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CONTENTS

Where Does Our Plastic Accumulate in the Ocean and What Does That Mean for the Future?

Hannah Ritchie

The world now produces more than 380 million tonnes of plastic every year, which could end up as pollutants, entering our natural environment and oceans.

Of course, not all of our plastic waste ends up in the ocean, most ends up in landfills: it's estimated that the share of global plastic waste that enters the ocean is around 3%.[1] In 2010 – the year for which we have the latest estimates – that was around 8 million tonnes.[2]

Most of the plastic materials we produce are less dense than water and should therefore float at the ocean surface. But our best estimates of the amount of plastic afloat at sea are orders of magnitude lower than the amount of plastic that enters our oceans in a single year: as we show in the visualization, it's far lower than 8 million tonnes and instead in the order of 10s to 100s of thousands of tonnes. One of the most widely-quoted estimates is 250,000 tonnes.[3]

If we currently pollute our oceans with millions of tonnes of plastic each year, we must have released tens of millions of tonnes in recent decades. Why then do we find at least 100 times less plastics in our surface waters?

This discrepancy is often referred to as the "missing plastic problem."[4] It's a conundrum we need to address if we want to understand where plastic waste could end up, and what its impacts might be for wildlife, ecosystems and health.

The Missing Plastic Problem

There are several hypotheses to explain the missing plastic problem.

One possibility is that it is due to imprecise measurement: we might either grossly overestimate the amount of plastic waste we release into the ocean, or underestimate the amount floating in the surface ocean. Whilst we know that tracking ocean plastic inputs and their distribution is notoriously difficult[5] the levels of uncertainty in these measurements are much less than the several orders of magnitude that would be needed to explain the missing plastic problem.[6]

Another popular hypothesis is that ultraviolet light (UV) and mechanical wave forces break large pieces of plastic into smaller ones.These smaller particles, referred to as microplastics, are much more easily incorporated into sediments or ingested by organisms. And this is where the missing plastic might end up.

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1. Jambeck, J. R., Geyer, R., Wilcox, C., Siegler, T. R., Perryman, M., Andrady, A., … & Law, K. L. (2015). Plastic waste inputs from land into the ocean. *Science*, 347(6223), 768-771.

2. The estimates for this figure range from around 4 to 12 million tonnes, with 8 million as a midpoint. In the context of this discussion, the uncertainty in this value is less important: the difference between ocean plastic inputs and observed plastic in surface ocean waters are orders of magnitude – rather than multiples – apart.

3. Eriksen, M. et al. Plastic pollution in the world's oceans: more than 5 trillion plastic pieces weighing over 250,000 tons afloat at sea. *Plos One 9*, e111913 (2014).

4. Lebreton, L., Slat, B., Ferrari, F., Sainte-Rose, B., Aitken, J., Marthouse, R., … & Noble, K. (2018). Evidence that the Great Pacific Garbage Patch is rapidly accumulating plastic. *Scientific Reports*, 8(1), 4666. Available at: https://www.nature.com/articles/s41598-018-22939-w.

5. Cressey, D. (2016). Bottles, bags, ropes and toothbrushes: the struggle to track ocean plastics. *Nature News,* 536(7616), 263.

6. Lebreton, L., Egger, M., & Slat, B. (2019). A global mass budget for positively buoyant macroplastic debris in the ocean. *Scientific reports*, 9(1), 1-10.

One proposed “sink” for ocean plastics was deep-sea sediments; a study which sampled deep-sea sediments across several basins found that microplastic was up to four orders of magnitude more abundant (per unit volume) in deep-sea sediments from the Atlantic Ocean, Mediterranean Sea and Indian Ocean than in plastic-polluted surface waters.[7]

But, new research may suggest a third explanation: that plastics in the ocean break down slower than previously thought, and that much of the missing plastic is washed up or buried in our shorelines.[8]

Plastics Persist for Decades and Accumulate on Our Shorelines

To try to understand the conundrum of what happens to plastic waste when it enters the ocean, Lebreton, Egger and Slat (2019) created a global model of ocean plastics from 1950 to 2015. This model uses data on global plastic production, emissions into the ocean by plastic type and age, and transport and degradation rates to map not only the amount of plastic in different environments in the ocean, but also its age.

The authors aimed to quantify where plastic accumulates in the ocean across three environments: the shoreline (defined as dry land bordering the ocean), coastal areas (defined as waters with a depth less than 200 meters) and offshore (waters with a depth greater than 200 meters). They wanted to understand where plastic accumulates, and how old it is: a few years old, ten years or decades?

In the visualization I summarized their results. This is shown for two categories of plastics: shown in blue are ‘macroplastics’ (larger plastic materials greater than 0.5 centimeters in diameter) and shown in red microplastics (smaller particles less than 0.5 centimeters).

There are some key points we can take away from the visualization:

Renewable Natural Resources Foundation

The Renewable Natural Resources Foundation (RNRF) is a nonprofit, public policy research organization. Its mission is to advance the application of science, engineering and design in decision-making, promote interdisciplinary collaboration, and educate policymakers and the public on managing and conserving renewable natural resources. Member organizations are:

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Editorial Staff: Robert D. Day, editor; Stephen Yaeger, assistant editor.

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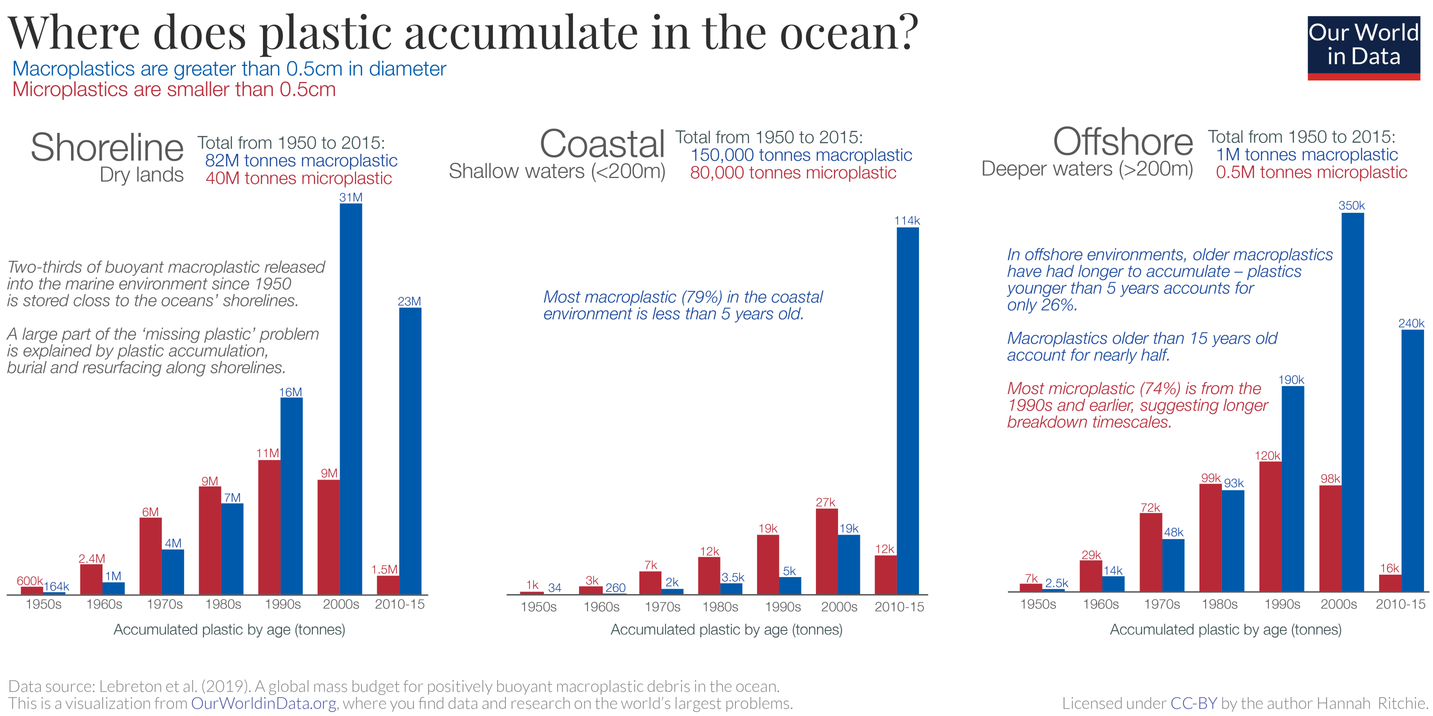
7. Woodall, L. C., Sanchez-Vidal, A., Canals, M., Paterson, G. L., Coppock, R., Sleight, V., … & Thompson, R. C. (2014). The deep sea is a major sink for microplastic debris. Royal Society Open Science, 1(4), 140317.

8. Lebreton, L., Egger, M., & Slat, B. (2019). A global mass budget for positively buoyant macroplastic debris in the ocean. Scientific reports, 9(1), 1-10.



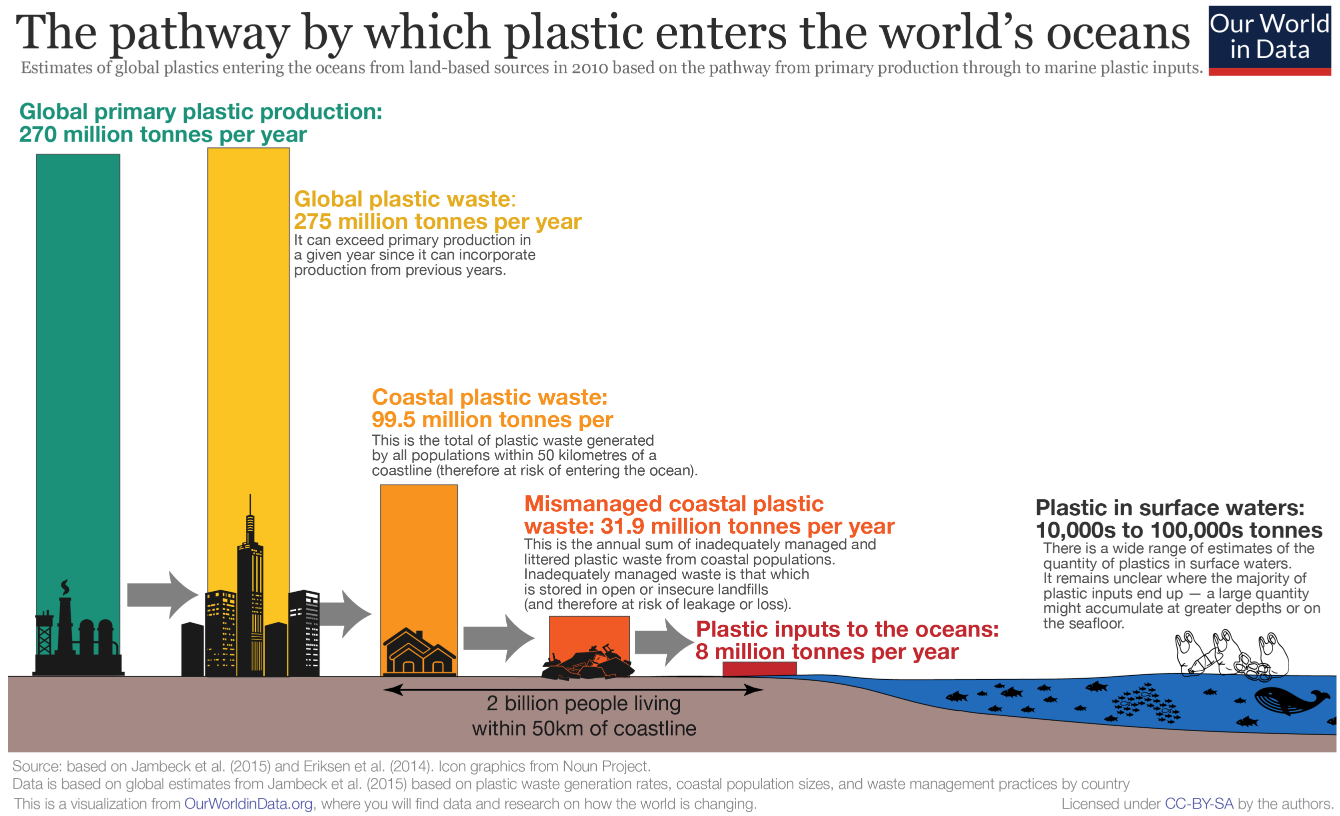
- The vast majority – 82 million tonnes of macroplastics and 40 million tonnes of microplastics – is washed up, buried or resurfaced along the world's shorelines.
- Much of the macroplastics in our shorelines is from the past 15 years, but still a significant amount is older suggesting it can persist for several decades without breaking down.
- In coastal regions most macroplastics (79%) are recent – less than 5 years old.
- In offshore environments, older microplastics have had longer to accumulate than in coastal regions. There macroplastics from several decades ago – even as far back as the 1950s and 1960s – persist.
- Most microplastics (three-quarters) in offshore environments are from the 1990s and earlier, suggesting it can take several decades for plastics to break down.

What does this mean for our understanding of the missing plastic problem? Firstly, is that the majority of ocean plastics are washed, buried and resurface along our shorelines. Whilst we try to tally ocean inputs with the amount floating in gyres at the centre of our oceans, most of it may be accumulating around the edges of the oceans. This would explain why we find much less in surface waters than we'd expect.

Secondly, accumulated plastics are much older than previously thought. Macroplastics appear to persist in the surface of the ocean for decades without breaking down. Offshore we find large plastic objects dating as far back as the 1950s and 1960s. This goes against previous hypotheses of the missing plastic problem which suggested that UV light and wave action degrade and remove them from the surface in only a few years.

How much plastic will remain in surface oceans in the coming decades?

The study by Lebreton, Egger and Slat challenges the previous hypotheses that plastics in the surface ocean have a very short lifetime, quickly degrade into microplastics and sink to greater depths. Their results suggest that macroplastics can persist for decades; can be buried and resurfaced along shorelines; and end up in offshore regions years later.



If true, this matters a lot for how much plastic we would expect in our surface oceans in the decades which follow. The same study also modelled how the mass of plastics – both macro and micro – in the world's surface waters might evolve under three scenarios:

1. we stop emitting any plastics to our oceans by 2020;
2. "emissions" of plastic to the ocean continue to increase until 2020 then level off;
3. "emissions" continue to grow to 2050 in line with historic growth rates.[9]

Their results are shown in the charts.

The scenarios of continued emissions growth are what we'd expect: if we continue to release more plastics to the ocean, we'll have more in our surface waters.

What's more striking is that even if we stopped ocean plastic waste by 2020, macroplastics would persist in our surface waters for many more decades. This is because we have a large legacy of plastics buried and awash on our shorelines which would continue to resurface and be transported to offshore regions; and existing plastics can persist in the ocean environment for many decades.

The amount of microplastics in our surface ocean will increase under every scenario because the large plastics that we already have on our shorelines and surface waters will continue to breakdown. And, any additional plastics we add will contribute further.

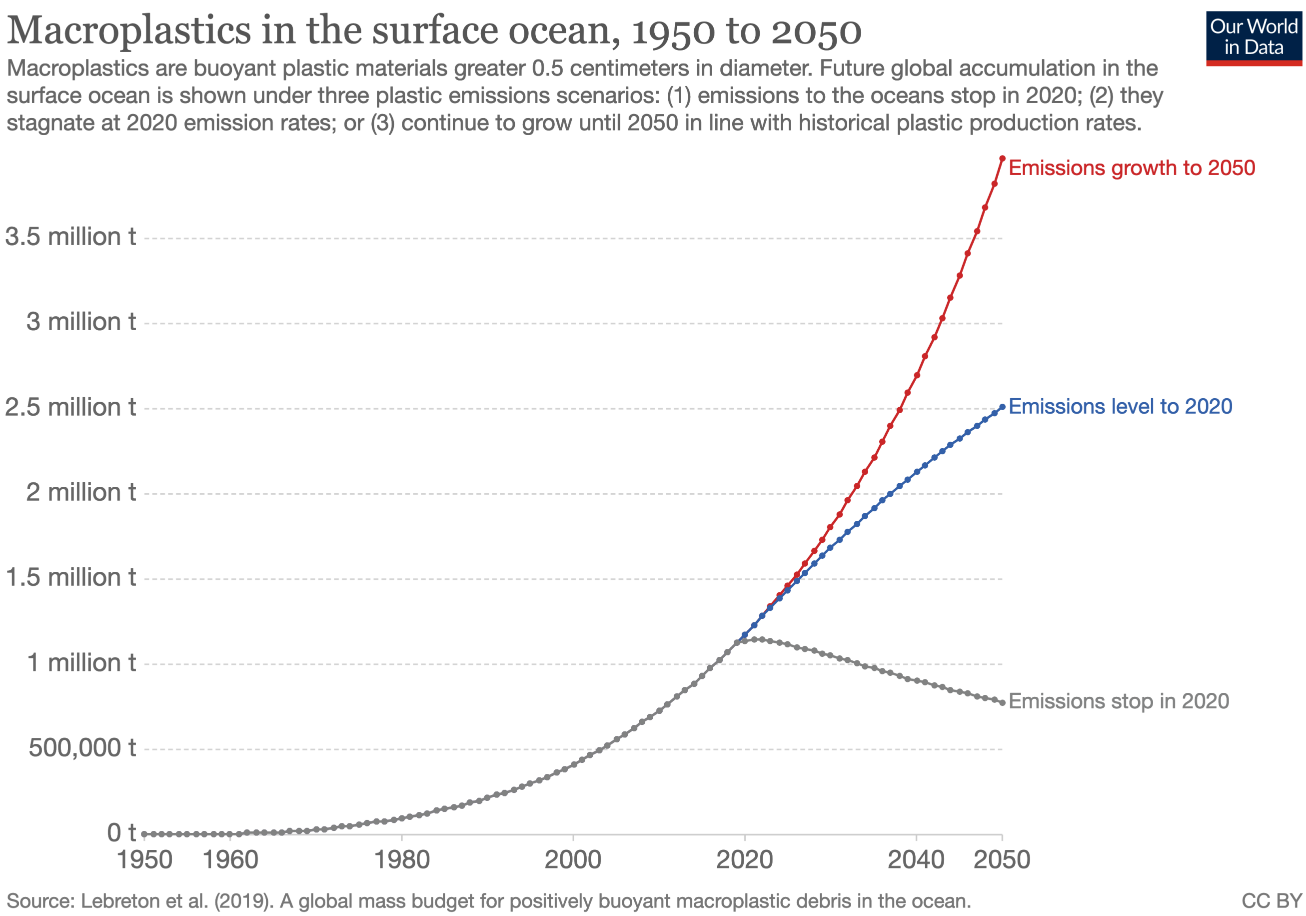
This also matters for how we solve the problem of ocean pollution.

If we want to rapidly reduce the amount of both macro- and microplastics in our oceans, these results suggest two priorities:

9. Under growth scenarios, the authors assume annual growth rates continue in line with the average increase in global plastic production over the decade from 2005-2015.

Number one — we must stop plastic waste entering our waterways as soon as possible. Most of the plastic that ends up in our oceans does so because of poor waste management practices – particularly in low-to-middle income countries; this means that good waste management across the world is essential to achieving this.

But this ambitious target alone will not be enough. We have many decades of legacy waste to contend with. This makes a second priority necessary – we have to focus our efforts on recapturing and removing plastics already in our offshore waters and shorelines. This is the goal of Slat, Lebreton and Egger – the authors of this paper – with their Ocean Cleanup project.



*This article and all graphics were originally published by Our World in Data. The original article can be found **here**.*

Perspective: Old News and New News About Plastics

Following are two brief news items. The first is about an old marketing campaign to promote public acceptance of plastics. The second is about the discovery of nanoparticles of plastic in the marine environment. — Eds.

The Myth of Plastic Recycling

Since plastics entered public use in the 1950s, their production has grown exponentially. Throughout the 1960s, 70s, and 80s, plastic grew to be ubiquitous in all types of consumer products. At the same time, understanding of the problems they cause for the environment – especially marine ecosystems – increased as well, leading to widespread public concern about the issue. This began in the 1960s when the impacts of plastic on marine ecosystems were first studied. Plastic was killing animals; numerous reports surfaced of marine organisms becoming entangled in plastic litter or ingesting small pieces of plastic, with fatal effects. Research on the negative impacts of plastic pollution on marine environments continued through the 1980s, **at which point the dramatically negative impacts of marine litter were reasonably well understood.**

In these decades, **greater public understanding of the issue led to calls to reduce plastic production and use, including legislative initiatives on the state and federal levels**. In 1971, New York instituted a tax on plastic bottles. In 1977, Hawaii banned plastic bottles all together. Both of these acts were struck down in the courts soon after being instituted, following legal challenges from the plastics industry. A ban on non-returnable plastic containers was introduced in Congress in 1973, but was never brought to vote after industry lobbyists insisted it would hurt manufacturing jobs. The booming plastics industry did not want its rapid growth to be cut off by legislation. Despite these early successes in the courts and Congress, the industry recognized that unless the perception of the industry could be improved from an environmental perspective, continued regulatory challenges were inevitable.

The challenge that the industry was facing was not one of how to make plastic production and consumption more sustainable. Their goal was to change public perception so that people would continue purchasing plastic products with a clear conscience and public objections would not be sufficient to pass legislation. With these goals in mind, the oil, gas, and plastic industry began a public relations campaign to promote recycling as the solution to the growing plastic crisis.

Starting in the 1990s, these companies funded advertisement campaigns in favor of recycling plastics, promising that they were actually a valuable commodity that would be repurposed into other useful products. The idea was that recycling would keep post-consumer plastics out of landfills and ocean environments. Oil companies even funded recycling centers and sorting machines. They devised a system of recycling symbols on products, telling consumers that their plastic waste could be recycled. This led to a drastic shift in public opinion on the plastic industry. Effort toward regulation was redirected toward promoting recycling initiatives, allowing the oil and gas industry to continue making billions of dollars off of plastic production. Unfortunately, the promise that recycling was keeping plastics out of landfills and the environment was never true.

Only about ten percent of plastic produced in the United States is recycled. The rest is buried in a landfill or pollutes the environment. Moreover, a significant amount of plastic was never being recycled, not even during the plastic industry's public relations campaigns of the 1990s. The basic economics of plastic recycling is unfavorable: it is more expensive to sort and recycle plastic than it is to produce new plastic using fossil fuel inputs. This harsh reality has prevented plastic from ever being recycled at scale. The public relations push promoting recycling caused people to believe that it was a viable solution to the plastic pollution crisis, but that was never the case.

A recent investigative report by National Public Radio, citing numerous internal documents and interviews with former industry executives, revealed that the oil industry knew that recycling was not a viable solution to plastic pollution before they began promoting it. They funded advertising and pilot initiatives and promoted putting recycling symbols on plastic products while knowing that the vast majority of plastic waste had no chance of being recycled. Since the 1990s, plastic production has increased drastically, increasing the amount of plastic being put into landfills and the environment. Recycling remains totally insufficient to combat the plastic pollution crisis. **The flow of plastic into the ocean is expected to triple by 2040.**

Nanoplastics Make Their Debut Discovery in Seawater

Many of the dangers of plastic in the ocean have been known since the 1960s and 70s, when scientific research first began to focus on the ecological effects of ocean plastic. While the harms that were identified by early studies were fairly obvious and visible – sea life becoming entangled in plastic objects, or ingesting small pieces of plastic, for instance – it has become increasingly apparent that ocean plastics have less visible impacts as well.

With time and exposure to the elements, particularly UV rays, plastic degrades and breaks up into smaller pieces. Eventually, these pieces become small enough to be termed “microplastics,” usually defined as particles less than 5 mm and greater than 100 nm in size. While it had been observed for decades that plastic items often break up into miniscule fragments in marine environments, a **2004 study** was the first to establish the ubiquity of microplastics in the ocean, including in seafloor sediments. **They are ingested by a wide range of marine organisms**, often with negative health impacts for organisms and ecosystems. **Microplastics have even been found in common seafood** like oysters, squid, and sardines.

More recently, an even smaller designation of plastic particle has begun to receive public attention as scientific understanding has improved. Nanoplastics are usually defined as particles of plastic less than 100 nm in size. These particles are the least well-understood marine plastic, but potentially the most harmful. Like microplastics, nanoplastics are often produced by the abrasion and degradation of larger pieces of plastic. **They have also been found to originate from primary sources** like waterborne paints, adhesives, coatings, biomedical products, and electronics.

In 2017, **nanoplastics were detected in seawater for the first time**. In water samples taken from the North Atlantic, these particles were detected using dynamic light scattering. This method was necessary because nanoparticles are too small to be directly observed. The study demonstrated that the particles were anthropogenic and attributable to a combination of plastics. The study of nanoplastics is still a frontier in this field, and little has been conclusively proven about their impacts on human health. However, their ubiquity in the environment and **ability to permeate easily through cell membranes** is a source of serious concern.

Managing Climate Risk in the U.S. Financial System

U.S. Commodity Futures Trading Commission

This article is an excerpt from a report of the same name, published in September 2020 by the U.S. Commodity Futures Trading Commission. It is unprecedented and commendable that the commission has studied the impacts of climate change on the U.S. financial system. – Ed.

Climate change poses a major risk to the stability of the U.S. financial system and to its ability to sustain the American economy. Climate change is already impacting or is anticipated to impact nearly every facet of the economy, including infrastructure, agriculture, residential and commercial property, as well as human health and labor productivity. Over time, if significant action is not taken to check rising global average temperatures, climate change impacts could impair the productive capacity of the economy and undermine its ability to generate employment, income, and opportunity. Even under optimistic emissions-reduction scenarios, the United States, along with countries around the world, will have to continue to cope with some measure of climate change-related impacts.

This reality poses complex risks for the U.S. financial system. Risks include disorderly price adjustments in various asset classes, with possible spillovers into different parts of the financial system, as well as potential disruption of the proper functioning of financial markets. In addition, the process of combating climate change itself—which demands a large-scale transition to a net-zero emissions economy—will pose risks to the financial system if markets and market participants prove unable to adapt to rapid changes in policy, technology, and consumer preferences. Financial system stress, in turn, may further exacerbate disruptions in economic activity, for example, by limiting the availability of credit or reducing access to certain financial products, such as hedging instruments and insurance.

A major concern for regulators is what we don't know. While understanding about particular kinds of climate risk is advancing quickly, understanding about how different types of climate risk could interact remains in an incipient stage. Physical and transition risks may well unfold in parallel, compounding the challenge. Climate risks may also exacerbate financial system vulnerabilities that have little to do with climate change, such as historically high levels of corporate leverage. This is particularly concerning in the short- and medium-term, as the COVID 19 pandemic is likely to leave behind stressed balance sheets, strained government budgets, and depleted household wealth, which, taken together, undermine the resilience of the financial system to future shocks.

The central message of this report is that U.S. financial regulators must recognize that climate change poses serious emerging risks to the U.S. financial system, and they should move urgently and decisively to measure, understand, and address these risks. Achieving this goal calls for strengthening regulators' capabilities, expertise, and data and tools to better monitor, analyze, and quantify climate risks. It calls for working closely with the private sector to ensure that financial institutions and market participants do the same. And it calls for policy and regulatory choices that are flexible, open-ended, and adaptable to new information about climate change and its risks, based on close and iterative dialogue with the private sector.

At the same time, the financial community should not simply be reactive—it should provide solutions. Regulators should recognize that the financial system can itself be a catalyst for investments that accelerate economic resilience and the transition to a net-zero emissions economy. Financial innovations, in the form of new financial products, services, and technologies, can help the U.S. economy better manage climate risk and help channel more capital into technologies essential for the transition.

Findings of the Report

This report begins with a fundamental finding—financial markets will only be able to channel resources efficiently to activities that reduce greenhouse gas emissions if an economy-wide price on carbon is in place at a level that reflects the true social cost of those emissions. Addressing climate change will require policy frameworks that incentivize the fair and effective reduction of greenhouse gas emissions. In the absence of such a price, financial markets will operate suboptimally, and capital will continue to flow in the wrong direction, rather than toward accelerating the transition to a net-zero emissions economy. At the same time, policymakers must be sensitive to the distributional impacts of carbon pricing and other policies and ensure that the burden does not fall on low-to-moderate income households and on historically marginalized communities. This report recognizes that pricing carbon is beyond the remit of financial regulators; it is the job of Congress.

A central finding of this report is that climate change could pose systemic risks to the U.S. financial system. Climate change is expected to affect multiple sectors, geographies, and assets in the United States, sometimes simultaneously and within a relatively short timeframe. As mentioned earlier, transition and physical risks—as well as climate and non-climate-related risks—could interact with each other, amplifying shocks and stresses. This raises the prospect of spillovers that could disrupt multiple parts of the financial system simultaneously. In addition, systemic shocks are more likely in an environment in which financial assets do not fully reflect climate-related physical and transition risks. A sudden revision of market perceptions about climate risk could lead to a disorderly repricing of assets, which could in turn have cascading effects on portfolios and balance sheets and therefore systemic implications for financial stability.

At the same time, this report finds that regulators should also be concerned about the risk of climate-related "sub-systemic" shocks. Sub-systemic shocks are defined in this report as those that affect financial markets or institutions in a particular sector, asset class, or region of the country, but without threatening the stability of the financial system as a whole. This is especially relevant for the United States, given the country's size and its financial system, which includes thousands of financial institutions, many regulated at the state level. Sub-systemic shocks related to climate change can undermine the financial health of community banks, agricultural banks, or local insurance markets, leaving small businesses, farmers, and households without access to critical financial services. This is particularly damaging in areas that are already underserved by the financial system, which includes low-to-moderate income communities and historically marginalized communities.

The report finds that, in general, existing legislation already provides U.S. financial regulators with wide-ranging and flexible authorities that could be used to start addressing financial climate-related risk now. This is true across four areas—oversight of systemic financial risk, risk management of particular markets and financial institutions, disclosure and investor protection, and the safeguarding of financial sector utilities. Presently, however, these authorities and tools are not being fully utilized to effectively monitor and manage climate risk. Further rulemaking, and in some cases legislation, may be necessary to ensure a coordinated national response.

While some early adopters have moved faster than others in recent years, regulators and market participants around the world are generally in the early stages of understanding and experimenting with how best to monitor and manage climate risk. Given the considerable complexities and data challenges involved, this report points to the need for regulators and market participants to adopt pragmatic approaches that stress continual monitoring, experimentation, learning, and global coordination. Regulatory approaches in this area are evolving and should remain open to refinement, especially as understanding of climate risk continues to advance and new data and tools become available.

Insufficient data and analytical tools to measure and manage climate-related financial risks remain a critical constraint. To undertake climate risk analysis that can inform decision-making across the financial system, regulators and financial institutions need reliable, consistent, and comparable data and projections for climate risks, exposure, sensitivity, vulnerability, and adaptation and resilience. Demand will likely grow for public and open access to climate data, including for primary data collected by the government. Public data will enable market participants to, among other things, compare publicly available disclosure information and sustainability-benchmarked financial products. At the same time, proprietary data and analytical products can introduce innovations that improve climate risk management. A key challenge will be how best to balance the need for transparency through public data on one hand, with the need to foster private innovation through proprietary data, on the other.

The lack of common definitions and standards for climate-related data and financial products is hindering the ability of market participants and regulators to monitor and manage climate risk. While progress has been made in this area thanks to voluntary disclosure frameworks and work by foreign regulators, the lack of standards, and differences among standards, remains a barrier to effective climate risk management. The problem is compounded by a lack of international coordination on data and methodology standards. A common set of definitions for climate risk data, including modeling and calculation methodologies, is important for developing the consistent, comparable, and reliable data required for effective risk management. Also, taxonomies or classification systems can help foster greater transparency and comparability in markets for financial products labeled as “green” or “sustainable.”

Climate-related scenario analysis can be a useful tool to enable regulators and market participants to understand and manage climate-related risks. Scenarios illustrate the complex connections and dependencies across technologies, policies, geographies, societal behaviors, and economic outcomes as the world shifts toward a net-zero emissions future. Scenario analysis can help organizations integrate climate risks and opportunities into a broader risk management framework, as well as understand the potential short-term impact of specific triggering events. Scenario analysis is gaining traction in several contexts, both domestically and internationally, and regulators are increasingly using scenario analysis to foster greater risk awareness among financial market actors.

Yet, the limitations of scenario analysis should be recognized. While useful, climate scenarios and the models that analyze them have important limitations. Scenarios are sensitive to key assumptions and parameters, most have been developed for purposes other than financial risk analysis, and they cannot fully capture all the potential effects of climate- and policy-driven outcomes. Scenario analysis should have a valuable place in the risk management toolkit, but it should be used with full awareness of what it can and cannot do.

The disclosure by corporations of information on material, climate-related financial risks is an essential building block to ensure that climate risks are measured and managed effectively. Disclosure of such information enables financial regulators and market participants to better understand climate change impacts on financial markets and institutions. Issuers of securities can use disclosure to communicate risk and opportunity information to capital providers, investors, derivatives customers and counterparties, markets, and regulators. Issuers of securities can also use disclosures to learn from peers about climate-related strategy and best practices in risk management. Investors can use climate-related disclosures to assess risks to firms, margins, cash flows, and valuations, allowing markets to price risk more accurately and facilitating the risk-informed allocation of capital.

Demand for disclosure of information on material, climate-relevant financial risks continues to grow, and reporting initiatives have led to important advances. Investors and financial market actors have long called for decision useful climate risk disclosures, and in 2019, more than 630 investors managing more than $37 trillion signed the Global Investor Statement to Governments on Climate Change, which called on governments to improve climate-related financial reporting. Disclosure frameworks have been developed to enhance the quality and comparability of corporate disclosures, most notably, the Task Force on Climate-related Financial Disclosures (TCFD). Also, in 2010, the U.S. Securities and Exchange Commission (SEC) published Commission Guidance Regarding Disclosure Related to Climate Change, which provides public companies with interpretive guidance on existing SEC disclosure requirements as they apply to climate change.

However, the existing disclosure regime has not resulted in disclosures of a scope, breadth, and quality to be sufficiently useful to market participants and regulators. While disclosure rates are trending in a positive direction, an update published by the TCFD found that surveyed companies only provided, on average, 3.6 of the 11 total TCFD recommended disclosures. Large companies are increasingly disclosing some climate-related information, but significant variations remain in the information disclosed by each company, making it difficult for investors and others to understand exposure and manage climate risks. In addition, the 2010 SEC Guidance has not resulted in high-quality disclosure across U.S. publicly listed firms; it could be updated in light of global advancements in the past 10 years.

In addition to the absence of an economy-wide carbon pricing regime in the United States, other barriers are holding back capital from flowing to sustainable, low-carbon activities. One involves the misperception among mainstream investors that sustainable or ESG (environmental, social, and governance) investments necessarily involve trading off financial returns relative to traditional investment strategies. Another is that the market for products widely considered to be “green” or “sustainable” remains small relative to the needs of institutional investors. In addition, lack of trust in the market over concerns of potential “greenwashing” (misleading claims about the extent to which a financial product or service is truly climate-friendly or environmentally sustainable) may be holding back the market. And policy uncertainty also remains a barrier, including in areas such as regulation affecting the financial products that U.S. companies may offer their employees through their employer-provided retirement plans.

These barriers can be addressed through a variety of initiatives. For example, a wide range of government efforts—through credit guarantees and other means of attracting private capital by reducing the risks of low-carbon investments—catalyze capital flows toward innovation and deployment of net-zero emissions technologies. A new, unified federal umbrella could help coordinate and expand these government programs and leverage institutional capital to maximize impact and align the various federal programs. Climate finance labs, regulatory sandboxes, and other regulatory initiatives can also drive innovation by improving dialogue and learning for both regulators and market innovators, as well as via business accelerators, grants, and competitions providing awards in specific areas of need. In addition, clarifying existing regulations on fiduciary duty, including for example, those concerning retirement and pension plans, to confirm the appropriateness of making investment decisions using climate-related factors—and more broadly, ESG factors that impact risk-return—can help unlock the flow of capital to sustainable activities and investments.

Derivatives markets can be part of the solution. Refinements or modifications could be made to existing instruments to reduce derivatives market participants’ risk exposure. For example, commodity derivatives exchanges could address climate and sustainability issues by incorporating sustainability elements into existing contracts and by developing new derivatives contracts to hedge climate-related risks. New products may include weather, ESG, and renewable generation and electricity derivatives. However, development of new derivatives will require that the relevant climate-related data is transparent, reliable, and trusted by market participants. This also applies to a wide range of asset classes that can direct capital to climate-related opportunities and help manage climate risk.

U.S. regulators are not alone in confronting climate change as a financial system risk; international engagement by the United States could be significantly more robust. Financial regulators and other actors have launched important initiatives to tackle the challenge. The United States already participates in the Basel Committee on Banking Supervision’s climate task force, the International Organization of Securities Commissions (IOSCO) sustainable finance network, and relevant committees within the Financial Stability Board (FSB) to study climate-related financial risks. However, at the federal level the United States is not yet a member of the Central Banks and Supervisors Network for Greening the Financial System (NGFS), the Coalition of Finance Ministers for Climate Action, or the Sustainable Insurance Forum (SIF). The Group of Seven (G7) and Group of Twenty (G20), in which the United States plays a central role, could also address this challenge and promote international cooperation, but only if the United States is supportive.

*The full report can be found **here**.*

We Are Losing the “Little Things That Run the World” – Insects

United Nations Environment Programme

Abstract

Insects make up about half of all known living organisms. They play key roles in, pollination, nutrient cycling, food chains of birds and other insectivores, and are one of the pillars of our ecosystems. However, the wide use of insecticides, fragmentation of habitats and climate change are placing multiple threats on them and their populations are under sharp decline. This Foresight Brief explores insect services, threats and solutions to sustain insect populations.

Introduction

Insects have been embedded in terrestrial ecosystems for over 400 million years. They make up about half of all known living organisms and three quarters of the animal kingdom (Schoonhoven et al., 2005). They have been called ‘the little things that run the world’ (Wilson, 1987). There is no doubt that they constitute, by their abundance, diversity and adaptability, a crucial component of life on earth. They enable the maintenance and dynamic equilibrium of ecosystems through the services they provide, such as pollination (Ockinger & Smith, 2007; Ollerton et al., 2011), herbivory and detritivory (Mattson & Addy, 1975; Yang & Gratton, 2014), nutrient cycling (Yang & Gratton, 2014), pest control, and food source provision for birds, mammals and amphibians. Recognition of their importance for human beings is however largely restricted to scientists, environmentalists, and naturalists. The alarming and accelerating loss of insect species and their populations over recent decades (Dirzo et al., 2014) is barely registered by the general public and is of little concern to policy and decision makers who focus on immediate demands for food security, human health, and economic development. Given the recent and independent documentation of drastic reductions (over 75%) in insect biomass *within protected areas* (nature reserves) in Germany (Hallmann et al., 2017) and in a National Park Puerto Rico (Lister & Garcia, 2018) over the last 3-4 decades, this situation must change. Insect conservation has become an urgent issue.

Despite recent headlines in the press referring to an

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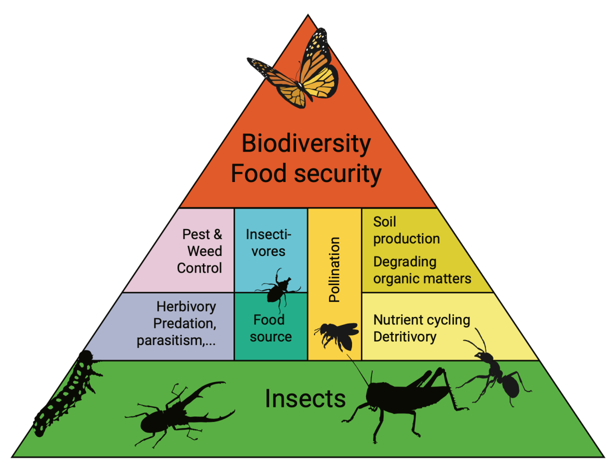

Insects play fundamental roles in the ecosystems, so maintaining insect populations is essential.

1. https://www.theguardian.com/environment/2018/jun/17/where-have- insects-gone-climate-change-population-decline; https:// www.nytimes. com/2018/11/27/magazine/insect-apocalypse.html

insect 'apocalypse' or 'Armageddon'[1], insect declines continue to attract insufficient attention, even within the conservation community. For example, in a recently published 353- page book on ecosystem services and poverty alleviation (Schrekenberg et al., 2018), insects, biocontrol of pests and pollinators are each mentioned only once, bees not at all. Yet food provision is crucially dependent on the ecosystem services provided by insects. Agriculture in its current form could not exist without insects. The tiny wasps and flies that are the invisible workers on every farm are seldom noticed, but they naturally control crop pests at no cost to us. Without them, crops would be devastated, livestock would be plagued, and dependence on agrochemicals, with all the associated environmental and financial costs, would be ruinous. To take just one example, the wasp (*Cotesia flavipes*) that was imported to East and Southern Africa to control the invasive Lepidoptera maize stem borer *Chilo partellus* in the 1990s is estimated to have saved the livelihoods of more than 130,000 rural farmers in the region. Cost benefit analysis suggests that the economic benefit over a 20-year period from this tiny wasp was 183 million dollars in Kenya (Kipkoech et al., 2006) and 39 million dollars in Zambia (Midingoyi et al., 2016), including savings on insecticides. More globally, over 75% of the world's 115 top crops benefit from pollination, accounting for 35% of food supplies (Klein et al., 2007). Gallai et al. (2009) estimate that insect pollination services to vegetables and fruits are worth 153 billion Euros a year. And without the insect life underground, nutrient recycling would stagnate, and soils would quickly become infertile.

The conservation of arthropod species cannot follow the same rules as vertebrate species. On the positive side, their higher levels of abundance and their capacity in terms of reproduction make them more resilient. It is clear from the studies of Hallmann et al. (2017) and Lister & Garcia (2018) that the current system of protected areas is failing to maintain viable populations of insect species. Equally, a focus on threatened species and the sites where they are found will not work as so few insects have been assessed for their Red List status, and many of those that have been red-listed are living in non-protected semi-natural habitats (e.g. *Carabus* beetles, swallowtail butterflies, and the Spanish moon moth, *Graellsia isabellae* in Europe). Some species rely directly on the management of the ecosystems by human activity. For example, the survival of the Hermit beetle, a well-known European flagship species, is mainly based on the special treatment of their hosts, which are hollow trees (Audisio et al., 2007; Hilszczanski et al., 2014). Similarly, the traditional approach to animal conservation involving restrictions on hunting and wildlife trade is rarely effective. Neither the prohibition of collection nor the protection of large areas of natural ecosystems are sufficient measures for the conservation of species that are crucial in the functioning of the ecosystems on a global scale.

There is an urgent need for the development of innovative solutions to preserve insects and the ecosystems where they live. These solutions must be more broadly targeted at conserving insect diversity in general rather than at particular species that are recognized as being endangered, and they must be based on an understanding of the forces that are currently driving general declines in insect abundance and on the attendant consequences. This Foresight Brief aims to contribute to a wider recognition of the challenges involved.

Causes of Insect Decline

The causes of this insect decline have been attributed to human actions and to associated climate and global ecological changes (Dirzo et al., 2014; Hallmann et al., 2017; Lister & Garcia, 2018). Hallmann et al. (2017) placed responsibility for the decline on agricultural intensification (insecticides, microbial pesticides, herbicides, year-round tillage, increased use of fertilizers and agronomic measures). The introduction of neonicotinoids (neonics) in the United States and Europe in the mid-1990s has been particularly damaging, especially as they have been applied on a prophylactic basis (regardless of actual need) on seeds. Only 20% of the insecticide present in the coating of the seeds is taken up by the crop, so the remainder of this persistent neurotoxin accumulates in soils and water bodies (Simon-Delso et al., 2015). Neonics, together with fipronil are increasingly being recognized as the DDT of the early 21st century, with knock-on effects throughout the food chains, and they have been strongly implicated as adversely affecting bees and other pollinators. An International Task Force on Systemic Pesticides (TFSP) has been set up to conduct a world-wide integrated assessment of their effects. The conclusions of the TFSP are very clear: neonicotinoids are threatening not only biodiversity but also ecosystem services and public health (Pisa et al., 2017).

Insect declines have resulted not only from the intensification of agriculture but also from its expansion. The extension of areas devoted to agriculture (especially in monocultures) eliminates biodiversity, destroys natural habitats, and fragments landscapes, together with transport systems, industrial plants, urban expansion and rural settlements. Continent-wide light pollution is impacting on moths and other nocturnal insects. Fragmentation increases the risk of extinction in populations of limited dispersers due to the combined effects of reduced population size and increased isolation. Reduced levels of gene flow among small remnant insect populations decrease genetic variability, increasing inbreeding and genetic drift, and consequently reducing survival and reproductive success (Willis et al., 2007). Fragmentation also increases extinction risks as insects become trapped in habitats that are adversely affected by climate change. The current situation is therefore quite unlike that faced by beetles in the Pleistocene when continuity of habitat allowed insects to simply move in response to advancing and retreating ice sheets (Coope, 1994). Lister and Garcia (2018) attributed the reductions in insect biomass that they observed in Puerto Rico to climate warming (2.0°C increase over the past 30 years). Because the location in which they worked is an isolated fragment of what used to be continuous rain forest, recruitment of insects from adjacent areas is prevented and indigenous insects that suffer from climate change are lost within their deteriorating habitat.

Consequences: Why is this issue important?

Reducing the insect diversity of ecological systems makes them less prone to cope with invasive species (Zavaleta & Hulvey, 2004), weakens regulation of pest populations by natural enemies (Perfecto et al., 2004; Tscharntke et al., 2005; Tylianakis et al., 2007), disturbs pollination (Klein et al., 2007) and reduces biomass transformation and decomposition rates. All these processes make ecosystems less resilient.

This much is clear to biologists. In order to mobilize action, a case must be clearly stated for the ecological and economic importance of insects. Ecological concerns center on the multifarious roles that insects play in maintaining ecosystem functions and the consequences if these roles are undermined by insect losses and extinctions. Ecology and economics are inextricably linked, but for decision makers, the latter take precedence, so there has been considerable effort to determine what insects are worth in monetary terms for the welfare of humankind. This is not an easy question to answer, since many of the services that insects deliver are diffuse and not directly related to consumable deliveries. The answers that have been suggested vary widely, but, taken together, they point to a total global economic value for all insect services that amounts to thousands of billion dollars a year. One estimate for just four services from wild insects (domesticated species such as honeybees and silkworms excluded) and for the US alone places the annual figure at 57bn USD (Losey & Vaughan, 2006).

Ecological Concerns: Trophic cascades

Lister and Garcia (2018) report declines in the abundance and diversity of frogs and birds in Luquillo rainforest (a national park in Puerto Rico), that were correlated with insect losses, and they attribute the former to the latter. While direct evidence for this causal link was lacking, such impacts on other taxa are a logical and inevitable consequence of insect extinctions. Insectivorous taxa, particularly birds, are the most obvious victims (Hallmann et al., 2014; Rioux Paquette et al., 2014). The British Trust for Ornithology has documented drastic falls for swifts in Britain since 1994. Similar declines in swallows and starlings have also been noted. Narango et al. (2018) found that most insectivorous birds are now absent or declining in urban areas, a result that they attribute to invasive plants and reduced food supplies.

The risk of trophic extinction cascades, both bottom-up and top-down, is real (Dirzo et al., 2014). Sanders et al. (2018) demonstrated secondary extinctions of other species in a field experiment following the harvesting of a parasitoid wasp, and showed that the probability of such extinctions was lower in complex communities because of trophic redundancy. The authors concluded that biodiversity losses “leading to a reduction in redundant interactions, can increase the vulnerability of ecosystems to secondary extinctions, which, when they occur, can then lead to further simplification and run- away extinction cascades”. As Ehrlich and Walker (1998) concluded: ‘A policy of trying to increase or at least to maintain redundancy in ecosystems will maximize the maintenance of ecosystem resilience’. Given the scale and extent of insect losses already recorded, the protection from trophic redundancy is being eroded. The danger of run-away trophic extinction cascades needs to be further investigated and closely monitored.

Ecological concerns: Loss of endemic species in critically endangered ecosystems

Although the most immediate pragmatic consequences of insect losses relate to their economic values, the extinction of endemic species remains a concern. For example, the highlands of Cameroon on the Cameroon Volcanic Line host many endemic species (Bergl et al., 2007). These highlands comprise submontane and montane forests, and patches of savannah. Several endemic insects specialized to the savannah ecosystems have been described, such as the grasshopper *Eyprepocnemis montana* (Mestre & Chiffaud, 2009), only known from the original specimens, or the extremely rare *Ophryodera pseudorusticana* on the Bamboutos Mountain (Werner, 2000). Due to severe deforestation for the production of potatoes, it has been difficult to discover places where they still occur. Three years of active research revealed a remnant of the original savannah with a maximum area of 10,000 m2 at an altitude of around 1000 m. asl. A second patch was found near the Kovifem forest at 2000 m. asl. These patches are found on top of a rocky area with a maximum area of 25,000 m2. They host several endemic grasshoppers, and one flower beetle (Cetoniidae) (Muafor et al., 2010), which is probably new to science. These remnants show the importance of small patches of preserved ecosystems. If the two savannahs described here disappear, endemic insects of high- altitude savannah ecosystems will be lost.

Ecological and economic concerns: Loss of ecosystem services

Insects do not just provide food for other organisms; they provide additional critical links in maintaining ecosystem functions and services. Most attention to date has focused on pollination. A recent review of pollination services (IPBES, 2016), based on almost 3,000 scientific publications, concluded “that 75% of our food crops and nearly 90% of wild flowering plants depend at least to some extent on animal pollination and that a high diversity of wild pollinators is critical to pollination even when managed bees are present in high numbers”. The IPBES assessment provides a detailed review of global estimates for the total economic value of pollination services to agriculture. These range from 160bn to 689bn USD per year, using 5 different methods, and standardized as 2015 USD values. As IPBES notes, they are calculated for the most overtly consumable benefits of pollination; they exclude those that flow from the pollination of 87.5% of wild flowering plants. The great majority of all pollinators are insects, and most insect pollinators are bees (over 20,000 species worldwide). The decline of “wild” bees and other pollinators may be an even more alarming threat to natural ecosystems and crop yields than the loss of honeybees (Garibaldi et al., 2013). Other pollinators include flies (especially hover flies), with butterflies, moths, beetles, wasps, thrips, and ants playing lesser roles. If insect pollination services are substantially damaged, there will be severe impacts on agricultural economies and food security. Aizen et al. (2009) project that world global crop production would fall by 3–8% in the absence of pollinators, intensifying demand for agricultural land. A decline in pollinator abundance will also be detrimental to wild plant species (Kluser et al., 2010). There could be another wave of run- away extinction cascades resulting from reduced seed set in wild flowering plants.

Unlike pollination, other ecosystem services (control of pests and invasives, decomposition and nutrient cycling, maintenance of soil structure and fertility) provided by insects are often difficult to link directly to consumables, and are therefore harder to evaluate in global monetary terms. Their effects are diffuse and can only be gauged in exceptional cases where the absence of the service in question has been sufficiently serious to warrant a concerted response. Examples include the control of alien invasive species such as *Chilo partellus* (referred to above) and the cassava mealybug (*Phenacoccus manihoti*). This cassava pest threatened the livelihoods of 200 million rural farmers in Africa in the 1980s, though it was virtually unknown in its native South America where it was controlled by (among others) an encyrtid wasp (*Epidinocarsis lopezi*). The African introduction of this wasp led to benefits estimated over 40 years at 8-37 billion dollars (Alene et al., 2005).

Overall, invasive species are estimated to cost the global economy 1.4 trillion USD a year (Pimentel et al., 2001). Classical biological control, involving the mass rearing and release into the new areas of natural enemies (most often insects) from their host countries is frequently the best and often the only solution. It has been applied to invasive weeds as well as to crop pests. The invasive water hyacinth, *Eichhornia crassipes* (Pontederiaceae) in Africa has been controlled since 1991 through regular releases of South American insects, the weevils *Neochetina eichhorniae* and *N. bruchi* (Col: Curculionidae), and the moth *Sameodes albiguttalis* (Lepidoptera: Pyralidae) (Neuenschwander et al., 1996; Wilson et al., 2007). These particular examples shed selective light on what is only a small portion of the overall value of natural biocontrols, estimated by DeBach (1974) to be effective against 99% of potential pests. As insect diversity and abundance are reduced on a global scale it will be become increasingly difficult to identify, locate and breed biocontrol species for emerging pests.

The single most pervasive service provided by insects, and possibly the most undervalued, is their role in developing and maintaining soil structure and fertility. They decompose plant and animal detritus, transforming biomass and releasing nutrients that sustain plant growth, preventing dung accumulation and attendant livestock pest problems, improving soil structure, reducing nitrogen losses from erosion and volatility, and increasing soil carbon and water storage (Mattson & Addy, 1975; Yang & Gratton, 2014). Losey & Vaughan (2006) estimate that the services provided in the US by dung beetles amount to 380 million USD per year.

In Australia, where the native beetles were unable to cope with the dung produced by introduced livestock, the introduction of just one species of deep-burying dung beetle is estimated to have improved pasture production by 30% (Doube, 2008). Dung beetles are but a small component of all the insect taxa that enable the rapid and effective recycling of nutrients, and animal dung is a minor component of all the organic inputs into this ecosystem process. Other relevant insect taxa include beetles, termites, ants, flies, cockroaches and springtails, and other organic inputs include vast amounts of dead plant and animal tissues.

The total economic value of insect contributions to this most vital of all ecological functions is beyond calculation. It is unlikely that it is under current threat, given the amount of redundancy involved in the dynamics of decomposition, but it is also evident that the use should be avoided of any persistent insecticide that accumulates in soils.

A surprising conclusion in Losey & Vaughan's valuation of insect benefits in the US was that the insect dependent value of recreation (fishing, hunting and bird watching) exceeded all the other three services (dung removal, pollination and pest control) considered: it contributed 49.93bn of the total estimate of 57.75bn USD. The US is probably a special case in this respect. More globally, a live butterfly exhibit industry has been established in the last 40 years, valued in the early nineties at 100 million USD a year (Parsons, 1992), and a large deadstock trade exists for a wide range of insects, particularly for butterflies and beetles.

Despite global and largely undocumented declines in butterflies, there is no evidence that the butterfly exhibit industry is suffering from a shortage of livestock supplies, but the deadstock trade creates perverse pressures on rare species that are in demand by collectors and it is capable of driving selected species to extinction. In some cases (notably birdwing butterflies) this danger is offset by captive breeding and ranching.

The black bee (Apis mellifera mellifera) (Photo L. Garnery).

What has/is being done? Four examples

Research on ecological intensification

Garibaldi et al. (2016) have demonstrated that crop yields could be increased by planting flower strips and hedgerows, providing nesting resources, more targeted use of pesticides, and/or restoration of adjacent semi- natural and natural areas. This ecological intensification exploits synergies between agriculture and biodiversity. In particular, it increases pollinator diversity. The authors used standardized protocols to document effects on crop yields of enriching flower visitation rates across 344 fields from 33 pollinator-dependent crop systems in small and large farms from Africa, Asia, and Latin America. For fields less than 2 hectares, yield gaps were closed by a median of 24% through higher flower-visitor density. For larger fields, such benefits only occurred at high flower-visitor richness. These findings show that the retention and establishment of natural habitats, at small but widespread scales, will not only benefit ecosystem services but also improve food provision and the livelihoods of poor farmers across the South.

Development of insect conservatories

The black bee (*Apis mellifera mellifera*) is a subspecies of the European honey bee *Apis mellifera*. Its natural distribution ranges cover a large part of the West Mediterranean from the Pyrenees to Scandinavia. It has colonized this area for nearly a million years and survived two glaciations (Ruttner, 1988; Garnery et al., 1992; Arias & Sheppard, 1996). This native bee has a distinctive genome (Garnery et al., 1998 a,b; Munoz et al., 2015, Pinto et al., 2014) that is adapted to the western European climate. Beekeeping developed in a traditional way until the last four decades and the diversity of natural populations had not been affected. During the last 20 years, however, efforts were made to rationalize beekeeping. Renowned, wrongly, as more aggressive and less productive than other subspecies of bees, the black honey bee was gradually abandoned by professional and amateur beekeepers who favoured the use of hybrids or other supposed highly productive honey bee subspecies.

The recent worldwide honey bee decline (causes reviewed in Van Engelsdorp & Meixner, 2010) has caused much concern. Colony losses have increased from 5-10% in the 90s to 25-30%. These losses have accelerated the honey bee trade in order to restore honeybee livestock, allowing the massive importation of exotic bees throughout the range of the black bee. Global queen and colony trade has also spread pathogen strains and bee parasites (Munoz et al., 2014; Wilfert et al., 2016). Because honey bee reproduction remains mainly natural, the forced interbreeding between these imported "exotic" bees and the black bee leads to erosion of its genetic heritage, to the detriment of the hardiness, climatic and geographical adaptations necessary for the natural maintenance of its natural diversity. The survival and maintenance of *Apis mellifera mellifera* in the wild is extremely compromised. There has been an unprecedented decline leading to its disappearance from some European countries. In response a number of black bee conservatories have been established in France.

Butterfly exhibits

Displays of wild butterflies flying freely in a contained environment have become established throughout the world, providing significant opportunities for ecotourism and for promoting insect conservation. They also contribute directly to conservation through the financial incentives they provide to rural farmers to maintain insect habitats in the tropics. These farmers rear butterflies and export the pupae to the butterfly exhibit industry which need a constant supply of livestock to maintain their attractiveness to visitors.

The linkage to conservation is explicit in cases where butterfly farms are deliberately established to build local support for threatened habitats with high biodiversity values. An example is Kipepeo project (Gordon & Ayiemba, 2003), where community-based butterfly farming was set up by Nature Kenya and the National Museums of Kenya to reduce local hostility to Arabuko- Sokoke, a forest which has been ranked as the second most important for bird conservation in mainland Africa. The reasons for hostility will be familiar to any conservationist working with the legacy of state- controlled forests in the developing world: poverty, resource-denial, wildlife crop-raiding, and hunger for land. Kipepeo was started in 1993 on a Global Environment Facility Small Grant of 50,000 USD. It has proved sustainable and has earned almost 2 million dollars to date. More importantly from a conservation perspective, together with other initiatives, it has changed local attitudes: a recent attempt to explore for oil in the forest was blocked by community protests[2].

The Task Force on Systematic Pesticides

In the 1960s, Rachel Carson in her Silent Spring raised awareness of the devastating impact of DDT on insect populations (Carson, 1962) which led to the setting up of an International Task Force on Systematic Pesticides. This led to the ban of DDT in USA in 1972, which subsequently initiated the Stockholm convention on Persistent

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2. https://africageographic.com/blog/forest-saved-as- community-says-no-to- oil/

Organic Pollutants (POPs). In 2009, a group of entomologists and ornithologists met in Notre Dame de Londres (a small village in France) to discuss shared concerns on the effects of a new generation of insecticides (neonicotinoids and fipronil) that had been introduced in the early 1990s. They concluded that this introduction was the probable cause of a sharp acceleration in what had hitherto been a gradual decline in the abundance of insects and insectivorous birds. They released a declaration entitled 'No Silent Spring Again' which led to the setting up of an International Task Force on Systematic Insecticides (TFSP). In the last 9 years the TFSP has examined over 1,100 scientific peer- reviewed papers and has published two sets of Worldwide Integrated Assessments (WIA) on its findings (WIA1: Bijleveld et al., 2015; Van der Sluijs et al., 2015; WIA 2: Giorio et al., 2017; Pisa et al., 2017; Furlan et al., 2018).

A third assessment is underway looking at impacts on human and mammalian health. The conclusions of the TFSP are unequivocal and have led to restrictions on the use of neonicotinoids in Europe and their outright ban in France and on the island on Marinduque in the Philippines. The ban on Marinduque was mandated because of the importance of this island's exports to the butterfly exhibit industry.

Ecological Networks

Ecological Networks (ENs) are "interconnected conservation corridors of high-quality habitat used to mitigate the adverse effects of landscape fragmentation and to connect with protected areas" (Samways, 2007; Samways & Pryke, 2016). The EN concept has been successfully applied in forestry plantation landscapes in South Africa and is increasingly recognized as a conservation tool for increasing the resilience of natural ecosystems, particularly in the context of climate change. It has proved to be particularly well suited to the conservation of small organisms such as insects, where corridors of as little as 200 m in width can make a significant difference to connectivity and ecosystem resilience.

What needs to be done?

Strengthen the capacity for insect taxonomy.

There is constantly dwindling capacity to identify insect species and biological organisms in general, termed as "taxonomic impediment" (Coleman, 2015). For many taxa there are no or too few specialists, especially for megadiverse ecosystems (Paknia et al., 2015). Even a group such as African grasshoppers, which was well covered between 1960 and 1980, is now poorly studied, with a shortage of expert taxonomists in the field. The problem is worse for other taxa of lesser economic importance. Without proper insect identification we cannot determine insect diversity in a given area and we are unable to quantify if it is increasing or decreasing.

Revive, support and initiate insect monitoring programs.

The recent publications of Lister and Garcia (2018) on declines in insect biomass within protected areas are like the ears of the hippo: they signal unseen dangers. Only a few countries (those with a rich tradition of natural history) have long term monitoring data on insect numbers and diversity. Entomologists in Africa (and elsewhere in the world) are painfully aware that insects are disappearing but they have little data to demonstrate the losses. Regional insect research organizations such as the International Centre of Insect Physiology and Ecology (icipe) in Nairobi should be supported to review historical data and to initiate strategically appropriate and systematic long-term monitoring programs. This action is needed not only to assess recent trends and the current situation, but also to track and evaluate impacts of future efforts to address the problem of insect decline.

Corynotrichius bicolor, endemic species of altitudinal zones of Cameroon (Photo P. Le Gall).

Intensify research on the drivers of insect decline and on the use and environmental impacts of pesticides and herbicides.

Currently we can only list possible causes; we are unable to rigorously assess their relative importance on any scale, whether global, national, regional or local. We cannot initiate counter measures to conserve insects if we don't know what is responsible for their decline. Insecticides are clearly a major concern. The efforts of the TFSP and other initiatives on the issue of pesticides need support to ensure that policy on agrochemicals is informed by the best possible scientific evidence.

Support innovative methods of pest control that do not rely on agrochemicals.

History has demonstrated that economic returns on successful biocontrol efforts can be massive. We are also on the cusp of new genetic technologies that could selectively control pest species and make pesticides redundant. Any perceived dangers of such methods must be assessed against the benefits that would accrue from reduced insecticide use. We are also on the cusp of new genetic technologies that could selectively control pest species and make pesticides redundant. Any perceived dangers of such methods must be assessed against the benefits that would accrue from reduced insecticide use.

Support research on climate change impacts on insects and connectivity.

We need a better understanding of the impacts of climate change on insect physiology and phenology. We also need a better understanding on the challenges and opportunities in using ecological networks to maintain and improve connectivity and resilience. Without connectivity, insects that are trapped in habitats with deteriorating climatic conditions are doomed to local extinction.

Improve public understanding of insect values.

Insects generally get bad press and many people, especially in urban areas, regard them with distaste. There are exceptions: butterflies and dragonflies are loved because of their aesthetic appeal, and bees are increasingly viewed as useful because of the value of bee products, their association with flowers and summer, and an increasing knowledge of their importance for pollination. We need to build on these positive perceptions and use them to instill awareness of our dependence on insects for life on earth and our own welfare. This message needs to be built into school curricula throughout the world.

What are the implications for policies?

Insect species should receive greater consideration on national or regional Red List of endangered species (Goergen et al., 2011). Very few African species of arthropods are considered in the CITES appendices listing the endangered or threaten species, apart from three species of the scorpions from the genus *Pandinus* and the South African stag-beetles genus *Colophon* listed in the appendix II. However, listing insects under CITES has had mixed impacts. In Papua New Guinea, while it may protect some birdwing butterfly species, it also hinders potential trade in some species that could be appropriately farmed.

Policies for insect conservation need to be different from those applied to plant and vertebrate species. The ability of insects to spread and to occupy niches in largely man-made ecosystems implies that policies for the conservation of insect species cannot depend only on highly preserved natural ecosystems. Further, trade can be a useful tool in conserving insect habitats (Gordon & Ayiemba, 2003; Hutton & Leader- Williams, 2003).

In some cases, there is a strong link between insect trade (for foreign collectors, for local or foreign insect consumers) and the livelihoods of poor rural communities. Living on forest insects, especially by collecting and breeding them for export, can incentivize local conservation efforts.

The International Task Force on Systemic Pesticides has concluded that the consequences of losing the invertebrate fauna due to continuous exposure to ubiquitous residues of neonicotinoids [and fipronil] are ... far reaching and cannot be ignored any longer". New regulations to restrict their use should be put in place urgently, as France has done totally, and EU partially. Policies should be put in place that encourage environmentally friendly alternatives to pesticides.

Environmental and agricultural policies need to recognize the positive economic values of natural habitats, ecological intensification, ecological networks, and insect conservatories, and to introduce incentives for their application in landscape management.

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News and Announcements

American Geophysical Union

AGU Fall Meeting

December 1-17, 2020

#AGU20 Fall Meeting will be one of the world's largest virtual scientific conferences, with exciting programming and events. This will be AGU's most diverse, engaging and dynamic Fall Meeting to date.

#AGU20 is scheduled from 1-17 December to accommodate over a thousand hours of virtual content to minimize conflicts while maximizing global engagement. Most content will be prerecorded or available as posters for attendees to view and peruse outside of scheduled sessions during the meeting.

For more information, click **here**.

American Meteorological Society

Priorities for a New Decade: Weather, Water, and Climate

A Statement of the American Meteorological Society

Weather, water, and climate (WWC) affect every community and every economic sector. Scientific observations and research in WWC help us meet basic human needs and create enormous opportunity for societal advancement. Near-term policy choices will help determine the nation's WWC capabilities and vulnerabilities for decades to come.

To ensure economic and societal well-being over the next decade, AMS recommends that the nation:

- develop the next generation of WWC experts
- invest in research critical to innovation and advanced services
- invest in observations and computing infrastructure
- create services that harness scientific advances for societal benefit
- prepare informed WWC information users
- build strong partnerships throughout the WWC enterprise
- implement effective leadership and management

For more information, click **here**.

American Society of Civil Engineers

Investing in Aging Water Infrastructure: Exponential Potential and the Cost of Inaction

A hidden network of pipes and pumps ensure water flows through homes and businesses, but people often take these critical systems for granted. This month the American Society of Civil Engineers (ASCE) and the Value of Water Campaign (VOW) partnered on a new economic report that quantifies water infrastructure investment and what happens when the nation fails to invest. With the research firm EBP, they sought to understand two contrasting futures: a future where we meet our water infrastructure needs and a future where we allow water infrastructure investment to fall further and further behind.

ASCE and VOW's report “The Economic Benefits of Investing in Water Infrastructure: How a Failure to Act Would Affect the US Economy Recovery” shows that closing the water investment gap brings enormous economic benefits and improves public health protection. As federal lawmakers consider how best to alleviate economic hardships caused by the COVID-19 pandemic and protect public health, it is critical they understand the role water plays in keeping communities safe and healthy and our economy flowing.

For more information, click **here**.

American Society of Landscape Architects Fund

reVISION ASLA 2020: A Virtual Experience

November 16-18, 2020

When a landscape architect faces a change in conditions for their project, they have to revise the plans—just as we've had to do with the conference when faced with the COVID-19 crisis.

reVISION ASLA 2020 is a reimagined, virtual experience for an evolving profession where you will get the opportunity to learn, connect, and celebrate landscape architecture—all from the safety of your own home.

For more information, click **here**.

American Water Resources Association

2020 Annual Water Resources Conference

November 9-11, 2020

AWRA will hold its 2020 Annual Water Resources Conference as planned this November, though with major changes due to extraordinary circumstances. The Conference will be held completely virtually. Registration is open and rates have been reduced so that you can take part in the conference that has earned a reputation as one of the most diverse and inclusive conferences in water resources management.

For more information, click **here**.

Society of Environmental Toxicology and Chemistry

SETAC North America 41st Annual Meeting

November 15-19, 2020

Adjusting to the continuously changing global situation and listening to members and staff, SETAC has decided to move their North America 41st Annual Meeting completely online.

The meeting will be held on the same dates, 15–19 November 2020. Building on the success of the first SETAC Science Conference (SETAC SciCon) earlier this year and the meeting theme, “2020 SETAC In Focus: Environmental Quality Through Innovative Science,” SETAC will aim to provide you with the best possible conference experience that is accessible, affordable and convenient.

For more information, click **here**.

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