

# Submarine cables and marine biodiversity





#### UNEP World Conservation Monitoring Centre

219 Huntingdon Road  
Cambridge, CB3 0DL  
United Kingdom

+44 (0) 1223 277314  
info@unep-wcmc.org  
www.unep-wcmc.org

#### The United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC)

is a global Centre of excellence on biodiversity. The Centre operates as a collaboration between UN Environment Programme and the UK registered charity WCMC. Together, we are confronting the global crisis facing nature. We do this through our unique position ensuring science, knowledge and insights shape global and national policy, and by collaborating with partners around the world to build capacity and create innovative solutions to environmental challenges. We use our position as respected custodians of powerful and trusted environmental data to create positive impact for people and nature.

#### Authors

Emma Calhoun  
Ruth Fletcher  
Chris McOwen  
Ian Ondo  
Vignesh Kamath Cannanure

#### International Cable Protection Committee Ltd

12 Fratton Road  
Portsmouth, PO1 5BX  
United Kingdom

+44 (0) 1590 681673  
secretariat@iscpc.org  
www.iscpc.org

**The International Cable Protection Committee Ltd (ICPC)** is a non-profit organisation. The International Cable Protection Committee is the world's leading organisation promoting submarine cable protection and resilience. With over 240 member organisations and government observers across 76 countries, the ICPC envisions a global network of reliable and resilient submarine cables that coexist with the marine environment.

#### Authors

John Wrottesley  
Dr. Michael Clare  
Kent Bressie  
Ryan Wopschall

---

#### External reviewers

Dr. Kristine E. Dalaker, Lecturer  
Australian National Centre for Ocean Resources and Security (ANCORS), University of Wollongong  
Daniela Diz  
Associate Professor of International Ocean Governance, The Lyell Centre, Heriot-Watt University, UK  
Malcolm Eccles  
OTECC Consultancy Ltd (Former ICPC Chair & Director)  
Dr David Freestone  
Executive Secretary, Sargasso Sea Commission; Visiting Scholar, George Washington University Law School, Washington DC.  
Ben Jobson, The Biodiversity Consultancy  
Ronald J. Rapp, Ph. D.  
Retired, Submarine Cable Industry Director  
Prof Murray Roberts  
University of Edinburgh  
Dr. Hiromitsu Todokoro  
Senior Advisor, Submarine Cable Planning, KDDI  
Dr Joe Turner, The Biodiversity Consultancy

©ICPC Ltd/UNEP/UNEP-WCMC, 2025

<https://doi.org/10.34892/V9NB-TR83>

#### Disclaimer

The contents of this report do not necessarily reflect the views or policies of ICPC, UNEP or contributory organizations. The designations employed and the presentations do not imply the expressions of any opinion whatsoever on the part of ICPC, UNEP or contributory organizations concerning the legal status of any country, territory, city or area and its authority, or concerning the delimitation of its frontiers or boundaries.

#### Citation

UNEP-WCMC and ICPC. (2025). *Submarine cables and marine biodiversity*.

UNEP promotes environmentally sound practices globally and in its own activities. Our distribution policy aims to reduce UNEP's carbon footprint.

# Executive summary

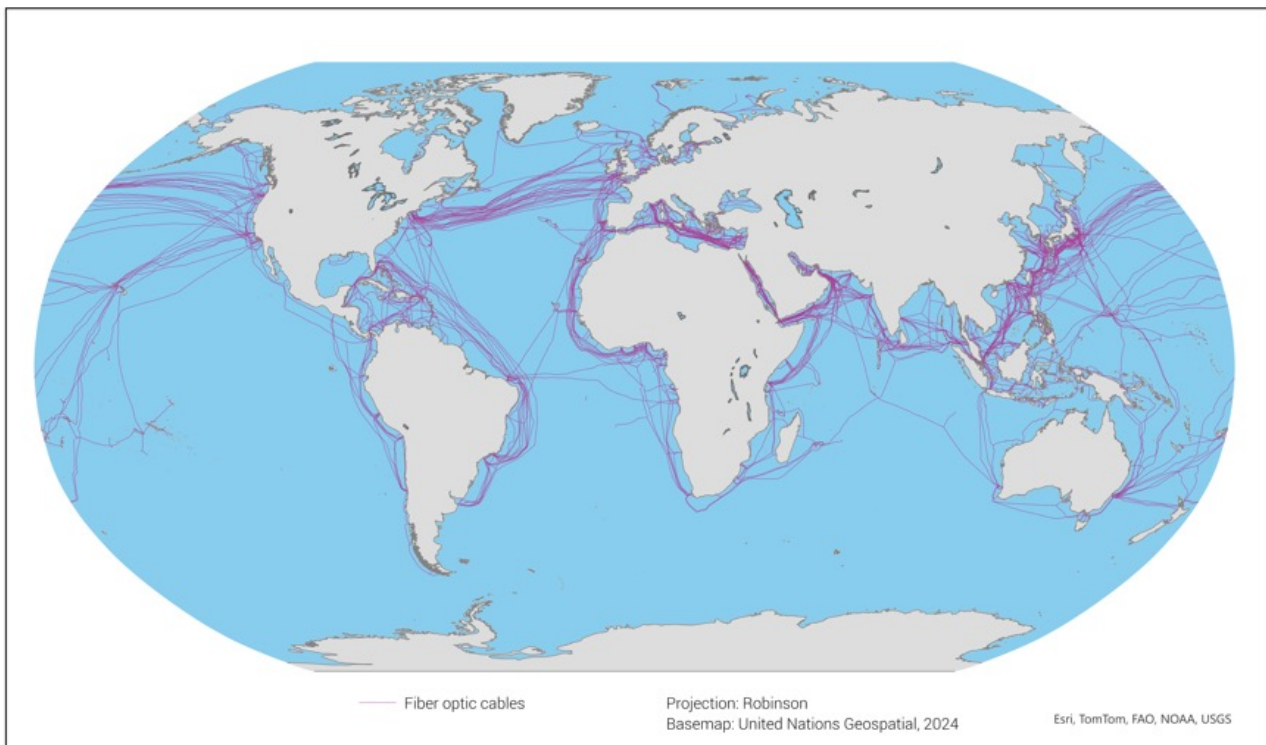


## Executive summary

**Submarine fibre-optic telecommunications cables** carry digital communications and internet traffic around the world. The network of cables connects all continents and traverses distances far greater than most other marine infrastructure.

Submarine cables run from shallow seas to the deepest parts of the ocean and in almost all cases cross international boundaries. While the cables themselves are small (17-21mm diameter) the network is vast, totaling 1.7 million kilometers (km) in length (Figure 1).

**The submarine cables network is growing and the ocean space where it is found is increasingly seeing competition for use. It is therefore timely to assess the potential impacts of cables on marine biodiversity.** Human activities in the ocean can impact coastal and marine biodiversity in many ways. Resource extraction and habitat disruption are the most important threats, along with the release of pollution and other damaging mechanisms. Given the multiple and compounding pressures on marine biodiversity, it is timely to synthesize and assess the latest understanding of the potential impacts associated with submarine cables.



The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.

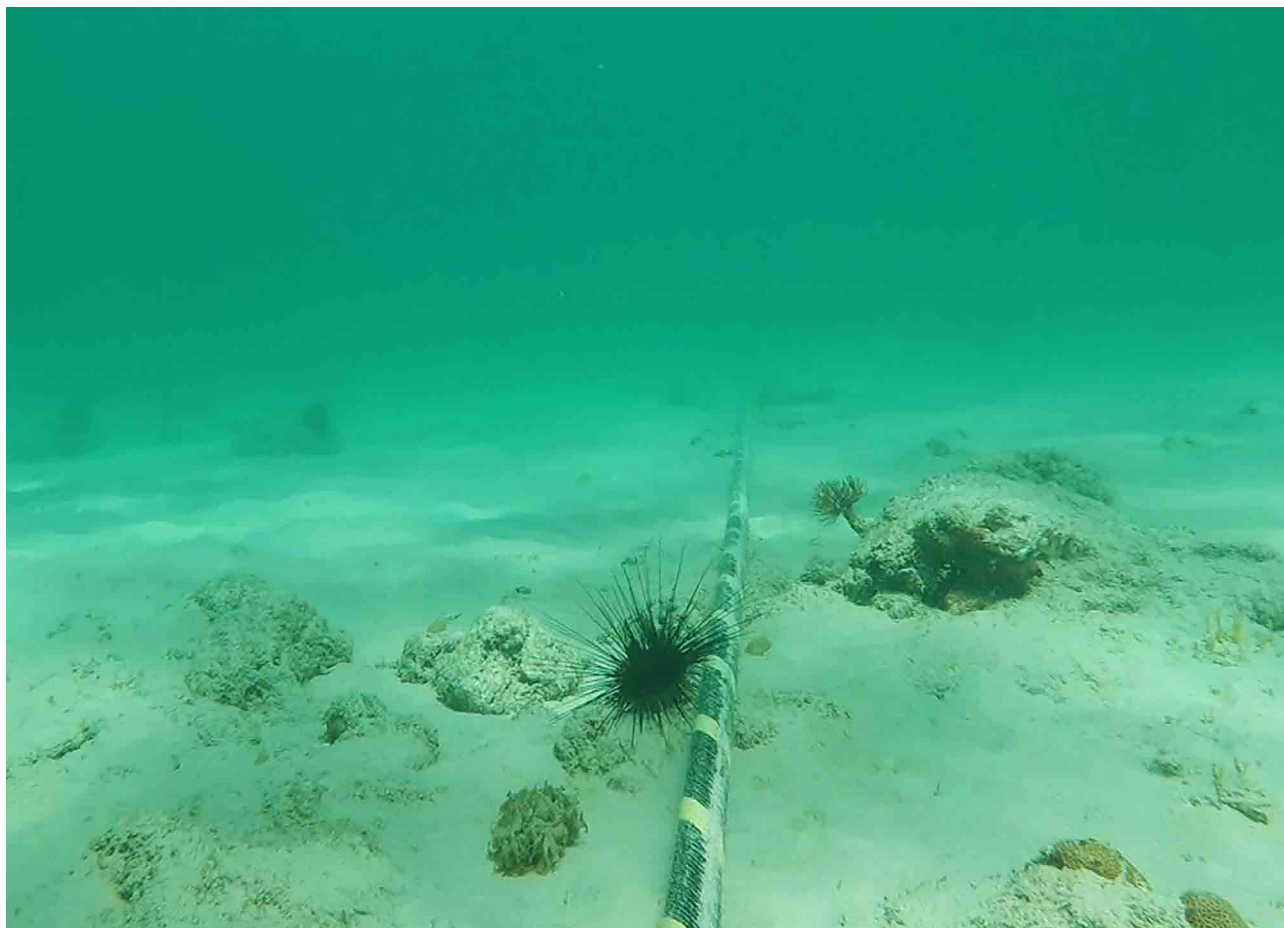
**Figure 1.** Global distribution of submarine telecommunications cables

## Executive summary

**The primary purpose of this report is to use a literature review to determine the potential global pressures and impacts that submarine cables have on marine biodiversity and to identify potential opportunities for any negative impacts to be mitigated.** To achieve these aims, this report:

- i) provides a review of the environmental pressures associated with submarine cables
- ii) appraises the potential impacts of submarine cables using an established framework
- iii) lists ways to minimize potential negative impacts
- iv) identifies opportunities to enhance biodiversity knowledge and understand the ocean environment using cable systems, while ensuring that the digital infrastructure remain resilient
- v) determines key recommendations for a variety of stakeholder groups to consider

**The scope of this report is global. It spans diverse settings from the deep ocean (defined in this report as >1,500 m) where cables are laid on the seafloor, to shallower seas (defined in this report as 0-1,500 m) where cables are typically buried for their own protection.** (damage to cable is often caused by accidental interactions with bottom-contact fishing and anchoring). Because the findings are a synthesis of a large body of evidence, specific situations might differ from the report's overall conclusions.



**Figure 2.** Sea urchin on a surface laid telecoms cable. Source: Glenn Lipsham

## Executive summary

**Overall, the analysis found that submarine cables have a relatively small footprint in the marine environment.** Globally less than 0.01% of the seafloor is within 10 meters (m) of submarine cables, indicating that the global spatial footprint of submarine cables is currently minimal.

The analysis found that potential pressures and resultant impacts from cable activities on marine biodiversity are generally minimal although they do vary spatially and over the cable lifecycle. The intensity of pressure is highest during installation in shallow waters since cables often need to be buried at these depths for their own protection. Burial techniques can result in physical damage and turbidity.

Approximately three quarters of submarine cables (74%) are found within territorial seas and the exclusive economic zones (EEZs), or within 200 nm from the coast. Around a quarter of submarine cables (26%) are in areas beyond national jurisdiction (ABNJ). Submarine cables are one of the few types of artificial infrastructure deliberately placed in ABNJ and the deep ocean.

...The majority of submarine cables are found within territorial seas and the exclusive economic zones (EEZs), or 200 nm from the coast (74%)...

The analysis found that the potential impact of cable laying on deep-sea habitats (beyond 1500m depth, irrespective of jurisdiction) is relatively low and can be minimized with careful route planning. However, further research is needed as there is insufficient science to be able to understand the relationship between potential cable impacts and the deep-sea and wider ecosystems.

Disruption to habitats is likely higher during installation and repair relative to the more benign long-term presence of cables once they are on the seafloor. Pressures are greatest in shallow waters during the pre-installation and installation phases due to the use of more invasive burial techniques. However, the report found pressures to be mostly short-term in nature. It was challenging to assess whether cable recovery caused habitat disruption as there is very little information on this. Further research in this area is required.

Submarine cable sensing technologies offer the opportunity to strengthen marine biodiversity data collection in parallel, although there are regulatory challenges to largescale implementation. Sensing technologies, which can detect environmental variables such as seismic activity, temperature, pressure and noise, can help fill existing data gaps in ocean-based environmental and ecological monitoring systems.

# Key Recommendations



## Key Recommendations

Recommendations based on the findings of the report are provided here for different stakeholders (the submarine cable industry and related associations, the scientific community, policymakers and regulators). There is also a series of recommendations relevant to all audiences

**For the submarine cable industry and related associations:** Enhance innovation and actively encourage and participate in knowledge sharing and cross-sectoral coordination and cooperation.

While the environmental impacts of submarine cables were found to be low (Table 6), there remain many opportunities to ensure that current and potential impacts are minimized. The submarine cable industry and related associations can play a critical role in driving innovation, improving environmental stewardship and fostering collaboration across sectors.

### **1. Continue to Integrate Marine Biodiversity Considerations from the Earliest Planning Stages**

Marine biodiversity should be a key consideration in cable routing and design from the earliest planning stages, wherever it has not already been prioritized. The identification of cable landing stations, route options and the design of any cable protection measures (e.g., burial, local physical structures for protection) will be strongly determined by logistical, regulatory and environmental factors initially identified during the desktop study phase of a project (ICPC 2008). The ICPC recommends that cable operators and owners “should ensure they are cognizant of any potential environmental impacts from the earliest planning stages and should strive to minimize those impacts throughout the full project lifecycle.” The ICPC also recommends that biological factors (e.g. flora and fauna populations such as presence of spawning grounds or migratory bird populations etc.) are considered in desktop studies (ICPC 2023a). The report reiterates the recommendation that marine biodiversity is made a key consideration in the desktop study stage to support the greater integration of it in early-stage route design.

The mitigation hierarchy<sup>1</sup> prioritizes avoidance as the first step, followed by minimization, restoration and, as a last resort, offset. Following this framework is critical to avoiding and minimizing negative environmental impacts. The ICPC recommends both avoidance, (preventing impacts entirely), and minimization, (reducing the duration or intensity of impacts that cannot be avoided) in cable routing (TBC 2015). To effectively mitigate potential environmental impacts and explore opportunities for restoration, it is essential to integrate marine biodiversity considerations from the earliest stages and throughout the project lifecycle.

### **2. Strengthen Industry Guidance on Mitigation Strategies**

To improve best-practice knowledge-sharing, the report recommends the ICPC publish a recommendation paper on the different mitigation options available to avoid and reduce

---

<sup>1</sup> For more information on the mitigation hierarchy please refer to <https://www.thebiodiversityconsultancy.com/services/site-level-advisory/mitigation-hierarchy>

## Key Recommendations

environmental and ecological impacts from submarine cables. The report recommends that the ICPC develops a comprehensive list and analysis of mitigation activities, including their relevant industry examples – both successful and unsuccessful. Engaging industry stakeholders in this process would help gauge support for various mitigation options and encourage their adoption. Given the limited understanding of impacts on less studied ecosystems, such as those in ABNJ, the report suggests that this report prioritize improving knowledge on cable activities, associated pressures, and their effects on deep-sea ecosystems.

### 3. Advance Research on Cable Decommissioning and Recovery

The report recommends that the cable industry conduct further research and analysis on cable decommissioning and recovery. Particularly, it recommends that industry conduct an analysis on the impacts of leaving cables in-situ versus removing them from the water once they are decommissioned. This research could improve the evidence available for determining environmental impacts and conducting comprehensive marine spatial planning. Decision-making regarding cable recovery is particularly relevant in the context of increased activity in the marine realm that is leading to competition for space.

### 4. Foster innovation and expand cable sensing technologies

The report recommends that industry associations continue advocating, particularly in discussions with regulators, for the potential of cable sensing to enhance understanding of marine ecosystems. Industry associations play a critical role in continuing to support important conversations around data-sharing and cable opportunities, such as cable sensing. The ICPC has published a paper detailing current cable sensing capabilities and the barriers to wider adoption (Clare 2023). Further discussion on multi-stakeholder collaboration is provided in the “For Collaboration Between Different Stakeholders” section.

**For the scientific community:** Expand the scientific evidence base on the interactions between submarine cables and marine species, habitats and ecosystems.

Scientific data enable evidence-based decisions. This report’s literature review determines the strength of available evidence for multiple types of impact on the marine environment from submarine cables and identifies where potential evidence gaps exist in the literature. Opportunities where future research can add value could include assessment of:

#### 1. Long-Term and Large-Scale Monitoring of Cable Impacts and Recovery

Impacts associated with submarine cable installation (particularly burial that disturbs the seafloor in shallower waters) have been shown to be short-lived, with the timescales for recovery of the seafloor depending upon the background environmental conditions (such as substrate type and hydrodynamic regime). Previous studies have relied upon point-sampling, across relatively small areas, at coarse timesteps (e.g., years). Advances in seafloor imaging and ecological characterization (e.g. through use of high-resolution camera-based Autonomous Underwater Vehicles) could permit more frequent timelapse surveys to be performed. These technologies could assess the location, rate and nature of recovery of seafloor ecosystems where cables are laid. Understanding the recovery of different habitat types to disturbance will provide improved knowledge on when and why type of monitoring should and should not occur. For example, in more sensitive

## Key Recommendations

ecosystems, like deep sea corals, visual mapping has not been effective as high-resolution photos do not provide enough detail to determine changes in coral polyps (Offshore Norge 2017). Visual monitoring is more useful for soft sediment habitats where change can be seen such as from the identification of a furrow.

### 2. Cumulative Impacts of Submarine Cables with Other Human Activities

While submarine cables typically have a minor impact, it is important to consider their contribution to cumulative impacts in areas affected by other human activities. There remains uncertainty over assessment of cumulative impacts across marine sectors and growing activities from cables, fishing, aggregate extraction, offshore renewables, oil and gas development and other seafloor uses add to this uncertainty. In addition, climate change further alters marine ecosystems, compounding stressors such as ocean warming, acidification and habitat shifts. Research that assesses these cumulative effects and disentangles the contributing factors is essential for providing the data needed for more environmentally-informed marine spatial planning (Halpern *et al.* 2015).

### 3. Species-Specific and Life Stage Responses to Cables

Species' responses to submarine cables vary depending on factors such as age, movement patterns, feeding behavior and reliance on echolocation. Understanding which species are most vulnerable, how this varies across life stages and where they are located is crucial for developing targeted and context-specific mitigation measures. This research is especially relevant given that the majority of cable length overlaps with EEZs (Table 4), where sensitive coastal habitats are found. Ecosystems such as marshes, eelgrass beds and mangroves are particularly vulnerable to human activities but often lack baseline data. This leads to insufficient understanding of their ecological dynamics (Zacharias and Gregr 2005). Addressing these knowledge gaps will help improve impact assessments and inform more effective conservation and management strategies.

Options to fill these gaps include:

- **Long-term Studies:** Conduct long-term monitoring and research to understand the prolonged impacts of cables, particularly those living on or beneath the seabed. Seabed monitoring examples include, but are not limited to, assessment of seabed respiration and deformation (Ge *et al.* 2022).
- **Impact Assessment Beyond Immediate Areas:** Expand studies to examine possible impacts (e.g., pollution or turbidity) beyond the cable installation zone focusing on ecosystem functioning, stability and productivity to capture broader environmental consequences.
- **Cumulative Impact Analysis:** Investigate the cumulative impacts of multiple cables laid in proximity and their interaction with other human activities in the marine environment. Developing predictive models can help assess correlations between multiple stressors, ecological variables (e.g., species abundance, ecosystem condition) and stressor interactions (Rullens *et al.* 2022).

**Policymakers and regulators:** Reduce data-sharing barriers and provide an overarching mechanism to plan the use of ocean space.

To support sustainable submarine cable deployment and minimize environmental impacts, policymakers and regulators should:

## Key Recommendations

### 1. Provide regulatory certainty and standardization

Facilitate policy cooperation and cohesion, as well as regulatory certainty and predictability. This is important at national, regional and multilateral levels and across industries, as although submarine cables are subject to several international treaties applicable to areas beyond national jurisdiction (including UNCLOS 1982), no intergovernmental organization regulates or licenses their installation. Regional industry associations such as ESCA (European Subsea Cables Association), NASCA (North American Submarine Cable Association), DKCPC (Danish Cable Protection Committee) and OSCA (Oceania Submarine Cable Association) have key roles to play regionally to engage with regional topics and policies. Other regional groups are being established in Asia, Africa and South America. A similar idea is outlined in the BBNJ Agreement under Article 47 (c) which proposes the promotion of “coherence among efforts towards the conservation and sustainable use of marine biological diversity of areas beyond national jurisdiction” among relevant organizations working in the marine space.

### 2. Support Knowledge Exchange and Transparent Data-Sharing

Address the regulatory complexities associated with multi use cables (e.g. telecommunications cables capable of collecting data for scientific research). Although UNCLOS provides freedoms for laying cables for telecommunication purposes, it does not provide the same freedoms for cables that may be used for scientific research. As a result, multi-use cables for both telecoms and scientific research purposes could face different regulation to cables that are used only for telecommunications. UNCLOS gives coastal states the right to impose restrictions on marine scientific research in EEZs, while the submarine cable industry does not face the same restrictions (Clare 2023). Marine research undergoes greater restrictions than cable activities. These regulatory and legal issues will be relevant both to individual states and applicable to areas beyond national jurisdiction given that cables transit multiple jurisdictions globally including ABNJ.

### 3. Integrate Submarine Cables into Marine Spatial Planning

To reduce conflicts, enhance resilience and minimize biodiversity impacts, policymakers and regulators should formally integrate submarine cables into Marine Spatial Planning (MSP) to ensure coordinated management of coastal and ocean space and minimize conflicts between offshore energy, fisheries, conservation efforts and telecommunications infrastructure. Considering cables alongside other marine activities enables sustainable co-existence and aligns infrastructure development with conservation goals.

**Collaboration between different industries and stakeholders:** Greater collaboration among submarine cable stakeholders is essential for achieving mutually beneficial outcomes.

Marine sectors and regulators often operate in isolation, which limits the sharing of knowledge and best practices and leads to duplicated efforts, hindering biodiversity conservation and restoration. The report encourages increased engagement, particularly in cable sensing and marine biodiversity data-sharing. Strategies to enhance collaboration among the marine industry (e.g., fishing, offshore renewables, cable, etc.), the scientific community and policymakers and regulators are outlined below.

## **Key Recommendations**

### **1. Strengthen collaboration to share knowledge, raise awareness, and develop best environmental practices**

Operating in isolation limits knowledge sharing, can result in a duplication of efforts and hinder a holistic understanding of biodiversity sensitivity and impacts. The submarine cable industry works with other private sector industries, conservation bodies and scientific researchers. Further strengthening cooperation and coordination with such stakeholders is vital for ensuring that the latest evidence informs best practices at local, regional and global scales. A example of good practice is the Environmental Impacts of Human Activities Committee under the OSPAR Convention, which unites policymakers, industry representatives and conservation agencies to assess impacts and develop mitigation strategies for development activities In the North Atlantic (Sinclair *et al.* 2023).

### **2. Enhance sharing of data gathered from cable-related activities with biodiversity specialists to enable joint research initiatives**

Data gathered through research conducted for submarine cable routing, installation, operation and removal has provided valuable insights into deep-sea currents, marine hazards (earthquakes, tropical storms, landslides) and seafloor disturbances, including recovery times after cable burial (Kraus and Carter 2018). As submarine cables are deployed in new ocean areas, it provides opportunities to collect new data to enhance environmental risk management, identify previously unrecognized impacts and improve mitigation strategies.

For example, cable sensing technologies, such as distributed acoustic sensing, pressure sensors, and temperature monitoring, can transform submarine cables into tools for detecting changes in the environment and biodiversity. However, the deployment of multi-use sensing technologies for both telecommunications and scientific research introduces regulatory uncertainty (UNCLOS 1982). Stronger engagement between regulators, the cable industry and the scientific community is needed to address these challenges and recognize the broader benefits of cable-based marine data collection, including (a) infrastructure protection and communication continuity, (b) enhanced environmental data, and (c) improved disaster warning systems.

The cable industry can both contribute to and benefit from existing cross-sectoral knowledge-sharing platforms that facilitate data exchange, research collaboration and technological innovation. Examples include the Global Biodiversity Information Facility, the Ocean Biodiversity Information System, the Global Ocean Observing System, and the Marine Data Exchange platform, as well as participation in initiatives such as the UN Decade of Ocean Science for Sustainable Development.

### **3. Make greater use of the reach and engagement of industry associations**

Industry associations like the ICPC play a vital role in facilitating stakeholder discussions, bringing together policymakers, regulators, industry representatives and academia at a global level. The ICPC actively engages with key international bodies, including the International Seabed Authority and International Hydrographic Organization, holds consultative status with the United Nations Economic and Social Council and participated in negotiations for the BBNJ Agreement. Ideally this engagement with international bodies will enable both the cable industry and other sectors to better understand and mitigate cumulative impacts from different activities.

## Contents

Executive Summary	iii
Key Recommendations	vii
Table of Contents	xiii
List of Acronyms	xiv
Introduction	1
Methodology	6
Results	12
Discussion	18
References	32
Appendix A (methodology)	37
Appendix B (results)	41
Appendix C (cable sensing info)	46
Appendix D (list of all reviewed literature)	47

## List of Acronyms

<b>ABMT</b>	Area-based Management Tool
<b>ABNJ</b>	Area Beyond National Jurisdiction
<b>APEI</b>	Areas of Particular Environmental Interest
<b>BBNJ</b>	Biodiversity Beyond National Jurisdiction
<b>DKCPC</b>	Danish Cable Protection Committee
<b>EBSA</b>	Ecologically or Biologically Significant Area
<b>EEZ</b>	Exclusive Economic Area
<b>EIA</b>	Environmental Impact Assessment
<b>ESCA</b>	European Subsea Cables Association
<b>HDD</b>	Horizontal Directional Drilling
<b>ICPC</b>	International Cable Protection Committee
<b>MPA</b>	Marine Protected Area
<b>MSP</b>	Marine Spatial Planning
<b>NASCA</b>	North American Submarine Cables Association
<b>OSCA</b>	Oceania Submarine Cable Association
<b>OSPAR</b>	Oslo and Paris Convention for the Protection of the Marine Environment of the North-East Atlantic
<b>UNCLOS</b>	United Nations Convention on the Law of the Sea
<b>UNEP-WCMC</b>	United Nations Environment Programme World Conservation Monitoring Centre
<b>VME</b>	Vulnerable Marine Ecosystem

# Introduction



## Introduction

# Growth in internet traffic and use of data-intensive applications continues to drive demand for new submarine cable construction.

Submarine fibre-optic telecommunication cables form the backbone of digital communication infrastructure that provides a foundation for society, connectivity, and commerce. While it is sometimes assumed that satellites are the primary means of ensuring global connectivity, submarine cables carry over 99% of global intercontinental data (Burnett and Carter 2017). The high capacity of fibre-optic cables and the ability to install them along relatively direct routes, make them the best infrastructure method for global communications. Submarine cables have been deployed since the 1850s, first with telegraph cables, then coaxial, and finally modern-day fibre-optic cables (first used in the late-1980s) (Carter *et al.* 2009). Fibre-optic telecommunication cables in the deep oceans average between 17-21 millimeters (mm) diameter, and there are approximately 600 in-service, with a total length of over 1.7 million km (TeleGeography n.d.).

This report focuses exclusively on submarine fibre-optic telecommunications cables. It does not review power transmission cables, whose main function (electricity transmission), technical characteristics, and resulting impacts differ from those of submarine telecommunications cables. A 2023 OSPAR report outlined the differences between the two types of cables, and found that impacts from electromagnetic field and thermal pressures, while relevant for power cables, were negligible for telecommunication cables (Sinclair *et al.* 2023). Pressures and impacts from the pre-installation and installation phases may be similar in some contexts, and the “Discussion” section of the report outlines where evidence from the power cable industry has been used to supplement literature on submarine fibre-optic telecoms cables (hereafter referred to as “submarine cables” and “cables”).

Global demand for internet capacity is increasing. This increase is largely due to increased demand for data-intensive activities such as broadband, cloud services and video streaming. Demand is particularly acute in more remote and under-served locations, and for connecting the large data centres to support this activity (Submarine Telecoms Forum 2023). Submarine cables are also vital for global financial systems. “SWIFT”, a messaging network, sends on average 15 million messages a day through submarine cables to banking organizations and corporate customers, accounting for over \$10 trillion financial transactions each day (Burnett and Carter 2019). Island nations and more remote locations are particularly dependent upon submarine cables to connect to the rest of the world (Burnett and Carter 2019).

## Minimizing the impact of submarine cables on biodiversity

Coastal and marine biodiversity has declined rapidly over the last century due to human activities such as exploitation of marine resources, pollution, coastal development and climate change (IPBES 2019). Biodiversity loss has resulted in less productive and resilient coastal and marine environments, with significant societal and economic consequences (Pawar 2016). Human (including climate-related) pressures on coastal and marine ecosystems are projected to increase. It is vital that every sector understands the impacts their activities can have on the natural world and implements approaches to avoid, minimize and mitigate them.

## Introduction

### Updated understanding of submarine cables impact on coastal and marine biodiversity.

In 2009, the International Cable Protection Committee (ICPC) and UNEP-WCMC report “Submarine Cables and the Oceans: Connecting the World” evaluated the impact of submarine cables on the coastal and marine environment. Since the report’s publication, approximately 700,000 additional km of submarine cables (a ~65% increase from 2009) have been installed. The footprint of blue economy sectors such as ports and harbors is also increasing (Carter *et al.* 2009). In this context, it is important to revisit the question:

...it is important to revisit the question: What impact do cables have on coastal and marine biodiversity and what are the best ways to minimize and mitigate any negative impacts?

What impact do cables have on coastal and marine biodiversity and what are the best ways to minimize and mitigate any negative impacts?

### Evolving regulatory regime for marine activities in areas beyond national jurisdiction

The United Nations Convention on the Law of the Sea (UNCLOS) grants freedoms to states to install, operate, and repair cables on the high seas, in the Area (the seabed and subsoil beyond the continental shelf), and in the exclusive economic zone and continental shelf areas of coastal states (UNCLOS 1982). However, no single intergovernmental organization is responsible for globally authorizing or regulating submarine cables. Instead, these activities are governed by a combination of treaties, customary international law, and the national laws and regulations of individual states.

The Agreement under the United Nations Convention on the Law of the Sea on the Conservation and Sustainable Use of Marine Biological Diversity of Areas Beyond National Jurisdiction (BBNJ Agreement) marks a significant milestone in advancing environmental protection in areas beyond national jurisdiction (ABNJ). As defined by UNCLOS, ABNJ includes both the water column beyond the exclusive economic zones of coastal states (extending up to 200 nautical miles) and the seabed and subsoil beyond continental shelves, known as “the Area.” Adopted on June 19, 2023 under the United Nations, the BBNJ Agreement seeks to address longstanding gaps in the UNCLOS framework by promoting the conservation and sustainable use of marine biodiversity in ABNJ. Although the Agreement has not yet entered into force (pending ratification by at least 60 countries<sup>2</sup>) it is expected to shape future governance of biodiversity in the high seas. A full review of national marine regulations is beyond the scope of this report, however, below we briefly highlight provisions of most relevance to submarine cables, namely Environmental Impact Assessments and Area-Based Management Tools including Marine Protected Areas. Implications of ongoing ISA discussions on deep sea mining may also be useful to consider further in the context of submarine cables.

### Environmental Impact Assessments (Part IV)

Under UNCLOS article 206, states must conduct environmental assessments when they have “reasonable grounds for believing that planned activities under their jurisdiction or control may cause substantial pollution of or significant and harmful changes to the marine environment”. Under the BBNJ Agreement, however, planned activities in ABNJ

---

<sup>2</sup> Access <https://tinyurl.com/3vhe6dtr> for the certified true copy of Agreement text and current treaty status.

## Introduction



**Figure 3.** Scuba diver installing articulated pipe to a cable. Source: Tide & West

under the jurisdiction or control of a Party are subject to a two-tiered screening and assessment process under Articles 27–39. Such activities could include submarine cable installation, operation, repair, and decommissioning. Key provisions from the BBNJ Agreement include:

- **Screening Threshold (Article 30):** Article 30 provides that if a planned activity “may have more than a minor or transitory effect on marine environment, or if effects of the activity are unknown or poorly understood,” the Party with jurisdiction or control over the activity must conduct a screening. The screening is a preliminary assessment that must include a description of the activity and an initial analysis of potential impacts (including potential cumulative impacts and the potential impacts in areas within national jurisdiction) and used to determine whether the EIA threshold (discussed below) is triggered.
- **EIA Threshold (Article 28(2)):** A Party must conduct an EIA if the planned activity “may cause substantial pollution or significant and harmful changes to the marine environment”—mirroring the UNCLOS Article 206 threshold.

Responsibility for determining whether thresholds are met, deciding if an environmental impact assessment is required<sup>3</sup>, preparing the EIA, and making decisions about whether an activity may proceed, including any associated mitigation or management measures, rests with the Parties authorizing activities in areas beyond national jurisdiction Article 34.

---

<sup>3</sup> “Parties shall, by using the best available science and scientific information and, where available, the relevant traditional knowledge of Indigenous Peoples and local communities, keep under surveillance the impacts of any activities in areas beyond national jurisdiction that they permit or in which they engage in order to determine whether these activities are likely to pollute or have adverse impacts on the marine environment” (Article 35)

## Introduction

The Agreement empowers the Conference of the Parties, based on recommendations from the Scientific and Technical Body, to adopt standards and guidelines to support the implementation of the EIA provisions under Part IV. These may include, among other elements: criteria for determining thresholds; an indicative (non-exhaustive) list of activities that do or do not require an EIA; requirements for EIA report content; guidance on assessing cumulative impacts<sup>4</sup> or impacts extending into national jurisdiction, and guidance on developing EIAs for activities proposed in areas identified as needing protection or special attention (Article 38).

### Area-Based Management Tools including Marine Protected Areas (Part III)

The BBNJ Agreement also introduces a process for establishing area-based management tools (ABMTs), including marine protected areas (MPAs), under Articles 17–26. ABMTs, including MPAs, will serve the purpose of conserving and sustainably using areas requiring protection, with measures at each site to be aligned with the achievement of specified objectives.

- An **ABMT** is a “tool, including a marine protected area, for a geographically defined area through which one or several sectors or activities are managed with the aim of achieving particular conservation and sustainable use objectives in accordance with this Agreement” (Article 1).
- An **MPA** “means a geographically defined marine area that is designated and managed to achieve specific long-term biological diversity conservation objectives and may allow, where appropriate, sustainable use provided it is consistent with the conservation objectives” (Article 1).

One or more Parties may propose an ABMT including MPA and “shall collaborate and consult, as appropriate, with relevant stakeholders, including States and global, regional, subregional and sectoral bodies, as well as civil society, the scientific community, the private sector, Indigenous Peoples and local communities [...]” (Article 19). The Conference of the Parties (COP) will make decisions on ABMT and MPA proposals, including on related measures (Article 23). Where measures are compatible with those adopted by relevant legal instruments and frameworks and relevant global, regional, subregional and sectoral bodies, decisions are to be made in cooperation and coordination with those. Decisions by the COP are to be generally by consensus or, in the absence of consensus, through qualified majority voting (Article 47). Parties may opt out of particular ABMTs, including MPAs, on grounds of inconsistency with UNCLOS and/or customary international law, unjustifiable discrimination, or inability to comply, but such opt-outs are time-limited (Article 23).

Overall, it remains to be seen how overarching objectives of ABMTs and MPAs under the BBNJ Agreement might be implemented by Parties to the Agreement and if there will be any implications for the cable laying industry.

---

<sup>4</sup> The BBNJ Agreement defines cumulative impacts as “the combined and incremental effects of past, present, and foreseeable activities, as well as climate change and ocean acidification” (Article 1)

# Methodology



## Methodology

### Methodological assumptions and limitations

This report was written to provide a global context, enabling the authors to determine a global snapshot of the impacts of submarine cables on marine biodiversity. A spatial and a literature analysis were undertaken. The authors recognize that pressures and their resulting impacts will be heavily context-specific (e.g., geographic region, type of equipment used, nuances of an individual cable project, etc.), and the conclusions reached are therefore not applicable to every individual cable. Instead they act as a conceptual overview that can be applied in considering cable impacts. For further information on any of the text in the “Methodology” section, please refer to Appendix A.

The spatial analysis overlapped the distribution of cables with global data on marine habitats and protected areas (including modelled data). The authors acknowledge that global data are not always accurate when applied at different scales. For further details on the methodology used to calculate the spatial footprint of cables globally please refer to Appendix A.

This report and analysis focus solely on the submarine communications cable industry. The findings on pressures and impact intensities and likelihoods are **not** intended to be used as a comparison to other marine industries. All statements are made relative to other pressures and impacts resulting from the cable industry alone.

### Methodological structure

The methodology for this report, adapted from [UNEP’s Governing Coastal Resources report](#) (2021), examines the drivers, pressures, impacts, and potential responses related to submarine cables and their effects on marine biodiversity. The terms used are defined as follows:

**Drivers:** *Social, economic and demographic factors influencing cable laying.* Drivers were identified in consultation with the cable industry and from the [“Submarine cables and the oceans: connecting the world”](#) report.

**Pressures:** *The stressors placed upon coastal and marine species, habitats and ecosystems.* The pressures considered in this analysis (Table 1) are based on the UK Joint Nature Conservation Committee’s [“Standardized list of pressures in the marine environment.”](#) and OSPAR’s Commission pressures.<sup>5</sup> These pressures (Table 1) are the ones that are focused on in the resulting literature review for all phases of the submarine cable lifecycle.

Note that while older coaxial cables caused entanglements with large megafauna, there has not been a recorded entanglement since 1960 and so entanglements are no longer deemed a relevant pressure arising from cable activities (Sinclair *et al.* 2023). Electromagnetic field (EMF) is also not included as a pressure as it is only applicable to power cables, not telecoms cables (Sinclair *et al.* 2023).

---

<sup>5</sup> Derived from the 2024 OSPAR publication “Subsea cables within the OSPAR marine area” which lists pressure categories of cable installation from OSPAR’s Joint Assessment & Monitoring Programme and Marine Strategy Framework Directive.

## Methodology

**Table 1.** Priority marine pressures from submarine telecommunications cables and descriptions (adapted from JNCC and OSPAR)

Theme	Potential pressure	Definition	Relevance to cables
<b>Physical damage</b>	Habitat structure changes	Physical change to another seabed type OR removal of substratum (burial)	Arising from cable burial
	Penetration and/or disturbance of the substrate below or on the surface of the seabed, including abrasion	Physical change to a seabed type without the removal of substratum	Arising from the placement of localized protective structures
	Turbidity	Changes in water clarity from sediment and organic particulate matter concentrations resuspended (Taormina <i>et al.</i> 2018)	Arising from suspension of sediments where cables are buried
<b>Other physical pressures</b>	Noise and disturbance changes	Sound pollution from ships or installation techniques	Arising from ships used to install and repair cables
	Death or injury by collision/vessel strike of marine megafauna*	Collision with static or moving objects not naturally found in the marine environment (e.g., boats, machinery and structures)	Associated with cable installation of maintenance activities
<b>Pollution and other chemical changes</b>	Releasing pollutants	Sewage and/or chemical pollution released from cable laying activities or cables themselves	Arising from seabed disturbance during cable burial

\* Cables are laid from vessels, so as with any ship-based activity, there is a possibility of ship strike. Whilst this pressure is rare, as there is a small likelihood that it can occur, it is included.

**Impacts:** *The consequences of the pressures resulting from activities in the lifecycle of a submarine telecommunications cable upon coastal and marine species, habitats and ecosystems.*

**Responses:** *Potential options for policymakers, the cable industry and other stakeholders to reduce potential negative environmental impacts to marine biodiversity during the lifecycle of a submarine telecommunications cable.*

### Literature analysis

*Assessing and quantifying potential pressures and impacts across the cable lifecycle.*

The assessment follows four key lifecycle phases of submarine cables: pre-installation, installation, operation, and decommissioning/recovery (Table 2).

Due to limited literature on the impact of submarine cables a “pathway” approach was used to link pressures to potential impacts (Figure 4). The analysis assessed

1. The strength of pressures from each cable lifecycle phase
2. The strength of impacts of those pressures on ecological components (species, habitats, ecosystem functioning)

## Methodology

**Table 2.** Cable lifecycle phases

Cable lifecycle phase	Description	Example Activities
<b>Pre-installation</b>	The planning and routing of cables; including exploratory surveys to identify effective, resilient and environmentally-responsible routes, in addition to route preparation measures such as Horizontal Directional Drilling (HDD) and pre-lay grapnel runs.	<ul style="list-style-type: none"> <li>• Desktop survey</li> <li>• Horizontal Directional Drilling (HDD)</li> <li>• Pre-lay grapnel runs</li> </ul>
<b>Installation</b>	The installation of cables; including laying directly on the seafloor (in deep water) and burying beneath the seabed (in shallow water to protect them).	<ul style="list-style-type: none"> <li>• Burial via ploughing</li> <li>• Burial via jetting</li> <li>• Laying on the seafloor</li> </ul>
<b>Operational</b>	The in-situ operation of cables; including repair activities in the infrequent case of faults.	<ul style="list-style-type: none"> <li>• Cable retrieval via grapnel</li> </ul>
<b>Decommissioning/ Recovery</b>	The decommissioning of cables after they have reached the end of their life, which may include leaving cables in-situ or recovering (in part or entirely).	<ul style="list-style-type: none"> <li>• Cable retrieval via grapnel</li> <li>• Pulling buried cables out of the seafloor</li> </ul>

The overall impact was determined by combining the strength of pressures from each cable lifecycle phase with the strength of impacts on ecological components. For more details on how impact scores were derived, refer to Appendix A.

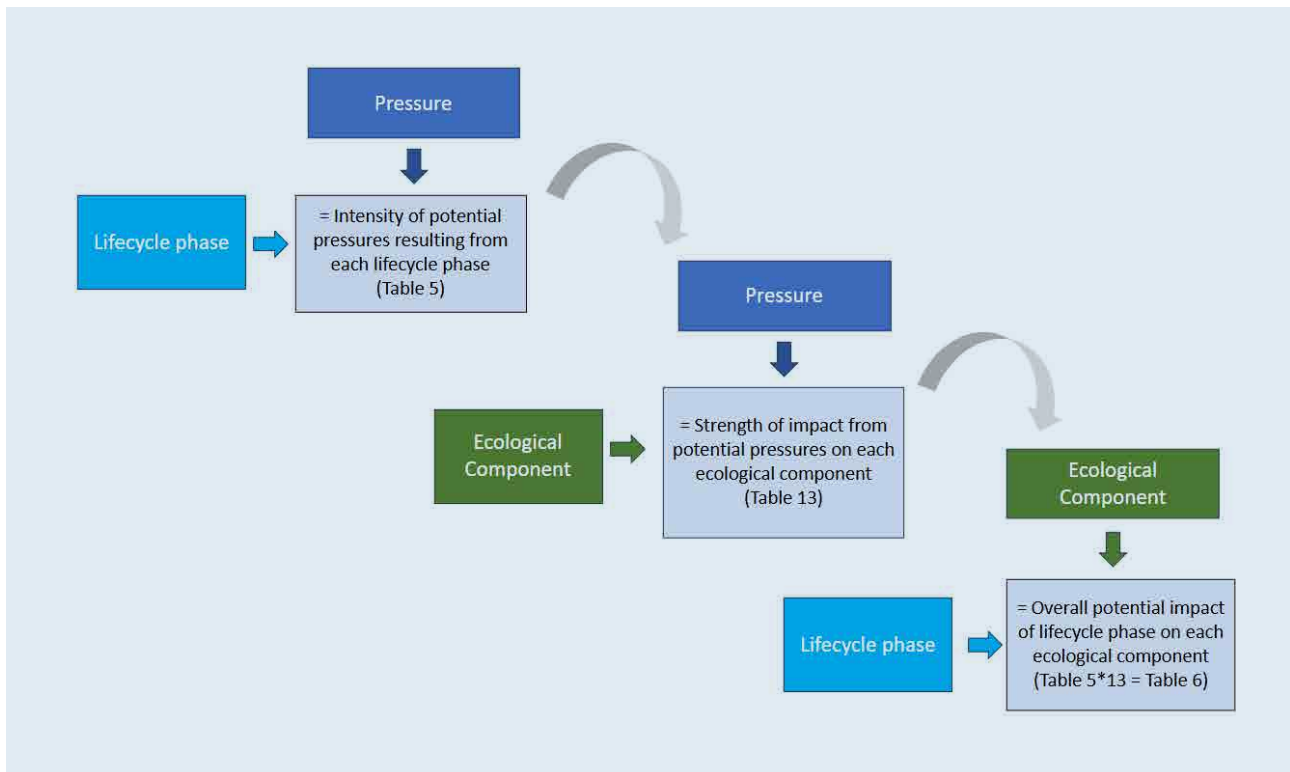
To classify the strength of pressures, the analysis considered the scale and duration of environmental changes:

- **High** – the pressure causes longer-term changes in surrounding conditions and/or reaching far outside of the immediate point of impact.
- **Moderate** – The pressure causes changes in surrounding conditions within a confined area around the immediate point of impact.
- **Low** – The pressure causes short-term changes in surrounding conditions and/or only at the immediate point of impact.

The strength of pressure was calculated separately for shallow (0-1,500m) and deep water (>1,500m). The method was derived from [UNEP's Governing Coastal Resources report](#) (2021). The assigned scores are relative to other activities within the cable lifecycle phase, not to other blue economy sectors.

To assess the robustness of relationships between pressures and impacts, the strength of evidence was categorized based on: Size (large, moderate, or small); Quality (high, moderate, or moderate-to-low); robustness (e.g., qualitative vs. quantitative) and credibility (e.g., sourced from a credible database (Table 3)). For more detailed information refer to Appendix A.

## Methodology



**Figure 4.** Visual representation of how pressure and impact strength ratings were determined for each lifecycle phase.

**Table 3.** Criteria used to assess the strength of the evidence.

Strength of evidence	Definition	What it means	Included in the analysis
<b>Strong</b>	High quality body of evidence, large in size, consistent and contextually relevant.	We are very confident that the activities associated with submarine cables does or does not create the anticipated pressure and/or impact. The body of evidence is very diverse and highly credible, with the findings convincing and stable.	Yes
<b>Moderate</b>	Moderate quality studies, moderate size evidence body, moderate level of consistency. Studies may or may not be contextually relevant.	We believe that the submarine cable industry may or may not create the anticipated pressure and/or impact. The body of evidence displays some significant shortcomings. There are reasons to think that contextual differences may unpredictably and substantially affect intervention outcomes.	
<b>Limited</b>	Moderate-to-low quality studies, moderate size evidence body, low levels of consistency. Studies may or may not be contextually relevant.	We believe that the submarine cable industry may or may not create the anticipated pressure and/or impact. The body of evidence displays very significant shortcomings. There are multiple reasons to think that contextual differences may substantially affect intervention outcomes.	No
<b>No evidence</b>	No/few studies exist.	There is no plausible evidence that the submarine cable industry does/does not create the indicated pressure and/or impact.	

## Methodology

### Literature review

The majority of the evidence used in this study was obtained from scientific literature cited from scientific literature and industry reports. Representatives from the cable industry were consulted to obtain industry reports, ICPC Recommendations and to better understand the processes involved in submarine cable activities.

Documents were included based on the following criteria:

- Focus on fibre-optic cables
- Studies on older telecommunications cables (e.g., coaxial, telegraph) that provide relevant insights for modern fibre-optic cables
- Peer-reviewed scientific papers that are reviews or meta-analyses
- Industry guidance for submarine telecommunications cables (e.g., ICPC's Recommendation No. 9 Minimum Technical Requirements for a Desktop Study)
- Documents addressing both fibre-optic telecommunication cables<sup>6</sup> and power cables in relation to environmental pressures or impacts
- The search was global in scope but restricted to the English language.

Using these criteria, 88 documents (listed in Appendix D) were used in the analyses and findings presented in this report, including some literature which was not directly referenced in the report. Details of the literature review and spatial analysis methodology can be found in Appendix A.

---

<sup>6</sup> Literature on power cables was included within the literature review where the potential pressures are similar (e.g., from physical routing), however, pressures specific to power cables (e.g., thermal and electromagnetic) were excluded.

# Results



## Results

This section presents a high-level summary of key findings from the literature review and spatial analysis. The “Discussion” section presents illustrative examples, additional evidence and specific industry activities that contribute to pressures and impacts.

**The “Discussion” section also addresses caveats, including limitations, uncertainties, and evidence that does not fully align with overarching conclusions. It therefore provides further context and nuance to the findings.**

### Spatial footprint

The 1,781,123 km of cables in the world are distributed across all oceans except the Southern Ocean (Appendix B), the majority in the exclusive economic zones of countries (1,316,790 km; 74%) (Figure 5). Globally, 0.0098% of the seafloor is within 10 m of submarine cables. The spatial distribution of cables in the ABNJ is about a quarter of what is in the territorial seas and EEZs (464,333 km; 26%).<sup>7</sup> These results suggest that the global spatial distribution of cables is minimal. Note that these spatial findings are not evidence of scale of impact and are an estimate (Appendix B).

Globally, 485,213 km of submarine cables pass through areas of biodiversity importance (with cables crossing 7% of these areas), (Table 4). Ecologically or Biologically Significant Marine Areas (EBSAs) cover vast ocean regions, making it neither always necessary nor feasible to route cables entirely around them. While cables cross a range of seafloor habitats, their overlap with certain sensitive habitats remains relatively low:

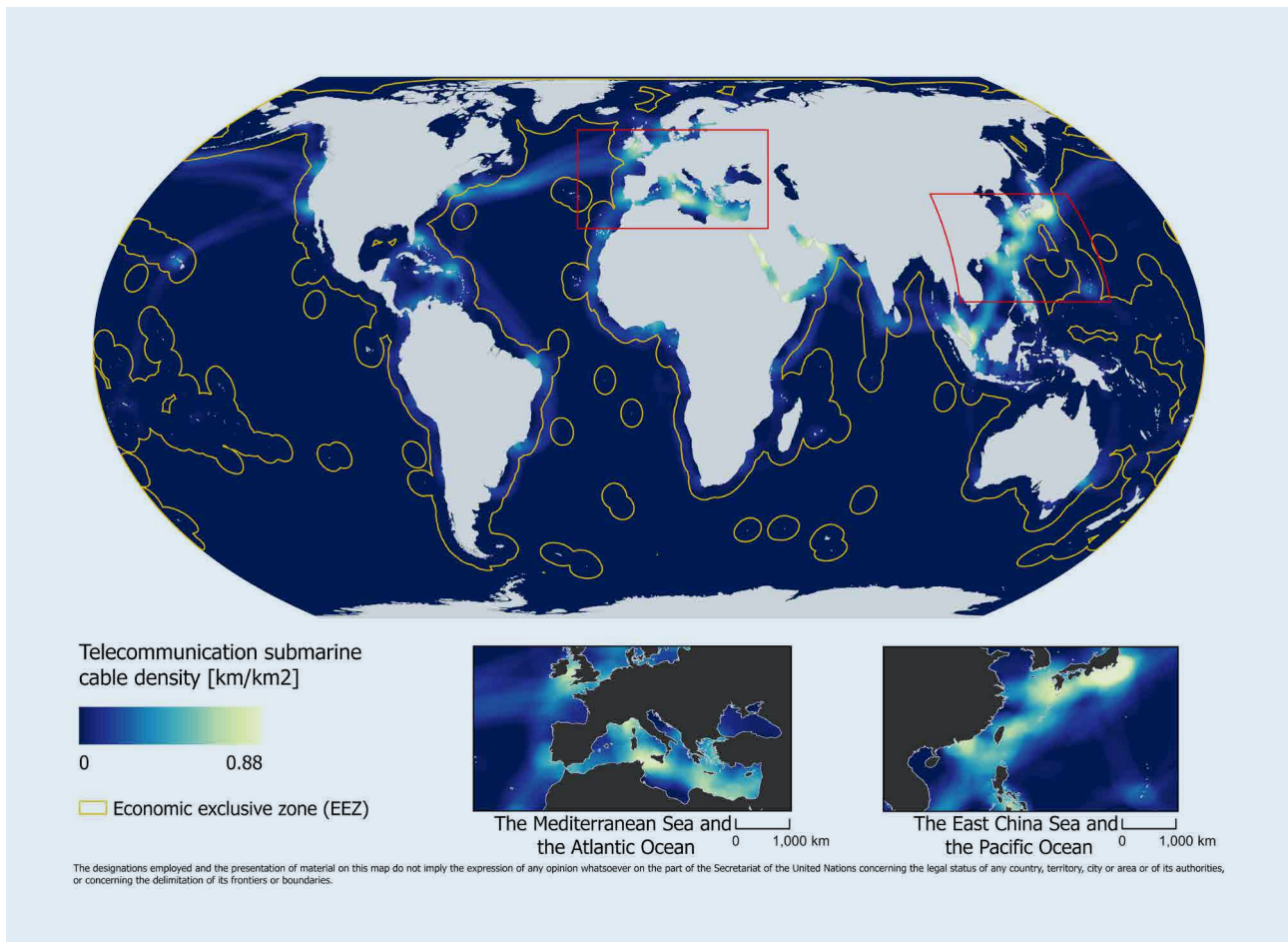
- Seamounts have 9,513 km of cable overlap (0.5% of global cable length; 0.1% of global seamount area).
- Seagrass habitats have 18.98 km of cable overlap, the highest among coastal habitats (0.3% of global cable length; .8% of global seagrass area).
- Cold-water corals have 3.66 km of cable overlap (<0.01% of global cable length; 0.1% of global cold-water corals area).

Overlap with protected or vulnerable areas does not necessarily indicate that cable activities will result in negative environmental impacts. For example, while 4% of MPAs overlap with cables and 9% of Vulnerable Marine Ecosystems (VMEs) overlap with cables, the actual risk of disturbance depends on site-specific factors, cable activities, and local conservation measures.

---

<sup>7</sup> The dataset used for this analysis does not delineate territorial waters or coastal zone boundaries; therefore, references to EEZs include the full area (seabed and water column) between 0 and 200 nautical miles from the border. The ABNJ figures also account for cables laid over extended continental shelf areas.

## Results



**Figure 5.** Cable density map. The map represents the cable length per unit area [km/km<sup>2</sup>] for a 10x10 km reference grid cell. Yellow indicates areas of high cable density, whereas dark blue indicates areas of low cable density based on the cumulative length of cable routes falling within a circular moving window of 250km radius around each grid cell, divided by the available marine area within the window.

## Results

**Table 4.** Summary statistics of the spatial footprint of cable routes overlapped with different habitats and area-based management tools globally. Footprint of cables within area-based management tools, areas of biodiversity importance and biogenic habitats at a global scale), within the Exclusive Economic Zones of countries and within Areas Beyond National Jurisdiction. Percentage of global cable coverage (area of environment type divided by global cable area. The first global percentage is the environment type area covered by cables over the total length of cables. The second global percentage is the environment type area covered by cables over the total area of environment type.

Environment type	Name	Cable length (km)				
		ABNJ	EEZ	Global	Global (1) %	Global (2) %
Area-based management tool	APEI	0	0	0	0	0
Area of biodiversity importance	EBSAs	183,686	301,531	485,213	27%	7%
Area-based management tool	MPAs	17,859	96,112	113,971	0.06%	4%
Area-based management tool	VMEs	11,043	885	11,927	0.70%	9%
Biogenic habitat	Cold Water Corals	0	4	4	<0.01%	0.1%
Biogenic habitat	Coral Reefs	0	444	444	0.02%	0.3%
Biogenic habitat	Mangroves	0	17	17	<0.01%	0.01%
Biogenic habitat	Saltmarshes	0	19	19	<0.01%	0.03%
Biogenic habitat	Seagrasses	0	5,561	5,561	0.30%	0.8%
Biogenic habitat	Seamounts	3,220	6,292	9,513	0.50%	0.1%

### Potential Pressures and Impacts from Submarine Cables

The literature review indicates that potential pressures and resultant impacts from cable activities are generally minimal, with localized and short-term effects. However, the intensity of pressures (Table 5) and impacts (Table 6) varies across the cable lifecycle, with certain activities generating higher pressures than others (Table 5). The intensity levels of pressures and impacts are not meant to be used in comparison with pressures and impacts arising from other marine industries, such as the fishing or energy industry.

### Potential Pressures across the Cable Lifecycle


- Habitat disturbance poses the greatest pressure, particularly in shallow waters, where cables are buried beneath the seabed for protection.
- Noise and pollution pressures, whilst infrequent and low in intensity may be locally important in areas of cable installation.
- The installation phase generates the highest pressure and greatest potential for ecological disturbance
- The operational phase—the longest phase, on average—generates the lowest potential pressures.

These pressures translate into varying levels of impact on marine biodiversity, depending on habitat sensitivity and species vulnerability.

## Results

**Table 5.** Potential pressures stemming from each phase of the cable lifecycle in shallow and deep waters

		Water Depth	Habitat structure changes	Penetration and/or habitat disturbance	Turbidity	Noise	Death or injury by collision	Pollution
Cable lifecycle phase	Pre-Installation	Shallow	1	3	3	1	1	1
		Deep	1	2	2	1	1	1
	Installation	Shallow	2	3	3	1	1	1
		Deep	1	1	1	1	1	1
	Operational (standard, no repair activities)	Shallow	1	1	0	0	0	1
		Deep	1	1	0	0	0	1
	Operational (includes repair activities)	Shallow	1	1	1	1	1	1
		Deep	1	1	1	1	1	1
	Recovery/Decommissioning	Shallow	2	2	2	1	1	1
		Deep	1	1	1	1	1	1

Cell colors represent the intensity of the **potential pressure** resulting from each cable phase  High Moderate Low  
 Cell numbers represent the **likelihood** of the pressure occurring (3 = High; 2 = Moderate; 1 = Low, 0 = No evidence found).

## Potential Impacts

While overall impacts remain low and relatively local to areas of disturbance, they are highest in shallow waters, where sensitive habitats (e.g., coral reefs) and species are more prevalent (Sinclair *et al.* 2023). This finding is consistent across most marine industries, as coastal areas host higher biodiversity and experience more human activity (Tixerant *et al.* 2011).

Despite low overall observed impacts, the true extent of impacts remains insufficiently understood for certain habitats, particularly those that are less studied or more difficult to monitor. In some cases, the lack of long-term data and in-depth ecological assessments makes it difficult to determine how submarine cables may affect marine biodiversity over time. Key knowledge gaps include:

- Deep-sea ecosystems – The effects of cable activities on deep-sea habitats, including the abyssal plain and hydrothermal vent communities, remain poorly documented due to the logistical challenges of research at extreme depths (Turner *et al.* 2019).
- Ecosystem functioning in sensitive habitats – While direct physical disturbance from cables is often limited and local, potential indirect effects—such as altered sediment dynamics, habitat fragmentation, or long-term changes to benthic communities—are not well understood (Table 14).

## Results

- Cumulative impacts – The interaction between cable activities and other marine pressures (e.g., climate change, fishing, offshore energy development) remains understudied, particularly in regions with increasing human activity.

Addressing these scientific gaps will help refine assessments of cable-related impacts and support more effective environmental management and mitigation strategies. The “Discussion” section will further explore these uncertainties and highlight areas where additional research is needed.

**Table 6.** Potential impacts of each phase of the cable lifecycle on species, habitats and ecosystem function in shallow and deep waters.

		Water Depth	Species		Habitats		Ecosystem Functioning		Average (Mean) Impact
Cable lifecycle phase	Pre-Installation	Shallow	High	2	Moderate	2	Low	1	Moderate
		Deep	Moderate	1	Low	1	High	1	Low
	Installation	Shallow	High	2	Moderate	2	Low	1	Moderate
		Deep	Moderate	3	Low	3	Low	1	Low
	Operational	Shallow	Moderate	1	Low	1	Low	0	Low
		Deep	Low	1	Low	1	Low	0	Low
	Decommissioning	Shallow	Moderate	2	Moderate	2	Low	0	Moderate
		Deep	Low	3	Low	3	Low	0	Low

Cell colors represent the strength of **potential impact** relative to other cable generated pressures  High  Moderate  Low

Cell numbers represent the strength of the underpinning **evidence base** (3 = High; 2 = Moderate; 1 = Low, 0 = No evidence found)

# Discussion



## Discussion

# The deployment, operation, and decommissioning of submarine cables follow a structured lifecycle.

This section examines these key phases of a cable's lifecycle and provides a comprehensive assessment of the potential impact on biodiversity associated with submarine cables, emphasizing industry best practices, mitigation measures, and regulatory guidance to ensure sustainable cable deployment and management.

- The **Pre-Installation Phase** focuses on route planning, environmental assessments, and surveying, ensuring that cables are strategically placed to minimize ecological impacts and avoid sensitive marine habitats. The initial stages of this phase tend to have minimal/temporary impact upon coastal and marine biodiversity, with pressures predominantly linked to some survey techniques.
- The **Installation Phase** involves cable laying and burial techniques, which may temporarily disturb the seabed and generate additional localized impacts from noise and pollution, particularly in shallow waters. The impact of this stage on coastal and marine biodiversity is primarily determined by whether a cable requires burial for protection or is surface laid (laid on the seafloor directly).
- The **Operational Phase** explores how cables interact with their environment over their approximately 25-year lifespan, including potential ecological interactions such as marine species colonization ("reef effect") and risks related to abrasion and entanglement. Whilst the potential impact of this stage is low, operational cables, and the surrounding biodiversity, are not generally monitored.
- Finally, the **Decommissioning Phase** considers the environmental trade-offs between leaving cables in place versus active removal, assessing how each option affects seafloor ecosystems and resource recovery efforts. The pressures and impacts arising from cable removal are similar to those of the installation phase, namely, physical damage, noise and pollution.

Each of these phases is discussed in detail below.

### Pre-installation of cables

*The pre-installation phase includes planning, route surveying, and preparation for cable installation. This stage is critical for identifying the most efficient, secure, and environmentally responsible cable routes.*

### Desktop Studies

Once cable landing sites (where cables connect to onshore telecoms systems) are identified, a desktop study is conducted to determine the most efficient and secure routes for the cables. Desktop studies are guided by ICPC's "Recommendation No. 9 Minimum Technical Requirements for a Desktop Study" and consider a range of factors that may vary based on local and national regulations. Information collected from the desktop survey includes:

## Discussion

- Relevant permitting and policy requirements
- The environmental, ecological, economic and cultural importance of locations along the route, principally obtained from published data
- The presence of other sectors (e.g., fisheries, renewable energy, shipping, other coastal infrastructure) along the route
- The presence of marine faunal and flora communities (including listed/threatened species and habitats) on or within close proximity to the route, principally obtained through ecological surveys from published maps

## Field Surveys

The desktop survey will provide an optimal route design that can then be surveyed in the field to fully characterize the route and avoid hazards or environmentally significant zones (Carter *et al.* 2009). Field surveys include consideration of:

- The seabed depth and the presence of any hazards and/or objects along a proposed route corridor. This is predominately obtained using vessel-based geophysical and geotechnical surveys.
- The physical properties and stability of the sediment along the route (Carter *et al.* 2009). This is obtained through geotechnical testing of the seabed, including sediment coring and/or cone penetration tests (CPTs).

Surveys are typically 500 m to 1 km in width and occur down to ~1,500 m or the determined water depth limit on where the cable will be buried into the sediment (Carter *et al.* 2009). Surveys are also carried out in water depths deeper than ~1,500m which corresponds to areas where a cable will be laid on the surface of the seabed. They should follow the precautionary approach and are guided by ICPC's "Recommendation 18 Minimum Technical Requirement for the Acquisition and Reporting of Submarine Cable Route Surveys" (2020).

## Final Route Selection and Seafloor Preparation

Final route selection is based on a balance of environmental considerations, technical feasibility, cost, and interactions with other marine sectors, while ensuring compliance with local and national legislation.



**Figure 6.** A grapnel array used to clear the seabed of debris and out of service cables. Source: courtesy of ICPC

## Discussion

Once a route is determined, a pre-lay grapnel run might be used to prepare the seafloor for installation. Where out of service cables cross the path of a new route, the old cable is removed or buried. Debris on the seabed is removed using a grapnel array as needed (see Figure 6); this is not required when cables are to be laid on the surface. Grapnels can create disturbances up to 1 meter wide, several kilometers long, and up to 1.5 meters deep (Sinclair *et al.* 2023). These disturbances have the potential to alter environmental conditions by causing sediments to enter the water column which can directly impact habitats and species. For sensitive habitats like coral reefs and seagrasses, this may lead to damage, although the impacts are highly variable and dependent on local ecology. For example, an environmental impact assessment (EIA) in Kenya of the use of grapnels to remove obstructive debris (which penetrated the seabed to 0.8 meters) concluded it would only have minor and highly localized impacts on the seabed (Environtech Consultancy Africa Ltd 2021).

The routing of cables should follow the hierarchy of avoid, reduce and mitigate (ICPC 2023b). Surveys and desktop studies are widely used to avoid or mitigate impacts upon sensitive species and habitats, particularly on hard bottom or reef habitats. Findings from the spatial analysis indicate that cable length overlapping with biogenic habitats (particularly sensitive coastal habitats) is minimal compared to the global footprint of biogenic habitats (e.g., <1% of cold-water corals overlap with cables) (Table 4).

**Table 7.** Intensity and likelihood of potential pressures related to the pre-installation phase.

Theme	Pressure	Intensity of potential pressure relevant to this lifecycle phase		Likelihood of potential pressure	
		Shallow	Deep	Shallow	Deep
Physical damage	Habitat structure changes	High	Moderate	1	1
	Penetration and/or disturbance of the substrate below or on the surface of the seabed, including abrasion	High	Moderate	3	2
	Turbidity	High	Moderate	3	2
Physical Other physical pressures	Noise and disturbance changes	Moderate	Moderate	1	1
	Death or injury by collision/vessel strike of marine megafauna	Moderate	Moderate	1	1
Pollution and other chemical changes	Releasing pollutants	Moderate	Moderate	1	1

Cell colors represent the intensity of the **potential pressure** resulting from the pre-installation phase


 High
  Moderate
  Low

Cell numbers represent the **likelihood** of the pressure occurring (3 = High; 2 = Moderate; 1 = Low, 0 = No pressure found).

## Discussion

Area-based management tools have higher proportions of overlap relative to individual habitats. A higher percentage of global cable length overlaps with areas of biodiversity importance and management tools. Many area-based management tools are found in shallower waters, where the highest density and the majority of cables are located (Sinclair *et al.* 2023). Protected areas are also large in size sometimes encompassing multiple ecosystem types. Spatial analysis of cable routing suggests evidence of cables being routed around and avoiding specific habitats (Table 4), potentially indicating efforts in the industry for avoidance as a first means of mitigation.

...The routing of cables generally follows the hierarchy of avoid, reduce and mitigate...

If a habitat cannot be avoided, micro-routing, a more precise form of routing used to route around individual features in an ecosystem, can be used to further minimize impacts. Examples include the use of geographical surveys to route cables in Scotland in order to avoid sensitive features within the 500 m survey corridor, including micro-routing through a rocky shore in a protected area (British Telecommunications Plc 2021). In another case in Bermuda, a benthic survey was undertaken, and the decision was made to weave the cable through a reef habitat.

To better understand the potential environmental pressures that can be identified in the pre-installation phase, Table 7 summarizes the intensity and likelihood of potential pressures across different depths. The table provides a comparative view of how pre-installation activities may generate pressures in both shallow (<1,500m) and deep (>1,500m) waters.

### Cable installation

*This phase involves the use of specialized vessels to lay and, where necessary, bury cables along the seabed to establish connections between landing points onshore.*

The installation of submarine cables involves specialized vessels that deploy including where necessary burying cables along the seabed to establish connections between landing points onshore. The process varies depending on water depth, seabed conditions, and environmental considerations, with different techniques used in shallow and deep waters.

#### Shallow Water Installation Process

In shallower waters, where cables are more vulnerable to external damage from natural processes or human activities, they are often buried beneath the seabed to protect them.

When landing a submarine cable – known as a shore end - typically, the cable is first pulled ashore from a cable ship using floats (Figure 7). Once positioned, it is fed through a sea plough, which lowers it to the seabed and simultaneously buries it by trenching the seafloor.

In environmentally sensitive coastal areas, horizontal directional drilling can be used instead, allowing the cable to be installed beneath the intertidal zone without disturbing the seabed surface (Sinclair *et al.* 2023).

## Discussion



Figure 7. Direct shore end installation. Source: courtesy of ICPC

Table 8. Intensity and likelihood of potential pressures related to the installation phase

Theme	Pressure	Intensity of potential pressure relevant to this lifecycle phase		Likelihood of potential pressure	
		Shallow	Deep	Shallow	Deep
Physical damage	Habitat structure changes	High	Moderate	2	1
	Penetration and/or disturbance of the substrate below or on the surface of the seabed, including abrasion	High	Moderate	3	1
	Turbidity	Moderate	Low	3	1
Physical Other physical pressures	Noise and disturbance changes	Moderate	Moderate	1	1
	Death or injury by collision/vessel strike of marine megafauna	Low	Low	1	1
Pollution and other chemical changes	Releasing pollutants	Low	Low	1	1

Cell colors represent the intensity of the **potential pressure** resulting from the installation phase

High
  Moderate
  Low

Cell numbers represent the **likelihood** of the pressure occurring (3 = High; 2 = Moderate; 1 = Low, 0 = No pressure found).

## Discussion

New cables will be laid either on new routes and to locations that have previously not been connected (for which conditions may be less well known), or close to existing routes (for which environmental conditions are often well understood) (ICPC 2023a). Both options may present challenges. For example, in the latter situation baseline conditions may have changed since the previous cables were laid.

### Deep Water Installation Process

Since human activities such as fishing and anchoring are less frequent at deeper depths, the primary concern is ensuring that the cable follows the designated marine survey route while maintaining the appropriate amount of slack. The cable is released from the ship and lowered to the seafloor, where it naturally settles into depressions or along the seabed contours. An onboard engineer adjusts both the cable tension and ship speed to ensure proper placement. Unlike shallow waters, where the cable is actively buried, deep-sea installation focuses on precise routing and stability, often in areas with uneven or rocky seabed conditions (Carter *et al.* 2009).

### Cable Installation Techniques and Burial Methods

Installation methods chosen depend on site-specific environmental and operational considerations.

- **Simultaneous Lay and Burial:** One of the most common methods for shallow-water installation, SLB involves a sea plough that simultaneously creates a trench (typically 0.5–2 m below the seafloor) while the cable is laid inside (Figure 8). Excavated sediment naturally falls back, covering the cable (Sinclair *et al.* 2023).
- **Post-Lay Burial (Jetting):** Where cables are first laid on the seabed and later buried, high-pressure water jets are used to fluidize the sediment around the cable, allowing it to sink into place. However, dispersion distances depend on the sediment type and the environmental conditions. For example, clay sediments tend to disperse further whilst sandy sediments tend to fall very close to the trench (Sinclair *et al.* 2023). The jetting technique can extend to 3 m below the seafloor and usually results in a trench less than a meter wide, dispersing sediments by 5 m on average (Carter *et al.* 2009) (Kogan *et al.* 2023) (Kraus and Carter 2018). The jetting technique is only used in specific conditions, such as the presence of a granular sandy seabed or steep slopes (Carter *et al.* 2009). In areas of hard seabed where the cable cannot be buried, the plough is recovered, and the armoured cable is surface laid directly on the seabed (Carter *et al.* 2009).
- **Surface Laying in Hard Seabed:** In areas with rocky or hard substrates where burial is not possible, cables can be laid directly on the seabed. To prevent damage, these cables are typically armored for additional protection (Carter *et al.* 2009).

Where cables require burial in shallower waters, the disturbance of seafloor sediments during cable installation can result in pressures from increased sediment, organic matter and microorganisms in the water column. However, impact is likely to be local and short-term.

Increased turbidity can have a wide range of impacts upon species, including impact on their vision, feeding and respiration (Lunt and Smeed 2020). Turbidity can also “smother” habitats and reduce light levels and primary productivity, impacting a range of habitats

## Discussion



**Figure 8.** Cable ship with plough for cable installation. Source: Global Marine Group

including seagrasses and coral reefs (Agion 2010; Kennish 2001). However, impacts from cable burial are often localized and short-lived. Kraus and Carter (2018) determined that the recovery time from physical disturbance from cable burial ranged, on average, from 1-5 years. Recovery time is dependent on multiple factors, including geography and geomorphic characteristics (e.g., habitat type, grain size, etc.) of the seabed. For example, in areas with active waves, currents and an adequate supply of sediment, recovery generally takes less than one year (Kraus and Carter 2018). Reduced waves and currents may result in recovery within 2 years, and can extend to up to 5 years if sediment supply is low (Kraus and Carter 2018).

Disturbing the seafloor can also release pre-existing accumulated pollution and chemicals from seafloor sediments into the water. During the process of burying cables micro quantities of heavy metals (e.g. lead and nickel) or other pollutants may be disturbed. Although this is highly unlikely in situations where environmental surveys and desktop studies are performed in the pre-installation phase to identify and avoid such hotspots (Mart et al. 1982). While the scale and likelihood of these pressures are small, the wider implications for the ecosystem are either poorly known or minimal. It should be noted that these potential impacts do not relate to cables laid in deeper waters (>1,500 m).

The ships and machinery used to lay cables have the potential to produce a variety of pollution including noise, but these impacts are likely to be minimal. Pollution from these vessels is not specific to the cable industry, but a potential pressure from all shipping activity in the marine realm. Whilst the cables themselves don't make noise, the excavators used to install cables onshore can be noisy (British Telecommunications Plc 2021). Noise from submarine cable surveys and installation activities are typically short-lived, high frequency and directional (Kuşku *et al.* 2018). Case studies on noise from

## Discussion

power cables during installation identified sound levels from 100 to 188.5 dB, however, the lack of standardized measurement methodologies lead to considerable uncertainty about noise impacts (Sinclair *et al.* 2023). There is evidence that vessel noise has the potential to impact the behavior, feeding and navigation of a number of species, including whales (Stone *et al.* 2017).

Sewage and persistent organic pollutants released by vessels during cable installation also have the potential to impact coastal and marine biodiversity. However, there is no recorded evidence of these being significant pollution-causing activities from the cable industry, with pollution largely controlled by regulations, such as under the United Nations Convention on the Law of the Sea (Sinclair *et al.* 2023).

The impact on deepwater habitats and species from physical disturbance are highly localized and minor due to the small diameter of cables (17-21 mm). This conclusion is supported by a range of evidence from observational studies. For example, the MARS hybrid power/telecoms cable, deployed on the shore end via horizontal directional drilling off the coast of California, was inspected post-installation and found negligible effect on seabed morphology from the cable. Additionally, there was no statistical difference in the abundance and distribution benthic fauna within 0-100 m of the cable pre and post-installation (Kuhnz *et al.* 2015).

Similarly, Kogan *et al.* (2006) found minimal effects of the surface-laid ATOC cable in northern California on organisms close to the cable (Kogan *et al.* 2006). Impacts upon the seafloor following the installation of high voltage power cables in the Bass Strait, Australia, disappeared 2 years after installation, whilst no significant changes in the benthic diversity and biomass was found 1 year after installing a power cable in the Baltic Sea (Andrzejewicz *et al.* 2003) (Sherwood *et al.* 2016). Power cables generate different types and magnitudes of impact than telecommunication cables. However, power cables are used as evidence here because they do exert some of the same pressures on the environment as telecoms cables, although at higher magnitudes given their larger size relative to telecoms cables. While observational studies are a good starting point for analysis, there is limited research exploring the short- and long-term impacts of cable installation on deep sea species, habitats and ecosystems (Table 14).

### Cable operation

*The typical life of a submarine cable is around 25 years. Cables can be in-situ for their full lifetime without any intervention unless they are damaged, for example, through fishing, anchoring or natural hazards (Kraus and Carter 2018).*

Repairs involve cutting the broken part of the cable with a grapnel and retrieving it from the water (Figure 9). Subsequently, in shallow waters, a new section of cable is connected and laid on the same route and reburied by jet-equipped ROVs (Carter *et al.* 2009). Cable repair is infrequent as cables are designed in ways to avoid and reduce damage, typically buried where feasible, and armored in shallower and coastal waters. In the case of reburial, pressures and impacts from the "Installation" section would apply. It is estimated that there are approximately 200 cable repairs per year world-wide; the large majority in shallow water (Palmer-Felgate 2024).

## Discussion



**Figure 9.** Damaged cable armor. Source: European Subsea Cables Association

### **Pressures and potential impacts from cable operation**

Overall, in-situ cables typically have negligible impact on coastal and marine biodiversity. However, there are some potential pressures and impacts associated with the operational phase when cables are in-situ in the ocean. These potential pressures and resulting impacts are rare, but still relevant to address.

Cables have the potential to create a “reef effect”, a term used to describe large infrastructure in the ocean being colonized by marine fauna (Sinclair *et al.* 2023). A study of a telecoms cable near the pioneer seamount in California found that numbers of cnidarians (e.g., jellyfish and anemones), echinoderms (e.g., sea stars), crustaceans (e.g., crabs) and worms were significantly higher along the cable than in control transects (Kogan *et al.* 2003). The species that had colonized the cable were already native to the area, and therefore did not pose a risk to the ecosystem (Kogan *et al.* 2006). Another study in Washington State found no significant change in abundance of bottom-dwelling species post-installation of a cable (Kogan *et al.* 2003) suggesting the in-situ cable did not have impacts on the local species. While there are minimal observational studies of the presence of the reef effect on telecoms cables (with most studies done on power cables), current evidence from power cables and wind turbines show that non-native invasive species occur more frequently in the upper part of the water column compared to deeper, subtidal areas (Sinclair *et al.* 2023).

## Discussion

**Table 9.** Summary of pressures relevant to operational phase (with repair activity).

Theme	Pressure	Intensity of potential pressure relevant to this lifecycle phase		Likelihood of potential pressure	
		Shallow	Deep	Shallow	Deep
Physical damage	Habitat structure changes	High	Moderate	1	1
	Penetration and/or disturbance of the substrate below or on the surface of the seabed, including abrasion	High	Moderate	1	1
	Turbidity	Moderate	Moderate	1	1
Physical Other physical pressures	Noise and disturbance changes	Moderate	Moderate	1	1
	Death or injury by collision/vessel strike of marine megafauna	Low	Low	1	1
Pollution and other chemical changes	Releasing pollutants	Moderate	Moderate	1	1

**Table 10.** Summary of pressures relevant to operational phase (with no repair activity).

Theme	Pressure	Intensity of potential pressure relevant to this lifecycle phase		Likelihood of potential pressure	
		Shallow	Deep	Shallow	Deep
Physical damage	Habitat structure changes	Low	Low	1	1
	Penetration and/or disturbance of the substrate below or on the surface of the seabed, including abrasion	Low	Low	1	1
	Turbidity	0	0	0	0
Physical Other physical pressures	Noise and disturbance changes	0	0	0	0
	Death or injury by collision/vessel strike of marine megafauna	0	0	0	0
Pollution and other chemical changes	Releasing pollutants	Moderate	Moderate	1	1

Cell colors represent the intensity of the **potential pressure** resulting from the pre-installation phase

 High
  Moderate
  Low

Cell numbers represent the **likelihood** of the pressure occurring (3 = High; 2 = Moderate; 1 = Low, 0 = No pressure found).

## Discussion

Abrasion from movement and vibration is a much less common pressure due to modern installation and slack management techniques. Abrasion to the seafloor or habitats occurs when a cable is suspended, deployed under tension and moves or causes vibrations (Kogan *et al.* 2003). As abrasion is also a cause of failure to the cable, the installer and owner is motivated to correct the issue quickly. The pressure is rare and more commonly found in coaxial cables, not modern day fibre-optic cables (Kogan *et al.* 2003).

Deepwater lightweight cables are designed with chemically inert materials, are rarely damaged when recovered, and have a low likelihood of creating potential pressures in the operational phase (Carter *et al.* 2019). A 2019 laboratory study found that cables can release low levels of zinc (<11 parts per million) when damaged. Laboratory studies demonstrated that zinc concentrations peaked after 2.5-6 months and then began to decline. While there are no studies of in-situ zinc pollution from cables, the addition of zinc to the marine environment would cause significant dilution from currents, further minimizing the risk of impacts. While the potential impact is likely to be negligible, zinc has the potential to impact the growth of microalgal species, impair physiological processes (Dinesh Kumar *et al.* 2014) and, where it accumulates in the sediment, it can impact filter feeding organisms (Yung *et al.* 2014).

Older telegraph cable systems historically posed an entanglement risk to marine biota. However, improvements in cable design and laying mean that there have been no records of whale entanglement since 1959 (Wood and Carter 2008). A 2005 study by the National Oceanic and Atmospheric Administration in the USA, found that several species of seals and sea lions were commonly documented to forage at depths where they might encounter cables crossing the Pacific Ocean (i.e., >100 m) (Bernthal 2005). Whilst it is possible that any species capable of diving to the depth of cables could become entangled in derelict gear (Bernthal 2005) this is unlikely to occur or result in long-term harm to the species.

### Decommissioning and recovering cables

At the end of a cable's lifecycle, it is either left in place or removed from the seabed and water. Where cables are left in place there have been no recorded occurrences of additional impacts. Where cables are to be removed a cable recovery plan is drafted following ICPC Recommendations and mitigation measures are put in place for the removal process. Cable removal involves the use of cable ships or specialist cable recovery vessels deploying cutting and holding grapnels which recover and remove the cable. Grapnels penetrate between 0.5-1.0 m into the seabed with surface plates that are ~50 cm wide (Carter *et al.* 2009). Chains are used to hold the cables and are approximately 20 cm wide (ABPmer 2020).

Once brought onshore, cables are either mechanically processed to separate out materials such as copper, polyethylene plastic and steel which can then be recycled, or transferred to another location where it can be re-laid (Carter *et al.* 2014).

## Discussion

**Table 11.** Summary of pressures relevant to decommissioning and recovery phase.

Theme	Pressure	Intensity of potential pressure relevant to this lifecycle phase		Likelihood of potential pressure	
		Shallow	Deep	Shallow	Deep
Physical damage	Habitat structure changes	High	Moderate	2	1
	Penetration and/or disturbance of the substrate below or on the surface of the seabed, including abrasion	High	Moderate	2	1
	Turbidity	Moderate	Low	2	1
Physical Other physical pressures	Noise and disturbance changes	Low	Low	1	1
	Death or injury by collision/vessel strike of marine megafauna	Low	Low	1	1
Pollution and other chemical changes	Releasing pollutants	Low	Low	1	1

Cell colors represent the intensity of the **potential pressure** resulting from the decommissioning and recovery phase

 High
  Moderate
  Low

Cell numbers represent the **likelihood** of the pressure occurring (3 = High; 2 = Moderate; 1 = Low, 0 = No pressure found).

### Pressures and potential impacts of decommissioning and recovery

Cable recovery is considered on a case-by-case basis, largely due to variances in regional regulation on recovery and cost decisions. Following the move from coaxial and telegraph to fibre-optic cables the majority of out-of-service cables are left in-situ. Currently there are hundreds of thousands km of decommissioned, redundant cables in the sea. The recovery industry is currently growing as several companies explore economic opportunities and models related to cable recovery.

The recovery of cables impacts species and habitats but clears space for the installation of new cables in the same place. Leaving decommissioned cables in place could reduce impacts upon coastal and marine biodiversity (Environtech Consultancy Africa Ltd 2021). Impacts to the seabed from submarine cable removal is similar to the installation phase. As mentioned in the “Recommendations” section, the report recommends a comprehensive cost-benefit analysis for decisions around choosing decommissioning versus recovery. Recovery of redundant cables can maximize the usable space available to new systems, freeing up previously disturbed seafloor and avoiding disturbance in undisturbed areas.

## Discussion

Most of the materials from recovered cables are recycled and re-introduced into the global supply chain. Plastic and steel from the original cable can be reused for a new cable, while fibres can be recycled to create glass (Carter *et al.* 2014). Fibres are not able to be reused in the cables themselves, however, can be used in other products, such as windowpanes. The creation of a circular economy in the cable industry has the potential to reduce the extraction of new resources from the natural environment and reduce carbon emissions. For example, sections of two analogue cables were reused to form a 27km cable system between the USA and Cuba (Beckman *et al.* 2014), whilst a section of the 1287 km Gemini-Bermuda fibre-optic cable system was created by cutting an out-of-service cable recovered from the continental shelf of the USA (Beckman *et al.* 2014).

### Potential opportunities relating to cables

There are a number of opportunities for the cable industry to make positive contributions towards global biodiversity conservation and sustainable management, a number of these are outlined below:

#### **Monitoring environmental conditions and the abundance and distribution of coastal and marine biodiversity**

Cables can be used to increase our understanding of how and where marine biodiversity is changing which is vital to support evidence-based management interventions to address the triple planetary crisis of biodiversity loss, climate change and pollution. Despite significant advancements in ocean monitoring technology, vast areas of the ocean remain either partially monitored or completely unmonitored. This is largely due to the immense size of the ocean and the associated costs and technological challenges. Therefore, there is a demand to find complementary ways to gather information to increase our understanding of the ocean and support its effective conservation and management.

The global network of submarine cables offers an opportunity to enhance ocean observation, and in future could offer opportunities for scientific monitoring in the deep ocean (greater than 2000 meters), where our knowledge is severely limited (Levin *et al.* 2019). Sensing technologies, which can detect environmental variables such as seismic activity, temperature, pressure, and noise, could help fill existing gaps by creating a vast network of ocean based environmental and ecological monitoring. For example, sensing technologies have been employed for

- **Monitoring Ocean Currents and Storms:** Cable-based sensors have been used to track ocean currents and detect extreme weather events in both shallow and deep water (Marra *et al.* 2022).
- **Tracking Marine Biodiversity:** Fibre-optic sensing has detected the mating and feeding calls of Fin, Baleen, and Blue whales, offering a new tool for non-invasive monitoring of marine megafauna (Landrø *et al.* 2022).
- **Earthquake and Tsunami Early Warning Systems:** Cable sensing can identify the location and magnitude of earthquakes and volcanic eruptions, helping to provide early warnings for tsunamis (Zhan *et al.* 2021; Marra *et al.* 2022).

## Discussion

- **Cable Health Monitoring:** Sensing technologies can also monitor the integrity of cables, reducing the need for repairs and minimizing disturbances to the seafloor (Landrø *et al.* 2022).

Several different approaches exist for integrating sensing capabilities into submarine cables, ranging from modifications to existing infrastructure to the deployment of new multi-purpose cables:

- **Fibre-Optic Sensing:** Uses existing telecommunications fibres to detect environmental variables such as temperature, pressure, and vibrations. This method can be applied to pre-existing cables without requiring structural modification (Clare 2024).
- **Scientific Monitoring and Reliable Telecommunications (SMART) Cables:** Requires the deployment of new, bespoke cables equipped with sensors, designed specifically for real-time environmental monitoring alongside telecommunications functions (Clare 2024).

Sensing systems can determine a variety of environmental changes depending on the technology used, and can include vibrations, pressure and temperature changes. For more information on different cable sensing technologies, please see Appendix C.

## Regulatory Considerations

The use of certain cable sensing technologies could raise material legal and regulatory concerns. For example, cable sensing—to be undertaken purely for scientific purposes—could result in regulation of submarine cables as marine scientific research (Friedman 2017; Bressie 2012).

### **Submarine cables offer potential opportunities for the protection and restoration of coastal and marine biodiversity.**

Cable protection zones are areas where anthropogenic activities that might negatively impact a cable such as anchoring or trawling are prohibited, potentially supporting the conservation and recovery of biodiversity. They have been an effective measure to reduce cable damage in areas of the world such as Australia, and principles of combining submarine cables and nature restoration could be explored further. There is an opportunity to integrate cable protection zones into marine spatial planning as “other effective area-based conservation measures”, or areas that are achieving the long term and effective in-situ conservation of biodiversity outside of protected areas (Coffen-Smout and Herbert 2000). However, the evidence base of cable protection zones resulting in increased biodiversity is severely limited and more research is required (Shears and Usmar 2006).

# References



## References

- ABPmer. (2020). *BT Technology Decommissioning of Subsea Telecommunication Cables in UK Waters Guidance on Environmental Impacts*.
- Agion, T. (2010). *Environment and Social Impact Assessment Study (ESIAs) Seychelles*.
- Andrulewicz, E., Napierska, D., & Otremba, Z. (2003). The environmental effects of the installation and functioning of the submarine SwePol Link HVDC transmission line: a case study of the Polish Marine Area of the Baltic Sea. *Journal of Sea Research*, 49, 337–345. [https://doi.org/10.1016/S1385-1101\(03\)00020-0](https://doi.org/10.1016/S1385-1101(03)00020-0)
- Beckman, R. L., Burnett, D. R., & Davenport, T. M. (2014). Out-of-Service Submarine Cables. In *Submarine Cables: The handbook of law and policy* (pp. 213–224). Martinus Nijhoff.
- Bernthal, C. (2005). *Analysis of Remediation Alternatives for the Pacific Crossing-1 North and East Submarine Fiber Optic Cables in the Olympic Coast National Marine Sanctuary*.
- Bressie, K. (2012). *Using submarine cables for climate monitoring and disaster warning - Opportunities and legal challenges*.
- British Telecommunications Plc. (2021). *R100 Scottish Isles Fibre-optic Project*.
- Burnett, D. R., & Carter, L. (2017). International Submarine Cables and Biodiversity of Areas Beyond National Jurisdiction: The Cloud Beneath the Sea. *The Law of the Sea*, 1(2), 1–72. [https://doi.org/10.1163/9789004351608\\_002](https://doi.org/10.1163/9789004351608_002)
- Burnett, D. R., & Carter, L. (2019). International Submarine Cables and Biodiversity of Areas Beyond National Jurisdiction. In *International Submarine Cables and Biodiversity of Areas Beyond National Jurisdiction* (pp. 1–72). BRILL. [https://doi.org/10.1163/9789004351608\\_002](https://doi.org/10.1163/9789004351608_002)
- Carter, L., Burnett, D., & Davenport, T. (2014). The relationship between submarine cables and the marine environment. In *Submarine Cables* (pp. 179–212). [http://www.geoscience.scar.org/geophysics/acoustics\\_1\\_2.pdf](http://www.geoscience.scar.org/geophysics/acoustics_1_2.pdf)
- Carter, L., Burnett, D., Drew, S., Marle, G., Hagadorn, L., Bartlett-McNeil, D., & Irvine, N. (2009). *Submarine cables and the oceans: connecting the world*.
- Carter, L., Collins, K., Creese, C., & Waterworth, G. (2019). Chemical and physical stability of submarine fibre-optic cables in the area beyond national jurisdiction (ABNJ). *SubOptic 2019*, 1–6.
- Clare, M. (2021). *Submarine Cable Protection and the Environment: An Update from the ICPC*. March, 27.
- Coffen-Smout, S., & Herbert, G. J. (2000). Submarine cables: a challenge for ocean management. *Marine Policy*, 24, 441–448. <http://www.iscpc.org>
- Dinesh Kumar, S., Santhanam, P., Selvaraju, A., & PROFILE Shenbaga Devi, S. A. (2014). Effect of different dosages of zinc on the growth and biomass in five marine microalgae. *International Journal of Fisheries and Aquaculture*, 6(1), 1–8. <https://doi.org/10.5897/IJFA2013.0393>
- Environmental and Social Impacts Assessment Study Report for the Proposed Installation of Peace Submarine Fibre Optic Cable in Kenya Territorial Waters Up To the Kenya Beach Manhole in Nyali, Mombasa County*. (2021). [https://www.nema.go.ke/images/Docs/EIA\\_1850-1859/ESIA\\_1855\\_TELKOM PEACE SUBMARINE CABLE\\_SR 2211-min.pdf](https://www.nema.go.ke/images/Docs/EIA_1850-1859/ESIA_1855_TELKOM PEACE SUBMARINE CABLE_SR 2211-min.pdf)
- Friedman, A. (2017). Submarine Telecommunication Cables and a Biodiversity Agreement in ABNJ: Finding New Routes for Cooperation. *The International Journal of Marine and Coastal Law*, 32, 1–35.
- Ge, Y., Chen, J., Zhang, P., Cao, C., Le, X., Ai, J., Zhou, P., & Liang, T. (2022). A novel technique for seabed strata deformation in situ monitoring. *Frontiers in Marine Science*, 9(September), 1–16. <https://doi.org/10.3389/fmars.2022.987319>
- ICPC. (2008). *Minimum Technical Requirements for a Desktop Study (also known as Cable Route Study)*. <http://www.iscpc.org>
- ICPC. (2023a). *ICPC Recommended Routing and Coordinating Criteria for Submarine Telecommunications Cables in Proximity to Other Such Cables*. <http://www.iscpc.org>
- ICPC. (2023b). *ICPC Recommended Routing and Coordinating Criteria for Submarine Telecommunications Cables in Proximity to Other Such Cables*. <http://www.iscpc.org>
- IPBES. (2019). *Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Service*. [www.ipbes.net](http://www.ipbes.net)
- Kennish, M. J. (2001). Coastal Salt Marsh Systems in the U.S.: A Review of Anthropogenic Impacts. *Journal of Coastal Research*, 17(3), 731–748.
- Kogan, I., Paull, C. K., Kuhn, L. A., Burton, E. J., Von Thun, S., Gary Greene, H., & Barry, J. P. (2006). ATOC/Pioneer Seamount cable after 8 years on the seafloor: Observations, environmental impact. *Continental Shelf Research*, 26, 771–787. <https://doi.org/10.1016/j.csr.2006.01.010>
- Kogan, I., Paull, C. K., Kuhn, L., Burton, E. J., Von Thurn, S., Greene, H. G., & Barry, J. P. (2003). *Environmental Impact of the ATOC/Pioneer Seamount Submarine Cable*. <https://www.researchgate.net/publication/268295233>

## References

- Kraus, C., & Carter, L. (2018). Seabed recovery following protective burial of subsea cables- Observations from the continental margin. *Ocean Engineering*, 157, 251–261. <https://doi.org/10.1016/j.oceaneng.2018.03.037>
- Kuhnz, L. A., Buck, K., Lovera, C., Whaling, P. J., & Barry, J. P. (2015). *Potential impacts of the Monterey Accelerated Research System (MARS) cable on the seabed and benthic faunal assemblages*. <https://www.mbari.org/wp-content/uploads/2016/02/MBARI-Potential-impacts-of-the-Monterey-Accelerated-Research-System-2015.pdf>
- Kuşku, H., Yiğit, M., Ergün, S., Yiğit, Ü., & Taylor, N. (2018). Acoustic Noise Pollution from Marine Industrial Activities: Exposure and Impacts. *Aquatic Research*, 1(4), 148–161. <https://doi.org/10.3153/AR18017>
- Levin, L. A., Bett, B. J., Gates, A. R., Heimbach, P., Howe, B. M., Janssen, F., McCurdy, A., Ruhl, H. A., Snelgrove, P., Stocks, K. I., Bailey, D., Baumann-Pickering, S., Beaverson, C., Benfield, M. C., Booth, D. J., Carreiro-Silva, M., Colaço, A., Eblé, M. C., Fowler, A. M., ... Weller, R. A. (2019). Global observing needs in the deep ocean. *Frontiers in Marine Science*, 6(May), 1–32. <https://doi.org/10.3389/fmars.2019.00241>
- Lunt, J., & Smee, D. L. (2020). Turbidity alters estuarine biodiversity and species composition. *ICES Journal of Marine Science*, 77(1), 379–387. <https://doi.org/10.1093/icesjms/fsz214>
- Mart, L., Rutzel, H., Klahre, P., Sipos, L., Platzek, U., Valenta, P., & Nurnberg, H. W. (1982). COMPARATIVE STUDIES ON THE DISTRIBUTION OF HEAVY METALS IN THE OCEANS AND COASTAL WATERS. In *The Science of the Total Environment* (Vol. 26).
- Pawar, P. R. (2016). Anthropogenic threats to coastal and marine biodiversity: A review. *IJMBR*, 4, 35–45. [www.fao.org/biodiversity](http://www.fao.org/biodiversity)
- Shears, N. T., & Usmar, N. R. (2006). *The role of the Hauraki Gulf Cable Protection Zone in protecting exploited fish species: de facto marine reserve?* [www.doc.govt.nz](http://www.doc.govt.nz)
- Sherwood, J., Chidgey, S., Crockett, P., Gwyther, D., Ho, P., Stewart, S., Strong, D., Whitely, B., & Williams, A. (2016). Installation and operational effects of a HVDC submarine cable in a continental shelf setting: Bass Strait, Australia. *Journal of Ocean Engineering and Science*, 1, 337–353. <https://doi.org/10.1016/j.joes.2016.10.001>
- Sinclair, D., Drews, A., & Wrottesley, J. (2023). *Environmental Impacts of Human Activities Subsea Cables within the OSPAR Maritime Area: Background document on technical considerations and potential environmental impacts*.
- Sinclair, D., Drews, A., Wrottesley, J., Dr Clare, M., Dr Mevenkamp, L., Judd, A., Wopschall, R., Tripp, H., & Ward, J. (2023). *Subsea Cables within the OSPAR Maritime Area: Background document on technical considerations and potential environmental impacts*.
- Stone, C. J., Hall, K., Mendes, S., & Tasker, M. L. (2017). The effects of seismic operations in UK waters: analysis of Marine Mammal Observer data. *Journal of Cetacean Research and Management*, 16, 71–85.
- Submarine Telecoms Forum. (2023). *2023-2024 Industry Report* (Issue 12).
- Taormina, B., Bald, J., Want, A., Thouzeau, G., Lejart, M., Desroy, N., & Carlier, A. (2018). A review of potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations and future directions. *Renewable and Sustainable Energy Reviews*, 96, 380–391. <https://doi.org/10.1016/j.rser.2018.07.026>
- TBC. (2015). *A cross-sector guide for implementing the Mitigation Hierarchy Prepared by The Biodiversity Consultancy*. [www.thebiodiversityconsultancy.com](http://www.thebiodiversityconsultancy.com)
- TeleGeography. (n.d.). *Submarine Cable Frequently Asked Questions*.
- Turner, P., Thaler, A., Freitag, A. and Colman Collins, P. (2019). Deep-sea hydrothermal vent ecosystem principles: Identification of ecosystem processes, services and communication of value. *Marine Policy*, 101, 118-124.
- United Nations Convention on the Law of the Sea, 10 December 1982
- Wood, M. P., & Carter, L. (2008). Whale entanglements with submarine telecommunication cables. *IEEE Journal of Oceanic Engineering*, 33(4), 445–449. <https://doi.org/10.1109/JOE.2008.2001638>
- Yung, M., Mouneyrac, C., Mei, K., & Leung, Y. (2014). Ecotoxicity of Zinc Oxide Nanoparticles in the Marine Environment. *Encyclopedia of Nanotechnology*, 1–17. [https://doi.org/10.1007/978-94-007-6178-0\\_100970-1](https://doi.org/10.1007/978-94-007-6178-0_100970-1)

# Appendixes



## Appendix A (methodology)

### Literature analysis

#### *Assessing and quantifying potential pressures and impacts across the cable lifecycle.*

Assessing and quantifying potential pressures and impacts across the cable lifecycle.

First, the strength of the pressures generated from each phase were categorized as “high”, “moderate”, “low”, “no impact found”, or “no studies found”. The strengths of pressures were determined in shallow waters (0-1,500m), where submarine cables are commonly buried due to exposure to other human activities, and deep waters (>1,500m), where cables are typically surface laid. The scores assigned are relative to other activities within the cable lifecycle phase, not to other blue economy sectors.

The strength of the pressures for each stage of the cable lifecycle were scored (a score of 3 was given for a high impact, 2 for a moderate impact, 1 for a small impact and 0 where no impact was found) and an average calculated across all pressures in a life cycle stage (Table 5). As each cable lifecycle phase can influence 7 potential pressures, the maximum influence of a cable lifecycle phase is 21 (7 x 3). To reflect the likelihood of a pressure occurring, a weighting (based on the evidence base obtained) was used, with a score of 3 given for a high likelihood, 2 for a moderate likelihood, 1 for a small likelihood and 0 where no likelihood / studies found (Table 12).

Next, the strength of the impact of each pressure on each ecological component (species, habitat, ecosystem functioning) was scored (a score of 3 was given for a high impact, 2 for a moderate impact, 1 for a small impact and 0 where no impact was found) and an average calculated across all pressures on each ecological component (e.g., a score of 1 for pollution’s (pressure) impact on species (ecological component)). As each pressure can influence 3 components of marine biodiversity, the maximum influence of a pressure is 21 (7 x 3).

Finally, the overall potential impact of each submarine cable phase on marine biodiversity was determined by combining the strength of impact between each cable lifecycle phase and pressure and the strength of impact between each pressure and marine biodiversity component. The potential impact score is derived numerically by multiplying the impact of each cable lifecycle phase on each pressure (rated 1-3) with the impact of each pressure on each marine biodiversity component (rated 1-3). For example, if the cable lifecycle phase has a low rating (1) for causing pollution and chemical changes, and pollution and chemical changes have a high rating (3) for impacting marine species, the potential impact score for cable installation on marine species will be moderate (2).

**Table 12.** Likelihood of pressures. How likely a pressure is to occur in a given cable lifecycle phase as evidenced through expert opinion or scientific literature.

Likelihood	Definition
High	The pressure is commonly witnessed in one of the cable lifecycle phases.
Moderate	The pressure is witnessed in some cases, but not the majority, in one of the cable lifecycle phases.
Low	The pressure is rarely/not likely to be witnessed in one of the cable lifecycle phases.

## Appendix A (methodology)

**Table 13.** Potential pressures stemming from each phase of the cable lifecycle in shallow and deep waters

		Water Depth	Pressures							
			Physical damage - extracti	Physical damage - disturbi	Turbidity (water clarity)	Noise	Death or injury by collision	Pollution		
Ecological component	Species	Shallow	3	2	2	3	0**	3		
		Deep	2	2	1	3	0**	2		
	Habitat	Shallow	2	2	1	0**	0**	2		
		Deep	2	2	1	0**	0**	1		
	Ecosystem functioning	Shallow	1	1	2	0**	0**	1		
		Deep	1	1	1	0**	0**	1		

Cell colors represent the intensity of the **potential pressure** resulting from each cable phase  High Moderate Low

Cell numbers represent the **likelihood** of the pressure occurring (3 = High; 2 = Moderate; 1 = Low, 0\* = No pressure found, 0\*\* = No evidence).

**Table 14.** Strength of evidence of each phase of the cable lifecycle resulting impacts on species, habitats and ecosystem function in shallow and deep waters

		Water Depth	Species	Habitats	Ecosystem Functioning
Deep					
Installation	Shallow				
	Deep				
Operational	Shallow			0**	
	Deep			0**	
Decommissioning	Shallow			0**	
	Deep			0**	

Cell colors and reciprocal numbers represent the strength of the underpinning **evidence base**

 High Moderate Low

## Appendix A (methodology)

As the maximum intensity of a pressure from any cable lifecycle phase is 3, and the maximum impact of a pressure on a marine biodiversity component is 3, and there are 7 pressures, the maximum cumulative impact of a single cable lifecycle phase on a marine biodiversity component is  $(3 \times 3) \times 7 = 63$ .

### Spatial analysis

A spatial analysis was undertaken to determine the global extent of cables and quantify the degree to which they spatially overlap, and hence potentially impact, coastal and marine biodiversity.

The analysis was conducted on a global scale, within Exclusive Economic Zones (0-200 nm from the baseline) and Areas Beyond National Jurisdiction. In the analysis, the extended continental shelf between 200 nm and 350 nm from the baseline is considered ABNJ. The degree of spatial overlap with coastal and marine biodiversity was estimated utilizing maps of ecosystem distribution (e.g., mangroves, seagrasses, coral reefs, salt marshes, seamounts, hydrothermal vents, abyssal plains, ridges, canyons, etc.) and areas of importance for conservation, including, vulnerable marine environments, marine protected areas, ecologically and biologically significant areas and areas of particular environmental interest. Two cable datasets were used: a “mitigated” dataset provided by Ocean IQ, where the routes are routed around ecological features and a “non-mitigated” dataset provided by TeleGeography where the cables are mapped in a straight line from one landing station to another. The seafloor is assumed to be planar.

Data was accessed from the following networks, organizations and web-portals:

- FAO data portal
- Regional Fisheries Management Organizations
- International Seabed Authority
- CBD Ecologically or Biologically Significant Marine Areas website
- Ocean Data Viewer
- GEBCO Gridded Bathymetry Data
- NOAA Data Portal
- World Bank Data Catalogue
- The World Database on Protected Areas (WDPA)
- The Maritime Boundaries Geodatabase of the Flanders Marine Institute

For each cable dataset and within each governance boundary (Exclusive Economic Zones and Areas Beyond National Jurisdiction), the report quantified the footprint of cables that physically intersect with coastal and marine biodiversity, in terms of:

- i. The length of cable (expressed in kilometers) intersecting coastal and marine biodiversity

## Appendix A (methodology)

- ii. The proportion of cable (expressed as the percentage of cable length relative to the total cable length within a given governance boundary) intersecting coastal and marine biodiversity
- iii. The density of cable (expressed as the cable length per square kilometers of the intersected marine feature) intersecting coastal and marine biodiversity

In addition, the ability to mitigate exposure of cables on coastal and marine biodiversity was determined by calculating the percentage difference in the footprint (length, proportion and density) of mitigated and not mitigated cable routes as follows:

$$\Delta Footprint_{\%} = \frac{Footprint_{mitigated} - Footprint_{not\ mitigated}}{Footprint_{not\ mitigated}} \times 100$$

Where,  $\Delta Footprint_{\%}$  is the estimated change in the footprint relative to the scenario with no mitigation measures. Negative values indicate a lower footprint, and positive values indicate a higher footprint.

## Appendix B (results)

**Table 15.** Summary statistics of change in the footprint between cable routes datasets.

Environment type	Name	Cable length (km)			% length change		
		ABNJ	EEZ	Global	ABNJ	EEZ	Global
Area-based management tool	APEI	0.00	0.00	0.00	-100		-100
Area of biodiversity importance	EBSAs	183,686	301,531	485,213	1	8	5
Area-based management tool	MPAs	17,859	96,112	113,971	31	0	4
Area-based management tool	VMEs	11,043	885	11,927	53	47	53
Biogenic habitat	Cold Water Corals	0.00	3.7	3.7	-100	-88	-89
Biogenic habitat	Coral Reefs	0.00	444	444		-78	-78
Biogenic habitat	Mangroves	0.00	17	17		-97	-97
Biogenic habitat	Saltmarshes	0.00	19.0	19.0		-91	-91
Biogenic habitat	Seagrasses	0	5,561	5,561		9	9
Biogenic habitat	Seamounts	3,220.4	6,292	9,513	-70	-66	-68

Footprint of cables within area-based management tools, areas of biodiversity importance and biogenic habitats at a global scale), within the Exclusive Economic Zones of countries and within Areas Beyond National Jurisdiction. % length change indicates the relative difference in footprint comparing mitigated (OceanIQ) and non-mitigated (TeleGeography) routes. A red cell indicates an increase in footprint, while a green cell indicates a decrease in footprint relative to the non-mitigated length.

**Table 16.** Summary statistics of submarine telecommunication cables across world oceans.

Region	Area (km <sup>2</sup> )	Cable length (km)	Cable proportion (%) <sup>1</sup>	Cable density (km/km <sup>2</sup> )
Arctic Ocean	5,141,822	284	0.02	<0.01
Indian Ocean	57,937,857	85,872	4.8	<0.01
North Atlantic Ocean	34,322,186	317,986	17.9	0.01
North Pacific Ocean	64,733,141	295,444	16.6	<0.01
South Atlantic Ocean	40,302,582	105,839	5.9	<0.01
South Pacific Ocean	76,258,970	78,665	4.4	<0.01
Southern Ocean	21,744,443	0	0.0	0.0
<b>All regions</b>	<b>300,441,001</b>	<b>884,090</b>	<b>49.6*</b>	<b>&lt;0.01</b>

\* Remaining cable length distributed across world seas (Table 17)

<sup>1</sup> Proportion relative to the total length of cable which is approximately 1,781,123 km.

## Appendix B (results)

**Table 17.** Summary statistics of submarine telecommunication cables across world seas

Region	Area (km <sup>2</sup> )	Cable length (km)	Cable proportion (%) <sup>1</sup>	Cable density (km/km <sup>2</sup> )
Adriatic Sea	139,069	2,853	0.2	0.02
Aegean Sea	190,563	8,113	0.5	0.04
Alboran Sea	54,475	2,402	0.1	0.04
Andaman or Burma Sea	607,960	8,073	0.5	0.01
Arabian Sea	4,206,837	67,273	3.8	0.02
Arafura Sea	1,017,086	2,184	0.1	<0.01
Baffin Bay	531,784	0	0.0	<0.01
Balearic (Iberian Sea)	79,808	1,535	0.1	0.02
Bali Sea	39,571	895	0.1	0.02
Baltic Sea	215,952	6,684	0.4	0.03
Banda Sea	687,749	5,035	0.3	0.01
Barents Sea	1,413,333	5,037	0.3	<0.01
Bass Strait	112,303	1,898	0.1	0.02
Bay of Bengal	2,189,549	18,011	1.0	0.01
Bay of Biscay	174,058	2,327	0.1	0.01
Bay of Fundy	15,998	42	0.0	<0.01
Beaufort Sea	432,511	294	0.0	<0.01
Bering Sea	2,272,448	2,214	0.1	<0.01
Bismarck Sea	341,997	3,126	0.2	0.01
Black Sea	421,909	4,598	0.3	0.01
Bristol Channel	5,744	520	0.0	0.09
Caribbean Sea	2,830,101	54,708	3.1	0.02
Celebes Sea	453,296	3,359	0.2	0.01
Celtic Sea	214,831	11,775	0.7	0.05
Ceram Sea	160,056	1,741	0.1	0.01
Chukchi Sea	347,227	1,628	0.1	<0.01
Coral Sea	4,094,414	18,588	1.0	<0.01

## Appendix B (results)

Region	Area (km <sup>2</sup> )	Cable length (km)	Cable proportion (%) <sup>1</sup>	Cable density (km/km <sup>2</sup> )
Davis Strait	751,202	1,761	0.1	<0.01
East Siberian Sea	635,157	0	0.0	0
Eastern China Sea	756,983	36,597	2.1	0.05
English Channel	81,330	3,270	0.2	0.04
Flores Sea	101,924	1,438	0.1	0.01
Great Australian Bight	1,320,714	3,439	0.2	<0.01
Greenland Sea	1,190,503	2,375	0.1	<0.01
Gulf of Aden	261,569	16,028	0.9	0.06
Gulf of Alaska	415,786	5,885	0.3	0.01
Gulf of Aqaba	3,535	557	0.0	0.2
Gulf of Boni	32,943	0	0.0	0
Gulf of Bothnia	113,603	786	0.0	0.01
Gulf of California	179,587	444	0.0	<0.01
Gulf of Finland	57,147	1,923	0.1	0.03
Gulf of Guinea	748,155	22,379	1.3	0.03
Gulf of Mexico	1,556,534	4,920	0.3	<0.01
Gulf of Oman	111,152	11,385	0.6	0.1
Gulf of Riga	18,706	0	0.0	0
Gulf of St. Lawrence	290,453	1,732	0.1	0.01
Gulf of Suez	10,377	3,769	0.2	0.4
Gulf of Thailand	295,388	7,309	0.4	0.02
Gulf of Tomini	56,234	0	0.0	0
Halmahera Sea	74,624	843	0.0	0.01
Hudson Bay	833,400	1,568	0.1	<0.01
Hudson Strait	200,335	346	0.0	<0.01
Inner Seas off the West Coast of Scotland	44,276	1,274	0.1	0.03
Ionian Sea	171,118	4,263	0.2	0.02

## Appendix B (results)

Region	Area (km <sup>2</sup> )	Cable length (km)	Cable proportion (%) <sup>1</sup>	Cable density (km/km <sup>2</sup> )
Irish Sea and St. George's Channel	45,909	2,451	0.1	0.05
Japan Sea	1,062,813	16,975	1.0	0.02
Java Sea	561,706	15,103	0.8	0.07
Kara Sea	900,141	316	0.0	<0.01
Kattegat	35,460	691	0.0	0.02
Labrador Sea	866,641	1,402	0.1	<0.01
Laccadive Sea	839,010	19,954	1.1	0.02
Laptev Sea	515,518	0	0.0	0
Ligurian Sea	16,906	1,465	0.1	0.09
Lincoln Sea	35,413	0	0.0	0
Makassar Strait	196,358	3,001	0.2	0.02
Malacca Strait	193,813	14,302	0.8	0.07
Mediterranean Sea - Eastern Basin	1,168,103	54,850	3.1	0.05
Mediterranean Sea - Western Basin	475,014	22,765	1.3	0.05
Molukka Sea	219,698	2,145	0.1	0.01
Mozambique Channel	1,383,956	10,874	0.6	0.01
North Sea	524,684	15,961	0.9	0.03
Norwegian Sea	1,440,786	5,447	0.3	<0.01
Persian Gulf	243,142	15,394	0.9	0.06
Philippine Sea	5,600,200	103,119	5.8	0.02
Red Sea	446,540	36,148	2.0	0.08
Rio de La Plata	31,654	32	0.0	<0.01
Savu Sea	105,326	2,475	0.1	0.02
Sea of Azov	39,470	0	0.0	0
Sea of Marmara	11,637	1,527	0.1	0.1
Sea of Okhotsk	1,612,613	2,647	0.1	<0.01
Seto Naikai or Inland Sea	18,045	202	0.0	0.01

## Appendix B (results)

Region	Area (km <sup>2</sup> )	Cable length (km)	Cable proportion (%) <sup>1</sup>	Cable density (km/km <sup>2</sup> )
Singapore Strait	2,660	2,098	0.1	0.8
Skagerrak	32,064	697	0.0	0.02
Solomon Sea	737,935	3,715	0.2	0.01
South China Sea	3,335,343	103,225	5.8	0.03
Strait of Gibraltar	1,657	368	0.0	0.2
Sulu Sea	334,131	3,118	0.2	0.01
Tasman Sea	3,332,883	18,559	1.0	0.01
The Coastal Waters of Southeast Alaska and British Columbia	124,489	5,033	0.3	0.04
The Northwestern Passages	1,065,529	0	0.0	0
Timor Sea	430,538	1,369	0.1	<0.01
Tyrrhenian Sea	216,733	9,460	0.5	0.04
White Sea	90,738	1,086	0.1	0.01
Yellow Sea	406,506	2,953	0.2	0.01
<b>All regions</b>	<b>62,265,126</b>	<b>870,130</b>	<b>48.9</b>	<b>0.01</b>

<sup>1</sup> Proportion relative to the total length of cable which is approximately 1,781,123 km.

## Appendix C (cable sensing info)

Submarine telecommunication cables, originally designed to carry data across oceans, can also be used for environmental sensing. By repurposing these cables, scientists can gather information about ocean conditions such as sound, temperature, pressure, and seismic activity. Technologies like DAS, DTS, and pressure sensing turn these cables into long-range, real-time monitoring systems that provide valuable data on oceanic and seismic activity. These innovations not only help in maintaining cable integrity but also contribute to global efforts in studying and protecting marine environments. The primary methods for sensing environmental conditions using submarine cables are outlined in Table 18.

**Table 18.** Applications of the different cable sensing techniques covered in this issue and SMART Cables. Taken from ICPC's Submarine Cable Protection and the Environment Issue #8 on Using cables to monitor the ocean.

Technology	Marine vessels	Anchors	Fishing	Seismic waves/ Earthquakes	Volcanic activity	Storms	Temperature	Temperature change	Salinity	Wave height (single wave)	Wave height (average value)	Ocean currents	Marine mammals	Subsurface imaging
	Useful for cable protection			Useful for scientific monitoring/observation										
Optical Interferometry	N	?	?	Y	Y	Y	N	N	N	?	?	Y	N	N
State of Polarisation	N	?	?	Y	Y	Y	N	N	N	?	?	Y	N	N
Distributed Acoustic Sensing	Y	Y	Y	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y
SMART Cables	Y	N	N	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N

Notes: 1) Earthquake-induced tsunamis are triggered by large vertical seafloor displacements, and most sensing modalities do not generally distinguish between horizontal and vertical axes (the exceptions being SMART cables and dedicated seafloor observatories).

## Appendix D (list of all reviewed literature)

- Agion, T. (2010). *Environment and Social Impact Assessment Study (ESIAS) Seychelles*.
- Albert, L., Deschamps, F., Elie Jolivet, A., Ed Eric Olivier, F., Chauvaud, L., & Chauvaud, S. (2020). A current synthesis on the effects of electric and magnetic fields emitted by submarine power cables on invertebrates. *Marine Environmental Research*, 159. <https://doi.org/10.1016/j.marenvres.2020.104958>
- Alice Leonard de Juvigny, T. M. D. , D. R. B. , and D. F. (2015). Submarine Telecommunication Cables in the Sargasso Sea. *International Journal of Marine and Coastal Law*, 30, 371–378.
- Andrulowicz, E., Napierska, D., & Otremba, Z. (2003). The environmental effects of the installation and functioning of the submarine SwePol Link HVDC transmission line: a case study of the Polish Marine Area of the Baltic Sea. *Journal of Sea Research*, 49, 337–345. [https://doi.org/10.1016/S1385-1101\(03\)00020-0](https://doi.org/10.1016/S1385-1101(03)00020-0)
- Antrim, L., Balthis, L., & Cooksey, C. (2018). *SUBMARINE CABLES IN OLYMPIC COAST NATIONAL MARINE SANCTUARY: HISTORY, IMPACT, AND MANAGEMENT LESSONS*. <http://www.sanctuaries.noaa.gov>
- Arellano Rodríguez, V. (2021). Submarine Cables and the Marine Environment: Bringing the First Submarine Cable to the Galapagos. *Ocean Development and International Law*, 52(3), 274–296. <https://doi.org/10.1080/00908320.2021.1959095>
- Austin, S., Wyllie-Echeverria, S., & Groom, M. J. (2004). A Comparative Analysis of Submarine Cable Installation Methods in Northern Puget Sound, Washington. *Journal of Marine Environmental Engineering*, 7, 173–184.
- Bald, J. et al. (2015) 'Acoustic characterization of submarine cable installation in the Biscay Marine Energy Platform (bimep)', *Bilbao Marine Energy Week, Bilbao, 20-24 April 2015*, (December). Available at: <https://tethys.pnnl.gov/publications/acoustic-characterization-submarine-cable-installation-biscay-marine-energy-platform>.
- Barnes, C. R., Meldrum, D., & Ota, H. (2016). Emerging subsea networks: new market opportunities for, and societal contributions from, SMART cable systems. *SubOptic*. <https://www.researchgate.net/publication/334749361>
- Beckman, R., Bressie, K., & Ong, J. (2024a). *LAW OF THE SEA AND SUBMARINE CABLES 2024 ICPC-CIL WORKSHOP REPORT*.
- Beckman, R. L., Burnett, D. R., & Davenport, T. M. (2014). Out-of-Service Submarine Cables. In *Submarine Cables: The handbook of law and policy* (pp. 213–224). Martinus Nijhoff.
- Bernthal, C. (2005). *Analysis of Remediation Alternatives for the Pacific Crossing-1 North and East Submarine Fiber Optic Cables in the Olympic Coast National Marine Sanctuary*.
- Bolam, S. G. (2011). Burial survival of benthic macrofauna following deposition of simulated dredged material. *Environmental Monitoring and Assessment*, 181(1–4), 13–27. <https://doi.org/10.1007/s10661-010-1809-5>
- Bressie, K., Creese, C., Coca, D., Connelly, M., & Stanshine, J. (2016). *Final Report - Clustering of Cables and Cable Landings*.
- British Telecommunications Plc. (2021). *R100 Scottish Isles Fibre-optic Project*.
- Burnett, D. R., & Carter, L. (2017). International Submarine Cables and Biodiversity of Areas Beyond National Jurisdiction: The Cloud Beneath the Sea. *The Law of the Sea*, 1(2), 1–72. [https://doi.org/10.1163/9789004351608\\_002](https://doi.org/10.1163/9789004351608_002)
- Carrasco De La Cruz, P. M. (2021). The Knowledge Status of Coastal and Marine Ecosystem Services - Challenges, Limitations and Lessons Learned From the Application of the Ecosystem Services Approach in Management. *Frontiers in Marine Science*, 8. <https://doi.org/10.3389/fmars.2021.684770>
- Carter, L. (2018, September 27). *ICPC Webinar: Cables and the marine environment - from ocean to cloud*. <https://www.iscpc.org/publications/webinar/>
- Carter, L., Burnett, D., & Davenport, T. (2014). The relationship between submarine cables and the marine environment. In *Submarine Cables* (pp. 179–212). [http://www.geoscience.scar.org/geophysics/acoustics\\_1\\_2.pdf](http://www.geoscience.scar.org/geophysics/acoustics_1_2.pdf)
- Carter, L., Burnett, D., Drew, S., Marle, G., Hagadorn, L., Bartlett-McNeil, D., & Irvine, N. (2009). *Submarine cables and the oceans: connecting the world*.
- Carter, L., Collins, K., Creese, C., & Waterworth, G. (2019). Chemical and physical stability of submarine fibre-optic cables in the area beyond national jurisdiction (ABNJ). *SubOptic 2019*, 1–6.
- Carter, L., Gavey, R., Talling, P. J., & Liu, J. T. (2014). Insights into submarine geohazards from breaks in subsea telecommunication cables. *Oceanography*, 27(2), 58–67. <https://doi.org/10.5670/oceanog.2014.40>
- Carter, L., Milliman, J. D., Talling, P. J., Gavey, R., & Wynn, R. B. (2012). Near-synchronous and delayed initiation of long run-out submarine sediment flows from a record-breaking river flood, offshore Taiwan. *Geophysical Research Letters*, 39(12), 1–5. <https://doi.org/10.1029/2012GL051172>

## Appendix D (list of all reviewed literature)

- Causey, B. D. (2005). Moving beyond paper parks: Improving compliance and enforcement: Measuring and improving marine protected area effectiveness. *California and the World Ocean - Proceedings of the Conference*, 697–703. [https://doi.org/10.1061/40761\(175\)63](https://doi.org/10.1061/40761(175)63)
- Clare, M. (2023). *Submarine Cable Protection and the Environment*. [www.iscpc.org](http://www.iscpc.org)
- Clare, M. A., Lichtschlag, A., Paradis, S., & Barlow, N. L. M. (2023). Assessing the impact of the global subsea telecommunications network on sedimentary organic carbon stocks. *Nature Communications*, 14. <https://doi.org/10.1038/s41467-023-37854-6>
- Clare, M. A., Yeo, I. A., Bricheno, L., Aksenov, Y., Brown, J., Haigh, I. D., Wahl, T., Hunt, J., Sams, C., Chaytor, J., Bett, B. J., & Carter, L. (2023). Climate change hotspots and implications for the global subsea telecommunications network. *Earth-Science Reviews*, 237. <https://doi.org/10.1016/j.earscirev.2022.104296>
- Clare, M. A., Yeo, I. A., Watson, S., Wysoczanski, R., Seabrook, S., Mackay, K., & Hunt, J. E. (2023). Fast and destructive density currents created by ocean-entering volcanic eruptions. *Science*, 381, 1085–1092. <https://doi.org/10.1126/science.adi3038>
- Coffen-Smout, S., & Herbert, G. J. (2000). Submarine cables: a challenge for ocean management. *Marine Policy*, 24, 441–448. <http://www.iscpc.org/>
- Davenport, T. (2012). Submarine communications cables and law of the sea: Problems in law and practice. *Ocean Development and International Law*, 43(3), 201–242. <https://doi.org/10.1080/00908320.2012.698922>
- Dinesh Kumar, S., Santhanam, P., Selvaraju, A., & PROFILE Shenbaga Devi, S. A. (2014). Effect of different dosages of zinc on the growth and biomass in five marine microalgae. *International Journal of Fisheries and Aquaculture*, 6(1), 1–8. <https://doi.org/10.5897/IJFA2013.0393>
- Dunham, A., Pegg, J. R., Carolsfeld, W., Davies, S., Murfitt, I., & Boutillier, J. (2015). Effects of submarine power transmission cables on a glass sponge reef and associated megafaunal community. *Marine Environmental Research*, 107, 50–60. <https://doi.org/10.1016/j.marenvres.2015.04.003>
- Duran, R., & Cravo-Laureau, C. (2016). Role of environmental factors and microorganisms in determining the fate of polycyclic aromatic hydrocarbons in the marine environment. *FEMS Microbiology Reviews*, 31, 814–830. <https://doi.org/10.1093/femsre/fuw031>
- Eassom, A., Chiba, S., Fletcher, R., Scrimgeour, R., & Fletcher, S. (2016). *Horizon scan of pressures on Biodiversity Beyond National Jurisdiction*. [www.unep-wcmc.org](http://www.unep-wcmc.org)
- Ekwere, K. (2016). Submarine Cables and the Marine Environment: Enhancing Sustainable and Harmonious Interactions. *China Oceans Law Review*, 1, 154–186. [http://www.unep-wcmc.org/resources/publications/UNEP\\_WCMC\\_bio\\_series/31.aspx](http://www.unep-wcmc.org/resources/publications/UNEP_WCMC_bio_series/31.aspx)
- Environmental and Social Impacts Assessment Study Report for the Proposed Installation of Peace Submarine Fibre Optic Cable in Kenya Territorial Waters Up To the Kenya Beach Manhole in Nyali, Mombasa County* (2021). Available at: [https://www.nema.go.ke/images/Docs/EIA\\_1850-1859/ESIA\\_1855\\_TELKOM\\_PEACE\\_SUBMARINE\\_CABLE\\_SR\\_2211-min.pdf](https://www.nema.go.ke/images/Docs/EIA_1850-1859/ESIA_1855_TELKOM_PEACE_SUBMARINE_CABLE_SR_2211-min.pdf) (Accessed: 20 December 2023).
- Friedman, A. (2017). Submarine Telecommunication Cables and a Biodiversity Agreement in ABNJ: Finding New Routes for Cooperation. *The International Journal of Marine and Coastal Law*, 32, 1–35.
- Gavey, R., Carter, L., Liu, J. T., Talling, P. J., Hsu, R., Pope, E., & Evans, G. (2017). Frequent sediment density flows during 2006 to 2015, triggered by competing seismic and weather events: Observations from subsea cable breaks off southern Taiwan. *Marine Geology*, 384, 147–158. <https://doi.org/10.1016/j.margeo.2016.06.001>
- Guo, Y., Marin, J. M., Ashry, I., Trichili, A., Havlik, M. N., Ng, T. K., Duarte, C. M., & Ooi, B. S. (2023). Submarine optical fiber communication provides an unrealized deep-sea observation network. *Scientific Reports*, 13(1). <https://doi.org/10.1038/s41598-023-42748-0>
- Hammar, L., Molander, S., Pålsson, J., Schmidtbauer Crona, J., Carneiro, G., Johansson, T., Hume, D., Kågesten, G., Mattsson, D., Törnqvist, O., Zillén, L., Mattsson, M., Bergström, U., Perry, D., Caldwell, C., & Andersen, J. H. (2020). Cumulative impact assessment for ecosystem-based marine spatial planning. *Science of the Total Environment*, 734. <https://doi.org/10.1016/j.scitotenv.2020.139024>
- Howe, B. M., Angove, M., Aucan, J., Barnes, C. R., Barros, J. S., Bayliff, N., Becker, N. C., Carrilho, F., Fouch, M. J., Fry, B., Jamelot, A., Janiszewski, H., Kong, L. S. L., Lentz, S., Luther, D. S., Marinaro, G., Matias, L. M., Rowe, C. A., Sakya, A. E., ... Wilcock, W. (2022). SMART Subsea Cables for Observing the Earth and Ocean, Mitigating Environmental Hazards, and Supporting the Blue Economy. *Frontiers in Earth Science*, 9. <https://doi.org/10.3389/feart.2021.775544>
- ICPC. (2023). *Best Practices Version 1.2 GOVERNMENT BEST PRACTICES FOR PROTECTING AND PROMOTING RESILIENCE OF SUBMARINE TELECOMMUNICATIONS CABLES*. <http://www.iscpc.org>
- ICPC. (2008a). *Minimum Technical Requirements for a Desktop Study (also known as Cable Route Study)*. <http://www.iscpc.org>

## Appendix D (list of all reviewed literature)

- ICPC. (2020). *Management of Decommissioned and Out-of-Service Cables*. <http://www.iscpc.org>
- ICPC. (2023). *ICPC Recommended Routing and Coordinating Criteria for Submarine Telecommunications Cables in Proximity to Other Such Cables*. <http://www.iscpc.org>
- Judson Kenworthy, W., Fonseca, M. S., & Whitfield, P. E. (2002). Analysis of Seagrass Recovery in Experimental Excavations and Propeller-Scar Disturbances in the Florida Keys National Marine Sanctuary. *IMPACTS OF MOTORIZED WATERCRAFT ON SHALLOW ESTUARINE AND COASTAL MARINE ENVIRONMENTS*, 37, 75–85. <https://about.jstor.org/terms>
- Kennish, M. J. (2001). Coastal Salt Marsh Systems in the U.S.: A Review of Anthropogenic Impacts. *Journal of Coastal Research*, 17(3), 731–748.
- Koboević, Ž., Mišković, D., Capor Hrošik, R., & Koboević, N. (2022). Analysis of sea pollution by sewage from vessels. *Sustainability (Switzerland)*, 14(1). <https://doi.org/10.3390/su14010263>
- Kogan, I., Paull, C. K., Kuhn, L. A., Burton, E. J., von Thun, S., Gary Greene, H., & Barry, J. P. (2006). ATOC/Pioneer Seamount cable after 8 years on the seafloor: Observations, environmental impact. *Continental Shelf Research*, 26, 771–787. <https://doi.org/10.1016/j.csr.2006.01.010>
- Kogan, I., Paull, C. K., Kuhn, L., Burton, E. J., von Thurn, S., Greene, H. G., & Barry, J. P. (2003). *Environmental Impact of the ATOC/Pioneer Seamount Submarine Cable*. <https://www.researchgate.net/publication/268295233>
- Kraus, C., & Carter, L. (2018). Seabed recovery following protective burial of subsea cables- Observations from the continental margin. *Ocean Engineering*, 157, 251–261. <https://doi.org/10.1016/j.oceaneng.2018.03.037>
- Kuhn, L. A., Barry, J. P., Buck, K., Lovera, C., & Whaling, P. J. (2011). *Potential impacts of the Monterey Accelerated Research System (MARS) cable on the seabed and benthic faunal assemblages*. [https://www.sanctuariesimon.org/regional\\_docs/monitoring\\_projects/100391\\_report2011.pdf](https://www.sanctuariesimon.org/regional_docs/monitoring_projects/100391_report2011.pdf)
- Kuhn, L. A., Buck, K., Lovera, C., Litvin, S., Whaling, P. J., & Barry, J. P. (2020). *Potential impacts of the Monterey Accelerated Research System (MARS) cable on the seabed and benthic faunal assemblages*. [https://www.mbari.org/wp-content/uploads/2020/11/MBARI-Potential-Impacts-of-the-Monterey-Accelerated-Research-System-2020\\_final.pdf](https://www.mbari.org/wp-content/uploads/2020/11/MBARI-Potential-Impacts-of-the-Monterey-Accelerated-Research-System-2020_final.pdf)
- Kuşku, H., Yiğit, M., Ergün, S., Yiğit, Ü., & Taylor, N. (2018). Acoustic Noise Pollution from Marine Industrial Activities: Exposure and Impacts. *Aquatic Research*, 1(4), 148–161. <https://doi.org/10.3153/AR18017>
- Landrø, M., Bouffaut, L., Kriesell, H. J., Potter, J. R., Rørstadbotnen, R. A., Taweestintanon, K., Johansen, S. E., Brenne, J. K., Haukanes, A., Schjelderup, O., & Storvik, F. (2022). Sensing whales, storms, ships and earthquakes using an Arctic fibre optic cable. *Scientific Reports*, 12(1). <https://doi.org/10.1038/s41598-022-23606-x>
- Lindsey, N. J., & Martin, E. R. (2021). *Fiber-Optic Seismology*. <https://doi.org/10.1146/10.1146/annurev-earth>
- Lunt, J., & Smee, D. L. (2020). Turbidity alters estuarine biodiversity and species composition. *ICES Journal of Marine Science*, 77(1), 379–387. <https://doi.org/10.1093/icesjms/fsz214>
- Marra, G., Fairweather, D. M., Kamalov, V., Gaynor, P., Cantono, M., Mulholland, S., Baptie, B., Castellanos, J. C., Vagenas, G., Gaudron, J. O., Kronjäger, J., Hill, I. R., Schioppo, M., Edreira, I. B., Burrows, K. A., Clivati, C., Calónico, D., & Curtis, A. (2022). Optical interferometry-based array of seafloor environmental sensors using a transoceanic submarine cable. *Science*, 376(6595), 874–879. <https://doi.org/10.1126/SCIENCE.ABO1939>
- Matias, L., Carrilho, F., Sá, V., Omira, R., Niehus, M., Corela, C., Barros, J., & Omar, Y. (2021). The Contribution of Submarine Optical Fiber Telecom Cables to the Monitoring of Earthquakes and Tsunamis in the NE Atlantic. *Frontiers in Earth Science*, 9. <https://doi.org/10.3389/feart.2021.686296>
- Meißner, K., Schabelon, H., Bellebaum, J., & Sordyl, H. (2006). *Impacts of submarine cables on the marine environment - A literature review*.
- Merck, T., & Wasserthal, R. (2009). *Assessment of the environmental impacts of cables*.
- Muhtadi, A., Waskito, D. H., & Prasetyo, D. F. (2023). Improving Safety of Marine Cable Survey Operation Through Safety Assessment using the Formal Safety Assessment Method (Case Study RV. Baruna Jaya). *IOP Conference Series: Earth and Environmental Science*, 1166(1). <https://doi.org/10.1088/1755-1315/1166/1/012031>
- Muneez, M., Vinesh, T., & Nai-Shyan, L. (2017). Protection of submarine optical fibre cables on the coral reefs of the Maldives. *Underwater Technology*, 34(4), 149–156. <https://doi.org/10.3723/ut.34.149>
- Petzold, K. (2019). *Sixth Power Project Caye Caulker Submarine Cable Environmental and Social Impact Assessment Final Report*.
- Poirier, W. D. (2009). *The effect of the installation of submarine cables on the growth of eelgrass in foreshore areas*.

## Appendix D (list of all reviewed literature)

- Pope, E. L., Talling, P. J., & Carter, L. (2017). Which earthquakes trigger damaging submarine mass movements: Insights from a global record of submarine cable breaks? *Marine Geology*, *348*, 131–146. <https://doi.org/10.1016/j.margeo.2016.01.009>
- Pope, E. L., Talling, P. J., Carter, L., Clare, M. A., & Hunt, J. E. (2017). Damaging sediment density flows triggered by tropical cyclones. *Earth and Planetary Science Letters*, *458*, 161–169. <https://doi.org/10.1016/j.epsl.2016.10.046>
- Ramirez-Llodra, E., Tyler, P. A., Baker, M. C., Bergstad, O. A., Clark, M. R., Escobar, E., Levin, L. A., Menot, L., Rowden, A. A., Smith, C. R., & van Dover, C. L. (2011). Man and the last great wilderness: Human impact on the deep sea. *PLoS ONE*, *6*(8). <https://doi.org/10.1371/journal.pone.0022588>
- Rhett, B., Cochran, E., Collins, J., Eble, M., Evans, J., Favali, P., Given, D., & Gledhill, K. (2023). *The scientific and societal case for the integration of environmental sensors into new submarine telecommunication cables*.
- Roman-Sierra, J., Navarro, M., Muñoz-Perez, J. J., & Gomez-Pina, G. (2011). Turbidity and Other Effects Resulting from Trafalgar Sandbank Dredging and Palmar Beach Nourishment. *Journal of Waterway, Port, Coastal, and Ocean Engineering*, *137*(6), 332–343. [https://doi.org/10.1061/\(asce\)ww.1943-5460.0000098](https://doi.org/10.1061/(asce)ww.1943-5460.0000098)
- Rousseau, C., Baraud, F., Leleyter, L., & Gil, O. (2009). Cathodic protection by zinc sacrificial anodes: Impact on marine sediment metallic contamination. *Journal of Hazardous Materials*, *167*, 953–958. <https://doi.org/10.1016/j.jhazmat.2009.01.083>
- Sampaolo, G., Lepore, D., & Spigarelli, F. (2021a). Blue economy and the quadruple helix model: the case of Qingdao. *Environment, Development and Sustainability*, *23*(11), 16803–16818. <https://doi.org/10.1007/s10668-021-01378-0>
- Sampaolo, G., Lepore, D., & Spigarelli, F. (2021b). Blue economy and the quadruple helix model: the case of Qingdao. *Environment, Development and Sustainability*, *23*(11), 16803–16818. <https://doi.org/10.1007/s10668-021-01378-0>
- Shears, N. T., & Usmar, N. R. (2006). *The role of the Hauraki Gulf Cable Protection Zone in protecting exploited fish species: de facto marine reserve?* [www.doc.govt.nz](http://www.doc.govt.nz)
- Sherwood, J., Chidgey, S., Crockett, P., Gwyther, D., Ho, P., Stewart, S., Strong, D., Whitely, B., & Williams, A. (2016). Installation and operational effects of a HVDC submarine cable in a continental shelf setting: Bass Strait, Australia. *Journal of Ocean Engineering and Science*, *1*, 337–353. <https://doi.org/10.1016/j.joes.2016.10.001>
- Sinclair, D., Drews, A., Wrottesley, J., Dr Clare, M., Dr Mevenkamp, L., Judd, A., Wopschall, R., Tripp, H., & Ward, J. (2023). *Subsea Cables within the OSPAR Maritime Area: Background document on technical considerations and potential environmental impacts*.
- Joint Nature Conservation Committee. *Standardised list of pressures in the marine environment*. (2011).
- Stone, C. J., Hall, K., Mendes, S., & Tasker, M. L. (2017). The effects of seismic operations in UK waters: analysis of Marine Mammal Observer data. *Journal of Cetacean Research and Management*, *16*, 71–85.
- ICPC. *Submarine Cables and BBNJ*. (2016).
- Talling, P. J., Baker, M. L., Pope, E. L., Ruffell, S. C., Jacinto, R. S., Heijnen, M. S., Hage, S., Simmons, S. M., Hasenhündl, M., Heerema, C. J., McGhee, C., Apprioual, R., Ferrant, A., Cartigny, M. J. B., Parsons, D. R., Clare, M. A., Tshimanga, R. M., Trigg, M. A., Cula, C. A., ... Hilton, R. J. (2022). Longest sediment flows yet measured show how major rivers connect efficiently to deep sea. *Nature Communications* *2022* *13*:1, *13*(1), 1–15. <https://doi.org/10.1038/s41467-022-31689-3>
- Taormina, B., Bald, J., Want, A., Thouzeau, G., Lejart, M., Desroy, N., & Carlier, A. (2018). A review of potential impacts of submarine power cables on the marine environment: Knowledge gaps, recommendations and future directions. *Renewable and Sustainable Energy Reviews*, *96*, 380–391. <https://doi.org/10.1016/j.rser.2018.07.026>
- Tonhá, M. S., Garnier, J., Araújo, D. F., Cunha, B. C. A., Machado, W., Dantas, E., Araújo, R., Kutter, V. T., Bonnet, M.-P., & Seyler, P. (2020). *Behavior of metallurgical zinc contamination in coastal environments: A survey of Zn from electroplating wastes and partitioning in sediments*. <https://doi.org/10.1016/j.scitotenv.2020.140610>
- Vasilescu, V.-F., & Dinu, D. (n.d.). *Installation of submarine cables and pipes in shallow waters and connecting them to the shore by the method of horizontal directional drilling*. <https://doi.org/10.1051/e3sconf/202128604007>
- Walker, K. (2014). *Tonga Cable Extension Project: Nuku'alofa, Ha'apai & Vava'u*. <https://documents1.worldbank.org/curated/en/292551468165259677/pdf/SFG2261-EA-P113184-Box396261B-PUBLIC-Discovered-5-26-2016.pdf>
- Wood, M. P., & Carter, L. (2008). Whale entanglements with submarine telecommunication cables. *IEEE Journal of Oceanic Engineering*, *33*(4), 445–449. <https://doi.org/10.1109/JOE.2008.2001638>

## Appendix D (list of all reviewed literature)

Yung, M., Mouneyrac, C., Mei, K., & Leung, Y. (2014). Ecotoxicity of Zinc Oxide Nanoparticles in the Marine Environment. *Encyclopedia of Nanotechnology*, 1–17. [https://doi.org/10.1007/978-94-007-6178-0\\_100970-1](https://doi.org/10.1007/978-94-007-6178-0_100970-1)

Zhan, Z., Cantono, M., Kamalov, V., Mecozzi, A., Müller, R., Yin, S., & Castellanos, J. C. (2021). Optical polarization-based seismic and water wave sensing on transoceanic cables. *Science*, 371(6532), 931–936. <https://doi.org/10.1126/SCIENCE.ABE6648>

Zhang, Z., & Yang, Y. (2015). *Numerical Study on Onset Condition of Scour Below Offshore Pipeline Under Reversing Tidal Flow*. 20.

Zoppini, A., Ademollo, N., Patrolecco, L., Langone, L., Lungarini, S., Dellisanti, W., & Amalfitano, S. (2018). *Distribution patterns of organic pollutants and microbial processes in marine sediments across a gradient of anthropogenic impact* \*. 242, 1860–1870. <https://doi.org/10.1016/j.envpol.2018.07.081>

