Horizon scan of pressures on Biodiversity Beyond National Jurisdiction

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Contents

Executive Summary

This horizon scan, reviews the historic trends, current status and future projections of three key pressures on biodiversity in areas beyond national jurisdiction. The three pressures are:

- Physical loss and damage to the seabed;
- Removal of biological resources; and
- Ocean acidification.

A number of activities contribute to each of these pressures, including bio-prospecting and marine scientific research, submarine cable laying, deep sea mining, energy facilities and fishing. The role of each of these activities in the generation of pressures on biodiversity beyond national jurisdiction is evaluated through a review of the peer-reviewed and grey literatures. The results show that some marine activities are not yet underway and therefore have no current implications (such as deep sea mining), but that they are predicted to generate implications in the future. In contrast, other marine activities are already underway in areas beyond national jurisdiction (such as fishing) and the impacts on the seabed and to biological resources are potentially significant. The differing temporal and spatial scales of the activities make them difficult to compare on a single assessment framework, however, it is clear that all of the activities and pressures are increasing in spatial footprint and intensity. Across all activities, regulators, industry bodies and individual companies are seeking to find ways to protect the marine environment while maintaining opportunities to exploit marine resources.

With respect to the proposed Implementing Agreement on the conservation and sustainable use of biodiversity in areas beyond national jurisdiction, it is clear that an Implementing Agreement that reflects the current use level of the areas beyond national jurisdiction would not accommodate the anticipated long-term change in use and pressure patterns. This horizon scan helps to identify those future changes that need to be accommodated in the Implementing Agreement.

تنفيذي ملخص

فيما المستقبلية والاحتمالات الراهن والوضع التاريخية التوجُّهات ،لآفاق استكشافال هذا يستعرض .الوطنية الولاية خارج الواقعة المناطق في البيولوجي التنوع لها يتعرض رئيسية ضغوط بثلاثة يتعلق هي الثلاثة الضغوط وهذه:

- البحر لقاع المادي والضرر الفقدان
- البيولوجية الموارد إزالة
- .المحيطات تحمُّض

ومدُّ العلمية البحرية والأبحاث البيولوجي التنقيب فيها بما الضغوط، هذه من كلٍ في أنشطة عدة تساهم هذه من كلٍ دور تقييم ويتم .والصيد الطاقة ومنشآت البحار أعماق في والتعدين البحر سطح تحت الأسلاك المنشورات مراجعة لاخلال من الوطنية الولاية نطاق خارج البيولوجي التنوع على الضغوط توليد في الأنشطة وبالتالي بعد، تبدأ لم البحرية الأنشطة بعض أن النتائج وتُبيِّن .الأقران لمراجعة الخاضعة وتلك الرسمية غير لها يكون أن المتوقع من أنه غير ،(البحار أعماق في التعدين مثل) الحاضر الوقت في تأثيرات لهات ليس الواقعة المناطق في بالفعل قائمة الأخرى البحرية الأنشطة بضع فإن بالمقابل، .المستقبل في تأثير والموارد البحر قاع من كلٍ على كبير تأثير لها يكون أن المحتمل ومن ،(الصيد مثل) الوطنية الولاية خارج اعتماداً بينها المقارنة الصعب من يجعل الأنشطة لهذه والمكانية الزمانية النطاقات اختلاف إن .البيولوجية والنطاق الشدة ناحية من بالازدياد آخذةٌ والضغوط الأنشطة كافة أن الجليِّ من أنه إلا واحد، تقييمي إطار على الوسائل لإيجاد الخاصة والشركات الصناعية والهيئات المنظّمين من كلٌ يسعى الأنشطة، كافة في و .المكاني .البحرية الموارد ثمارا ستفرص على الحفاظ مع البحرية البيئة بحماية الكفيلة

الولاية خارج الواقعة المناطق في البيولوجي التنوع حفظ حول المقترح التنفيذي بالاتفاق يتعلق وفيما الحالي المستوى على مبنياً أًتنفيذي أًاتفاق أن البديهي فمن مستدام، نحوٍ على واستخدامه الوطنية في الطويل المدى على عالمتوقّ رللتغيّ أًملائم كوني لن طنيةالو الولاية خارج الواقعة المناطق في للاستخدام التي المستقبلية التغيرات هذه تحديد في يساعد للآفاق الاستكشاف هذا إن .والضغوط الاستخدام أنماط .التنفيذي الاتفاق في استيعابها ينبغي

执行摘要

本天际线扫描评述了国家管辖范围以外区域的生物多样性所面临的三种主要压力的历史趋势、现状和未来预期。这三种压力是：

- **海床有形**损失和损坏；
- **生物**资源动用；
- **海洋酸化。**

包括生物勘探和海洋科学研究、海底电缆铺设、深海采矿、能源设施和渔业在内的多种活动都可导致以上压力。通过对同行评议及灰色文献进行评审，我们评估了以上每种活动如何对国家管辖范围以外的生物多样性产生压力。评估结果表明，虽然有些海上活动尚未进行，目前暂无影响（如深海采矿），但预计会在将来产生影响。相比之下，其他海上活动已经在国家管辖范围以外的区域进行（如渔业），并且可能对海床和生物资源产生相当巨大的影响。由于这些活动所处的时间和空间不一，因此很难在单一的评估框架中进行对比，但显然所有这些活动和压力的空间范围和强度都**在增加。在所有活**动当中，监管机构、行业组织和企业都在努力设法保护海洋环境，同时保留利用海洋资源的机会。

就有关保护和可持续利用国家管辖范围以外区域生物多样性的拟订实施协议而言，如果实施协议仅反映国家管辖范围以外区域的当前利用水平，显然就无法涵盖可预见的使用和压力模式的长期变化。本天际线扫描即可帮助确定在实施协议中需包括在内的此类预期变化。

Résumé exécutif

Cette analyse prospective examine les tendances historiques, l'état actuel et les projections futures de trois pressions clefs sur la biodiversité dans les zones situées au-delà des juridictions nationales. Les trois pressions sont :

- La perte physique et l'endommagement des fonds marins ;
- Le prélèvement des ressources biologiques ; et
- L'acidification des océans.

Un certain nombre d'activités contribuent à chacune de ces pressions, y compris la prospection biologique et la recherche scientifique marine, la pose de câbles sous-marins, l'exploitation minière en haute mer, les installations énergétiques et la pêche. Le rôle de chacune de ces activités dans la création de pressions sur la biodiversité au-delà des juridictions nationales est évalué à travers une revue de la littérature grise et évaluée par des pairs. Les résultats montrent que certaines activités maritimes n'ont pas encore commencé et n'ont donc pas de répercussions actuelles (telles que l'exploitation minière en haute mer), mais qu'elles devraient avoir des répercussions à l'avenir. En revanche, d'autres activités maritimes sont déjà en cours dans des zones situées au-delà des juridictions nationales (comme la pêche) et les impacts sur les fonds marins et les ressources biologiques sont potentiellement importants. Les différentes échelles temporelles et spatiales des activités les rendent difficiles à comparer sur la base d'un seul cadre d'évaluation, mais il est clair que toutes les activités et pressions augmentent en termes d'empreinte spatiale et d'intensité. Dans toutes les activités, les régulateurs, les industries et les entreprises cherchent à trouver des moyens de protéger le milieu marin, tout en maintenant les possibilités d'exploiter les ressources marines.

En ce qui concerne l'Accord d'Exécution proposé sur la conservation et l'utilisation durable de la diversité biologique dans les zones situées au-delà des juridictions nationales, il est clair qu'un Accord d'Exécution reflétant le niveau d'utilisation actuel des zones situées au-delà des juridictions nationales ne permettra pas le changement anticipé à long terme des tendances en matière d'utilisation et de pression. Cette analyse prospective permet d'identifier les changements futurs devant être pris en compte dans l'Accord d'Exécution.

Резюме

В этом общем обзоре обстановки рассмотрены исторические тенденции, текущее состояние и будущие прогнозы трех ключевых факторов давления на биоразнообразие в районах за пределами национальной юрисдикции. Эти три давления - :

• физическая утрата и повреждение морского дна;

• Удаление биологических ресурсов; а также

• Подкисление океана.

Ряд деятельностей способствует каждому из этих давлений, включая Биопиратство и морские научные исследования, прокладка подводных кабелей, глубоководная добыча полезных ископаемых, энергетика и рыболовство. Роль каждой из этих видов деятельности в формировании нагрузки на биоразнообразие за пределами национальной юрисдикции оценивается посредством обзора рецензируемых и серых литератур. Результаты показывают, что некоторые морские виды деятельности еще не ведутся и, следовательно, не имеют текущих последствий (таких, как глубоководная добыча), но, по прогнозам, они будут иметь последствия в будущем. В отличие от этого, другие морские виды деятельности уже ведутся в районах за пределами национальной юрисдикции (таких, как рыболовство), а воздействие на морское дно и биологические ресурсы потенциально являются значительными. Разные временные и пространственные масштабы деятельностей затрудняют их сравнение на единой основе оценки, однако ясно, что все виды деятельности и нагрузки увеличиваются в пространственном следе и интенсивности. Во всех сферах деятельности регулирующие органы, отраслевые органы и отдельные компании стремятся найти способы защиты морской среды, сохраняя при этом возможности использования морских ресурсов.

Что касается предлагаемого Соглашения об осуществлении по сохранению и устойчивому использованию биоразнообразия в районах за пределами национальной юрисдикции, ясно, что в таком Соглашении об осуществлении, которое отражает нынешний уровень использования районов за пределами национальной юрисдикции, не будут учитываться ожидаемые долгосрочные изменения в Использования и давления. Это сканирование горизонта помогает идентифицировать те будущие изменения, которые должны быть учтены в Соглашении об осуществлении.

Resumen Ejecutivo

El presente análisis prospectivo analiza las tendencias históricas, el estado actual y las proyecciones futuras de tres presiones clave sobre la biodiversidad en zonas situadas fuera de la jurisdicción nacional. Las tres presiones son:

- Pérdida física y daño en los fondos marinos,
- Remoción de recursos biológicos, y
- Acidificación de los océanos.

Una serie de actividades, incluidas la bioprospección e investigación científica marina, el tendido de cables submarinos, la minería en alta mar, la infraestructura energética y la pesca, contribuyen a cada una de estas presiones. Se evaluó el rol de cada una de estas actividades en la generación de las presiones sobre la biodiversidad en zonas situadas fuera de la jurisdicción nacional mediante una revisión de literatura examinada entre pares y literatura gris. Los resultados muestran que algunas actividades marinas aún no se encuentran en curso y, por lo tanto, no tienen implicancias en la actualidad (por ejemplo minería en alta mar). Sin embargo, se espera que las mismas generen implicancias en el futuro. Por otro lado, hay otras actividades marinas (tales como pesca) en desarrollo en zonas situadas fuera de la jurisdicción nacional y los impactos de las mismas en los fondos marinos y sobre los recursos biológicos son potencialmente significativos. Si bien las diversas escalas temporal y espacial de las actividades dificultan la comparación mediante un único marco de evaluación, es claro que todas las actividades y presiones son mayores en cuanto a la huella espacial e intensidad. De entre todas las actividades, reguladores, entes de la industria y compañías individuales están buscando encontrar formas para proteger el ambiente marino manteniendo oportunidades para explotar sus recursos.

En relación con el acuerdo de implementación sobre la conservación y el uso sostenible de la biodiversidad en zonas situadas fuera de la jurisdicción nacional propuesto, es claro que un acuerdo de implementación que refleje el nivel de uso actual de las zonas situadas fuera de la jurisdicción nacional no consideraría el cambio de largo plazo que se anticipa en cuanto al uso y los patrones de presión. Este análisis prospectivo contribuye a la identificación de esos cambios futuros que deben ser tomados en consideración en el acuerdo de implementación.

1 Introduction

1.1 Context

Marine Areas Beyond the National Jurisdiction (ABNJ) occupy approximately 64 per cent of the surface of the Earth's ocean (Global Ocean Commission, 2014) and 95 per cent of its volume (Katona, 2014). ABNJ comprise the "High Seas", the water column beyond Exclusive Economic Zones and the seabed "Area" beyond extended continental shelves (Wright & Rochette, 2016). ABNJ hold highly diverse ecosystems, which provide a wide range of marine ecosystem services that support human society, health and economy. Nearly half of biological productivity of the global oceans and more than 10 per cent of annual world fish catches by weight, including commercially valuable species, are produced in areas beyond national jurisdiction (Rogers et al., 2014; Sumaila et al., 2015). The Area supports ecosystems such as hydrothermal vent and cold seep communities, and deep sea coral reefs (Rogers et al., 2015), which can host ecologically and evolutionally unique assemblages of organisms of conservation interest (Davies et al., 2007).

Until the mid-20th Century, the remoteness and challenging conditions within ABNJ offered deep sea ecosystems some degree of protection from pressures created by human activities. However, increasing demand for marine resources and technological innovations, combined with a regulatory framework focused on freedoms rather than protections, has resulted in increased human activities in ANBJ (Merrie et al., 2014). Activities taking place in, or are planned for ANBJ include, fishing (e.g. illegal, unreported and unregulated fishing), seabed mining, cable deployment, shipping, waste dumping, bioprospecting, energy generation and marine scientific research. In addition, global pressures such as climate change, ocean warming and ocean acidification affect areas beyond national jurisdiction.

This project develops a practical set of Legal Options to support those involved in the dialogue around the protection and sustainable use of marine biodiversity in areas beyond national jurisdiction (BBNJ). The conservation and sustainable use of BBNJ is a critical conservation and political issue for which there is broad UN-led international consensus supporting the development of a new legally binding instrument. However, there is limited agreement concerning the pressures likely to affect BBNJ and therefore uncertainty over what measures should be included within the proposed new legal instrument and how it should be framed (Houghton, 2014). This project has undertaken a horizon scan of pressures on BBNJ, and a review of legal options for the conservation and sustainable use of BBNJ, to generate a foundation analysis of BBNJ issues. This foundation analysis provided a basis for discussion at a specially convened, high-level international deliberative workshop attended by invited marine conservation and legal experts. During the workshop, the building blocks of a prioritised conservation agenda were developed.

This document explores *selected* key anthropogenic pressures to BBNJ through a Horizon Scan. Horizon scanning is "*the systematic search for, and examination of, potentially significant medium- to long-term threats and opportunities within a given field or discipline*" (Sutherland et al., 2015). This scan will focus on identifying:

i. Selected human activities that may affect BBNJ;

ii. Review of the evidence related to the effects of the selected pressures on BBNJ;

iii. The future trends of the effects of human activities on BBNJ.

For each activity we examine the past, present and future status of the pressure it creates, and summarize present-day and possible future effects of the pressure on BBNJ. There is still much to learn about areas beyond national jurisdiction and therefore there are significant gaps in our knowledge. Major knowledge gaps requiring investigation are also highlighted. Issues relating to the potential management of the activities and global stressors, including legal protection mechanisms, are beyond the scope of this review. However, the legal situation is discussed in detail in the corresponding Legal Scan. The two documents, the Horizon Scan of Pressures and the Legal Scan, will be brought together in the Legal Options Document.

1.2 Terminology

The link between human activities and their effect on marine ecosystems can be described using a simple three step process (Fig. 1). This process starts with an **activity** (e.g. fishing) that generates a **pressure** (e.g. the removal of target and by-catch species), which has an **effect** on an ecosystem (e.g. by reducing biomass and changing species interactions) (Knights et al., 2013). The same pressure can be caused by a number of different activities (e.g. the removal of species can be caused by both fishing and bio-prospecting) and a single activity can contribute to multiple pressures (e.g. fishing can contribute towards the removal of target species, physical loss and damage to the seabed, pollution). For more detailed definitions of the terms associated with pressure pathways see Table 1.

Figure 1: A diagrammatic representation of a simple pressure pathway

Table 1: A definition of terms associated with pressure pathways (definitions taken from (Tillin et al., 2010), with the exception of global stressors).

Term	**Definition**
Activity	Human social or economic action or endeavours that may create pressures on the marine environment.
Pressure	The mechanism (both direct and indirect) through which an activity has an effect on any part of the ecosystem. The nature of the pressure is determined by activity type, intensity and distribution.
Effect	The effects (or consequences) of a pressure on a component.

2 Methods

2.1 Choosing a focus for the Horizon Scan

A broad range of human activities occur in areas beyond national jurisdiction, generating pressures which have an effect on the marine environment. Examples of human activities in these areas are, fishing, scientific research, and shipping. Gjerde *et al* (2008) created a list of existing and emerging human activities in areas beyond national jurisdiction which is summarised in Appendix 1. In addition to these activities, there are a number of indirect pressures on the marine environment, such as ocean acidification, deoxygenation, and sea temperature increases. These arise from activities occurring within national jurisdiction, including the emission of greenhouse gases (Clarke Murray et al., 2014). A recent review of human activities and the pressures they exert on coastal and marine ecosystems identified 39 human activity categories and 34 pressure types, allowing for over 1000 possible activity-pressure combinations (JNCC, 2015). A literature review exploring all possible activity-pressure combinations would be a daunting prospect. Consequently, for the purposes of this horizon scan the decision was made to prioritise those pressures considered to be of greatest threat to BBNJ both in the present day and in the future as independent or cumulative impacts.

2.1.1 Prioritisation of pressures

The choice of pressures included in this horizon scan was informed by the results of a survey of marine experts invited to attend a meeting of the Global Ocean Commission[1] focused on the High Seas (held in Oxford, 2014). This survey collated the views of 22 international marine experts from a variety of disciplines to identify the highest priority threats facing the High Seas. Survey results identified ocean acidification and pressures associated with fishing practises (such as physical loss and damage to the sea bed and the removal of biological resources) as having the greatest effect on BBNJ and requiring the most urgent conservation action. The international experts represented a range of backgrounds and there was representation of both men and women. The meeting was under the Chatham house rule so it is not possible to list the participants.

The survey results were corroborated by other studies. These included a survey of regional experts to gauge the relative vulnerability of New England marine ecosystems to current and emerging anthropogenic stressors which identified ocean acidification as one of the top stressors for offshore habitats within the Exclusive Economic Zone (Kappel et al., 2011). A study on the spatial and temporal changes in cumulative human impacts on the world's ocean described the human footprint on the open ocean as being dominated by the many stressors associated with climate change, including ocean acidification (Halpern et al., 2015). A survey of 135 experts from 19 countries which ranked the vulnerability of global marine ecosystems to anthropogenic threats highlighted demersal fishing as the greatest ocean-based threat (Halpern et al., 2007). The Census of Marine Life (2000-2010), the largest global research programme on marine biodiversity, reported overfishing as the greatest current threat to biodiversity, but the impacts associated with climate change present the greatest long term threat (COML, 2010).

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[1] http://www.some.ox.ac.uk/research/global-ocean-commission/

Based on these sources of evidence, the decision was made to focus the horizon scan on three categories of pressure (see Table 2):

- Physical loss and damage to the seabed;
- Removal of biological resources; and
- Ocean acidification (from the release of carbon dioxide).

Table 2: Priority marine pressures considered within this horizon scan (pressure descriptions were adapted from the Intercessional Correspondence Group on Cumulative Effects (ICG-C) list of pressures (ICG-C, 2011).

Pressure Category	Pressure	Description
Physical loss and damage to the seabed	Physical loss (smothering)	The permanent change of one marine habitat type to another marine habitat type through a change in substratum, including to an artificial substratum (e.g. to concrete through the installation of infrastructure).
	Physical damage (extraction)	Temporary and/or irreversible change to habitat structure due to the removal of substratum (e.g. from marine mineral extraction).
	Physical damage (abrasion)	Penetration and/or disturbance of the substrate below the surface of the seabed (e.g. from certain fishing activities or anchoring).
	Physical damage (siltation)	Changes in the rate of siltation (e.g. from dredging or construction activities).
Removal of biological resources	The direct extraction of target species	Targeted exploitation of biological resources, including by fishing and bioprospecting
	The direct extraction of non-target species	The non-targeted removal of biological resources, including, accidental by-catch
Ocean acidification	Ocean acidification	The increased acidity of the ocean caused primarily by uptake of carbon dioxide (CO_2) from the atmosphere

The existing and emerging marine activities identified as being associated with these three key pressure categories were bio-prospecting and marine scientific research (MSR), submarine cable laying, deep sea mining, energy facilities and fishing[2]. The relationships between these activities and the three pressure categories is presented in Figure 2. The scale and intensity of these activities will be examined in the main body of this report to identify their impact on BBNJ.

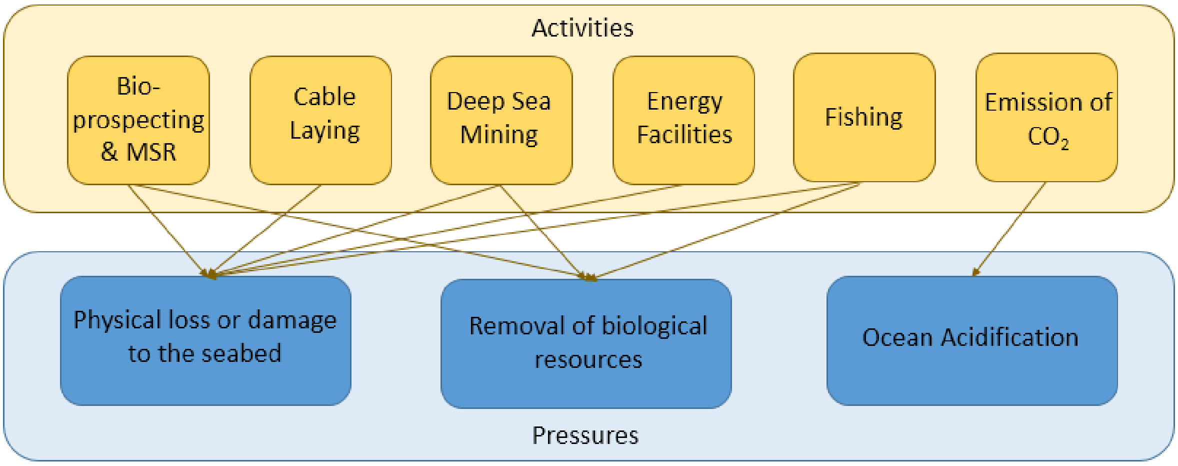

Figure 2: A diagram depicting the relationship between existing and emerging human activities in areas beyond national jurisdiction and the three priority pressures discussed within this horizon scan. It should be noted that all activities listed also contribute to CO_2 emissions.

Inevitably, some marine activities have been excluded from this review, as have some of the pressures generated by activities included in the review. This does not mean that these activities and pressures do not affect BBNJ, but that those pressures and activities included in the review were prioritised.

2.2 Literature review methodology

The horizon scan was undertaken following a structured document review process. Both academic and grey literature were extensively searched using the following terms: "Areas Beyond National Jurisdiction" OR "Deep Sea" OR "High Seas" OR "Open Ocean" AND "Human" OR "Man Made" OR "Anthropogenic" AND "Activity" OR "Pressure" OR "Stressor" OR "Threat" OR "Impact". This search was further supplemented by searching specific terms associated with the maritime activities included in Figure 2. These activity-specific terms were paired up with: "Deep Sea" OR "High Seas" AND "Environmental Impact" OR "Status" AND "Trend" OR "Technology" AND "Innovation". All searches were performed using both the ISI Web of Knowledge and Google Scholar search engines. Notable grey literature included the First World Ocean Assessment (Inniss et al., 2016) and a review of the impacts of fisheries on open-ocean ecosystems (Crespo et al., 2016). Relevant literature identified through this searching process was evaluated for its content in relation to the current status and future trends of the relevant activity and in relation to the actual and potential impacts of the activity on BBNJ.

[2] For the purposes of this horizon scan the activity 'constructing installations' was not included as a separate category as it was believed to be adequately incorporated within the other activities listed. Due to the overlapping nature of bio-prospecting and MSR the decision was also made to combine these activities into a single category.

3 Horizon Scan

3.1 Structure

The following activities are considered in detail:

- Bio-prospecting and scientific research;
- Cable laying;
- Deep-sea mining;
- Energy facilities;
- Fishing;
- Carbon dioxide emissions.

3.2 Bio-Prospecting and Marine Scientific Research

Bio-prospecting is the exploration and exploitation of biodiversity for commercially valuable genetic and biochemical resources (Rademaekers et al., 2015). These resources are primarily used by the pharmaceutical, biotechnology and cosmetic industry to develop new medicine, chemicals or cosmetics (Rademaekers et al., 2015). Bio-prospecting in the marine environment can be considered as a form of applied marine scientific research for commercial rather than academic research purposes (Arico & Salphin, 2005). A subset of sampling techniques used for marine scientific research, such as trawling, drilling and other (invasive) technologies, are also used for bio-prospecting (Rademaekers et al., 2015). These commercially driven activities are often reliant on strategic partnerships with academic institutions (Arico & Salphin, 2005). As such, for the purpose of this study, bio-prospecting and related marine scientific research activities are considered jointly. There is great potential for genetic discovery in areas beyond national jurisdiction as only a fraction of the potential species inhabiting the deep sea are currently described (Rademaekers et al., 2015). It is estimated that the success rate in finding previously undescribed active chemicals in marine organisms is 500 times higher than that for terrestrial species (Arrieta et al., 2010). Hydrothermal vents and cold seeps are thought to provide the greatest potential for finding new bio-resources in the deep sea (Rademaekers et al., 2015). Seamounts can host extremely rich macrofauna communities, while hydrothermal vents can harbour genetically unique life adapted to the extreme conditions (Arico & Salphin, 2005).

3.2.1 Historic trends, current status and future projections

The exploration of deep seabed areas first started towards the end of the nineteenth century. Today, a host of exploration and research activities are undertaken to study the ecology, biology and physiology of deep seabed ecosystems and species. At least 14 biotechnology and other companies, predominantly based in North America and Europe, are known to be actively involved in product development and/or in collaboration with research institutions in search of new substances and compounds from deep sea organisms and genetic material (UNEP, 2006).

Advances in technologies for observing and sampling the deep ocean, such as submersibles and Remotely Operated Vehicles (ROVs), have opened up previously unexplored areas to scientific research. At the same time, developments in molecular biology have increased our capacity to investigate and make use of marine genetic material (GOC, 2013). Since the late 1990s, the number of marine species with genes associated with patents has grown at a rate of almost 12 per cent per year (Arrieta et al., 2010). The exploitation of biological and genetic marine resources has generated almost 18,000 natural products and 4,900 patents (Rademaekers et al., 2015), and marine species are about twice as likely to yield at least one gene in a patent compared to their terrestrial counterparts (Arrieta et al., 2010). An estimate of the total value of anti-cancer drugs derived from marine biodiversity, a fraction of the total pharmaceutical market, is around $500 billion to $5.5 trillion USD (Erwin et al., 2010).

In the deep sea, bioprospecting is still in its infancy (Ramirez-Llodra et al., 2011), however, the global market for biotechnology is growing. In 2004, the generated revenue from bioprospecting was estimated in the region of $2.4 billion USD, with an average growth of 5.9 per cent per year between 1999 and 2007 (Rademaekers et al., 2015). However, due to the high costs (average daily expedition cruise operating cost of about $30,000 USD) associated with dedicated academic deep sea research programmes, bio-prospecting activities are restricted to countries that can afford the investment (Ruth, 2006). To date, bio-prospecting research activities have been largely undertaken inside national jurisdictions. However, bio-prospecting research underway in areas beyond national jurisdiction is currently concentrated in a limited number of locations such as the East Pacific Rise and Mid-Atlantic Ridge (Oldham et al., 2014).

3.2.2 Associated Pressures

i. Pressure: Physical loss and damage to the seabed

Bio-prospecting research in the deep sea has been linked to both positive and negative effects (Arico & Salphin, 2005). Amongst the positive effects, both bio-prospecting and marine scientific research contribute significantly to expanding our knowledge of the deep sea (Arico & Salphin, 2005). However, through the selective direct removal of seabed material and associated fauna, bio-prospecting and marine scientific research can negatively affect benthic communities (Ruth, 2006). Biological and geological sampling operations can affect vent faunal communities through the creation of sediment plumes, disturbance, or vessel-sourced pollution. These effects are likely to intensify, as vent sites become the focus of more intensive and systematic long-term investigation (Rademaekers et al., 2015). To reduce this risk, sophisticated technologies have been developed so as to reduce potential impacts on the seabed (Arico & Salphin, 2005). For example, developments in deep sea photographic and video capabilities, carried on ROVs and Autonomous Underwater Vehicles (AUVs), are reducing the intensity of many sampling activities (Rademaekers et al., 2015). In addition, a number of negative effects associated with bio-prospecting can be further reduced by undertaking the recovery of samples in accordance with accepted methodologies for marine scientific research, which have been designed to minimise environmental impacts (GOC, 2013). Broadly, the combination of small sample sizes, non-specific sampling techniques, technological standards and high costs make deep sea bio-prospecting a limited threat to BBNJ at present (Ruth, 2006).

ii. Pressure: Removal of biological resources

Based on a review of the literature and interviews with 23 experts, it has been concluded that as long as collection and harvesting of deep sea biological resources remains small in scale (size of area) and intensity (quantity) and with the aim of synthesising the active ingredients in laboratories, the environmental impacts of exploiting marine biological resources via bio-prospecting will remain very small (Rademaekers et al., 2015). This result is consistent with the findings of Oldham *et al*. (2014) who undertook a three-month expert Delphi study to identify key issues and potential options for the conservation and sustainable use of deep sea marine genetic resources. The marine experts consulted during this study were in agreement that, whilst care is required, research on marine genetic resources has very limited environmental impact unless specifically targeted at rare or endangered species where effects may be disproportionate (Oldham et al., 2014). To date, most commercial bio-prospecting activity has originated from genetic resources obtained from sedentary species. However, it is important to note that the focus of bio-prospecting expeditions is not limited to ecosystems of the benthic environment, and that targeted extraction of species for the purpose of bio-prospecting can occur also within the pelagic zone which may generate different impacts (Greiber, 2011).

3.2.3 Summary

The current status and forecasted trends suggest that marine-derived biotechnology and natural products are strong industries worldwide, and are likely to continue to grow in scope, activities and applications (Greco & Cinquegrani, 2016). However, experts are unsure whether increasing interest in deep sea organisms will translate into investment. Commercial interest in deep sea marine genetic resources is currently considered to be emergent but limited (Oldham et al., 2014). However, it is likely that unique genetic material will be found in extreme environments such as those found in the deep ocean which will attract focused interest. As a result of the relatively limited investment and the small spatial footprint of bio-prospecting and associated marine scientific research, it is considered that this activity creates relatively little pressure on BBNJ.

3.3 Cable Laying

A submarine cable is a cable laid on or beneath the seabed which transmits telecommunication signals or electric power across stretches of the ocean. The diameter of submarine cables is generally very small, but can vary according to the potential risk to the integrity of the cable. In areas where cables are vulnerable to damage from other activities, such as fishing, cables are often coated with one or more layers of armour and can be up to 50 millimetres in diameter. However, over 80 per cent of global cable length is situated in water depth greater than 1,500 metres (and therefore largely beyond the potential impacts of fishing), and as such additional protection is not undertaken. In these circumstances, typical cable diameters are 17-20 millimetres (Carter et al., 2009).

In circumstances in which submarine cables are not vulnerable from other activities, they are commonly laid on the surface of the seabed with little or no protection. Where protection is needed from accidental damage arising from other activities, cables can be cut into, or buried, in the seabed. Techniques generally involve the use of a ship-towed grapnel or plough to create a trench or furrow into which the cable can be placed. Depending on the circumstances, the trench can remain open, or be filled (Carter et al., 2009). Where cables cannot be buried, for example in areas of exposed bedrock, they are laid directly on the sea bed and may be fully or partially covered with concrete or other protection (Meißner et al., 2006). Various methods are used to minimise seabed disturbance during the cable-laying process. For example in shallow waters, when crossing seagrass beds, cables may be placed in narrow slit trenches and re-planted with seagrass or placed in conduits beneath the seagrass bed (Simcock, 2016).

3.3.1 Historic trends, current status and future projections

Submarine cables have been used for communication since the late 19th century. However, the last 20 years in particular has seen their importance grow considerably, with the submarine telecommunications network now an integral part of modern society with more than 95 per cent of all international communications now transmitted via submarine fibre-optic cables (Benn et al., 2010). There are currently 293 in-service and 28 planned submarine telecommunication cables worldwide (TeleGeography, 2017) with a combined length of around 1 million km (Carter et al., 2009) . Submarine telecommunication cables are considered to be faster and cheaper than satellite alternatives (Rogers et al., 2015), and as such the industry is expected to continue to grow, either through the upgrading existing cables or laying new cables. In addition to telecommunications services, submarine cables are rapidly gaining importance in the transmission of electric power, including from offshore renewable energy sources to terrestrial grids (Meißner et al., 2006). The longest submarine power cable currently in use transmits 700 Megawatts over 600 kilometres from Norway to the Netherlands (Rogers et al., 2015). Expansion of the cable-laying industry is therefore influenced by long-distance power transfer needs and by growth of the renewable energy sector.

3.3.2 Associated Pressures

i. Pressure: Physical loss and damage to the seabed

The installation of cables on or under the seabed can disturb the benthic environment (Carter et al., 2009). For example, skids supporting a cable plough can leave an imprint on the seabed, particularly in zones of soft sediment, which can potentially cause sediment compaction and lead to the disturbance of, and damage to, marine fauna (Benn et al., 2010). However, disturbance effects related to submarine cables are generally localized (Meißner et al., 2006) and the precise nature of any disturbance will vary according to the cable type, seabed type, depth of burial and plough type (Carter et al., 2009). The overall width of the disturbance strip produced by the plough and skids in direct contact with the seabed is expected to range from 2 to 8 metres in width (Carter et al., 2009). The disturbance related to cable burial is therefore relatively limited in its extent (Carter et al., 2009).

In an assessment of the relative spatial extent of major human activities in the deep North East Atlantic, Benn et al (2010) described the spatial extent of telecommunication cables to be low to moderate in comparison to other activities. Cable laying is a non-repetitive procedure in which most impacts are restricted to the cable installation and recovery phases (Meißner et al., 2006), which occurs relatively infrequently owed to the high reliability and long life span of submarine cables (20-25 years) (Carter et al., 2009). Such a life span may seem long on human timescales, however is comparably short when considering the timescale on which some deep sea ecosystems form which can be thousands of years. The seabed may be disturbed periodically for cable repairs; however, deep ocean repairs account for less than 15 per cent of all cable faults (Carter et al., 2009). In addition, modern cable-laying techniques and improved technical standards have enhanced the precision of cable placement, potentially allowing for the avoidance of ecologically and biologically sensitive areas such as seamounts, submarine canyons and hydrothermal vents, which are also unsuitable as cable routes due to the risk of natural hazards.

Based on this information it can be concluded that submarine cables have a limited effect on BBNJ. This conclusion is supported by a comprehensive study undertaken more than a decade ago Kogan et al (2003, 2006) which showed no statistical difference in the abundance and distribution of animal groups living in and on the seabed within 1 and 100 metres of a surface-laid cable. In an assessment of past, present and future effects of human-related activities on deep sea habitats and their communities Ramirez-Llodra et al. (2011) also predicted underwater cables to have a minimal effect on deep sea habitats (Ramirez-Llodra et al., 2011).

3.3.3 Summary

In summary, the installation of submarine cables on or under the seabed has the potential to disturb the benthic environment. However, because disturbance effects are generally localised, the current effect of cable laying on BBNJ is estimated to be relatively limited. The telecommunication industry, however, is predicted to expand over the coming years. It is therefore possible that submarine cables could pose a greater threat to BBNJ in the future. Further research on the impacts of submarine cables is required to confirm the current position that they have a limited impact.

3.4 Deep Sea Mining

Three forms of deep sea mineral resources have been considered thus far for commercial exploitation: manganese nodules on abyssal plains, cobalt-rich crusts on seamounts, and polymetallic sulphide deposits at sites of hydrothermal vents (Ramirez-Llodra et al., 2011). Deep sea mining typically focuses on valuable minerals such as silver and gold but in particular copper, manganese, cobalt, zinc and rare earths (ISA, 2004; Rademaekers et al., 2015). The deep sea mining industry is currently at an advanced exploration stage (Ramirez-Llodra et al., 2011). Exploration research uses a combination of autonomous, tethered, or human-occupied vehicles, towed camera sleds, and cabled observatories to engage in observation, sampling, and instrument deployment and recovery (Van Dover, 2014). In practice, nodules will be collected and separated from the sediment, whereas sulphides and crusts will be excavated or scraped. The material will then be lifted to the sea surface with risers where solid ore will be separated from the pumped liquid and stored on ships or platforms prior to transfer to the shore for processing (Rogers et al., 2015). However, methods for handling liquid by-products produced during the separation process are still under discussion (Rogers et al., 2015). Methods proposed for extracting minerals resources include: mechanical cutting, grabbing and magnetic separation (Van Dover, 2014).

To date, no industrial exploitation of deep sea mineral resources has occurred in areas beyond national jurisdiction, however, mining both within and beyond national jurisdiction is likely to become increasingly prevalent within the next decade. The International Seabed Authority has issued 26 exploration licences (as of 2016); various Pacific Island States, including Fiji and the Solomon Islands, have issued deep sea exploration licenses for areas within waters under national jurisdiction (Baker et al., 2016); and Papua New Guinea has issued a mining license, with mining potentially due to begin as early as 2018 (Tighe, 2015).

3.4.1 *Historic trend, current status and future projections*

To date, the International Seabed Authority has issued 26 licences covering 1.2 million square kilometres of ocean floor in areas beyond national jurisdiction (WWF, 2015), with the majority involving manganese nodule mining (Rademaekers et al., 2015). Currently such exploratory ventures are largely being undertaken by wealthy, developed countries or major emerging economies. However partnerships between developing countries and industrial partners with access to the necessary technology and capital have been established to initiate large operations which involve substantial financial and environmental risk (Rademaekers et al., 2015). Areas of interest to mining entities include the abyssal plain, seamounts and hydrothermal vents around the Clarion-Clipperton Zone in the Pacific Ocean, in parts of the Indian Ocean and along the Mid-Atlantic Ridge (Rademaekers et al., 2015). In April 2014, Papua New Guinea and Canada's Nautilus Minerals Inc. reached the first-ever commercial agreement for deep sea mining (Rademaekers et al., 2015) as a result, the first deep sea mining operations for seabed massive sulphides are likely to commence within Papua New Guinea's exclusive economic zone (Rogers et al., 2015).

Due to long-term decreases in the productivity of the metal industry, an increased reliance on the use of rare earths within many high-tech products (including mobile phones), and a rapidly growing global middle class consumer base, the demand for minerals has increased dramatically, creating a potential opportunity for deep sea-derived minerals as an alternate supply (Roche & Feenan, 2013). Increasing market prices for metals have further incentivised the exploration of the deep sea for minerals (Rademaekers et al., 2015). Currently there is a "gold rush" amongst States to claim areas of the deep sea lying in areas beyond national jurisdiction for the exploitation of deep sea metal deposits and, although marine mineral mining is still in its infancy, by 2020 an expected 5 per cent of the world's mineral supplies could be mined from the seabed(Rogers et al., 2015).

Despite increasing exploratory efforts, technologies for the mining of deep sea minerals remain immature (Rademaekers et al., 2015) and the prospect of mining of depths between 2,000 and 6,000 metres is limited. Whilst there is demand for minerals, the cost associated with exploitation in deep sea environments leads to great uncertainty in the commercial viability of deep sea mining in areas beyond national jurisdiction. As such, financial input into research and development is currently limited (Rademaekers et al., 2015). However, an assessment of the economic viability of mining within the national jurisdictions of various Pacific Island countries has been undertaken (Cardno, 2016). This found that deep sea mineral mining in Papua New Guinea is economically viable, but not in the Republic of the Marshall Islands due to the inherent costs associated with technology development (Cardno, 2016). Consequently, deep sea technologies developed for mining within exclusive economic zones could be used in areas beyond national jurisdiction, and the financial and capacity benefits obtained from mining in exclusive economic zones could spill over into areas beyond national jurisdiction, allowing for further research and technology development.

3.4.2 *Associated Pressures*

i. Pressure: Physical loss and damage to the seabed

Mining activities have the potential to cause substantial physical harm to deep sea ecosystems, with exploitation activities likely to have a greater effect on marine ecosystems than exploration (Rademaekers et al., 2015). During exploration, physical disturbance will primarily come from drilling for ore samples and remotely operated vehicle sampling (Rademaekers et al., 2015). To date, known effects of such exploration activities, such as the physical destruction and removal of habitat structures and associated fauna, are thought to be spatially localised, at least for hydrothermal vent regions (Van Dover, 2014). Effects in the abyssal plain may be much longer lived- for example, 26 years after experimental mining operations in the Clarion-Clipperton Zone, Tropical Eastern Pacific, a study into deep sea assemblages determined that no recovery has occurred since those operations (Miljutin et al., 2011). In addition, one study (Ramirez-Llodra et al., 2011) suggested that manganese nodule mining could ultimately be the largest-scale human activity to affect the deep sea floor directly, however other authors have disagreed (Rademaekers et al., 2015).

The expected physical effects of seabed mining include:

i. The direct loss of habitat and organisms during the process to remove minerals (Van Dover, 2014). Nodule-mining activities are predicted to remove roughly the top 5 centimetres of sediment, removing or damaging most fauna directly in the path of the mining head (Ramirez-Llodra et al., 2011).
ii. The degradation of habitat quality through re-shaping of the seabed (Van Dover, 2014). The removal of benthic materials is expected to alter the seabed leaving a flatter and more uniform surface with compressed sediment underneath which could be unsuitable for re-colonisation and habitat recovery (Allsopp et al., 2013). Organisms may be subject to a radical change in habitat conditions with soft particles settling from the mining plume replacing hard substrate (Rademaekers et al., 2015).
iii. The smothering of organisms by the resettlement of suspended sediment and chemical effluent. Deep sea mining has the potential to produce near bottom, mid-water and near surface sediment plumes in the water column which extend the area of physical effects of mining activities on sea floor communities (Rademaekers et al., 2015).

A single mining operation is projected to remove nodules and near-surface sediments from 300–700 square kilometres of seafloor per year. Re-deposition of sediments suspended by mining activities is expected to disturb seafloor communities over an area perhaps two to five times this size, depending on oceanic currents and oceanographic conditions (Ramirez-Llodra et al., 2011).

The impact of deep sea mining is expected to vary considerably based on the type of deposit being mined (Rademaekers et al., 2015). For example, hydrothermal vents are considered to be particularly vulnerable to even small scale mining operations due to the site-specific nature of the species inhabiting these habitats (Rademaekers et al., 2015). Van Dover (2014) hypothesised that in a region where there is only a single geographically constrained mining event, vent communities may re-establish within years, as they do following volcanic eruptions. However, the structure and function of the resulting communities may well differ from those that existed prior to mining (Van Dover, 2014). Active hydrothermal vents have been documented to have rapid re-colonisation processes, however, the exact speed of recovery is likely to be dependent upon the locality of mining, as well as, the geological setting and resulting longevity and distribution of vent sites (Rogers et al., 2015). While vent ecosystems are naturally exposed to fallout of minerals from black-smoker plumes, the intensity of sediment plumes generated during mining activities may be in excess of natural exposures at the local scale during certain phases of operations (Van Dover, 2014). Currently, there is not enough known about the faunal communities occupying hydrothermal vents to accurately predict the effects of deep sea mining (Ramirez-Llodra et al., 2011).

3.4.3 Summary

Deep sea mining is still in an exploratory phase and as such, current effects on BBNJ are thought to be minor. However, effects associated with the future exploitation of deep sea mineral resources, are thought to be potentially more significant. Although there is uncertainty around the precise scale and type of effects arising from seabed mining, though both have the potential to be substantial if mining becomes economically viable. Additionally, limited research into ecological communities in some regions makes accurately predicting effects difficult. The increasing demand for minerals and state efforts to claim areas of the seabed for mineral exploration in areas beyond national jurisdiction mean the potential threat to BBNJ from deep sea mining is likely to increase.

3.5 Energy facilities - Oil and gas exploitation

The offshore oil and gas industry involves drilling wells into the seabed to extract underlying crude oil and natural gas deposits. Fixed platforms are traditionally used for the exploration and production of oil and gas at depths greater than 400 metres. However, floating production facilities have become predominant in offshore development due to the high costs associated with the construction and disposal of fixed rigs in water deeper than 400 metres. Ships known as Floating Production, Storage and Offloading systems (FPSOs) have become the primary choice for field development in many areas of the world (Kloff & Wicks, 2004). An alternative to large sea surface platforms are subsea completion systems connected together by flowlines to form large production ensembles, enabling oil and gas from numerous wells to be pumped to a single production station (Maribus gGmbH, 2014). Despite available technologies, at present, there are thought to be few oil or gas resources found beyond the continental margin, thus it is unlikely that substantial exploitation will occur in areas beyond national jurisdiction. Additionally, there is no mechanism through which High Seas oil and gas exploration licenses are awarded, and thus no protection provided to companies partaking in such activities. However, in instances in which a country's continental shelf is extended beyond 200 nautical miles, deep sea oil exploitation may occur in the Area, where the overlying water column is beyond national jurisdiction (NAFO, 2016).

3.5.1 Historic trend, current status & future projections

Exploitation of deep sea hydrocarbons began in the Gulf of Mexico in 1979 (Davies et al., 2007) and by 1986 the industry had already expanded into waters greater than 1,500 metres in depth (GOC, 2014). With many reserves exhausted in shallower waters, companies have moved to greater depths to access new sources (WWF, 2015). Between 1997 and 2006 the number of wells in waters depths greater than 1,500 metres increased from 17 to 500 (Davies et al., 2007) and offshore oil and gas production is expected to continue to increase in the coming years (GOC, 2014). Approximately 33 per cent of oil and 25 per cent of natural gas consumed globally currently comes from underwater areas (GOC, 2014), with 7 per cent coming from water depths greater than 400 metres. However, the limited production is largely due to the fact that 38 per cent of deep water fields are currently still under development (Maribus gGmbH, 2014). The most important offshore production regions currently include the North Sea, the Persian Gulf, Western and Central Africa, the Gulf of Mexico, the Mediterranean, the Caspian Sea and Southeast Asia. However, new regions such as East Africa, the Mediterranean and the Arctic, are also attracting the attention of investors (GOC, 2014).

With the latest high-resolution geophysical exploration technology, scientists are now able to detect oil and gas deposits in the seabed to a depth of 12 kilometres. As a consequence, many major new deposits have been discovered or newly surveyed in the deep sea (Maribus gGmbH, 2014). According to recent studies, 481 larger fields were found in deep and ultra-deep waters (>2000 metres) between 2007 and 2012 which accounts for over 50 per cent of the newly discovered larger offshore fields (Maribus gGmbH, 2014). The increase in potential deep-water production is reflected in the dramatic increase in investment in deep-water drilling, from $58 billion USD in 2001-2005 to $108 billion USD in 2008-2012, and investment is projected to continue to increase (Rogers et al., 2015). Due to demand for energy, deep water oil and gas production, although costly, is now a lucrative business (Maribus gGmbH, 2014). With drilling and extraction technology also becoming increasingly sophisticated, it is now possible to extract oil and gas at ever greater depths (Cordes et al., 2016). The most recent world record offshore drilling depth was established in January 2013 off the coast of India at a depth of 3,165 metres (GOC, 2014).

3.5.2 Associated Pressures

i. Pressure: Physical loss and damage to the seabed

Physical effects on the sea bottom may occur as a result of installing pipelines, cables, bottom rigs, templates, skids, and platforms including platform legs and anchoring (OSPAR, 2009). These effects are largely restricted to the footprint of these structures. In a study from the Northeast Atlantic, historical monitoring has demonstrated that the effects of seabed disturbance are largely transient, with re-colonisation of disturbed seabed habitats occurring within relatively short timescales (OSPAR, 2009). However, re-colonisation rates may vary across different regions due to differences in underlying geology, species biology and species' adaptation capabilities. In addition, oil and gas installations can, over time, provide an opportunity for new benthic organisms, usually associated with hard substrates, to colonise new areas (OSPAR, 2009). Due to the number and length of pipelines placed on or under the seabed the overall physical effects of pipelines is considered to be greater than those from other types of offshore energy facilities (OSPAR, 2009). Pipelines are comparable to submarine cables in their effects (Ramirez-Llodra et al., 2011) (see section 3.3), although they tend to be substantially larger (between 10-20 metres in diameter) and much shorter (OSPAR, 2009).

In addition to structures on the seafloor, drill cuttings (cuttings and fluids associated with drilling activities discharged at the location of the well) constitute a part of the oil and gas operations footprint (Benn et al., 2010). Cuttings can build up into piles around the platforms, particularly in areas where currents are generally weak (OSPAR, 2009). A single production platform may discharge in the region of 15,000 cubic metres of drilling cuttings after an average drilling of 50 wells (Kloff & Wicks, 2004). A study of the effects of oil and gas exploration and exploitation in the Gulf of Mexico showed that drilling muds were deposited in the near-field areas, causing patchy zones of disturbed benthic communities (CSA, 2006). When estimating the spatial extent of oil and gas industry activities in the North East Atlantic, Benn *et al*. (2010) applied a circular buffer of radius 83 metres to all wells, platforms and templates in order to represent the physical presence of cuttings.

In many parts of the world, offshore activities are regulated to reduce waste deposited on the seabed, for example the 1993 ban on discharging oil-based muds and cuttings in the North Sea following the discovery of elevated levels of contaminants in waters surrounding Norwegian platforms (Harris et al., 2016). The oil industry has generally shown environmental responsibility in its exploration of the deep sea, with the greatest environmental impacts largely being a result of accidental discharge (Ramirez-Llodra et al., 2011). For example the discharge of an estimated 4.9 million barrels of oil over 87 days following an explosion on the Deepwater Horizon platform in the Gulf of Mexico (Harris et al., 2016). Technological advancements, including better navigational equipment and remotely operated vehicles, have also improved accuracy in the placement of offshore infrastructure, thus facilitating the avoidance of vulnerable marine communities and reducing associated physical effects (OSPAR, 2009).

3.5.3 Summary

Offshore oil and gas production is expected to increase, with activities moving into ever deeper waters. However, governance mechanisms affording commercial protection of discoveries in areas beyond national jurisdiction are likely to be required before companies invest in extraction activities in these areas. In addition, given the preference for the use of floating production facilities, which have minimal contact with the seabed in deeper waters, direct physical effects of oil and gas operations on the seabed within areas beyond national jurisdiction are likely to be negligible, at least in the near-to-midterm. However, the potential risks from accidental spillages could be considerable as the technology for managing spills in distant High Seas environments has yet to be fully developed. Therefore the threat associated with offshore oil and gas production could be considered relatively low, noting an increase in threat when considering the potential for spills.

3.6 Fishing

In areas beyond national jurisdiction, both pelagic and benthic/demersal (deep sea) fishing activities take place and each can be associated with different pressures. The most commonly used techniques for demersal fishing are bottom trawling and bottom longlines (Clark et al., 2015). Bottom trawling is used to catch approximately 80 per cent of the deep sea fish stocks landed from areas beyond national jurisdiction (UNEP, 2006). Trawls used in the deep sea are modified forms of shallow water trawls (Davies et al., 2007), the main difference being the use of heavier and larger gear in the deep sea (Clark et al., 2015). Trawl doors can weigh up to 2000 kilograms (Clark et al., 2015) and nets are often reinforced by chains to strengthen them and add weight to maintain close contact between the net and the seafloor (Davies et al., 2007). Trawling effort can be intense, with hundreds, or even thousands, of tows repeatedly carried out (Ramirez-Llodra et al., 2011). High Seas fishing efforts are typically targeted at specific species or habitats. For example, deep-sea fishing efforts are often targeted at particular habitat types such as seamounts and ridges that provide favourable conditions (for example shelter and food) which encourages aggregations of deep water species (Clark et al., 2015). Research into impact minimisation on deep sea habitats is ongoing within the fishing industry. In addition, guidelines produced by the FAO and other fisheries bodies are used by the fishing industry to limit impacts.

3.6.1 Historic trends, current status and future projections

In the 1950s and 1960s the High Seas fishing industry expanded rapidly following declines in traditional continental shelf fisheries, caused by diminishing stocks and stricter fisheries regulations. The shift in effort into areas beyond national jurisdiction coincided with improvements to fishing gear and the development of large and powerful refrigerated vessels capable of spending extended periods at sea (Davies et al., 2007). Since then global fish production has grown steadily with food fish supply increasing at an average annual rate of 3.2 per cent. Key drivers of such growth include: human population expansion, rising incomes, urbanization, expansion of fish production and more efficient distribution channels (FAO, 2014). All these factors have led vessels to explore progressively deeper and more distant waters (Ramirez-Llodra et al., 2011). A recent study estimated that the mean depth of fishing has increased at a linear rate of 62.5 metres per decade, corresponding to an increase of about 350 metres for the period since 1950 (R. a. Watson & Morato, 2013). The majority of High Seas fishing for deep water species is carried out by around ten nations. Most of these countries are well developed and, in some cases, rely heavily on subsidies to remain profitable (GOC, 2014). This has raised concerns regarding the equitable sharing of resources, as currently only a few countries are benefiting from exploitation of this area (Sumaila et al., 2015). In contrast, a greater number of countries are involved in pelagic fishing in the High Seas.

New techniques for deep water fishing which better maintain the health of deep sea ecosystems are being developed, however these are not necessarily in the implementation phase yet (Pham et al., 2014). A proposed approach is the use of regulated deep sea longlining as an alternative to deep sea bottom trawling, which is anticipated to reduce by-catch of cold-water corals and limit damage to benthic communities (Pham et al., 2014). By-catch is an issue particularly relevant to both deep sea and pelagic fishing. A range of measures have been implemented to reduce the risk of by-catch in fishing activities. The focus of these measures is either to keep fishing gear away from by-catch species (i.e. time–area closures), or to keep by-catch species away from fishing gear (i.e. making the gear less attractive) (Horodysky et al., 2016). Although very few technical solutions to by-catch are entirely effective, there are few fisheries-related by-catch problems that do not have a technical solution and for these fisheries, the avoidance of interactions is an option (MRAG, 2010).

Global demand for fish as a protein source is expected continue to increase (Daly, 2016). With a growing population fish is often seen as a solution to protein and micronutrient needs (Merino et al., 2012). Unsustainable fishing practices continue to increase, with the current statistic of 31% stocks being unsustainably fished, primarily within national jurisdiction (FAO 2016b). The percentage of biologically unsustainable fisheries does not disaggregate to different regions, including the high seas, and there is evidence that high seas fisheries are not increasing. However, continuing demand and potential for future collapses in fish stocks within EEZs because of unsustainable exploitation, there is likely to be a driver for further expansion of high seas fisheries.

3.6.2 Associated Pressures

i. Pressure: Physical disturbance of the seabed

While the role of High Seas bottom trawl fishing may be relatively minor in terms of total global marine fisheries output and value, some research indicates that it causes major and disproportionate damage to deep sea ecosystems (UNEP, 2006). Halpern *et al*. (2007) identified 'demersal, destructive fishing' (e.g. demersal trawl) as the most consistently high-rated threat to oceanic ecosystems. In the Northeast Atlantic, the spatial extent of bottom trawling is predicted to be orders of magnitude greater than that for other activities (Benn et al., 2010). It is estimated that a single trawling excursion has the potential to physically disturb up to 100 square kilometres of seafloor (Davies et al., 2007). It is important to note, however, that there is currently no definitive method to identify: i) bottom trawling vessels; ii) where trawls start and end; and iii) the size of the gear deployed. The spatial extent of bottom trawling is often estimated from Vessel Monitoring System (VMS) datasets but there are limitations to this approach. For example, from vessel monitoring systems data, it is not possible to be certain when fishing gear is in contact with the seafloor (Benn et al., 2010). Automatic Ship

Identification Systems data from satellite sources may provide greater spatial coverage of potential trawling activities in the near future (McCauley et al., 2016).

The practice of bottom trawl fishing is causing international concern due to the damage that occurs to benthic habitats during the passage of a trawl (Davies et al., 2007). In the deep sea, trawling can alter the physical properties of surface sediments through the mixing of soft sediments and the erosion of upper layers, exposing denser, older sediments in the trawl path (Clark et al., 2015). The passage of the trawl can also re-suspend large quantities of sediment which has the potential to smother neighbouring ecosystems (Davies et al., 2007). Sediment plumes can be up to 2-4 metres high in the water column, covering a width of 120-150 metres depending on the size of the trawl gear (Clark et al., 2015). The effects of fishing activities therefore have the potential to extend well beyond the targeted area of the fishery (Clark et al., 2015).

Heavy trawling can also reduce the diversity and biomass of benthic invertebrates (Ramirez-Llodra et al., 2011). Changes to benthic communities can be rapid, persistent, and occur with low levels of fishing effort. This is because many deep sea species are sessile with erect and fragile forms which are generally relatively long-lived and slow-growing. Communities associated with biogenic habitats formed by deep sea corals and sponges are among the most susceptible to fishing effects (Clark et al., 2015). For example, losses of up to 98 per cent of the coral cover of seamounts have been recorded as a result of deep sea bottom trawl fishing (UNEP, 2006). The deep sea is characterised by low current speeds and sedimentation rates, and as a result, trawling damage can persist over extended periods of time (Davies et al., 2007). Recovery of deep sea cold-water assemblages from benthic fishing disturbance is also likely to be much slower compared to those in shallower systems, (Ramirez-Llodra et al., 2011). However, it should be noted that there is a relatively small footprint of regulated fishing within the deep seas in areas beyond national jurisdiction at this time. It has been calculated by FAO that only 5 per cent of deep water areas beyond national jurisdiction is potentially fishable, and of this 5 per cent, three quarters, is currently closed for fishing (FAO, 2016). The majority of deep seas fishing is taking place above 400 metres (FAO, 2016).

ii. Pressure: Removal of biological resources (target and non-target species)

Challenges of Illegal Unreported and Unregulated fishing

In 2016, a study on the state of the world's fisheries reported that over exploitation of global fish stocks has increased and estimated that 31.5 per cent of the world's marine fish stocks were overfished, based on 2013 data, (FAO, 2016)). Of particular note are High Seas and straddling and migratory fish stocks which are especially vulnerable to overfishing, including through illegal, unreported and unregulated fishing. It has been estimated that 64 per cent of straddling stocks in areas beyond national jurisdiction are overfished or experiencing overfishing in comparison to 28.8 per cent of stocks in national jurisdiction (Crespo et al. 2016), illustrating the management challenges that exist in ABNJ. Illegal, unreported and unregulated fishing activities, including those undertaken in the High Seas, are estimated to harvest 11-26 million metric tonnes of fish per annum, equating to $10-23 billion USD (Hazin et al., 2014).

Between 2000 and 2010, an average of 10 million tonnes of highly migratory and straddling fish stocks were caught annually on the High Seas, representing 12 per cent of the average global annual marine fisheries catch (Rogers *et al*., 2014; Sumaila *et al.*, 2015). The increasing incidence of overfishing of marine stocks can have significant effects on species physiology (such as decreases in average body mass leading to changes in reproductive cycles and population recovery capacity), on community structure (for example through the removal of top predators and changes in trophic interactions) and on ecosystems themselves (such as through reductions in biodiversity or regime shifts, affecting ecosystem resilience to other pressures such as climate change) (Crespo et al., 2016). Many deep seas fisheries have followed a 'boom and bust' cycle, in which after very high initial catches per unit effort, stocks become rapidly depleted over short time scales (<5 years) and are no longer able to support commercial fisheries (Clark et al., 2006). Consequently, many deep sea fisheries have collapsed or are beginning to show warning signs of population decline (Norse et al., 2012).

Deep sea species generally have long life spans, slow growth rates and delayed maturity, which makes them poorly adapted to sustained heavy fishing pressure (Ramirez-Llodra et al., 2011). In addition, the tendency of some deep sea species to form large, dense aggregations for reproduction, makes them easy targets for trawlers and thus highly susceptible to over-exploitation (UNEP, CBD, & SBSTTA, 2008). As a result of these traits, a serial collapse that has taken 50 years in coastal marine fisheries may take only 5-10 years in the deep sea (Druel et al., 2013). Due to their greater vulnerability, many deep sea fish species targeted by fishing activities now meet the IUCN criteria for being critically endangered (Norse et al., 2012). Such declines in population size are associated with a number of biological consequences including: reduced genetic diversity, lowered reproductive success and increased susceptibility to disease. However, recent figures from FAO indicate that, for the deep seas fishing fleet, the total catch in 2014 was around 150,000 tonnes and only 25 per cent of the deep sea catch from areas beyond national jurisdiction in 2014 was from below 400 metres (FAO, 2016). Therefore deep sea fisheries currently have limited extent and catch at depths greater than 400 metres.

Pelagic fisheries in areas beyond national jurisdiction are also threatened by overfishing. For example, Tuna species account for the largest share of value and the second largest share of total catch from the High Seas. However, over the last half century stocks of tuna and related species have declined on average by 60 per cent, and the majority of these stocks are either fully or over-exploited (Sumaila et al., 2015). Other large pelagic species such as sharks are caught in both targeted fisheries and as by-catch, and it has been estimated that population declines of up to 90 per cent in top predators such as sharks have occurred (Crespo et al., 2016). By-catch of non-target pelagic species and undersized juveniles of target species caught during fishing activities has been known to exceed the amount of saleable fish (UNEP, 2006). In addition to this, lethal 'ghost fishing' by gear that is lost or abandoned by fishing vessels takes a further toll (UNEP, 2006). Due to low relative current energy, nets lost in deeper waters have been estimated to continue to fish for periods of at least 2-3 years (Davies et al., 2007). Abandoned long lines in shallower High Seas areas also have the potential to snare large and long-lived species such as albatross, petrels, sea turtles and sharks, many of which are already threatened with extinction (UNEP, 2006).

3.6.3 Summary

Fishing is considered by many to be one of the greatest present-day threats to open ocean and deep sea ecosystems. The trend towards High Seas fisheries is predicted to increase with new technology making these areas more accessible (Inniss et al., 2016). Overfishing therefore remains a significant threat to both pelagic and benthic species, the effects of which include increased species extinction risk, decreases in species' ranges, and reductions in average body mass which can ultimately impact trophic structures (Crespo et al., 2016). Fishing activities in areas beyond national jurisdiction can also exert considerable pressure on ecosystems as well as fish stocks, depending on the methods used. For example deep sea trawling can cause residual damage to sensitive benthic habitats such as seamounts, and the unsustainable removal of pelagic and benthic non-target species as by-catch.

At present, the area of deep seabed affected by bottom trawling is likely to be much greater within EEZs than in ABNJ, however, the exact figures are unknown. There are limited bottom fisheries catches at depths near 2000 metres (Watson & Morato, 2013) and an analysis by FAO suggested that only 25 per cent of deep sea fish catches were from below 400 metres (FAO, 2016). Given the great depths of the water column in areas beyond national jurisdiction, large areas are currently still inaccessible to bottom trawling technology, and Regional Fishery Management Organisations have the power to keep many areas closed to fishing unless stringent assessment measures are complied with. However, technological advances will allow increasing access to the Area in the future. Therefore, the current threat to ecosystems from deep sea fishing may increase in the future. Likewise, the current threat from biomass reduction is considered to be relatively high due to pressures from overfishing, by-catch of non-target species and illegal unreported and unregulated fishing. This is occurring in the context of increasing human populations and increased demand for marine fish products, particularly in low income countries (Rice & Garcia, 2011).

3.7 Emission of Carbon Dioxide

Oceanic uptake of carbon dioxide (CO_2) is estimated to account for approximately 30 per cent of total anthropogenic carbon dioxide emissions (IPCC, 2014). Increasing carbon dioxide concentrations have altered the chemical balance of seawater, which by the beginning of the 21st century, had already increased in acidity (pH levels lowering from 8.17 to 8.06). This process, known as Ocean Acidification, has occurred throughout the global ocean and is expected to continue or potentially accelerate in future (Pörtner et al., 2011).

Ocean acidification threatens a wide range of ecosystems and fisheries in areas beyond national jurisdiction, from shallow pelagic areas to the deep sea. Temporal and spatial expansion of the pressures associated with ocean acidification are difficult to manage through national-level initiatives. Therefore, political awareness of ocean acidification and improved international mitigation strategies are particularly important in mitigating and managing the impacts of ocean acidification in areas beyond national jurisdiction (Secretariat of the Convention on Biological Diversity, 2014).

Many marine organisms, including plankton and corals, have shells or exoskeletons made from calcium carbonate ($CaCO_3$), and these are often referred to as calcareous organisms. In order to form a calcium carbonate shell, organisms require a substantial supply of carbonate ions (CO_3^{2-}) dissolved in seawater. The concentration of carbonate ions throughout the water column is therefore important, with a high saturation (i.e. large amounts of carbonate ions dissolved in the seawater, otherwise known as 'over-saturated' waters) required for shell formation. Surface waters typically have a high saturation, whereas deeper waters are often under-saturated in calcium carbonate ions, making it difficult for organisms to form shells at depth (Fabry et al., 2008).

Ocean acidification is therefore particularly problematic for shell-forming species. Increased dissolution of carbon dioxide into seawater results in a lower pH and the production of bicarbonate ions (instead of carbonate ions), which ultimately reduces carbonate saturation of the water (Doney et al., 2009). As such, there is less carbonate available to calcareous organisms, making it increasingly difficult for marine organisms to form shells or skeletons. Often this results in a prolonged shell-forming processes, or the creation of deformed carbonate structures that may hinder organism health and survival. The problems associated with ocean acidification do not only affect individual organisms, but entire food webs, as many calcareous organisms play fundamental roles in the food chain, for example certain types of plankton.

3.7.1 Historic Trend, Current Status and Future Projection

Time-series observations of marine carbonate chemistry have reported acidification of the Atlantic and Pacific surface waters since the 1980s (Bindoff et al., 2007). The increase in acidity is already greater than would be likely through natural variability (Friedrich et al., 2012). The impacts of ocean acidification are more pronounced in colder ocean regions, including temperate and arctic areas, whereas tropical regions of the world are currently not affected as badly (Olafsson et al., 2009; (Feely et al., 2009). Acidification is greater in colder ocean regions because carbon dioxide is more soluble at lower water temperatures, resulting in a greater decrease in pH and a more pronounced lowering of carbonate saturation (Steinacher et al., 2009; Denman et al., 2011). In addition to temperature, the salinity of seawater also affects the rate of ocean acidification. In Arctic regions, ice melt, precipitation and river discharges all input large quantities of freshwater into the ocean, which reduces seawater pH (Vélez-Belchí et al., 2010). This effect is particularly prominent in localised areas of freshwater input, for example at river mouths (Denman et al., 2011; Christian et al., 2010). However, it can be noted that in the Arctic Ocean, seasonal ice melt also has a similar effect, meaning that species here may be adapted to occasional changes in salinity (Yamamoto-Kawai et al., 2011). Variation also exists within the water column, in which deep water shell forming species are at greater risk from acidification due to inherently lower carbonate ion saturations at greater depths and the associated difficulty in shell formation (Byrne et al., 2010; Orr et al., 2005).

The implications of low temperature and salinity for ocean acidification mean that ecosystems in the high latitudes are at greater risk from the effects of ocean acidification. Global models predict that by the end of the 21st Century, ocean acidification will have progressed most severely in the Polar Regions (Bopp et al., 2013). By the end of the 21st Century, shallower waters are likely to also be affected by ocean acidification under a 'business as usual scenario' for future anthropogenic carbon dioxide emissions (Orr et. al., 2005). Further effects of acidification in shallower waters may impact primary and secondary producers (e.g. phytoplankton and zooplankton respectively), which are predominantly located in surface waters up to 200 metres depth. These plankton species support communities throughout the entire water column via their role in the food chain and thus acidification could have an effect on whole ecosystems. By 2100, low latitude (tropical) surface waters are predicted to remain saturated with respect to calcium carbonate (Secretariat of the Convention on Biological Diversity, 2014). However the effects of ocean acidification have already been observed in these areas despite the high saturation of carbonate ions. For example, observed decreases in pH, which can hinder the calcification process of corals and reduce growth rates of some plankton species. For example, the North Atlantic Ocean is a major sink for anthropogenic carbon dioxide (Khatiwala et al., 2013) which may adversely affect skeletal formation and hence the structure of deep sea corals in the Atlantic Ocean (Guinotte et al., 2006; Turley et al., 2007).

International global observation and data sharing efforts mean that the current status of ocean acidification is relatively well documented (Pörtner *et al*, 2014). However, knowledge gaps exist, including:

- Long-term change (inter-annual ~ decadal) due to lack of long-term field observations;
- Influence of pH change on physiological and biological processes of non-shelled organisms, including fish;
- Physiological tolerance, acclimation of individual species, and resilience of communities to increases in ocean acidification;
- Impacts on the higher trophic level animals, including fish and top predators throughout the food web;

3.7.2 Associated Pressures

i. Pressure: Ocean Acidification

Ocean acidification decreases the availability of carbonate ions in seawater. This results in low carbonate saturation, making shell formation more difficult and slow, and thus increasing the vulnerability of shell-forming species. For example coral uses carbonate ions to form its calcium carbonate skeleton, which forms the basis for coral communities. Ocean acidification can therefore impact individual coral species, and entire coral ecosystems by altering their foundations. Ocean acidification affects ecosystems in areas beyond national jurisdiction to differing degrees, ranging from impacts on individual species or communities, to impacts on regional ecosystems (Fabry et al. 2008).

Marine organisms adapted to oceanic conditions associated with the pre-industrial era cannot tolerate such rapid changes in ocean chemistry as their adaptive response will be too slow to allow survival in the acidified conditions predicted for the 21st Century (Orr et al. 2005). A range of laboratory studies have evaluated the effects of higher acidity (low pH) conditions on both calcareous species and also on non-calcareous species, including fish (Breitburg et al., 2015; Secretariat of the Convention on Biological Diversity, 2014). There are more studies on shell building species and thus the effects are better known than on non-calcareous species. See Figure 3 for a diagrammatic explanation of the pressure pathway.

Studies have noted that ocean acidification has the potential to alter food-web structures, which may ultimately result in declining fish stocks, and degrade regulatory and supporting services such as carbon and nutrient cycles. For example:

- A decrease in pteropod (a type of shelled plankton) populations might affect the biomass of the phytoplankton they feed on (Hopkins, 1987) and impact some fish species including salmon, which primarily feed on these animals (Armstrong et al., 2005);
- Impacts on deep sea corals can result in the deterioration of entire deep sea coral ecosystems and the associated bio-engineer species that support complex ecological communities, including rare and endangered species (Roberts, 2015);
- A decrease in calcifying plankton would alter efficiency of biological carbon absorption and transport to the deep sea (Schiebel, 2002).

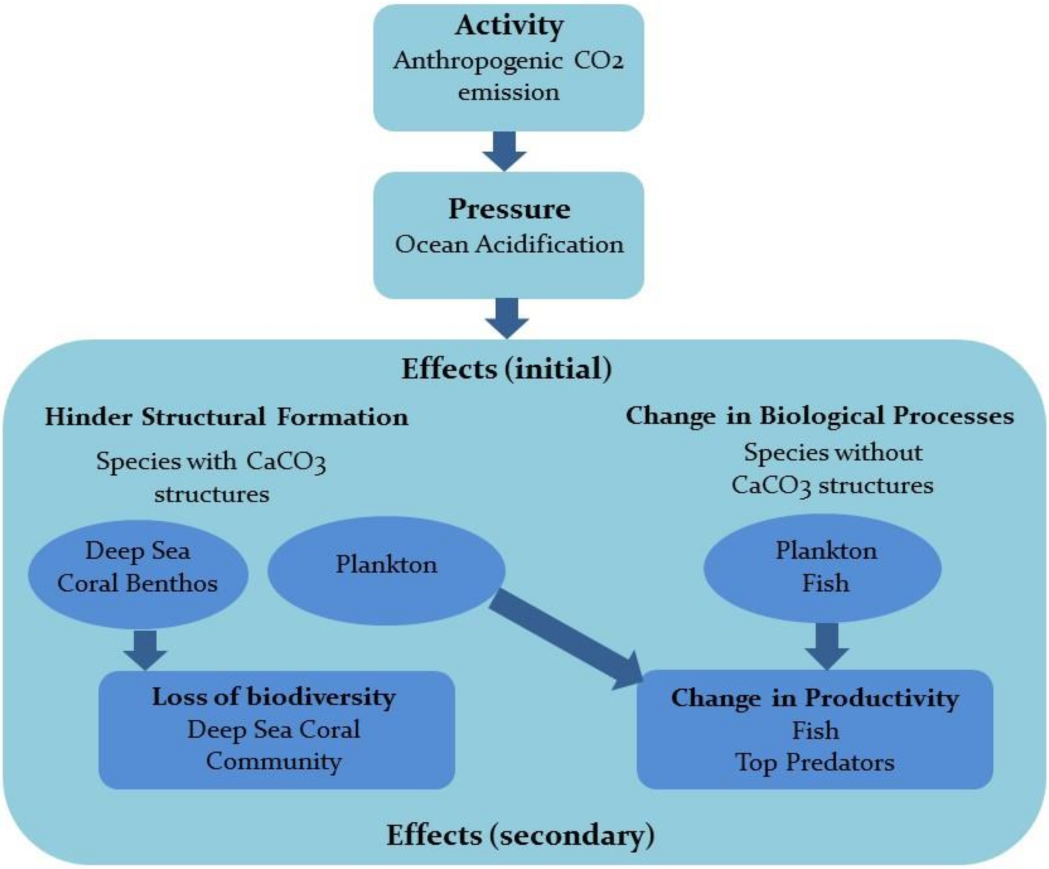

Figure 3: A diagrammatic representation of the pressure pathway associated with ocean acidification

3.7.3 Summary

Anthropogenic carbon dioxide emissions to the Earth's atmosphere have accelerated absorption of carbon dioxide into the global ocean, resulting in acidification of waters in the oceans, including in areas beyond national jurisdiction. Increase in acidity (lowering of seawater pH) has been observed and future projections indicate the threat of acidification to BBNJ will be significant. Species with calcium carbonate structures, such as certain types of plankton and coral (deep sea corals are relevant to areas beyond national jurisdiction), are facing the greatest threat from ocean acidification, which hinders the precipitation of calcium carbonate. Although ocean acidification is a global phenomenon, the extent and magnitude of threats to ecosystems are regionally specific due to differences in ecosystem structures and physical and chemical water properties. Among the most vulnerable regions are the Arctic Ocean and high northern latitude regions, the North Atlantic deep sea, and North Pacific intermediate and deep waters. However caution is also necessary in areas considered to be less vulnerable, as ocean acidification may potentially affect the biology and ecology of endemic keystone species, for example Antarctic krill in the Antarctic Ocean. In addition, calcareous shell and skeletal formation capabilities may also be reduced in lower latitude regions that are currently over saturated with calcium carbonate. However, the effects of ocean acidification on biological processes have been studied almost exclusively in laboratory experiments, thus in-situ acidification effects on individual organisms (including those without calcium carbonate structures), communities, and food webs are not fully understood. Finally, the impacts associated with ocean acidification are likely to interact synergistically with other global pressures, such as water temperature increases, oxygen decreases and changes in salinity. However these interactions and associated impacts are also relatively unknown. Therefore, a high level of uncertainty exists regarding the extent of ocean acidification-induced impacts on BBNJ and the associated economic interests and food provision/security it provides, and consequently the threat from ocean acidification could be considered as high

4 Summary

At present, there are a limited range of activities that take place in areas beyond national jurisdiction. However, this review has shown that all of these activities are increasing in their scale and pressure, and, according to the current research literature, some are already having an impact on deep sea biodiversity. The global population continues to increase and with it, demand for resources. Over the long-term it seems likely that all activities will increase. As such, it is likely that biodiversity in areas beyond national jurisdiction will come under greater pressure in the future. For some activities, such as deep sea mining, there is no current active exploitation occurring in ABNJ although the granting of concessions is still ongoing. For fisheries, data disaggregation between EEZ fisheries and ABNJ stocks is difficult, as is an assessment of the impact of IUU. At this point in time, there does not seem to be an increasing trend in ABNJ fisheries. However, global demand for fish protein is expected to increase which may be a driver to increase activities in currently unexplored areas. Technological capacity increases is likely to support greater exploration in distance and depth, and also the ability to operate activities such as energy generation, far from shores. The emissions of CO2 are currently predicted to increase unless there is significant, and hoped for, mobilisation of action on this area. Further work is required to understand the quantification of the pressures on marine biodiversity. This document only was able to qualitatively assess the pressures from the existing literature.

It should be noted that an increase in activities may not result in direct pressures on biodiversity if methods are used which do not result in impact, or impacts are appropriately mitigated. The exception to this is emissions of CO2, although if activities are undertaken using renewable energy there would be mitigation of this issue. The role of the new Implementing Agreement will be crucial to this. If it can manage activities, both existing and new, ensuring that they are undertaken to minimise the pressures on biodiversity, long-term sustainability could be achieved. In this context, it is important that any negotiations for a future Implementing Agreement is formulated in such a way as to enable adaptation to future changes in pressures and conditions. It is also important that the negotiations involve a wide range of stakeholders, including groups that are inclusive of both males and females, representative deep-sea activity groups, and sectoral decision-making bodies. Gender balance and inclusive negotiations would therefore help to ensure a new agreement can address key stakeholder priorities for sustainable use, including those stakeholders which are underrepresented in sectoral activities.

Table 3: Summary of trends associated with each pressures on BBNJ

Activity	Potential Pressure	Trend in Activity
Bio-prospecting and MSR	Physical loss or damage to seabed	Increasing
	Removal of biological resources	Increasing
Cable Laying	Physical loss or damage to seabed	Increasing
Deep Sea Mining	Physical loss or damage to seabed	Increasing
Energy Facilities	Physical loss or damage to seabed	Increasing
Fishing	Physical loss or damage to seabed	Increasing
	Removal of biological resources	Increasing
Emission of CO_2	Ocean acidification	Increasing

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Appendix 1

Existing and emerging human activities within Areas Beyond National Jurisdiction (sourced from Gjerde *et al.*, 2008)

Status	**Activity**
Existing	Fishing
	Shipping
	Dumping of waste and other matter
	Laying submarine cables
	Marine scientific research
	Bio-prospecting
	Constructing artificial islands and installations
	Military activities
	Overflight
	Archaeological/ salvage activities
Emerging	Activities proposed to sequester CO_2
	Exploration and exploitation of seabed mineral resources (e.g. deep sea mining
	Energy facilities
	Open ocean aquaculture
	Deep sea tourism