Driving scientific consensus on ocean-based natural climate solutions

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NASA Carbon Monitoring System Policy Speaker Series

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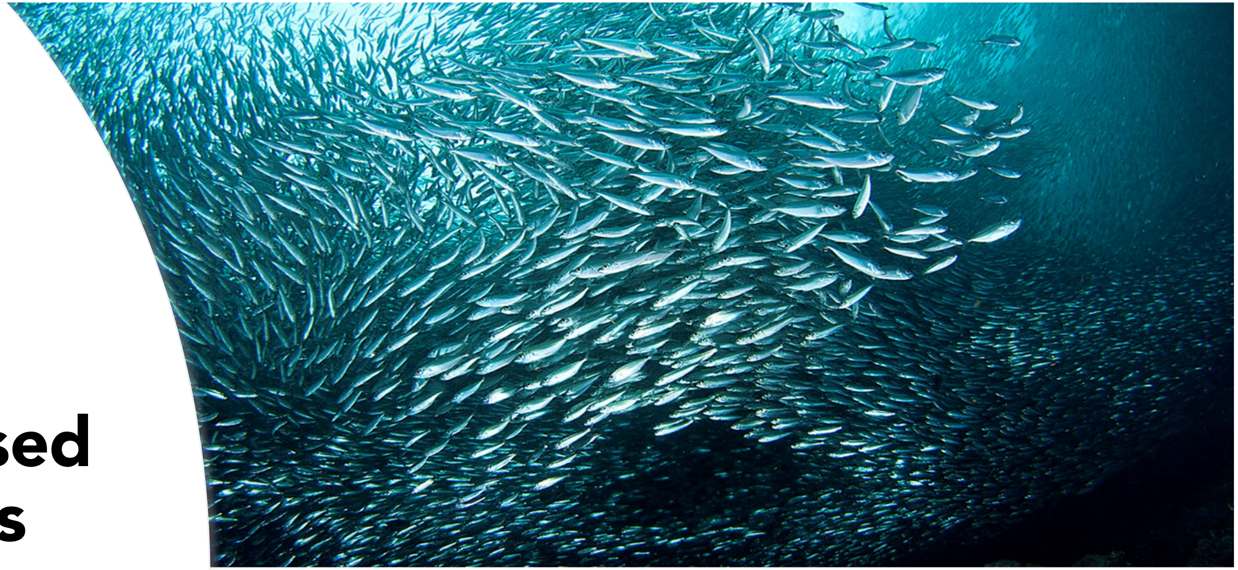
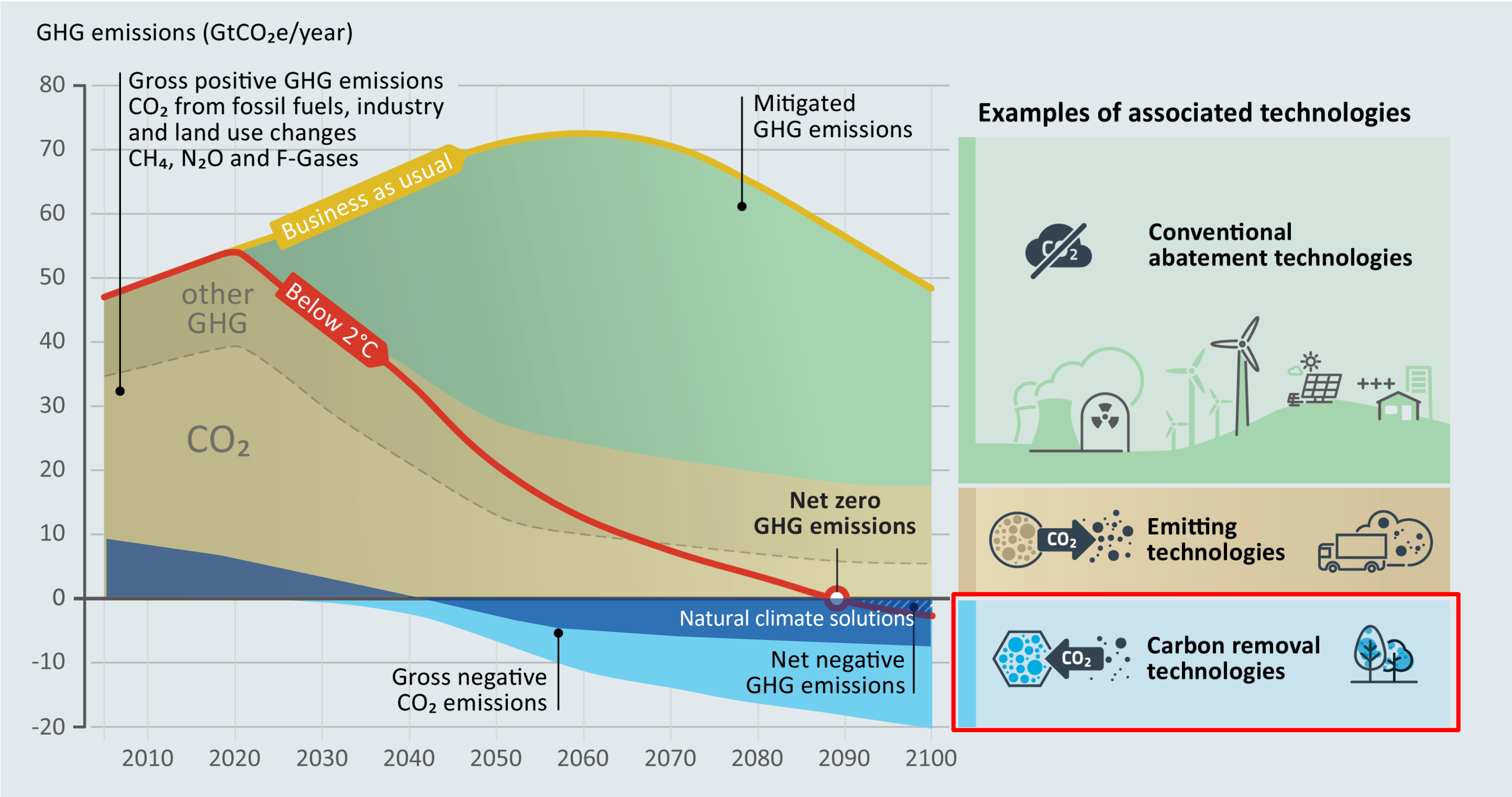


Agenda

- Carbon dioxide removal and natural climate solutions
- Blue carbon: Definitions and typology
- Process & methods: EDF's NCS scoping effort
- Results: Preliminary findings from our work in open ocean systems
  - Avoidance of emissions through controls on bottom-disturbing activities (benthic trawling, seabed mining)
  - Avoidance of emissions through limitation/prohibition on new fishing in the mesopelagic ocean
  - Sequestration of C via rebuilding of epipelagic fish populations
  - Sequestration of C via rebuilding of Great whale populations
- Questions/discussion – NASA synergies?

The need for carbon dioxide removal*



* Also, negative emissions technologies (NETs)

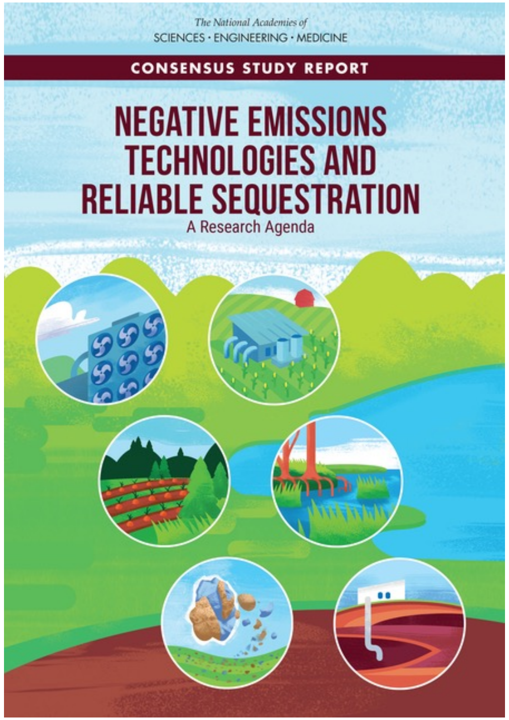
Modified from UNEP, 2017

CDR is a spectrum of approaches

- Can distinguish among methods by …
  - degree of *engineering* required
  - degree to which *technology* is used to manipulate natural ecosystem/ biogeochemical processes
- At one extreme: Solutions such as enhanced mineral weathering, various forms of carbon capture, utilization and storage (CCUS)
- At the other: Natural climate solutions

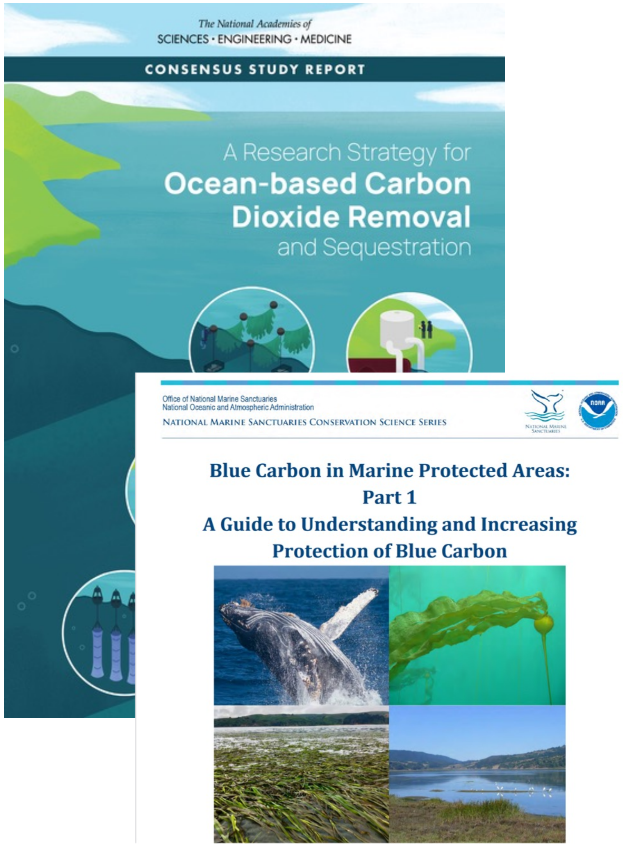
Strategies that aim to avoid greenhouse gas (GHG) emissions or sequester carbon from the Earth's atmosphere by protecting, managing, restoring or enhancing ecosystems

Griscom et al., 2017



Increasing interest in ocean CDR

- Size and scale
- Relative remoteness
- Very large C reservoirs with long residence times
- Complex biogeochemical processes provide multiple possible "levers" for intervention



Ocean-based NCS and CDR

Undisturbed system

Substantial use of technology
Heavy manipulation of ocean physics or biogeochemistry

Natural climate solutions

- Emphasize **co-benefits** apart from C sequestration, such as biodiversity, jobs, coastal protection
- Can be implemented to achieve justice and equity objectives
- Ocean NCS aim to increase or restore stocks of **blue carbon**

Technological/geoengineering approaches

- Significant biogeochemical or mechanical intervention in natural systems
- Potentially large C sequestration potential, but fewer co-benefits
- Risks and possible downsides not clearly known

Ocean-based NCS and CDR

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Heavy manipulation of ocean physics or biogeochemistry

Undisturbed system

Natural climate solutions

Technological/geoengineering approaches

- Protection and restoration of **blue carbon** ecosystems

- Macroalgal cultivation to remove CO_2 from surface waters

- Ocean fertilization: Addition of nutrients (usually Fe) to increase NPP

- Artificial upwelling; artificial downwelling
- Ocean alkalinity enhancement
- Electrochemical CO_2 capture
- Subseafloor injection & geologic storage

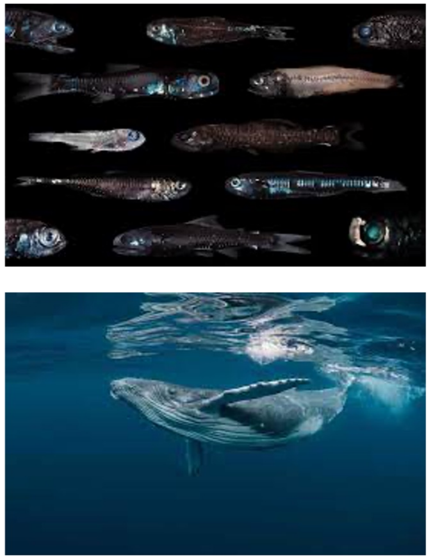
Blue carbon

- *Blue carbon*, ca. 2011: "Carbon sequestered in vegetated coastal ecosystems, specifically mangrove forests, seagrass beds, and salt marshes." (Mcleod et al., 2011)
- *Blue carbon*, ca. 2022: "Carbon captured by the world's ocean and coastal ecosystems." (NOAA NOS)

Nearshore coastal systems

Macroalgal systems

Open ocean systems



EDF-Bezos Earth Fund NCS project

- Explore and quantify **carbon sequestration potential** and **co-benefits** of NCS across different components of the Earth system
- Identify key scientific uncertainties and socioeconomic considerations
- Assess relative readiness of pathways (41 total) to serve as a source of high-quality carbon credits
- Identify and catalyze high-leverage interventions that could contribute significantly to global decarbonization

Tropical forests

Temperate forests

Agricultural soils

Ocean systems

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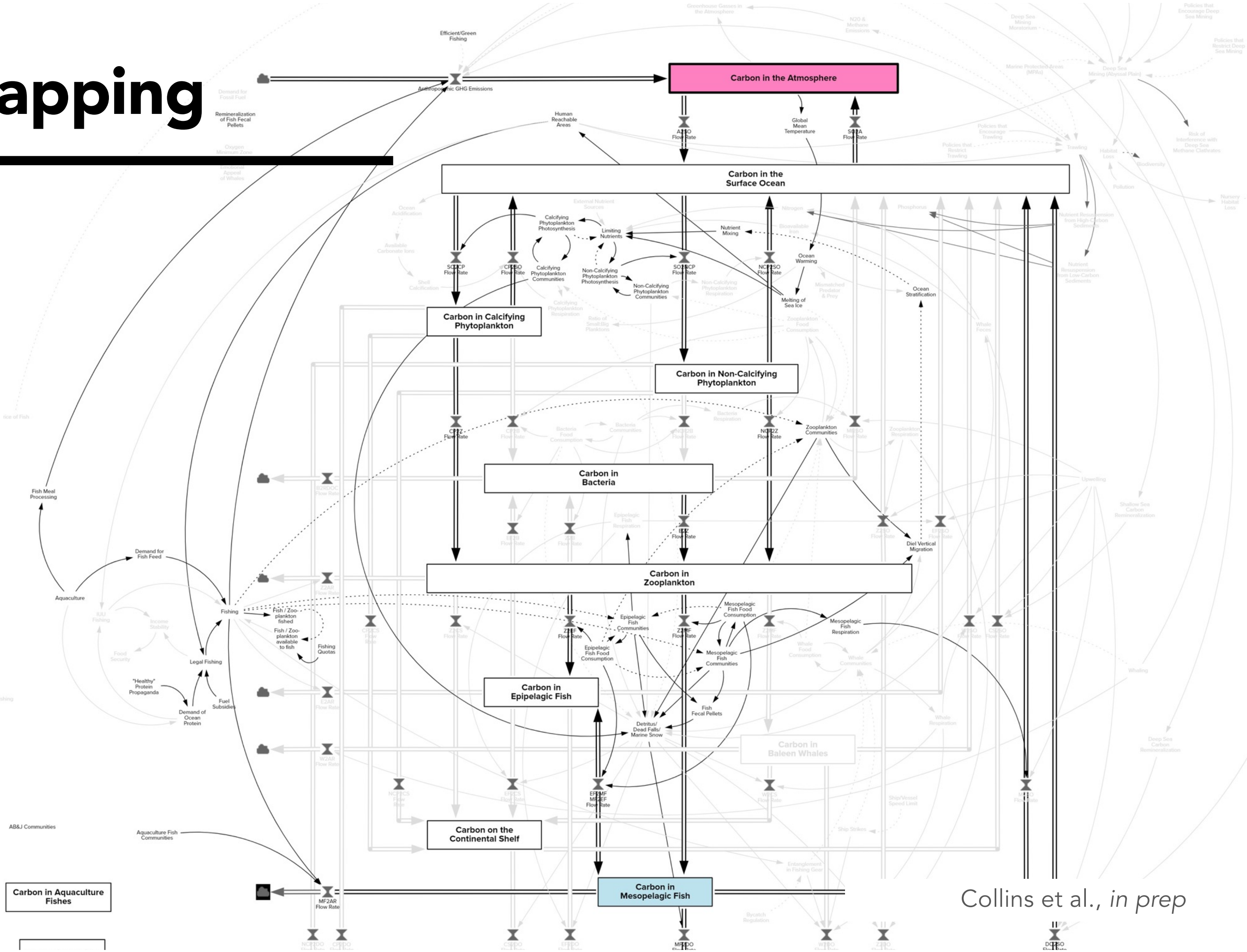
EDF-BEF NCS project: Ocean systems approach

- Approach: Convene outside experts (70+; academia, government, NGO community, practitioners) to **build consensus** on ocean NCS across three domains:
  - Nearshore/traditional blue carbon
  - Macroalgal systems
  - Open ocean systems
- Series of workshops using a **systems-mapping approach** to identify biogeochemical and ecological linkages, and linkages between natural systems and human elements

Systems mapping

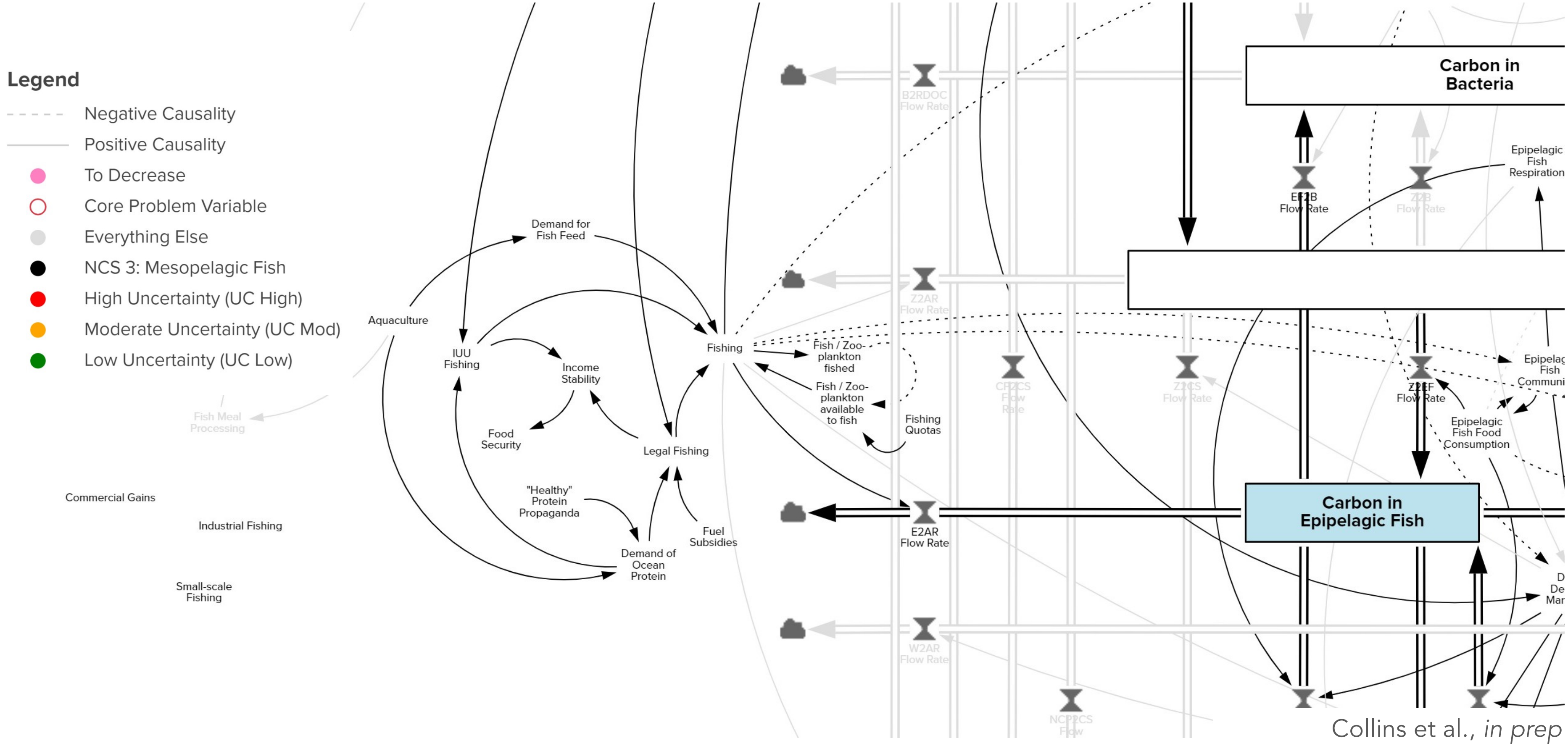
Legend

- - - - Negative Causality
—— Positive Causality
● To Decrease
○ Core Problem Variable
● Everything Else
● NCS 3: Mesopelagic Fish
● High Uncertainty (UC High)
● Moderate Uncertainty (UC Mod)
● Low Uncertainty (UC Low)



Collins et al., *in prep*

Systems mapping



Collins et al., *in prep*

Project timeline

- Currently: Open ocean workshop complete; macroalgal systems in progress now; nearshore blue carbon workshops kicking off soon
- April-May 2022: Domain workshops complete
- June-July 2022: Synthesis workshops to identify most promising pathways (fewest ecological/socioeconomic risks & most co-benefits while also sequestering CO_2)
- The future: Targeted research to reduce key uncertainties; explore most promising interventions

Preliminary results from the open ocean

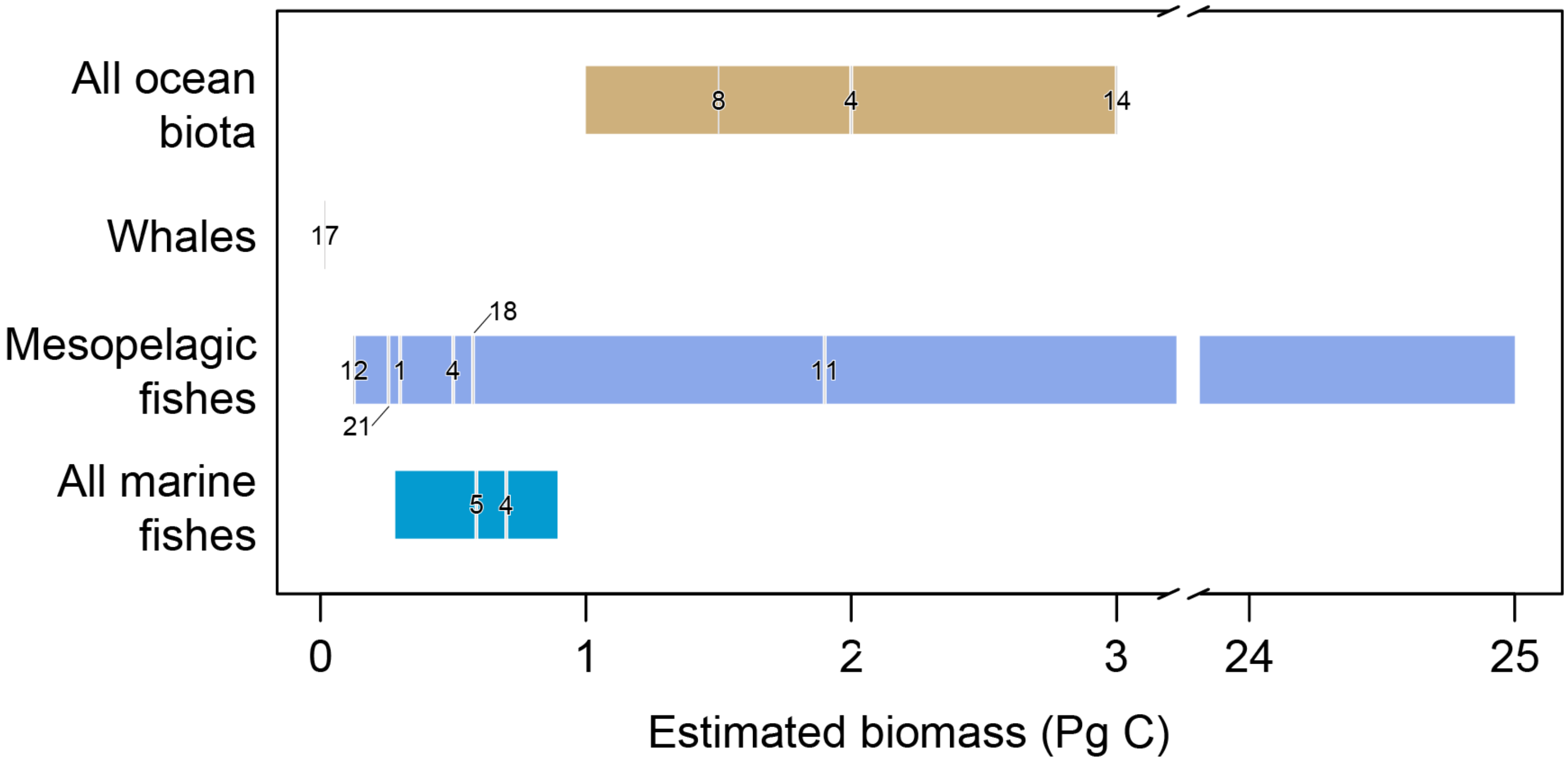
- Convened 24 experts to examine four possible pathways:
  - Avoid new emissions through controls on bottom-disturbing activities (benthic trawling, seabed mining)
  - Avoid new emissions through limitation/prohibition on new fishing in the mesopelagic ocean
  - Sequester C via rebuilding of epipelagic fish populations
  - Sequester C via rebuilding of Great whale populations

Overall findings

- No open ocean pathways near readiness to serve as source of high-quality C credits, *but the science supports some immediate actions*
- Open ocean pathways lag terrestrial NCS significantly in both market readiness and scientific certainty
- Fundamental uncertainties exist in physics, biogeochemistry, ecology
- Climate change confounds the establishment of actionable restoration goals
- *MRV will be a particular challenge in the open ocean:*
    - Remote sensing not nearly as effective a tool as in terrestrial or coastal settings
    - Models likely to be a part of any MRV scheme since continuous, direct observations almost always impossible

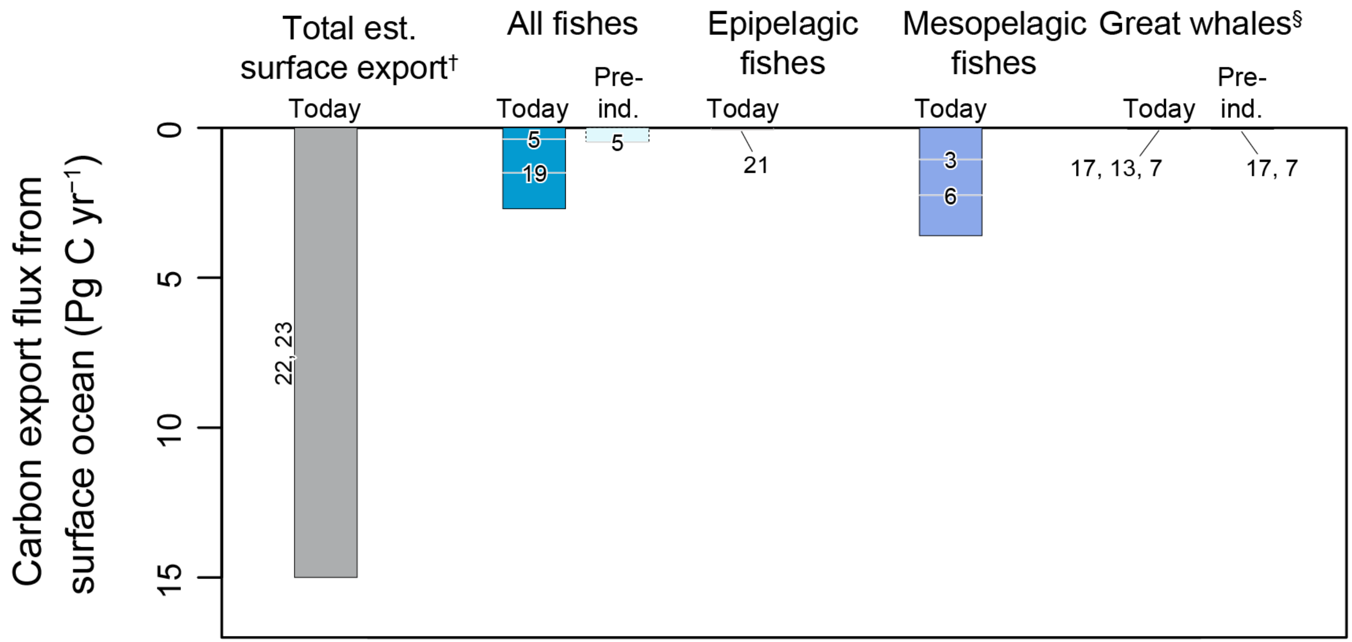
Collins et al., *in prep*

Fundamental uncertainties: Ocean biomass



Collins et al., *in prep*

Fundamental uncertainties: Ocean C fluxes



Collins et al., *in prep*

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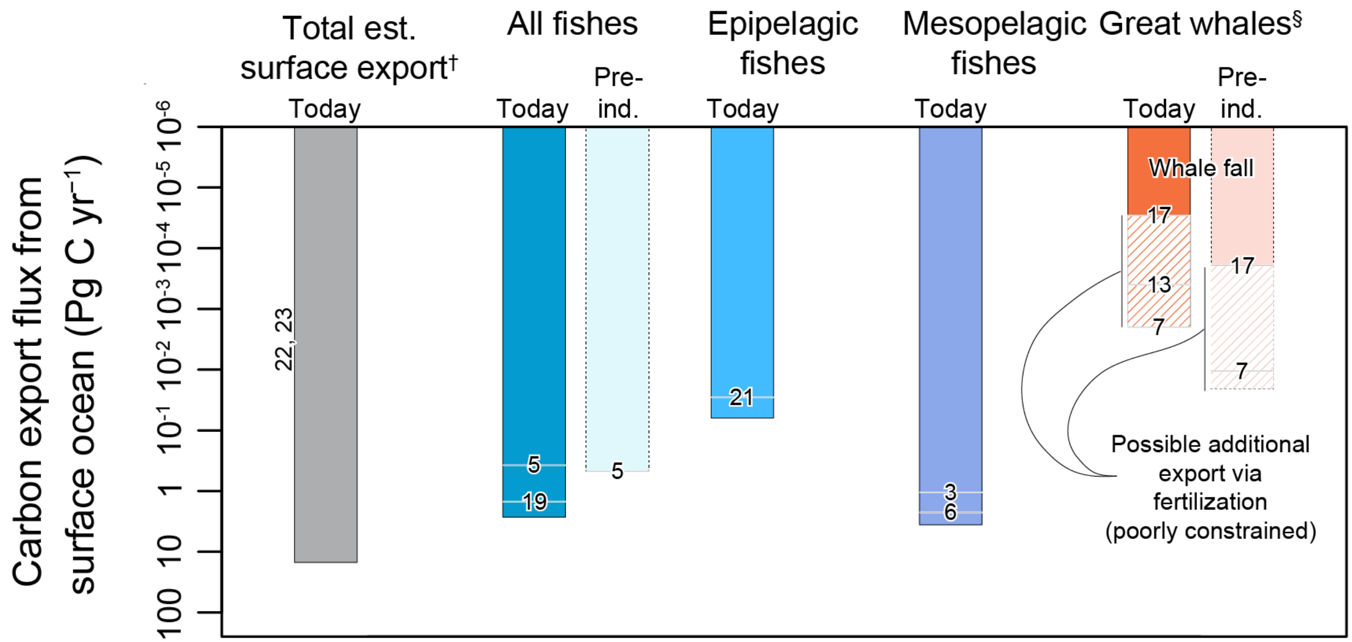

Collins et al., *in prep*

Findings: Bottom-disturbing activities

- Disturbance of marine sediments could lead to partial remineralization of C into CO_2, some of which will eventually ventilate to atmosphere
- Quantity of C remineralized highly dependent on previous disturbance, existing sediment redox regime, type of disturbance
- Timescale of ventilation dependent on depth, ocean circulation
- One estimate places possible remin. rate at ~ 0.4 Pg C yr^{-1} (Sala et al. 2021) but this figure is highly uncertain
  - Compare Paradis et al. (2021): 0.06 Pg C yr^{-1}

Collins et al., *in prep*

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Needs further study. Moratorium on new benthic trawling in emerging Arctic is a possible intervention w/limited socioeconomic impact.

  - Compare Paradis et al. (2021): 0.06 Pg C yr^{-1}

Collins et al., *in prep*

Findings: Avoided targeting mesopelagic fishes

- Mass balance approaches suggest these species may transport as much as 2.25 (0.9 – 3.6) Pg C yr^{-1} from surface to deep ocean as part of their diel vertical migrations (Boyd et al., 2019)
- Very wide range, but *even at lower limit of uncertainty, flux is still likely very large in magnitude*
- No existing commercial fisheries targeting these species
- No regulations exist, and absence of commercial activity is purely a function of technological limitations (all processing must be done at sea)

Collins et al., *in prep*

Findings: Avoided targeting mesopelagic fishes

- Mass balance approaches suggest these species may transport as much as 2.25 (0.9 – 3.6) Pg C yr^{-1} from surface to deep ocean as part of their diel vertical migrations (Boyd et al., 2019)

Sufficient scientific basis for action today: While magnitude of flux mediated by these species highly uncertain and thus not sufficient as basis for C credits, **targeting of these species would likely short circuit 10-20% of total ocean biological pump export**.

Collins et al., *in prep*

Findings: Rebuilding epipelagic fish populations

- Fish may export as much as 1.5 Pg C yr^{-1} from surface ocean (Saba et al. 2021) through variety of mechanisms (deadfall, fecal pellets, diel migration, etc.)
- Mariani et al. (2020) suggest contribution from deadfall alone was reduced by a total of 21.8×10^{-3} Pg due to commercial fishing between 1950 and 2014; Bianchi et al. (2021) estimate 0.8 Pg C decline in fecal pellet export
- No reliable models exist for specific species or w/output precise enough to support C crediting

Collins et al., *in prep*

Findings: Rebuilding epipelagic fish populations

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Needs further study. Modeling overall C footprint of high-value species could provide basis for management bodies to value as agents of C sequestration rather than solely as extractable protein.

enough to support C crediting

Collins et al., *in prep*

Findings: Rebuilding of Great whale populations

- Least certain and least actionable of the four pathways we considered
- Two mechanisms through which whales hypothesized to contribute to C export:
  - "Whale fall": Least uncertain, on order of 10^{-5} Pg C yr^{-1}, with pre-whaling contribution estimated at 10^{-4} Pg C yr^{-1}
  - Indirect fertilization: Highly uncertain; minimal empirical evidence.
    - Whales hypothesized to deliver limiting nutrients to surface ocean in feces, stimulating primary production by phytoplankton; some of this newly fixed biomass then assumed to be exported to deep ocean
    - Contemplated primarily in Fe-limited regions of Southern Ocean
  - Existing estimates have relied on assumed values for several critical scaling parameters
  - Estimates of total possible contribution on order of 10^{-3} Pg C yr^{-1}

Collins et al., *in prep*

Findings: Rebuilding of Great whale populations

- Least certain and least actionable of the four pathways we considered
- Two mechanisms through which whales hypothesized to contribute to C export:

Needs further study. Actionable interventions not clear as evidence indicates many species already recovering at maximum possible rates. While highly uncertain as a basis for C credits, myriad other imperatives to pursue whale conservation.

  - Existing estimates have relied on assumed values for several critical scaling parameters
  - Estimates of total possible contribution on order of 10^{-3} Pg C yr^{-1}

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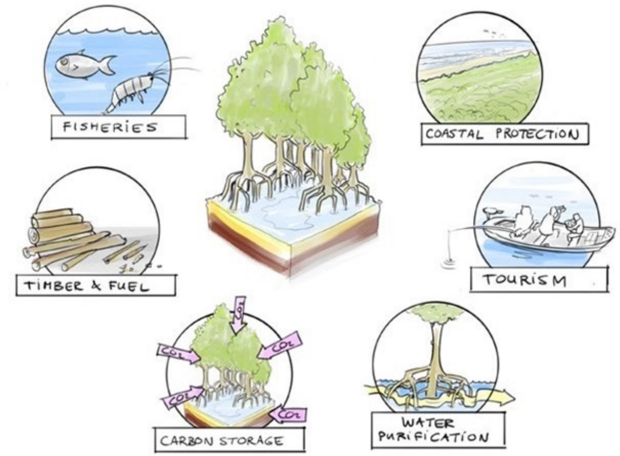
Future directions: Innovation needed

- Basic research: Better understanding of many elements of ocean C cycle
  - C crediting requires high level of precision
  - All of these require measurement of relatively small perturbations against "large natural background cycling and storage" (NASEM, 2020)
  - "Bottom up" approach: Develop C footprints for fishes & whales?
- Innovative methods for MRV: Can we achieve precision & certainty using combination of models, *in situ* observations & remote sensing?
- How can we attribute C sequestration or other services provided by migratory animals (fish, whales) to specific geographical areas/jurisdictions (e.g., MPAs or specific EEZ)?

A parting thought on primary and co-benefits

Coastal and open ocean blue carbon NCS pathways provide …

- Increased ecosystem resilience through biodiversity enhancement
- Human-centered ecosystem services:
  - Jobs (recreation, fishing, etc.)
  - Coastal protection (e.g., from storm surge)
  - Water quality benefits (processing of excess sediment, organic carbon, N & P)
- Fisheries benefits: Coastal blue carbon systems serve as nursery habitats; the open ocean sustains countless populations



A parting thought on primary and co-benefits

Given the persistent uncertainties associated with many blue carbon NCS pathways, should C sequestration be a co-benefit subordinate to other ecosystem services?

Questions & discussion

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