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Marine ecosystems in peril: Time to prepare for super El Niño

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A new El Niño has begun and is projected to develop later this year into one of the strongest on record (1). The El Niño Southern Oscillation is a cyclical climate phenomenon driven by complex interactions between the ocean and the atmosphere. During the warm El Niño phase, surface temperatures in the central and eastern tropical Pacific can rapidly increase by ~5 °C or more. Super El Niños are especially strong events in which the peak Oceanic Niño Index (ONI) exceeds 2 °C (2). Whether anthropogenic climate change is directly influencing this amplitude remains an active area of research. What is clear is that the long-term warming trend, driven by greenhouse gas emissions, is increasing the ocean's temperature baseline, so that each successive El Niño peaks from a higher starting point and pushes temperature extremes still higher. The combination of natural El Niño oscillations and anthropogenic warming is leading to more frequent and stronger marine heatwaves, i.e., discrete, prolonged periods of anomalously warm water at specific locations (3–5).

With sea surface temperatures already at record highs, global mean temperatures this summer and into 2027 are likely to exceed the records set in 2024, whether or not this event is ultimately verified as a super El Niño. The 2026 US-UK Scientific Forum on Shifts and Tipping Points in Ocean Systems, cohosted by the US National Academy of Sciences and the UK Royal Society, identified El Niño as a climate phenomenon capable of triggering rapid shifts or tipping points in marine ecosystems. The program of US-UK Scientific Forums, established in 2008, fosters long-term scientific partnership between the United Kingdom and the United States to address global scientific challenges.

Rather than viewing the developing El Niño solely as an acute environmental disaster, we should also see it as a global stress test for marine ecosystems, management institutions, and scientific observing systems. As the ocean continues to warm, events like this will become increasingly important opportunities to evaluate adaptation strategies, improve forecasting, and better understand how marine ecosystems respond to climate extremes and approach ecological tipping points.

The two most recent super El Niños (1997–1998 and 2015–2016) reshaped weather and ecosystems worldwide, and their most familiar consequences played out on land. In some regions, warmer, wetter conditions fueled outbreaks of infectious disease–including cholera, plague, and dengue (6)—and heat-related mortality (7). In others, severe drought drove crop failures, wildfires, and peatland fires across South America and Southeast Asia (8)—along with hydropower shortfalls and energy shortages in countries such as Colombia and Zambia (9).

Although less immediately apparent, impacts in the ocean are also widespread and profound, particularly where species approach their thermal limits (10). A super El Niño can trigger catastrophic coral bleaching, as thermal stress forces corals to expel the symbiotic algae they depend on ref. 11. Because reefs support about a quarter of all marine species, their degradation has cascading effects on fishes, invertebrates, and other organisms (12). Elsewhere, the disruption of coastal upwelling off western South America decimates the phytoplankton production anchoring the food web, starving small pelagic fishes (and dependent predators such as marine mammals and seabirds) and shutting down fisheries such as the Peruvian anchoveta, leading to billions of dollars in economic losses and hardship for coastal communities. The consequences extend well beyond biodiversity and fisheries. Marine heatwaves also threaten ecosystem services including coastal protection, carbon sequestration, tourism, recreation, nutrient cycling, and the cultural values associated with healthy oceans. As these services deteriorate, their impacts cascade through economies and societies, reinforcing the need for proactive management before extreme conditions develop. Marine scientists and managers should prepare now (Fig. 1), not only to reduce ecological and societal impacts but also to use this event as a large-scale natural experiment to improve future prediction, management, and understanding of marine ecosystems in a warming world (13). Even where the window to act on this event has passed, the plans, permits, partnerships, and facilities assembled now will build capacity for the next El Niño, and the warmer ocean of the future.

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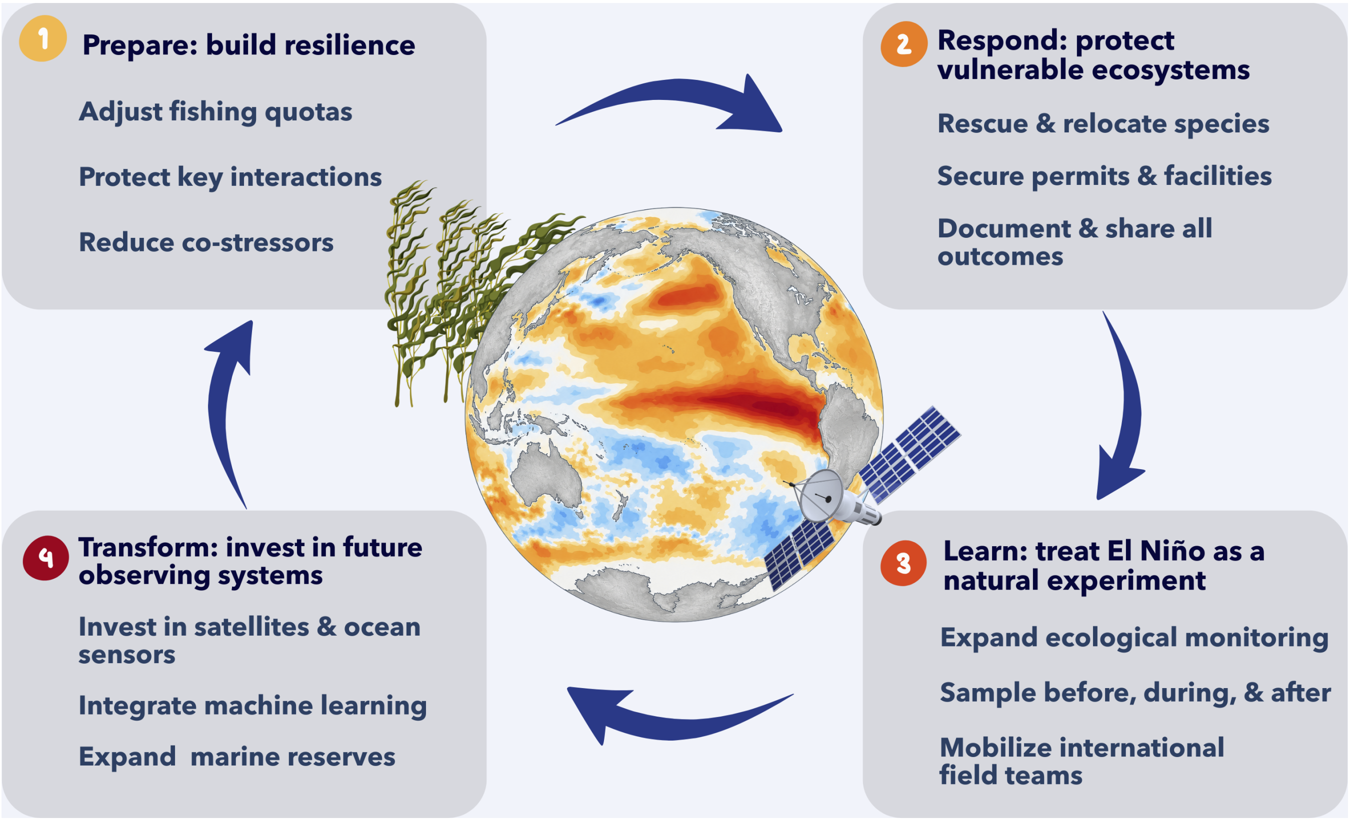

Fig. 1. **Actions marine scientists and managers can take in response to the developing super El Niño. These actions aim to reduce ecological impacts and to leverage the event to better understand how ocean warming and other aspects of climate change are affecting marine species and ecosystems.**

Prepare: Build Resilience

First, managers should immediately implement measures to maximize the resilience of marine populations and ecosystems. Crucially, fisheries managers should prepare to adjust quotas to reduce pressure on exploited species. Because the coming extreme temperatures will reduce the biomass and catch of most harvested fishes and invertebrates (14), limiting catch can give depleted stocks a better chance of survival during the event and of postevent recovery (15). At the ecosystem level, restricting or banning the harvest of strong interactors like herbivorous fishes, top predators, and detritivores can buffer entire communities and reduce vulnerability to disturbance and disease (16). In coastal California, for example, predatory sheephead wrasse consume sea urchins (whose grazing on habitat-forming giant kelp intensifies during marine heatwaves), protecting the kelp forest and associated community (17). Since sheephead, like many other top predators, are often depleted by fishing, closures can increase their density and restore trophic cascades (18). Where predators are too depleted to respond in time, managers can intervene directly, such as culling urchins to relieve grazing pressure on kelp (17).

Managers and policymakers can also relieve other stressors on marine ecosystems while heat stress peaks, temporarily curbing sedimentation and other forms of pollution. Localized cooling and shading interventions could also be tested: strategies such as shade structures, artificial upwelling, and marine cloud brightening are under active development, though most remain at proof-of-concept stage and raise unresolved governance questions (19). Unfortunately, we know little about which of these interventions work or how to allocate limited resources among them. Therefore, their outcomes should be documented and shared (failures included) to build a more robust evidence base. Wherever possible, assessments should include controls—sites where no action was taken—so that effects can accurately be measured.

Respond: Protect Vulnerable Ecosystems

Second, managers should prepare for localized rescue missions, including transplanting and temporarily removing sensitive organisms when doing so is feasible and scalable. During the 2023–2024 El Niño, for example, conservation teams collected 25 individuals of the critically endangered Tasmanian red handfish, housed them for several months, and returned them to the wild once temperatures had cooled. Elsewhere, wild and nursery-grown corals were transplanted to deeper, cooler waters or relocated to aquaria during the peak of the 2024 marine heatwave. Such rescues appear to be most effective when carried out just before or during a marine heatwave (17), which makes advance planning essential. The logistics of collecting, transporting, housing, and returning organisms are daunting; securing funding and permits, engaging stakeholders, lining up holding facilities, and preparing to document and share outcomes must begin now, so that teams are ready to act in the coming months.

Learn: Treat El Niño as a Natural Experiment

Third, population and community monitoring should be expanded to take advantage of the opportunity that El Niño and super El Niño events create to understand a rapidly changing natural world. Because El Niño temporarily and rapidly warms large areas of the ocean surface, it enables ecologists to observe how warming affects organisms, populations, and communities, and how those changes scale up to ecosystem functioning. Coral bleaching during the 1982–1983 El Niño provided the first indication that anthropogenic warming threatened tropical reefs (20), and the first global mass bleaching event occurred during the 1997–1998 super El Niño (21, 22). Individual events differ both in overall intensity and the spatial pattern of warming, exposing organisms to a range of thermal conditions. This variation enables scientists to quantify nonlinear functional responses to warming, including the thermal thresholds that signal tipping points and the limits of adaptation. The strongest El Niño-driven ecological science will sample before, during, and after the event, comparing replicate control and impacted sites (a Before-After-Control-Impact, or BACI, design) or sites spanning a gradient of warming (a response surface design). However, monitoring is costly, and rapid deployment of equipment and personnel is logistically demanding; these constraints are compounded by the current funding landscape and political climate. Capturing these fleeting events will require sustained advocacy for funding and mobilization of collaborative, international teams dedicated to timely ecological data collection.

Beyond warming, El Niño offers a rare chance to study interacting stressors in situ. Greenhouse gas emissions are simultaneously driving ocean acidification, deoxygenation, increased stratification, and reduced nutrient flux (23, 24), and El Niño can trigger several of these changes at once. The 2015–2016 super El Niño, for example, caused spatially correlated marine heatwave and low-chlorophyll events (25). While typically studied in the laboratory (26), El Niño can be used to investigate multifactor dynamics in situ and at large spatial scales. This is especially relevant where lab and field studies may disagree. Multifactor laboratory studies find that antagonistic interactions (where one stressor dampens another) between climate stressors dominate, while synergistic effects account for only 16% of outcomes (27). Whether this pattern holds in nature remains unknown. As species interactions often mediate the impacts of climate stressors in complex, scale-dependent ways, field results may diverge from small-scale laboratory manipulations. Ecologists should take advantage of El Niño as a natural experiment to tackle these pressing questions in climate change ecology.

Transform: Invest in the Observing Systems of the Future

Fourth, there is an urgent need for longer-term investment in the ocean's observing and forecasting systems. Detecting and predicting El Niño events and marine heatwaves depends on an infrastructure backbone of satellites, deep-ocean sensors, and autonomous platforms such as Argo floats and uncrewed vehicles (28). Extending and integrating these systems would not only sharpen early warning of ecological and societal disruptions across marine systems but also generate the long, global time series that increasingly powerful data-intensive methods such as machine learning require to forecast impacts (29, 30). Marine conservation should likewise be redesigned for a more extreme ocean, with larger, better-integrated pipelines from data collection to analysis that can inform climate-resilient marine protected areas, targeted restoration, and the protection of ecosystems able to adapt and shift as conditions change.

Some of the most valuable interventions cannot be assembled reactively and are most effective when implemented years prior to an El Niño event. A fisheries closure, for instance, may take years to rebuild predator populations to the point where they can exert top–down control on prey such as urchins. Fully protected, no-take marine reserves, which cover only about 1.7% of the ocean, should be expanded and maintained rather than implemented in response to uncertain forecasts. Long-term investments are also needed to build more resilient marine food systems and coastal economies through adaptive fisheries management, diversified aquaculture, and climate-resilient coastal infrastructure. Finally, none of this will be possible without robust national and international coordination: shared marine data systems, fisheries agreements, partnerships with indigenous fisheries, and ocean governance that account for the historical responsibility of industrialized nations for global climate change. Together, these efforts must prepare coastal communities for ongoing changes.

The developing super El Niño, expected to cause extensive marine heatwaves worldwide through 2026 and 2027, presents formidable challenges for the ocean science and marine resource communities. While its ecological and societal impacts are likely to be severe, this event also presents a rare opportunity to improve forecasting, evaluate management interventions, identify ecological tipping points, and strengthen the observing systems needed for a rapidly changing ocean. Success should therefore be measured not only by the impacts we avoid during this event but also by whether it leaves us better prepared for the warmer ocean that lies ahead.

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