https://doi.org/10.5194/egusphere-2026-5117
Preprint. Discussion started: 26 August 2026

An Estimate of the Global Marine Carbon Flux of Cold-Water Corals

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Abstract. Marine calcification constitutes an important component of the global carbon cycle by sequestering carbon. During skeletal growth corals accumulate carbon, with numerous studies have highlighted their potential contribution to long-term carbon storage. This study compiles data from 32 published studies attempting to provide first estimates of the annual global carbon accumulation through cold-water corals. Carbon accumulation rates from individual reef systems were averaged and calculated up to global scale. As the worldwide coral covered area remains incompletely constrained, two different approaches were used, based on (i) coral mound density and (ii) regional coral area percentages, to asses the global suitable area. In addition, the proportion of living coral cover and the percentage of exposed mounds were taken into account. The global carbon accumulation was estimated using Monte-Carlo uncertainty propagation. The resulting simulations yielded probability distributions for the global carbon accumulation, from which the mean, median and 5th and 95th percentiles were derived. The mound-density-based approach resulted in medians, 5th and 95th percentiles of 0.003 ($8.7\text{x}10^{-5}$ - 0.079) Gt C yr^{-1}, whereas the area-based approach yielded 0.0022 ($2.0\text{x}10^{-5}$ - 0.086) Gt C yr^{-1}. The calculated means are approximately one magnitude higher than the corresponding medians, reflecting the asymmetrical and strongly right-skewed distribution. Consequently, most Monte Carlo realizations produced relatively low carbon accumulations, whereas only a small number of parameter combinations resulted in substantially larger values. The uncertainty spans approximately four orders of magnitude, emphasizing strongly the need for additional observational data to better constrain the parameters.

The estimated global carbon accumulation of cold-water corals is approximately one magnitude lower than published estimates for tropical corals and two orders of magnitudes lower than the pelagic carbon burial. Compared with other carbon reservoirs cold-water corals therefore likely play a subordinate role in the global carbon cycle, but may locally be of importance. The estimated accumulation corresponds to a burial of 0.01% (mound-density-based) or 0.076% (area-based) of the global annual oceanic net uptake of CO_2. As anthropogenic CO_2 emissions continue to rise, cold-water coral ecosystems are increasingly threatened by ocean acidification and warming. However, the implications of these environmental changes for the global carbon cycle are expected to be considerably greater for tropical coral reefs and pelagic carbonate-producing systems.

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1 Introduction

The ocean contains the largest active carbon reservoir on Earth and continuously exchanges carbon dioxide (CO_2) across the air-sea interface, thereby regulating the atmospheric CO_2 concentration on long timescales(DeVries (2022), Revelle and Suess (1957), Nevison et al. (2008), Sarmiento and Gruber (2006)). Carbon budget estimates indicate that the Oceans has absorbed approximately 25% of annual human-made emissions, with a global net uptake of CO_2 of 2.9 Gt C yr^{-1} in 2023 (Friedlingstein et al. (2024)).

Three main processes govern this critical climate buffer: the solubility pump, the biological pump, and the carbonate pump. The solubility pump is a physicochemical process driven by temperature, wind speed, and the air–sea CO_2 gradient. Here, solely dissolved CO_2 can be exchanged, although it accounts for only about 1% of the dissolved inorganic carbon fraction. This dissolved CO_2 also fuels the biological pump, in which surface phytoplankton fix carbon through photosynthesis. Following death or grazing, phytoplankton and other microscopic organisms form particulate organic matter ("marine snow") that sinks through the water column. Most of this particulate organic carbon is remineralized before reaching the seafloor, and only a small fraction is ultimately buried in marine sediments.

The third mechanism, the carbonate pump, is driven by the precipitation of calcium carbonate by marine calcifiers such as corals, pteropods, and coccolithophores. During calcification, bicarbonate and calcium ions are converted into $CaCO_3$. Carbonate ions account for approximately 10% of the dissolved inorganic carbon pool, and carbonate particles are more efficiently preserved during sinking than organic matter, resulting in a comparatively larger proportion being buried in marine sediments (Sarmiento and Gruber (2006), DeVries (2022), Cartapanis et al. (2018), Frankignoulle et al. (1994)).

Consequently, the production and burial of biogenic carbonates in marine sediments and coral skeletons represent an important long-term carbon sink in the ocean. Among marine carbonate-producing organisms, cold-water corals (CWCs) are widely distributed throughout the world's oceans. In recent years, advances in deep-sea exploration technologies, together with the recognition of their widespread occurrence within the thermocline (approximately 200–1200 m water depth), have led to the discovery of numerous framework-forming CWC ecosystems. These ecosystems are typically associated with continental shelf margins, seamounts, and other topographic highs. Nevertheless, despite their global distribution, CWC reefs remain among the least explored marine carbonate-producing ecosystems (Roberts et al. (2006), Roberts et al. (2009), Hebbeln et al. (2019), Fragkopoulou et al. (2025)). Growing awareness of the ecological importance of these highly diverse ecosystems has stimulated the first quantitative assessments of their role in regional carbon budgets (Edinger et al. (2025) , Titschack et al. (2009), Titschack et al. (2015), Titschack et al. (2016), Greiffenhagen et al. (2025), Greiffenhagen et al. (2026)).

CWCs occur as solitary individually, colonies and patch reefs but also as larger reefs and giant mounds. These coral carbonate mounds develop in cyclic patterns, reaching high aggradation rates during periods of active mound accumulation while building coral framework and aggregating sediments. Coral mounds can rise several hundreds of meters above the seafloor and accumulate over several thousand to millions of years, thereby burying carbon on geological timescales (Roberts et al. (2006), Greiffenhagen et al. (2026)).

Globally, the most relevant species for the formation of these extensive carbonate deposits is *Desmophyllum pertusum* (for-

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merly known as *Lophelia pertusa* – or the white coral). However, other species such as *Madrepora oculata*, *Solenosmilia variabilis*, *Dendrophyllia*, and many others generate significant seafloor carbonate deposits. These framework forming corals exhibit high grazing rates, grow fast with rates of cm per year, and have fast reproduction cycles, which allow the building of entire reefs (Roberts et al. (2006), Roberts et al. (2009)). Their habitats provide some of the most biodiverse ecosystems of the upper thermocline ocean, thus mesopelagic zone (Henry and Roberts (2017)). This ocean region harbours one of the largest ecosystems and fish stocks on the planet (Herndl and Reinthaler (2013)). Life in this zone is stimulated by particulate organic carbon supplied through the biological carbon pump and seasonal entrainment of surface waters in deeper layers (Dall'Olmo et al. (2016)). The occurrence and development of coral reefs in this zone are controlled by numerous environmental parameters, including temperature, pH, oxygenation, strong bottom water currents and/or tidal dynamics stimulating seasonal mixing, the availability of suitable hard substrates, and most importantly primary production, thus particulate organic carbon supply (Davies et al. (2008), Davies and Guinotte (2011), Cairns (2007), Roberts et al. (2009)). Although comparatively little is known yet about health threats, such as viruses and illnesses, several groups of marine organisms are recognized as important predators. Primary predators include specialized sea stars (e.g., Hippasteria and Evoplosoma), certain sea urchins (e.g., Cidaris cidaris), parasitic gastropods, and various benthic fishes and crabs (Stevenson and Rocha (2013), Mah et al. (2010)).

However, CWC reefs accumulate discontinuously, with centennial- to millennial-scale cycles of reef proliferation and decline Roberts et al. (2009). In particular, climate-driven changes of thermocline environments in subpolar regions, as wells as variations in primary productivity in coastal upwelling regions influence the population density and survival of CWC reef like ecosystems (Frank et al. (2009), Frank et al. (2011)). Equally important for the long-term development of coral mounds in successive generations is the continuous supply of stabilizing sediment to fill the space and consolidate the reefs (Wienberg and Titschack (2017)).

When evaluating carbon fluxes and storages related to these deep-sea ecosystems, periods of high coral abundance and active reef aggradation are of particular importance, whereas phases of reef decline and sparse coral growth are characterized predominantly by hemipelagic sedimentation. Since hemipelagic carbonate sedimentation is inherent part of the carbonate storage capacity of such coral reefs like environments of the mesopelagic ocean both contribute to the overall rate of carbon storage. Consequently, the regional carbonate accumulation rate is the sum of coral carbonate production and background sedimentation (Titschack et al. (2009)). The high abundance of coral carbonate in coral bearing sediments and the shear size of the seafloor topographic structures found, for example, in the North Atlantic, suggest that these ecosystems are possibly substantial carbonate sinks compared to sedimentation alone. Additionally, individual coral growth rates and reproduction and opportunistic development are comparable to other marine carbonate-producing ecosystems, including tropical corals coralline algea and bryozoan facies (Titschack et al. (2016)).

The first estimates of carbonate accumulation for entire mound provinces indicate that these ecosystems may play an important role in regional or possibly even carbon storage. Twelve published studies have demonstrated the potential of CWCs as significant local carbon sinks through their carbonate accumulation up to 32.18 g C cm^{-2} kyr^{-1}, similar to tropical corals (Greiffenhagen et al. (2026), Greiffenhagen et al. (2025), Edinger et al. (2025), Titschack et al. (2009), Titschack et al. (2015), Titschack et al. (2016), Dorschel et al. (2007), Tamborrino et al. (2022), Cathalot et al. (2015), Hebbeln et al. (2019)). Building

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on the approach proposed by Dorschel et al. (2007) and the growing number of studies on CWC reefs, here we attempt to estimates the global carbon accumulation of CWCs. To achieve this, data from 32 published studies investigating the input variables (carbon accumulation rates, coral mound covered area, live coral cover, exposed mounds) were compiled. These data provide the basis for a first calculation of the global carbon accumulation and classification of CWC in the carbon cycle, although substantial uncertainties remain. The resulting median of carbon accumulation rates is approximately 40 times lower than the highest regional accumulation rates reported in literature, while the mean estimate is approximately one order of magnitude lower than these regional peak values.

2 Methods

To estimate the global carbon accumulation of CWCs, we adapted the approach of Dorschel et al. (2007). The calculation incorporates the coral carbon accumulation rate, the globally habitable area for CWCs, the proportion of suitable seafloor covered by coral mounds, the percentage of the live coral cover and the fraction of exposed mounds were taken into account. A visualization of these input parameters is shown in Figure 1.

These variables are combined into the following equation to estimate the global carbon accumulation of CWC mounds:

$$\begin{aligned}\text{Global C Acc (Gt C yr}^{-1}) = {} & \text{Coral C Acc rate (g C cm}^{-2}\text{ kyr}^{-1}) \\ & \times \text{Habitable area (km}^2) \\ & \times \text{Mound covered area (\%)} \\ & \times \text{Live coral cover (\%)} \times \text{Exposed mounds (\%)} \\ & \times 10^{-8}\end{aligned} \quad (1)$$

The carbon accumulation rate (g C cm^{-2} kyr^{-1}) was projected on the global area covered by CWCs by multiplying the the globally suitable habitat area by the proportion of seafloor covered by coral mounds. Because the coral mound cover was estimated using two independent approaches (see below), the global carbon accumulation was calculated separately for each approach. Finally, the estimated accumulation was adjusted for the proportion of live coral cover, representing the fraction of corals actively producing carbonate, and for the proportion of exposed coral mounds, which are capable of ongoing carbonate accumulation. A conversion factor of 10^{-8} was applied to obtain the final result in units of Gt C yr^{-1}.

To quantify the uncertainty of the global carbon accumulation by CWCs, Monte Carlo uncertainty propagation was applied. All input variables were compiled from multiple published studies, except for the suitable habitat area, which was taken from the global habitat model of Fragkopoulou et al. (2025). The coral accumulation rate dataset comprises 43 values from ten studies. For the mound-density-based approach, seven values from six studies were compiled, whereas the area-based approach includes ten values from seven studies. The live coral cover dataset consists of 29 observations from eleven studies, while the proportion of exposed mounds was derived from four observations reported in four studies. A complete compilation of all input

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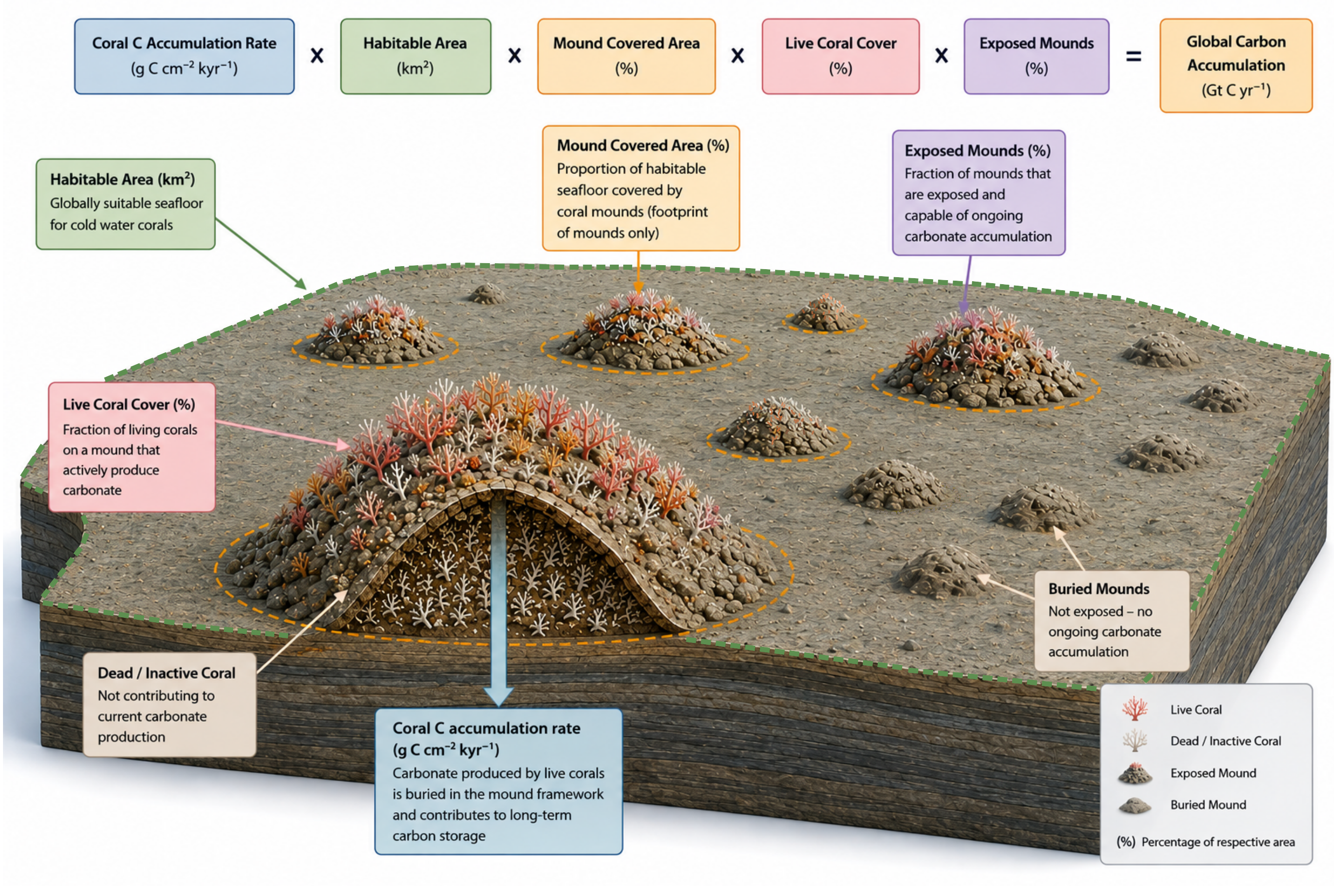

Figure 1. Visualization of the input parameters of the global carbon accumulation including coral C accumulation rate, suitable habitat area, mound covered area, fraction of live coral cover and exposed mounds.

data is provided in Tables 1, 3, 2, 4, and 5.

Following Dorschel et al. (2007), the carbonate content of CWC mound provinces can generally be considered as the sum of coral-derived carbonate and hemipelagic background carbonate. However, the methods used to quantify these components differ among studies. Here, the approach of Dorschel et al. (2007) was adapted to estimate global carbon accumulation by considering only the coral-derived carbonate accumulation. Background sedimentation was not included because it represents part of the general pelagic sedimentation associated with marine primary production rather than carbonate production by CWCs.

Most studies quantified coral-derived carbonate accumulation by combining carbonate measurements from sediment cores with digital image analyses. This approach distinguishes between coral-derived carbonate, consisting primarily of aragonite produced and subsequently redistributed through coral bioerosion, and hemipelagic background carbonate, which is dominated

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by calcite derived from coccolithophores and planktonic foraminifera deposited between the coral framework (Titschack et al. (2009)). Alternative approaches have also been applied. Oevelen et al. (2009) estimated carbonate accumulation using linear inverse modelling constrained by literature data together with biomass and respiration data. Cathalot et al. (2015) derived accumulation rates using the non-invasive aquatic Eddy Correlation technique. Lindberg and Mienert (2005) estimated carbonate production of Norwegian reefs based on previously published production rates. Hebbeln et al. (2019) combined multibeam bathymetry and GIS analyses with accumulation estimates from Dorschel et al. (2007), Titschack et al. (2015), Titschack et al. (2016), and Hamilton (1976). In contrast, Tamborrino et al. (2022) estimated carbonate accumulation from morphometric analyses of mound volumes.

To upscale the coral accumulation rates to the global scale, the area occupied by coral mounds first had to be estimated. For this purpose, the global habitat suitability model of Fragkopoulou et al. (2025) was used. Based on stacked species distribution models covering a depth range from 0 to 7377 m, they estimated a present-day suitable habitat area of approximately 179.9 million km^2 with a mean water depth of 456 m, thus centering in the mesopelagic zone. Predicted species richness varies considerably among ocean basins (Fig. 2), with the highest richness occurring in the western Atlantic between French Guiana and North Carolina, USA, and in the western Pacific between New Zealand and Japan. Moderate species richness was predicted for the North Atlantic Ridge, the northeastern Atlantic including the Mediterranean Sea, and eastern Africa, whereas most deep offshore regions were characterized by comparatively low species richness. Species richness, however was not explicitly considered in the present analysis. Instead, we assumed that all suitable habitats include at least one of the dominant framework-building coral species, *Madrepora oculata* or *Desmophyllum pertusum* (formerly *Lophelia pertusa*), which are primarily responsible for carbonate accumulation in CWC reef ecosystems.

To estimate the proportion of the predicted suitable habitat that is covered by coral ecosystems, two independent approaches were applied.

The first approach was based on reported coral mound densities and the mound footprint area. For this purpose, data from six studies were compiled (Paull et al. (2000), Huvenne et al. (2003), Hebbeln et al. (2019), Iacono et al. (2014), Savini et al. (2014), Tamborrino et al. (2022)).

The second approach estimated coral mound cover directly as the fraction of the surveyed seafloor occupied by coral mounds. Data from seven studies were compiled (Hebbeln et al. (2019), Paull et al. (2000), Savini et al. (2014), Sowers et al. (2024), De Clippele et al. (2021a), Di Giovanna et al. (2025), Tamborrino et al. (2022)). Most estimates were derived from ship-based geophysical surveys, whereas Di Giovanna et al. (2025) estimated coral mound distribution using a habitat suitability model.

Coral mounds consist of living and dead coral framework, bioeroded coral rubble, and accumulated sediments. Because only living corals actively precipitate calcium carbonate and therefore contribute to ongoing carbon accumulation, only the fraction of live coral cover needs to be considered in the global accumulation estimate. Data on live coral cover in CWC mound provinces were compiled from eleven studies (Sowers et al. (2024), De Clippele et al. (2017), De Clippele et al. (2021b), De Oliveira et al. (2022), Conti et al. (2019), Roberts et al. (2003), Lim et al. (2018), Edinger et al. (2025), Maier et al. (2021), Vad et al. (2017), Cordes et al. (2023)).These studies quantified live coral cover using Structure-from-Motion photogrammetry

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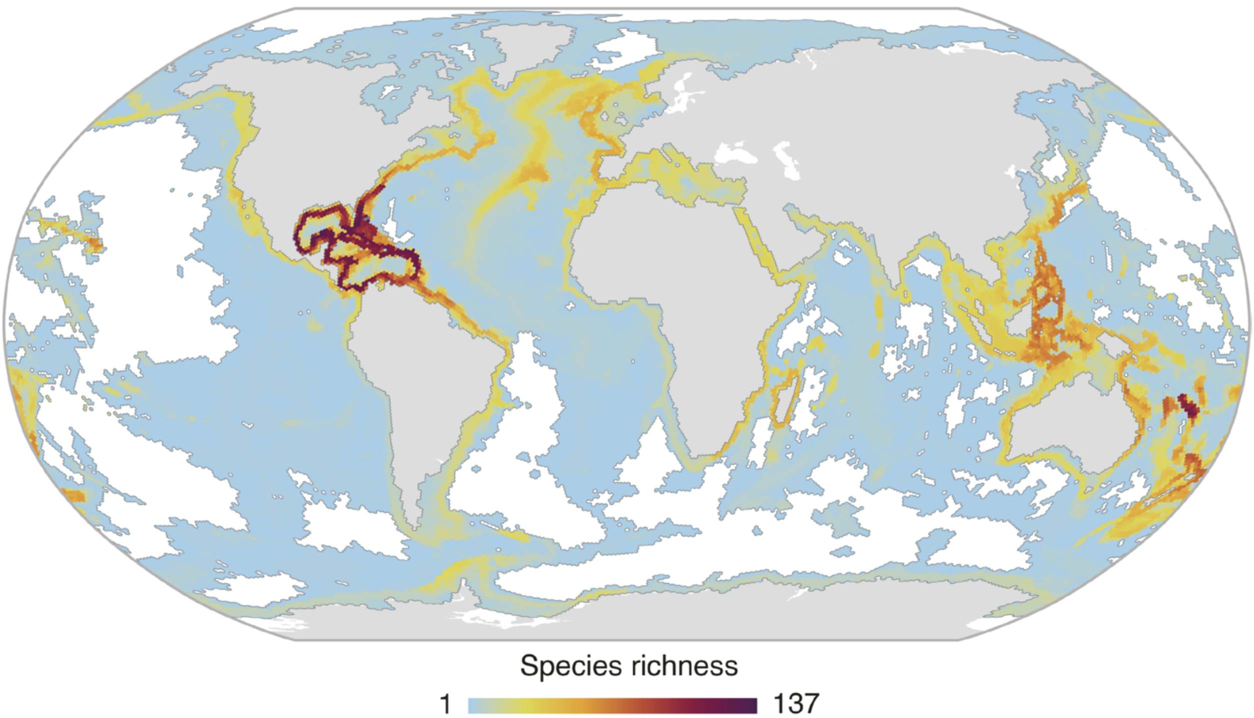

Figure 2. Distribution of the present-day CWC species richness, including 741 species. Figure taken from Fragkopoulou et al. (2025).

derived from Remotely Operated Vehicle (ROV) imagery and bathymetric data acquired by multibeam sonar surveys.

During the late stages of their development, coral mounds may become progressively buried by sediment and eventually incorporated into the surrounding seafloor. Completely buried mounds, such as those described by Huvenne et al. (2003) and De Mol et al. (2002), no longer support active coral growth and therefore do not contribute to contemporary carbon accumulation. Consequently, only exposed coral mounds were considered in the present analysis.
Coral mounds may also become partially buried depending on their position relative to the off-bank sediment depocenter, when coral growth and sedimentation rate are near equilibrium. In return, mound densities are high where coral growth rates are roughly equivalent to off-bank deposition rates. If both scenarios occur, an area of exposed mounds can be found adjacent to buried mounds (Correa et al. (2012)).
To estimate the proportion of exposed relative to buried coral mounds, data from four studies were compiled(Vandorpe et al. (2017), Steinmann et al. (2020), De Mol et al. (2002), De Mol et al. (2007)).

The uncertainty associated with the global carbon accumulation estimate was quantified using the Monte Carlo uncertainty propagation described below. For each parameter in 1, the median (50th percentile) together with the 5th and 95th percentiles

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was derived from the compiled literature data and used to define a continuous probability distribution. The carbon accumulation rate is represented by a lognormal distribution as the values are right-skewed distributed and strictly positive. Its parameters were calculated analytically from the 5th, 50th and 95th percentiles, with the median defining the location parameter and the distance between the 5th and 95th percentiles defining the spread of the distribution. The live coral cover, coral mound cover and proportion of exposed mounds were represented by beta distributions as these variables are expressed by fractions bound between 0 and 1. For each beta distribution, the two shape parameters were estimated by numerical optimization. The parameters were selected by minimizing the sum of squared differences between the 5th, 50th and 95th percentiles of the fitted beta distribution and the corresponding percentiles derived from the literature data. The resulting distributions therefore reproduce the central tendency and the observed uncertainty range of each input parameter. The global suitable habitat area of 179,905,947 km^2 was kept constant because it was taken directly taken from the global habitat model of Fragkopoulou et al. (2025) and no uncertainty range for this area was given. For the Monte Carlo propagation, 200,000 random realizations were generated for each uncertain input parameter. In each realization, one value was independently sampled from each fitted distribution and inserted into 1, resulting in one estimate of the global carbon accumulation. This procedure was performed separately for the area-based and mound-density-based estimates of coral mound cover. The resulting 200,000 global accumulation estimates for each approach were then used to derive the mean, median, 5th and 95th percentile, with the latter defining the propagated uncertainty range of the global estimate.

3 Results

3.1 Carbon accumulation rates

The summary statistics of the compiled coral carbon accumulation rates, including the mean, median, and the 5th and 95th percentiles, are presented in Table 1. Listed are the coral and background-sediment derived, as well as the total carbon accumulation rates and if from sediment cores available the age and aggradation rate.

Table 1: Compilation of published carbon accumulation rates

Reference	Core	Age (kyr BP)	Aggradation rate (cm kyr^{-1})	Accumulation rate (coral) (g C cm^{-2} kyr^{-1})	Accumulation rate (background sediment) (g C cm^{-2} kyr^{-1})	Accumulation rate (total) (g C cm^{-2} kyr^{-1})
Greiffenhagen et al. (2026)	GeoB16310-2	0–10	49.0	1.31 ± 0.5	4.01 ± 0.34	5.56 ± 0.37
Greiffenhagen et al. (2026)	GeoB16310-3	0–10	34.0	0.4 ± 0.2	2.72 ± 0.33	3.28 ± 0.28
Greiffenhagen et al. (2026)	GeoB16313-2	0–10	40.0	0.82 ± 0.23	3.4 ± 0.13	4.41 ± 0.2
Greiffenhagen et al. (2026)	GeoB16318-1	0–10	24.0	0.18 ± 0.1	2.14 ± 0.32	2.43 ± 0.26

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Reference	Core	Age (kyr BP)	Aggradation rate (cm kyr^{-1})	Accumulation rate (coral) (g C cm^{-2} kyr^{-1})	Accumulation rate (background sediment) (g C cm^{-2} kyr^{-1})	Accumulation rate (total) (g C cm^{-2} kyr^{-1})
Greiffenhagen et al. (2026)	GeoB16310-2	68–114	6.0	0.19 ± 0.05	0.61 ± 0.42	0.82 ± 0.05
Greiffenhagen et al. (2026)	GeoB16310-3	68–114	4.0	0.11 ± 0.04	0.42 ± 0.03	0.54 ± 0.02
Greiffenhagen et al. (2026)	GeoB16318-1	68–114	10.0	0.16 ± 0.11	1.0 ± 0.2	1.19 ± 0.23
Greiffenhagen et al. (2026)	GeoB16310-2	161–172	12.0	0.15 ± 0.09	1.3 ± 0.04	1.49 ± 0.05
Greiffenhagen et al. (2026)	GeoB16310-3	161–172	9.0	0.26 ± 0.01	1.01 ± 0.03	1.29 ± 0.01
Greiffenhagen et al. (2026)	GeoB16310-3	215–257	13.0	0.24 ± 0.11	1.32 ± 0.09	1.61 ± 0.08
Greiffenhagen et al. (2025)	GeoB18116-2	372–390	16.0	0.63	1.33	2.1
Greiffenhagen et al. (2025)	GeoB18116-2	340–367	53.0	2.52	3.81	6.7
Greiffenhagen et al. (2025)	GeoB18116-2	297–319	49.0	2.16	3.71	6.4
Greiffenhagen et al. (2025)	GeoB18116-2	220–285	11.0	0.63	0.63	1.3
Greiffenhagen et al. (2025)	GeoB18116-2	201–208	115.0	6.33	7.44	14.7
Greiffenhagen et al. (2025)	GeoB18116-2	108–115	147.0	4.15	8.74	13.6
Greiffenhagen et al. (2025)	GeoB13729-1	9–12	135.0	7.38	5.77	14.1
Edinger et al. (2025)	BobECO CS01	0.051–0.627	104.6	1.78		
Edinger et al. (2025)	BobECO CS01	0.627–2.019	47.6	0.49		
Titschack et al. (2009)	U1317E	1600–2700	15.0	0.84	1.24	2.076
Titschack et al. (2009)	U1317E	0–800	5.0	0.23	0.46	0.68
Titschack et al. (2015)	POS325-472	1.615–9.869	68.8	4.33	0.624	4.92
Titschack et al. (2015)	POS325-359	0.799–4.089	138.3	9.84	2.46	12.36
Titschack et al. (2015)	PS70-35-2	1.505–2.626	35.8	2.35	0.31	2.64
Titschack et al. (2015)	PS70-35-3	0.619–2.56	69.5	6.40	1.15	7.52
Titschack et al. (2016)	GeoB13729-1	9.811–10.56	197.5	16.02	6.70	22.7
Titschack et al. (2016)	GeoB13729-1	10.56–10.98	530.3	32.18	15.3	47.48
Titschack et al. (2016)	GeoB13729-1	10.89–11-21	189.3	10.1	5.46	15.55

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Reference	Core	Age (kyr BP)	Aggradation rate (cm kyr^{-1})	Accumulation rate (coral) (g C cm^{-2} kyr^{-1})	Accumulation rate (background sediment) (g C cm^{-2} kyr^{-1})	Accumulation rate (total) (g C cm^{-2} kyr^{-1})
Titschack et al. (2016)	GeoB11135-2	1.10–6.00	111.7	13.16	1.70	14.87
Titschack et al. (2016)	GeoB11185-1	0–5.65	9.6	0.72	0.252	0.98
Titschack et al. (2016)	GeoB11185-1	5.65–9.54	5.1	0.17	0.18	0.34
Titschack et al. (2016)	GeoB11185-1	9.54–14.69	89.3	5.32	2.11	7.43
Titschack et al. (2016)	GeoB11185-1	14.69–	6.7	0.19	0.20	0.4
Titschack et al. (2016)	GeoB11186-1	1.53–6.46	52.7	2.45	1.55	4.0
Titschack et al. (2016)	GeoB11186-1	6.46–9.82	5.7	0.22	0.18	0.4
Titschack et al. (2016)	GeoB11186-1	9.82–12.80	52.8	3.52	1.66	5.17
Titschack et al. (2016)	GeoB11186-1	12.80–	6.0	0.072	0.19	0.26
Dorschel et al. (2007)	GeoB6728-1	0–178	0.47–1.41	0.002		0.033
Dorschel et al. (2007)	GeoB6729-1	0–170	0.43–0.89	0.002		0.034
Dorschel et al. (2007)	GeoB6730-1	0–7.8	1.52–6.79	0.047		0.62
Hebbeln et al. (2019)			15.0			0.96
Oevelen et al. (2009)				2.94		32.7
Cathalot et al. (2015)						40.86 ± 3.32
Lindberg and Mienert (2005)				0.65–2.26		
Tamborrino et al. (2022)				0.114		
			Mean:	3.32	2.59	7.30
			Median:	0.82	1.32	2.55
			5th percentile:	0.05	0.19	0.12
			95th percentile:	12.86	7.75	32.20

The compiled dataset yields a mean carbon accumulation rate of 3.32 g C cm^{-2} kyr^{-1} and a median of 0.82 g C cm^{-2} kyr^{-1}. As the distribution of the carbon accumulation rates is right-skewed (Fig. 3), the median was selected as the representative measure for the subsequent estimation of global carbon accumulation. The 5th and 95th percentiles are 0.05 g C cm^{-2} kyr^{-1} and 12.86 g C cm^{-2} kyr^{-1}, respectively.

The accumulation rates were compiled from CWC reefs distributed in several geographic regions. The Irish shelf margin is the best represented region, contributing data from three independent studies. Two studies each investigated reefs in the Mediterranean Sea and on the Norwegian shelf, while one study each reported accumulation rates from the Gulf of Mexico, the French Atlantic margin, and the Namibian shelf. The Namibian shelf represents the only study area located in the Southern Hemisphere.

3.2 Coral mound covered area

The summary statistics for the mound-density-based estimate of coral mound cover are presented in Table 2.

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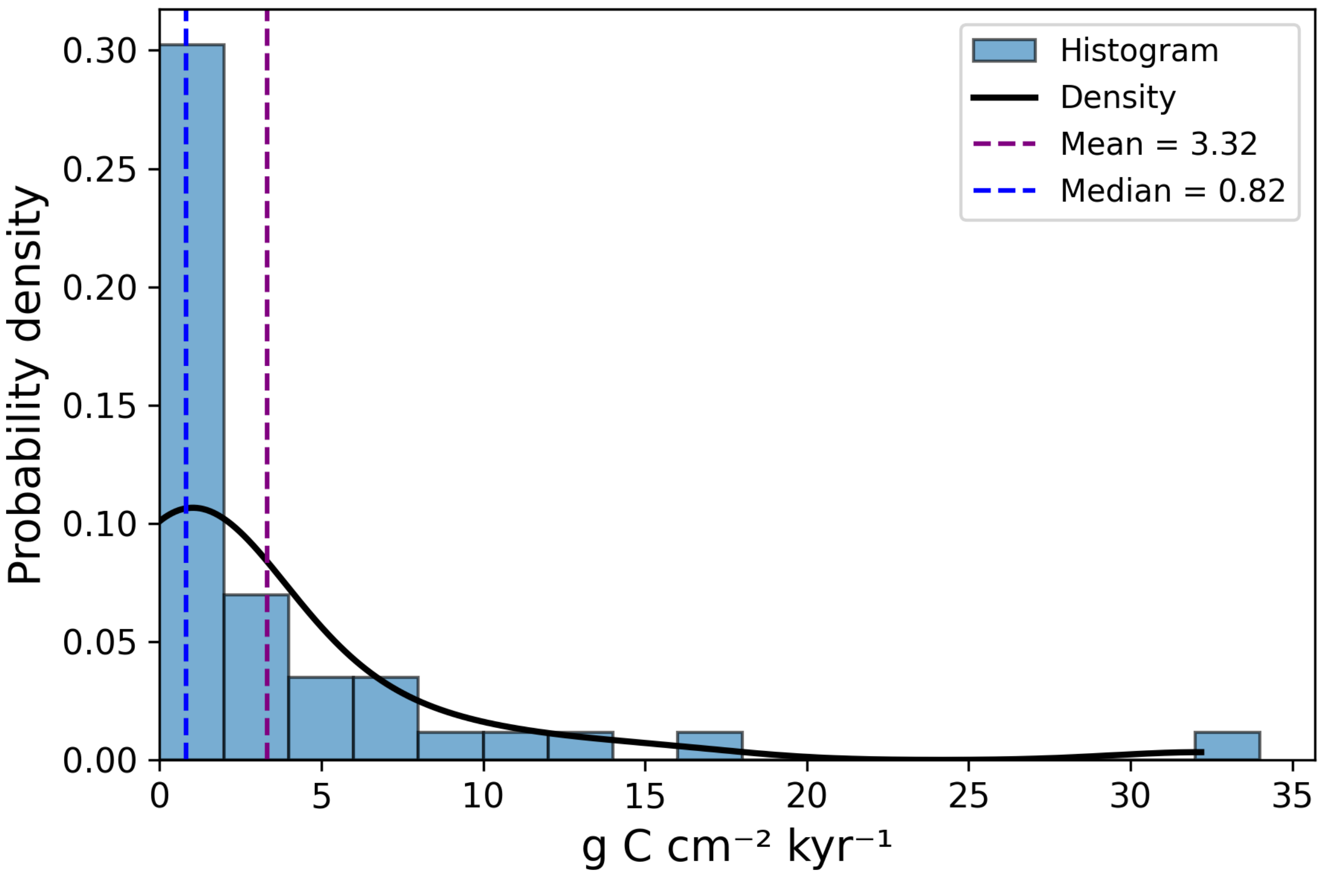

Figure 3. Distribution of the coral carbon accumulation rates. Shown is the probability density (black line), the mean (dashed violet) and the median (dashed blue). As a bin size 2 g C cm^{-2} kyr^{-1} was chosen.

Table 2: Mound-density-based percentage of coral mound covered area

Reference	mound density (km^2)	mean footprint area (m^2)	Mound covered area (%)
Paull et al. (2000)	0.3	10000	0.3
Huvenne et al. (2003)	0.93	51000	4.74
Hebbeln et al. (2019)	2.4	14500	3.84
Iacono et al. (2014)	5	34000	17.0
Savini et al. (2014)	1	35000	3.5
Tamborrino et al. (2022)	10.1	4085.9	4.13
Tamborrino et al. (2022)	8.9	3914.3	3.48
		Mean:	5.23
		Median:	3.5

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Reference	mound density (km^2)	mean footprint area (m^2)	Mound covered area (%)
		5th percentile:	1.25
		95th percentile:	13.32

The compiled dataset yields a mound-density-based mean area cover of 5.23% and a median of 3.5%, with the 5th and 95th percentile amounting to 1.25% and 13.32%, respectively. As for the carbon accumulation rates, the median was used in the subsequent calculation of global carbon accumulation.

The mound density data compiled originate from study areas located along the Irish shelf margin, in the Alboran Sea, along the Moroccan Atlantic margin, in the Ionian Sea, on the Namibian shelf, and on the Florida–Hatteras slope. The Namibian shelf is the only study area located in the Southern Hemisphere.

The summary statistics for the area-based estimate of coral mound cover are presented in Table 3.

Table 3: Area-based percentage of coral mound covered area

Reference	Studied area (km^2)	Mound covered area (km^2)	Mound covered area (%)
Hebbeln et al. (2019)	1440	48.5	3.3
Paull et al. (2000)	120000	400	0.3
Savini et al. (2014)	2000	68	3.4
Sowers et al. (2024)	133581	26064	19.51
De Clippele et al. (2021a)	1.7	0.309	18.18
Di Giovanna et al. (2025)			0.53
Di Giovanna et al. (2025)			0.047
Di Giovanna et al. (2025)			0.07
Tamborrino et al. (2022)	95	5.7	6.0
Tamborrino et al. (2022)	100	2.9	2.9
		Mean:	5.42
		Median:	3.1
		5th percentile:	0.06
		95th percentile:	18.91

The compiled dataset yields an area-based mean mound cover of 5.42% and a median of 3.1%, with the 5th and 95th percentile of 0.06% and 18.91%, respectively. Because the distribution is strongly asymmetric, the median was again used in the subsequent calculation of global carbon accumulation.

The area-based estimates were derived from reef systems located off the southwestern coast of Australia, the southeastern coast of the United States, along the Moroccan Atlantic margin, in the Ionian Sea, the Hebridean Sea, on the Namibian shelf, and on the Florida–Hatteras slope.

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3.3 Live coral cover

The summary statistics for the proportion of live coral cover are presented in Table 4.

Table 4: Percentage of living corals on a mound

Reference	Dead corals (%)	Live corals (%)
Sowers et al. (2024)	26.0	7.0
Sowers et al. (2024)	18.0	2.0
Sowers et al. (2024)	6.0	2.0
De Clippele et al. (2017)		6.0
De Clippele et al. (2021b)	45.0	3.0
De Oliveira et al. (2022)	4.0	4.0
Conti et al. (2019)	12.5	2.0
Roberts et al. (2003)	28.0	23.0
Lim et al. (2018)	31.61 ± 2.75	16.0 ± 1.42
Edinger et al. (2025)	5.25 ± 2.1	2.65 ± 0.72
Maier et al. (2021)	14.0 ± 11.0	8.0 ± 12.0
Vad et al. (2017)		14.0 ± 2.0
Vad et al. (2017)		15.0 ± 2.0
Vad et al. (2017)		22.0 ± 1.0
Vad et al. (2017)		20.0 ± 2.0
Vad et al. (2017)		27.0 ± 2.0
Vad et al. (2017)		12.0 ± 2.0
Vad et al. (2017)		22.0 ± 5.0
Vad et al. (2017)		17.0 ± 2.0
Vad et al. (2017)		11.0 ± 1.0
Vad et al. (2017)		16.0 ± 1.0
Vad et al. (2017)		19.0 ± 3.0
Vad et al. (2017)		16.0 ± 2.0
Vad et al. (2017)		10.0 ± 2.0
Vad et al. (2017)		22.0 ± 2.0
Vad et al. (2017)		13.0 ± 2.0
Vad et al. (2017)		18.0 ± 3.0
Vad et al. (2017)		17.0 ± 3.0
Vad et al. (2017)		18.0 ± 3.0
Cordes et al. (2023)		22.5 ± 1.7

Mean:	13.58
Median:	15.5
5th percentile:	2.0
95th percentile:	22.78

The compiled dataset yields a mean live coral cover of 13.27% and a median of 15.0%, with the 5th and 95th percentile of 2.0% and 22.6%, respectively. As the distribution is approximately symmetrical, the mean was used in the subsequent calculation of global carbon accumulation.

Most observations were obtained from reefs along the Irish shelf margin, which are represented by seven studies. Additional

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data were compiled from the northeastern Atlantic margin, the Hebridean Sea, and reef systems off the southeastern coast of the United States.

3.4 Exposed mounds

The summary statistics for the proportion of exposed coral mounds are presented in Table 5.

Table 5: Percentage of exposed mounds

Reference	fraction buried:exposed	Exposed mounds (%)
Vandorpe et al. (2017)	3.7	21.2
Steinmann et al. (2020)	0.4	71.43
De Mol et al. (2007)	0.36	71.44
De Mol et al. (2002)	0.67	60.0
	Mean:	56.52
	Median:	65.72
	5th percentile:	27.2
	95th percentile:	73.14

The compiled dataset yields a mean exposed mound fraction of 56.52% and a median of 65.72%, with the the 5th and 95th percentile of 27.2% and 73.14%, respectively. The median was used in the subsequent calculation of global carbon accumulation.
The compiled data on exposed mound fractions originate from reef systems located along the Irish shelf margin, the northern Argentine margin, and the southern Gulf of Cádiz.

3.5 Global carbon accumulation

Using the input variables described above and Eq. 1 , the global carbon accumulation of CWC ecosystems was estimated. The resulting mean, median, and the 5th and 95th percentiles for both the mound-density-based and area-based approaches are summarized in Table 6.

Table 6: Global carbon accumulation of cold-water corals

	Mean (Gt C yr^{-1})	Median (Gt C yr^{-1})	5th percentile (Gt C yr^{-1})	95th percentile (Gt C yr^{-1})
Area-based	0.023	0.0022	2×10^{-5}	0.086
Mound-density-based	0.021	0.003	8.7×10^{-5}	0.079

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4 Discussion

4.1 Methodological limitations and uncertainties

The calculated CWC accumulation values exhibit mean and median values that differ by approximately one order of magnitude, indicating an asymmetric and right-skewed distribution. Therefore, the median values are likely more representative of carbon accumulation than the mean values. This indicates that most Monte-Carlo simulations result in relatively low carbon accumulations, while only a small number of parameter combinations produce substantially higher values. Coral carbon accumulation rates follow a lognormal distribution and exert the strongest influence on the global accumulation estimates. This distribution likely contributes to the right-skewed nature of the global estimates, reflecting the presence of rare but highly productive reefs that account for exceptionally high accumulation values.
The uncertainty range of CWC accumulation spans several orders of magnitude; both the mound-density-based and area-based estimates cover approximately four orders of magnitude. This highlights the limited availability of representative measurements of the individual factors controlling the global accumulation and indicates that the estimates are highly sensitive to variations in the input parameters. The second-largest influence is attributed to mound cover, followed by live coral cover and exposure. Nearly all parameters exhibit sensitivity ranges exceeding their respective median values, emphasizing the substantial impact of parameter uncertainties on the derived accumulation estimates.

Considering all represented locations in the compiled studies, a clear geographic bias can be identified. All living coral cover percentages were derived from reefs located in the Northern Hemisphere. Accumulation rates, mound densities, and mound exposure estimates include only a single study with data derived from the Southern Hemisphere. In contrast, the area percentage includes multiple values from Southern Hemisphere locations. No studies are available yet from the Pacific Ocean. Following the semi-closed oceanic basin of the Mediterranean Sea, the Irish shelf margin is the most strongly overrepresented region within the available dataset. Therefore, the regional environmental conditions of overrepresented study areas bias the global estimate, leading to a most likely overestimation, since these coral ecosystems are known today as the most active around the world. However, CWC habitats require specific environmental conditions for development, and suitable substrates to occur, which are distributed globally. Thus, applying topographic boundary conditions (seamounts, offshore banks, and canyons) provide a basis for attempting to upscale local observations to the global scale. Overall, the predominance of Northern Hemisphere study sites is considered a geographic sampling bias, which we estimate has a small impact compared to the inherent variability and uncertainty in the parameters. Individual values derived from the same region exhibit substantial variability. Among the study areas used for accumulation rate estimates, three are located at the Irish shelf margin; however, Dorschel et al. (2007) and Oevelen et al. (2009) reported accumulation rates differing by three orders of magnitude despite being derived from this region. Similarly, Titschack et al. (2016) calculated accumulation rates varying by one order of magnitude from the same sediment core. These observations confirm that CWC accumulation rates and thus aggradation rates exhibit considerable local variability and may vary over timescales encompassing glacial–interglacial cycles (Frank et al. (2009), Wienberg and Titschack (2017), Wefing et al. (2017)).

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The lowest cover percentage derived from mound density estimates was reported by Paull et al. (2000) from data collected offshore Florida, southwestern USA, whereas the highest value was obtained by Iacono et al. (2014) in the Alboran Sea. The area-derived estimate provided by Sowers et al. (2024) for the Blake Plateau, offshore Florida, is two orders of magnitude higher than the percentage reported by Paull et al. (2000). This further demonstrates the substantial variability in coral mound coverage estimates. For living coral cover, seven out of eleven studies were based on data collected at the Irish shelf margin. Even within this region, reported values span several orders of magnitude, highlighting considerable spatial variability.
Due to the limited number of studies of mound exposure, robust conclusions regarding regional or global differences in mound exposure remain challenging. This parameter may represent another potential source of uncertainty, as CWC mounds can occur under contrasting exposure conditions, ranging from completely buried structures (e.g., Huvenne et al. (2003); De Mol et al. (2002)) to fully exposed reefs. Only four studies investigated areas where both occur. Incorporating the relative proportion of buried versus exposed reef sites, together with their regional distribution, could improve future estimates and reduce associated uncertainties.

The compiled core-based accumulation rates include records spanning from 0 to 390 ka, with Titschack et al. (2009) extending the temporal coverage back to the Late Pliocene (<2.7 Ma) (see Table 1). Most records include the Holocene period (<11.7 kyr), during which the full range of accumulation rate variability is represented, including the highest observed values. However, the lowest accumulation rate, reported by Dorschel et al. (2007), also partly falls within the Holocene interval. The comparatively lower accumulation rates are associated with intervals corresponding to the Last Glacial Maximum (LGM; 19–26.5 kyr BP). Lastly, two regions in the southern Atlantic, off Angola and Brasil host active CWC ecosystems largely independent of climate. Nevertheless, regions such as the Gulf of Cadiz, Mauretenian are known to substantially increase CWC activity and mound aggradation during colder climate periods, whereas other regions such as in the Norwegian Sea and Rockall Trough cease coral ecosystems. Known ranges of accumulation rates, are however similar in all regions for different times and suggest a strong coupling of individual coral colony growth and supply of sediments (Wienberg and Titschack (2017)).

At the temporal resolution available in the compiled dataset, the broad distribution of accumulation rates appears largely independent of age, suggesting that regional and local environmental conditions may exert a stronger control on the mound accumulation than temporal variations in climate state. But, the climate state is likely to influence the total available ecosystem space, with reefs retracting into subtropical regions during global cooling and expanding into the sub-polar oceans upon climate warming. More extensive datasets with higher temporal resolution are required to further elucidate the relationship of regional mound growth and sedimentation and the spatial influence through the background climate state. Overall, most accumulation rates were calculated over broad age intervals, limiting the ability to assign individual estimates to specific climatic periods, such as glacial or interglacial conditions. Consequently, it is not possible to determine whether global CWC accumulation is predominantly controlled by accumulation rates associated with particular climate states. Instead, the wide temporal distribution may indicate that the estimated global accumulation represents a range of climatic conditions rather than a specific climate regime. Furthermore, the compiled dataset likely encompasses different stages of mound development, as reported mound aggradation rates span from 0.47 (low coral density and colony growth) to 530 cm/kyr (nearly the vertical extension rate of a

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single colony), reflecting substantial variability in mound growth dynamics.

In summary, the high uncertainty of the global accumulation estimate results from the combination of several factors: the large variability among individual parameter estimates, the limited number of available studies, and the uneven geographic distribution of studied locations, particularly the strong representation of Northern Hemisphere sites. The large spread between individual values indicates that CWC accumulation is highly heterogeneous, controlled by a combination of local environmental conditions, habitat characteristics, and strong spatial and temporal variability. Additionally, the scarcity of long-term and high-resolution records and the absolute absence of long term monitoring restricts the ability to separate spatial variability from temporal trends or climate-related effects. The geographic bias further increases uncertainty of our carbon flux estimates because regional conditions cannot fully represent the global distribution of CWC habitats. Therefore, although the compiled estimates provide a first approximation of global CWC carbon accumulation, reducing uncertainty requires additional measurements from underrepresented regions, particularly the Southern Hemisphere and Pacific Ocean, as well as improved temporal and spatial constraints on accumulation processes. Integrating spatially distributed observations with higher-resolution chronological frameworks would enable a more robust assessment of the factors controlling global CWC carbon accumulation. Overall, a generalized biophysical model of the framework forming coral ecosystems describing the corals spatial and temporal evolution, as well as the physical mound accumulation additionally considering coral degradation and sedimentation, would help improve the feasibility to estimate global carbon fluxes based on punctuated regional observations.

4.2 Comparing the area-based and mound-density-based approaches

The two approaches yield median estimates within the same order of magnitude. The mound-density-based approach results in a median value approximately 1.4 times higher than that obtained from the area-based approach. The area-based scaling approach may either over- or underestimate the global extent of coral occurrence, depending on the representativeness of the underlying sparse observations. Surveys are typically conducted at known reef locations, where coral presence is expected, potentially resulting in an overestimation of coral cover fractions. When extrapolated globally, this sampling strategy may therefore lead to an overestimation of the coral-covered area. Conversely, if observations include larger areas without suitable coral habitat, the estimated coral cover may be underestimated.

The mound-density-based approach may provide a more direct representation of the spatial distribution of CWC habitats. However, buried mounds may be included in the estimates, and coral mound footprint areas exhibit substantial variability. For example, De Mol et al. (2002) documented a coral mound with a footprint area of 5.5 km^2, whereas De Clippele et al. (2017) reported footprint areas as small as 0.3 m^2. In many regions mounds occur as ridges or even as lineament of carbonate mounds driven by local bottom water dynamics and even tectonics (Ramos et al. (2023)). The slightly higher median estimate derived from the mound-density-based approach may further indicate that regions with locally high concentrations of coral mounds contribute disproportionately to the overall carbon accumulation.

Despite the conceptual differences between the two scaling approaches, both produce estimates of comparable magnitude, and their uncertainty ranges show substantial overlap. The large uncertainties primarily reflect the limited spatial coverage of

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available observations and the high sensitivity of the estimates to uncertainties in parameters controlling coral occurrence and coverage. Therefore, while both approaches provide independent estimates of global CWC accumulation, improved spatial constraints either through observations or simulation of coral distribution and mound characteristics are required to further reduce uncertainty.

4.3 Global context

For comparison, the global carbon accumulation associated with pelagic carbonate burial and tropical coral ecosystems is considered.

Pelagic calcium carbonate production represents a well-established component of the global carbon cycle and is commonly referred to as the carbonate pump. Although large quantities of calcium carbonate are produced in the surface ocean, most of this material is dissolved and recycled during sinking through the water column, particularly in the mesoplagical zone of remineralization. Only a small fraction of the exported carbonate reaches the seafloor and is ultimately buried in marine sediments (Cartapanis et al. (2018), Ziveri et al. (2023)). Current estimates of global pelagic calcium carbonate burial range from 0.1 to 0.3 Gt C yr^{-1} (see table 7).

Table 7: Global carbon accumulation through pelagic burial

Reference	Global carbon accumulation (Gt C yr^{-1})
Cartapanis et al. (2018)	0.1-0.3
Milliman et al. (1999)	0.132
Feely et al. (2004)	0.1-0.17
Catubig et al. (1998)	0.1033

In carbonate platform environments and warm-water reef ecosystems, benthic organisms represent the dominant calcium carbonate producers (Cartapanis et al. (2018)).

Tropical coral ecosystems constitute another important component of marine carbonate cycling, with global reef area estimates ranging from 284,300 km^2 (Freiwald et al. (2004)) to 345,000 km^2 (Vecsei (2004)). Estimates of global carbon accumulation by tropical corals span from 0.014 to 0.52 Gt C yr^{-1} (see table 8).

Table 8: Global carbon accumulation of tropical corals

Reference	Global carbon accumulation (Gt C yr^{-1})
Vecsei and Berger (2004)	0.0144-0.0492
Vecsei (2004)	0.078-0.1
Kinsey and Hopley (1991)	0.111
Milliman (1993)	0.11
Kleypas (1997)	0.1284
Jones et al. (2015)	0.132, 0.168, 0.3672, 0.5184

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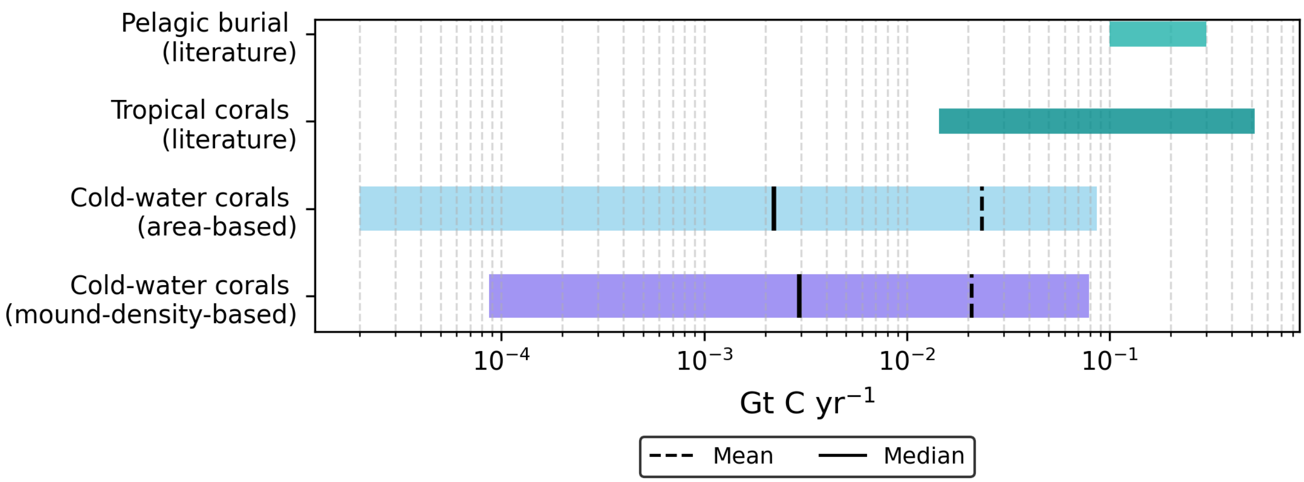

Figure 4. Global carbon accumulations through pelagic burial (0.1-0.3 Gt C yr^{-1}), tropical corals (0.014-0.52 Gt C yr^{-1}) and cold-water corals (area-based: 5%-95% = 2.0×10^{-5}-0.086, mean=0.023, median=0.0022 (Gt C yr^{-1}); mound-density-based: 5%-95% = 8.7×10^{-5}-0.079, mean=0.021, median=0.003 (Gt C yr^{-1}).

Figure 4 compares the global carbon accumulation estimates of pelagic burial and tropical coral ecosystems with the newly derived area-based and mound-density-based estimates for CWC systems.

The calculated CWC accumulation estimates fall within the lower range of these global carbonate sinks but nevertheless represent a measurable contribution to marine carbon cycling. Using the area-based approach, the global carbon accumulation ranges from 2.0×10^{-5} to 0.086 Gt C yr^{-1} (5–95%), with a median of 0.0022 Gt C yr^{-1}. The mound-density-based approach produces a 5–95% uncertaiinty range of 8.7×10^{-5}–0.079 Gt C yr^{-1}, a median of 0.003 Gt C yr^{-1}. These estimates indicate that CWC ecosystems represent a relatively small but non-negligible component of the global marine carbon cycle. CWC carbon accumulation is approximately two orders of magnitude lower than global pelagic carbonate burial and at least one order of magnitude lower than the estimated accumulation associated with tropical coral ecosystems. However, the upper range of CWC estimates overlaps with the lower estimates for tropical corals, which extend down to 0.014 Gt C yr^{-1}. This highlights that, despite their smaller global extent, CWC ecosystems contribute measurably to marine carbonate accumulation. In addition, benthic coral carbonate is also buried in a less structured and yet unknown amount by solitary coral species, adding a further yet unknown component to total flux balance.

In 2023, the global ocean represented a net carbon sink of 2.9 ± 0.4 Gt C yr^{-1} (Friedlingstein et al. (2024)). Relative to this global oceanic carbon uptake, the estimated CWC accumulation corresponds to only 0.76‰(area-based) or 1.0‰(mound-density-based). When compared directly with the fossil CO_2 emission flux of 9.6 ± 0.5 Gt C yr^{-1} released to the atmosphere (Friedlingstein et al. (2024)), CWC accumulation represents 0.23‰(area-based) or 0.31‰(mound-density-based). Therefore, while CWC ecosystems are unlikely to represent a significant contribution to the global oceanic carbon sink in terms of total magnitude, their contribution is still relevant within the context of marine carbonate production and in particular long-term carbon storage. Their significance may be particularly important at regional scales and over geological timescales, where persistent accumulation in coral mounds contributes to the sequestration of carbonate material. Hence, for shelf regions with presently active cold-water coral habitats, maintaining the health of these ecosystems contribute to the regional carbon sink adding further value in addition to stimulating biodiversity and fish reproduction.

During the precipitation of $CaCO_3$, CO_2 is released as a consequence of carbonate ion removal from seawater. Although marine calcification is often described as a carbon sink, it is important to consider that the removal of carbonate from seawater increases dissolved CO_2 concentrations and therefore partially counteracts carbon sequestration (Frankignoulle et al. (1994)). In freshwater systems, the assumption that one mole $CaCO_3$ is released per mole of deposited CO_2 is nearly valid. However, in seawater, this effect is reduced due to the buffering capacity of the marine carbonate system, resulting in an estimated release of approximately 0.6 mol CO_2 released per mol $CaCO_3$ (Ware et al. (1992)). This reduction is related to the homogeneous buffering effect of the carbonate–bicarbonate system. The ratio between CO_2 release and $CaCO_3$ precipitation, the $CO_2/CaCO_3$ flux ratio (Ψ), and can rise toward 1.0 as temperature falls and pCO_2 rises. In surface waters, Ψ values average approximately 0.66, while values below 1000 m depth reach approximately 0.85 (Smith and Mackenzie (2016)). Assuming an average flux ratio Ψ of 0.66 the CO_2 release associated with global CWC carbon accumulation can be estimated based on the amount of CO_2 generated per mole $CaCO_3$ precipitated. The resulting values are presented in Table 9. The global CWC accumulation estimate of 0.0022 Gt C yr^{-1} corresponds to a potential production of 0.0014 Gt C yr^{-1}. The accumulation of 0.003 Gt C yr^{-1} corresponds to a potential production of 0.002 Gt C yr^{-1}. Now the accumulation noting the carbon buried by CWC can be weighted against the carbon production through calcification.

By accounting for the CO_2 released during calcification, the net carbon removal associated with CWC accumulation can be estimated by balancing carbonate carbon burial against calcification-related CO_2 production. Subtracting the potential CO_2 release from the total carbon accumulation results in net values of approximately 0.0008 and 0.001 Gt C yr^{-1} for the area-based and mound-density-based approaches, respectively. These values represent the fraction of CWC-associated carbon accumulation that may effectively be removed from the active global carbon cycle.

Table 9: Global carbon accumulation of cold-water corals in source-sink-relation

	Carbon accumulation (Gt C yr^{-1})	Potential carbon production (Gt C yr^{-1})	Theoretical sink (Gt C yr^{-1})
Area-based	0.0022	0.0014	0.0008
Mound-density-based	0.003	0.002	0.001

Compared to other marine carbon reservoirs, CWC ecosystems likely represent a subordinate component of the global carbon cycle. Under increasing anthropogenic CO_2 emissions, CWCs are exposed to environmental stressors such as ocean acidification and ocean warming. However, the implications of these changes for global carbon cycling are likely more pronounced for tropical coral ecosystems and pelagic carbonate systems due to their substantially larger contributions to global carbonate production and carbon fluxes. Nevertheless, despite their relatively small contribution at the global scale, CWC ecosystems represent important components of regional carbon budgets, as demonstrated by Greiffenhagen et al. (2025) and Hebbeln et al.

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(2019). Since those occur at the shelf break and are often within exclusive economic zones and national waters, protecting and maintaining the carbon burial and ecosystem diversity may be important in national flux balances.

5 Conclusions

This study provides the first estimates of global CWC carbon accumulation based on the approach introduced by Dorschel et al. (2007), aiming to quantify the contribution of CWCs within the global carbon cycle. Local coral carbon accumulation rates were scaled to a global estimate using the global suitable habitat area determined by Fragkopoulou et al. (2025), combined with estimates of living coral cover and mound exposure. Two independent approaches, a mound-density-based approach and an area-based approach, were evaluated using Monte-Carlo uncertainty propagation. The median global carbon accumulation was estimated at 0.0022 Gt C yr^{-1}, 5%-95% = 2.0×10^{-5}-0.086 (area-based) and 0.003 Gt C yr^{-1}, 5%-95% = 8.7×10^{-5}-0.079 (mound-density-based).

The estimates span approximately four orders of magnitude, reflecting the substantial uncertainty associated with global CWC accumulation. The difference of approximately one order of magnitude between means and medians further indicates an asymmetric, right-skewed distribution dominated by a limited number of high accumulation scenarios.

All input parameters exhibit considerable sensitivity, emphasizing the need for improved constraints on the controlling factors. Currently, only a limited number of studies provide estimates of local accumulation rates, mound density, coral-covered area, living coral percentage, and mound exposure. Although CWCs are distributed globally, substantial knowledge gaps remain regarding their spatial distribution and environmental controls. Available datasets are strongly biased toward the Northern Hemisphere and, in some cases, represent only individual regions. Furthermore, while suitable CWC habitats occur throughout the global ocean, only approximately 28.7% of the seafloor has currently been mapped (GEBCO Compilation Group (2024)). Consequently, reducing the uncertainty of global CWC carbon accumulation requires substantial improvements in habitat mapping, spatial coverage, and regional observations.

Compared with global carbon accumulation estimates from tropical coral ecosystems and pelagic carbonate burial, CWC accumulation occurs within a lower range, differing by approximately one to two orders of magnitude. Although CWCs may contribute significantly to regional and in particular national carbon budgets, their contribution to the global carbon cycle is comparatively limited. Relative to the global oceanic net CO_2 uptake of 2.9 ± 0.4 Gt C yr^{-1}, the estimated CWC accumulation corresponds to only 0.76‰(area-based approach) or 0.1‰(mound-density-based approach) of the annually absorbed carbon.

As atmospheric CO_2 concentrations continue to increase, understanding the capacity and vulnerability of marine carbon reservoirs remains essential for predicting future changes in the global carbon cycle. Climate change affects ocean conditions on decadal and shorter timescales, exposing CWC ecosystems to rapidly changing environmental conditions. However, the consequences of these changes for the global carbon cycle are expected to be considerably smaller for CWCs than for tropical coral ecosystems and pelagic carbonate systems due to their comparatively lower contribution to global carbon fluxes. Nevertheless, CWCs remain relevant as long-lived carbonate structures that contribute to regional carbon storage in the mesopelagical zone and provide valuable insights into marine carbon cycling over geological timescales.

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Code availability. All python code is available upon request to the corresponding author.

Data availability. Data for this study are available upon request to the corresponding author.

Author contributions. ATS: data compilation, Monte-Carlo-simulation, interpretation, manuscript writing, conceptualization NF: supervision, manuscript writing, conceptualization

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