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November 2026

Ocean Maelstrom: navigating the climate storm

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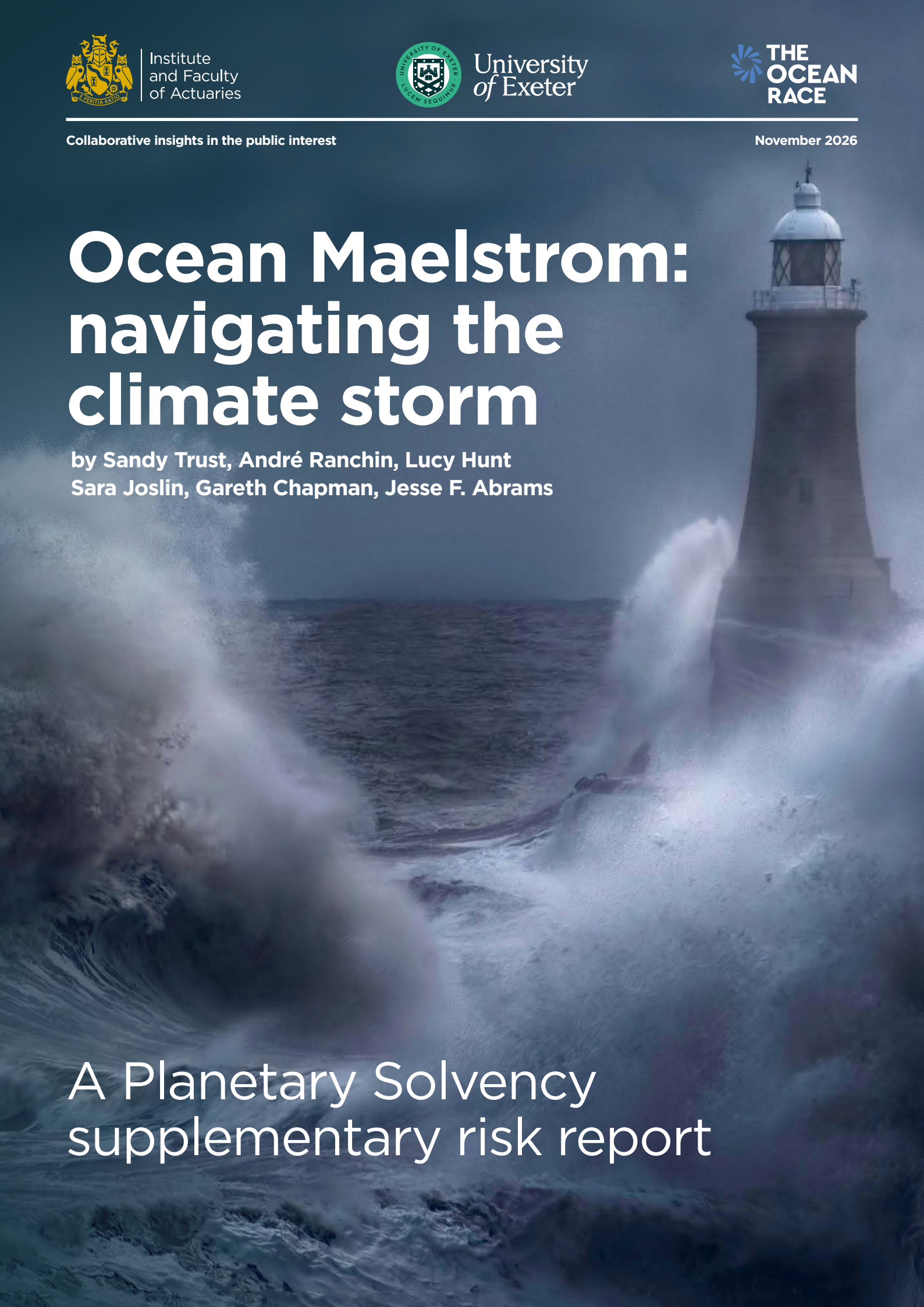

A Planetary Solvency supplementary risk report

Leaving systemic and catastrophic risks to this vital global system unaddressed could have severe consequences for humanity and the Earth system.



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The authors would like to thank all the individuals and organisations who contributed their expertise, insights and constructive challenge during the development of this report. In particular, we are grateful to members of the Senior Advisory Panel and wider review group, including colleagues from academia, finance, ocean science, policy and civil society, whose comments helped strengthen both the scientific foundations and practical relevance of the paper. We would especially like to acknowledge the contributions of: Professor Nicola Ranger (Earth Capital Nexus), Will Oulton (Chair, Ocean Conservation Trust), Chip Cunliffe (Ocean Risk and Resilience Action Alliance), Faith Ward (Faith in RI), Nick Wise (Ocean Mind), Robert Gardner (Rebalance Earth), Professor Tim Lenton (University of Exeter), Professor Aled Jones (Anglia Ruskin University), Francois Mosnier (Planet Tracker), Michelle Bender (Ocean Vision Legal) and Ian Trim. We are also grateful to the University of Exeter for their ongoing support of the Planetary Solvency research and The Ocean Race for their partnership in the development of this report.

Foreword



> Extending the framing of Planetary Solvency to Ocean Solvency marks an important step.

David Obura, Chair, Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES)

Extending the framing of Planetary Solvency to Ocean Solvency marks an important step. Why? Because it recognises that we have one ocean, by far the largest biome on the planet, and that leaving systemic and catastrophic risks to this vital global system unaddressed could have severe consequences for humanity and the Earth system alike.

We can hope that this marks a significant shift, with global economic and financial systems finally recognising that their primary asset and critical infrastructure is at risk. The positive aspect of apportioning responsibility is that these systems also hold the solution. However, when facing the final and largest component of our living biome, bending the curve may only come through systemic and profound shifts in what markets and financial systems value, and how they operate.

That is, changes across views, structures and practices, on how businesses impact and depend on nature, in the language of the Transformative Change and Business and Biodiversity assessments of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES).

Bringing the language of risk and actuaries to the table speaks to the largest and longest-term business and financial actors in ways that can ideally leverage their existing decision levers to systemic change.

As high-impact events once considered exceptionally rare become the new normal, their interactions and lack of independence amplify instability and unpredictability. This is what business and finance call 'risk', and many key actors have shown both the appetite and the capacity to develop innovative responses to high-risk situations.

These dynamics are playing out clearly in coral reefs, with three major global reports released within a few months of each other showing accelerating decline and heightened risks of extinction and collapse[1]. This is occurring while the planet crosses the landmark 1.5°C warming threshold and a super-El Niño – unlike any previously experienced - has only just started and is still growing.

Echoing David Attenborough's statement on the ocean, and given the prominence of climate change as the most pervasive global risk, it is worth remembering that "if we save coral reefs, we save our world".

What were localised collapses of coral reef socio-ecosystems are aggregating and merging into regional catastrophic losses. Should uncertainty about when this may become global delay action, or should we apply risk-framing to avoid getting close to that point? Surely the greater the avoidance margin, the greater the success, and the least cost (and impacts) incurred. Currently, economic and financial decision-making are still treating coral reefs as an acceptable sacrifice.

Central to this systemic, resilience-based approach is understanding that natural capital and related economic, social, human and other capitals are fundamentally important stocks. By contrast, finance is not a stock independent of these or an end in itself, but a facilitator of conversions from nature to produced capital to social and human capital. The planetary and ocean insolvency approaches make this explicit: harms that are externalised from economic and financial decision-making are not eliminated, merely transferred. As those impacts accumulate within natural and social systems, they eventually reappear as heightened economic, financial and societal risks.

This approach does a lot more than diagnosis, and it does not just illustrate the problems. It also points to the mechanisms and levers for delivering solutions, and the primary role of finance through system stability investment. Critically, it also expands the horizon to focus not just on financial risk, but on the existential risks that ocean and planetary insolvency pose to economies, cultures and nature.



Surely the greater the avoidance margin, the greater the success, and the least cost (and impacts) incurred.



The Ocean Race foreword

Sir David Attenborough, after a century on the planet, highlighted the importance of ocean restoration: "If we save the sea, we save our world." His conclusion was unequivocal: protecting and restoring the ocean is one of the most important priorities for safeguarding humanity's future.

Following our current course risks irreversible decline in ocean health, with stark implications for climate stability, food security and global economic resilience. The ocean plays a critical role in regulating our climate, providing our water and enabling the conditions that support our society and economy. Ocean health is fundamental to Planetary Solvency, the Earth system's capacity to support human prosperity on an ongoing basis.

A maelstrom is a powerful whirlpool that pulls objects into a swirling mass of water. It represents the volatile situation we are now faced with as ocean health deteriorates. Multiple reinforcing pressures and risks are converging, creating a challenging environment to navigate.

As the natural system in which we live becomes more volatile, we are entering an era of higher risk. Like sailors preparing for a storm, we have no choice but to batten down the hatches, reduce sail and prepare our societies for the fierce winds and waves of climate disruption. But unlike sailors, we have some agency over our environment. We can steer another course and reduce the severity of the storm we must navigate. We can take action to stabilise the climate, restore nature and reduce the ferocity of the ocean maelstrom.

We will need to act together in a coordinated fashion, recognizing what different actors can and can't deliver. While all are impacted by ocean health and other planetary risks, not everyone has agency to directly mitigate these risks.

Action requires a shift in mindset, informed by a realistic assessment of the level of systemic risk we face, and the urgent necessity of stewarding the Earth system away from the whirlpool. We need the courage to evolve our dominant economic model. To remember that nature is the foundational asset that supports our society and economy. And we need to see how critical ocean health is for the stability of that foundation.

Our worldview must move away from exploiting the ocean as an unlimited resource and using it as a convenient sink, towards maintaining resilient ocean systems. A key enabler of this is enhanced ocean literacy and systems thinking, supporting economic and financial actors to understand how ocean degradation drives financial and economic risks.

The story that follows moves from diagnosis to action. We begin by examining why ocean risks are often overlooked despite the ocean's fundamental role in supporting human prosperity. We then consider what may happen if these risks continue to accumulate unchecked before turning to the evidence and practical steps that can help build resilience.

We can choose to stabilise the climate. We can choose a healthy ocean. We can actively restore marine ecosystems, manage ocean resources within safe limits, and integrate ocean health into economic and financial decision-making. We can and must change course, recognising that our human society and the Earth system are interconnected, and that we have a profound responsibility to steward it wisely.

> **If we save the sea, we save our world.**

The Ocean is central to Earth's capacity to regulate climate, yet we are pushing vital parts of this system closer to tipping points. This report reinforces the need to consider risks as interacting cascades, not isolated hazards—and why accelerating positive tipping points in protection, restoration and clean technology is now essential.

Professor Tim Lenton OBE – Chair in Climate Change and Earth System Science, University of Exeter

Marine heatwaves, acidity extremes and oxygen loss are not future risks. They are already happening, often together and in the same places, pushing marine ecosystems into new states. When these extremes strike together, their impact can be far greater, yet risk frameworks still assess them separately, if at all. This record-breaking El Niño will only increase these compound extremes, while disrupting rainfall and harvests on land. That is how a heatwave in the ocean becomes a food-price shock on land.

Professor Regina R Rodrigues – Professor of Physical Oceanography and Climate, Federal University of Santa Catarina

The ocean's systemic importance is not in doubt: it regulates the climate, shapes weather and water, sustains food and trade, and has absorbed more than 90% of the excess heat from human activity. Its degradation creates systemic risks to economies and financial systems, and those risks need the same seriousness, and the same kind of governance, that we now apply to systemically important financial institutions. Critical ocean systems are too big to fail, and should be designated and governed accordingly.

Professor Nicola Ranger – Executive Director, LSE Earth Capital Nexus

For long-term asset owners, a stable climate and a healthy Ocean are preconditions for durable investment returns and members' future wellbeing. That means looking beyond conventional, diversifiable risks to consider plausible systemic scenarios. Ocean Maelstrom is a useful illustration of how interconnected Ocean, climate and geopolitical shocks could affect assets, liabilities and retirement outcomes at the same time.

Faith Ward – Chair, Institutional Investors Group on Climate Change

Capital is a claim on the future. But that claim is only worth something if the future remains capable of honouring it. Asset owners are accustomed to asking what returns they can extract from the future. They must now ask whether their investments are strengthening or undermining the future's capacity to deliver those returns. We need smart capital: capital that understands these existential risks and invests in protecting and regenerating the systems that make long-term value possible. A healthy Ocean is part of that capacity. Ocean recovery is not philanthropy; it is fundamental to preserving the future on which our assets depend.

Indy Johar – Founder, Dark Matter Labs

The ocean is our life support system, we cannot take its health for granted. From my experience at sea, I know how much we stand to lose if we fail to protect it. Finance has a critical role to play in shaping a different future, directing investment towards solutions that allow the ocean, and the communities that depend on it, to thrive. The ocean unites us all and represents our shared future, we must act now.

Paul Meilhat – Co-skipper, United by the Ocean Sailing Team

As sailors, we know that success and survival depend on preparing for the conditions we face, not the conditions we wish for. Yet society is sailing blindfolded towards a deadly storm, dangerously unprepared for the scale of the risks and running out of time to change course. We all deserve to understand the truth about the risks facing our Ocean and climate, and what they mean for our everyday lives, livelihoods and financial security. This report makes those connections clear. Sport has an extraordinary power to influence hearts and minds, but financial institutions have the power to translate that influence into action, by directing capital towards the protection and restoration of the natural systems on which our economies and societies depend.

Laura Baldwin – Olympic sailor

Ocean risk is financial risk, and it is already landing on coastal communities, on insurers' balance sheets and on the budgets of the most exposed nations. Ocean Maelstrom shows how quickly these pressures can cascade. The task now is to price that risk and move capital at scale into building resilience: the reefs, mangroves and a healthy Ocean that protect people, livelihoods and the long-term value our economies depend on.

Chip Cunliffe – Co-Founder & Senior Director, Ocean Risk and Resilience Action Alliance

Healthy marine ecosystems are critical infrastructure. Oyster reefs, seagrass meadows and salt marshes protect coastlines, improve water quality and support fisheries, yet much of their economic value remains unpriced.

To finance ocean restoration at scale, we must move from paying for environmental damage to paying for resilience. Marine Resilience Units could measure and verify these outcomes, while long-term Resilience Purchase Agreements could enable beneficiaries to pay for them, creating contractual cashflows that institutional investors can underwrite.

That is how we turn ocean resilience into investible shared infrastructure, helping secure a thriving ocean and a world worth living in for future generations.

Rob Gardner – CEO & Co-Founder, Rebalance Earth

The microfibers case study illustrates the constructive role investors can play in protecting Ocean health. By working together and engaging companies and policymakers on practical solutions, investors can help turn awareness of pollution risks into action. This approach was systematic: a structured, collaborative engagement with clear objectives, time-bound milestones and transparent reporting of progress. The recent report from the UK APPG on microplastics, adopted the objective of this engagement as a clear policy ask. Protecting the Ocean should be part of how we exercise stewardship and safeguard long-term investment value.

Will Oulton – Chair, Ocean Conservation Trust

We must respond to the climate and Ocean emergency as a global risk-management challenge for our societies and economies, not merely an environmental one. The priority is a credible policy led recovery plan to stabilise the climate: reduce emissions rapidly, remove greenhouse gases at scale, repair damaged natural systems and build resilience to the disruption already locked in.

Professor Sir David King – Chair, Climate Crisis Advisory Group



Ocean Maelstrom: navigating the climate storm | Ocean Race Supporters



Executive summary

Ocean risks do not remain environmental risks. They can cascade through food systems, supply chains, inflation, economic growth, financial markets and retirement outcomes.

Ocean health is declining in many regions, reducing the ability of the ocean to continue providing the critical services upon which human societies and economies depend. Today we assess risks to Ocean Solvency as Severe, with the potential to become Catastrophic if global and local ocean objectives are not delivered. Without a course change, current emissions and warming trends make catastrophic warming above 2°C before 2050 plausible. The ocean is therefore both a critical source of climate resilience and a potential source of systemic risk.

Ocean risks do not remain environmental risks. They can cascade through food systems, supply chains, inflation, economic growth, financial markets and retirement outcomes. Ocean Solvency therefore matters not only to environmental policymakers, but also to governments, regulators, investors, insurers, pension funds and wider society.

This report moves from diagnosis to action. We explain why ocean risks are systematically overlooked despite their importance to human prosperity **(Part 1)**, explore the consequences through the Ocean Maelstrom systemic risk scenario **(Part 2)**, and conclude with the evidence, implications and actions needed to strengthen resilience **(Part 3)**.

Ocean Solvency risk assessment:

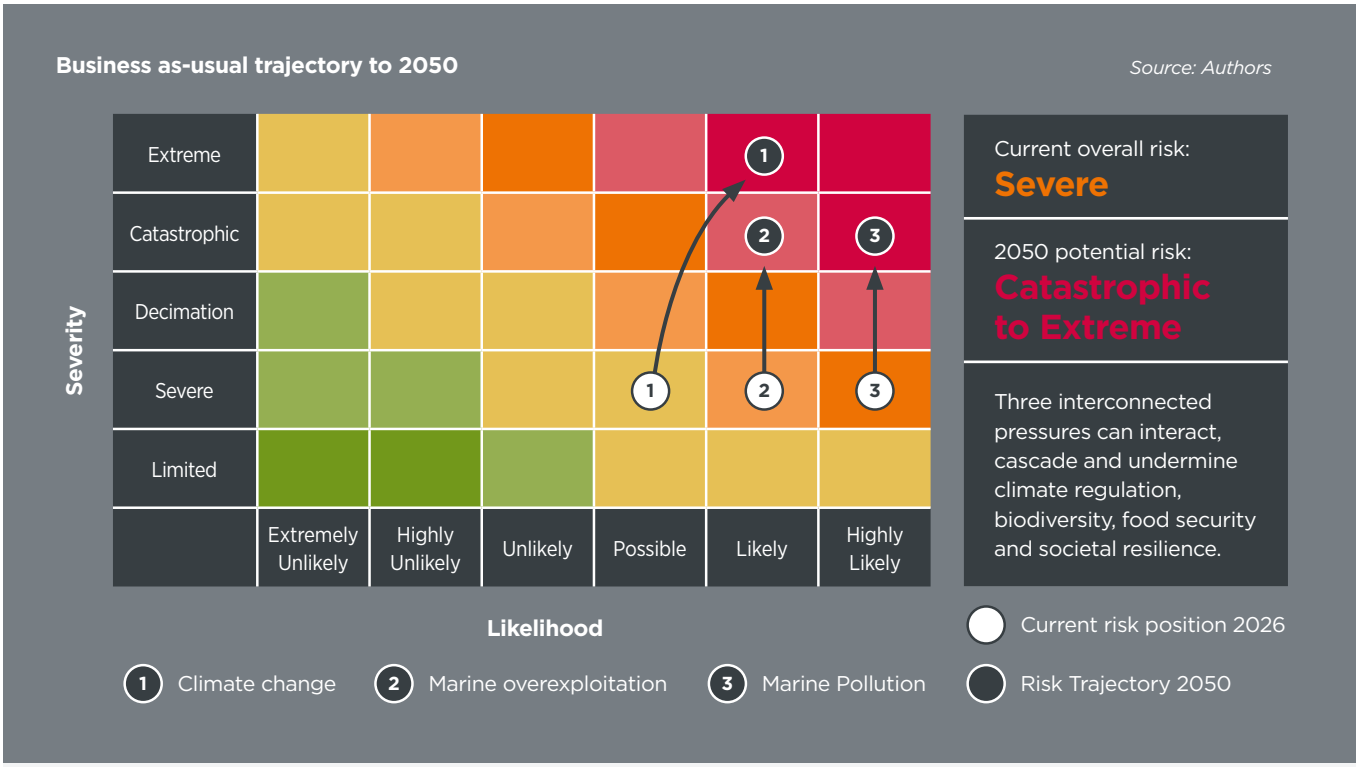
Figure 1 on the next page assesses Ocean Solvency across three interacting dimensions: climate change, marine overexploitation and marine pollution. Together, they provide an indication of the ocean's ability to continue supporting Planetary Solvency and human prosperity.

Ocean risk matters for retirement outcomes

Global pension funds hold more than US$68 trillion of assets. In the Ocean Maelstrom scenario, ocean-related shocks contribute to a 15% reduction in global economic output by 2035. Such significant economic disruption could severely impact retirement outcomes through shocks to investments and high inflation driving cost of living pressures – acting to reduce both the affordability of pension contributions and the buying power of pension savings in retirement.

This is not an actuarial projection, it is a risk warning. These events become likely if we do not change course. Further information on how to interpret a risk matrix is included in the **appendix.**

Figure 1: Ocean Solvency risk assessment



Catastrophic risks for these three categories are defined as:

1. **Climate change:** Global warming of over 2°C by 2050; high number of ocean-relevant tipping points triggered with partial tipping cascade. Ocean circulation (incl. Atlantic Meridional Overturning Circulation (AMOC)) severely impacted, disrupting global heat and nutrient distribution. Major coral reef extinction across multiple geographies; accelerating ice-sheet melt drives severe sea-level rise.
2. **Marine overexploitation:** Global fisheries collapse across most major ocean basins. Unmanaged, opportunistic extraction dominates as governance frameworks fail. Loss of fisheries as a viable food source drives severe protein and livelihood crises for billions in coastal and island communities.
3. **Marine pollution:** Pervasive, basin-scale hypoxia – widespread plastic and toxic loading render large ocean regions unable to support complex marine life; eco-system services (carbon sequestration, oxygen production, water purification) breakdown at a regional scale, compounding climate-driven ocean stress.

This is not an actuarial projection, it is a risk warning. These events become likely if we do not change course. Further information on how to interpret a risk matrix is included in the **appendix**.

In the language of risk, this reinforces the finding that the world is operating well outside any prudent Planetary Solvency risk appetite, that seeks to minimise the risk of societal disruption from the loss of critical ocean support services. The window to implement realistic, risk-informed policies is closing.

However, some components of ocean health recover quickly when they are allowed to do so and research has identified a number of opportunities to enable this, such as establishing large-scale Marine Protected Areas, fisheries rebuilding, kelp and seagrass restoration and sustainable aquaculture. Governance and execution of ocean health restoration initiatives are now critical to maintaining Ocean Solvency, and, in turn, Planetary Solvency.

Why Ocean Health Matters

- **Planetary Solvency recognises that our society and economy are part of the Earth system.**
  Nature provides essential services such as food, water, air, energy, raw materials and climate regulation. Nature is not a luxury; it is our most fundamental form of critical infrastructure. Yet we are currently running down the stock of this global common asset. We risk Planetary Insolvency and global catastrophic risks, including structural economic decline.

- **The ocean is by far the largest and most systemically important part of nature, underpinning the functionality of major Earth systems which provide these essential services.**
  This means Ocean Solvency is a prerequisite for Planetary Solvency. The water cycle, oxygen production, food for billions, global trade and climate regulation all depend on a solvent ocean. Climate change would be significantly worse already without the ocean, which has absorbed most of the excess heat and one quarter of human carbon emissions.

Ocean risks are severe and could become catastrophic

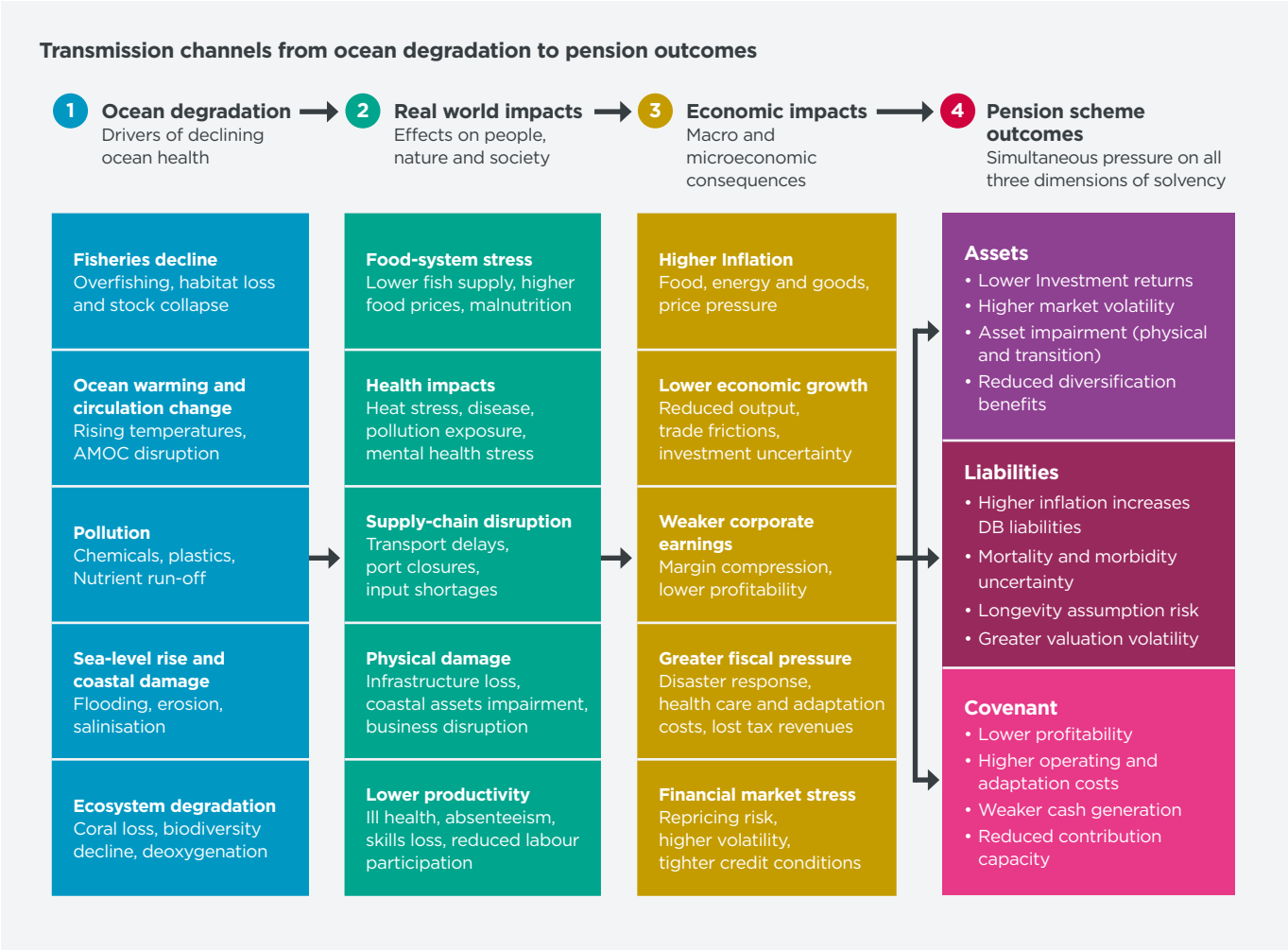
- **Our assessment indicates that Ocean Solvency is already under severe stress and could become catastrophic without a policy-led change of course.**
  Climate change, pollution and marine overexploitation are increasing the risk of Ocean Insolvency: a state in which the ocean can no longer reliably provide the critical services upon which society and the economy depend.

- **Ocean risks are systemic, interacting and increasingly non-linear.**
  Tipping points are major shifts in ocean systems, such as the weakening of major ocean currents, the loss of coral reefs or the destabilisation of ice sheets, which collectively act to increase the pace of climate change and the impact severity. Tipping points are becoming more likely and environmental risk increases significantly above 1.5°C of warming, a temperature threshold we are now passing.



Ocean risks transmit to our society and economy

Figure 2: How ocean risk reaches pension schemes *Source: Authors*



- **Ocean risks transmit to socio-economic systems and can drive financial risks, including inflation and shocks to growth.**
  Channels include disruption to shipping, extreme weather events, food shocks, accelerated global warming and changes to the water cycle. These shocks can transmit to macro-economic and financial impacts, ultimately putting future retirement adequacy at risk.

- **Our dominant economic model is blind to ocean risk.**
  Conventional economic risk assessments of climate change start by assuming economic growth will continue, no matter how severely our society and economy are disrupted by environmental degradation. These risk assessments, which are prevalent among financial institutions and finance ministries, exclude any consideration of ocean risks and tipping points, leading to apparently benign risk outputs that are misleading.

- **Ocean Maelstrom is a plausible systemic risk scenario that addresses this blindness.**
  A super El Niño, accelerated AMOC slowdown, coral tipping, geopolitical amplification, fisheries collapse and sea-level rise could compound between 2027–2035 into overlapping, mutually reinforcing shocks — with transmission into food price inflation, stagflationary pressure, insurance withdrawal and sovereign stress.

- **Our pensions case study shows that, as ocean risks transmit to impact assets, liabilities and contributions, retirement adequacy could be threatened.**
  Unlike conventional pension risk assessments, Ocean Maelstrom is a systemic, less diversifiable risk that existing risk frameworks are not designed to capture. Those in governance positions now have a fiduciary basis for embedding ocean health into investment beliefs and strategic asset allocation, considering ocean investments (blue bonds, transition funds, natural capital vehicles) and targeted governance engagement, individually and collaboratively.

Recommendations for policymakers to support Ocean Solvency

Figure 3: Planetary Solvency recovery plan

Source: IFOA, Parasol Lost – Recovery Plan needed, Trust et al 2026



The Planetary Solvency Recovery Plan provides a framework for restoring the stability and resilience of the Earth system. Because Ocean Solvency is a prerequisite for Planetary Solvency, many of the actions required to restore Planetary Solvency are also necessary to recover and maintain Ocean Solvency. The recommendations below therefore highlight how the wider Planetary Solvency Recovery Plan applies to the ocean.

- **Enabling the mindset shift to become Planetary Solvency managers.**
  We need to recognise our profound responsibility to steward the Earth system back towards stability, as well as delivering for more of society. Planetary Solvency helps to reconnect finance and the economy with the biosphere, part of a toolkit to enable this upgrade to our operating system. Ocean Solvency provides a practical example of why long-term prosperity depends on maintaining the health and resilience of natural systems. Actuaries have a real opportunity to play an active role, combining expertise in long-term risk management, systems thinking and financial resilience to help society navigate emerging threats to economic prosperity and human wellbeing.

- **Realistic risk assessment, communication and action.**
  Governments, regulators and financial institutions should adopt more realistic approaches to assessing environmental risks, drawing on national security and solvency methodologies. Assessments should incorporate Earth system changes and explore how these may propagate through societies, economies and financial systems. The resulting risks should be communicated clearly to decision-makers, investors and the wider public, supporting a shared understanding of systemic vulnerabilities and helping build the mandate for mitigation, adaptation, resilience-building and the protection and restoration of ocean health.

- **Rapidly executing a Planetary Solvency recovery plan.**
  Net zero is increasingly a necessary but not sufficient condition for reducing the risk of severe Earth system disruption. A Planetary Solvency recovery plan should accelerate mitigation and adaptation through stronger policy support, rapid deployment of existing solutions, action on near-term opportunities such as methane reduction, and research into climate stabilisation options. Recognising that resilient societies depend upon resilient natural systems, Nature should be treated as a strategic partner in recovery efforts. Protecting, restoring and stewarding ocean and natural ecosystems at scale can help strengthen resilience, reduce systemic risks and support long-term prosperity.

- **Closing the ocean governance and execution gap.**
  Ocean systems can recover rapidly when pressures are removed, but execution is now the principal constraint. Extensive global treaties now in place signal a commitment to ocean health. However, there is a significant 'say-do' gap in ocean restoration efforts. Given the catastrophic risks that may arise by the failure to achieve these objectives, enforcement of global ocean health commitments should now be linked to national security and the Planetary Solvency recovery plan.

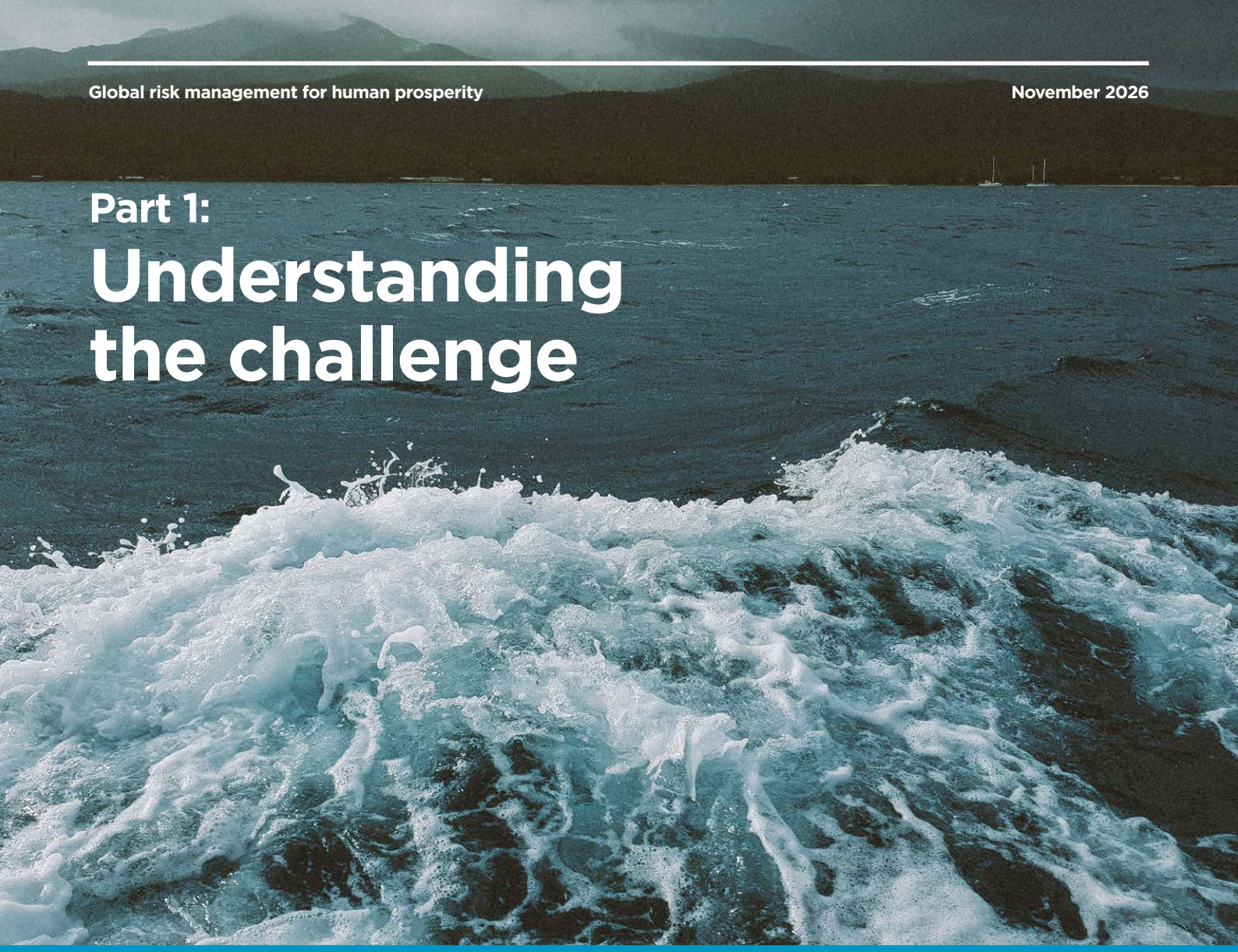


Given the catastrophic risks that may arise from the failure to achieve these objectives, enforcement of global ocean health commitments should now be linked to national security.

Recommendations for financial and economic actors

- **Develop an appropriate strategy to support ocean health.**
  Financial actors, although impacted by Ocean Solvency and other planetary risks, have a genuinely limited ability to mitigate them directly. This reinforces the need for collaboration, policy support, and the development of new financial structures that enable financial actors to allocate capital to systemic risk reduction. Furthermore, rational, solvency-protecting actions by individual financial institutions (e.g. insurance withdrawal from high-risk areas) can create societal-level harms that fall outside any single institution's mandate, pointing to a need for expanded regulatory remit and cross-system coordination.

- **Develop and scale innovative financing structures to support ocean health.**
  The blue economy is growing rapidly and there are already multiple ocean-positive investment structures that allow financial institutions to allocate capital to systemic risk reduction. These are typically novel and non-standard, requiring collaborative work to further develop and scale. Supporting institutions that enable this systems-level collaboration at scale should be a key priority.



Part 1: Understanding the challenge

Understanding why ocean-related risks remain overlooked despite the ocean's fundamental role in supporting human prosperity, resilience and long-term economic stability.

This section explores:

I. Navigating ocean blindness

Why ocean risks are routinely overlooked in economic and financial decision-making.

II. The ocean blind spot

Why ocean health underpins resilience, prosperity and planetary stability.

1 Understanding the challenge
2 The cost of ocean blindness
3 Evidence, exposure and action

I: Navigating ocean blindness

Ocean risks are largely absent from economic and financial decision-making. In this section we explain why risks to ocean health, and therefore Ocean Solvency, are commonly underestimated, and why this matters for financial and economic actors.

The ocean provides many of the essential services upon which human prosperity depends, including climate regulation, food production, oxygen generation, the water cycle and global trade. Yet these services are largely invisible within conventional economic thinking and financial decision-making. This creates a form of ocean blindness: the failure to recognise how deteriorating ocean systems can affect economic and financial outcomes.

Commonly-used climate-risk assessment methodologies generally exclude ocean risks such as ocean acidification, marine ecosystem collapse, tipping points, biodiversity loss and changes in ocean circulation. As a result, many assessments may understate risks to ocean health, Ocean Solvency and the wider economy.

For financial and economic actors, this matters because future financial outcomes increasingly depend on the stability of the Earth system. Standard economic and financial models assume a functioning climate, resilient ecosystems and stable global trade. These assumptions implicitly rely on Ocean Solvency continuing. No portfolio can diversify away a general deterioration in the Earth systems on which the economy depends.

Climate change is a risk-management problem

There is a central distinction between two broad approaches to assessing climate and nature risks:

- **A resilience or solvency approach** asks whether plausible adverse outcomes could threaten system viability, and what actions are needed to reduce the probability of failure.
- **An optimisation approach** focuses on expected outcomes and trade-offs, often using central estimates and economic modelling.

A risk-led solvency approach seeks to reduce the probability of insolvency, or ruin, to an acceptable level, rather than relying on central estimates. This shifts the objective from predicting the most probable future to reducing the chance of the civilizational scale disaster Planetary Insolvency represents.

These approaches can produce markedly different conclusions, particularly where tipping points, systemic risks and deep uncertainty are involved.

Illustration of the blind spot

Two recent studies illustrate the divergence in outputs:

- **Global ecosystem degradation and collapse threaten UK national security and prosperity**[2].
  Without significant increases in UK food system and supply chain resilience, it is unlikely the UK would be able to maintain food security if ecosystem collapse drives geopolitical competition for food.

- **By 2050, Climate change could reduce average income by 3% to 15%**[3].
  In addition, "substantial impacts [are] expected from other extreme climate-related events, such as flooding, wildfires and drought. As such, the figures above are likely to constitute significant underestimates of the overall impacts of climate change on GDP".

While both studies are evidence-based, they communicate radically different levels of urgency. The first reflects a solvency approach focused on avoiding system failure. The second reflects a more conventional economic assessment based on central estimates. The contrast highlights why risks to Ocean Solvency may be underestimated by decision-makers relying solely on optimisation-based approaches.

Ocean blindness: the failure to recognise how deteriorating ocean systems can affect economic and financial outcomes.

Figure 4: Limitations of econometric optimisation approach

Source: Authors



- A global economic recession caused by climate change is not foreseen, even in the worst-case scenario.
- Economic growth is assumed to continue.
- Physical climate risks are still not exhaustively modelled.
- Sea level rise and ocean acidification are excluded.
- Tipping points are excluded.
- No allowance for conflict or migration.
- Nature related health risks excluded.
- Human health impacts not covered.
- Disconnect with actual climate change.

The optimisation approach has been widely used and is particularly prevalent in the assessment of climate impacts for financial and economic actors: treasuries, financial regulators, banks, insurers, investment firms and pension funds. This is despite significant research [4] identifying serious methodological flaws, most recently 'Recalibrating Climate Risk'[5].

Methodological limitations are also carefully noted by the Network for Greening the Financial System[6] (NGFS), a group of central banks and regulators. These limitations include no consideration of sea-level rise, ocean acidification, tipping points or nature-related risks, including those related to the ocean. *'Parasol Lost: Recovery plan needed'*[7] draws parallels with the Global Financial Crisis, where a combination of model limitations, cognitive biases, governance weaknesses and misplaced confidence contributed to widespread institutional and systemic risk management failures.

In particular, the optimization approach treats ongoing GDP growth as a foundational assumption leading to the counterintuitive observation that 'A global economic recession caused by climate change is not foreseen, even in the worst-case scenario'[8].

This is because "Economists assume 3% annual GDP growth continues indefinitely into the future, irrespective of climate change damage severity. The 20% GDP damage is then subtracted from that growth-enlarged total pie, of a fictional future world without climate change"[9].

Why this matters

The assessment presented in this report is informed by a solvency perspective. As demonstrated by the ocean's classification as one of the four Taskforce on Nature-related Financial Disclosure (TNFD) realms of nature, its health is not an environmental issue that exists in isolation[10]. As ocean systems deteriorate, impacts can propagate through food systems, supply chains, inflation, economic growth, public finances and financial markets before ultimately affecting social and economic outcomes.

For readers interested in the methodological foundations of this assessment, **Appendix C: Planetary Solvency Methodology and Climate-Risk Assessment** provides further detail on:

- the RESILIENCE framework
- solvency versus optimisation approaches
- climate damage functions and model limitations
- evidence on climate sensitivity and warming trajectories
- the relationship between ocean health, Ocean Solvency and the wider Planetary Solvency framework.

The consequence of these blind spots is that systemic ocean risks may be underestimated. To illustrate what may remain hidden when ocean health, and therefore Ocean Solvency, is excluded from mainstream decision-making, this report develops a plausible systemic-risk scenario, Ocean Maelstrom, showing how overlooked risks can accumulate and cascade through societies, economies and financial systems.

II: The ocean blind spot

In this section we cover the critical role that ocean health plays in maintaining resilience, prosperity and Planetary Solvency. Those readers familiar with ocean science may wish to skip ahead.

Ocean health is essential to maintain Ocean Solvency: the ocean's ongoing ability to provide the critical services upon which human prosperity depends. Maintaining ocean health is therefore a prerequisite for maintaining Planetary Solvency.

- **Ocean health** refers to the condition and functioning of marine ecosystems.
- **Ocean solvency** refers to the continued ability of societies and economies to prosper because the ocean continues to provide critical ecosystem services.

In this sense, ocean health is a prerequisite for ocean solvency.

The ocean is the largest part of our planet's natural systems, playing a fundamental role in maintaining the stable Earth system conditions that enabled our global society to evolve. As ocean health deteriorates, the ability of the ocean to maintain this stability is degraded, with socio-economic consequences. The conditions needed to deliver financial services to society on an ongoing basis, including insurance and the provision of adequate retirement outcomes, are also weakened. Protecting and restoring ocean health moves from an environmental concern to an economic and societal priority, closely linked to enabling ongoing human prosperity. In financial services, there is a concept of Globally Systemically Important Banks (G-SIBS), put in place following the Global Financial Crisis. Earth Capital Nexus have proposed the creation of Globally Systemically Important Natural Systems (G-SINS)[11]; the ocean would be amongst the most important of these.

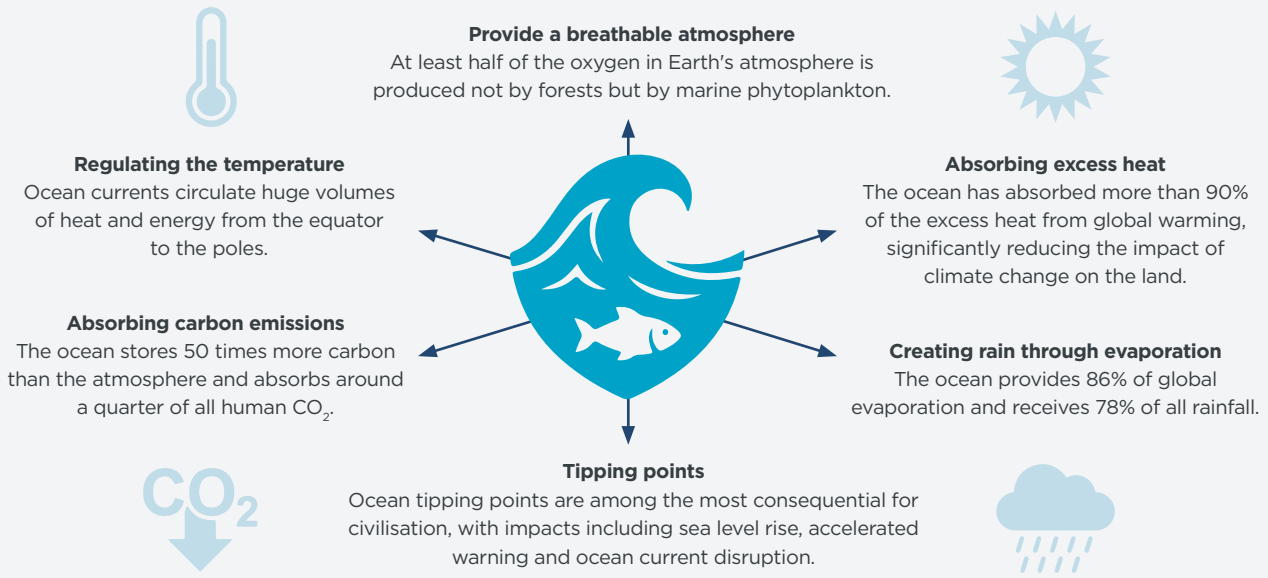
The ocean's critical role

The ocean is the largest part of nature. As Arthur C. Clarke observed, "How inappropriate to call this planet Earth when it is clearly ocean." The ocean gives Earth its distinctive blue colour — the source of its famous 'blue dot' description. But the ocean gives much more than that: it is *'The Unsung Guardian of Planetary Health'*[12], stabilising the climate, supporting the resilience of the Earth system as a whole and supporting life on Earth.

The ocean provides non-substitutable ecosystem services worth an estimated $12 trillion annually[13], including regulating the climate by acting as a heat and carbon sink, providing food security for billions and generating significant economic value[14].



Figure 5: The ocean - our life support system *Source: Authors*



In fact, it seems the more we discover about the ocean, the more we realise just how fundamental it is to our lives. It enables our life-support system, contributes to our health and supports our global economy.

Although not front of mind for many of us, the ocean plays a critical role in maintaining the stability and functionality of the biosphere, as illustrated in *figure 5* above.

I. Climate regulation and heat absorption

The Earth system has accumulated more than 500 times as much energy in the 50 years since 1971 than our total energy use in 2024[15]. The ocean has absorbed more than 90% of this excess heat, significantly reducing the impact of climate change on the land[16]. The ocean is the primary reason climate impacts have not been worse.

The ocean acts as the planet's heat redistribution system, absorbing surplus solar energy at the equator and transporting it toward the poles. The AMOC transports a staggering 1.2 petawatts of heat[17], around 60 times humanity's entire energy consumption. Without this circulation, the tropics would likely become significantly (or in places, lethally) hotter, while higher latitudes would freeze further. Northwestern Europe's relatively mild climate is a direct function of this oceanic heat transport. Disruption of these currents represents one of the most consequential tipping points in the Earth system.

II. Carbon and oxygen cycles

At least half of the oxygen in Earth's atmosphere is produced not by forests but by marine phytoplankton, microscopic organisms drifting near the ocean surface.

The ocean stores approximately 50 times more carbon than the atmosphere, and currently absorbs around a quarter of all human CO_2 emissions every year. Marine life alone sequesters the equivalent of 10 billion tonnes of CO_2 annually — more than a quarter of annual emissions.

III. Water cycle

The ocean provides 86% of global evaporation and receives 78% of all rainfall[18]. It dominates global water exchange with the atmosphere and is therefore central to precipitation and freshwater availability on land. The terrestrial water cycle, central to agriculture and human settlement, is a subsidiary of the ocean's water cycle.

IV. Trade and livelihoods

More than 80% of all goods traded internationally are moved by sea and more than 99% of international data travels by subsea cable. Maritime shipping is the physical infrastructure on which the modern global economy depends. Witness the disruption in recent years when critical canals or straits are closed, even for short periods of time, or the concern over the potential for subsea cables to be damaged.

The global ocean economy (fishing, shipping, offshore energy, coastal tourism and marine biotechnology) was valued at USD 2.6 trillion in 2020 by the OECD[19], doubling in real terms since 1995. If the ocean economy were a country, it would rank in the top 10.

Food, water and energy:

Fisheries and aquaculture currently sustain 600 million people worldwide[20], the majority in developing countries. More than 3.3 billion people obtain at least 20% of their daily animal protein from fish and seafood[21], with fish making up around 17% of total global animal protein consumption. Around 300 million people drink fresh water obtained through desalination, which provides over half of drinking water in some arid countries.

Offshore wind, wave, tidal and ocean thermal energy represent a rapidly expanding share of renewable energy capacity. Alongside offshore oil and gas, the ocean is increasingly central to the global energy transition, with offshore wind alone a primary driver of projected growth in the ocean economy to 2030 and beyond.

Individually, these benefits range from important to critical. Taken together, it becomes clear that the ocean is not simply a resource to be managed; it is a fundamental enabler of human existence. Every breath, every meal, every raindrop, every traded good, every stable climate - all are, in some measure, gifts of the ocean. As Helen Czerski puts it, "the ocean is the big beast in Earth's planetary machinery"[22]. Protecting ocean health is therefore not a moral issue, nor the protection of a distant natural environment or enigmatic ocean megafauna; we are quite simply protecting ourselves, our health, our livelihoods and our economies.

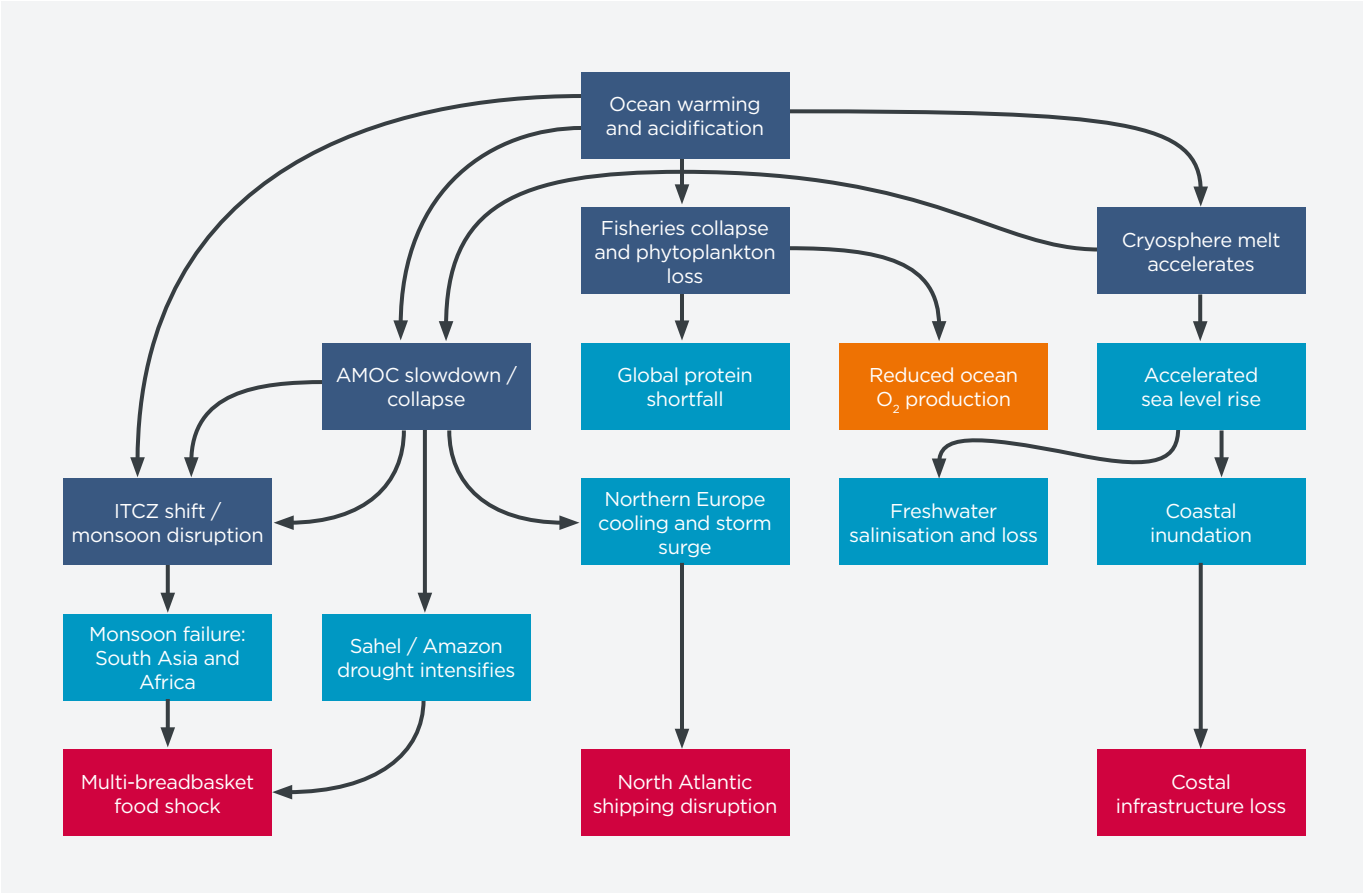
Systemic implications – transmission mechanisms

From an ocean health perspective, these are not isolated environmental statistics - they are warning lights on the dashboard that underpins monetary stability, trade, food systems, coastal infrastructure, economic growth and a stable climate. Several critical indicators are already in red territory, while others point to deterioration or increasing instability.

Of particular concern is the interaction between these risks: ocean warming, acidification, biodiversity loss, fisheries stress and circulation changes do not occur independently, but reinforce one another and increase the likelihood of wider systemic disruption. This is illustrated in *Figure 6* below, which illustrates how one ocean risk can cascade to drive other risks and impacts. This is not an exhaustive risk analysis.

Figure 6: Ocean risk transmission mechanisms

Source: Authors



The planetary risk challenge for financial actors

In this paper, we apply the Planetary Solvency RESILIENCE framework to ocean health and Ocean Solvency. Our thesis is that economic activity and financial stability rest on ocean health, due to the range of critical services provided by the ocean. We bring this to life by exploring a pension case study, which demonstrates why failure to manage ocean health directly risks future retirement incomes. While the case study focuses on pensions, the principles hold for other economic actors such as banks, insurers and treasuries.

The Planetary Solvency report *Tipping into the Wild Unknown*[23] recommends that financial firms develop qualitative narrative scenarios that incorporate nature-related risks and recognise systemic risk.

Understanding the importance of ocean health and Ocean Solvency is only the first step. Equally important is understanding how a deterioration in ocean health could propagate through society and the economy. To explore these transmission pathways, this report develops a plausible systemic-risk scenario, *Ocean Maelstrom*, which illustrates how interacting ocean, climate and geopolitical pressures can trigger cascading impacts across societies, economies and financial systems.



Our thesis is that economic activity and financial stability rest on ocean health, due to the range of critical services provided by the ocean.



Part 2:
The cost of ocean blindness

When overlooked ocean risks interact with climate, economic and geopolitical pressures, creating cascading impacts across society, the economy and financial systems

This section explores:

IV. Ocean Maelstrom

The systemic risk scenario illustrating how overlooked ocean risks can interact and create cascading impacts.

1 Understanding the challenge

2 The cost of ocean blindness

3 Evidence, exposure and action

III: Ocean Maelstrom – A systemic risk scenario

Ocean Maelstrom is a plausible, adverse systemic-risk scenario, not a forecast. It explores how six individually plausible ocean and geopolitical pressures could interact between 2027 and 2035, producing impacts greater than the sum of their parts.

Each trigger is supported by existing scientific or geopolitical evidence. Ocean Maelstrom does not assume certainty that all events occur together. Rather, it examines the consequences should several recognised risks interact within the same period, amplifying their combined effects. The scenario is intended as a stress test of resilience rather than a prediction of future events.

Scenario drivers: climate, geopolitics and sustained ocean pressure

- Sustained geopolitical fragmentation affecting ocean governance, fisheries access and shipping lanes.
- Weak or unenforced international ocean regulation (High Seas Treaty commitments, International Seabed Authority (ISA) seabed mining oversight) allowing exploitation to continue despite ecological stress.
- An unprecedented, 'super' El Niño event beginning in 2026 and continuing through 2027, releasing substantial stored heat from the Pacific and raising global average temperatures by as much as 0.2°C over 18 months — equivalent to a full decade of historical warming.

In line with Planetary Solvency RESILIENCE principles, Ocean Maelstrom is risk-led and science-informed. It is not a forecast of the most likely future, but an internally consistent illustration of how known, individually plausible ocean risks could compound into a systemic shock. Like all scenarios, it is subject to uncertainty and should be viewed as a tool for testing resilience and informing decision-making, rather than predicting future outcomes.

Ocean Maelstrom is risk-led and science-informed.

Trigger events

1. **Compounded El Niño and accelerated warming**
   The super El Niño amplifies existing ocean heat-content extremes, driving intense marine heatwaves, altered rainfall patterns and shifts in the Inter-Tropical Convergence Zone. Regions dependent on stable monsoon systems and productive upwelling ecosystems, including South and Southeast Asia, West Africa and the Peru-Chile anchovy fishery, experience severe disruptions to food production across both marine and terrestrial systems.

2. **Accelerated AMOC slowdown**
   The heat pulse increases Greenland/Arctic melt to accelerate AMOC slowdown, with shifts in North Atlantic temperature gradients and sub-polar gyre disruption apparent by the early 2030s. This leads to changed weather patterns, harvest disruption, accelerated Eastern seaboard sea level rise and temperature extremes.

3. **Coral reef tipping point**
   Sustained marine heatwaves push warm-water coral reefs decisively past their thermal tipping threshold. Reef-dependent fisheries, coastal protection and tourism economies experience rapid, near-irreversible decline across the Indo-Pacific, Caribbean and Coral Triangle.

4. Geopolitical amplification

Existing tensions in critical maritime chokepoints (analogous to current Strait of Hormuz disruption) compound the climate-driven shocks. Distant-water fishing fleets, facing collapsing catches in traditional grounds, expand aggressively into contested or lower-income coastal states' exclusive economic zones, escalating maritime disputes. Deep-sea mining proceeds unilaterally in some jurisdictions amid fragmenting international governance, further damaging fragile ecosystems and increasing diplomatic friction.

5. Fisheries and food system stress

Compounding biological stress (marine heatwaves, coral loss and deoxygenation), together with geopolitical fishing pressures, drives multiple regional fish-stock collapses. The resulting multi-region food security shock coincides with El Niño-driven agricultural losses on land, amplifying pressure on global food systems.

6. Accelerated sea-level rise from cryosphere melt

Concurrent destabilisation of the West Antarctic and Greenland ice sheets, triggered independently but reinforced by the same warming pulse, accelerates global sea-level rise and contributes to further weakening of the AMOC. Coastal property, ports and infrastructure in vulnerable, high-exposure regions face increasing inundation and storm-surge risks, while AMOC slowdown further elevates relative sea levels along parts of the eastern seaboard of North America.

A critical feature of Ocean Maelstrom is the interconnectedness of the six triggers, as illustrated in *Figure 7* below. For example:

- Cryosphere melt weakens the AMOC, altering regional weather and compounding agricultural disruption.
- Ecological decline and resource scarcity amplify geopolitical tension, weakening the cooperation needed to address the underlying risks.

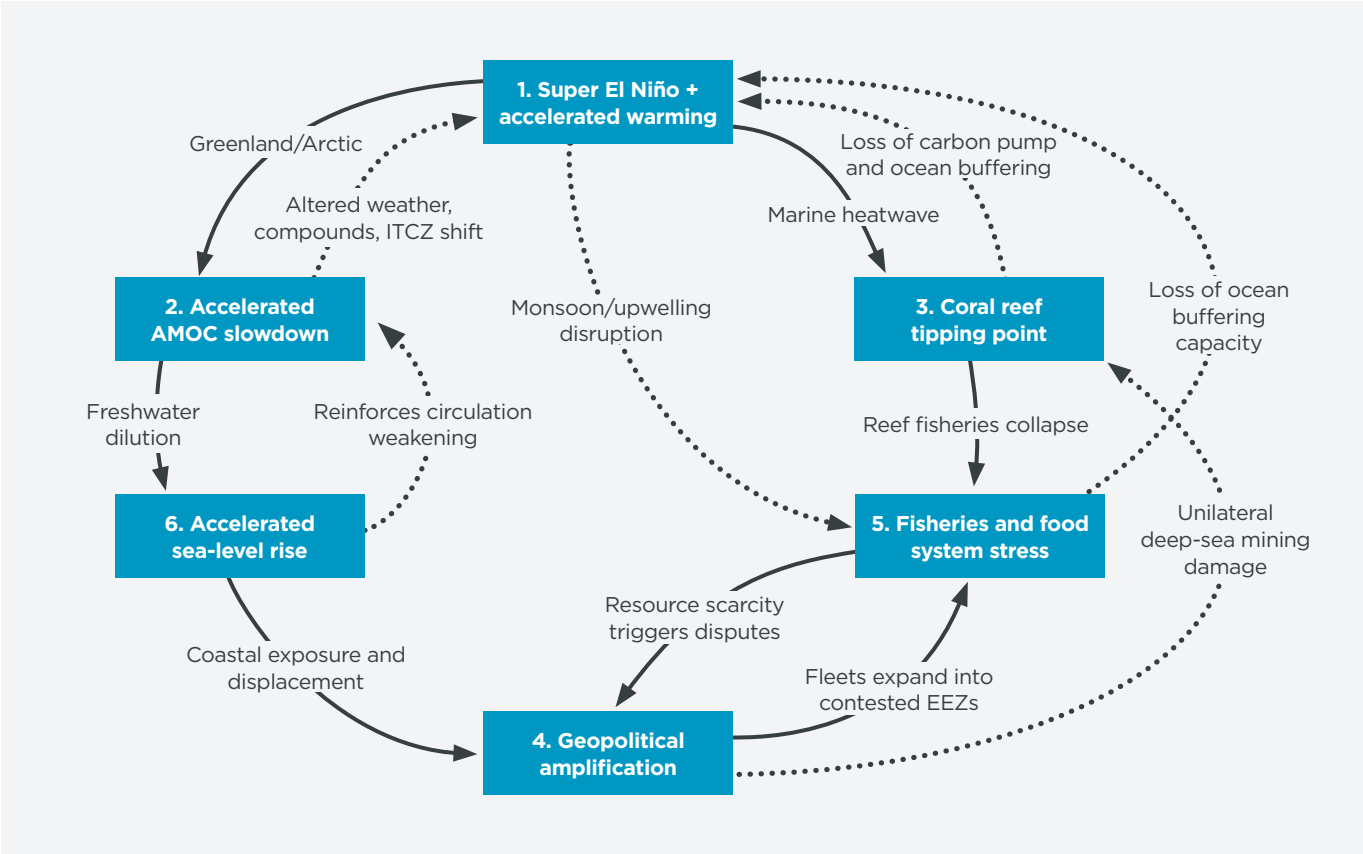
This scenario would negatively impact each dimension of the ocean risk impact matrix (warming, pollution, biodiversity), as well as increasing geo-political tensions and economic stress.

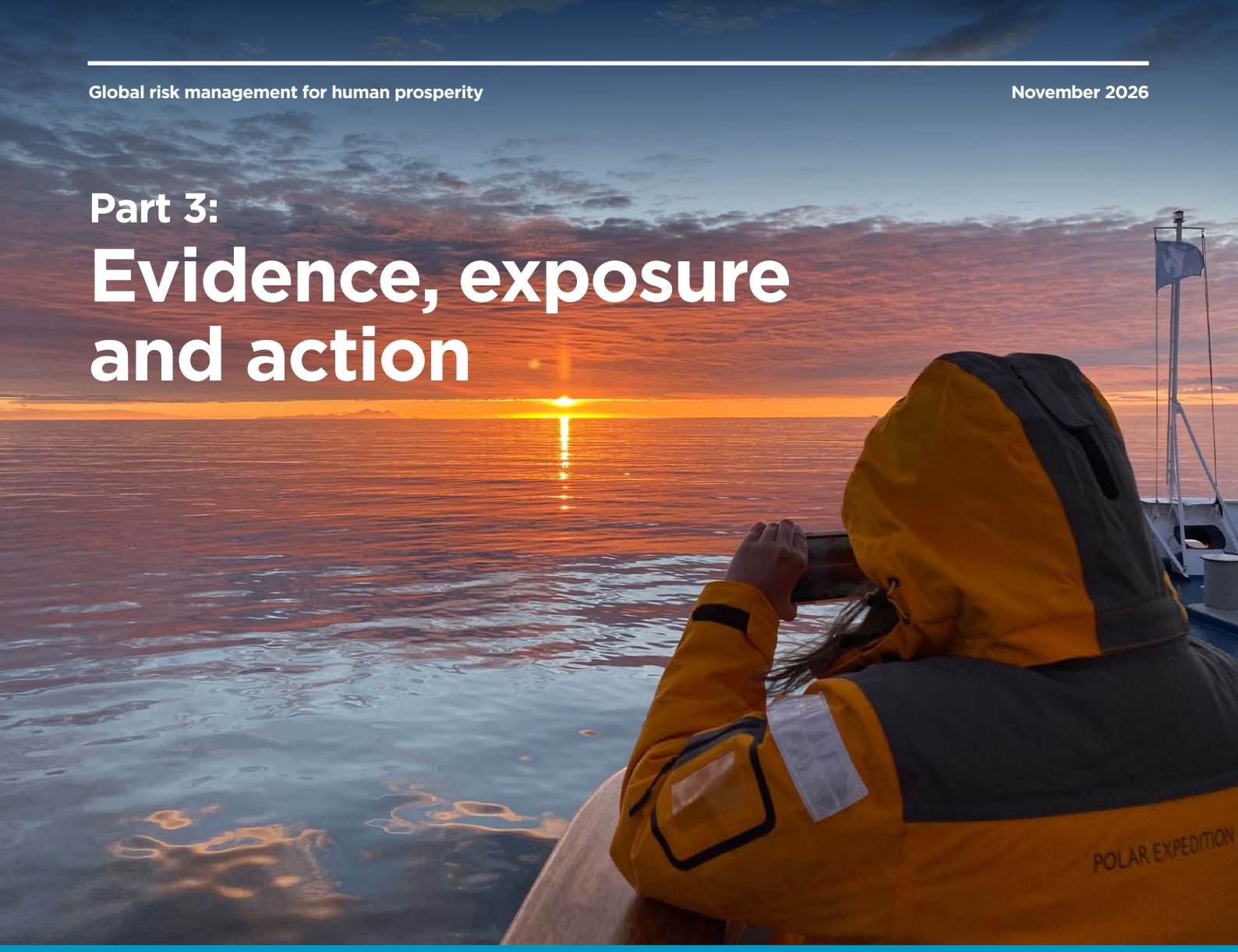
Transmission channels

These interacting physical and geopolitical shocks transmit through food, trade, inflation, insurance, sovereign and financial-market channels. The following section examines implications for pensions. Further analysis on transmission channels can be found in Planet Tracker's 'Catch it like it's hot'[24].

Figure 7: Ocean Maelstrom interactions

Source: Authors





Part 3: Evidence, exposure and action

Examining the evidence underpinning ocean-related risks, assessing economic and financial exposure and identifying pathways to strengthen resilience.

This section explores:

IV. Ocean risks and tipping points

Evidence underpinning the scenario.

V. From ocean health to pension outcomes

Implications for pension funds and long-term investors.

VI. The ocean say-do gap

Why actions remain insufficient.

VII. Recovery plan recommendations

Strengthening resilience and stewardship

1 Understanding the challenge

2 The cost of ocean blindness

3 Evidence, exposure and action

IV: Ocean risk and tipping

In this section, we provide further analysis to support the Planetary Solvency ocean risk assessment presented in the Executive Summary, which draws on evidence from the Planetary Health Check, Ocean Health Index, IPBES and World Ocean Assessment. We explore non-linearity, ocean tipping points and the potential for cascading risks.

What is particularly concerning from a risk-management perspective is that the estimated probabilities of crossing major climate and ocean tipping points are substantially higher than the levels of failure risk typically accepted in insurance and other safety-critical sectors.

As discussed further in **Appendix A**, recent research suggests that the probability of the AMOC already being committed to collapse may be comparable to the odds of losing Russian Roulette. Such levels of risk would be considered unacceptable in many other areas of human endeavour. These concerns may be further amplified if the higher climate sensitivity estimates discussed in *Parasol Lost: Recovery Plan Needed* prove correct, as these would increase both the likelihood and duration of temperature overshoot. This reinforces the importance of rapidly moving to a solvency-based approach, which seeks to reduce the probability of failure to acceptably low levels.

Planetary Solvency ocean risk assessment

The 2025 Planetary Health Check[25] warns that the ocean's life-support systems have entered the "danger zone." Ocean systems face three key risks: climate change, pollution and marine overexploitation. These are placing pressure on marine ecosystems, undermining biodiversity and the ocean's ability to regulate the climate, with impacts including warming, acidity, pollution, dead zones, dramatic reductions in biomass and biodiversity, coral reef bleaching and ice melt. These risks do not operate in isolation: they interact and reinforce one another, increasing the likelihood of ecosystem disruption, regional collapse and wider economic and societal impacts.

The Ocean Health Index (OHI)[26] provides a composite score of how well the ocean delivers a suite of ecological, social and economic "goals" across 220 coastal countries and territories. After more than a decade of annual assessments, global average scores hover in the low 70s out of 100, with limited evidence of sustained improvement and persistent underperformance on habitat condition and biodiversity. IPBES[27] warns that "Human activities have had a large and widespread impact on the world's oceans". Despite significant pledges and commitments, adequate oversight and enforcement are lacking[28].

The third World Ocean Assessment (WOA)[29] complements this with a narrative synthesis: despite some local successes, "overall ocean health is poor and deteriorating", with cumulative impacts from warming, acidification, pollution, overexploitation and habitat loss pushing many systems beyond historically observed ranges. Further, risks are accelerating beyond model projections: for example, marine heatwaves, seasonal acidification events and oxygen depletion are now causing ecosystem regime shifts[30].

These messages are reinforced in the 10th Copernicus Ocean State report[31] which highlights both ocean extremes, including unprecedented ocean heat variations and concerning long term trends. Taken together, these reports tell us the stability and functionality of the ocean is under sustained, systemic strain.

We illustrate our assessment of Ocean Solvency against this context in the diagram on the following page, finding that the ongoing ability of the ocean to support our society is threatened. The risk rating is calibrated against the Ocean Solvency impact matrix, shown in **Appendix C**, with the RESILIENCE principles. The purpose of the dashboard is not to predict specific outcomes, but to provide an indication of whether the underlying health of the ocean system is strengthening or weakening over time.

Such levels of risk would be considered unacceptable in many other areas of human endeavour.

A: Climate change
Ocean warming and circulation

Risk rating:	Risk trajectory:
SEVERE	**DETERIORATING**

- Ocean temperatures and heat content at record highs, majority of excess planetary energy absorbed by ocean, but heat sink capacity may decline (possibly offset by impacts from coral reef loss[32]).
- AMOC moving into tipping-point danger zone; slowdown already measurable and accelerating.
- Marine heatwaves increasing in frequency/intensity; sea-level rise accelerating from cryosphere melt.
- In 2026, the global ocean recorded its warmest summer on record. The developing El Niño has added a major Pacific heat pulse to this.

B: Pollution
Ocean chemistry and novel compounds

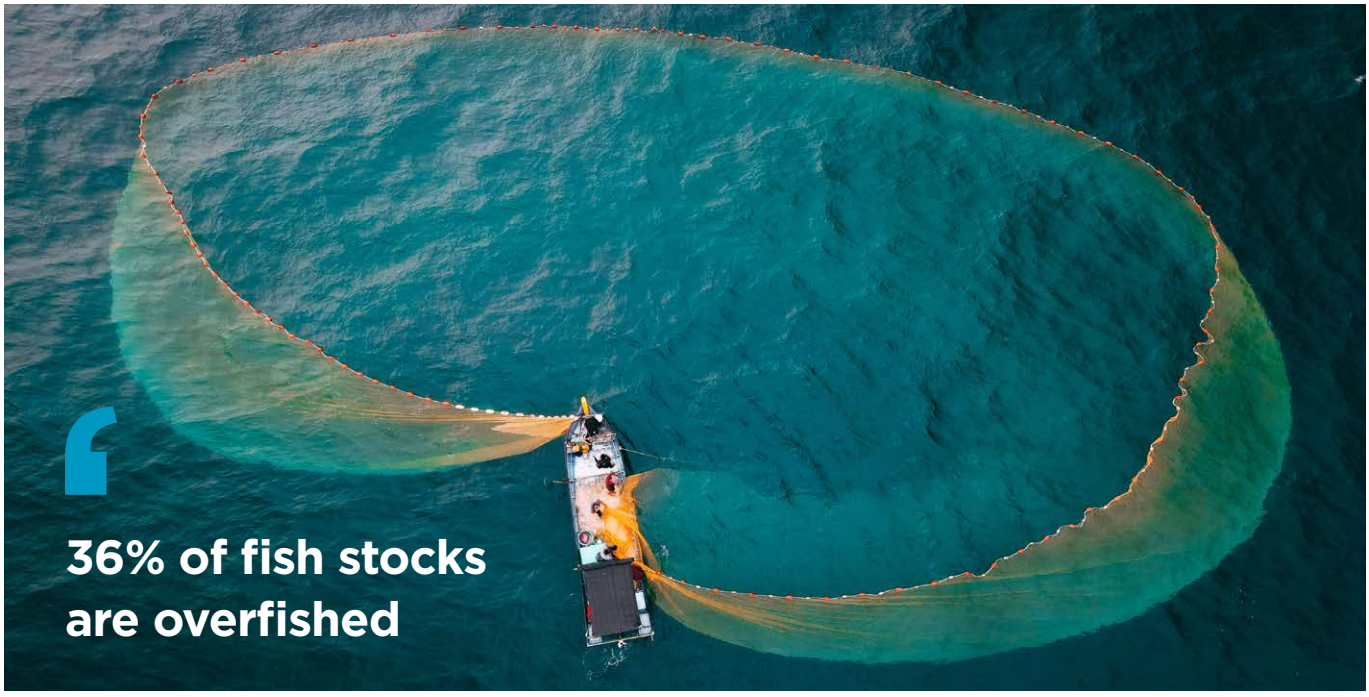
Risk rating:	Risk trajectory:
SEVERE	**DETERIORATING**

- Ocean acidification since pre-industrial era; ocean absorbed significant CO2 since 1980s but carbon sink capacity may decline[ii].
- Significant deoxygenation expansion since mid-20th century; hundreds of hypoxic dead zones globally.
- Microplastics detected from surface to deep sea; emerging food-chain liability across supply chains.

C: Exploitation
Biodiversity and biological systems

Risk rating:	Risk trajectory:
SEVERE	**DETERIORATING**

- 36% of fish stocks overfished; sustainable stocks fallen from 90% (1974) to 65% (2021); trend accelerating and fisheries resilience declining.
- Coral reefs: An estimated 70-90% of warm-water coral reefs are projected to experience severe decline at 1.5°C of warming, rising to more than 99% functional loss at 2°C. This would result in significant wider marine biodiversity loss.
- Bottom trawling weakens biological carbon pump; fisheries policy is a currently unrecognised climate policy lever.
- Impact of noise pollution on marine animals and cephalopods



ii | Counterintuitively, the decline of coral reefs may provide an increase in the ocean carbon sink capacity due to declining coral calcification, illustrating the importance of a systems approach.

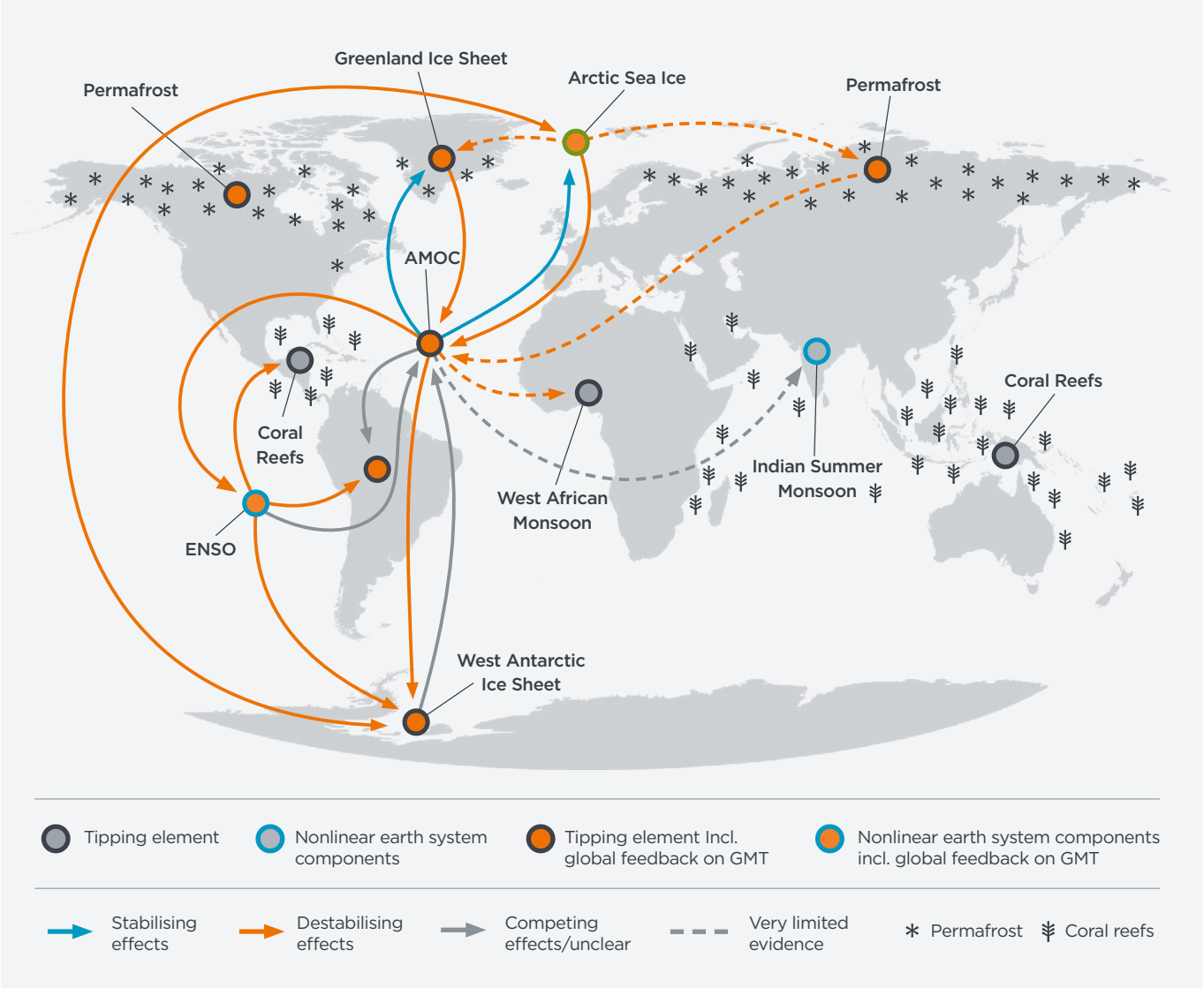
Ocean tipping points

A tipping point is a critical threshold in a natural system where gradual pressure leads to a much larger shift, often pushing the system into a new state that can be abrupt and hard or impossible to reverse. Once a tipping point is crossed, change can become self-reinforcing, making it more difficult for ecosystems and societies to adapt.

Figure 8 below shows a number of major tipping points and their interactions. It is important to understand that these are not independent processes and tipping points can act to accelerate other tipping points. For example, the Greenland Ice Sheet tipping into irreversible decline would increase the flow of freshwater into the North Atlantic, increasing the disruption to deep-water formation processes and the likelihood of AMOC slowdown or collapse.

This analysis illustrates how ocean tipping points would drive abrupt, consequential and irreversible changes to major Earth-system processes, with impacts including additional warming, disruption of fisheries and accelerating sea-level rise. Further detail on individual tipping elements and AMOC-related risks is provided in **Appendix A**

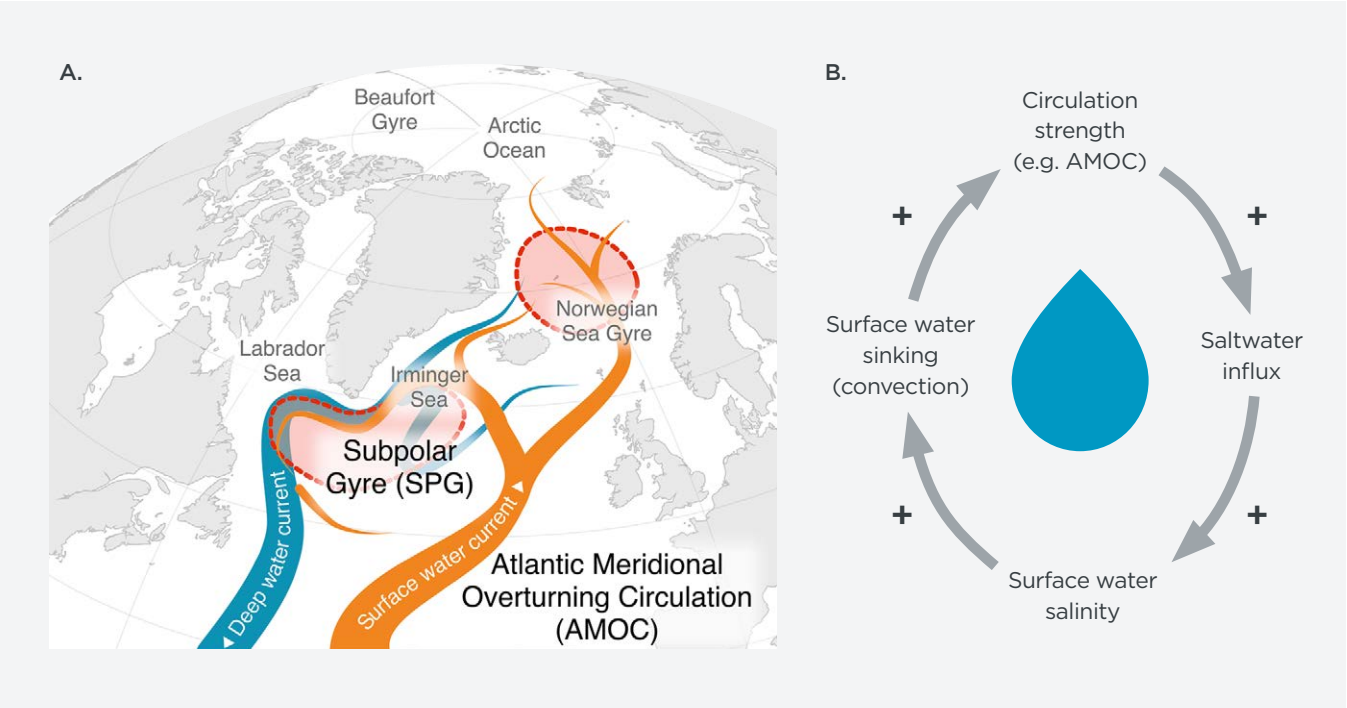
Figure 8: Interactions between tipping elements on a world



Source: Wunderling et al, Climate tipping point interactions and cascades: a review[34], Creative Commons

ii | Counterintuitively, the decline of coral reefs may provide an increase in the ocean carbon sink capacity due to declining coral calcification, illustrating the importance of a systems approach.

Figure 9: Ocean circulation systems in the North Atlanticmap



Source: Loriana et al, Tipping points in ocean and atmosphere circulations [35], Creative Commons

Figure 9 above illustrates the major ocean currents in the North Atlantic and, on the right, the processes that drive them. The surface currents (in orange) are connected to the deep-water currents (in blue) through sites where dense (i.e cold and salty) water sinks, driving over-turning (in pink).

In the future, fresh water from ice melt is expected to reduce the salinity of surface water and disrupt the deep-water formation process, weakening the AMOC significantly – or even collapsing the flow [36].

The examples presented in this section illustrate why ocean risks cannot be understood solely through gradual trends or historical experience. As pressure on ocean systems increases, the potential for non-linear change and cascading impacts becomes more relevant to policymakers, regulators and investors. While there remains uncertainty around the timing and severity of individual tipping points, the evidence suggests that the resilience of critical ocean systems is being progressively eroded. This reinforces the Ocean Solvency assessment presented above and highlights the importance of considering ocean-related risks within long-term resilience and risk-management frameworks. Further discussion of ocean tipping points and the AMOC is provided in **Appendix A.**

As pressure on ocean systems increases, the potential for non-linear change and cascading impacts becomes more relevant to policymakers, regulators and investors.

V: From ocean health to pension outcomes

In this section, we illustrate how risks driven by the Ocean Maelstrom scenario translate into socio-economic risks, with the potential to affect financial outcomes We consider impacts on the pension system, exploring how future retirement income adequacy could be put at risk and how these risks could be mitigated.

A systems view matters for pension outcomes because long-term investment returns ultimately depend on the health of the environmental systems that support economic production, social stability and human wellbeing. Ocean health may be as important to future retirement adequacy as pension contributions, given the ocean's significant role in Earth's climate.

The Global Pension Assets Study 2026[37] reports global pension assets reached $68.3 trillion in 2025 across 22 major markets, representing around 1/3rd of global capital markets[38]. The study shows a structural shift to defined contribution (DC) pensions: in the largest seven markets (P7), 63% of assets are now DC, with defined benefit (DB) schemes "maturing, paying out benefits and de-risking", especially in the UK.

A substantial proportion of pension assets supports people whose retirement extends well beyond 2040, making long-term Earth-system stability directly relevant to member outcomes.

Why planetary risks are different

Conventional pension risk analyses typically focus on:

- Equity market corrections, which primarily affect assets.
- Changes in longevity assumptions, which primarily affect liabilities.
- Interest rate stresses, which impact both assets and liabilities.
- Covenant or contribution deterioration, which primarily affects employer or individual pension contributions.

Ocean-related risks are different because they have the potential to affect assets, liabilities and covenant strength simultaneously, as well as driving inflation. These transmission channels are illustrated in ***Figure 2*** earlier in this report. This creates a form of systemic risk that may be broader, more persistent and less diversifiable than many conventional pension risks - particularly if traditional risk models assume underlying system stability.

As a result, ocean risk should not be viewed as a sector-specific environmental issue. It is more appropriately understood as a systemic risk with the potential to affect the fundamental drivers of long-term retirement adequacy.

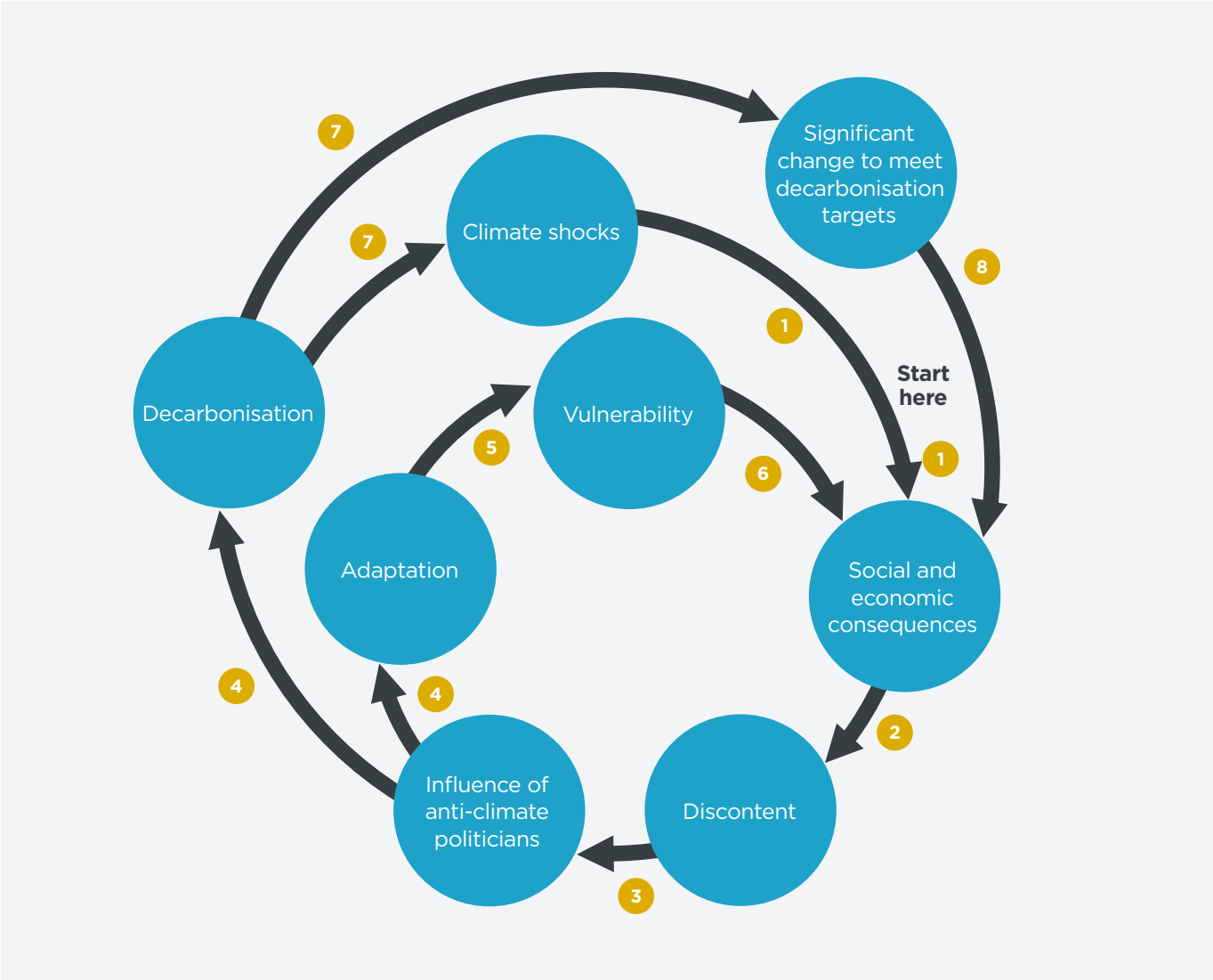
Collectively, these risks could negatively impact retirement outcomes, summarised in *Table 1*.

Table 1: Summary of impacts on pension schemes from ocean-driven risks

Channel	Pension effect
Growth and inflation	Lower real returns, higher indexed liabilities and reduced contribution capacity from firms and individuals
Interest rates	Funding-ratio volatility and pressure on long-duration assets
Corporate exposure	Lower earnings and weaker sponsor covenants in exposed sectors
Sovereign exposure	Currency, credit and refinancing stress in ocean-dependent economies
Real assets	Repricing of coastal property, ports and infrastructure as physical risk and insurance costs rise
System feedback	Reduced fiscal and financial capacity to fund adaptation and ocean restoration

Figure 10: The derailment risk dynamic

Source: Strategic Climate Risks Initiative



The derailment dynamic

Derailment risk[39] describes the dynamic where society is too distracted by escalating crises to address the root causes. Critically, the macro-financial and geo-political channels feed back into the physical scenario:

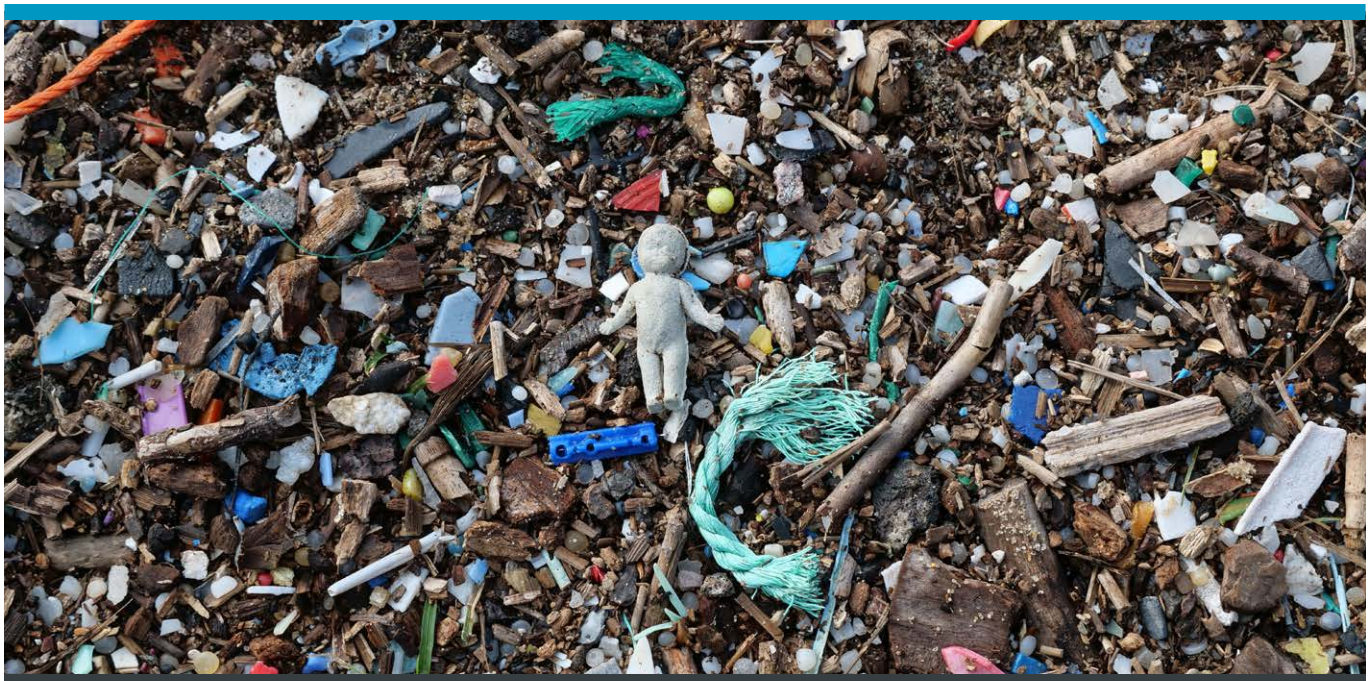
- A lack of global consensus may increase the difficulty of implementing coordinated ocean governance;
- Reduced fiscal and economic headroom may limit capital availability for ocean restoration and climate stabilisation investment, reinforcing the underlying drivers of Ocean Maelstrom disruption.

Implications for pensions governance

The central insight of this report is that Ocean Solvency supports Planetary Solvency, and Planetary Solvency supports Pension Solvency and future retirement outcomes. Identifying, assessing and managing financially material risks that could affect member outcomes is a clear requirement for those charged with governance. The evidence presented in this report suggests that planetary and, in particular, ocean-related risks are now relevant to that responsibility.

Because many pension models assume underlying system stability, they may understate the pace, non-linearity and systemic consequences of ocean risk.

As with climate risk more broadly, the greatest danger lies not just in the scale of ocean-related threats but in the persistent underestimation of their pace, non-linearity and systemic consequences — making early, precautionary action markedly less costly than a disorderly, delayed response.



Case study
Microplastics policy advocacy[40]

Since 2020, First Sentier Investors has led an investor coalition, in collaboration with the UK's Marine Conservation Society, to encourage manufacturers of domestic and commercial washing machines to fit microfibre filtration technology as a standard feature. In addition to engaging with companies, the coalition has also engaged with policymakers and regulators. There has been considerable progress, including the introduction of filtration technologies by manufacturers and increasing policy and regulatory attention to microfibre pollution in jurisdictions including France, the UK, the EU and Australia. This demonstrates how investors can engage constructively to improve ocean health.

Five practical questions for those in governance positions to ask are:

1. Which ocean-related transmission channels could affect assets, liabilities and contributions simultaneously?
2. Which material risks are excluded from our current scenarios?
3. How would one severe, short-horizon systemic scenario change our decisions?
4. Which indicators would warn that risk is crystallising?
5. Which actions can we take directly, and which require policy or collective engagement?

Recent publications that provide further guidance include:

- '*Using scenario analysis for future resilience*'[41], a practical guidance from Accounting for Sustainability (A4S)
- The *'Climate Investing Framework'*[42] from The Investment Consultant Sustainability Working Group, which provides practical suggestions.

The preceding sections have illustrated how ocean risk could manifest and transmit into pension outcomes. The following section explores ocean health recovery, providing case studies, an overview of the investment landscape and the 'say-do' gap between global ocean health commitments and their execution.

VI: The ocean say-do gap

In this section we highlight the opportunity for ocean health recovery, highlighting a small number of examples. We summarise the development of ocean finance and the commitment to ocean health indicated by global treaties. We also examine the ocean governance gap, highlighting the persistent mismatch between stated ambitions, implementation and enforcement. A number of contemporary examples demonstrate how this ocean "say-do" gap continues to impede progress towards agreed objectives.

The opportunity – ocean recovery is quick and can be material

Our Planetary Solvency recovery plan highlighted the opportunity to work with nature at scale. Protecting and restoring marine carbon sinks, including the restoration of marine biomass, offers significant carbon sequestration potential. Action on over-fishing and bottom trawling, including implementation of marine protected areas, are an urgent priority.

This opportunity was reinforced by the *Tipping Points Playbook*[43], a study produced by the University of Exeter for The Earthshot Prize. The study examined positive tipping points capable of triggering rapid, self-reinforcing environmental recovery and found that 11 of the 51 solutions analysed related to reviving the oceans.

The systemic dynamics described on the risk side also have the potential to operate on the recovery side, via positive tipping points and co-benefits.

For example:

1. **Rapid decarbonisation** and action on climate change could lower ocean heat stress and acidification rates, reducing tipping point likelihood.
2. **Implementing Marine Protected Areas at scale** allows ecosystems and fish stocks to recover, supporting fisheries[44].
3. **Mangrove and seagrass restoration,** backed by policy and finance, supports carbon capture at scale, coastal protection and climate mitigation.

Some components of ocean recovery, such as fish stock recovery, can occur relatively quickly[iii], and often deliver benefits beyond the boundaries of protected areas.

A UN report[45] documents 237 projects globally, with the most activity focused on coral, mangrove and seagrass restoration.

Examples include:

1. **Isle of Arran, Scotland**
   As a result of intensive fishing by bottom trawlers, local waters were literally emptied of fish in the 80s, with negative impacts for local communities. Two local people eventually managed to establish the first community marine reserve in the UK, including a 'no-take zone'. Since then, lobster and scallop numbers have quadrupled within the zone, and scallops have increased even more in the wider area. The recovery has benefited the environment and fishers.

2. **Reviving tengefus in Kenya**
   In Kenya, before colonisation, fishers typically used a technique known as tengefu. It involved temporarily closing some fishing grounds so that fish populations could replenish and future harvests could be maximised. A number of communities have revived this traditional practice, with impressive results. In areas where tengefu closures have been implemented, fish biomass is estimated to be four to five times greater than in adjacent areas. As a result, the per-capita income of fishers operating near these areas is reported to be 135% higher than that of fishers operating without such restrictions.

iii | Seagrass recovery can range from ~1 to more than 20 years, while mangroves can require decades. Coral recovery can be slow or fail under recurrent heat stress. Deep-sea ecosystems recover much more slowly, with recovery periods potentially extending to several decades or centuries.

Wider initiatives include the development of ocean rights, improved monitoring of ocean activity leveraging satellite data and AI and collaboration between NGOs and governments to support improved enforcement. These case studies illustrate the essential role of ocean protection, collaboration and robust ocean governance in recovery efforts across the world.

Ocean Rights[46] build on the broader 'Rights of Nature' movement, which recognises nature, ecosystems and species-populations as rights bearing entities with legal standing. Applied to the ocean, this approach reframes marine systems not as assets to be exploited, but as living systems with inherent rights to exist, regenerate and maintain ecological integrity. Early precedents are emerging through national legislation, local governance initiatives and indigenous stewardship models, alongside growing academic interest.

A commitment to ocean health

A substantial governance architecture already exists, including United Nations Convention on the Law of the Sea (UNCLOS), the High Seas Treaty, the UN Fish Stocks Agreement, the 30x30 target, the ISA and the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR).

Taken together, these represent decades of patient multilateral diplomacy, genuine scientific input and real political capital. This framework, if implemented as intended, would deliver meaningful improvements in ocean health. The principal problem is not the absence of commitments, but weak implementation, monitoring and enforcement.

Developing ocean-positive investments

The ocean investment ecosystem is developing rapidly, with more financial actors entering this space, novel financial structures emerging and frameworks being established. Examples include:

- **Investable vehicles**
  The Ocean Risk and Resilience Action Alliance report[47] links ocean health to Planetary Boundaries and summarises six key areas of ocean investment: renewable energy, ocean technology, blue infrastructure, aquaculture and fisheries, ocean conservation and ridge-to-reef.

  The World Economic Forum projects that the ocean economy could double to $5.1 trillion by 2050[48]. Investors are increasingly targeting "living resources" (e.g. sustainable aquaculture) and "ocean energy" (e.g. offshore wind and wave power) as high-growth segments that decouple economic gain from environmental harm. Private investment firms are emerging, such as Katapult Ocean, which exclusively focus on ocean investment.

- **Standard and definitions**
  The Ocean Investment Protocol, launched in mid-2025, is a framework[49] that helps financial institutions move beyond 'pilot projects' to large-scale investments. It provides metrics for 'ocean-positive' outcomes, allowing banks to track if their money is actually restoring biodiversity or just 'blue-washing'. Other emerging models include Seatrees, which channels funding into coastal ecosystem restoration projects such as mangrove, seagrass and coral restoration while providing impact reporting to funders and corporate partners.

- **Revenue models including blue carbon**
  UK-based Rebalance Earth is pioneering the development of nature as an asset class, including developing novel financial structures that allow pension schemes to invest in projects such as oyster reef restoration[50].

  New research into 'Blue Carbon', the carbon captured and stored by ecosystems such as seagrass meadows, mangroves and tidal marshes, is improving understanding of how these ecosystems can contribute to climate mitigation. This can create revenue opportunities through carbon markets, helping to fund the conservation and restoration of these habitats while also delivering biodiversity, coastal resilience and water-quality benefits.

  This is still a small but growing market: a 2025 review[51] identified 81 Blue Carbon projects globally, covering 2 million hectares, with annual emission reductions of around 20.4 $MtCO_2e$.

- **Risk sharing and blended finance**
  Banks are acting to support the development of the Blue Bond market. BNP Paribas document the current state of the market and refer to a $12 trillion economic opportunity in clean ocean technology by 2050[52]. Mechanisms have been developed to improve risk-return profiles through de-risking mechanisms (such as guarantees, first-loss provisions)[53].

The ocean health 'say-do' gap

Consistent execution remains a challenge, however, with a gap between commitments and implementation. Several bodies, such as CCAMLR and the ISA, and voluntary declarations such as the Nice Action Plan, rely on consensus or voluntary compliance. A small number of blocking states can neutralise multilateral intent, even where rules are sound and the science is clear.

Despite growing recognition of ocean risks and ambitious international commitments, implementation continues to lag behind stated objectives. This can be viewed through three dimensions set out in the *Ocean Protection Gap Report 2026.*

The Ocean Protection Gap, 2026

- **Ambition gap:** Current national commitments imply only 12-15% of the ocean will be protected by 2030, well short of the agreed 30% target.
- **Implementation gap:** Around 10% of the global ocean is designated as protected or conserved, but only around 3.5% is assessed as effectively protected.
- **Finance gap:** Delivering marine 30×30 is estimated to require approximately US$16 billion per year, compared with current spending of approximately US$1.8 billion per year.

Source: ***Ocean Protection Gap Report 2026*** *– Together for the Ocean*

This is the ocean 'say-do' gap. There is no lack of rules, but a systematic and, in places, widening divergence between what the rules say and what happens in practice. *Figure 11* below sets out some examples of the gap between what the public is led to believe and what is actually happening in five areas where this gap is pronounced.

The say-do gap follows a consistent structure: an internationally credible-sounding label, body, or target creates public and investor confidence, while enforcement capacity, political will, or basic monitoring lags far behind the label's implied protection.

Figure 11: The ocean health 'say-do' gap

Initiative	What the public sees	What is actually happening
Marine protected areas (MPAs) Governments protecting large areas of ocean. For example, the UK has designed 377 MPAs covering over a third of its seas; global "30x30" pledge to protect 30% of oceans by 2030.	**A safer healthier ocean** Large areas set aside for nature, with stronger protection and biodiversity recovery.	**Protection on paper, not in practice** Bottom trawling is permitted in 90% of UK offshore MPAs. Vessels spent at least 20,600 hours fishing inside UK offshore MPAs in 2024 (55% French, 19% UK). A leaked EU report proposes banning trawling in MPAs only by 2030
Antarctic krill fishery (Sustainable 2 certification) Krill fishing is regulated by CCAMLR and the largest harvester holds a Marine Stewardship Council "blue tick" sustainability label.	**Regulated and sustainable** Manages by CCAMLR, with certification from the Marine Stewardship Council.	**Critical safeguards failing** A key 2024 conservation measure lapsed after China and Russia blocked its renewal. In 2025 the fishery rapidly exhausted its 620,000 tonne quota in small areas near whale feeding grounds. Studies link this to reduced humpback whale pregnancy rates. NGOs call for an immediate moratorium and reassessment of the certification process.
Fishing quotas / total allowable catches (TACs) Quotas are set through the EU Common Fisheries Policy based on "best available" science from ICES, with an 11% target for stocks outside safe biological limits.	**Science-based management** Quotas designed to keep stocks within safe biological limits, using the best available science from ICES	**Quotas set above the science** UK, Norway, Iceland, Faroe Islands set a 2026 mackerel quota 72% higher than ICES recommended maximum, on a stock ICES separately said needed a 77% cut. Over the last 15 years catches have exceeded scientific advice by 39%. NGOs say this is an "endemic" pattern, with catch limits routinely above the 5% stock-collapse risk threshold in multi-annual plans.
Deep sea mining Governance (ISA) The International Seabed Authority (ISA), a UN-backed body with 172 member states, is negotiating a "mining code" to regulate seabed extraction as the "common heritage of mankind".	**Global governance in place** A UN-backed body with 172 members working on a mining code to ensure responsible seabed extraction.	**Rules ignored, loopholes exploited** More than 40 ISA members support a moratorium, yet the US is issuing unilateral permits under a 1980 law, identifying 70 million acres for leasing. The ISA extended a contract for a company under investigation for potential breaches. The ISA has said unilateral mining would be "unlawful" but has no enforcement mechanism against non-member states.
Forced labour in seafood supply chains Seafood sold under retailer sustainability and ethical sourcing labels, backed by corporate self-audits and supply chain codes of conduct.	**Ethical and responsible** Labels and audits to ensure workers' rights and fair treatment throughout supply chains.	**Workers still exploited** ILO finds 1 in 8 migrant workers in SE Asian fishing and processing in forced labour (34% at sea for 6+ months). Half had identity documents withheld; average recruitment fees USD 2,580 (up to USD 8,730 for Vietnamese workers). Globally, ~128,000 in forced labour on fishing vessels; 1 in 5 fish caught via IUU fishing, where labour abuses are common. Corporate self-audits are structurally unable to detect abuse.

VII: Recovery plan recommendations

The central challenge is now execution. The following recommendations point to actions that regulators, professional bodies, advisers and major financial institutions could take to mitigate systemic risk. We distinguish between actions led by policymakers and those led by financial institutions, while recognising that systemic ocean risk can only be reduced through coordinated action.

Recommendations for policymakers

1. **Incorporate Planetary Solvency into national security risk assessments**

   Iceland has classified AMOC collapse as a national security risk[54] and the UK government published a national security assessment of biodiversity risk, finding global ecosystem degradation and collapse threaten UK national security[55].

   More broadly, countries now need to implement structured risk assessments, using national security risk assessment methodologies, to inform urgent adaptation activity and build support for mitigation, including protecting and restoring ocean health. These assessments should incorporate Earth system changes and how these transmit to societal risks.

2. **Communicate the level of risk and collaborate on solutions**

   Realistic risk assessments must be communicated to build and maintain support for risk mitigation. These should be public, similar to information updates provided during the Covid crisis.

   Policymakers must collaborate with civil society, business and finance on solutions, recognising the risk delineation presented here and the need to take a forward-looking systems view to developing solutions. A particular area of focus should be ensuring continuity of financial services across society: banking, insurance and pension provision.

3. **Approve a Planetary Solvency recovery plan to stabilise the Earth system**

   Planetary Solvency is threatened and a recovery plan is needed: a fundamental, policy-led change of direction, informed by realistic risk assessments that recognise our current market-led approach is failing, accompanied by an action plan that considers broad, radical and effective options[56].

   Key components of the plan should include working with nature on a global scale; this should also include structured delivery of the global ocean protection initiatives underway, recognising the ocean's critical influence.

4. **Adopt a Planetary Solvency mindset**

   A shift in perspective is needed, one that recognises that humanity is not separate from nature but embedded in, and reliant on, it. Furthermore, we are now required to actively steward the Earth system.

   To maintain Planetary Solvency, we need to put in place mechanisms that ensure our social, economic and political systems respect the planet's biophysical limits, thus preserving or restoring sufficient natural capital for future generations to continue receiving ecosystem services.

5. **Develop a vision for human progress to earn citizens' support**

   Surveys consistently show broad levels of concern and high levels of support for governments taking appropriate action on climate change, but in a contested information space it has been challenging to maintain consensus for climate and nature action. These actions are often presented as highly technical, expensive or restrictive, adding to people's daily burdens. The challenge for leaders is "not only to elevate climate and nature as issues, but also to elevate a vision for the future: to help citizens restore human progress as their aspiration and expectation for society"[57].

> **A shift in perspective is needed.**

Recommendations for financial services

1. **Recognise the systemic risk Earth system instability represents**

   Financial systemic risk became embedded in global financial governance after the Global Financial Crisis. This framework must now be expanded to capture Earth system risks, giving Globally Systemically Important Natural Systems[58] the same importance as Globally Systemically Important Banks and Insurers. Individual financial firms, as well as financial regulators, should implement structured, realistic, systemic risk assessments that meet the Planetary Solvency RESILIENCE principles to build understanding of risk position, trajectory, transmission channels and potential severity of impact.

2. **Understand the limits of dominant financial and economic models**

   Well-established model validation standards should be rigorously applied to assessment of climate and nature risks, recognising the limitations of first-generation models and the need to appropriately understand model solutions from external vendors. Institutions should confirm whether salient risks are captured, exploring omissions qualitatively through narrative scenario analysis, and quantitatively through out-of-model adjustments.

3. **Develop narrative systemic risk scenarios and devote time to these**

   Risk management is ultimately an exercise in imagination: envision what could go wrong and take action if the outcome is outside risk appetite. History has repeatedly shown that over-reliance on models and quantitative risk outputs can limit imagination, with plausible risk events dismissed as unlikely or impossible. Narrative scenarios help to unlock people's imagination and are a key part of understanding risks, particularly where these are novel or less familiar. Narrative scenario exercises may be a critical part of effective systemic risk management going forward, and institutions should think about how best to incorporate these in governance structures.

4. **Build systemic risk capability and capacity across financial services**

   Those in governance positions require support to develop their understanding of systemic risk, including understanding how Earth-system volatility can transmit through socio-economic systems to impact financial objectives. Curated events such as the Chapter Zero Planetary Solvency[59] experiential session for non-executive directors can support this and be replicated by institutions for their boards.

   Longer term, finance curricula must be updated to incorporate systems thinking and Earth system science. Actuaries, regulators and wider economic actors should have some familiarity with key concepts such as Planetary Solvency, Planetary Boundaries, the Economics of Biodiversity and tipping points.

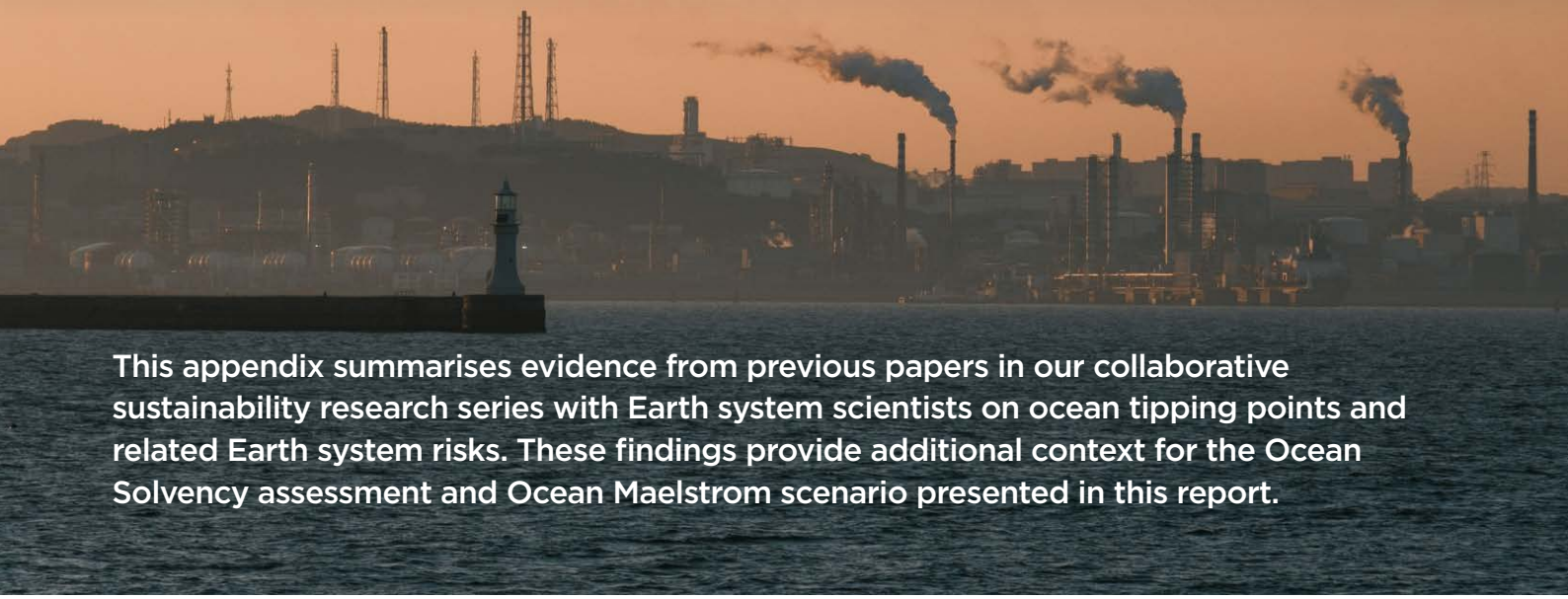
5. **Actively contribute to scaling solutions to mitigate systemic risk**

   It is important to recognise the limits on individual financial institutions' ability to manage and mitigate systemic risks driven by Earth system volatility. Systemic risk reduction remains a relatively new and non-standard area of work for many financial institutions. As a result, only larger firms may currently have the capacity to dedicate meaningful resources to it, highlighting the importance of industry collaboration, shared tools and common frameworks.

   Nonetheless, alongside the ocean-specific innovations described in this paper, solutions are being developed to help pension schemes and other investors allocate capital towards resilience and systemic risk reduction, such as the Strategic Asset Allocation in Resilience Investments (SAARI)[60] initiative. This approach could be replicated to further scale the ocean investment asset classes described. Additionally, financial firms may need to develop more structured policy engagement and systems-level stewardship approaches to support policymakers in implementing and enforcing ocean-related commitments, agreements and treaties.

> **Well-established model validation standards should be rigorously applied to assessment of climate and nature risks**

Appendix A: Ocean tipping point evidence base



This appendix summarises evidence from previous papers in our collaborative sustainability research series with Earth system scientists on ocean tipping points and related Earth system risks. These findings provide additional context for the Ocean Solvency assessment and Ocean Maelstrom scenario presented in this report.

A.1 Ocean tipping points

The table below sets out high level analysis for a number of ocean tipping points and their implications. This is not exhaustive.

Tipping point	Impact assessment	Wider implications
Coral reef collapse	Research suggests warm-water coral reefs have crossed a thermal tipping point, with 84% impacted by bleaching between 2023 and 2025[61]. Greater than 99% lost if we reach 2 degrees[62].	Reduces biodiversity, fisheries support and natural coastal protection. Implications for insurance costs and threats to tourism, food security and livelihoods.
Atlantic Meridional Overturning Circulation (AMOC)	New probabilistic modelling estimates the likelihood that we are already committed to AMOC collapse at between 10% and 23%[63].	Major climate disruption, abrupt regional change[64], significantly colder European winters[65], knock-on impacts for ecosystems, collapse of Northern Hemisphere staple crop production[66], risks to water systems, infrastructure and economic stability.
Antarctic ice sheet instability	A 1–2°C temperature risk could trigger the long-term collapse of about 40% of marine ice volume in West Antarctica[67].	Long-term, irreversible multi-metre sea-level rise, with major risks for coastal ecosystems, cities, infrastructure, insurance and adaptation costs.
Deoxygenation	Key oxygen thresholds are being approached rapidly, directly reducing habitable space for marine life and weakening ecosystem functioning. The ocean has roughly 500 coastal dead zones.	Biodiversity loss, food-system stress and economic damage for sectors and communities that depend on healthy marine ecosystems.

A.2 AMOC: A case study in ocean system risk

We explore the potential impact of AMOC slowdown in more detail below.

The consequences of AMOC weakening could be catastrophic. Northern Hemisphere staple crop-growing capacity could be significantly reduced. More than half the land suitable for growing wheat and maize could be lost[68]. At the same time, regional temperature patterns could be significantly altered. In some scenarios, significant cooling could occur in parts of northern Europe[69], with the potential for sea ice to reach as far South as Glasgow and Edinburgh should a collapse occur. This would happen even as global average temperatures continued to rise, disrupting weather systems, water availability and agricultural productivity.

Another impact of AMOC slowdown is accelerated sea-level rise on the Eastern seaboard. Although the physics are complex and it is hard to be precise, this effect, alongside accelerated glacial melt, could result in sea-level rise well ahead of IPCC worst-case scenarios. This would be in addition to recent concerns that sea-level rise is accelerating[70] and may have been underestimated[71].

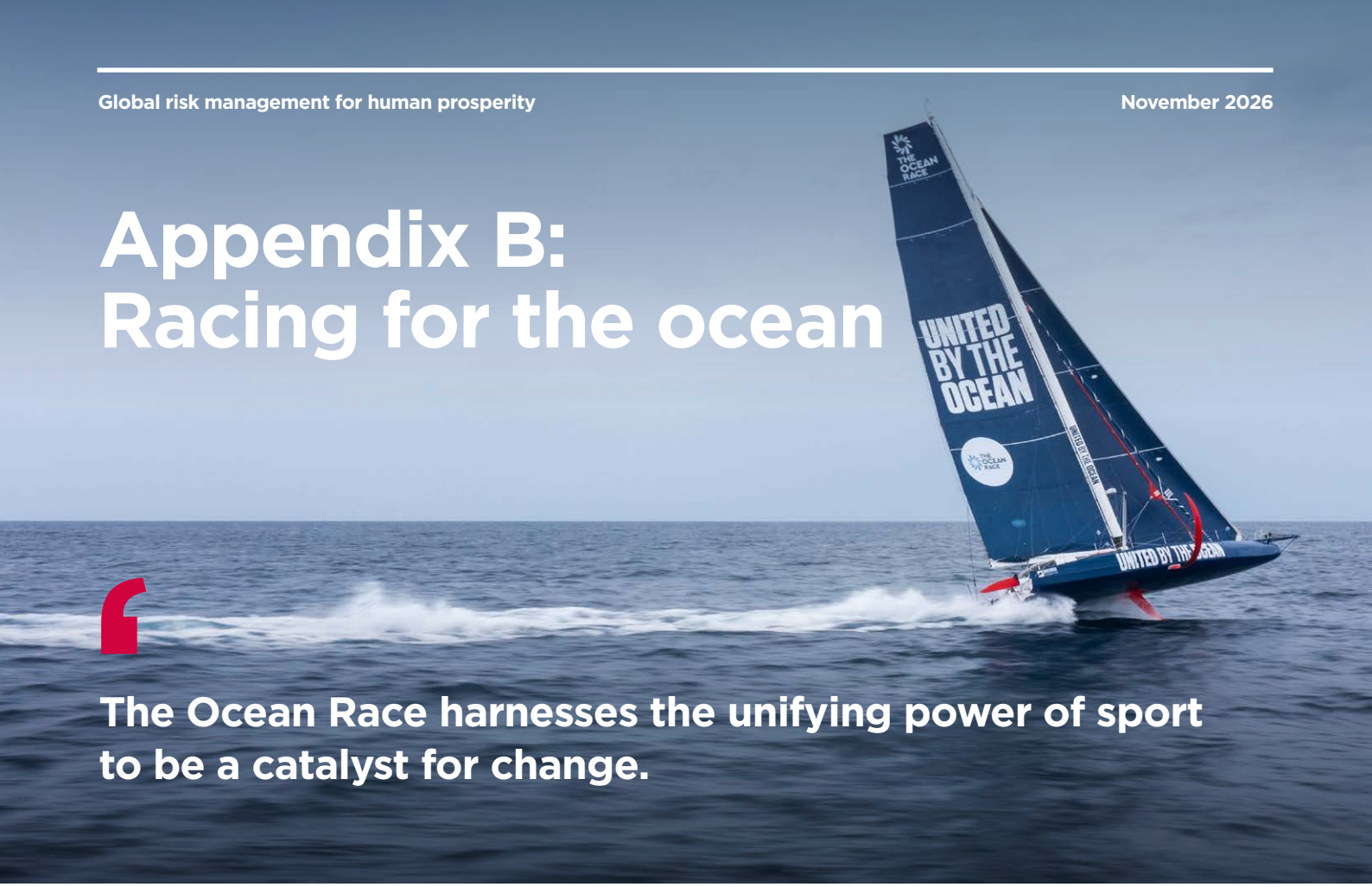
A consensus range across the literature is roughly 15-20cm of additional AMOC-attributable dynamic sea level rise under a realistic 21st-century weakening scenario, rising to 50cm-1m of additional regional sea level rise in the low-probability but physically plausible scenario of a full AMOC collapse[72].

A.3 Conclusion

The ocean tipping points discussed in this appendix illustrate why Ocean Solvency cannot be assessed solely through historical trends or incremental change. The potential for abrupt, non-linear shifts in critical ocean systems means that future risks may be significantly greater than those implied by past experience alone. While the likelihood, timing and severity of individual tipping points remain uncertain, their potential consequences are sufficiently material to warrant consideration within resilience planning and long-term risk management. Taken together, these risks provide further support for the report's central conclusion that maintaining Ocean Solvency is an important component of wider societal and economic resilience.

The potential for abrupt, non-linear shifts in critical ocean systems means that future risks may be significantly greater than those implied by past experience alone.

Appendix B: Racing for the ocean



The Ocean Race harnesses the unifying power of sport to be a catalyst for change.

Since 1973, The Ocean Race has been the ultimate test of a team and a human adventure like no other.

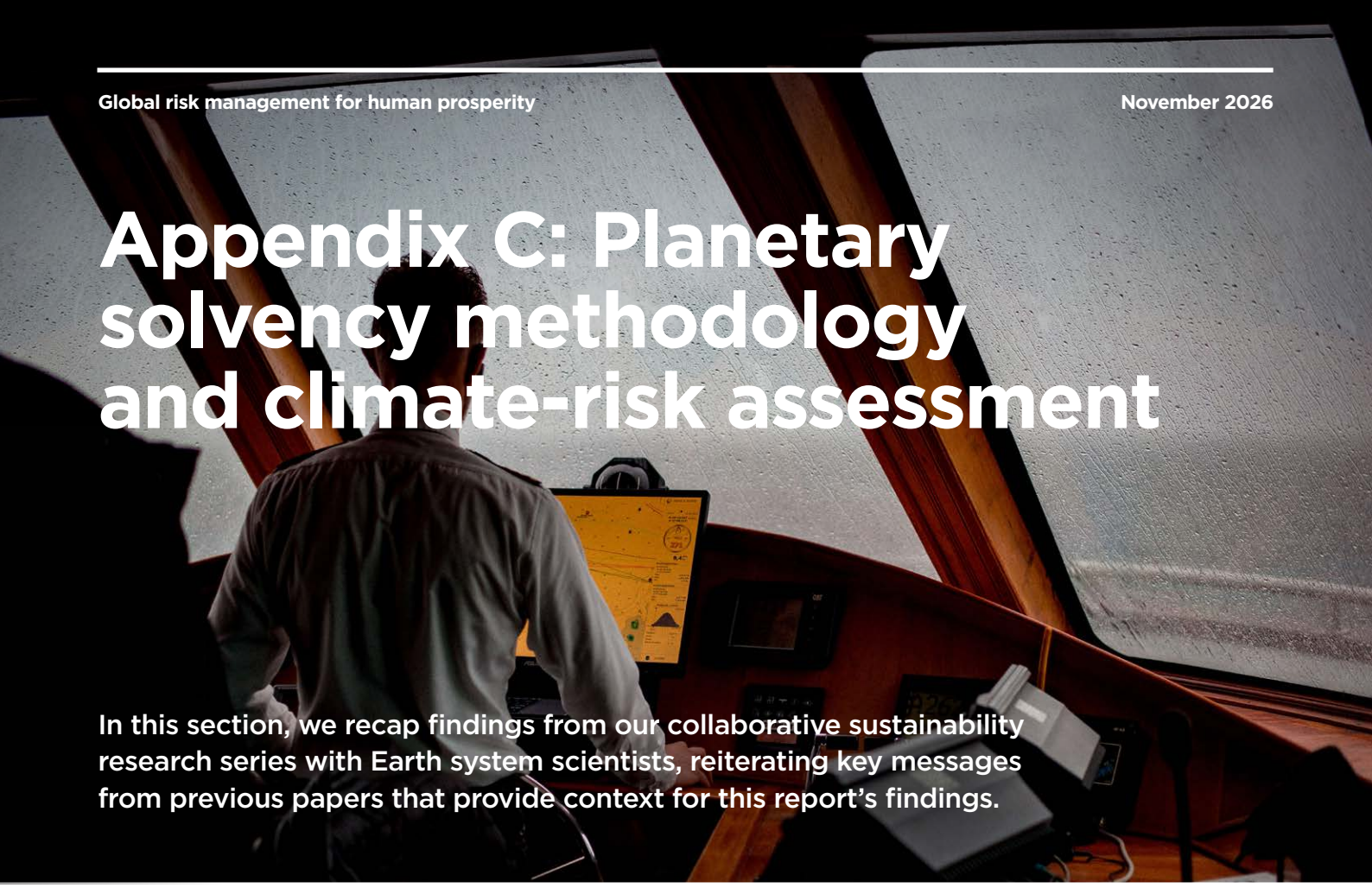
Racing around the world, through remote waters like the Southern Ocean, sailors have seen firsthand the devastating impact of pollution, climate change and industrial overfishing on the marine environment.

The Ocean Race harnesses the unifying power of sport to be a catalyst for change. Through its dedicated Racing for the Ocean sustainability programme, the organisation seeks to deepen understanding of our blue planet, inspire action to protect the seas and set new standards for sustainability in sailing, and beyond.

Racing for the Ocean, which aligns with the UN Ocean Decade Vision 2030 Challenge 10: restoring society's relationship with the ocean, has three main pillars: Impact, Footprint and Legacy. Through Impact and Legacy, The Ocean Race engages people in sustainability, raises awareness of ocean issues and inspires action. Key initiatives include a pioneering Science programme, which provides millions of pieces of data to world-leading organisations researching ocean health, Learning programmes, which have been used by over 255,000 students in 90 countries, and summits, which bring together leaders and ocean advocates to accelerate solutions to the issues affecting the seas. Ocean health campaigns further extend this work, inspiring the public to take action to protect the ocean.

The 'Footprint' pillar sets ambitious targets for the operational elements of the Race, with a focus on minimising the environmental impacts of the events, promoting responsible sourcing, and measuring and reducing greenhouse gas emissions emissions. New approaches to event delivery are frequently trialled, to help to raise sustainability standards across the sport and wider events industry. As a signatory of the UNFCCC's Sports for Climate Action Framework, The Ocean Race is committed to a 45% absolute reduction in GHGs by 2030 and to achieving Net Zero by 2040. These commitments reflect the Race's efforts to make sustainability an integral part of how the competition is delivered, demonstrating how elite sport can help drive progress towards a healthier ocean and a lower-carbon future.

Find out more at **www.theoceanrace.com**



Appendix C: Planetary solvency methodology and climate-risk assessment

In this section, we recap findings from our collaborative sustainability research series with Earth system scientists, reiterating key messages from previous papers that provide context for this report's findings.

Financial and economic actors need to recognise that future financial outcomes will increasingly be impacted by Earth system instability. Standard economic and financial services models assume a functioning and stable system, but this can no longer be taken for granted. No portfolio can diversify away a general collapse in ecological stability, nor can additional financial capital buy back a stable climate once its regulating systems have failed.

A mindset shift is needed towards "a regenerative economic model that places human and planetary flourishing at its core."[73] Such a shift must recognise that we are part of the Earth system and that we depend on it. We must also understand that climate change and nature loss, driven by human activity, now threaten the stability of the Earth system.

Climate change is a risk management problem

In our policy briefing for COP27, the actuarial profession reiterated the message that climate change is a risk management problem on a global scale, but we are not treating it as such[74]. We suggested 1.5°C should be seen as similar to a solvency or ruin limit for our global society, given the level of risk that crossing this limit entails.

A risk management or solvency approach seeks to minimise the probability of exceeding this limit. This is in contrast to an optimisation approach, which provides markedly different outputs.

A. **A resilience or solvency approach** asks whether plausible severe outcomes could threaten system viability and what level of protection or resilience is needed. Recognising that material risks are often difficult to quantify reliably, it combines stress testing, tail-risk scenarios and expert judgement to inform decision-making.

B. **A central-estimate or optimisation approach** typically focuses on expected or median outcomes, estimated relationships and trade-offs between costs and benefits. These approaches can be highly informative, but their outputs depend on which physical, ecological and systemic channels are represented.

A risk-led solvency approach seeks to reduce the probability of insolvency, or ruin, to an acceptable level, rather than relying on central estimates. This shifts the objective from predicting the most probable future to reducing the chance of the civilizational-scale disaster that Planetary Insolvency represents.

The optimisation approach has been widely used and is particularly prevalent in the assessment of climate impacts for financial and economic actors: treasuries, financial regulators, banks, insurers, investment firms and pension funds. This is despite significant research[75] identifying serious methodological flaws, most recently *'Recalibrating Climate Risk'*[76].

Methodological limitations are also carefully noted by the Network for Greening the Financial System[77] (NGFS), a group of central banks and regulators, as including no consideration of sea-level rise, ocean acidification, tipping points or nature-related risks, including those related to the ocean. In *'Parasol Lost: Recovery plan needed'*[78], we draw parallels to the Global Financial Crisis, when a range of contributory factors lead to widespread institutional and systemic risk management failures.

Illustration of divergent outputs

Two papers published earlier in 2026 illustrate the differences in conclusions and messaging when different methodologies are applied. Consider the following two statements, the first resilience-led, the second optimisation-led:

A. Global ecosystem degradation and collapse threaten UK national security and prosperity[79].
Without significant increases in UK food system and supply chain resilience, it is unlikely the UK would be able to maintain food security if ecosystem collapse drives geopolitical competition for food.

B. By 2050, climate change could reduce income for the average person, by between 3 and 15%[80].
In addition, substantial impacts [are] expected from other extreme climate-related events, such as flooding, wildfires and drought. As such, the figures above are likely to constitute significant underestimates of the overall impacts of climate change on GDP.

The LSE paper (B) is a sophisticated example of the optimisation approach critiqued in *'Recalibrating Climate Risk'* (GDP growth assumed, still GDP/econometric-based, still using benefit-cost ratios, excluding tipping points).

The resilience message (A) is radically different and should, in theory, drive a radically different societal response. However, this approach is not widely used: in most cases, financial and economic actors continue to be presented with outputs from the optimisation approach, disincentivising action.

Figure 12 below illustrates different possible outcomes. The quadratic line, which shows no appreciable GDP damage even at high levels of warming, underpins many estimates of the economic impact of climate change used in the optimization approach.

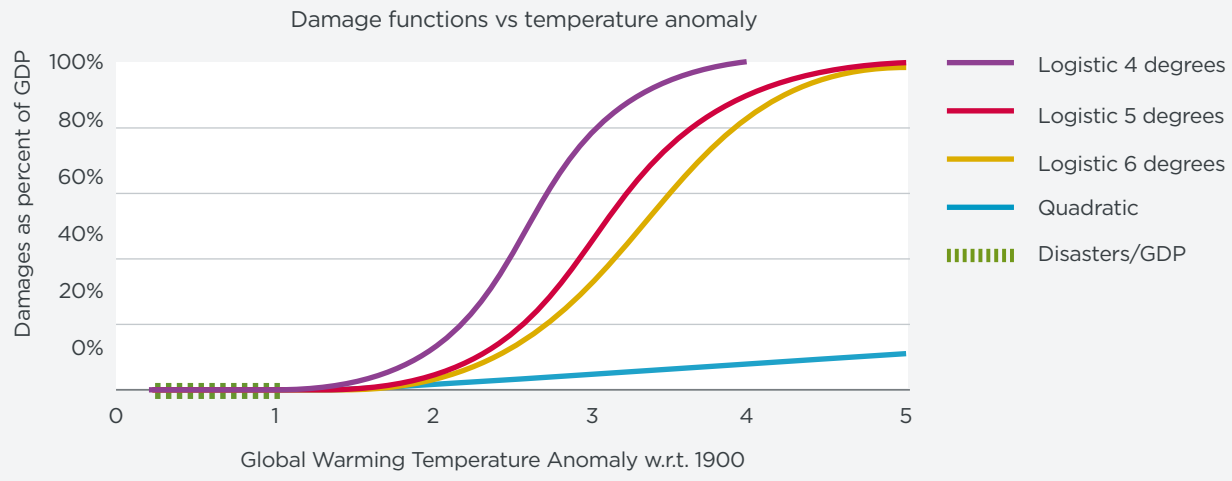
In this approach, GDP growth is a foundational assumption. "Economists assume 3% annual GDP growth continues indefinitely into the future, irrespective of climate change damage severity. The 20% GDP damage is then subtracted from that growth enlarged total pie, of a fictional future world without climate change." [81]

The logistic lines adopt a different methodology. It is assumed that there is a level of warming that cannot be adapted to (i.e a risk of ruin), and a mathematical formula is developed that takes us from today's damages to total loss. It is impossible to know what level of global warming society would be unable to adapt to, hence the range of possibilities outlined below. In *'Recalibrating Climate Risk'*, the median collapse threshold, derived through expert elicitation, was 3.4°C.

While precision is impossible, the rate of loss increases significantly between 2°C and 3°C, with considerable variation depending on the assumptions used.

Figure 12: Climate damage functions – GDP vs temperature

Source: Emperor's New Climate Scenarios, IFOA.



Source: Carbon Tracker (forthcoming), Keen et al, IFoA analysis. Reproduced with permission.

Climate change is happening faster than expected

Key findings in *'Parasol Lost – Recovery Plan needed'*[82] included:

- Emissions, the energy imbalance and the rate of warming are all increasing, making catastrophic warming of greater than 2°C before 2050 likely unless action is taken to change course.
- Other factors, which are not always considered, may act to accelerate warming, including loss of albedo, loss of aerosol cooling, degradation of natural carbon sinks and reductions in ocean heat uptake.
- The Earth's climate is likely to be more sensitive to greenhouse gases than our central estimate, meaning that at current levels of GHGs we may be on course for much more warming than expected.
- Both the amount and the duration of overshoot above the 1.5°C temperature limit are critical drivers of tipping point risk.

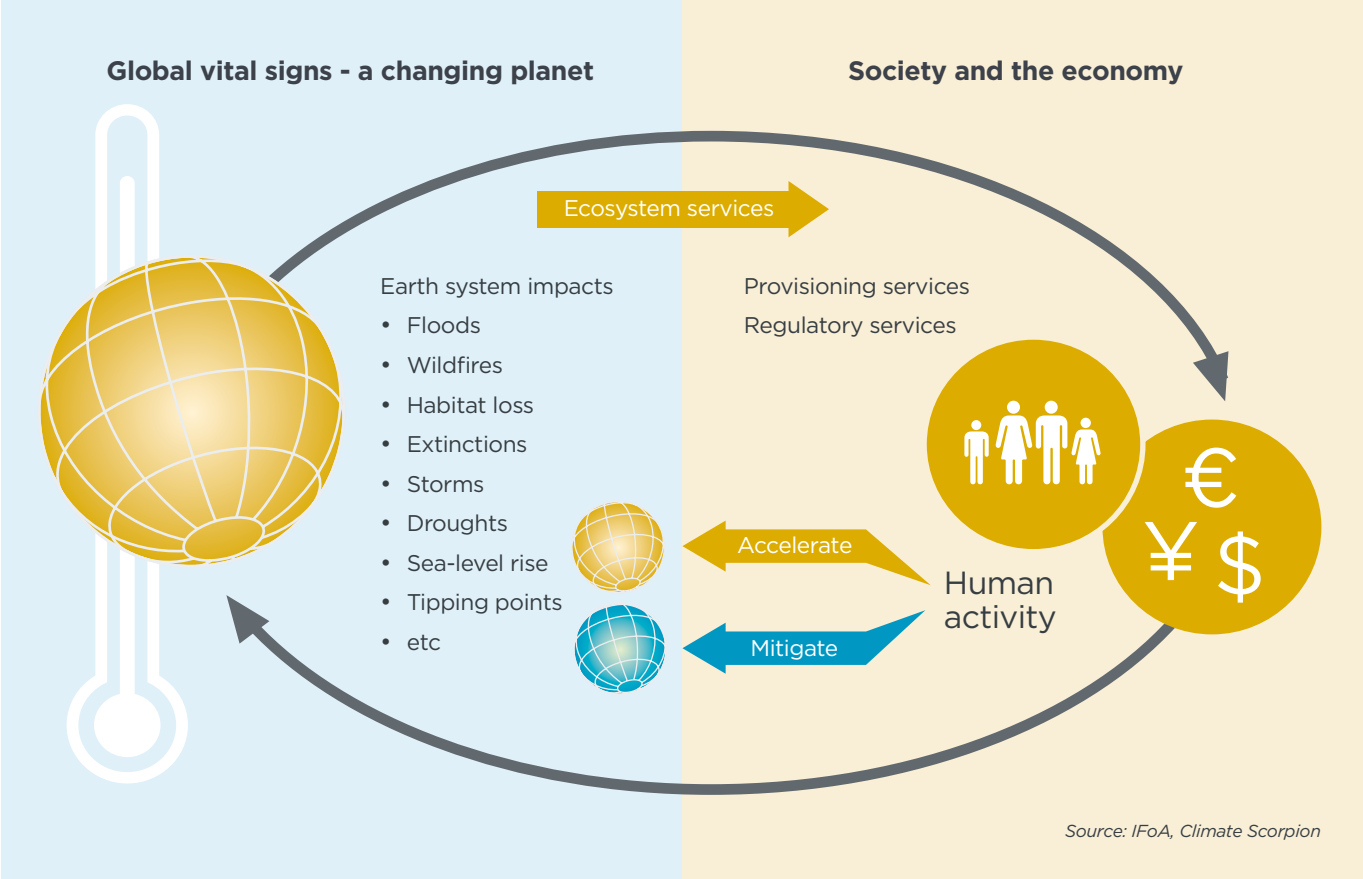
The higher sensitivity means more warming for any given level of emissions and a faster approach to dangerous temperature thresholds, significantly increasing both the likelihood and proximity of tipping points in the Earth system. Additional warming will intensify fires, floods, heatwaves, storms, droughts and sea-level rise, with cascading impacts across critical human systems, including food security, water availability, transport infrastructure and public health.

Nature is our most foundational critical infrastructure

The Dasgupta Review[83] emphasised that the economy is embedded within, and wholly dependent upon, nature. Building on this insight, Planetary Solvency proposes applying resilience and solvency-style risk management principles to maintaining the Earth system functions upon which society and the economy depend.

Earlier Planetary Solvency reports developed the RESILIENCE framework to assesses the ongoing ability of the Earth system to support our human society and economy. If critical ecosystem services are disrupted, then cascading impacts across human systems can be expected to occur: for example, to food, water, energy, infrastructure or manufacturing systems, with associated societal and economic shocks.

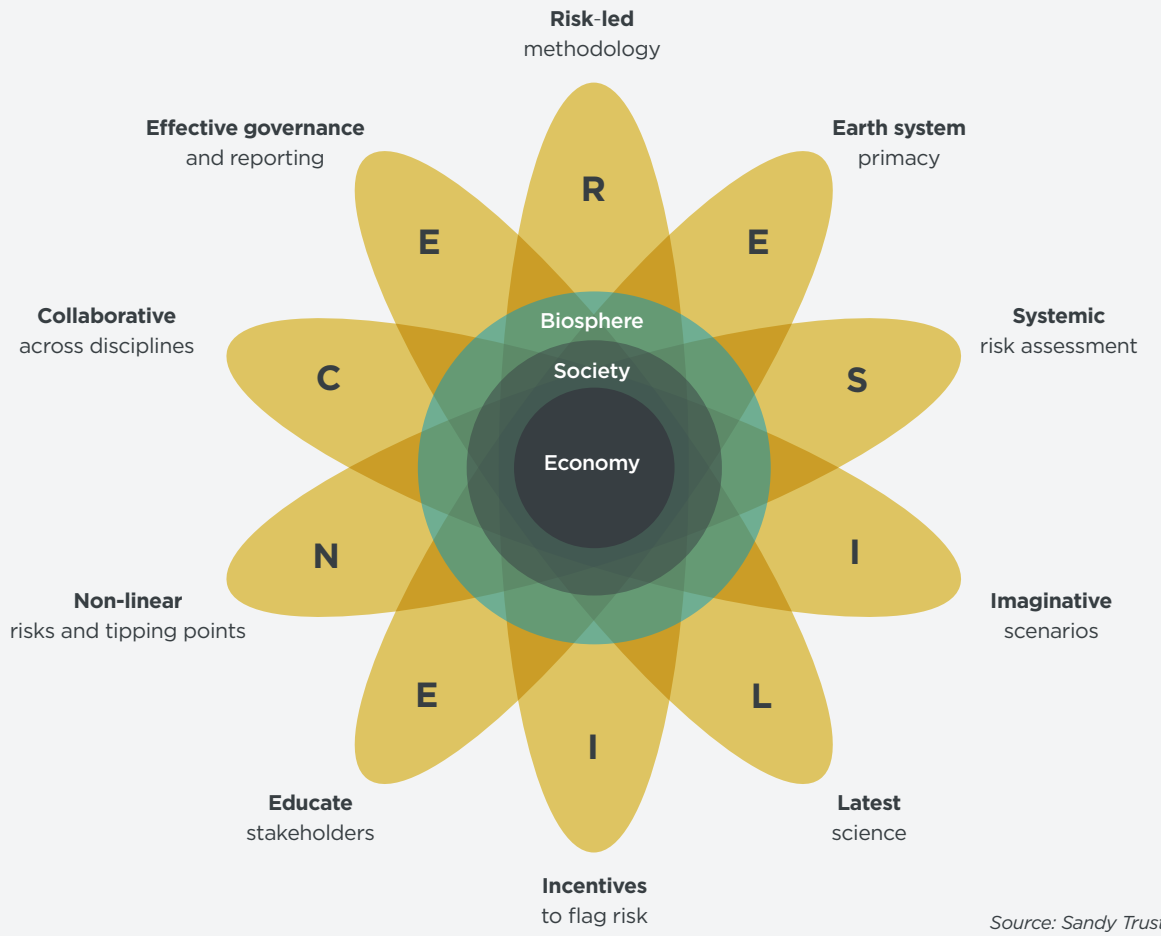
Figure 13: Interaction between human activity and the Earth *Source: IFOA, Planetary Solvency – finding our balance with nature, Trust et al*



Pension funds are owners of financial assets; but the return on these assets and the prosperity of current and future beneficiaries is influenced by the Earth system. Current capital market models and assumptions underpinned by Modern Portfolio Theory assume a stable Earth system, which is no longer an appropriate assumption.

The Planetary Solvency RESILIENCE principles, designed to support effective and realistic Planetary Solvency risk assessments, are summarised in *Figure 14* and *Table 2* below:

Figure 14: The Planetary Solvency RESILIENCE principles *Source: IFOA, Planetary Solvency – finding our balance with nature, Trust et al*



Source: Sandy Trust, IFoA

Resilience means the ability to bounce back after a disturbance, the capacity to maintain essential function and the potential for transformation.

Table 2: Summary of the RESILIENCE principles system *Source: IFOA, Planetary Solvency – finding our balance with nature, Trust et al*

Principle	Explanation
Risk-led methodology	Set clear risk limits and track trends using a global dashboard.
Earth system primacy	Prioritise Earth system health over short-term economic metrics.
Systemic risk assessment	Assess interconnections between societal and environmental risks.
Imaginative scenarios	Assess tail risks and combinations of risks.
Latest science	As IPBES and IPCC reports take several years to produce, there is a need to incorporate current science in a more timely fashion.
Incentives to flag risk	Reward risk identification and communication, even if unlikely, to mitigate scientific reticence and consensus.
Educate stakeholders	Invest time in building ecological, climate and systemic risk literacy amongst policymakers.
Non-linear risks and tipping points	Consider exponential risks, the potential for unprecedented threshold events and the impact of tipping points.
Collaborative across disciplines	Work across science, risk, security, private and public sectors to build deeper insights and reduce blind spots.
Effective governance and reporting	Embed into appropriate governance structures, maintain independence and report transparently.

Resilience means the ability to bounce back after a disturbance, the capacity to maintain essential function and the potential for transformation. The RESILIENCE principles are designed to make society resilient though effective and realistic global risk management practices.

An Ocean Solvency risk impact matrix is shown in *Figure 15* on the next page.

The matrix is a classification tool, not a projection. Each column should be read separately: reaching a given severity level in one dimension does not mean the same level has automatically been reached in another. The dimensions interact, so a worsening climate rating may increase the likelihood of severe biodiversity, economic or societal impacts. However, the timing and scale of those consequences must be assessed separately.

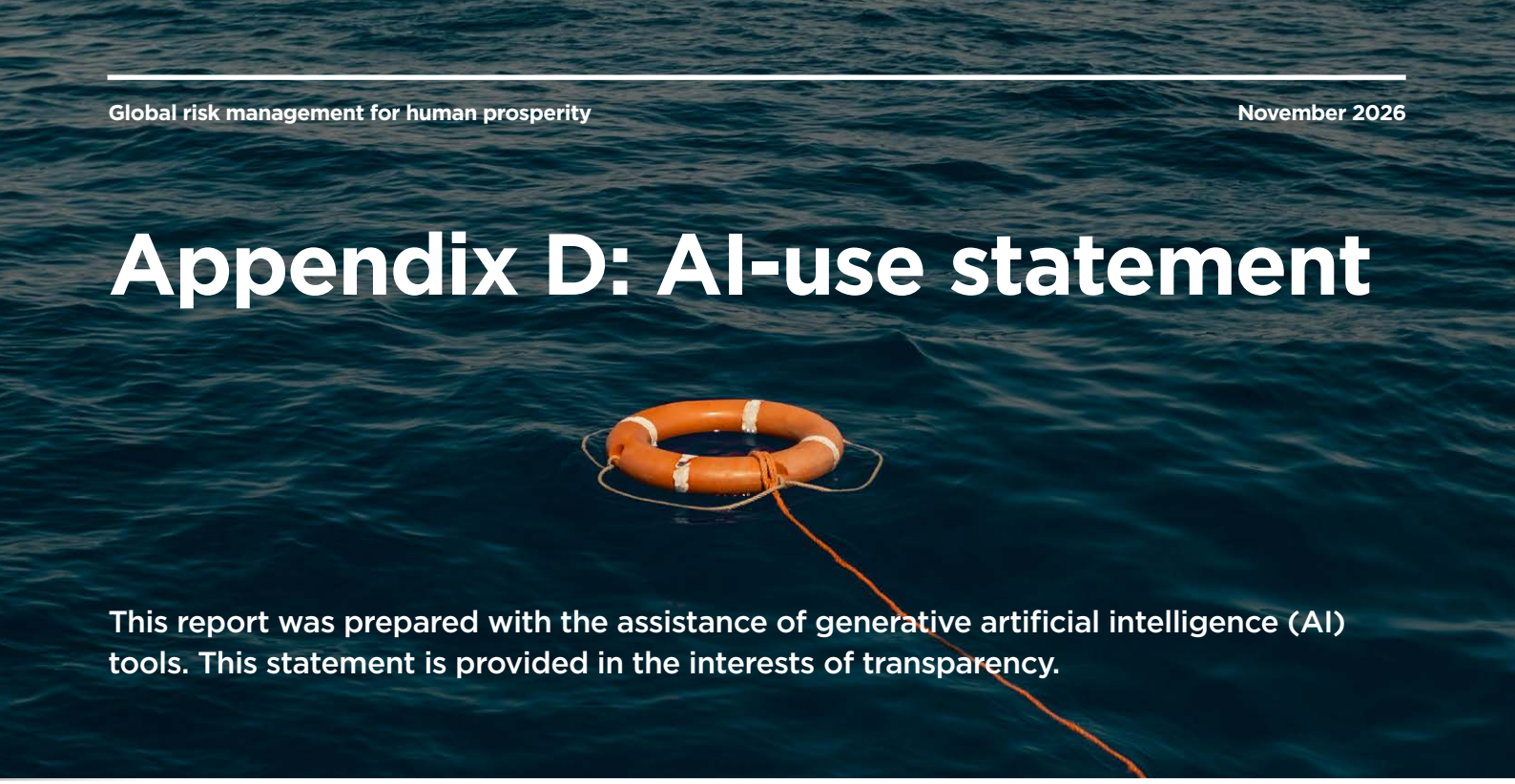
This matrix applies the Planetary Solvency risk impact framework (Limited, Severe, Decimation, Catastrophic, Extreme) to three ocean-specific risk dimensions: marine overexploitation, marine pollution and climate change. Impact levels are calibrated to be consistent with the financial and non-financial impact thresholds (GDP losses, human mortality) set out in the original Planetary Solvency risk impact matrix (IFoA, 2025).

The matrix focuses on the principal risk drivers affecting Ocean Solvency. It should be read alongside broader integrated frameworks that consider ecological integrity, governance, stewardship and societal outcomes. The Ocean Impact Matrix is consistent with wider integrated governance frameworks that recognise environmental, social and economic outcomes as interdependent, including the Nature's Rights Integrated Rights Framework.

Figure 15: Planetary Solvency ocean risk impact matrix *Source: Authors 2025*

Impact level	Marine overexploitation (over-fishing & unsustainable extraction)	Marine pollution (plastic, chemical, nutrient)	Climate change (warming, acidification, deoxygenation, SLR)	Combined whole-system impact (Planetary Solvency alignment)
Limited	Global fish stocks predominantly within sustainable limits; localised overfishing in some regions with slow stock recovery. Illegal, unreported and unregulated (IUU) fishing persists but does not yet materially affect global protein supply. Some regional fisheries collapse (e.g. specific stocks) but global catch remains broadly stable.	Plastic and chemical pollution continues to accumulate in coastal waters and garbage patches; nutrient run-off drives occasional, localised algal blooms and hypoxic zones. Marine ecosystem services remain largely functional at the global scale, though degraded in heavily impacted coastal regions.	Ocean warming and acidification proceed in line with global warming remaining below 1.5°C by 2050, with limited overshoot. Coral bleaching events are recurrent but reef systems retain some recovery capacity. Ocean tipping points (AMOC weakening, ice-sheet melt contribution to sea-level rise) remain largely avoided.	Ongoing, significant ocean-related losses (fisheries decline, coastal damage, biodiversity loss) accumulate but remain within adaptive capacity. Consistent with Planetary Solvency Limited impact: GDP losses <1% (>$1tn annual losses), human mortality <1% (~80 million deaths) from all associated causes globally.
Severe	Multiple major global fisheries in serious decline; regular collapse of regionally important stocks (e.g. further depletion of key food-security fisheries). IUU fishing and habitat destruction (bottom trawling) materially reduce ecosystem resilience and carbon sequestration capacity in affected regions.	Chemical, nutrient and plastic pollution cause regular, expanding hypoxic ("dead") zones and harmful algal blooms across multiple coastal regions. Some critical ecosystem services (nursery habitats, water filtration, coastal protection) begin to show sustained impairment.	Global warming limited to 1.5°C by 2050 following overshoot. Ocean acidification and deoxygenation accelerate; some proximate ocean-relevant tipping points are triggered (e.g. widespread coral reef die-off, initial AMOC slowdown signals). Sea-level rise begins to displace low-lying coastal populations.	Regular global food and water crises linked to fisheries and coastal ecosystem stress; some socio-political fragmentation in fishery-dependent and climate-vulnerable states. Consistent with Planetary Solvency Severe impact: GDP losses ≥5% (>$10tn annual losses), human mortality ≥10% (~400 million deaths).
Decimation	Widespread collapse of major global fisheries; global catch volumes fall sharply, with severe consequences for roughly 3 billion people dependent on seafood for protein. Deep-sea and Southern Ocean extraction expands into previously unexploited stocks as accessible fisheries are depleted.	Chronic, large-scale hypoxia and eutrophication render substantial coastal areas uninhabitable for marine life; plastic and chemical loading materially impairs reproduction and food-web function across multiple taxa. Severe reduction in several critical ecosystem services (nursery grounds, water purification, coastal buffering).	Global warming limited to 2°C by 2050; several ocean-relevant climate tipping points triggered, including substantial coral reef loss globally and accelerating AMOC weakening. Sea-level rise and ocean stratification materially reduce the ocean carbon and heat sink function, amplifying atmospheric warming.	Frequent global food and water crises; failure of vulnerable coastal and small island states; mass mortality events in fisheries and coastal-dependent populations. Consistent with Planetary Solvency Decimation impact: GDP losses ≥10% (>$10tn annual losses), human mortality ≥10% (>800 million deaths).
Catastrophic	Global fisheries collapse across most major ocean basins; effectively unmanaged, opportunistic extraction dominates as governance frameworks fail. Loss of fisheries as a viable food source drives severe protein and livelihood crises for billions in coastal and island communities.	Pervasive, basin-scale hypoxia and toxic loading render large ocean regions unable to support complex marine life; ecosystem services (carbon sequestration, oxygen production, water purification) break down at a regional scale, compounding climate-driven ocean stress.	Global warming of 2°C or more by 2050; high number of ocean-relevant tipping points triggered with partial tipping cascade. Ocean circulation (AMOC) severely impacted, disrupting global heat and nutrient distribution. Major coral reef extinction across multiple geographies; accelerating ice-sheet melt drives severe sea-level rise.	Low-lying coastal regions and island states lost; heat, water and food stress drive involuntary mass migration of billions; catastrophic mortality from disease, malnutrition, fires and conflict linked to ocean-system collapse. Consistent with Planetary Solvency Catastrophic impact: GDP losses ≥25%, human mortality ≥25% (>2 billion deaths).
Extreme	Global marine food production effectively ceases as a reliable resource; near-total collapse of critical fish stocks across all ocean basins. Extraction-based marine economies (fisheries, aquaculture reliant on wild inputs) cease to function as viable systems.	Ocean-wide chemical, plastic and nutrient loading combines with thermal and oxygen stress to drive breakdown of marine ecosystem function at a planetary scale; pollution becomes a self-reinforcing driver of further ecosystem and climate degradation rather than a discrete, manageable pressure.	Global warming of 3°C or more by 2050; multiple ocean-relevant tipping points triggered in a tipping cascade, including AMOC collapse, large-scale ice-sheet disintegration and associated severe sea-level rise, and near-total loss of coral reef ecosystems. Breakdown of several critical Earth-system services reliant on ocean regulation of heat, carbon and water.	High level of extinction of higher-order marine life; significant socio-political fragmentation and/or state failure in coastal and island nations, with rapid, enduring loss of capital and societal identity; frequent large-scale mortality events. Consistent with Planetary Solvency Extreme impact: GDP losses ≥50%, human mortality ≥50% (>4 billion deaths).

Appendix D: AI-use statement



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The environmental cost of AI was also considered, with these tools used selectively where they added genuine value rather than by default.

On this basis, the authors are satisfied that AI has been used responsibly, transparently and in line with the standards of research integrity expected of this work.



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Global risk management for human prosperity

November 2026

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