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Early and Heterogeneous Coral Bleaching Across the Eastern Tropical Pacific During the Fourth Global Coral Bleaching Event

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Abstract

Mass coral bleaching is commonly associated with basin-scale heat stress, but its impacts often emerge as spatially uneven mosaics shaped by local oceanography, thermal history, and coral assemblage composition. Here, we compiled 334 opportunistic field observations of coral conditions from 97 sites in six countries of the Eastern Tropical Pacific (ETP), collected between January 2023 and October 2024 through a coordinated regional reporting effort, to document the spatial and temporal expression and taxonomic composition of bleaching during the Fourth Global Coral Bleaching Event. These records provide a regional chronology of observed bleaching, color alteration, and mortality, revealing differences across areas in the timing, duration, and reported condition of bleaching observations. Bleaching observations in the region were concentrated in the second half of 2023, with reports of severe bleaching and mortality mainly in México, El Salvador, Panamá, and Colombia. In Ecuador (Galápagos), bleaching observations extended through 2024 and were dominated by color alteration and partial bleaching rather than widespread mortality. Records were concentrated in the dominant reef-building genera *Pocillopora*, *Porites*, and *Pavona*, although the number and composition of records differed among countries. These observations describe a prolonged and spatially heterogeneous biological response to regional heat stress across the ETP from 2023 to 2024. Our results also emphasize the value of coordinated regional reports for detecting bleaching onset, documenting temporal patterns, and identifying taxa and areas.

INTRODUCTION

Coral reef ecosystems entered the present era of climate warming after centuries of exploitation, coastal development, and other local disturbances had already altered their structure and function (Pandolfi et al. 2003). Since the mid-20th century, global coral cover has declined by approximately 50%, with associated losses in biodiversity, ecological processes, and ecosystem services (Eddy et al. 2021). Recurrent mass bleaching has become one of the main pathways through which ocean warming accelerates this decline (Gutierrez et al. 2024). Evidence from the Pacific, Caribbean, and Great Barrier Reef shows that repeated heat stress can reduce structural complexity, shift coral assemblages, and reorganize reef-associated communities across years to decades (Barkley et al. 2018; Stuart-Smith et al. 2018; Magel et al. 2019; Muñiz-Castillo et al. 2019; Gutierrez et al. 2024).

Coral bleaching converts thermal exposure into ecological change through linked physiological, demographic, and structural processes (Brown 1997; Glynn et al. 2018). At the colony scale, thermal stress can disrupt the association between corals and their Symbiodiniaceae, resulting in coral bleaching. This disruption reduces autotrophic energy acquisition and increases the probability of partial or whole-colony mortality when stress is prolonged (Brown 1997; Hughes et al. 2017). At the reef scale, bleaching-associated mortality can reduce live coral cover, shift species composition, simplify habitat structure, and alter the balance between reef accretion, bioerosion, and algal dominance (Stuart-Smith et al. 2018; Magel et al. 2019). Consequently, the ecological outcome of a bleaching event depends on the severity and trajectory of the response at the colony level, which are shaped by the magnitude and

duration of thermal stress, local anthropogenic pressures, coral taxonomy, and the capacity of colonies to recover or progress from paling and partial bleaching to mortality (Brown 1997).

In the Eastern Tropical Pacific (ETP), coral bleaching is strongly influenced by the El Niño-Southern Oscillation (ENSO), the dominant coupled ocean-atmosphere mode of interannual climate variability in the tropical Pacific (Clarke 2014; Glynn et al. 2017). ENSO alternates between warm El Niño phases, when weakened trade winds and changes in thermocline structure elevate sea temperatures and reduce upwelling, and cool La Niña phases, when strengthened trade winds and shoaling thermoclines can intensify the intrusion of cold, nutrient-rich waters into shallow reef habitats (Clarke 2014; Fiedler and Lavín 2017; Glynn et al. 2017). Both phases can affect coral physiology, particularly when thermal stress is compounded by changes in nutrient availability and water quality, potentially exceeding corals' capacity for acclimatization (Harborne et al. 2017; Nalley et al. 2023). During the 1982–1983 El Niño, severe coral bleaching and mortality occurred in Panamá, the Galápagos Islands, and Costa Rica, with bleaching affecting up to 83% of live coral cover. In the Gulf of Chiriquí in Panamá, *Millepora* spp. suffered almost complete mortality, and several reef-building coral species populations declined. In contrast, impacts in the Mexican Pacific were either limited or not quantitatively assessed (Glynn 1983; Glynn 1984; Glynn et al. 1988; Cortés et al. 1984; Reyes-Bonilla 2003). The 1997–1998 event also varied geographically, with bleaching reported across México, Costa Rica, Panamá, Colombia, and Ecuador, and strong impacts in the Gulf of Chiriquí and the Galápagos Islands, and comparatively limited effects in the Gulf of Panamá (Glynn et al. 2001; Vargas-Ángel et al. 2001; Reyes-Bonilla et al. 2002; Spillman et al. 2011). During the 2015–2016 ENSO, live coral cover declined by 50–75% along the Pacific coast of Costa Rica and Cocos Island, while central Mexican Pacific reefs showed contrasting outcomes ranging from temporary coral-cover losses and recovery to sustained mortality and macroalgal overgrowth (Alvarado et al. 2020; Cruz-García et al. 2020; Nava et al. 2021). The ETP record therefore shows that ENSO-related bleaching differs among localities in onset, duration, severity, and recovery, reflecting the interaction between regional climate forcing and local reef conditions (Zapata et al. 2026). This historical heterogeneity highlights the importance of examining whether contemporary regional-scale heat stress produces synchronous biological responses across the ETP or spatially distinct trajectories among reef systems.

The 2023–2024 marine heatwave provided an opportunity to examine how bleaching unfolded across this historically heterogeneous region during the Fourth Global Coral Bleaching Event. Although the global event was formally declared in 2024, bleaching observations from the ETP began during 2023, preceding global recognition of the event and in some locations, the establishment of the 2023 El Niño conditions (Reimer et al. 2024; López-Pérez et al. 2024; Nava et al. 2025). Here, we compiled opportunistic reports of coral bleaching across the ETP to document its timing, duration, spatial extent, and taxonomic composition. Our objective was to map where and when bleaching was documented across the ETP and identify which coral species were affected during the Fourth Global Coral Bleaching Event.

MATERIALS AND METHODS

Study area

The Eastern Tropical Pacific (ETP) extends from the Gulf of California to Ecuador and includes continental shelf habitats, four oceanic islands (Revillagigedo, Cocos, Malpelo, and the Galápagos Islands), and an atoll (Clipperton) (Glynn et al. 2017; Reyes-Bonilla et al. 2021). Regional assessments estimate approximately 593 km² of different types of coral reefs in the ETP, equivalent to ~ 0.2% of the world's coral-reef area, distributed across nine countries (Zapata et al. 2026). While a separate assessment based on a more restrictive coral-reef category estimated approximately 139 km² for the region, corresponding to ~ 0.04% of the global coral-reef extent (Arriaga-Madrigal et al. 2026). Coral diversity is relatively low, with local assemblages commonly dominated by a restricted set of zooxanthellate scleractinian genera, including *Pocillopora*, *Porites*, *Pavona*, *Gardineroseris*, and *Psammocora* (Cortés et al. 2017; Glynn et al. 2017; Reyes-Bonilla et al. 2021). Reef development is spatially discontinuous and geomorphologically limited, occurring as small fringing reefs, patch reefs, coral communities on basaltic or terrigenous rocky substrata, and low-relief carbonate frameworks rather than extensive reef platforms with zonation (Glynn 2017; Glynn et al. 2017; Toth et al. 2017). Oceanographic conditions across the study region include warm, low-salinity surface waters overlying a strong shallow thermocline, as well as oxygen-poor subsurface waters, equatorial divergence, wind-driven circulation, and localized coastal upwelling (Fiedler and Lavín 2017). Seasonal upwelling in the gulfs of Tehuantepec (México), Papagayo (Costa Rica) and Panamá introduces cooler, nutrient-rich, CO_2-enriched and sometimes low-pH or hypoxic waters into shallow reef habitats (Stuhldreier et al. 2015). In contrast, northern Mexican sites experience strong seasonal thermal ranges, whereas the Galápagos Islands are influenced by interactions among the South Equatorial Current, the Equatorial Undercurrent, the Peru-Humboldt system and seasonal warm-water incursions (Fiedler and Lavín 2017; Glynn 2017; Alvarado et al. 2017; Manzello et al. 2017; Glynn et al. 2018).

Coral bleaching records

Given the global extent of the 2023–2024 bleaching event, we compiled 334 opportunistic field records of coral condition across 97 sites in the ETP between January 2023 and October 2024 through a rapid regional reporting effort coordinated by members of the ETP Regional Node of the Global Coral Reef Monitoring Network. Each record represents a field observation made at a specific site and date, documenting the coral taxon observed and its condition, including bleaching severity or mortality when present. We collected records during ongoing field activities or received them from established local collaborator networks. Because survey methods, sampling effort, survey timing, and reporting frequency were not standardized across sites or countries, we used the resulting dataset only to characterize the timing, spatial distribution, and taxonomic composition of reported bleaching observations, not to estimate or quantitatively compare bleaching prevalence among countries. It included 34 coral reefs, 41 coral communities, and 22 rocky reefs, with observations recorded at depths ranging from 2.0 to 20.6 m. Each report was entered into an online shared database and curated to retain the observer, reporting contact, country, locality, site, date, geographic coordinates, habitat type, depth, *in situ* temperature at the

time of the bleaching record (when available), affected coral taxon, coral condition, bleaching severity, and estimated extent of bleaching. Each record represents a coral-condition observation for a given taxon at a specific site and date. However, the original observation scale was not consistently reported and could refer to a single colony, several colonies, or a broader site assessment. Therefore, we use site only as the observation's geographic location and do not interpret individual records as standardized estimates of bleaching prevalence at the colony or reef scale. Coral condition was classified into seven categories: healthy coral, tissue discoloration, bleaching of 1–25%, bleaching 26–50%, bleaching 51–75%, bleaching 76–100%, and recently dead coral, which was recorded when colonies exhibited a denuded white skeleton with no tissue and no visible algal colonization. We did not classify color changes not consistent with loss of pigmentation (e.g., pink, blue, or purple pigmentation responses, disease lesions, sediment cover, or algal overgrowth) as tissue discoloration or bleaching. We did not attribute old mortality, characterized by eroded corallites or colonization by filamentous algae, macroalgae, crustose coralline algae, or sessile invertebrates, to the 2023–2024 event. Because taxonomic resolution varied across reports, we conducted biological summaries primarily at the genus level.

Sea surface temperature and thermal-stress characterization

We characterized thermal conditions associated with bleaching observations using monthly mean sea surface temperature (SST, °C) from the NOAA Coral Reef Watch CoralTemp v3.1 product, accessed through NOAA ERDDAP. CoralTemp provides a gap-free, internally consistent 5-km SST record from 1985 to the present and forms the SST basis of NOAA Coral Reef Watch bleaching heat-stress products (Liu et al. 2014; Skirving et al. 2020). Bleaching records provided the observation month, year, country, and geographic coordinates for each report. We extracted monthly SST rasters for the full 2023–2024 observation period to describe the regional thermal context across the ETP (Supplementary Fig. 1).

We defined the spatial domain using Marine Ecoregions of the World (Spalding et al. 2007). We cropped and masked monthly NOAA SST rasters to this regional extent, then plotted them with a common color scale to allow direct comparison across months and years. We overlaid bleaching-report locations on the corresponding monthly SST layers, and arranged monthly panels by year to visualize seasonal and interannual variations in thermal conditions during the bleaching event (Supplementary Fig. 1).

We generated country-level thermal summaries by matching each observation coordinate to the nearest NOAA CoralTemp 0.05° grid cell. These summaries provide broad regional thermal context and should not be interpreted as site-specific thermal exposure, particularly in oceanographically heterogeneous regions such as the Galapagos Archipelago. We extracted monthly SST time series for each occupied grid cell from 1985 to 2024 and averaged them within countries. For each country, we calculated the maximum monthly mean temperature (MMM) as the warmest climatological monthly mean SST during the 1985–2012 baseline period used by NOAA Coral Reef Watch climatologies (Liu et al. 2014; Heron et al. 2015). We defined the bleaching threshold as MMM + 1°C, consistent with the NOAA Coral Reef Watch thermal-stress framework used to identify temperatures associated with increased bleaching risk

(Liu et al. 2014; Heron et al. 2016; Skirving et al. 2020). We calculated monthly positive thermal exceedance for 2023 and 2024 as the difference between observed monthly SST and the MMM + 1°C threshold when SST exceeded that threshold. We defined the monthly accumulation window for each country-year as the period between the first and last month with SST above the bleaching threshold. We summarized bleaching records by country, year, and month, and plotted them with point size proportional to the number of reports. Because the analysis used monthly SST rather than daily SST, thermal exceedance values represent monthly anomalies relative to the MMM + 1°C threshold and are not equivalent to NOAA Degree Heating Week estimates.

RESULTS AND DISCUSSION

The 2023–2024 bleaching records show that coral stress in the ETP developed as a prolonged, spatially uneven event rather than a single synchronous regional pulse (Fig. 1). Low levels of bleaching were first reported in the Galápagos in early February 2023, whereas coral reefs in El Salvador were already experiencing high to very high (up to 90% of the extent of reef-site bleaching; Fig. 1a,b) bleaching severity by that time. These early observations preceded the establishment of the 2023 El Niño and indicate that coral stress was already detectable at some ETP locations before the strongest regional warming developed later in the year (Fig. 1b). As thermal stress intensified throughout 2023, bleaching observations became increasingly widespread across the ETP, coinciding with the development of the Fourth Global Coral Bleaching event against a background of elevated ocean temperatures (Reimer et al. 2024; Spady et al. 2026). This pattern also aligns with evidence that recent global bleaching events are no longer isolated anomalies but part of a trajectory of increasingly recurrent heat stress across reef systems worldwide (Hughes et al. 2017, 2018; Sully et al. 2019; Cole et al. 2026; Eakin et al. 2026).

The temporal structure of the reports differed among the six countries (Fig. 1). México had the most observations, with repeated bleaching and mortality records in mid-to-late 2023 (Fig. 1b). El Salvador had fewer records but included early and recurrent severe bleaching, with most records classified as severe bleaching. The first record was reported in February 2023, and the last in March 2024 (Fig. 1a,c). Panamá showed a shorter documented observation window, with reports concentrated between July–October 2023, whereas Colombia presented severe bleaching and mortality records mainly during the second half of 2023. The available Galápagos records contrasted with those from continental reefs by spanning the longest documented observation period (From February 2023 to August 2024) and were dominated by tissue discoloration and low-level bleaching rather than widespread mortality (Fig. 1c,d). Thus, the available Galápagos observations were consistent with a prolonged but predominantly sublethal response, dominated by tissue discoloration and partial bleaching, in contrast to the severe bleaching and mortality reported from several continental ETP locations. This pattern may partly reflect the strong seasonality and variable thermal environment of the Galápagos, where seasonal changes in equatorial circulation and upwelling, together with short-term temperature fluctuations, have an influence on cumulative heat exposure and coral responses to thermal stress (Glynn et al. 2018; Cole et al. 2026).

The asynchronicity observed in the occurrence of bleaching argues against a simple latitudinal progression along the ETP coastline and insular sites. Instead, early observations near the equator and Central America in February 2023, severe late-2023 records in México and parts of Central and northern South America, and differences in the timing, reported severity, and temporal span of documented observations indicate a spatiotemporal mosaic of thermal stress and coral responses. Although the absence of observations before or after a country's documented reporting period cannot be interpreted as evidence that corals were healthy or that bleaching had ceased, apparent differences in bleaching duration might reflect both biological responses. Similar decoupling between regional heat stress and local outcomes has been reported elsewhere, where exposure history, local stressors, depth, local oceanographic conditions, original reef condition, and species composition modify the ecological consequences of marine heatwaves (McClanahan et al. 2019; Donovan et al. 2021; Gove et al. 2023; Eakin et al. 2026).

The bleaching records show that the event affected the key reef-building taxa of the ETP (Fig. 2), as it included 12 scleractinian species assigned to five genera: *Pocillopora*, *Porites*, *Pavona*, *Psammocora* and *Gardineroseris* (Fig. 2). Across the region, bleaching was most frequently reported for *Pocillopora*, *Porites* and *Pavona*, consistent with their dominance in shallow marginal reefs along the region (Cortés et al. 2017; Glynn et al. 2017). However, the frequent representation of these genera in the dataset should not be interpreted as evidence of higher bleaching susceptibility, because genus-specific abundance and sampling effort were not standardized across sites. Although we could not assign relative vulnerability categories based on the bleaching records, the taxonomic structure of the bleaching observations remains important due to the differential ecological consequences in the reefs. Severe mortality in branching *Pocillopora* can rapidly reduce habitat complexity in shallow ETP reefs (Cabral-Tena et al., 2020), whereas mortality in massive *Porites* and *Pavona* can alter carbonate persistence and longer-term recovery trajectories (Tortolero-Langarica et al., 2022).

Recent evidence from southern México illustrates how severe bleaching and mortality in dominant ETP reef builders can translate into broader reef degradation. The 2023 event caused extensive bleaching and mortality in *Pocillopora* spp., *Porites panamensis*, and *Pavona gigantea* (López-Pérez et al. 2024), and long-term observations from Zihuatanejo showed that repeated El Niño-associated stress in 2015 and 2023 shifted reefs from high live-coral cover to dominance by dead coral and algae by 2024 (Nava et al. 2025). These biological losses have functional consequences since carbonate-budget analyses from ETP reefs showed that the Fourth Global Coral Bleaching Event reduced reef carbonate production and shifted some reefs toward net erosional states, linking bleaching mortality to loss of reef-building capacity rather than only to declines in live coral cover (Medellín-Maldonado et al. 2026). Together, these observations indicate that bleaching of dominant reef-building taxa can affect outcomes from colony mortality to reef-scale structural and carbonate-production processes. However, genus identity alone cannot infer the magnitude of these responses, because thermal tolerance can also vary among host lineages and their associated symbionts. Within ETP *Pocillopora*, for example, thermal responses can vary with host lineage and Symbiodiniaceae composition, including associations with the thermotolerant

symbiont *Durusdinium glynnii*, which has been documented across multiple locations in the ETP (Palacio-Castro et al. 2023; Millán-Márquez et al. 2024; Connelly et al. 2026).

Our bleaching records tracked the monthly SST patterns, although the timing and strength of this correspondence varied among countries (Fig. 3). Country-level SST exceeded the MMM + 1°C threshold in different months and for varying durations, indicating that local environmental settings shaped bleaching responses rather than a single ETP-wide threshold. The intensity of bleaching is mediated by the interaction of thermal thresholds with human-related local stressors, thermal history, frequency, depth, local oceanographic features, and coral community composition (Heron et al. 2016; Hughes et al. 2018; Safaie et al. 2018; McClanahan et al. 2019; Skirving et al. 2020; Spady et al. 2026). In 2023, the strongest concentration of bleaching reports coincided with warm-season SST anomalies in the second half of the year (July to October), when severe bleaching and dead-coral records were most evident in México, El Salvador, Panamá, and Colombia.

Seasonal warming was broad across the Mexican and Central American Pacific, whereas Ecuador and the Galápagos presented stronger spatial thermal heterogeneity associated with equatorial and upwelling circulation (Supplementary Fig. 1). Our observations document a prolonged sequence of relatively low-level bleaching and tissue discoloration in the Galápagos compared with the more severe damage reported at continental ETP locations. Upwelling and high-frequency temperature variability may contribute to lower bleaching risk through a reduction of cumulative warm-water exposure, but also because the local coral populations have been exposed to variable thermal histories (Safaie et al. 2018; Randall et al. 2020). Notwithstanding, Athese highly variable environments are still at risk in years wothcan expose corals to cold stress, low carbonate saturation, hypoxia, or abrupt thermal transitions, especially during ENSO phase shifts (Fiedler and Lavín 2017; Manzello et al. 2017; Rhoades et al. 2023). Therefore, the Galápagos sequence may reflect the influence of these interacting environmental processes, although our observational data do not directly test their effects. We therefore hypothesize that the highly variable thermal environment of the Galápagos may contribute to prolonged biological stress characterized by tissue discoloration and partial bleaching, even when broad regional thermal summaries do not predict uniformly severe bleaching. Testing whether similar responses occur across other equatorial and environmentally variable reefs requires standardized observations coupled with site-level thermal data.

Based on bleaching observations, the timing and severity, as well as the temporal span of documented records, varied among locations, revealing a spatially and temporally heterogeneous regional pattern. This pattern is consistent with regional thermal forcing interacting with local oceanographic conditions, thermal histories, and coral assemblage composition to shape reef responses during the event. These observations suggest that coordinated regional monitoring across the ETP can contribute to the early detection of ENSO-associated coral stress and reveal contrasting patterns of coral response across locations, but such early detection cannot rely on a single thermal threshold or geographic area because local environmental conditions and reef characteristics can strongly modify biological responses to regional heat stress. Sustained monitoring is therefore particularly important for detecting changes

through time and distinguishing among recovery, persistent stress, mortality, and potential refuge responses. Continued coordinated reporting and post-event field assessments by the ETP Regional Node of the GCRMN will be necessary to determine which sites are recovering, which shifted toward persistent mortality or algal dominance, and which apparent refugia remain functional under repeated ENSO-driven heat stress.

Beyond the regional patterns documented here, this compilation highlights a broader challenge for coral-bleaching surveillance: coordinated networks can capture the spatial and temporal extent of major events across scales that no single monitoring program can achieve, but their value depends on the comparability of the underlying observations. In the ETP, retrospective harmonization was required because survey methods, sampling effort, and observational units differed among contributors, limiting formal comparisons of bleaching timing, duration, and severity. Similar inconsistencies occur globally, where bleaching records span multiple metrics and often lack sufficient methodological metadata (Rivera-Sosa et al. 2025). Importantly, comparability does not require a single field protocol; heterogeneous datasets can be integrated when each observation is accompanied by standardized information on when, where, and how it was collected, the sampling effort and response denominator, explicit records of unbleached corals and surveys with no bleaching, and clearly defined metrics of bleaching and recent mortality (Donner et al. 2017; Wicquart et al. 2022; van Woesik and Kratochwill 2022; Zapata et al. 2026). Reporting these core metadata under FAIR principles would preserve methodological flexibility while enabling observations from future ENSO-driven bleaching events to be synthesized robustly across regional and global scales (Wilkinson et al. 2016; Rivera-Sosa et al. 2025)

Declarations

Contribution

Conceptualization, QJP, RVJC, and ABA; methodology, QJP, RVJC, ABA and FAZ; validation, QJP, RVJC, ABA and FAZ; formal analysis, QJP and RVJC; resources, all authors; writing—original draft preparation, QJP and RVJC; writing—review and editing, all authors; visualization, QJP and RVJC; supervision, QJP and RVJC; funding acquisition, all the authors. All authors have read and agreed to the published version of the manuscript.

Ethical approval

Not applicable.

Conflict of interest

The authors declare no competing interests or other interests that could be perceived as influencing the results and/or discussion reported in this paper.

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Author Contribution

Conceptualization, QJP, RVJC, and ABA; methodology, QJP, RVJC, ABA and FAZ; validation, QJP, RVJC, ABA and FAZ; formal analysis, QJP and RVJC; resources, all authors; writing—original draft preparation, QJP and RVJC; writing—review and editing all authors; visualization, QJP and RVJC; supervision,QJP and RVJC; funding acquisition, all the authors; All authors have read and agreed to the published version of the manuscript.

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Data Availability

All the data and code are available in the GitHub repository (https://github.com/Eastern-Tropical-Pacific-Node/Coral_Bleaching.git).

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Figures

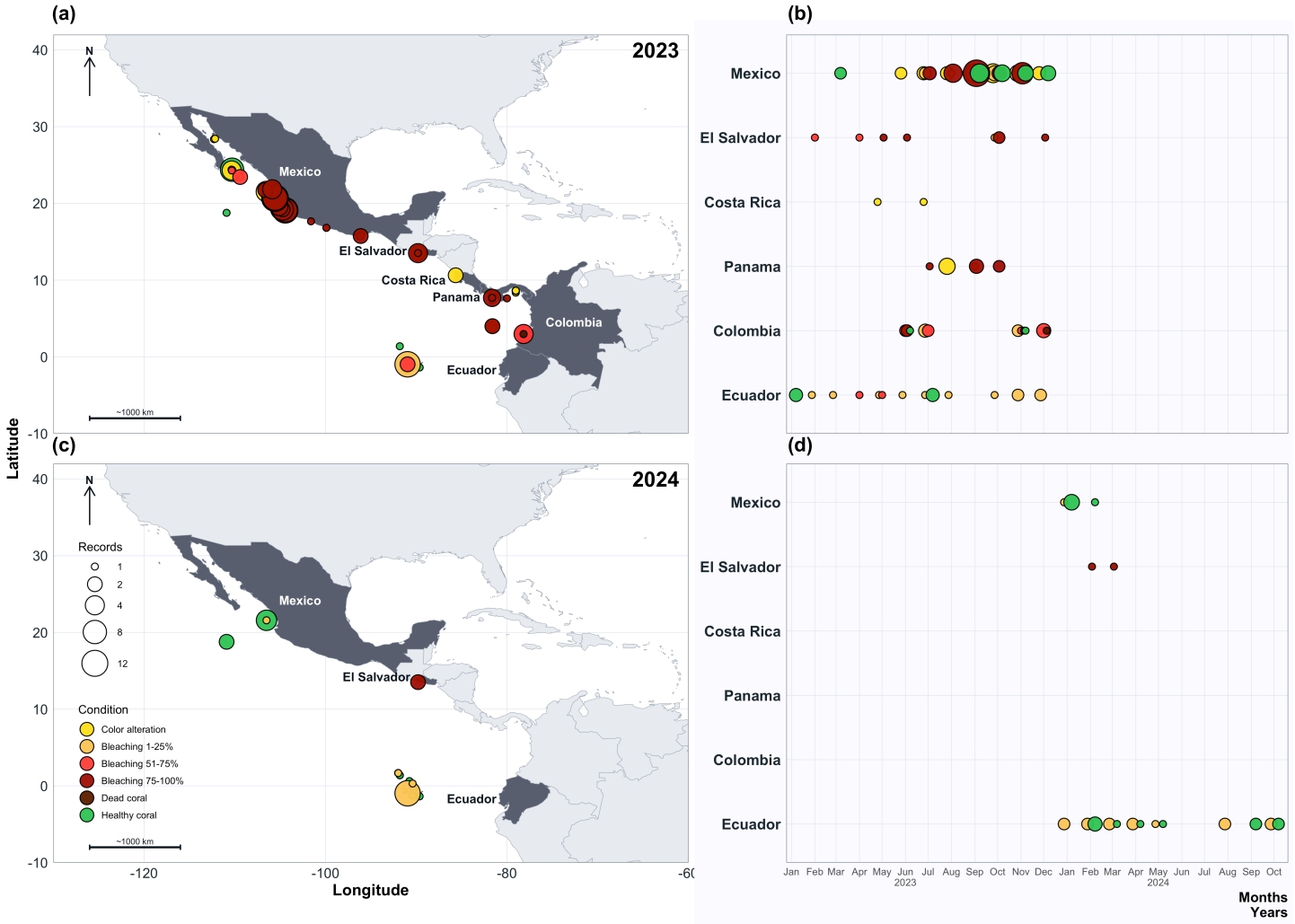


Figure 1

Spatial distribution of coral bleaching records across the Eastern Tropical Pacific during 2023–2024 (a, c). Timeline of coral bleaching records by country in 2023 and 2024 (b, d). Point size is proportional to the number of records, and color indicates coral condition.

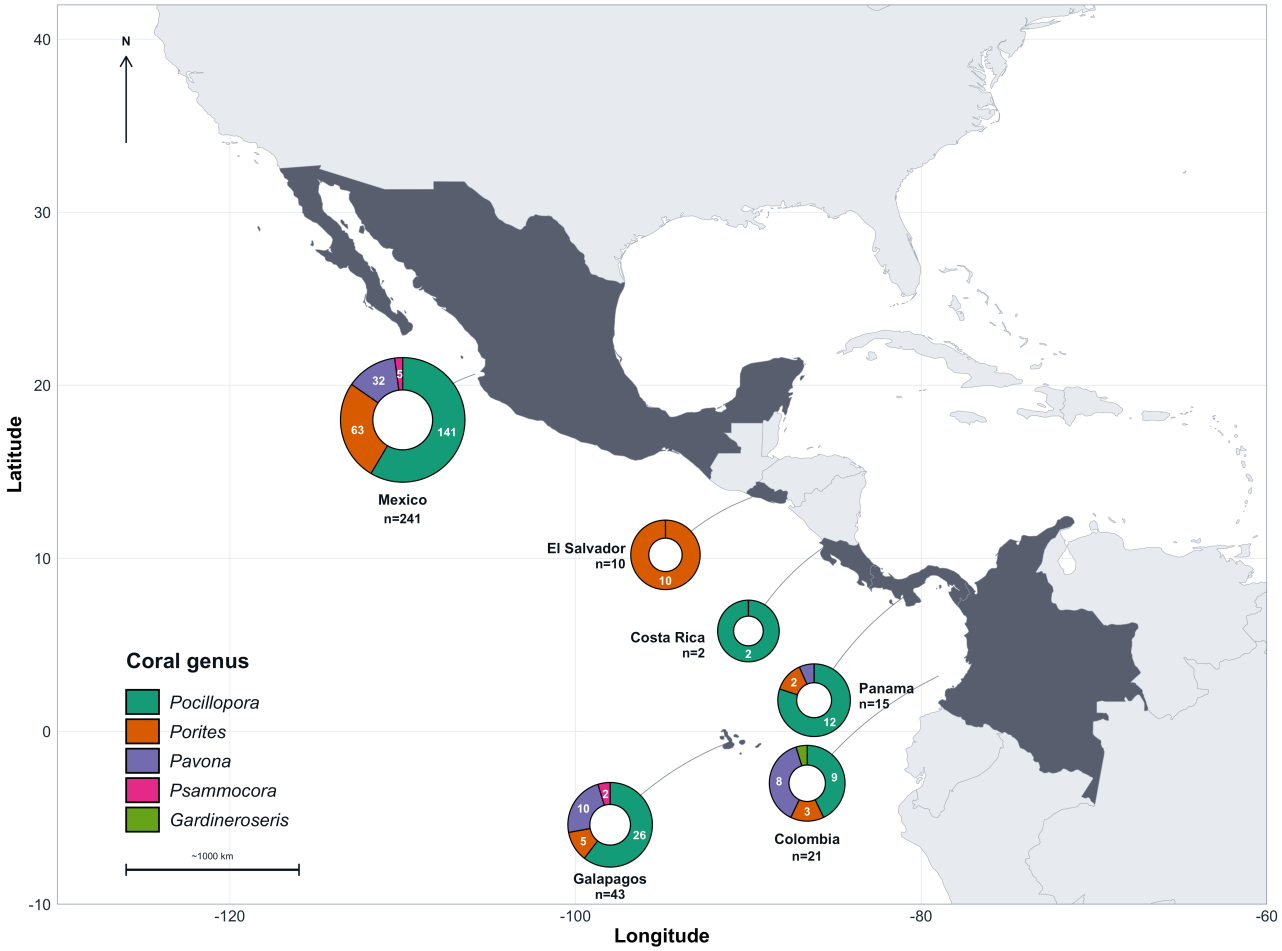


Figure 2

Taxonomic composition of coral bleaching records across the Eastern Tropical Pacific during the 2023–2024 bleaching event. Five scleractinian genera were reported over time: *Pocillopora*, *Porites*, *Pavona*, *Psammocora*, and *Gardineroseris*. Numbers inside each chart indicate genus-level reports counts, and values below country or regional labels indicate the total number of genus-level records represented.

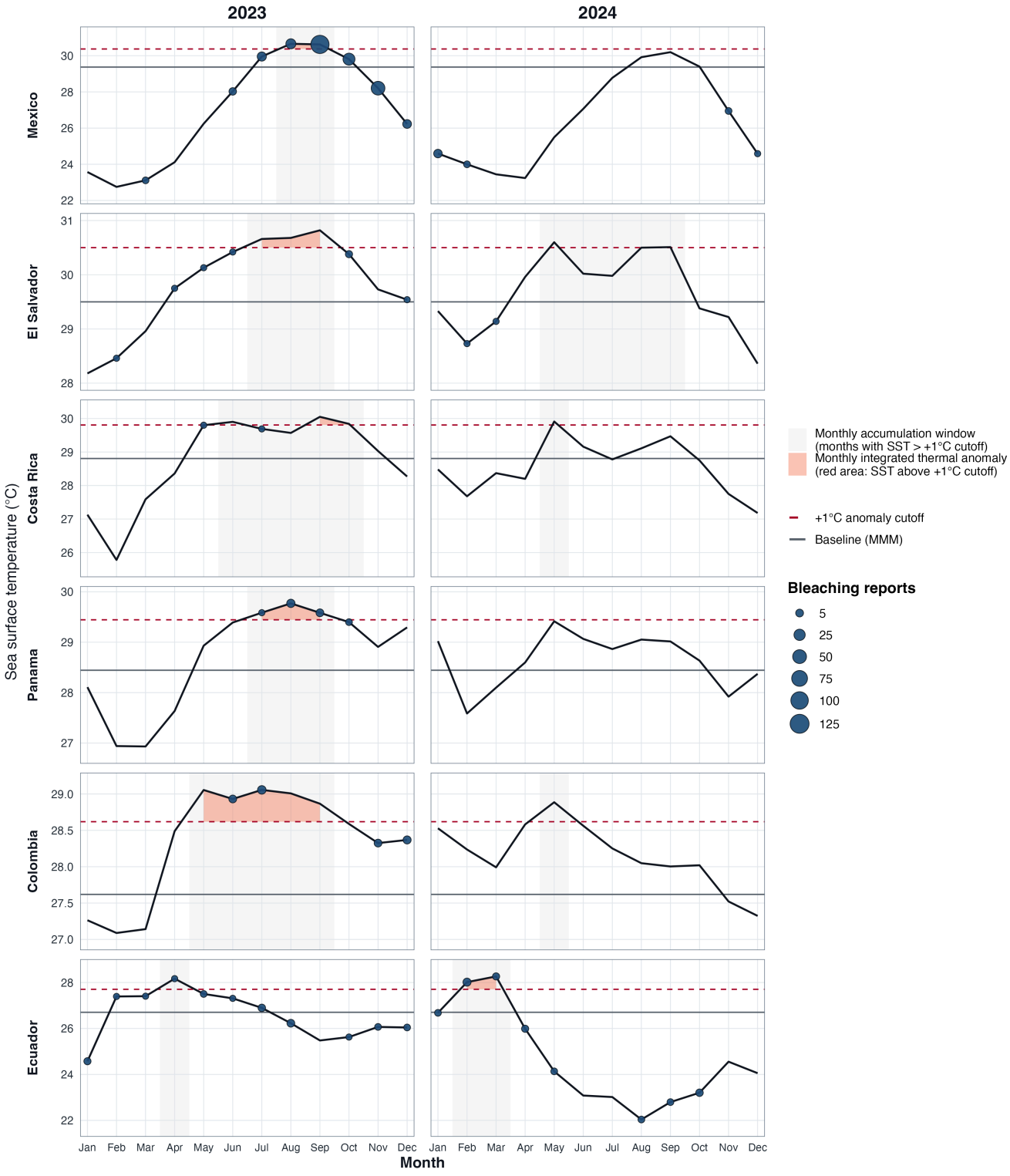


Figure 3

Country-level monthly sea surface temperature conditions and bleaching reports during 2023 and 2024. Monthly mean sea surface temperature (SST) was extracted from NOAA Coral Reef Watch CoralTemp v3.1 for grid cells associated with bleaching-report locations. Solid horizontal lines indicate the maximum monthly mean temperature (MMM), and dashed red lines indicate the MMM + 1°C bleaching threshold. Red shaded areas show monthly thermal exceedance above the MMM + 1°C threshold, and

grey vertical bands indicate the monthly accumulation window between the first and last month exceeding the threshold within each country-year. Points show monthly bleaching reports, with point size proportional to the number of records.

Supplementary Files

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- SupplmetaryFigure1.png