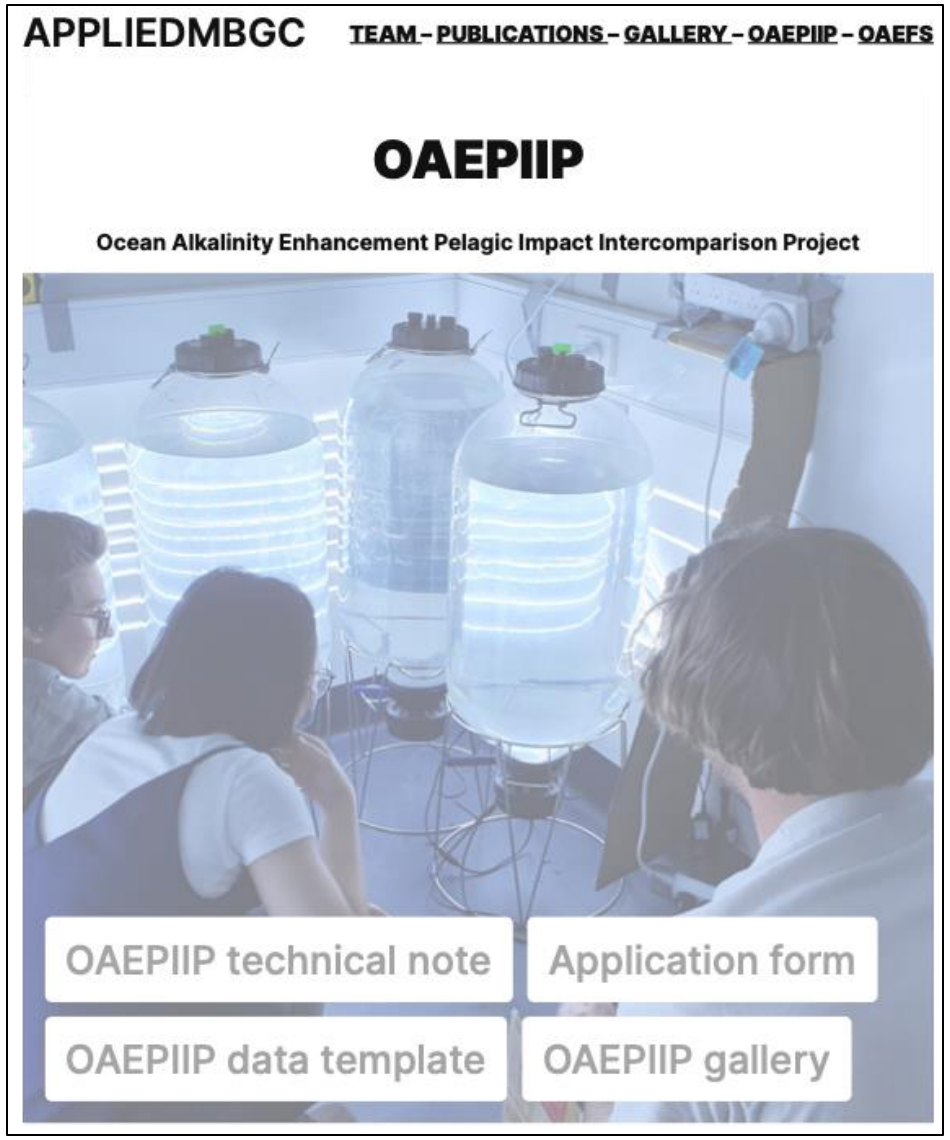
Statistics

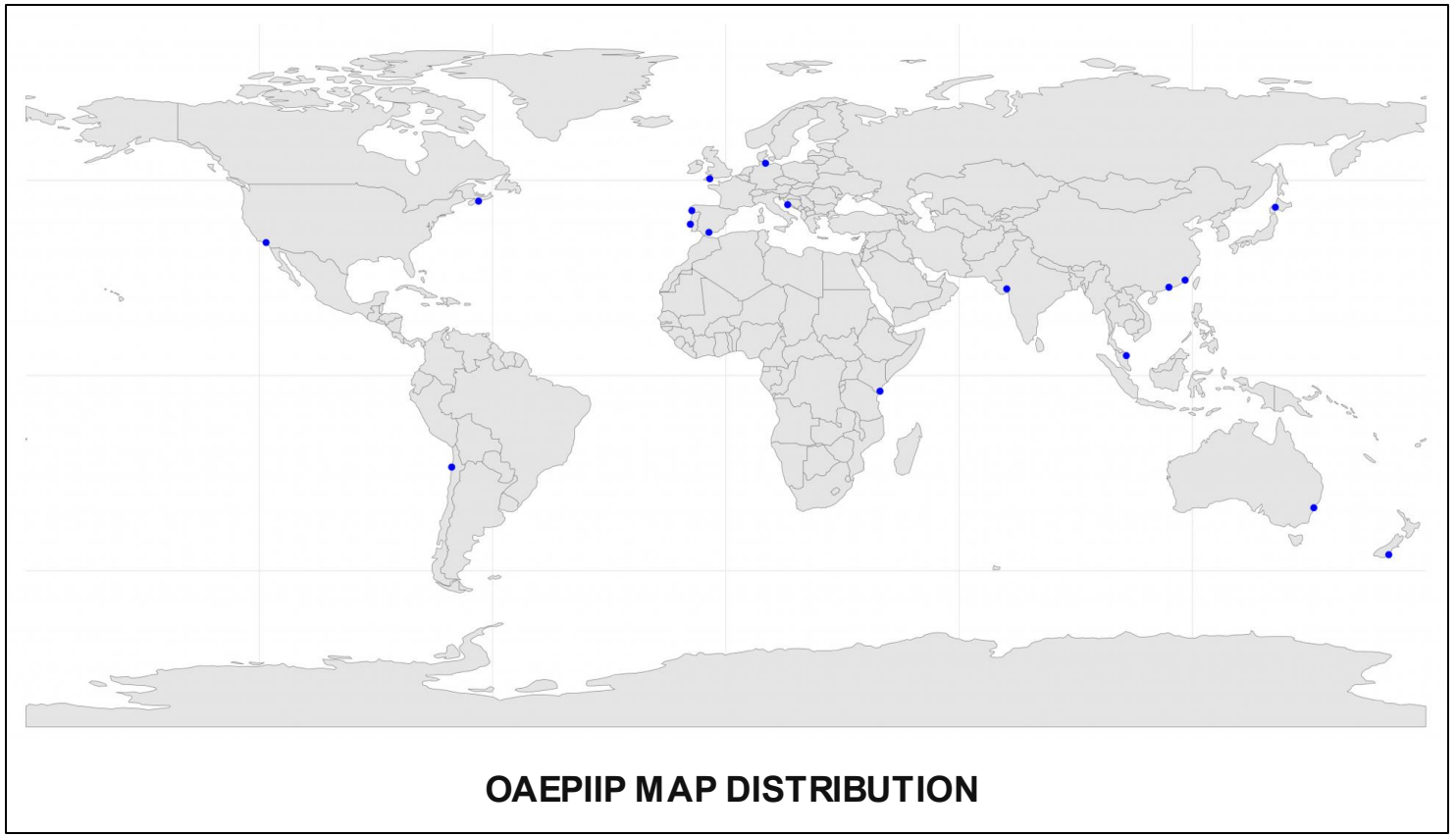




- **risk assessment studies for BC are rare** in PICES countries
- most of research study is domestic, while several international projects are ongoing

OAEPIIP

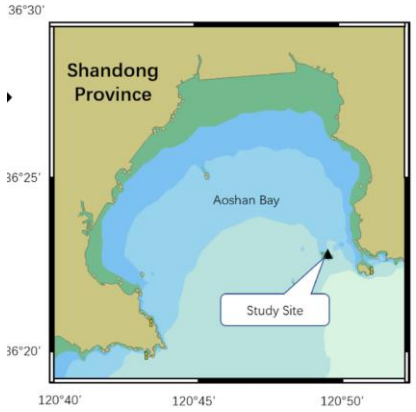


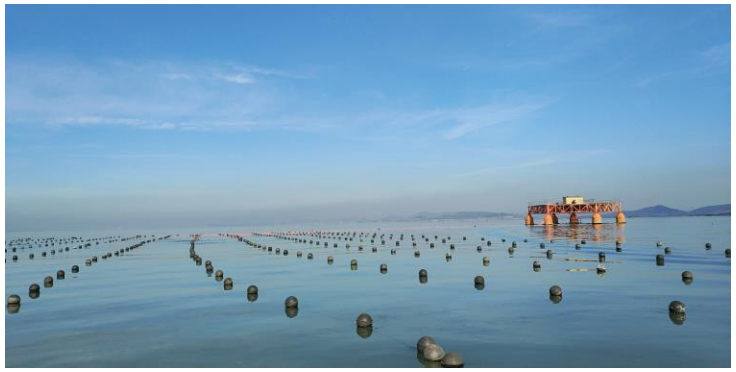


OAEPIIP MAP DISTRIBUTION

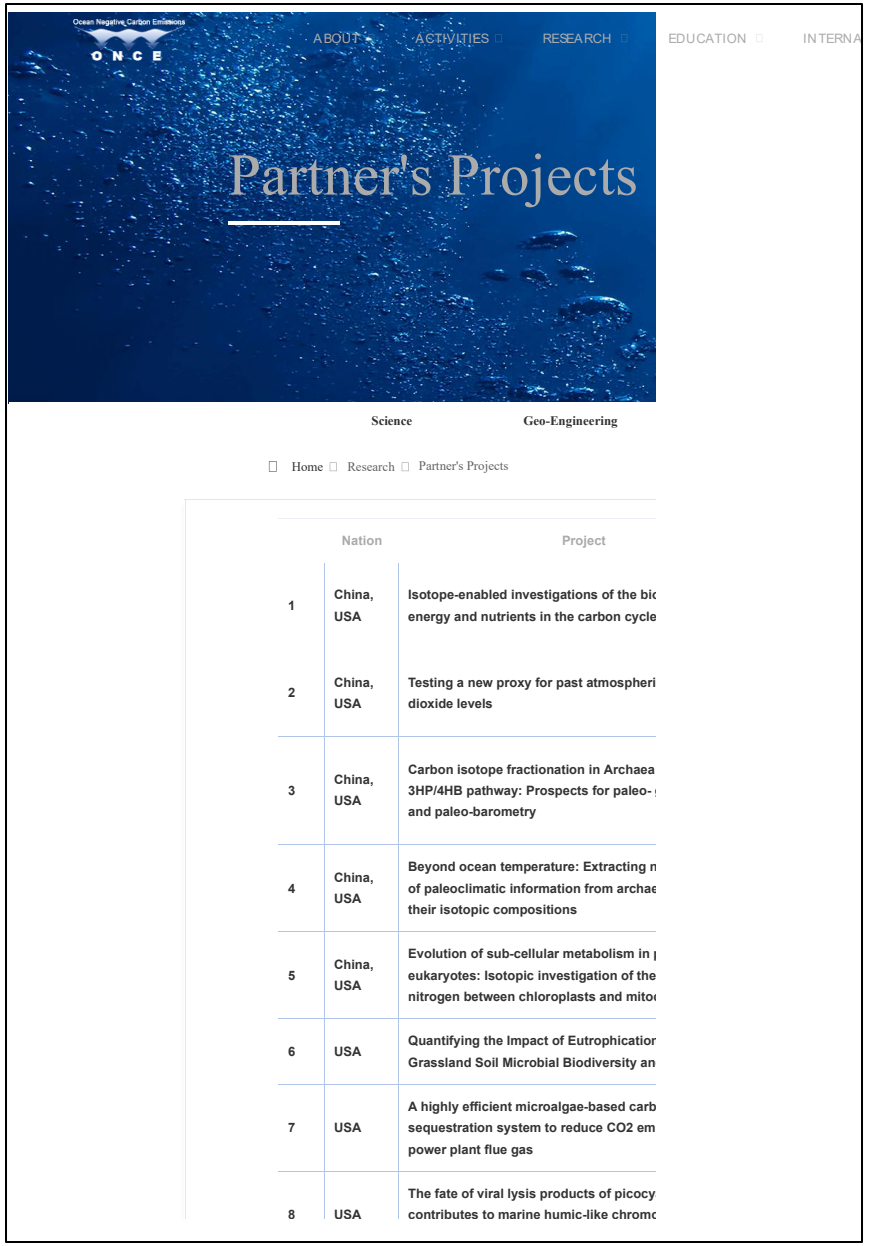
- led by Tasmania Univ.
- Conveying OAE rearing experiments for phytoplankton with common methodology / protocol
- US, Japan, and China are involved from PICES countries

Global ONCE





- UN-endorsed project led by China
- Tackles on several mCDR technologies containing BC and OAE
- Many collaborative studies between US and China



Protocols / manuals

List of protpcols / manuals of mCDR*(itaric indicate science discussion paper preliminary to the practical protocols/manuals)*

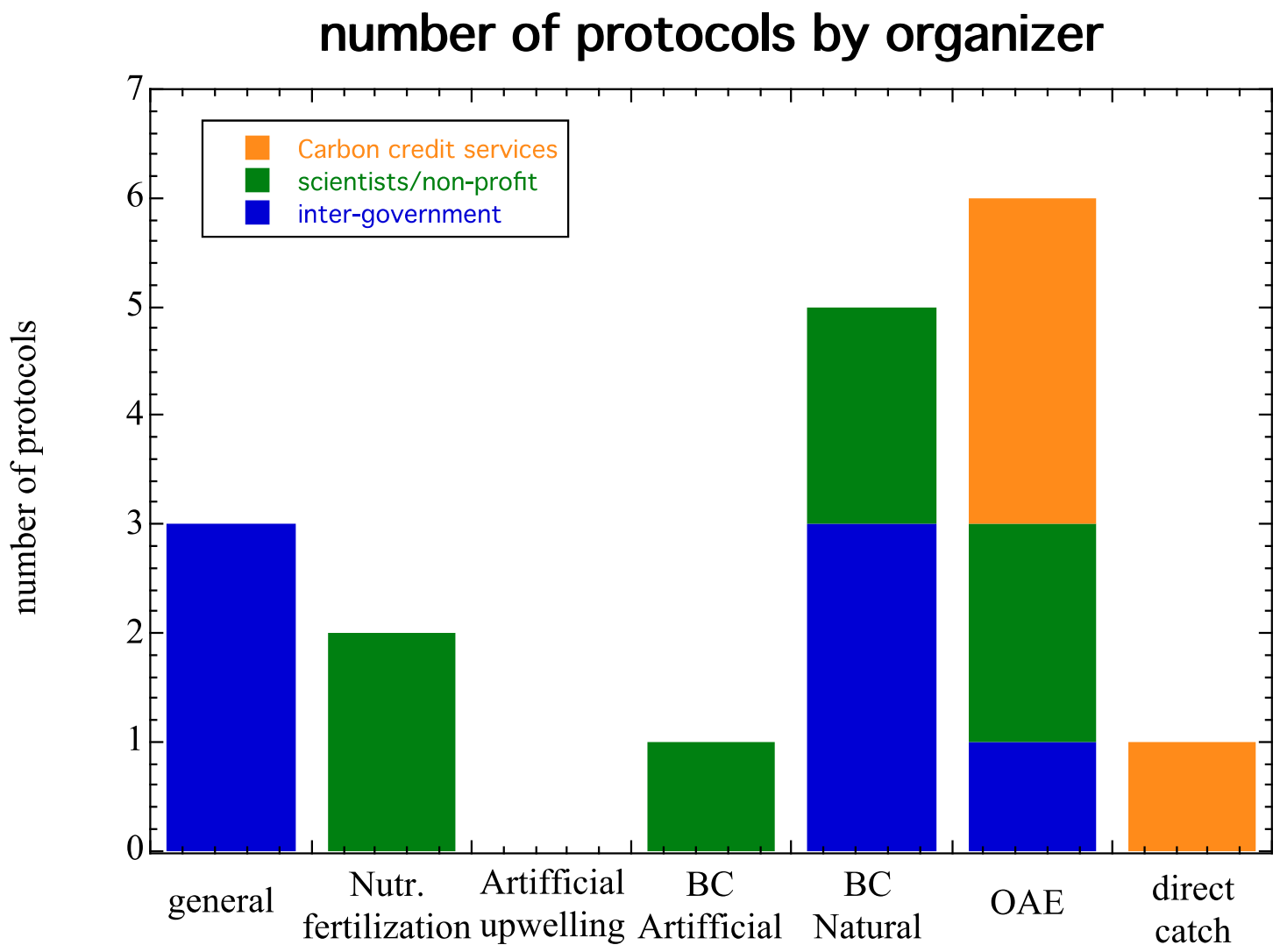
classification	Product name	Lead Institution / Program	Founder	Project PI	PI of the Product	summary of project / URL
Common techniques / procedures for all mCDR technologies	ISO 14064-2: Greenhouse gases -- Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements	ISO	ISO			https://www.iso.org/standard/66454.html
	Essential Ocean variables specification sheets	IOCCP	IOCCP			https://goosocean.org/what-we-do/framework/essential-ocean-variables/
	Establish international standards for technologies to reduce CO2 in the ocean, including various methods for reducing mCDR, accounting and modeling, engineering technologies, the formulation and publication of international standards for carbon credits	ISO	ISO	Yanli Lei	Yanli Lei	ISO/TC 8 - Ships and marine technology
Nutrient Fertilization (includng iron)	*ANSWERING CRITICAL QUESTIONS ABOUT PHYTOPLANKTON CARBON SOLUTIONS*	*Ocean Visions*	*Ocean Visions*	*Eric Schwaab (Ocean Visions)*	*Eric Schwaab (Ocean Visions)*	https://oceanvisions.org/wp-content/uploads/2025/09/Draft-Phytoplankton-Carbon-Solutions-Report_FINAL.pdf
	Paths Forward for Exploring Ocean Iron Fertilization	*Exploring Ocean Iron Solutions (ExOIS)*	*Exploring Ocean Iron Solutions (ExOIS)*	*Ken Buesseler (WHOI)*	*Ken Buesseler (WHOI)*	https://oceaniron.org/wp-content/uploads/sites/54/2023/10/PathsForward-ExOIS-Full.pdf
Artificial upwelling and downwelling						
Artificial blue carbon (Seaweed cultivation)	*ANSWERING CRITICAL QUESTIONS ABOUT SINKING MACROALGAE FOR CARBON DIOXIDE REMOVAL*	*Ocean Visions* *MBARI*	*Ocean Visions* *MBARI*	*David Koweek (Ocean Visions)*	*David Koweek (Ocean Visions)*	https://oceanvisions.org/wp-content/uploads/2022/10/Ocean-Visions-Sinking-Seaweed-Report_FINAL.pdf
	2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands	IPCC	IPCC	Takahiro Hiraishi (JIGES)	Takahiro Hiraishi (JIGES)	https://www.ipcc.ch/publication/2013-supplement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories-wetlands/
	Manual for the Creation of Blue Carbon Projects in Europe and the Mediterranean	IUCN	IUCN	María del Mar Otero (IUCN)	María del Mar Otero (IUCN)	https://iucn.org/resources/file/manual-creation-blue-carbon-projects-europe-and-mediterranean

Protocols / manuals (continued)

Natural blue carbon (Recovely of marine ecocyctem)	COASTAL BLUE CARBON : methods for assessing carbon stocks and emissions factors in mangroves, tidal salt marshes, and seagrass meadows	International Blue Carbon Initiative	conservation international / IOC-UNESCO / IUCN	Jennifer Howard (conservation international)	Jennifer Howard (conservation international)	http://thebluecarboninitiative.org/manual/
	High Quality Blue Carbon practitioners guide	Ocean risk alliance	UK government, ORRAA	Mark Beeston (conservation international)	Mark Beeston (conservation international)	https://oceanriskalliance.org/wp-content/uploads/High-Quality_Blue_Carbon_Practitioners_Guide_Oct2024.pdf
	Protocals for the quatitative evaluation of natural coastal blue carbon and efficient developemnt method of coastal seaweed bed	Fisheries Research and Education Agency (FREA)	Agriculture,Forestry and Fisheries Research Council	Kazuhiro Hori	FREA	This protocol specified quatitative evaluation method of CO2 inventory per area for several types of Japanese coastal seaseed meadow. No English URL
Ocean Alkalibity Enhancement	Guide to Best Practices in Ocean Alkalinity Enhancement Research	OACIS (Monaco Foundation)	ClimateWorks Foundation OACIS	Jean-Pierre Gattuso (CNRS)	Andreas Oschlies (GEOMAR)	https://sp.copernicus.org/articles/2-oae2023/
	Technical note: Ocean Alkalinity Enhancement Pelagic Impact Intercomparison Project (OAEPIIP)	OAEPIIP (Univ of Tasmania)		Lennart Thomas Bach (UTAS)	Lennart Thomas Bach (UTAS)	https://bg.copernicus.org/articles/21/3665/2024/
	Ocean Alkalinity Enhancement Data Management Protocol	Submarine Scientific / NOAA	Submarine Scientific / NOAA	Jacki Long (Submarine Scientific)	Jacki Long (Submarine Scientific)	https://zenodo.org/records/17154989
	Protocols for Ocean Alkalinity Enhancement from Coastal Outfalls	ISOMETRIC	ISOMETRIC	Sophie Gill	ISOMETRIC	https://registry.isometric.com/protocol/ocean-alkalinity-enhancement/1.0#footnote-label
	Protocols for Electrolytic Seawater Mineralization	ISOMETRIC	ISOMETRIC	Jennifer Yin	ISOMETRIC	https://registry.isometric.com/protocol/electrolytic-seawater-mineralization/1.0#contributors
	Protocols for Wastewater Alkalinity Enhancement	ISOMETRIC	ISOMETRIC	Jing He	ISOMETRIC	https://registry.isometric.com/protocol/wastewater-alkalinity-enhancement/1.1#contributors
Electrochemical Engineering	Protocols for Direct Ocean Capture and Storage	ISOMETRIC	ISOMETRIC	Jennifer Yin	ISOMETRIC	https://registry.isometric.com/protocol/direct-ocean-capture-storage/1.0#contributors

- Most technology now has ***at least* one** international protocols / manuals
- **General protocol for planning / implementing CDR projects** also available. (ISO 14064-2)
- **General protocols for ocean observation** (IOCCP EOV manuals) are applicable for mCDR monitoring

But several protocols overlaps...



- Several mCDR technologies have **more than one** protocols.
- Different sector provides different protocol.
- Existence of **general protocol** over the ones for each technology.

...Are these consistent?

Current findings and questions

Nutrient fertirization

- International scientist groups now arguing with its protocols.

Artificial upwelling

- MtC project already implementing in China.
- **No international protocols**

Artificial/Natural Blue carbon

- MtC~KtC project already implementing in Japan and Korea.
- Many studies for methodology, **no risk study.**
- **Several protocol**s co-exist.

OAE and Direct carbon catch

- ~KtC project already implementing in US and Canada.
- Many risk studies, but **often luck biologist in implementing project member**
- **Several protocols** co-exist.

Current findings and questions

Questions(1): implementation level

- Currently only one project is now implementing for artificial upwelling.
  Do we need common protocol at this time? Or, it should be made later?
- Most of OAE projects are implementing without biological oceanographers.
  Is this safe, as they follow OAE protocols that minimize biological inpact?
- No studies are projected for risk assessment of natural Blue Carbon technology (ca., protection of natural seaweed bed).
  Is it needless in principle? Or, do we need some studies?

Questions(2): governance level

- Currently several protocols co-exist in a mCDR technology.
  Are these consistent? If not, who make consistency among these?
- We found existence of general protocol for all CDR projects.
  Is each protocols for specific mCDR technology consistent with this?
- General protocols for basic ocean observation also exist.
  Does ocean observation methodology in each mCDR protocol matchs with this?

Questions for discussion(1)

・Currently only one project is now implementing for artificial upwelling.
Do we need common protocol at this time? Or, it should be made later?
*protocol is under developing

・Most of OAE projects are implementing without biological oceanographers.
Is this safe, as they follow OAE protocols that minimize biological inpact?
*not only biologist but fisheries scientists and communities
*"biologist" contains large specto;
*needs to measure large amount of bioloical data to do this.

・No studies are projected for risk assessment of natural Blue Carbon technology
(ca., protection of natural seaweed bed).
Is it needless in principle? Or, do we need some studies?
*less impact for "restoration of coastal ecosystem, but "artificial blue carbon" will need biological risk assessment
*LCA estimation on carbon MRV will important
*depends on "where" and who use it.
*ISO devides natural/artificial/GHG reduction

Questions for discussion(2)

・Currently several protocols co-exist in a mCDR technology.
Are these consistent? If not, who make consistency among these?
*each protocols is “custamized” one of general protocol (e.g., IPCC)
*need to make consistency between local protocols

・We found existence of general protocol for all CDR projects.
Is each protocols for specific mCDR technology consistent with this?

・General protocols for basic ocean observation also exist.
Does ocean observation methodology in each mCDR protocol matchs with this?
*

・Need for protocols for ”side effects” assessment. (MRV for risk)

Following activities of this WS

#Completion of “mCDR project list”

*S-CC requests missing information for mCDR projects / researches / protocols until the end of 2025.
please contact to WS Conveners.

#Writing PICES Report on the analysis of “mCDR project list”

* By the next S-CC business meeting (ca. Sept. 2026), **WS Conveners will analyze completed mCDR list, and make a PICES Report draft with the proceedings of this WS.**
* **We welcome submission of extended proceedings from the WS presenters. (not compulsory)**

#Need for additional WS in PICES 2026 for further discussion?
Yes, hopefully with ICES