Policy Brief and Technical Background Paper

Advancing Biodegradable Materials in Fish Aggregating Devices (FADs) Toward Safe and Sustainable-by-Design Fisheries Plastics

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Executive Summary

Fish aggregating devices (FADs) and synthetic fishing gear are increasingly recognised as a significant source of marine plastic pollution, ghost fishing, and long-term ecological harm. Conventional fisheries plastics such as polyethylene (PE), polypropylene (PP), and nylon are engineered for durability under harsh marine conditions. While this durability is essential during operational use, it becomes a major environmental liability when gear is abandoned, lost, or discarded at sea (ALDFG). Lost FADs and associated appendages can continue to entangle marine species for extended periods while gradually fragmenting into persistent microplastics.

The scale of the problem is substantial. Studies estimate that up to 40% of drifting FADs may be lost or unrecovered during operations (Richardson et al., 2022; Imzilen et al., 2022). This has led Regional Fisheries Management Organisations (RFMOs), including the Inter-American Tropical Tuna Commission (IATTC) and the Western and Central Pacific Fisheries Commission (WCPFC), to explore material substitution strategies and biodegradable alternatives for FAD construction.

Catchgreen has developed biodegradable polyester-based fishing gear and FAD components using polybutylene succinate (PBS) and related biodegradable polymer blends. These materials are designed to maintain operational performance during active deployment while reducing long-term environmental persistence if lost in marine environments. This approach aligns with the concept of "programmed degradation," whereby materials retain sufficient durability during use but progressively lose functionality following prolonged environmental exposure.

PBS differs fundamentally from conventional polyolefin plastics because its chemical structure contains ester linkages susceptible to hydrolysis and microbial degradation. Under suitable marine conditions, PBS undergoes a two-stage degradation process involving hydrolytic breakdown followed by biological assimilation by naturally occurring microorganisms. Unlike conventional plastics, which may fragment while remaining chemically intact, PBS-based materials have the potential to undergo progressive biological conversion into carbon dioxide, water, and biomass.

Research from South Korea and elsewhere has reinforced the relevance of PBS and PBS-based blends for fisheries applications. Studies evaluating PBS fishing gear under seawater–sediment interface conditions demonstrated measurable biodegradation accompanied by reductions in tensile strength and molecular weight, together with microbial colonisation associated with degradation pathways (Kim et al., 2023). These findings are particularly relevant because lost fishing gear and FAD appendages frequently settle at the seabed, where biologically active sediment environments may facilitate degradation processes.

Catchgreen has already piloted biodegradable fisheries materials in crab pots and lobster pots in Norway and South Africa, while PBS-based ropes have also been tested in modified gillnets and in seaweed farming systems in Kenya. Current research undertaken with SINTEF in Norway is evaluating four different Catchgreen PBS grades using advanced analytical techniques, including respirometry, pyrolysis GC-MS, FTIR spectroscopy, tensile testing, and microbial community analysis. Early findings indicate measurable reductions in tensile strength and evidence of hydrolytic degradation processes consistent with international PBS biodegradation studies.

Importantly, the objective of biodegradable fisheries materials is not immediate or rapid degradation. Rather, the goal is controlled durability: maintaining structural integrity during operational use while reducing long-term persistence if materials are lost at sea. This distinction is critical in fisheries applications, where ropes, appendages, and gear components must withstand prolonged UV exposure, abrasion, hydrodynamic stress, and mechanical loading.

Despite growing interest in biodegradable fisheries materials, major regulatory and standards gaps remain. Existing marine biodegradability standards, including ISO and ASTM methodologies, were primarily developed for thin films and single-use plastics tested under controlled laboratory conditions. They do not adequately address thick, load-bearing fisheries materials such as ropes, braided lines, or structural FAD appendages designed for extended operational use.

As a result, there are currently no internationally harmonised standards specifically designed for biodegradable fishing gear and FAD systems. Scientific and policy discussions increasingly support integrated assessment frameworks combining laboratory biodegradation testing, seawater–sediment interface studies, ecotoxicological analysis, mechanical performance evaluation, and real-world pilot deployments under operational conditions. This reflects a broader transition toward a "safe and sustainable by design" approach for fisheries plastics, recognising that material performance depends not only on polymer chemistry, but also on environmental conditions, product geometry, and application-specific design.

Application-specific pilot deployments are therefore essential for evaluating operational performance, degradation behaviour, environmental interaction, and post-loss outcomes under realistic fisheries conditions. Pilot-generated evidence can also support future standards development by informing performance-based criteria for biodegradable fishing gear and FAD systems.

Catchgreen therefore proposes a phased, science-based approach to biodegradable FAD implementation involving:

1. Controlled pilot deployments under real fisheries conditions;
2. Independent scientific monitoring and validation;
3. Integration of laboratory and field evidence;
4. Development of application-specific standards frameworks;
5. Support for RFMO regulatory discussions on FAD material substitution.

While current evidence supports the potential suitability of PBS-based systems for fisheries applications, long-term degradation behaviour under different marine habitats and operational conditions still requires continued field validation and harmonised standards development.

Biodegradable fisheries materials are not a standalone solution to marine plastic pollution. However, when carefully designed, scientifically evaluated, and responsibly implemented, they may provide an important tool for reducing the long-term ecological impacts associated with persistent synthetic fishing gear and lost FAD components.

1. Introduction

Fishing gear play a critical role in global food systems, but its reliance on highly durable synthetic plastics has created significant and persistent environmental challenges. Materials such as polyethylene, polypropylene, and nylon are engineered for strength and longevity under extreme marine conditions, including prolonged exposure to saltwater, UV radiation, and mechanical stress. These properties are essential for operational performance; however, they also result in long-term persistence when gear is abandoned, lost, or discarded (ALDFG).

Fish aggregating devices (FADs) are of particular concern in this context. Due to their widespread use and drifting nature, a significant proportion are lost at sea, with estimates suggesting that up to 40% may not be retrieved (Richardson et al., 2022; Imzilen et al., 2022). Once lost, FADs and associated synthetic components can continue to impact marine ecosystems through ghost fishing, entanglement of non-target species, and the gradual accumulation of microplastics as materials fragment but do not biodegrade. Conventional polymers are highly resistant to biological degradation and may persist in marine environments for decades or longer, meaning that their environmental impacts can continue well beyond their operational lifespan.

Catchgreen has developed biodegradable polymer-based products designed to reduce long-term environmental persistence while maintaining functional durability during service life. This paper provides a technical overview of the polymer platform used in Catchgreen products, explains the degradation behaviour of biodegradable polymers in marine environments, and the interaction between polymer chemistry, environmental conditions, and microbial communities. The paper further outlines performance characteristics relevant to fisheries applications and describes the current regulatory and certification landscape governing biodegradable materials in FAD and fisheries contexts.

2. Polymer Platform: Polybutylene Succinate (PBS)

Catchgreen's products are primarily manufactured using polybutylene succinate (PBS), an aliphatic polyester that has gained increasing attention for applications where reduced environmental persistence is desirable. PBS is synthesised through the polycondensation of succinic acid (or dimethyl succinate) and 1,4-butanediol. The resulting polymer contains ester linkages within its backbone. These ester bonds are susceptible to hydrolysis and enzymatic attack under appropriate environmental conditions, which fundamentally distinguishes PBS from conventional polyolefins.

Unlike polyethylene or polypropylene, which consist of stable carbon–carbon backbones resistant to microbial attack, PBS is chemically designed to allow controlled breakdown. This difference in polymer chemistry underpins its potential suitability for marine-facing applications where mitigation of long-term plastic accumulation is a priority.

Recent reviews of sustainable netting materials have identified PBS, PBAT, PHA, and related polyester-based composite systems as among the most promising candidates for marine fishing and aquaculture applications due to their balance between processability, mechanical performance, and potential biodegradability (Pagnotta, 2025). Among these, PBS and PBS-based copolymers have emerged as particularly promising for fisheries applications because they provide a favourable balance between mechanical durability and controlled marine degradability under operational conditions. However, not all biodegradable or bio-based polymers are equally suitable for marine environments. Some materials, including many PLA formulations, may biodegrade effectively under industrial composting conditions while remaining highly persistent under ambient marine conditions. Other biodegradable polymers may present limitations including excessive brittleness, water sensitivity, insufficient long-term mechanical stability, or degradation rates that are either too slow or too rapid for active fishing applications. For example, PLA materials may exhibit limited flexibility and slow biodegradation in seawater, while some PHA systems may degrade too rapidly for extended operational deployment. Marine biodegradability is therefore highly habitat-specific and depends on environmental factors including temperature, oxygen availability, salinity, sediment interaction, hydrodynamic conditions, and microbial community composition. This distinction between bio-based, compostable, and genuinely marine-biodegradable materials is increasingly recognised within international scientific and policy discussions on marine plastics and fisheries gear substitution (SAPEA, 2020; Dilkes-Hoffman et al., 2019; European Bioplastics, 2023).

As a result, PBS, PBSAT, and related polyester blends are increasingly being investigated for fishing nets, ropes, and marine gear applications where materials must maintain structural integrity during active deployment while reducing long-term persistence if lost. Studies have reported that PBS-based monofilaments can achieve fishing performance comparable to conventional nylon gear in certain applications when appropriately engineered for the intended use environment (Kim et al., 2021; An et al., 2022).

An additional advantage of PBS is its feedstock flexibility. It may be produced using fossil-derived intermediates or bio-based feedstocks such as fermentation-derived succinic acid. Importantly, the origin of the carbon does not alter the chemical structure of the polymer. Mechanical properties, processing behaviour, crystallinity, and degradation pathways remain governed by polymer architecture rather than feedstock source. While bio-based PBS may offer greenhouse gas or carbon footprint benefits, biodegradability performance is determined by the polymer chemistry itself. It is further technically feasible to incorporate recycled fossil-based feedstocks through chemical recycling pathways to support circular carbon use, however it is not yet widely implemented at scale

Modern industrial production of PBS can be conducted without heavy metal catalyst residues, relying instead on alternative catalytic systems that avoid leaving regulated metals in the finished polymer. This is particularly important for marine applications, where material safety and ecotoxicological considerations are relevant.

Fisheries research programmes, particularly in South Korea, have increasingly focused on PBS and PBS-based copolymers for marine fishing applications. Research institutions and manufacturers have developed biodegradable fishing gear systems using PBS, PBSAT, and related polyester blends specifically engineered to balance tensile performance, operational durability, and controlled biodegradation in marine environments.

Catchgreen is also moving toward the adoption of Korean-developed PBS/PBAT biodegradable polymer blends as part of its next-generation marine-degradable FAD and fishing gear strategy. These blends are increasingly considered promising candidates for fisheries applications because they are designed to maintain sufficient mechanical integrity during active deployment while progressively degrading under long-term marine exposure conditions. This reflects a broader international shift toward application-specific biodegradable polymer systems designed specifically for marine fishing environments rather than adapted from single-use plastic applications.

3. Marine Biodegradation Mechanism

PBS undergoes degradation through a two-stage process. The first stage involves hydrolysis of ester bonds when exposed to moisture, resulting in cleavage of polymer chains and progressive reduction in molecular weight. As molecular weight decreases, the material becomes increasingly susceptible to microbial action. In the second stage, naturally occurring microorganisms secrete enzymes that metabolise the shortened polymer chains, ultimately converting the material into biomass, carbon dioxide, water, and naturally occurring compounds.

This degradation pathway differs fundamentally from simple physical fragmentation. Conventional plastics may fragment into progressively smaller particles while remaining chemically intact, contributing to the long-term accumulation of persistent plastic and microplastic pollution in marine ecosystems. In contrast, true biodegradation involves progressive microbial mineralisation and biological assimilation rather than the mere formation of smaller persistent fragments. This distinction is particularly important for fishing gear and FAD applications, where environmental outcomes depend not only on visible breakdown but also on whether long-term plastic persistence is reduced.

Marine biodegradation behaviour is highly dependent on environmental context. This process is not a characteristic inherent to a material alone but is an emergent property of a system comprising the polymer, the specific marine environment, and the biological community present (Lott et al., 2020). Temperature, oxygen availability, microbial diversity, salinity, hydrodynamic conditions, and sediment interaction all influence degradation kinetics. Recent marine biodegradation assessments further demonstrate that degradation rates differ substantially across marine habitats, including pelagic waters, coastal sediments, estuarine systems, and deep-sea environments (GO!PHA, 2026). Tropical surface waters may accelerate hydrolysis and microbial activity, whereas cold deep-sea environments can significantly slow biodegradation processes due to reduced microbial metabolism and low temperatures. This has led to growing recognition that future marine biodegradability standards may require habitat-specific assessment criteria rather than relying on generic biodegradation thresholds.

In marine environments, microbial communities capable of degrading polyesters tend to be more abundant in sediment-rich, biologically active zones than in the open water column. As a result, the seawater–sediment interface is considered particularly relevant when evaluating the long-term environmental behaviour of biodegradable fishing gear. This is especially important because lost fishing gear and FAD appendages frequently sink and accumulate at the seabed, where ghost fishing can continue for extended periods (Kim et al., 2023; SAPEA, 2020).

PBS has a density greater than seawater (typically >1.2 g/cm^3), whereas HDPE floats (<1.0 g/cm^3) and nylon is close to neutral buoyancy (~1.1 g/cm^3). Consequently, PBS-based ropes or appendages that are lost are more likely to sink to the seabed rather than remain afloat indefinitely. This sinking behaviour may increase interaction with sediment-associated microbial communities and potentially facilitate biodegradation under favourable environmental conditions.

Real-world degradation timelines depend strongly on material thickness, crystallinity, geometry, product design, and environmental exposure. Thick, load-bearing ropes and structural components will degrade more slowly than thin films under identical conditions. Degradation behaviour therefore cannot be generalised across applications and requires application-specific testing under realistic environmental conditions.

Recent research from South Korea has provided important empirical evidence regarding the biodegradation behaviour of PBS fishing gear under marine sediment conditions relevant to ghost fishing. Kim et al. (2023) evaluated PBS fishing gear using ISO 19679-based seawater–sediment interface protocols designed to simulate conditions where lost fishing gear commonly accumulates. The study demonstrated measurable biodegradation of PBS through biological conversion to carbon dioxide over a 180-day period, accompanied by reductions in molecular weight and tensile properties. The authors concluded that degradation proceeded through hydrolytic initiation, surface abrasion, and microbial assimilation of degradation products. Importantly, microbial analysis identified the genus *Rhodococcus* as a dominant organism associated with PBS biodegradation in marine sediment environments.

These findings are particularly relevant for FAD applications because they demonstrate that PBS-based fishing materials can undergo progressive biodegradation under realistic marine conditions rather than simply fragmenting into persistent plastic particles. The study also reinforces the importance of combining physicochemical degradation analysis with respirometric and microbial assessment methods when evaluating biodegradable fishing gear and marine polymer systems.

4. Implications for Ghost Fishing

Ghost fishing remains a major global concern. Lost nets and gear constructed from conventional polymers may continue to entangle marine life for extended periods. Because

PBS-based materials gradually lose tensile strength as degradation progresses, the functional lifespan of lost gear may be shortened compared to conventional synthetic gear.

Studies such as Brakstad et al. (2022) have documented measurable reductions in mechanical strength of biodegradable fishing nets over multi-year marine immersion, while conventional nylon nets showed negligible change. Other researchers, including Grimaldo et al. (2018–2020), have raised questions regarding initial strength and durability, suggesting that some reduction in ghost fishing may stem from lower initial mechanical properties rather than gradual degradation alone. These findings underscore the importance of careful application-specific design.

The relevance of biodegradable fishing gear for ghost fishing prevention has also been reinforced through Korean research on PBS fishing nets in marine sediment environments. Kim et al. (2023) concluded that biodegradable fishing gear has the potential not only to replace conventional non-degradable fishing gear, but also to reduce long-term ghost fishing impacts through progressive biodegradation after loss. Their findings demonstrated measurable reductions in tensile properties and molecular weight of PBS fishing gear during marine sediment exposure, supporting the concept that biodegradable materials may reduce long-term persistence and ecological impact relative to conventional plastics.

In some contexts, pilot testing of biodegradable components has shown no adverse impact on catch performance, as demonstrated in studies involving escape mechanisms in crab pots (Bilkovic et al., 2012; Wilcox & Hardest, 2016). Performance equivalence depends on matching material properties to specific gear functions.

The broader fisheries literature increasingly describes biodegradable fishing gear using the concept of "programmed degradation," whereby materials are intentionally engineered to retain sufficient operational performance during active use while progressively losing functionality after prolonged environmental exposure or loss at sea. (Kim et al., 2021; Bae et al., 2023).Recent reviews of biodegradable net systems have highlighted this balance between functional durability and controlled end-of-life degradation as a central design objective for next-generation fishing gear. (Kim et al., 2021; An et al., 2022).

Studies involving PBS fishing nets have demonstrated that degradation behaviour can be intentionally influenced through factors such as polymer composition, yarn diameter, mesh configuration, and blend engineering. (Park et al., 2017; Bae et al., 2023).This reinforces the importance of designing biodegradable FAD appendages and fishing components as application-specific systems rather than treating biodegradability as a single uniform material property.

These findings reinforce the importance of application-specific design for biodegradable fishing gear and FAD systems. Material performance depends not only on polymer chemistry, but also on structural configuration, operational loading, and environmental exposure conditions.

5. Regulatory and Certification Landscape

The absence of internationally harmonised standards for marine biodegradable plastics remains one of the major barriers to the large-scale adoption of biodegradable materials in fisheries and aquaculture applications. Although increasing attention is being directed toward alternative materials capable of reducing the long-term environmental impacts associated with persistent synthetic plastics, regulatory clarity remains limited for durable, load-bearing marine systems such as fishing nets, ropes, FAD appendages, aquaculture infrastructure, and seaweed farming equipment.

Existing biodegradation standards developed by organisations including ASTM, ISO, and NOAA were primarily designed for thin films and packaging materials tested under laboratory-controlled conditions. While these methodologies provide important screening tools for evaluating biodegradation potential, they do not adequately address the operational requirements of fisheries applications, where products must withstand prolonged marine exposure, hydrodynamic loading, abrasion, UV exposure, and mechanical stress while remaining functional over extended deployment periods.

Respirometric methodologies used in standards such as ASTM D6691-09, ASTM D7473-12, ISO 18830, ISO 19679, and ASTM D7991-15 evaluate biological conversion of plastics into carbon dioxide under controlled aerobic conditions. However, these methods may also be influenced by biofilm respiration occurring on the material surface, making interpretation more complex for thick and durable marine products exposed over long periods. Existing protocols generally establish mineralisation thresholds between approximately 60% and 70% carbon conversion within specified timeframes, but these frameworks were not designed to evaluate products intentionally engineered for controlled and gradual degradation under real marine operating conditions.

The TÜV Austria “OK Marine Biodegradable” certification currently represents one of the most recognised marine biodegradability labels available internationally. The certification evaluates biodegradation under simulated marine laboratory conditions and is primarily intended for single-use plastics and relatively thin materials. It establishes defined disintegration and mineralisation thresholds within fixed timeframes. However, the certification framework was not developed for thick ropes, braided lines, molded structural components, or products required to maintain mechanical integrity during prolonged fisheries deployment. As a result, while TÜV Marine certification provides an important reference point, it does not yet constitute a complete certification pathway for durable FAD systems or other long-life fisheries applications.

Scientific literature increasingly recognises the limitations of applying thin-film biodegradation methodologies to load-bearing fishing gear and marine infrastructure. Many marine biodegradation studies continue to be conducted under highly controlled laboratory conditions that may not accurately reflect real environmental exposure, particularly for ropes, monofilaments, structural components, and fishing nets exposed to variable marine habitats and long operational lifetimes (SAPEA, 2020; Dilkes-Hoffman et al., 2019; Kim et al., 2023).

There is therefore growing recognition that future certification pathways for biodegradable fisheries materials will require integrated and performance-based assessment approaches. European standards discussions increasingly support the adoption of “3-tier” marine biodegradation assessment systems combining:

- laboratory biodegradation testing under controlled conditions;

- mesocosm or tank-based environmental simulations;
- and field validation under real marine exposure conditions.

EU-linked initiatives such as the ANIPH project have proposed integrated assessment frameworks capable of evaluating biodegradation, persistence, residence time, ecotoxicity, and operational performance across environmentally relevant marine conditions (GO!PHA, 2026). These approaches seek to improve reproducibility while overcoming the limitations associated with laboratory-only biodegradation testing. Fisheries engineering literature similarly concludes that numerical modelling, laboratory testing, tank trials, and real-world field validation must all be integrated to adequately assess both operational performance and environmental behaviour (Kim et al., 2021; Bae et al., 2023; An et al., 2022).

Marine biodegradability is also increasingly understood as a habitat-specific phenomenon rather than a single universal material property. Degradation behaviour may differ substantially across pelagic waters, coastal sediments, estuarine systems, and deep-sea environments depending on temperature, oxygen availability, salinity, microbial diversity, hydrodynamic conditions, and sediment interaction (GO!PHA, 2026). This distinction is particularly important for fishing gear and FAD systems because lost components may transition between multiple marine environments over their operational and post-loss lifecycles. As a result, future standards frameworks may require habitat-specific assessment methodologies rather than relying solely on generic laboratory-derived biodegradation thresholds.

Biodegradability assessment must also consider the complete product formulation rather than only the base polymer resin. Additives, pigments, stabilisers, coatings, plasticisers, compatibilisers, and degradation intermediates may all influence environmental safety outcomes and therefore require integrated ecotoxicological assessment alongside mineralisation testing (Zimmermann et al., 2020; GO!PHA, 2026). This is particularly relevant for fisheries and aquaculture products intentionally designed for long-term marine exposure and demanding mechanical performance requirements.

Engineering studies on sustainable fishing gear further demonstrate that biodegradable fisheries materials cannot be evaluated independently of product geometry, mesh structure, yarn diameter, knot configuration, braid architecture, and hydrodynamic behaviour (Pagnotta, 2025). Construction variables strongly influence tensile performance, drag characteristics, deformation behaviour, operational lifespan, and degradation kinetics in marine environments. These findings reinforce the importance of integrated material-and-design optimisation when developing biodegradable FAD systems, fishing nets, ropes, and aquaculture infrastructure.

Addressing these regulatory and technical gaps will require coordinated engagement with international and regional standard-setting bodies. Collaboration with the International Organization for Standardization (ISO) is particularly relevant for developing performance-based standards capable of integrating durability requirements, marine exposure conditions, degradation pathways, and environmental safety metrics into coherent certification frameworks. Engagement with ISO technical committees focused on plastics, marine environmental testing, and fisheries gear would support the development of application-specific methodologies rather than relying exclusively on generic film-based criteria.

Regional and continental organisations also play an important role in shaping emerging standards frameworks. Engagement with bodies such as ASTM International, ANSI, ECOS Europe and Africa, and national bureaus of standards can help ensure that environmental integrity, transparency, scientific credibility, and practical fisheries considerations are embedded within future certification systems.

The absence of internationally harmonised standards places a disproportionate burden on developing economies, which may struggle to adapt to fragmented or inconsistent regulatory requirements, potentially affecting market access and participation in emerging sustainable fisheries value chains. It is therefore essential that standards and regulations are developed inclusively, in consultation with developing countries, while ensuring that producers are supported through technical assistance, capacity building, technology transfer, and appropriate financing mechanisms. Without such support, emerging regulatory frameworks risk unintentionally excluding producers in developing economies from participation in global fisheries and aquaculture markets.

6. Catchgreen Biodegradable Fishing Gear: Product Development, Performance, and Scientific Validation

Catchgreen develops biodegradable fishing gear and marine components in custom sizes and configurations for fisheries and aquaculture applications. Products include ropes of varying diameters and load ratings, twines and braided lines, nonwoven mats and shade-cloth-type materials, and attraction appendages specifically designed for FAD applications. Materials can be produced with or without UV stabilisers, depending on the required service life and environmental exposure profile. Where stabilisers are used, Catchgreen prioritises certified biodegradable additives to minimise environmental impact and avoid the introduction of persistent pollutants into marine environments.

In FAD applications, biodegradable materials may be used for hanging appendages, streamers, panels, ropes, and non-entangling components. Catchgreen has already piloted biodegradable materials in collaboration with Dsolve and SINTEF (The Foundation for Industrial and Technical Research at the Norwegian Institute of Technology) across a range of fisheries applications, including crab pots and lobster pot trials in South Africa. In aquaculture contexts, PBS-based ropes have also been piloted in seaweed farming systems and in modified gillnets by the Kenyan Fisheries Research Institute.

Field observations indicate that PBS-based ropes can remain fully functional for between two and five years under operational conditions, depending on environmental exposure, product design, and deployment specifications. The design objective is therefore not immediate degradation, but rather controlled durability. Products are engineered to maintain structural integrity during operational use while reducing long-term persistence if lost or abandoned in the marine environment.

This principle of controlled durability aligns with the broader concept of “programmed degradation” increasingly discussed within the fisheries literature, whereby materials are intentionally engineered to retain sufficient operational performance during active use while progressively losing functionality after prolonged environmental exposure or loss at sea. Material selection, yarn diameter, braid structure, knot configuration, mesh geometry, and hydrodynamic exposure collectively influence both operational performance and post-loss degradation behaviour (Pagnotta, 2025)

To better understand degradation behaviour and long-term performance characteristics, four different Catchgreen grades of PBS are currently undergoing scientific evaluation by SINTEF in Norway. The research programme applies multiple analytical tools, including respirometric analysis, thermal desorption pyrolysis GC-MS (TD/pyrGC-MS), scanning electron microscopy (SEM) and optical microscopy, differential scanning calorimetry (DSC), Fourier transform infrared spectroscopy (FTIR), potentially X-ray photoelectron spectroscopy (XPS), tensile (mechanical) testing, and analysis of microbial community composition using 16S rRNA amplicon sequencing.

The project has been running for approximately 36 months, and conclusive results are not yet available for all analytical methods. However, partial loss of surface material and measurable reductions in tensile strength have already been observed in laboratory-tested samples. FTIR results indicate that early-stage degradation likely occurred through the removal of lower molecular weight species from the surface, consistent with predicted hydrolytic initiation. This is indicated by a shift in carbonyl peaks from 1715 cm^{-1} to 1711 cm^{-1} in some grades. Surface roughness has also increased in at least two samples.

These findings are consistent with Korean studies evaluating PBS fishing gear under marine sediment conditions. Kim et al. (2023) similarly observed progressive reductions in tensile properties and molecular weight during biodegradation, while identifying hydrolysis and surface erosion as key degradation mechanisms. Their work further demonstrated that marine sediment microbial communities play an important role in PBS biodegradation pathways. The importance of sediment-interface testing is increasingly recognised because lost fishing gear and FAD appendages frequently accumulate on the seabed, where environmental conditions differ substantially from those in the open water column. Temperature, oxygen availability, microbial diversity, salinity, hydrodynamic conditions, and sediment interaction can all influence biodegradation behaviour and degradation kinetics.

Ongoing pyrolysis GC-MS analyses are being supplemented with GC-MS/LC-MS quantification of specific degradation products over time (primary degradation), enabling extrapolation of degradation rates beyond the test period. By combining respirometric and chemical analyses, it is possible to assess both primary (component-specific) and ultimate (conversion to CO_2 and water) biodegradation pathways. This distinction is important because physical fragmentation alone does not necessarily indicate true biodegradation. Conventional plastics may fragment into progressively smaller particles while remaining chemically intact, contributing to persistent microplastic accumulation in marine ecosystems. In contrast, true biodegradation involves progressive microbial mineralisation and biological assimilation into carbon dioxide, water, biomass, and naturally occurring compounds.

The broader scientific and regulatory discussion is increasingly moving toward integrated “3-tier” assessment frameworks combining laboratory biodegradation testing, mesocosm or tank-based environmental simulations, and field validation under real marine exposure conditions (GO!PHA, 2026). Such approaches are particularly relevant for fisheries applications because they allow operational performance, environmental persistence, ecotoxicity, and degradation behaviour to be evaluated simultaneously under realistic deployment conditions. There is also growing recognition that biodegradability assessments must consider the complete product formulation rather than only the base polymer resin, since additives, pigments, stabilisers, coatings, and degradation intermediates may influence environmental safety outcomes.

Based on these biodegradability tests, together with the existing body of scientific knowledge regarding PBS behaviour in marine environments, it is possible to conclude that Catchgreen's PBS-based materials demonstrate characteristics consistent with marine biodegradability. The available evidence indicates that the materials undergo progressive hydrolytic and microbial degradation under marine conditions rather than persisting solely through physical fragmentation. While further long-term field validation and harmonised standards development remain important, the current results provide a strong scientific basis for supporting the suitability of these materials for controlled pilot trials in fisheries, aquaculture, and FAD applications.

7. Integrated Design Approaches for Biodegradable Fishing Gear

The development of biodegradable fishing gear increasingly requires an integrated systems-based engineering approach rather than simple substitution of conventional plastics with biodegradable polymers. Operational performance, environmental behaviour, and degradation pathways are influenced not only by polymer chemistry, but also by product geometry, yarn structure, mesh configuration, knot design, braid architecture, hydrodynamic loading, and environmental exposure conditions (Pagnotta, 2025). As a result, biodegradable fishing systems must be designed as complete functional systems in which material properties and structural engineering are optimised simultaneously.

This approach is particularly important for fisheries and FAD applications because marine gear is exposed to complex and highly variable operating conditions, including tensile loading, abrasion, UV radiation, biofouling, hydrodynamic stress, and repeated mechanical deformation. Product performance therefore depends on the interaction between polymer composition and engineering design. Parameters such as yarn diameter, crystallinity, mesh orientation, knot tightness, filament structure, and blend composition can significantly influence tensile strength, flexibility, drag characteristics, operational lifespan, and degradation behaviour under marine exposure conditions (Park et al., 2017; An et al., 2022; Bae et al., 2023).

In contrast to conventional petroleum-based plastics, which are primarily optimised for maximum durability and persistence, biodegradable fishing materials must balance operational reliability with controlled end-of-life degradation. This has led to increasing use of the concept of "programmed degradation," whereby materials are intentionally engineered to maintain sufficient performance during active deployment while progressively losing structural integrity following prolonged environmental exposure or loss at sea. Achieving this balance requires careful optimisation of polymer formulation, processing conditions, stabiliser selection, and product design according to the intended fishery and deployment environment.

Hydrodynamic behaviour is also an important consideration in biodegradable fishing gear design. Drag forces, water flow, sediment interaction, and mechanical fatigue may influence both operational performance and degradation kinetics over time. For FAD appendages and non-entangling structures, flexibility, buoyancy, density, and abrasion resistance may all affect deployment behaviour and long-term environmental interaction. Because PBS-based materials are denser than seawater, lost components may sink and interact more directly with sediment-associated microbial communities, potentially influencing post-loss degradation pathways.

Engineering studies increasingly support the use of numerical modelling, laboratory simulation, tank testing, and field validation as complementary tools for optimising biodegradable fishing systems (Kim et al., 2021; Bae et al., 2023). Numerical and hydrodynamic modelling can assist in predicting stress distribution, deformation behaviour, and operational lifespan under different deployment conditions, while laboratory and mesocosm testing provide insight into degradation pathways and material response under controlled environmental exposure. However, real-world pilot deployments remain essential because marine environmental variability cannot be fully replicated under laboratory conditions.

This integrated design philosophy is particularly relevant for future biodegradable FAD systems, where environmental performance depends not only on whether materials biodegrade, but also on how products behave during use, after loss, and during long-term interaction with marine ecosystems. Effective biodegradable fisheries systems must therefore be evaluated across the full product lifecycle, including operational functionality, catch performance, durability, degradation behaviour, sediment interaction, ecotoxicological safety, and post-loss environmental persistence.

8. Standards Development, Scientific Validation, and Pilot-Based Evidence

Building on the integrated design principles discussed above, standards development for biodegradable fishing gear increasingly requires assessment systems capable of evaluating both operational performance and environmental behaviour under realistic marine conditions.

Although the need for harmonised standards for biodegradable fisheries materials is widely recognised, significant regulatory and methodological gaps remain. Existing marine biodegradation standards developed by organisations including ASTM, ISO, and NOAA were primarily designed for thin films and packaging materials evaluated under controlled laboratory conditions. While these methodologies provide important screening tools for assessing biodegradation potential, they do not adequately address the operational realities associated with durable fisheries products such as ropes, braided lines, fishing nets, and structural FAD appendages exposed to prolonged marine deployment, mechanical loading, abrasion, UV exposure, and hydrodynamic stress.

Respirometric methodologies used in standards such as ASTM D6691-09, ASTM D7473-12, ISO 18830, ISO 19679, and ASTM D7991-15 evaluate biological conversion of plastics into carbon dioxide under controlled aerobic conditions. These methods are valuable for understanding degradation pathways and mineralisation potential, but interpretation becomes more complex for thick and durable marine products exposed over extended periods, particularly where biofilm respiration and heterogeneous degradation processes occur simultaneously. Existing standards therefore provide important mechanistic insight but remain insufficient as stand-alone certification frameworks for long-life fisheries applications intentionally designed for controlled durability rather than rapid disintegration.

The TÜV Austria “OK Marine Biodegradable” certification currently represents one of the most recognised marine biodegradability labels available internationally. However, the certification framework was developed primarily for relatively thin materials and single-use applications rather than products required to maintain structural integrity during prolonged marine deployment. Consequently, while TÜV Marine certification provides an important reference point for marine biodegradability screening, it does not yet constitute a complete validation pathway for durable fishing gear, ropes, aquaculture infrastructure, or FAD systems.

A further challenge is that marine biodegradability cannot be treated as a single universal material property. Scientific understanding increasingly recognises that biodegradation is highly habitat-specific and influenced by environmental variables including temperature, oxygen availability, salinity, microbial diversity, sediment interaction, UV exposure, and hydrodynamic conditions (GO!PHA, 2026). A material that biodegrades effectively in warm shallow coastal waters may behave very differently in cold deep-sea environments. This distinction is particularly important for fisheries applications because lost fishing gear and FAD appendages may transition between multiple marine habitats over their operational and post-loss lifecycles.

The seawater–sediment interface is especially relevant in this context because lost fishing gear and FAD components frequently accumulate at the seabed, where biologically active sediment environments may facilitate degradation processes differently from the open water column. As a result, generic laboratory-derived biodegradation thresholds may not adequately represent real environmental behaviour across different marine systems.

Standards discussions are therefore increasingly moving toward integrated and performance-based assessment frameworks combining laboratory biodegradation testing, mesocosm or tank-based environmental simulations, and field validation under realistic marine exposure conditions. Emerging European discussions support the adoption of “3-tier” marine biodegradation assessment systems incorporating:

- laboratory biodegradation testing under controlled conditions;
- mesocosm or tank-based environmental simulations;
- and field validation under real marine exposure conditions.

EU-linked initiatives such as the ANIPH project have proposed integrated frameworks capable of evaluating biodegradation, persistence, residence time, ecotoxicity, and operational performance simultaneously across environmentally relevant marine conditions (GO!PHA, 2026). These approaches aim to improve reproducibility while overcoming some of the limitations associated with laboratory-only biodegradation methodologies.

Scientific literature also increasingly emphasises that biodegradability assessment must consider the complete product formulation rather than only the base polymer resin. Additives, pigments, stabilisers, coatings, plasticisers, compatibilisers, and degradation intermediates may all influence environmental safety outcomes and therefore require integrated ecotoxicological assessment alongside mineralisation testing (Zimmermann et al., 2020; GO!PHA, 2026).

For fisheries and aquaculture applications, the challenge is not simply whether a material biodegrades, but whether it can maintain sufficient operational performance during use while reducing long-term environmental persistence after loss. Materials used in fishing gear and FAD systems must therefore balance tensile performance, abrasion resistance, flexibility, hydrodynamic behaviour, UV stability, and controlled degradation pathways within the context of specific deployment conditions. This reflects the broader transition toward a "safe and sustainable by design" approach for fisheries plastics.

Application-specific pilot deployments are consequently essential for evaluating the real-world suitability of biodegradable fisheries materials. Controlled pilot programmes allow simultaneous assessment of operational durability, catch performance, environmental interaction, degradation behaviour, and post-loss outcomes under realistic exposure conditions. Such pilots can evaluate tensile integrity during use, abrasion resistance, sinking behaviour, ghost fishing risk, sediment interaction, and long-term material transformation within actual marine environments rather than relying solely on laboratory simulation.

Pilot deployments also generate the type of evidence necessary for future standards development and regulatory alignment. Real-world observations can help inform performance-based criteria defining acceptable durability during operational use together with measurable reduction in persistence following loss or abandonment. These forms of evidence are particularly relevant for RFMO discussions on FAD material substitution, where regulators require demonstration that alternative materials are both functionally effective and environmentally preferable relative to conventional plastics.

Catchgreen has therefore developed a structured model for multi-site pilot deployment of PBS-based FAD appendages alongside conventional HDPE components across different marine environments. These pilots are designed to monitor mechanical performance, operational handling, catch outcomes, material condition, degradation behaviour, and post-loss environmental interaction over extended deployment periods.

Importantly, these pilots are not intended to demonstrate that PBS is universally or rapidly biodegradable under all marine conditions. Rather, the objective is to determine whether substituting highly persistent synthetic materials with PBS-based alternatives can maintain fisheries performance while measurably reducing long-term environmental persistence and ecological impact associated with lost or abandoned FAD components.

The overall objective is therefore evidence-based substitution: maintaining operational effectiveness while reducing long-term environmental harm relative to conventional plastics. Data generated through these pilot programmes will be important for informing regulatory dialogue, supporting future standards development, guiding product optimisation, and enabling scientifically robust environmental claims aligned with emerging international best practice.

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