SeaAhead
BLUETECH INNOVATION

IN COLLABORATION WITH:

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THE WIND, WINGS, FINS, AND SHELLS:

Innovations to Support Biodiversity in Offshore Wind

June 2024


Ørsted


The Venterra Group

SeaAhead

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Executive Summary

OFFSHORE WIND'S AMBITIOUS GROWTH

The offshore wind (OSW) industry is expanding rapidly, experiencing a 15% growth in 2023, with 7.7GW of new offtake contracts awarded in the U.S.[1] Ambitious industry-leaders are asking: beyond its role in the energy transition, can offshore wind also have a net-positive impact on biodiversity? Achieving this goal requires not just mitigating harm and restoring affected habitats, but enhancing them into healthier ecosystems. This pursuit of net positive impact creates significant opportunities for innovative startups.

THE OPPORTUNITY: BIODIVERSITY INNOVATIONS IN OSW

To understand the opportunity for startups and investors, SeaAhead analyzed our database of >2,000 ocean-related startups and with support from partners Ørsted and Venterra Group, categorized a sample of >150 relevant to supporting biodiversity in OSW as:

- **Protections**: Startups that avoid, reduce, and mitigate harm to biodiversity, including from turbine collisions, disturbances from vessels, and noise.
- **Restorations**: Startups that restore and enhance the natural environment through habitat structures or by directly restoring affected species.
- **Enabling Technologies**: Startups that facilitate biodiversity by sensing, measuring and collecting essential data, and communicating and providing data insights for decision-making.

This report highlights key companies seeking to drive this transformation. These startups are innovating across all stages of the offshore wind development timeline, with positive impacts for all affected species groups. We also identified co-use opportunities, which can address biodiversity while accomplishing additional goals, such as aquaculture production or carbon removal in the wind farm space.

THE KEY ROLE OF TECHNOLOGY IN THE NET-POSITIVE FUTURE

Through this report, we offer actionable insights for investors and stakeholders committed to a sustainable and thriving marine ecosystem. Beyond technological potential, startups must navigate a complex political and regulatory environment, stakeholder conflict, and data operability challenges. As a capital-intensive industry, there are long development timelines and general risk aversion, which pose hurdles for the introduction of new technology. Success will favor those startups that include other industry benefits in their business models alongside their biodiversity benefits, such as cost reduction, permitting time reduction, conflict mitigation, and safety improvements. Access to supportive resources during early startup development stages from leading corporations, the public sector, and philanthropy can provide the validation needed for investors and uptake within the supply chain. Successfully integrating these technologies will be essential for meeting the ambitions of the offshore wind industry to protect and restore natural ecosystems during the transition to a low-carbon future.

MARKET MAP OF INNOVATIONS SUPPORTING BIODIVERSITY IN OFFSHORE WIND:

Protections

FROM TURBINE COLLISION

spoor, STRIX

FROM VESSEL USE

Photon, Aloft Systems, Synthetik, pasca

FROM NOISE IMPACTS

ThayerMahan, AdBm

Restorations

ECOSYSTEM STRUCTURES

NATRX, Archireef, Kind Designs, ECONCRETE, ARC Marine

RESTORATION

Coral Vita, REEFGEN

CO-USE

VESTA, Equatic, VYCARB, INVERSA, reefy, ecoSPARS

Enabling Technologies

SENSING AND MEASURING

Whale Seeker, stream ocean, SeaDeep, Ocean Data Network, Nature Metrics, katchi, Aquatic Labs, Greensea IQ, planblue, SEATREC, bedrock ocean exploration

ROBOTICS SYSTEMS

SeaTrac, HonuWorx, OpenOcean Robotics, Saildrone

DATA INSIGHTS

Apeiron Labs, ITHACA, bluemvmt, ocn.ai, CurrentLab, atdepth MRV

COMMUNICATION

JET CONNECTIVITY, HAVGUARD, HydroLINC

[1]Global Offshore Wind Market Report 2024 (ERM)


Ørsted

Introduction

As an emerging sector in the United States, offshore wind has the potential to foster innovations that benefit both people and the planet, avoiding and minimizing ecosystem impacts. As an ocean innovation and investment company, SeaAhead has an interest in understanding the startups and use cases for applying technology to support biodiversity in offshore wind. Drawing on the knowledge of offshore wind developer Ørsted, and offshore wind energy services organization The Venterra Group, along with several external interviews, SeaAhead applied a taxonomy to a dataset of startups to provide investors with insights into this space.

This whitepaper focuses on the potential of offshore wind innovation in biodiversity protection, highlights technology and startups in the “bluetech” landscape, and classifies startups based upon their impact in the sector. It is intended to serve as a roadmap for venture investors as they engage with relevant startups. We first address the state of offshore wind in the United States, outline the existing frameworks for examining biodiversity impacts, and review relevant global policy. The study will then discuss the methodology employed for the collection and taxonomic analysis of the startup data, followed by insights drawn from the analysis and opportunities for further innovation. Finally, we look to the surrounding context. While there is extensive literature on biodiversity impacts from offshore renewable energy, this paper will be framed through the unique lens of innovation and investment. Through innovation, the offshore wind industry can thoughtfully monitor impacts and mitigate harm. They have the potential to restore ecosystems to pre-installation status – or ideally, even healthier.

Offshore Wind as an Emerging Sector in the U.S.

Offshore wind energy has emerged as a pivotal player in the transition toward clean energy. This is particularly true for dense urban coastal cities, such as those found on the East Coast of the U.S. where access to other sources of renewable energy may be more constrained. In addition to being able to site renewable energy near urban centers, higher wind speeds and consistency in direction means offshore installations require fewer turbines to produce the same amount of energy as onshore wind farms.[2] The ocean covers over 70% of the planet, with 64% of U.S. waters considered "suitable" for offshore wind development.[3] These facts, alongside the efficiency and localization capabilities of offshore wind, have made for explosive growth in the industry that marks a fundamental shift in the renewable energy landscape.

To date, the U.S. has established roughly 240MW of offshore wind energy capacity.[4] In 2023 alone, there was a 15% growth in the U.S. offshore wind energy pipeline, despite the headwinds the industry has faced, driven by interest rates and a nascent domestic supply chain.[5] Beyond the U.S., the global offshore wind energy market also had a strong year of global growth in 2023 with the Global Wind Energy Council citing 8.8 GW of new offshore wind added onto the grid.[6] The total capacity of U.S. offshore wind projects reached 68 GW by the end of 2023.[7] 2024 has shown continued progress through new sites such as Southfork Wind and Sunrise Wind from Ørsted and Eversource, with a projected 132 MW and 924 MW capacity respectively.[8] Many others, such as Equinor's Empire Wind (810MW), Bay State Wind, Avangrid's Vineyard Wind (806MW), Ørsted's Revolution Wind (704MW), and Park City Wind (804MW) add to the growing capacity in the United States.[9]

The U.S. saw 7.7GW of new offtake contracts awarded in 2023.[10] While the installed base is still small, the pipeline is growing rapidly across 32 lease sites, with a total expected capacity of over 50GW.[11] Offshore wind project development, construction, and operation is projected to create approximately 83,000 jobs in the U.S. by 2030, with an industry investment projected to deliver $25 billion per year in economic output.[12] The scale of this undertaking is remarkable considering the U.S. only began development in the offshore wind industry in 2016, with 30 MW at Block Island Wind Farm off the coast of Rhode Island.[13] Given the projected growth of the industry, avoiding and minimizing impacts on marine life and enhancing biodiversity where possible are key concerns.

A Changing Climate and Offshore Wind

The ocean is home to 80% of the world's biodiversity.[14] As our climate changes, it drives biodiversity loss. Changing temperatures and chemistry in the ocean are causing irreversible ecosystem damage, an increase in disease transmission, and climate-driven extinction events.[15] The clean energy transition is crucial to reducing carbon emissions – therefore, moving to renewable energy sources may help reduce the negative impacts of increased CO_2 levels on global biodiversity.

> **"The energy transition is critical, and there are a lot of misconceptions about renewable energy. The reality is that there is no entirely benign energy source. So, we need to anticipate impacts and mitigate them; it's impossible to do something and not have any impact."**
>
> **GREG WATSON, MASSACHUSETTS ENERGY FACILITIES SITING BOARD**

[2]Offshore Wind Development and its Comparison with Onshore Counterpart
[3]United States Offshore Wind Energy Atlas
[4]Canary Media: First Big U.S. Offshore Wind Farm is Open
[5]Offshore Wind Market Report 2023 Edition (ACP)
[6]Offshore Wind Market Report 2023 (Energy.gov)
[7]Global Offshore Wind Market Report 2024 (ERM)
[8]Sunrise Wind, Southfork Wind
[9]U.S. Offshore Wind Projects in Development, Canary Media
[10]Global Offshore Wind Market Report 2024 (ERM)
[11]Offshore Wind Market Report 2023 (Energy.gov)
[12]Offshore Wind Market Report 2023 Edition (ACP)
[13] Ørsted's Block Island Wind Farm
[14]National Geographic One Ocean
[15]Biodiversity – Our Strongest Defense Against Climate Change, United Nations

As nations rally behind emissions reduction goals, offshore wind power has the potential to deliver reliable, scalable clean energy. There are opportunities to leverage developing technologies to facilitate a clean energy transition that minimizes harm to the environment and further, there is an ambition to leave ecosystems in a healthier state than they were before these developments. Innovation is imperative.

Ask Helseth, founder of Spoor AI, a startup using AI to identify and mitigate avian species disruption in offshore wind farms, understands the importance of integrating new technology into this space, **"I started my career working for NGOs for climate change, but as I worked, I began to realize that, in order to make a significant impact on the causes you care about, you need to build a business around the solutions you're creating, it's one of the only ways to have scalability."**

Frameworks for Assessing Biodiversity Impacts

To categorize innovations that can support a clean energy transition that is net-positive for nature, we looked to existing frameworks. We wanted to know how the public and private sector, including environmental regulators and offshore wind developers, assess and track both impacts on nature and benefits to biodiversity from proposed mitigation, conservation, and restoration interventions.

Measuring innovation impact for the ocean remains a critical challenge, which is why efforts like the emerging framework created by the 1000 Ocean Startups Alliance, called the Ocean Impact Navigator (OIN), are increasingly relevant. The OIN serves as an impact framework for investors and startups to glean information based on categories of impact and standardized reporting. This framework coalesces around six main impacts ranging from "Thriving and Restored Marine Habitats" to "Positive Socio-Economic Outcomes.[16]" Startups communicating on impact KPIs in this way simplify measurement for the ocean innovation ecosystem.

> **"In the science world, biodiversity is clearly defined as number of species per unit of area. In other sectors or contexts, however, it's muddled and often used more broadly to describe perceived positive, healthy, or balanced conditions."**
>
> **ANNIE MURPHY, PH.D., INSPIRE ENVIRONMENTAL**

The Science Based Targets Initiative (SBTI) & Science-Based Targets for Nature (developed through the Science Based Targets Network (SBTN)) are also relevant, as large companies, including Ørsted, are using or considering the use of their methodologies for tracking net zero or biodiversity objectives, respectively. As startups develop their own sustainability plans and reports, the SBTI/SBTN process can provide a common language and offers a clear pathway for using science to define targets to assess and report on impacts.[17]

Additionally, certain governmental regulations and policies now require biodiversity considerations. For example, in the U.K., the Biodiversity Net Gain Policy (BNG) came into place in February 2024 and states that all new developments must feature measures to enhance or create habitats that compensate for any biodiversity loss associated with a project.[18] The European Union has adopted a "Do No Significant Harm (DNSH)" principle that assesses whether an investment or economic activity that contributes to an environmental objective does not significantly harm any other environmental objectives.[19] Similarly, in the Netherlands, cost-benefit guidelines award "biodiversity points" during the bid phase and serve as a practical policy method for incentivizing the implementation of innovations.[20]

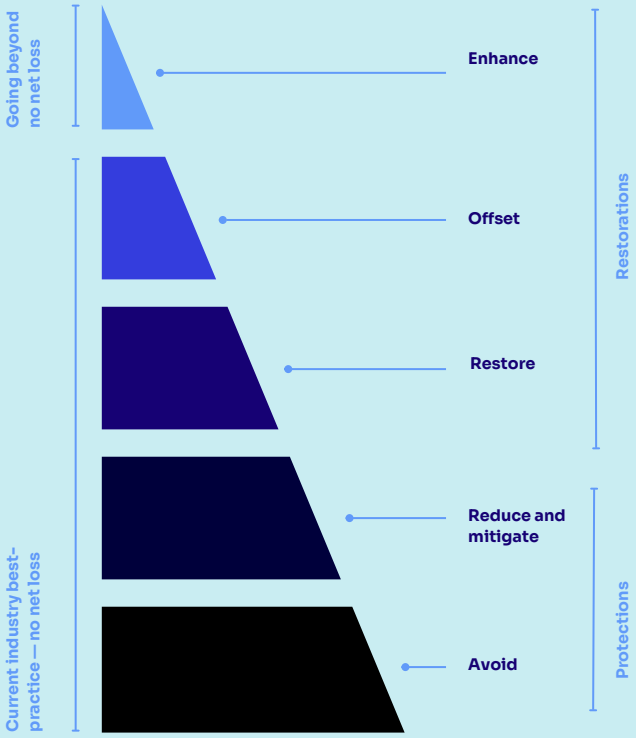
[16]1000 Ocean Startups Ocean Impact Navigator
[17]Science Based Targets Initiative (SBTI)
[18]Biodiversity Net Gain Policy UK
[19]EU's Do No Significant Harm Principle
[20]Government of The Netherlands Policy on Nature and Biodiversity

As the European offshore wind industry has more operating history than its burgeoning American counterpart, it should be able to offer insights about ecosystem impacts. Despite this history, the overarching sentiment is that impact assessment must be done on a case-by-case basis, reflecting site-specific considerations.[21] Monitoring and measurement are thus critical to evaluating impacts of offshore wind on ocean ecosystems.

While existing frameworks are important to highlight, none were the perfect fit for a discussion on biodiversity innovations in offshore wind. Thus, we looked to yet another structure, the mitigation hierarchy, as pictured below, which covers much of what was needed for this context and could be built upon. A further discussion of this process and our taxonomy development follow below.

A Taxonomy for Understanding Startup Innovations that Affect Biodiversity in Offshore Wind

The Mitigation Hierarchy



The mitigation hierarchy provides a commonly used conceptual framework for understanding how actors within the bluetech landscape intersect with the environmental concerns and priorities of environmental regulators and offshore wind developers. As shown in the figure to the left, “no net loss” has been the industry best practice and is often codified in national and state regulations. This aims for a natural system that is, overall, in the same state before and after a development activity. Going beyond no net loss, thereby having a net-positive impact (NPI) on biodiversity, has only recently become a key topic in offshore wind development. Ørsted, for example, has the ambition to have a net-positive impact on biodiversity for all its new renewable energy projects commissioned by 2030 or later.[22] This goal of enhancement adds another level to the mitigation hierarchy and another market for potential innovations.

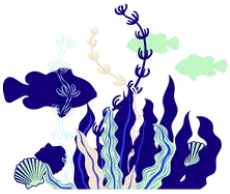
With these considerations in mind, the startup ecosystem for biodiversity and offshore wind was categorized based on several factors such as stage of use, application, species affected, and type of technology. The co-use potential for technology was also assessed. Each of these categorization approaches are described in greater detail in the following pages.

[21] How European Wind Farm Expansion Impacts Biodiversity
[22] Ørsted – Uniting Action on Climate and Biodiversity

A Simplified Mitigation Hierarchy for Startups

For the purposes of this paper, we simplify the mitigation hierarchy to define two major categories and a third cross-cutting, support category:

Efforts to avoid, reduce and mitigate harmful ecological impacts, here called **Protection**.



Techniques to restore, offset and enhance, which not only preserve but also restore natural systems, here called **Restoration**.

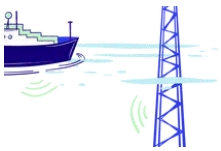
To support these two major groups of efforts, **Enabling Technologies** will play a critical role.

PROTECTION: TECHNOLOGIES TO AVOID, REDUCE, AND MITIGATE IMPACT

Protection technologies represent efforts by developers and the supply chain at large to avoid impacts on biodiversity and where these cannot be avoided, to minimize them. Technologies that allow stakeholders to avoid harm are those that reduce a negative impact directly. Disturbances can exist in the form of noise, vessel traffic, or physical interference of turbines both above and below the surface. Protection solutions may look like:

Protection From Turbine Collision: Detecting and curtailing operations when avian animals are nearby.

Protection from Harm from Vessel Use: Changing equipment design or operations to minimize wildlife disruptions.



Protection From Noise Impacts: Mitigation of acoustic disturbances from offshore wind farms.

RESTORATION : INNOVATIONS THAT RESTORE, OFFSET, OR ENHANCE THE ENVIRONMENT

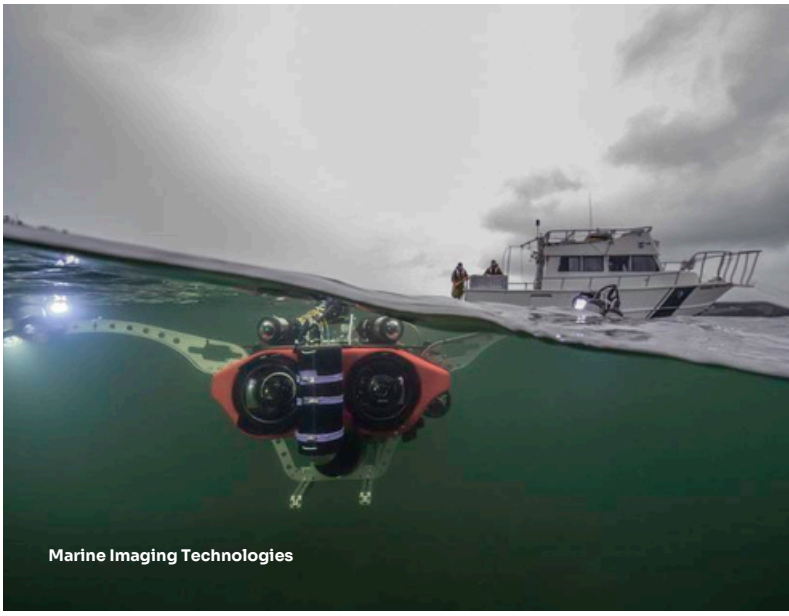
Restoration technologies represent efforts by the industry to first return what has been impacted to the prior condition, to compensate for those impacts that could not be restored, and finally, to enhance biodiversity beyond the state it was in prior to the offshore wind farm's implementation. These can include:

Restoration: Restoration of keystone or structural species (bivalves, corals, seagrass) to encourage regrowth of ecosystems.

Ecosystem Structures: Introducing biomimetic structures to drive biodiversity in the wind farm space.

ENABLING TECHNOLOGIES: FACILITATING PROTECTION AND RESTORATION EFFORTS

Enabling technologies are innovations that allow the industry to assemble the necessary information, through both real time and archival data. These technologies are used to implement Protection and Restoration techniques but do not directly avoid harm or restore habitats. The burgeoning field of bluetech innovation introduces cutting-edge sensors, submersible drones, and real-time monitoring systems that can facilitate the minimization of ecological impacts at lower costs. By proactively identifying ecologically sensitive areas prior to construction, important habitats can be protected. Monitoring parameters such as noise levels and underwater vibrations can facilitate swift corrective actions to curtail adverse effects. These technologies were categorized as follows:



Marine Imaging Technologies

Sensing and Measuring: Gathering data from the marine environment, including sensors monitoring marine life via cameras, passive acoustic sensors, chemical sensors, and in-situ monitoring systems.

Data Insights: Using data to create digital twins or predict phenomena in the marine environment, including seafloor models and predictive technologies for where certain animals will be located.

Robotics Systems: Operating systems to navigate the marine environment without manual operation, including underwater, surface, and aerial monitoring, which are equipped with other enabling technologies such as sensors and communication systems.

Communication Systems: Transmitting technologies that enable communication between devices involved in the subsea or surface space, as traditional land-based communication strategies do not function through water.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Many startups fall into multiple enabling technology categories, such as robotics systems with novel technology to sense and measure or communicate in real time. Addressing biodiversity challenges will require a multi-pronged approach.

Additional Startup Classifications

Alongside the mitigation hierarchy, startups and emerging technology innovations were assessed based on which species they helped protect or restore, the stage of an offshore wind operation in which they're relevant, and whether the company could be considered a co-use, as defined below.

OPPORTUNITIES FOR CO-USE INNOVATIONS IN THE OFFSHORE WIND SPACE

A potential area for innovation in offshore wind comes from the geographical presence of structures, power, and communications in the ocean. Here, we define co-uses as those technologies whose inclusion in an offshore wind farm is an additional potential economic use of that area, such as is found in siting an aquaculture operation alongside a wind farm or in using the site to facilitate the addition of technologies that sequester ocean carbon. Co-use of the offshore wind farm space can be an efficient and economic use of space. However, it can also bring complications with understanding the source of increased maritime activity impacts to key species. Co-uses also have practical considerations like insurance implications, and requires agreements between all parties.

> **"I am an advocate for co-use, especially aquaculture. Using the same footprint for multiple things can be great, but regulation can certainly be a barrier. Ecological impacts can be additive or not, which makes it challenging to assess potential interactive impacts of wind and aquaculture during permitting."**
>
> **ANNIE MURPHY, PH.D., INSPIRE ENVIRONMENTAL**

IMPACTS ON MARINE SPECIES

Novel technologies and their impacts often affect specific species. Categorizing these species groups can help identify gaps and opportunities for new innovations, including species of concern that existing innovations do not yet solve for. Six broader species categories were used: Benthic Invertebrates (excluding corals), Corals, Plants, Fish, Marine Mammals and Turtles, and Birds and Bats.

OPPORTUNITIES BY STAGE OF WIND FARM DEVELOPMENT

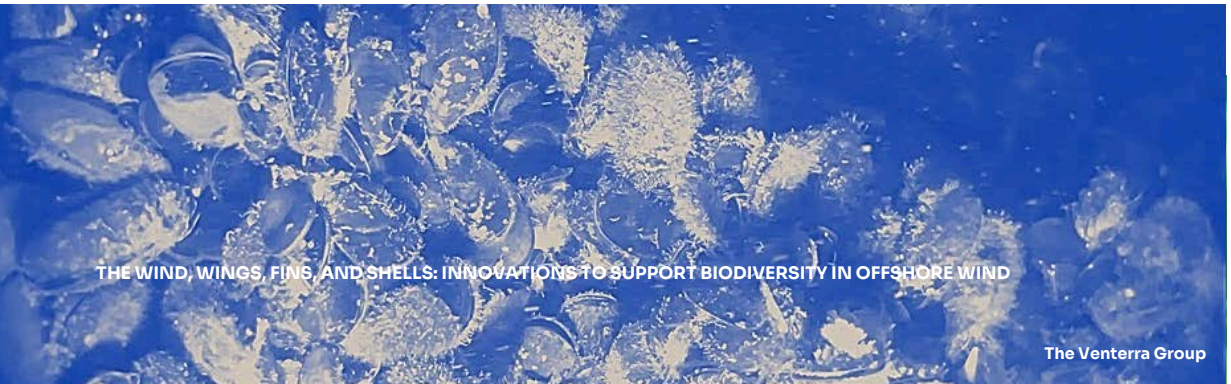
There likewise may be opportunities to identify if technology innovations cluster within certain stages of the offshore wind farm development process. Four major stages were defined for this purpose:

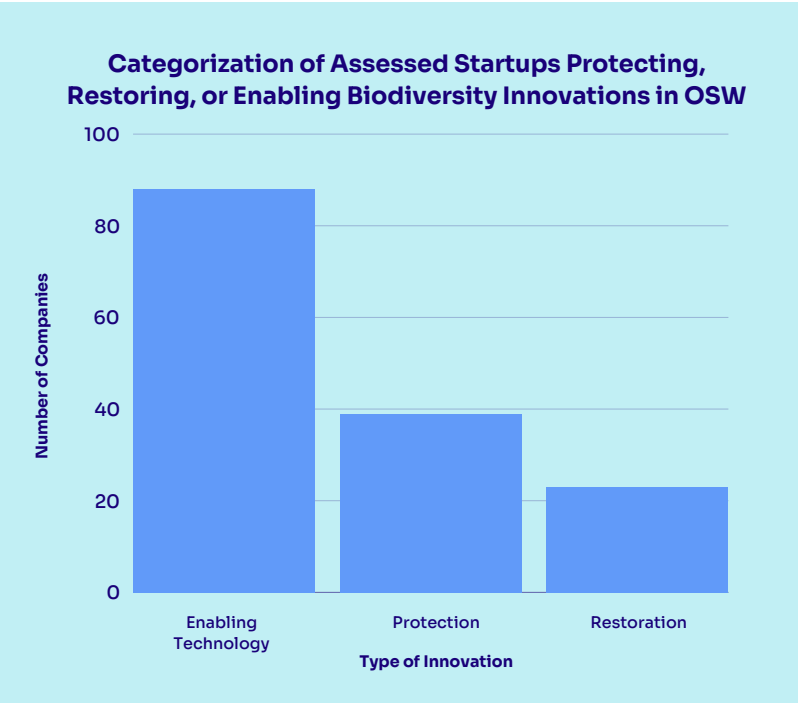
1. **Planning Design and Permitting:** Includes site selection, surveying, grid design, permitting, and all steps before construction.
2. **Installation**: Construction stage of the offshore wind farm.
3. **Operations and Maintenance**: Activities that take place when wind farms are installed and producing energy.
4. **End of Life**: Operations of the wind farm are no longer viable, and the structure removed as required by relevant authorities.

While repowering can be an important stage in the life of an offshore wind farm, innovations during this time don't significantly differ from Operations and Maintenance or End of Life and were thus not individually distinguished.

Innovation Insights: What the Data Shows About Emerging Tech in Biodiversity and Offshore Wind

With these frameworks in hand, the team analyzed SeaAhead's database of >2,000 bluetech startups, narrowing the field to focus on those that have both a clear relevance for the offshore wind industry and an impact on biodiversity. We selected >150 startups as relevant, with about half having a direct protection or restoration impact, the rest enabling technologies. Particularly in the case of enabling technologies, these sets of startups are an indicative sample of a much larger pool. While this is not an exhaustive review of all innovations in the space, the addition of further companies was not perceived to add value to the discussion after the initial 150 were investigated.





Protection Technologies Pinpoint and Mitigate Harm for Key Species

Startups categorized in "Protection" deal with mitigating harm to marine life including potential threats from acoustic disturbances, either from vessel operations or from the turbines themselves, vessel strikes to marine mammals and turtles, and physical seabed disturbances from the installation of fixed turbines and cables.[23]

In one example, developers face growing demands for bird and bat monitoring alongside their infrastructure to avoid collisions or disruption. Several startups, including **Spoor AI** and **Strix**, are specifically addressing this concern, integrating advanced, autonomous systems in offshore wind farms that can sense, measure, and predict the presence of avian animals to subsequently halt or slow energy production. While most monitoring technologies are classified as enabling technologies, those that use monitoring insights to take action to mitigate harm are classified as protections. These innovations can draw on real-time and historical data to integrate species-specific collision mitigation.

Many hurdles must be overcome for technologies like these to make their way into the supply chain for an industry as complex as offshore wind. For example, vessel related interventions enter the supply chain in one of two ways. If a service vessel is owned by the developer, their procurement team can specify the requirements for the necessary technology. However, if vessel operations are outsourced, the supplier would also need to accept the usefulness of the specific technology. Developers can encourage the use of protection technology by including mandates in their procurement packages and by being willing to pay any additional costs associated with their inclusion.

COMPANY SPOTLIGHT: PROTECTION

Thayer Mahan

GROTON, CT, U.S.

$50M in Series C and C+ funding (*Company reported*), for a total of >$62M (*Crunchbase*)

Classification: Protection - Vessel Use & Noise Impacts
Species: Marine Mammals and Turtles
Stage: All

Thayer Mahan is pioneering in the use of maritime surveillance techniques for use in offshore biodiversity monitoring and impact mitigation. The company's offerings include applying a combination of visual, electro-optical and acoustic monitoring technologies developed for the defense industry to monitor, track and protect marine mammals during construction. They are also bringing partner technology to market by implementing bubble curtains during installation, aimed at limiting acoustic harm to marine mammals and other sensitive species.

[23]For the purposes of this white paper, the focus remains on fixed turbines as opposed to floating offshore wind (FLOW) as most of the projects coming online in the US are fixed and data from fixed turbine farms in Europe is far more abundant.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Structural and Species Restoration Propels Recovery Within the Offshore Wind Farm

Startups actively working to restore the marine environment will be essential to achieving a net positive impact for offshore wind. These companies fell into two major groups, those introducing biomimetic structures to the environment to encourage regrowth of species and ecosystems, such as **ARC Marine**, and those directly restoring ecologically resilient species, also to encourage the return of a diverse and abundant biomass, such as **Reefgen**. Others aim to co-locate macroalgae and mollusk aquaculture at offshore wind farms, which may lead to both economic and biodiversity benefits.[24]

In the area of biomimetic structures, solutions like artificial habitats and construction materials designed to enhance biological growth can play an instrumental role in the restoration of ecosystems affected by construction activities. The integration of these designs within wind farm installations, such as within the scour protection or in the overlay systems for seafloor cables, like those being designed by **ECOncrete**, can provide habitat and support species diversity and growth, thereby propelling recovery from impacts and, in many cases, restoring degraded habitats.

Often, restoration technologies are provided to OSW developers as a part of a much larger procurement package. These technologies can enter the supply chain at the material supply level, the engineering firm level, or even the developer level. When a restoration intervention involves directly planting ecologically important species, it is often subcontracted to restoration experts.

COMPANY SPOTLIGHT: RESTORATION

Natrx

RALEIGH, NC, U.S.

Raised >$3.5M in Oct '23 seed round, with total raised >$5.2M (*Company reported*)

Classification: Restoration - Ecosystem Structures
Species: Invertebrates, Corals, Plants, Fish
Stage: Operations and Maintenance

Natrx uses software to assess and develop solutions for coastal asset protection and then manufactures nature-compatible project-specific systems. Their custom, 3D-printed modules, 'Exoforms,' are designed to get stronger over time as nature grows into and alongside them, promoting energy dissipation, sediment deposition, habitat creation, and biodiversity. Their infrastructure can be placed in an offshore wind farm to drive growth and abundance of marine life while protecting assets. The company positions that their technology requires less labor and emits less CO_2 than other solutions. (Disclosure: SeaAhead is an investor)

[24] Seaweed and Mussel Farms Improve Biodiversity (The Nature Conservancy)

COMPANY SPOTLIGHT: ENABLING TECHNOLOGY

NatureMetrics

GUILDFORD, U.K.

Raised £11.9M in recent round, bringing total raised to £30.7M (Companies House Filings)

Classification: Enabling Technology - Sensing and Measuring
Stage: All

NatureMetrics performs biodiversity monitoring using environmental DNA (eDNA) sampling technology. eDNA techniques can pick up DNA traces left behind in the environment, which can then be used to monitor and measure the presence of species, including those difficult to detect using other methods. The company claims greater accuracy and consistency over visual surveys. This type of data for an offshore wind farm can contribute to achieving a net positive impact by providing a view on species richness in the area during planning, for comparison with species richness at other development stages to inform the need for interventions.

Enabling Technologies for Monitoring Operations and Impact are Flourishing

Monitoring and measuring biodiversity is a difficult task, especially when baseline data sets do not exist and multiple ecological measures are changing simultaneously. Technologies that can adeptly maneuver these remote, offshore projects and then communicate back are thus crucial to the success of both the protective and restorative interventions and the industry at large.

NUMBER OF ENABLING TECHNOLOGIES BY CATEGORY IN THE DATA SET

Where companies are relevant in multiple categories, they are counted more than once.

72	25	26	14
Sensing and Measuring	**Data Insights**	**Robotics Systems**	**Communications**

Robotic systems provide the ability to collect and report on biodiversity data without the need for large crews or vessels, limiting some of the safety concerns when operating in the offshore environment and potentially offering cost efficiencies. We limited inclusion in this category only to those systems with sufficient payload capability to include cameras or acoustic monitoring, including startups **Saildrone** and **SeaTrac**. These systems can carry the novel sensing and measuring systems other startups are developing that can help to identify and track species, including environmental DNA (eDNA) monitoring from companies like **Nature Metrics**. **Seatrec** is developing technology to extend the operating deployments of subsea devices and by powering them with energy harvested from water column temperature differences.

Communications between these devices and the teams tasked with monitoring interventions has historically been difficult. Startups including **Hydronet** and **WSense** are working to improve real-time monitoring capabilities.

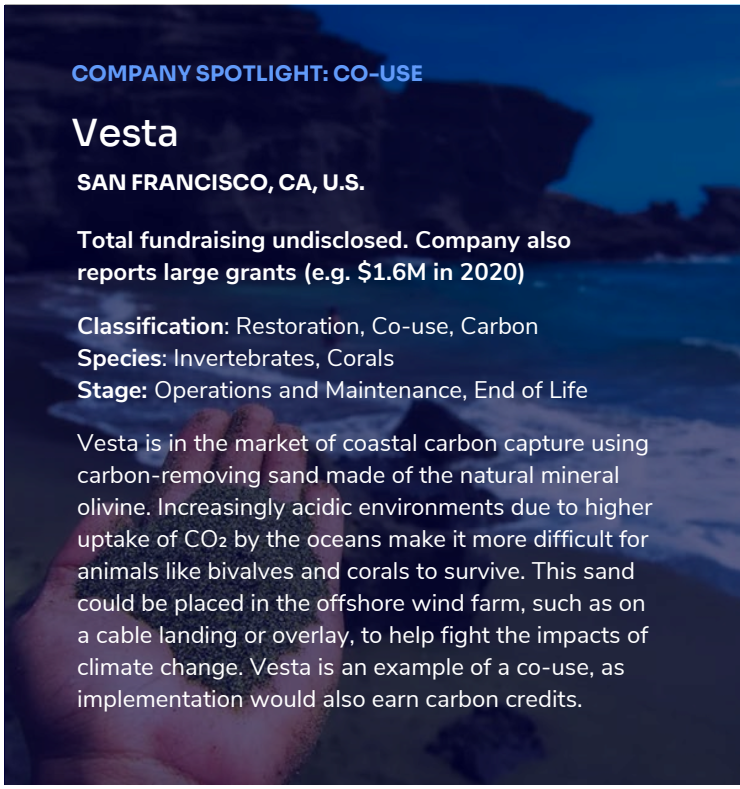
> **"What is top of mind for me is communication in real time. We need to get to a point where we can define when an ecosystem is healthy, be it through sensing platforms or eDNA, without physically being there to collect the data. So, scaling up affordable and deployable systems that can transmit information in real time is extremely important."**
>
> DR. COLLEEN HANSEL, WOODS HOLE OCEANOGRAPHIC INSTITUTION

Once all of this data has been collected and returned to shore, it then needs to be interpreted. Many startups are aiming to make this information more readily accessible and easily interpreted. Companies like **Bluemvmt** are bringing easier data manipulation and visualization to stakeholders. Given the large expense of most sensing and monitoring platforms, there will be a need to use modeling tools and AI to interpret how these data points translate to what is occurring over large areas. These startups, including **atdepth MRV**, can then enable better decision-making through predictive capabilities and provide systems for reporting and verification of impacts.

When an OSW developer is interested in enabling technology for biodiversity, it is typically because monitoring is required by regulation or because it has been identified as critical to other priorities, including transparency with key stakeholders.

Co-Use Innovations Can Address Biodiversity Through Adjacencies

As previously discussed, co-use opportunities are those that take place in the physical space of the wind farm, but are for other economic uses beyond renewable energy. Some companies are aiming to take advantage of the economic and biodiversity benefits of co-locating aquaculture in the offshore wind space.[25] Another example of a co-use opportunity is companies aiming to capture or sequester carbon, which can include mitigating ocean acidification. Companies like **Vycarb** or **Vesta**, which directly sequester CO_2 from the oceans through limestone or mineral sand, can be good examples of ways to make use of OSW-dedicated spaces. These startups may mitigate harm to bivalves, corals, and other animals under stress in low pH environments. There are also innovations that aim to grow and sink seaweed to directly sequester carbon, but evidence suggests the effects are under-researched and therefore not included in this scope.[26]



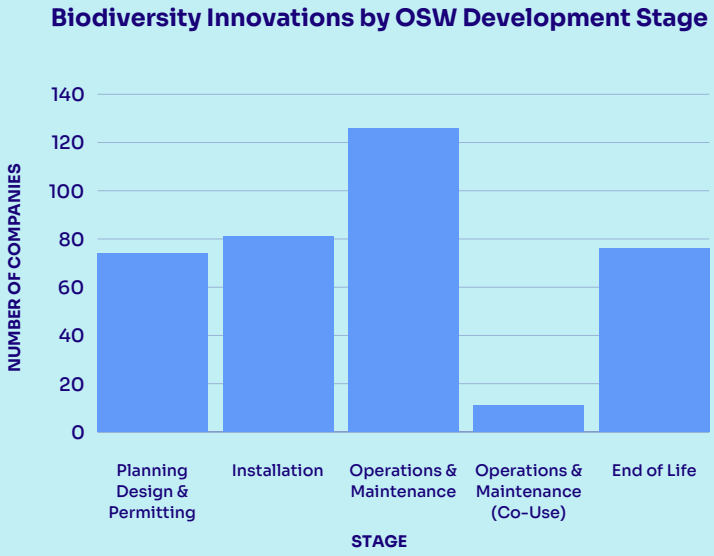
Novel Technology Applies Along the Offshore Wind Development Timeline and Across Species

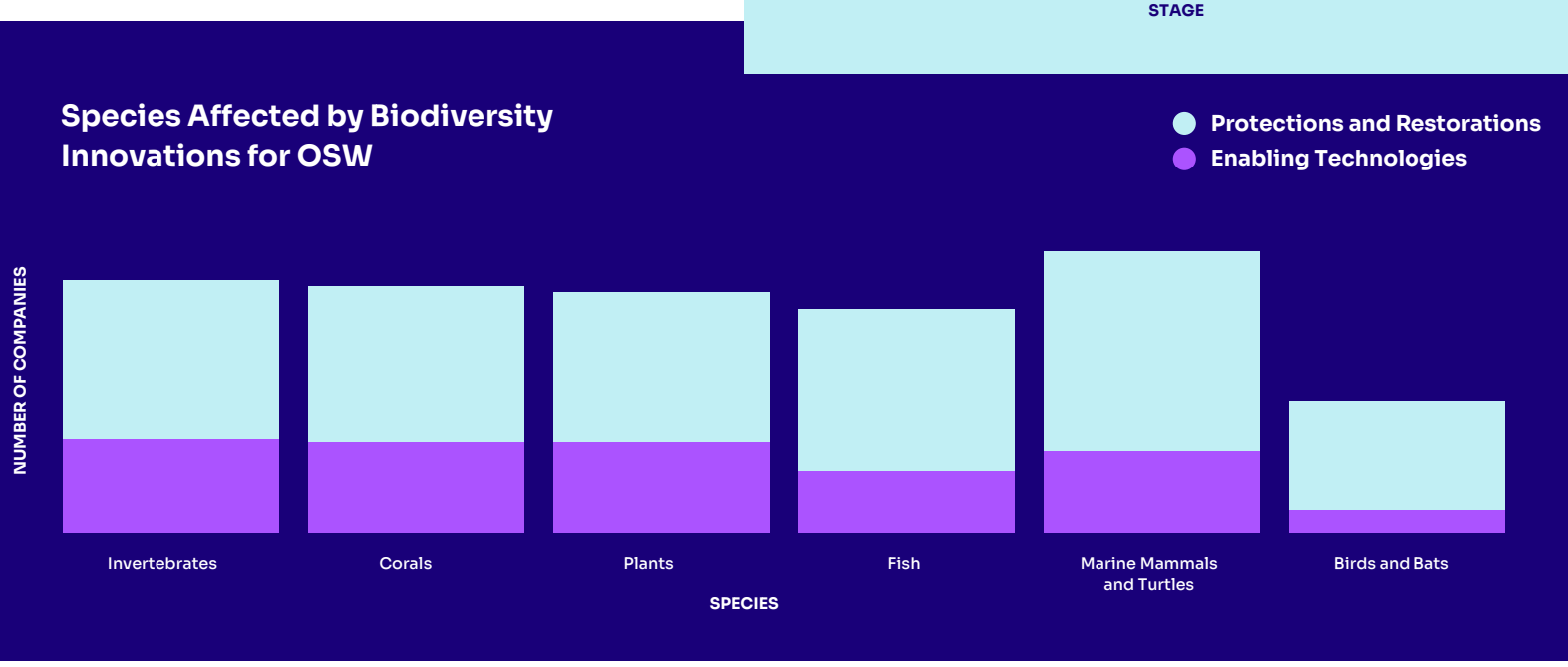
Innovations were also assessed based on stage in the development of an offshore wind farm. While most technologies are active during the operations and maintenance stages of an operation, there is plenty of market opportunity during both the planning stage, such as data insights technologies, and the installation stage, such as in addressing the demand for approaches that make the installation process less disruptive to marine life and ecosystems. Technologies employed during the planning stages included digital twinning technologies, biodiversity assessment tools, and vessel-related harm mitigation. Solutions involved in the operations stage of an offshore wind project relate directly to avoiding harm and restoring habitat, such as through the creation of reef structures at the bases of turbines or in cable overlay protections. Some companies within the operations and maintenance stage were classified as co-uses, including deep-water aquaculture and carbon sequestration solutions (broken out separately in the following graphic).

[25]Seaweed and Mussel Farms Improve Biodiversity (The Nature Conservancy)
[26]Deep-Ocean Seaweed Dumping for Carbon Sequestration

In startup development, timing is everything. One consideration for investors is when the startup needs to 'get into a project' versus when their technologies will actually be implemented. For instance, it takes several years between specifying scour protection to deploying in the construction phase. This long sales cycle can be a risk, both in missing the appropriate entry point, as well as in securing the financial resources for the intermediate periods. This risk may be mitigated through identifying complementary faster markets for the same technology.

Note: Startups in both graphics can be classified as applying to multiple categories.





Beyond the OSW stage, these companies were also assessed based on which species they had an impact on. Marine mammals, specifically endangered whale species, have attracted significant public attention. Companies like **Parker Maritime Technologies**, working to quiet industrial-scale vessel operations, have the opportunity to support this effort. Beyond marine mammals, however, it is also crucial to consider invertebrate, fish and other species groupings that together uphold a thriving ecosystem. Many of the startups in this dataset were successful in addressing species at all trophic levels, such as **Open Ocean Robotics**. Additionally, although avian animals can be drawn to the light from the turbines' nacelles or to the aggregation of fish around the bases, studies chronicling bird and bat collisions with turbines are nascent and often inconclusive.[27] Thus, monitoring technologies are becoming increasingly crucial from a baseline data perspective. Fish are less often affected by offshore wind installation and operations, as they can largely coexist in the space, which could explain why startups protecting fish are less common. In the U.S. marine ecosystem, the focus is on protection of Essential Fish Habitat (EFH) for specific focal commercial and recreational species.[28]

[27] Update on the current state of knowledge on the impacts of offshore wind farms on birds in the OSPAR Region
[28] BOEM Renewable Energy State Activities

Context Considerations as Technologies that Support Biodiversity Come to Market

The climate crisis and global biodiversity crisis are inextricably linked. The scaling of global offshore wind offers a potential opportunity to address both. By bridging the gap in knowledge and facilitating data-driven decision-making, advancements have the opportunity to guide the industry towards a future where clean energy and ecological health can go hand-in-hand. By providing a framework for startups to address challenges to biodiversity from offshore wind, the innovation ecosystem can be problem-focused, which will make these solutions more attractive to developers, regulators, conservationists, and investors. Advancing towards this future will demand a collaborative spirit among the diverse stakeholders that have interests in the ocean commons, from renewable energy developers to the supply chain, from environmental NGOs to policymakers, scientists, and entrepreneurs.

Key Barrier to Entry for Innovation: Policy and Regulation

The role of policy in steering offshore wind energy development cannot be understated. Governments, through their tender offerings, set the incentives for the industry. Broader policies may also support comprehensive approaches to biodiversity enhancement during development decisions, such as the BNG discussed above, and the developing Marine Net Gain framework in the United Kingdom. Policy also guides permitting, another potential area for comprehensive incorporation of, and emphasis on, nature-inclusive solutions. By providing clear guidance, regulators can then incentivize biodiversity-enhancing technology, rules for decommissioning, and risk-reduction opportunities.

For startups, there are barriers to wide-scale adoption both in the regulatory environment, as regulators are often prescriptive about which technologies are required, and in the risk-adversity of the sector driven by the initial high costs of introducing new technology in the offshore environment. We have found that success rates for hardware companies are higher when pilot tests, typically performed in other sectors or use cases, are completed before the technology is campaigned to decision-making bodies within the developer. When they do move toward procurement, these technologies can enter the supply chain as part of a research package initiated and often directly managed by the developer.

Given the pace at which innovation develops, regulators are pressed to adapt. Today, many new technologies are held back by the lack of regulatory flexibility, particularly in the permitting phase. This is complicated by the gap in consensus on the most accurate and effective way to measure and improve biodiversity. To date, there is limited at-sea infrastructure that can be used to ‘ground truth’ innovations, particularly those that are used to measure biodiversity impacts, making it difficult to gain confident investor engagement. Biodiversity-focused startups therefore have a high ‘burden of proof,’ and a long timeline for return on data, making it less likely that investors will invest in first-of-a-kind solutions. Because of the consequent difficulty born from this, creating a marketable product that achieves regulatory approval is challenging. Offshore wind, given the presence of infrastructure, could present an opportunity to accelerate this market by facilitating the evaluation of these technologies in a real-world environment.

> **“The inoperability of the data is a challenge and it’s stifling to innovation because investors look for market proof, so fragmentation scares a lot of people.”**
>
> **MARCELINO ALVAREZ, FOUNDER & CEO, PHOTON MARINE**

Lack of Data Sharing and Stakeholder Collaboration Could Inhibit Growth

Project development for offshore wind is highly location-specific and regionalized, making it complicated to scale biodiversity technology used by one project to all other companies and sites. The types of data that can feasibly be collected can also differ from location to location. Lack of baseline data on species lists and abundance makes measuring before and after the introduction of offshore wind, by change in population abundance, for example, doubly hard.

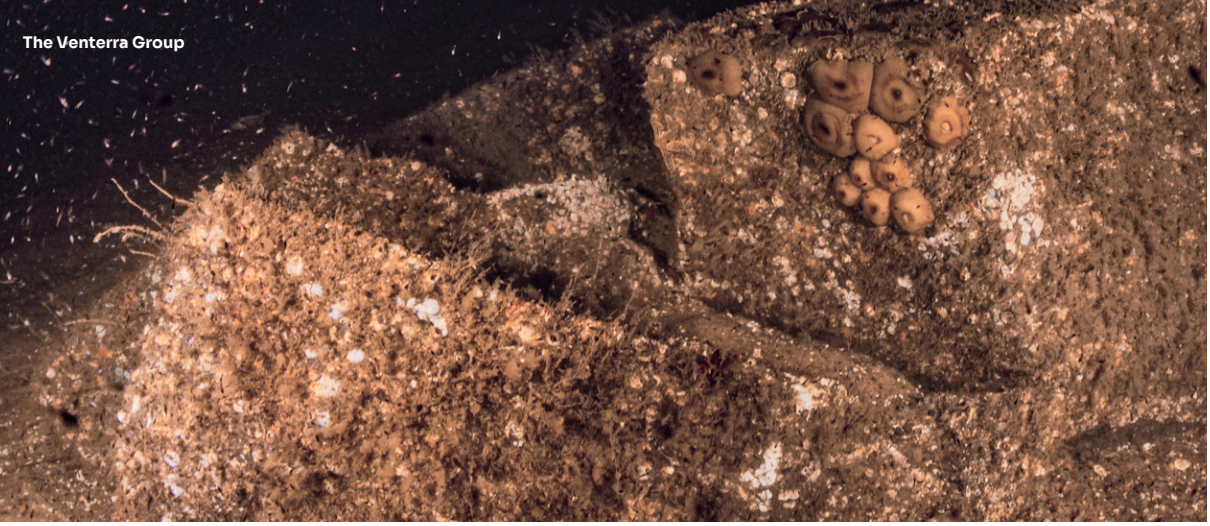
> **"In New England, there just isn't good baseline data. Everything is already happening, as opposed to projects that collect several years of data before commencing. We are interested in the cumulative impacts of OSW development on habitats and migratory corridors, not just impacts from an individual lease area. eDNA is great, but migratory species that are passing through can be more difficult to detect without acoustic tagging or visuals."**
>
> **MICHELLE CHO, NEW ENGLAND AQUARIUM**

A further challenge arises when considering the siloed nature of the ocean data sources between academics, entrepreneurs, philanthropists, non-profit leaders, and the public sector. Integrating new technologies and startups into a nascent but growing industry such as offshore wind is one way to bridge this gap. Collaborative partnerships between stakeholders are vital to harnessing the full potential of innovation.


The Venterra Group

> **"Collaboration and data sharing don't naturally happen in the course of doing business, so these are things that need to be invested in and incentivized. We have the opportunity to take advantage of data management technology to aggregate data generated from individual offshore wind farms and make it accessible, developing platforms to create a safe space where we can ask the right questions together, while protecting legitimate proprietary business interests."**
>
> **FARA COURTNEY, OUTER HARBOR CONSULTING AND MOCEAN**

These partnerships can pool resources, share data, and combine expertise to create a more comprehensive and accurate understanding of offshore ecosystems. Conversely, stakeholder conflict can pose a threat to the efficacy of these solutions.


The Venterra Group

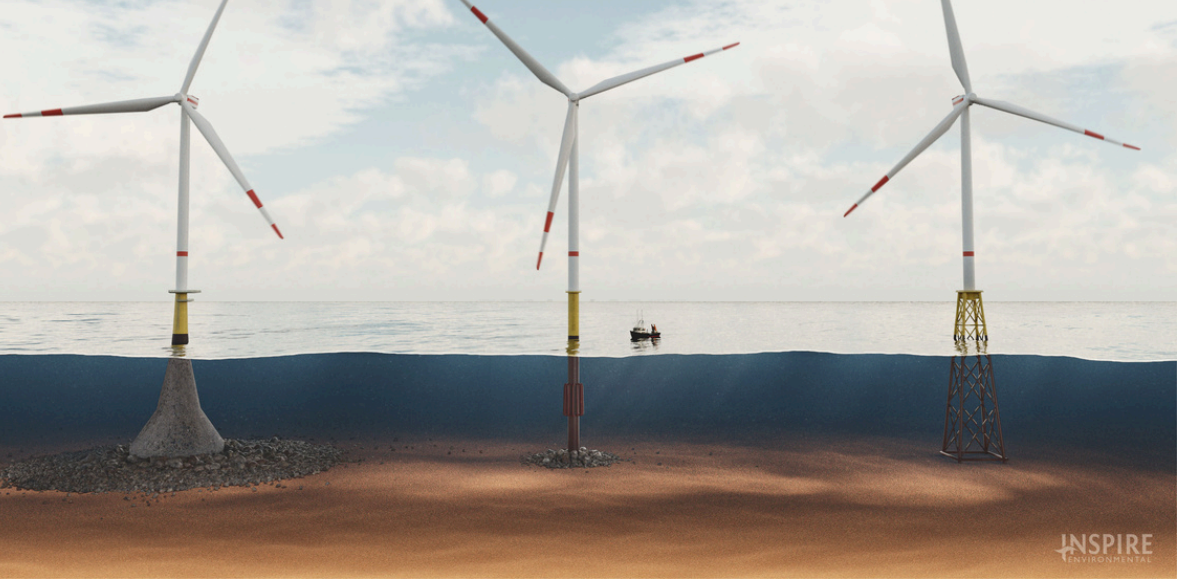
Attracting Investment in a Risk-Averse Sector

There exists a level of risk for investors driven by a lack of consensus around the efficacy of solutions. Biodiversity startups are held to a high standard; before these companies can secure early investment or deploy a pilot, they are being asked to show traction and science-backed data. This is an area where public and philanthropic funding sources can fill an important gap, as non-dilutive funding during the early stages of startup development can provide crucial support. When knowledgeable startup incubators and accelerators are involved earlier in the startup journey, these technologies can receive a level of validation which makes them more attractive to developers, and this involvement with large industry players can be positive for their investment prospects.

> **"Generally, [a startup's involvement with industry] is attractive [to investors]. It facilitates a joint development agreement where industry is paying for the pilot to help prove this [new technology] out, which often leads to a satisfied customer. These customers then buy multiple units, telling their colleagues about its success, and that, from an investment perspective, is good news."**
>
> **ADAM DE SOLA POOL, ANGEL INVESTOR**

When technology is integrated into large projects with long lifecycles, it can result in contracts that can offer financial stability for the startups, which is attractive for investors. Additionally these early wins can help to address risk aversion in the sector, as initial successes with one developer or in another related industry can make the technology more appealing. However, getting to that point can be a challenge, as startups need to enter the process early, since many decisions are made in the bidding process or early stages of OSW development. Investors must then have the capacity to enable the startup to wait, or diversify markets, in the period between winning a bid and implementation. It is also important for investors to consider the role of politics in a startup's success, as significant changes can occur to federal or state support for wind development if presidential administrations or other governmental bodies change leadership.

Another interesting tension investors will consider before funding a given venture is the offshore wind sector's readiness to take on cutting-edge technology. A sector like banking, for example, necessitates large, internal tech-savvy teams that are at the forefront of innovation so that they can maintain a competitive edge in a fast-moving marketplace. Biodiversity technologies in offshore wind, on the other hand, can be perceived as a nice-to-have, not a need-to-have, if not required by regulation or other mandates. Given heavy regulation, and that prices are largely the result of energy markets and not driven by adding additional value for the customer, startup solutions that can meet core developer needs for reducing costs and risks will have an easier time raising capital.



Moving Towards a Net-Positive, Low-Carbon Future

In the face of a changing climate, alternative energy solutions like offshore wind are set to play a leading role in the transition. As we move toward this low-carbon future, the offshore wind industry can set a new standard by not only mitigating harm to biodiversity but by fostering renewal. Corporations in the offshore wind supply chain are beginning to commit to understanding and reporting on their biodiversity impacts, which is the first step in a wider movement toward a commitment to a net positive impact for the industry. To meet the challenge, startups have emerged, bringing technologies to market that have the opportunity to protect species from the potential negative impacts of development and restore ecosystems, while enabling stakeholders to better monitor and manage impacts. Many of these technologies have additional benefits including cost reduction, conflict mitigation, and safety improvements. To be successful, these startups require a regulatory environment that is both flexible to the introduction of new technologies and provides the right incentives for continuous improvement. It is this, alongside corporate commitments to pilot and implement new technologies, that will set the stage for increased investment activity and successful young companies.

Acknowledgements

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Selected Startups Innovating for Biodiversity in Offshore Wind

The following startups were featured above and are representative of the larger dataset of innovations.Funding information drawn from in-program connection, Company announcements (CA), CrunchBase (CB), or PitchBook (PB).

COMPANY	CLASSIFICATION	STAGE	SPECIES	FUNDS RAISED
Aloft Systems	Protection From Vessel Use	Installation, Operations and Maintenance, End of Life	Marine Mammals and Turtles	BlueSwell Cohort III, Raised <$1M in capital and non-dilutive grants. (PB)
Aquatic Labs	Enabling Technology Sensing and Measuring	Planning Design and Permitting, Installation, Operations and Maintenance, End of Life	-	BlueSwell Cohort II, Undisclosed Seed Round. (PB)
ARC Marine	Restoration Ecosystem Structures	Operations and Maintenance, End of Life	Invertebrates, Corals, Fish	Raised $3.41M in capital. (PB)
atdepth MRV	Enabling Technology Data Insights	Planning and Permitting, Installation, Operations and Maintenance, End of Life	-	A BlueSwell Cohort IV member, recently awarded a >$2.5M ARPA-E Grant. (CA)
Bluemvmt	Enabling Technology Data Insights	Planning Design and Permitting, Operations and Maintenance, End of Life	-	BlueSwell Cohort IV, Funding undisclosed.
ECOncrete	Restoration Ecosystem Structures	Operations and Maintenance (Co-use)	Invertebrates, Corals, Plants, Fish	Raised $21.25M of capital and $1.83M of non-dilutive grants. (PB)
Hydronet	Enabling Technology Communication	Planning Design and Permitting, Installation, Operations and Maintenance, End of Life	-	Funding undisclosed.

(continued)...

COMPANY	CLASSIFICATION	STAGE	SPECIES	FUNDS RAISED
Ithaca Clean Energy	Enabling Technology Data Insights	Planning Design and Permitting, Installation, Operations and Maintenance, End of Life	-	Revenue generating. Raised <$1M in capital and non-dilutive grants. (PB)
Katchi	Enabling Technology Sensing and Measuring	Installation, Operations and Maintenance	-	Funding undisclosed.
Open Ocean Robotics	Enabling Technology Robotics Systems	Planning Design and Permitting, Installation, Operations and Maintenance, End of Life	-	Raised $1.5M in capital and $1.83M in non-dilutive grants. (PB)
Parker Maritime Technologies	Protection From Noise Impacts	Installation, Operations and Maintenance, End of Life	Marine Mammals and Turtles	Latest deal was a Seed round of $500,000. (PB)
Photon Marine	Protection From Vessel Use	Installation, Operations and Maintenance, End of Life	Marine Mammals and Turtles	Raised $3.69M in capital. (PB)
PlanBlue	Enabling Technology Sensing and Measuring	Planning Design and Permitting, Installation, Operations and Maintenance, End of Life	-	Raised $1.25M in capital and $5.62M in non-dilutive grants. (PB)
Reefgen	Restoration Restoration	Operations and Maintenance, End of Life	Invertebrates, Corals, Plants, Fish	In Nov '21, received a National Science Foundation grant. Total funds raised $1.19M. (PB)
Saildrone	Enabling Technology Robotics Systems, Sensing and Measuring	Planning Design and Permitting, Installation, Operations and Maintenance, End of Life	-	Raised $186.2M in capital. (PB)

(continued)...

COMPANY	CLASSIFICATION	STAGE	SPECIES	FUNDS RAISED
Seatrac	Enabling Technology Robotics Systems, Sensing and Measuring	Planning Design and Permitting, Installation, Operations and Maintenance, End of Life	-	Raised $3.8M in capital. Latest round of $0.9M in 2024. (PB)
SeaTrec	Enabling Technology Sensing and Measuring	Planning Design and Permitting, Installation, Operations and Maintenance, End of Life	-	Raised $3.17M in capital and $3.38M in non-dilutive grants. (PB)
Spoor AI	Protection From Turbine Collision	Operations and Maintenance	Birds and Bats	Raised $5.59M in capital. Ørsted invested. (PB)
Stream Ocean	Enabling Technology Sensing and Measuring	Planning Design and Permitting, Installation, Operations and Maintenance, End of Life	-	Raised one round of an undisclosed size. (PB)
Vycarb	Restoration Co-use, Carbon	Operations and Maintenance (Co-Use)	Invertebrates, Corals	BlueSwell Cohort IV, Funding undisclosed.
Whale Seeker	Enabling Technology Sensing and Measuring	Planning Design and Permitting, Installation, End of Life	Marine Mammals and Turtles, Birds and Bats	Has raised $0.2M in capital and $1.39M in non-dilutive grants. (PB)
WSense	Enabling Technology Communication	Planning Design and Permitting, Installation, Operations and Maintenance, End of Life	-	Raised $13.95M in capital. (PB)

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Image: Ørsted