ATLAS Deliverable 5.2
Expert assessment of risks to ecosystem services from diverse human drivers in the Atlantic deep sea

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Abstract

In order to assess risks of human drivers in the ocean to ecosystem services supplied by the Atlantic deep sea, we carried out an expert risk assessment amongst the ATLAS project members, using a Delphi approach with two rounds. Central human drivers and ecosystem services were elicited, vetted and developed into a survey. The survey was presented at the ATLAS project general assembly in Mallorca in 2017, where the scientists were given an introduction to the concepts of ecosystem services. They were asked to assess the effects and likelihood of human drivers on ecosystem services provided by Atlantic waters. A total of 30 responses were received, analysed, organized and then presented in a new survey which was developed in SurveyMonkey, and distributed to the project members. In this way the experts could in the second round assess the judgement of their peers, and decide whether to adjust their responses. From the second round a total of 20 responses were received, identifying human drivers posing the most risk to ecosystem services to be pollution, temperature change, ocean acidification, fisheries and cumulative effects. The services most impacted are the provisioning services of fish and shellfish, biodiversity, both as a supporting and cultural services, as well as the supporting service of habitats. Tourism and blue biotechnology were not seen to provide serious risk to any ecosystem services, as was the case for oil/gas and mining, though the former two provided greater positive effects in relation to ecosystem services than the latter two.

1. Introduction

Human drivers perceived to pose most risk to ecosystem services in the Atlantic deep sea are ***pollution***, ***temperature change***, ***ocean acidification***, ***fisheries*** and ***cumulative effects***, and the services most impacted are the provisioning services of ***fish and shellfish***, and the ***supporting and cultural services of biodiversity***, as well as the supporting services of ***habitats***.

Despite the “out of sight, out of mind” nature of the oceans, we are becoming increasingly aware of the fact that oceans are highly impacted by humans through fisheries, pollution and different climate related effects (Halpern et al. 2008). Furthermore, the pressures on ocean environments are increasing with population growth. The European Commission Blue Growth Strategy seeks to support sustainable growth in the marine and maritime sectors as a whole, with a focus on 5 key sectors: aquaculture, coastal tourism, marine biotechnology, ocean energy and seabed mining. This support may pose a challenge to the business and policy communities seeking to balance societal needs with environmental sustainability. One way to consider the balance between the blue growth economic agenda and sustainability is to assess the potential impacts or risks of blue growth on the ecosystem services provided by the deep sea.

Ecosystem services are usually described as those services or benefits that ecosystems provide for humans. There exist a number of different ecosystem service frameworks that have been developed over the last fifteen years. We apply the Millennium Ecosystem Assessment’s (MEA 2005) framework in our analysis (see Figure 1 below). This framework includes supporting services that feed into the direct services to humans; the provisioning, regulating and cultural services. A number of newer frameworks, such as TEEB, CICES and IPBES do not include supporting services explicitly in their service portfolio (TEEB 2010; CICES 2013; IPBES 2017). The motivation for not including the supporting services is largely due to the issue of double counting values. When monetarily estimating the value of ecosystem services, supporting services cannot be valued separately, as their values are inherently included in the value of the direct services that they feed into. As we do not carry out any valuation in this study, double counting is not an issue we need to take into account. Furthermore, in our study area, the deep sea, most ecosystem services are removed in time and space from humans, and hence very many services are of the supporting type (Armstrong et al. 2012).

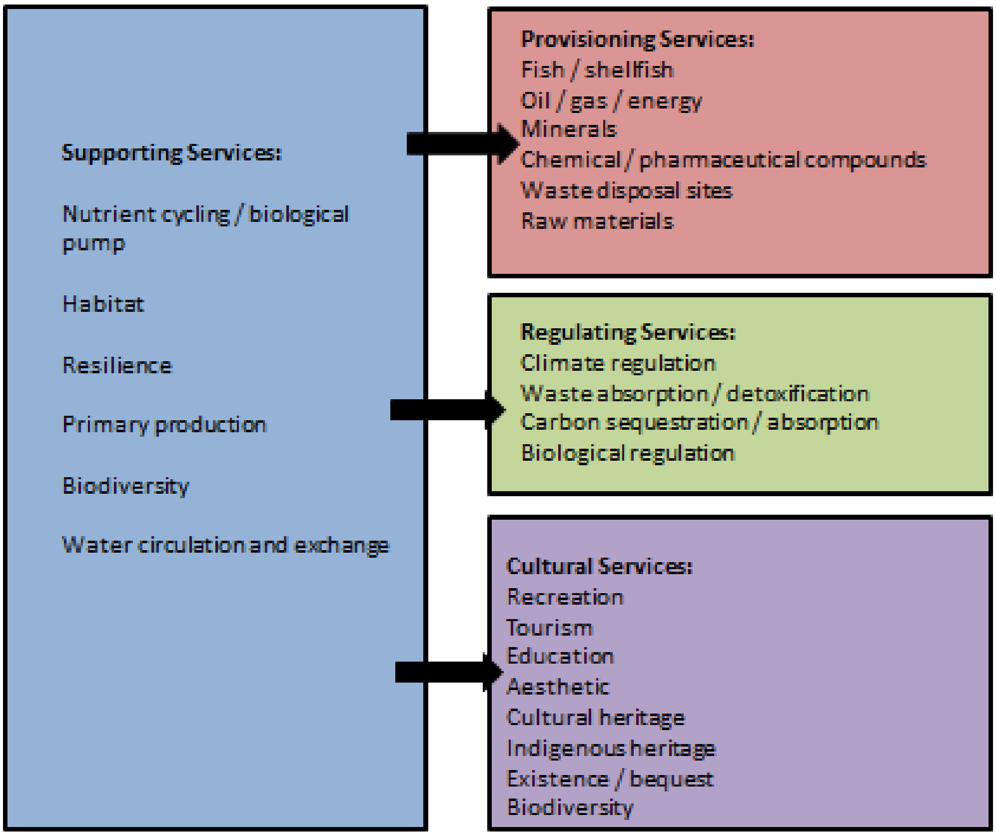

Figure 1. Ecosystem services in the deep sea, using the Millennium Ecosystem Assessment framework.

In the ocean, global change and human activities have major impacts on marine ecosystems, their processes and functions. These impacts again affect and pose risks in relation to services that the ecosystems provide to humans. In order to assess any form of risk, hazards and their consequences and probability of occurrence need to be identified. There is a multitude of studies assessing risks of specific activities, such as oil spills, aquaculture or shipping on specific resources, environments, ecosystems or their functions in the marine (Soares and Teixeira 2001; Olita et al. 2012; Copp et al. 2016). However, there few studies that integrate risk assessments and ecosystems services (see Nienstedt et al. (2012) for a terrestrial example), or are mainly limited to the discussion regarding the approach (Faber and van Wensem 2012; Galic et al. 2012). There are several reasons for the lack of literature. For one, the assessment of risks in relation to *natural environments* or *ecosystems* is often very demanding in itself. Knowledge is limited, and the consequences can be highly diverse as well as controversial. Bringing the risk analysis one step further, to *ecosystem services*, can, therefore, be even more challenging. A second issue is; who are the experts that should assess the risk to ecosystem services? Clearly, natural scientists well versed in ecology are natural experts in relation to risks to ecosystems, but who are the experts in relation to ecosystem *services*? Ecosystem services are after all services from ecosystems that provide benefits to humans (MEA 2005), i.e. the link to humans is essential. Though natural scientists may describe the impacts on ecosystems, can they also assess impacts on services to humans from ecosystems? Many economists assess values connected to ecosystem services (TEEB 2010), but are they necessarily the experts to assess unvalued risks, i.e. risks to ecosystem service provision as such? Though, social scientists, in general, have not criticized the concept of ecosystem services to the same degree as some ecologists have (Silvertown 2015; Morelli and Møller 2015), they cannot be said to completely embrace it. And yet, who could be more qualified to identify what benefits humans obtain from ecosystems than social scientists? However, social scientists have often focused more on the interaction between humans, the different types of relationships, etc, than perhaps individual or societal beneficiary interactions with ecosystems. Therefore, due to lack of specific experts in this matter, we have chosen to use a broader set of expertise to assess the risks to ecosystem services in the deep sea; we apply as our expert base the members of the ATLAS project which consists of a large variety of expertise in relation to the deep sea. The experts range from physical oceanographers (WP1), ecosystem modelers (WP2), deep sea ecologists (WP3), deep sea genetic specialists (WP4), natural resource economists and social scientists (WP5), and marine policy specialists (WP6 & 7).

Why is it of interest to assess risks to *ecosystem services*, rather than environments, ecosystems or ecosystem functions? Clearly, the push within the EU for marine ecosystem based management is central in the aim for a broader perspective on the use of marine resources (MSFD 2008). The concept of ecosystem services, which has in recent years increasingly appeared in research, but also in policy and management (see for instance the MAES: Mapping and Assessment of Ecosystems and their services, under Action 5 of the EU Biodiversity Strategy to 2020, and the EU Blue Growth Strategy) brings nature's contributions to humans to the forefront. Assessing risks to these services brings the consequences of human drivers directly in contact with societal aspects, i.e. the risks are brought closer to the issues that managers and politicians are directly considering. Whereas risks to ecosystems and their functions are of course important, there is at least one layer of knowledge between the output of these kinds of assessments and the human dimensions that managers and policy makers relate to. In going directly to the ecosystem services, we bring the risks of human drivers in a sense closer to home. This is especially important regarding risks related to the deep sea, since the knowledge of these deep ecosystems and their services are limited, and since the deep sea is often both spatially and temporally distant to the services that humans value. It is, therefore, all the more important to make this link, in order to identify the riskiest drivers, and from this provide input into where more work must be done to mitigate or adapt to the risks involved.

The risk assessment we have chosen to undertake is applied using a Delphi approach, i.e. an iterative expert –based survey approach in order to see whether perceptions may reach more consensus based on information about one's peers choices in a previous round of the survey. Hence, in this study we carry out the following; we assess **risks of human activities or drivers** on **ecosystem services** in the deep sea, using expert elicited **risk assessments** in a **Delphi** format. The results expand our knowledge of how a broad set of ecosystem services from the deep-sea are impacted by human activities. Furthermore, the study provides input in relation to future priorities regarding research in the Atlantic deep sea.

2. Methods

Delphi survey

The Delphi method has its origins from the RAND Corporation in the 1950s and 1960s and was largely motivated by the need for improved forecasting and securing some form of judgement convergence (Dalkey 1968). Over the years it has been utilized in a multitude of different assessments spanning from health issues (Steen et al. 2014; Keller et al. 2015) to challenges in the pulp and paper industry (Toppinen et al. 2017). The method is largely used in order to obtain some form of opinion consensus, and yet avoiding the influence of dominant individuals. In recent years at has also increasingly been applied in relation to environmental issues, such as valuation (Strand et al. 2017), and especially in relation to issues where there is limited ecological knowledge (Scolozzi, Morri, and Santolini 2012).

The method is usually characterized by three main concepts; 1) anonymity – the participants, usually experts in the field, are contacted by mail or email, 2) iteration – a single survey is carried out two or more times and 3) feedback – the surveys following the first, convey results from previous surveys. The Delphi method relies on a panel of experts in order to gather information; this is often due to limited knowledge regarding the service or good. The technique gathers expert opinion, usually in an iterative, anonymous survey with feedback. The survey is therefore sent around twice or more. In the second round, the information regarding the results of the first round is distributed in order to allow the experts to re-evaluate their previous assessment and to see if there may be some more agreement or convergence regarding the issue surveyed. The objective is to allow information produced by an expert group to be evaluated, building consensus over time (see the stages in the Delphi approach in Table 1).

Table 1. Stages in Delphi survey approach

Steps	
1	Definition of problem
2	Selection of experts
3	Survey instrument development
4	Testing of survey instrument
5	Distribute 1st survey
6	Analysis of 1st round results, and development of presentation for 2nd survey
7	Distribute 2nd survey
8	Analysis of 2nd round results, comparison to 1st round, develop report

Though the Delphi process is presumably more reliable than a single survey, the method has been critiqued for group pressure rather than knowledge development leading to consensus in repeated surveys (Woudenberg 1991). The Delphi approach is however also roundly defended, especially in relation to complex issues (de Loë et al. 2016) and topics where information is not easily come by (Landeta 2006). Also in other fields where surveys are used, giving respondents time to reflect, discuss and gather information is seen as a way to secure responses that are more reliable (MacMillan, Hanley, and Lienhoop 2006).

Risk assessment

The risk assessment survey was developed based on literature on ecosystem services in the deep sea (Armstrong et al. 2012; Galparsoro, Borja, and Uyarra 2014; Thurber et al. 2014), and assessment of relevant human drivers in the research group (see Table 2), and tested on different project members. After revisions, a special session was held for all project members at the 2nd ATLAS General Assembly in April 2017 to gather data for the Delphi ecosystem service risk assessment. The session included a brief introduction to the aims of the work, the Delphi method and ecosystem services. The project members were given some explanatory material (see Appendix 1) and the survey in an Excel sheet via email (see Appendix 2), and asked to complete it. A few project members submitted the survey during the project meeting, while most were submitted in the following weeks. Anonymity was guaranteed. A total of 30 surveys were submitted and included for analysis. The responses in the surveys were analysed, figures were made to present relevant results and a new survey using results from the first survey (see Appendix 3) was developed using SurveyMonkey (https://www.surveymonkey.net/) (see Appendix 4 for an example page). This second survey was distributed to the ATLAS project members at the end of October 2017, and two reminders were sent out. By mid-November 20 surveys from participants who had taken part in the first round were received. These were then analysed, and compared to the first round, as presented in the Results section.

Table 2. Human drivers identified for the Delphi survey risk assessment

Identified Human Drivers
Tempertaure change
Ocean Acidification
Fishing
Pollution
Oil and Gas
Mining
Tourism
Blue Biotechnology

Risk is the product of two entities, consisting of 1) some measure of the consequences of an occurrence and 2) the likelihood that the occurrence will take place. Usually, the occurrence is defined as some hazard. However, occurrences need not be hazards causing negative effects, though this is usually what we worry most about, and are most interested in identifying. In our case, the hazards are presented as the combination of different human drivers impacting on ecosystem services. These drivers need not always lead to negative effects on all ecosystem services and in some cases provide positive effects, or there may indeed be reasons to believe some drivers may have both positive and negative effects. Our study involves a large number of ecosystem services and human drivers across the North Atlantic ocean. It is recognized that there is currently limited knowledge on the deep sea and this leads to increased uncertainty in the study. As such experts could note positive and negative effects in our assessment. Hence the assessment allows for positive and negative effects, with a scale of 1-5 (from very low severity to very high severity), as well as neither being applicable for some drivers in relation to some ecosystem services. The likelihood of the effect occurring is also measured on a scale of 1-5 (very low probability to very high probability).

After receiving the responses from the experts, the results were analysed and organized in order to be included in the second round of the survey. Presenting risk reporting matrices in the fashion of likelihood and effect as shown in **Error! Reference source not found.**, where the two axes are represented by rank numbers, is not uncommon (see for instance FAO guidelines for Ecosystem Approach to Fisheries http://www.fao.org/fishery/eaf-net/eaftool/eaf_tool_4/en#EAFTool-EAFToolSynergy).

Such a presentation of risk may, however, be problematic, and must be used with caution (Cox Jr. 2008). Risk assessment, in general, can also be critiqued based on normative aspects and in relation to problems of aggregation (Stirling 1998). However, caution is largely suggested in relation to decision-making in high-risk situations. For the use of assessing risk aspects in relation to broad categories of ecosystem services, such as we are carrying out here, many of the cautions are less problematic.

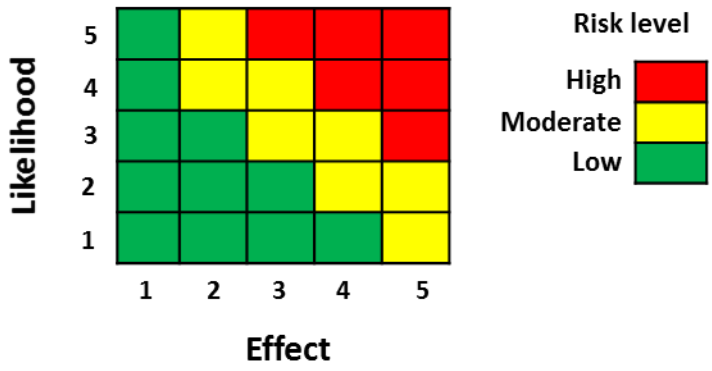

Figure 2. Risk reporting matrix

It is, however, worth noting the choice of grid lines in the risk matrix (i.e. where the high, moderate and low risk is assigned) is highly subjective. Clearly, these lines should be determined by some aim to "minimize the maximum loss of misclassified risks" (Cox Jr 2008, p 510), but this requires a lot more knowledge regarding consequences than is available for our study and is seldom problematized in risk assessments.

3. Results

The results from the First Delphi survey can be found in Appendix 3, where we present the text that was used in the Second Delphi survey in order to illustrate results from the first survey. As the first round of the Delphi is used to inform respondents in the following round in order to potentially secure greater consensus in the second round, we will in the following concentrate on the output from the second round. In our presentation of the results from the first survey, we showed first the perceptions of *negative* effects, as these are of most interest in relation to policy, research, mitigation and adaptation. Similar figures for the results from the Second Delphi survey, as that of the first round (in Appendix 3), are presented in Appendix 5. The general impression these figures give is that the supporting services are perceived to be the most negatively impacted, of the four service types.

As we are operating with ordinal variables, we use the median severity and the median likelihood of the negative effects, for all services and all drivers. The resulting high, medium and low risk effects of human drivers on different ecosystem service assessments are presented in Figure 3.

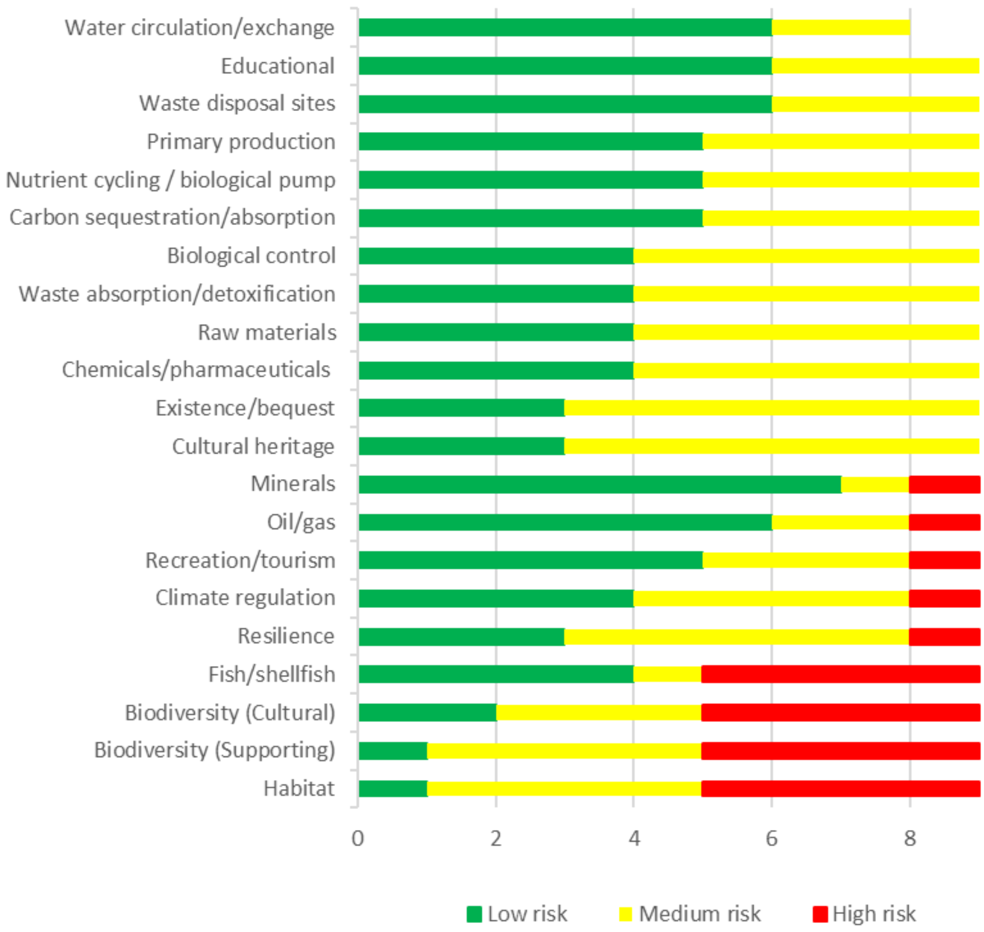

Figure 3. Ecosystem service risk levels from the nine human drivers. From the assessment of negative effects of human drivers on ecosystem services.

Here we observe that Habitat, Biodiversity (both as supporting and cultural services), as well as Fish/shellfish are the services most at risk. The services of Resilience, Climate regulation, Recreation/tourism, Oil/gas and Minerals are only at high risk in relation to one driver each (and the latter two solely in relation to their own drivers), while the remaining services only appear at at medium and low risk.

In Figure 4 we illustrate the different human drivers, and how they impact on the 21 ecosystem services as regards high, medium and low risks.

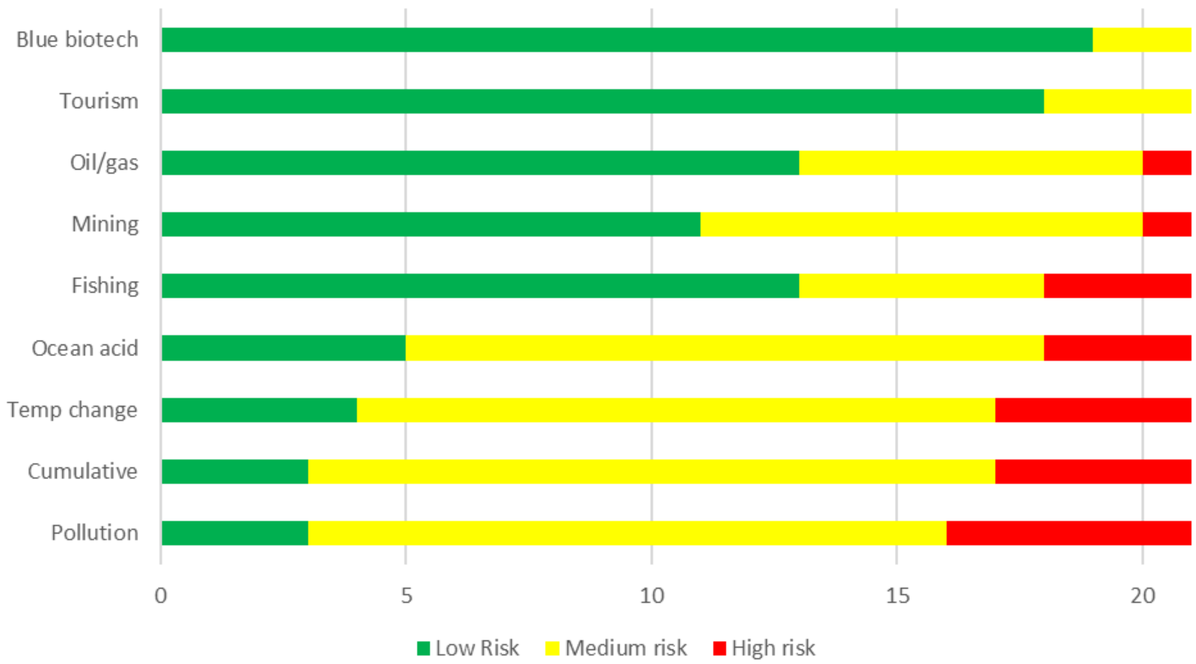

Figure 1: Human driver risk levels upon ecosystem services, From the assessment of negative effects of human drivers on ecosystem services,

Pollution causes high risk to most services (effecting five services), while temperature change and cumulative impacts cause high risk to four ecosystem services respectively. These are followed by ocean acidification and fishing, causing high risk to three ecosystem services. Tourism and blue biotechnology are not perceived to have any high risk impacts on ecosystem services, and oil/gas, and mining are only perceived to be high risk in relation to services from these industries themselves.

In Figure 5 we have included the *positive* effects of the different human drivers on different ecosystem services, in order to view the expectation of positive versus negative effects of different human drivers[1]. Each separate figure in Figure 5 shows the positive and negative effects, using green and red coloured bubbles, respectively. The size of the bubble illustrates how many services are represented at each point of likelihood and severity of effect. Here we observe that for temperature change, ocean acidification, pollution, fisheries and cumulative effects, the negative effects come at far higher risk

[1] We chose not to develop a single risk measure by using the product of the two digits from effect and likelihood, despite this not being uncommon in the literature (Staples et al. 2014), as products of ranked measures may give spurious results when compared (Hubbard and Evans 2010; Cox Jr. 2008).

levels than the positive. This can be seen from the red bubbles concentrating to the upper right of the figures, while the green are more to the left. For oil and gas, mining and tourism, this effect is less clear, especially for the two latter human drivers.

When comparing the first and the second Delphi rounds, it is clear that in the in the second round there was a greater perception of high risk. Mainly services that were at high risk from some drivers (such as fish/shellfish, biodiversity and habitat), received additional high risk gradings in relation to other drivers as well. It is, however, worth noting that the second round is only based on 20 responses versus 30 in the first round. Comparing the bubble graph in Appendix 3 with Figure 5 also shows that the second round assessment has a greater spread, but mainly in relation to the positive effects. For instance, although the positive cumulative effects are thought to be low in the first round, in the second round the positive cumulative effects are more scattered, indicating responses that are more diverse.

After the risk assessment we asked how certain, on a scale of 1 to 5 (with 1 being very uncertain and 5 being very certain), the respondents were regarding their answers. The median level was 3 for both surveys, but the average certainty decreased slightly from the first to the second round.

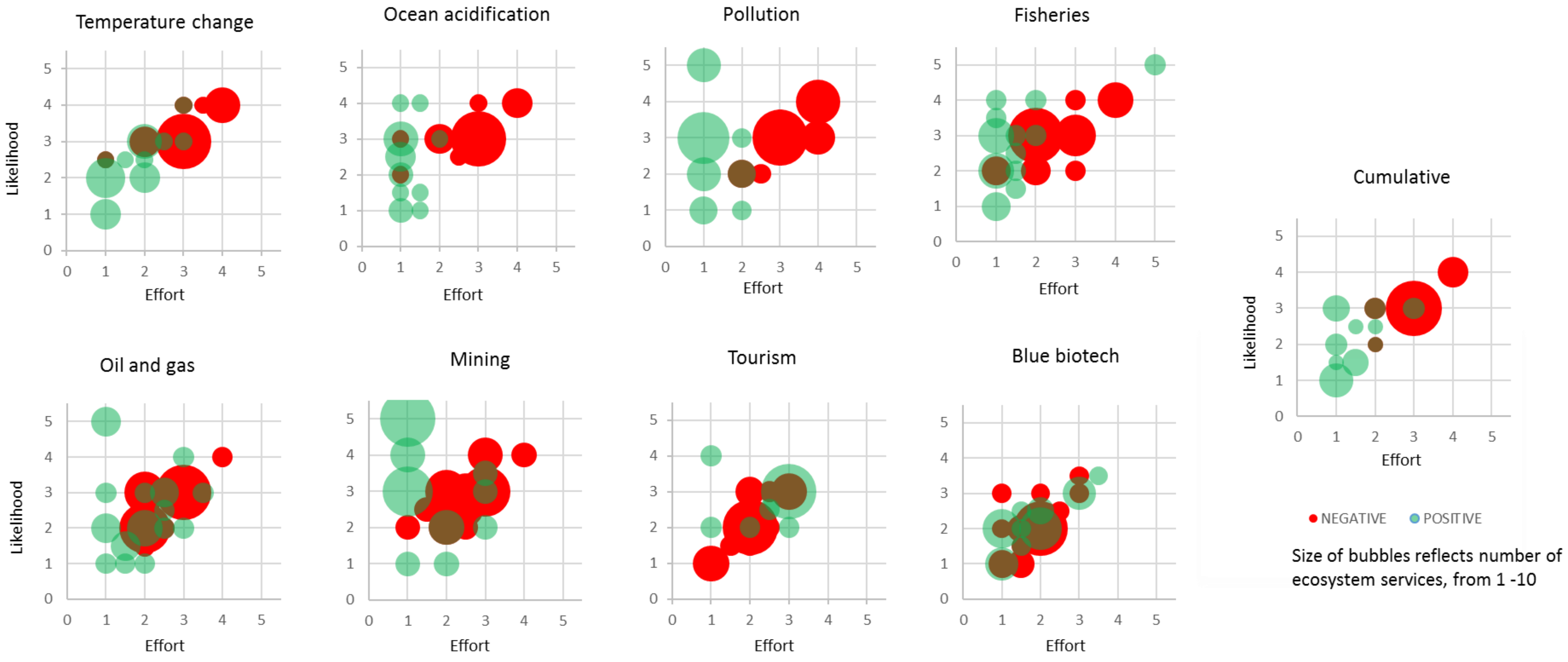

Figure 5. Risk assement for different ecosystem services: Median likelihood, positive (green) and negative (red) median effect of different human impacts.

4. Discussion

The survey points to four high risk human drivers: pollution, temperature change, ocean acidification nd fisheries, in addition to the cumulative effects. This is similar to the work by Halpern et al. (2008), who using a number of databases combined with an expert judgement based area assessment, show how Northern Atlantic ecosystems, especially in the east, are highly impacted, and identify central drivers behind these impacts. The authors show that the climate drivers (sea temperature, UV and ocean acidification), impact the largest ocean areas. However, though fishing covers far less area, different aspects of fishing (different types of by-catch as well as habitat modification), was perceived to pose similar threat levels as that of the climate factors. Interestingly pollution was given far less attention in the Halpern et al. (2008) study than it is in our results. This may be a result of further knowledge about the extent of marine pollution over the last 10 years, or that pollution is perceived to have a greater impact on ecosystem services than on marine ecology, the latter which was the focus of the Halpern et al. (2008) study.

In our study, the four main drivers, pollution, temperature change, ocean acidification and fisheries, in addition to cumulative effects, are followed by oil/gas and mining, though interestingly these two industries are seen as far less risky in relation to ecosystem services. Blue biotechnology and tourism are perceived to provide the greatest positive effects and likelihoods, with oil/gas and mining following them.

The main contribution of this study is to focus on risk to ecosystem services, rather than marine ecology or ecosystems, which is what is usually studied. Here we observe that the most threatened ecosystem services, i.e. services with high risk levels in relation to most human drivers, are fish and shellfish, biodiversity (both as a supporting and a cultural service) and habitats. Provisioning (fish/shellfish), cultural (biodiversity) and supporting services (biodiversity and habitats) are perceived to be at risk from the largest number of human drivers. The only regulating service at risk was climate regulation, due to temperature change. Indeed, supporting services were perceived to be the most at risk. This is noteworthy, as when focusing on ecosystem services most of the newer frameworks (TEEB 2010; CICES 2013; IPBES 2017) largely do not include supporting ecosystem services. An important message is that if the focus is only given to the three ecosystem service types that directly impact humans (provisioning, regulating and cultural), we may clearly ignore important impacts and their risks.

This study has a number of qualifications worth mentioning. One is that the numbers of responses are limited, especially in the second round. Attempting to gather more responses would strengthen the study. Potentially organizing the likelihood in a different fashion, for instance in probabilities rather than ranks, would allow a more multiplicative presentation (probability multiplied by effect), though as mentioned earlier, this is not without its problems. Giving the respondents more information must be evaluated against the time needed to carry out the survey. Yet, more information on the variance in the results could have been informative. The survey is very large and demands a lot of the respondents. One option could be to limit a follow-up survey to the most high risk drivers and ecosystem services, in order to probe these further.

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Appendix 1. Delphi survey explanatory material

Dear scientist,

As part of WP5 we are aiming to identify the **risks and pressures** to **ecosystem services** in the North Atlantic from existing and potential future economic activity. To achieve this we are carrying out a Delphi study among scientists to probe for information on risks to ecosystem services that the ocean provides.

The Delphi method relies on a panel of experts to gather information; this is often due to limited knowledge regarding the service or good. The technique gathers expert opinion, usually in an iterative, anonymous survey with feedback. The objective is to allow information produced by an expert group to be evaluated, building consensus over time.

The survey is therefore sent around twice or more. In the second round the information regarding the results of the first round are distributed in order to allow the expert to re-evaluate their previous assessment and to see if there may be some more agreement or convergence regarding the issue surveyed.

We realise that you may not have detailed knowledge regarding parts of the survey. Note however that the survey is an attempt to assess expert *opinion*, especially where knowledge is limited, as in the deep sea. This is therefore a survey of your personal opinion.

The risk assessment matrix is the central part of the survey, but the table of ecosystem services in case study areas, and the follow-up questions are also central to different deliverables in WP5.

Attached is an explanation of the survey.

THE SURVEY EXPLAINED

1. Please enter the relevant personal information.

Example:

Your nationality:	Norwegian
Your expertise:	Economics
Your gender:	female

2. Ecosystem services are listed along the side of the risk matrix and the table of case study ecosystem services. If you feel central services are missing, please add to the Other box.

Ecosystem services:	
Provisioning	Fish/shellfish
	Oil/gas/energy
	Minerals
	Chemicals/pharmaceuticals
	Waste disposal sites
	Raw materials
	Other….
Regulating	Climate regulation
	Waste absorption/detoxification
	Carbon sequestration/absorption
	Biological control
	Other….
Cultural	Recreation/tourism
	Educational
	Cultural heritage
	Existence/bequest
	Biodiversity
	Other….
Supporting	Nutrient cycling / biological pump
	Habitat
	Resilience
	Primary production
	Biodiversity
	Water circulation/exchange
	Other….

Note that in the risk assessment matrix we are asking you to refer to the **North Atlantic** overall (i.e. not just your case study area). Associated human pressures are shown in the top row of the matrix. Additional risks or pressures can be added to the 'Other' box at the end.

The first four human activity/impacts in the risk matrix:

Temperature change			Ocean acidification			Fishing			Pollution		
Pos/Neg	Effect	Likelihood	Pos/Neg	Effect	Likelihood	Pos/Neg	Effect	Likelihood	Pos/Neg	Effect	Likelihood

The different human activity/impacts are to be assessed using the three measures below:

Positive and/or negative effect	(+, - or na, i.e. positive effect, negative effect or not applicable)
Long run effect - up to year 2100	(Number shows degree of severity of effect from 1 to 5 where 1 = very low to 5 = very high degree of severity)
Likelihood of effect occuring	(Number shows how probable it is that there will be an effect upon the ecosystem service 1 = very low to 5 = very high probability)

I. e. identify whether each activity / impact will have a positive or negative effect on the different ecosystem service. If you think there may be both positive and negative effects, then you can put this in on the separate lines in the relevant boxes (see example below).

Then rank both the *effect* and the *likelihood* of the effect occurring on scales of 1 to 5.

Example of filling in the matrix (note: If you think some activities/impacts are not applicable in relation to some ecosystem services, then just write na in the Pos/Neg box):

		Temperature change			Ocean acidification			Fishing		
Ecosystem services:		Pos/Neg	Effect	Likelihood	Pos/Neg	Effect	Likelihood	Pos/Neg	Effect	Likelihood
Provisioning	Fish/shellfish	+	3	3	-	3	2	-	4	4
		-	4	5						
	Oil/gas/energy	na			na			na		
	Minerals	na			na			na		

After you have filled in the matrix, please assess your personal *certainty* with regard to your assessment (on a scale from 1 to 5), and state which aspects you are most certain and uncertain about.

Example:

On a scale of 1 to 5 (1 = very uncertain, 5 = very certain) how certain do you feel about your answers:		2
Are there some aspects above that you feel very certain or uncertain about?		
	Very certain:	Fishing effects
	Very uncertain:	Ocean acid

In the Ecosystem service table, we ask you to state the case study area (or areas) you are referring to, and then tick the cell if the relevant ecosystem service is present.

Example using the LOVE and Azorean case study areas:

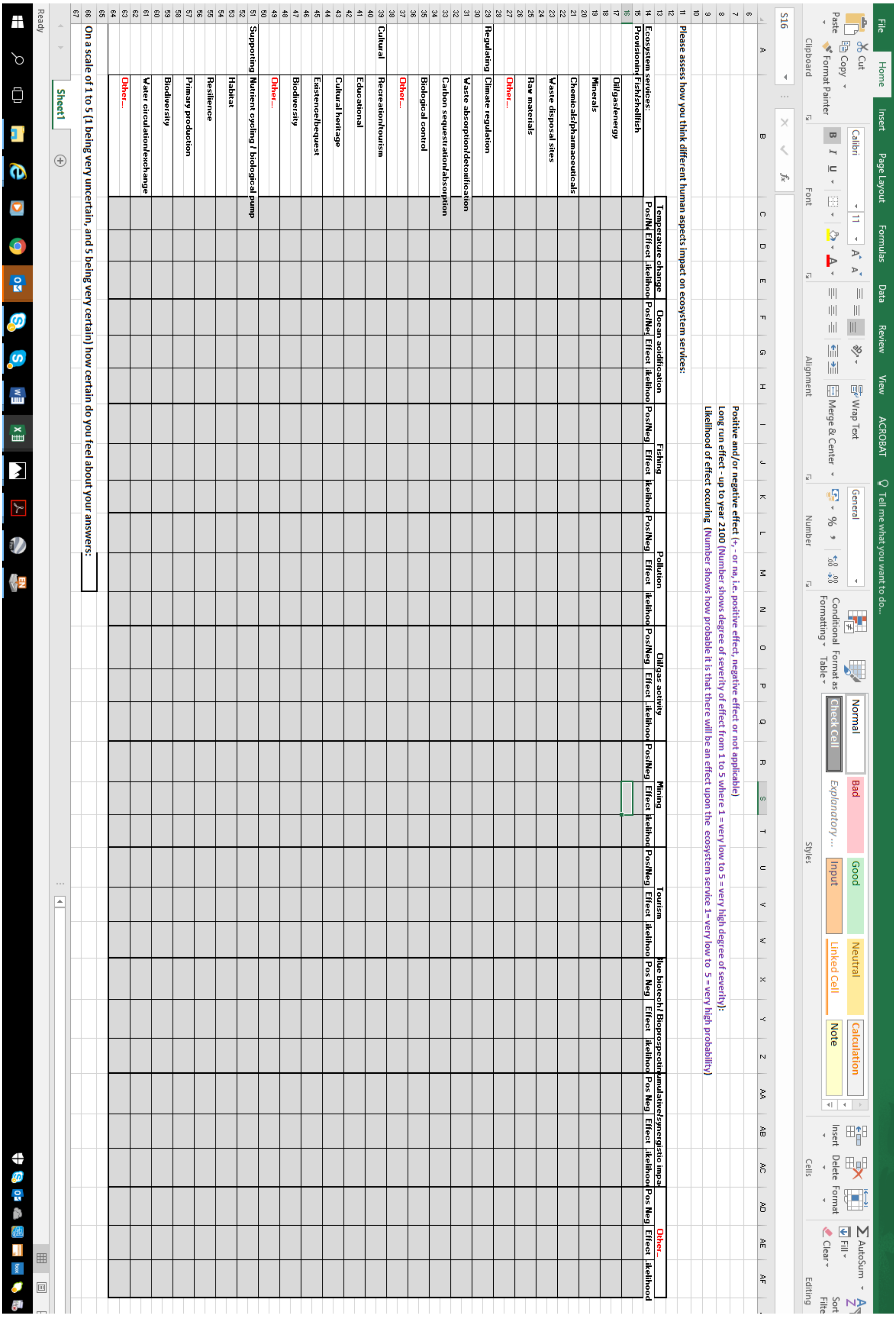
Please note the ecosystem services you believe to be present in *a (or several) Atlas case study areas*			
		Case study area: LOVE	**Case study area:** Azores
Ecosystem services:		***Tick for presence***	***Tick for presence***
Provisioning	**Fish/shellfish**	x	x
	Oil/gas/energy	x	
	Minerals		x
	Chemical/Pharmaceuticals	x	x
	Waste disposal sites	x	x
	Raw materials	x	
	Other....		
Regulating	**Climate regulation**	x	x
	Waste absorption/detoxification	x	x
	Carbon sequestration/absorption	x	x
	Biological regulation	x	x
	Other....		
Cultural services	**Recreation**	x	

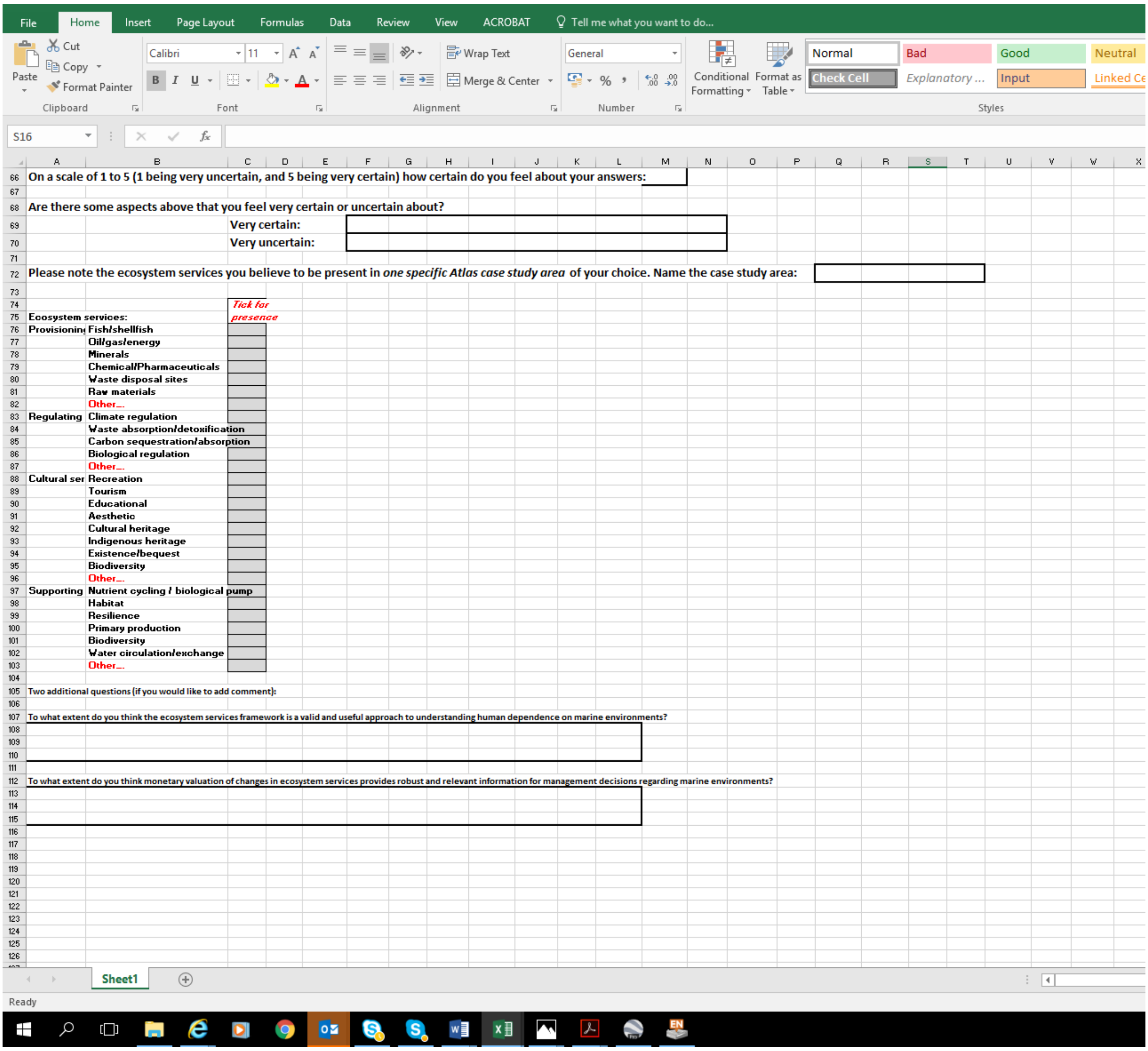
The final open-ended questions in the survey are valuable input for WP5, and give you an opportunity to comment.

Please remember to send to **claire.armstrong@uit.no**

Thank you very much!

Appendix 2. The Delphi survey – version 1





On a scale of 1 to 5 (1 being very uncertain, and 5 being very certain) how certain do you feel about your answers:

Are there some aspects above that you feel very certain or uncertain about?

Very certain:

Very uncertain:

Please note the ecosystem services you believe to be present in *one specific Atlas case study area* of your choice. Name the case study area:

Ecosystem services:		Tick for presence
Provisioning	Fish/shellfish	
	Oil/gas/energy	
	Minerals	
	Chemical/Pharmaceuticals	
	Waste disposal sites	
	Raw materials	
	Other...	
Regulating	Climate regulation	
	Waste absorption/detoxification	
	Carbon sequestration/absorption	
	Biological regulation	
	Other...	
Cultural ser	Recreation	
	Tourism	
	Educational	
	Aesthetic	
	Cultural heritage	
	Indigenous heritage	
	Existence/bequest	
	Biodiversity	
	Other...	
Supporting	Nutrient cycling / biological pump	
	Habitat	
	Resilience	
	Primary production	
	Biodiversity	
	Water circulation/exchange	
	Other...	

Two additional questions (if you would like to add comment):

To what extent do you think the ecosystem services framework is a valid and useful approach to understanding human dependence on marine environments?

To what extent do you think monetary valuation of changes in ecosystem services provides robust and relevant information for management decisions regarding marine environments?

Appendix 3. Text in the 2nd Delphi survey about results from the 1st Delphi survey. Assessing the risk in the Delphi survey – first round

For Tables 1 and 2 below we computed median scores for all negative effects and likelihoods that experts scored for the ecosystem services in Round 1 of the ATLAS Delphi survey. These median scores were used to classify the effects and likelihoods into five classes ranging from “very low” effects and likelihoods to “very high” effects and likelihoods. The colour coding is given in the tables below.

Table 1. The negative effect of human activities on ecosystem services

Classes	Effect/Likelihood	Colour
Very low	1.0 to 1.7	
low	greater than 1.7 to 2.5	
medium	greater than 2.5 to 3.3	
high	greater than 3.3 to 4.1	
very high	greater than 4.1 to 5.0	

Table 2 The likelihood of negative effects on ecosystem services

Median Effect and Likelihood on all Ecosystem Services

In these bubble plots we graph the median effect and likelihood of all human impacts upon all ecosystem services. The sizes of the bubbles are determined by the number of services in each median category. The green bubbles are the number of services that are positively impacted, while the red are the services that are negatively impacted. For instance. When looking at the top left bubble plot, it presents the median effect and likelihood of temperature change on ecosystem services. Here we observe that there is a large number of services with a median of about 3 for both effect and likelihood, but a few services with high negative risk, i.e., the red bubble at point (4,4).

We created these plots by first dividing responses into positive and negative effects on ecosystem services. We then computed frequencies for each coordinate of effects and their corresponding likelihood scores. The coordinates of effects and likelihoods were plotted as bubbles and the sizes of the bubbles are determined by the frequencies. We performed the above two procedures for negative and positive effects separately.

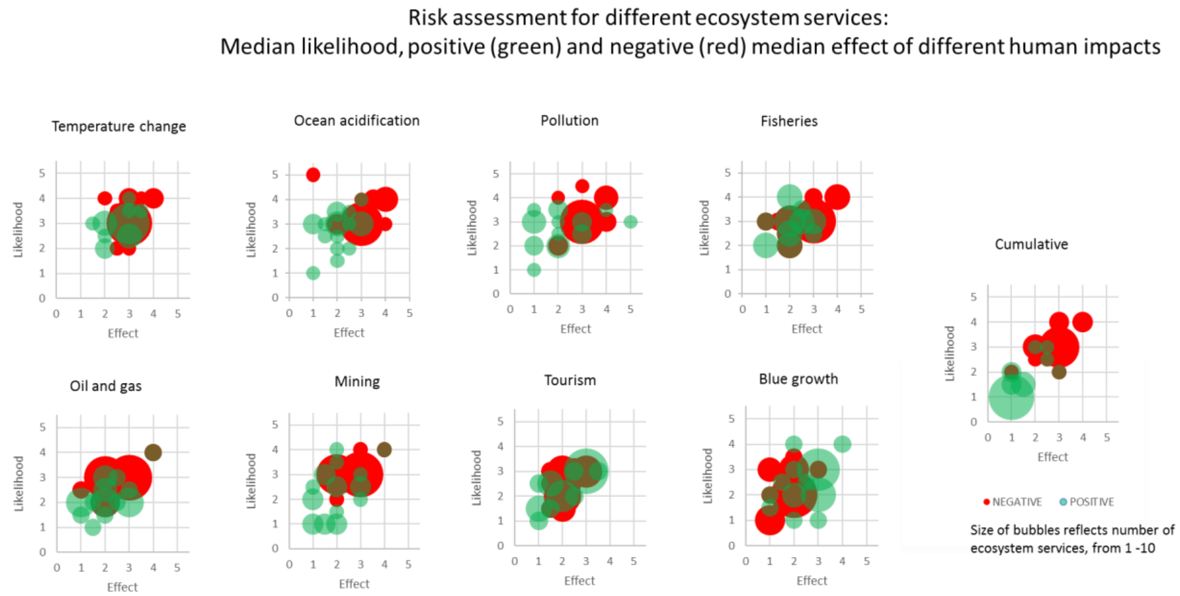


Figure 1. The risk connected to human impacts on ecosystem services

Ecosystem Services Risk Assessment Matrix

The median scores we presented for both effects and likelihoods separately in Tables 1 and 2 above, were combined for risk assessment using the risk assessment matrix in Table 3 below. In the risk assessment matrix, high effects and high likelihoods indicate high risk and low effect and low likelihoods indicate low risk.

If we use a risk reporting matrix such as the one given in Figure 2 below, we find that there are only services at high risk level in our study where the median likelihood and effect are (4,4). I.e. there are no cases of the remaining red areas in the figure below.

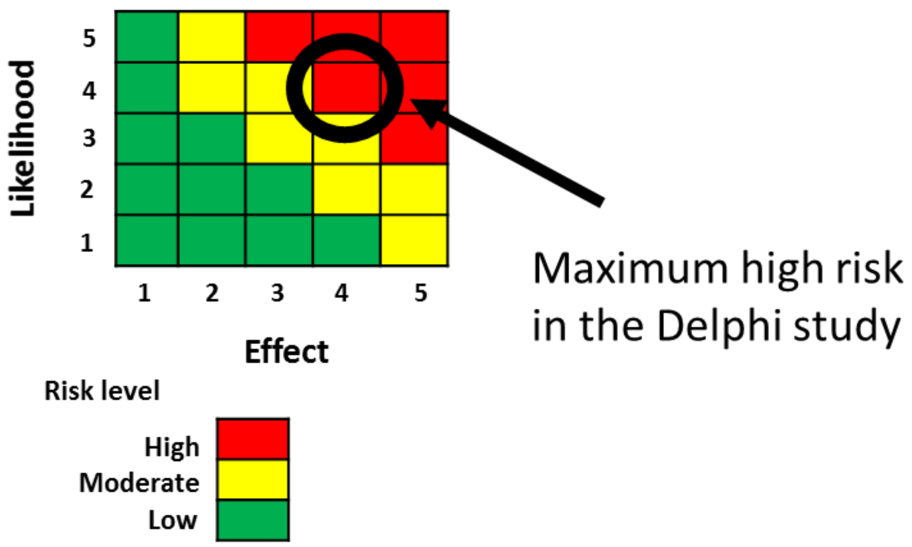


Figure 2. Risk reporting matrix

For two human drivers, tourism and blue biotech, there are no high risks perceived for ecosystem services. Ocean acidification and pollution results in 3 services at high risk, temperature change and fishing puts 2 services at high risk, while oil/gas and mining puts 1 service at high risk (oil/gas/energy and minerals!) at high risk. Interestingly cumulatively only two services are at high risk – biodiversity as a cultural and as a supporting service. This despite the fact that several services are at high risk from several human drivers (this is the case for services biodiversity, fish/shellfish and climate regulation). Some services are at risk from one driver only (this is the case for oil/gas/energy, mining, carbon sequestration/absorption and habitat.

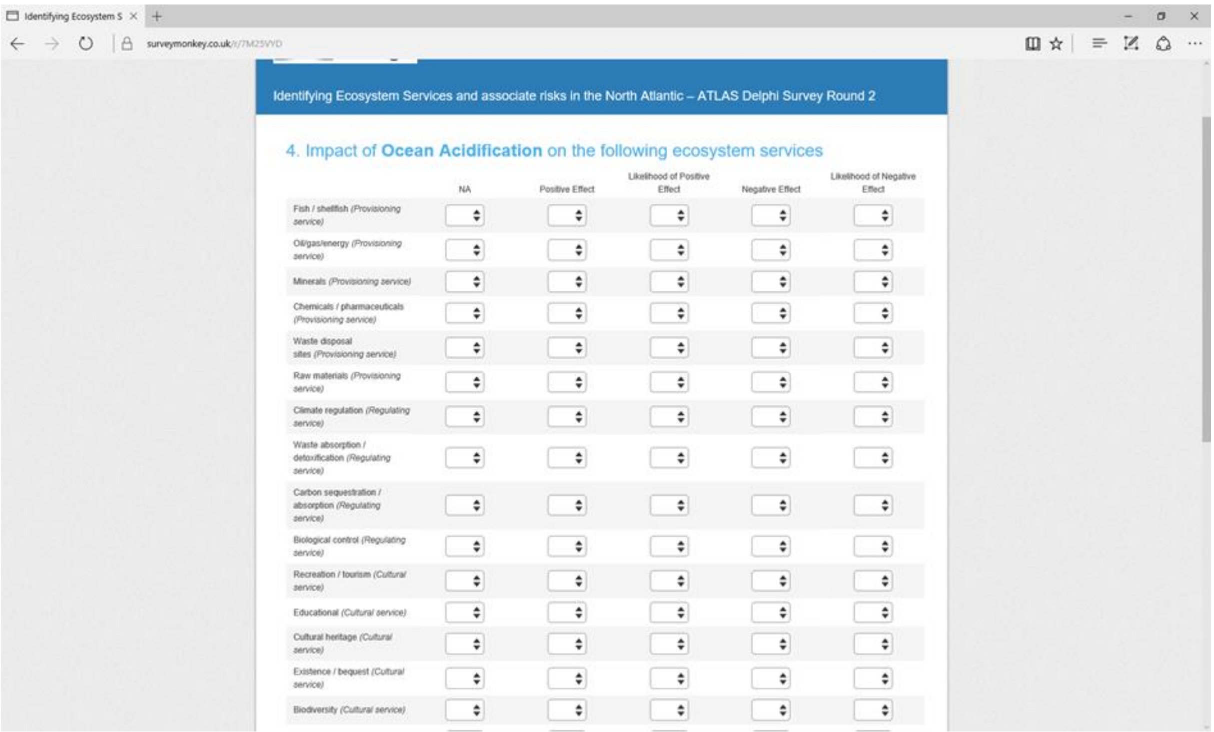
Table 3.

		TEMPERATURE CHANGE		OCEAN ACIDIFICATION		FISHING		POLLUTION		OIL/GAS		MINING		TOURISM		BLUE BIOTECH		CUMULATIVE	
		Effect	Likelihood	Effect	Likelihood	Effect	Likelihood	Effect	Likelihood	Effect	Likelihood	Effect	Likelihood	Effect	Likelihood	Effect	Likelihood	Effect	Likelihood
Provisioning	Fish/shellfish	-3	-4	-3	-4	-4	-4	-4	-4	-2	-3	-3	-3	-2	-3	-2	-2	-3	-4
	Oil/gas/energy	-2	-4	-4		-1	-3	-2	-2	-4	-4	-2	-3	-2	-2,5	-1,5	-2	-3	-3
	Minerals	-2,5	-3,5	-1	-5	-2	-3	-2	-2	-2	-2,5	-4	-4	-1,5	-2,5	-2	-2	-2,5	-2,5
	Chemicals/pharmaceuticals	-3	-2	-3	-3	-2,5	-3	-3	-3	-2	-2	-3	-3	-2	-2,5	-3	-3	-2,5	-3
	Waste disposal sites	-2,5	-2	-2	-3	-2	-3	-3	-4,5	-1	-2,5	-3	-3	-3	-3	-1	-3	-1	-2
	Raw materials	-3	-4	-2	-3	-2	-2	-2,5	-3	-2	-3	-3	-3	-1,5	-3	-2	-2	-2	-2,5
Regulating	Climate regulation	-4	-4	-4	-4	-1,5	-3	-3	-3	-3	-3,5	-2	-3	-2	-1,5	-1	-2	-3	-3
	Waste absorption/detoxification	-2,5	-3	-3	-3	-2	-2	-3	-3	-2	-2	-3	-3	-2	-2	-2	-2	-3	-3
	Carbon sequestration/absorption	-4	-4	-4	-3	-2	-2,5	-3	-3	-3	-3	-2	-3	-2	-1,5	-1	-3	-3	-3
	Biological control	-3	-3	-3	-3	-3	-3	-3	-3	-2	-3	-2	-2	-2	-2,5	-2	-3	-3	-3
Cultural	Recreation/tourism	-3	-3	-3	-3	-3	-3	-4	-3	-3	-3	-2	-3	-2	-3	-1,5	-1,5	-2	-3
	Educational			-3	-3	-3	-3	-3	-3	-3	-2,5	-2	-3	-2	-2	-1	-1	-2	-3
	Cultural heritage	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-2,5	-2,5	-3	-1	-1	-2,5	-3
	Existence/bequest	-3	-3	-3,5	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-2	-2	-3	-3
	Biodiversity	-3	-3	-4	-4	-3	-3,5	-4	-4	-3	-3	-3	-3	-2	-3	-2	-3	-4	-4
Supporting	Nutrient cycling / biological pump	-3	-3	-3	-3	-3	-3	-3	-3	-2	-3	-2	-3	-2	-2,5	-1	-1	-3	-3
	Habitat	-3	-3	-3,5	-4	-4	-4	-4	-3	-3	-3	-3	-4	-2	-2	-2	-2	-3	-4
	Resilience	-3	-3	-3	-3	-3	-3,5	-3	-3	-3	-3	-3	-3	-1,5	-1,5	-2	-2	-3	-3
	Primary production	-3	-3	-3	-3	-2	-3	-3	-3	-2	-2	-2	-3	-2,5	-3	-2	-3	-3	-2
	Biodiversity	-3,5	-4	-4	-4	-3	-4	-4	-4	-2	-3	-3	-3	-2	-2	-2	-2,5	-4	-4
	Water circulation/exchange	-3	-3	-3,5	-4	-2	-2,5	-2	-4	-2	-3	-2	-3,5	-3	-3	-2	-3,5	-2	-3
No high risk services		**2**		**3**		**2**		**3**		**1**		**1**		**0**		**0**		**2**	
Negative case																			

colour coding gives cases where both effect an likelihood is 4 - i.e. highes negative risk in survey

So to sum up; 3 provisioning services (fish/shellfish, oil/gas and minerals), 2 regulating services (climate regulation and carbon sequestration/absorption), one cultural service (biodiversity) and 2 supporting services (biodiversity and habitat) are at high risk (level 4,4). Ocean acidification and pollution impacts most services (3), followed by temperature change and fishing (2 each).

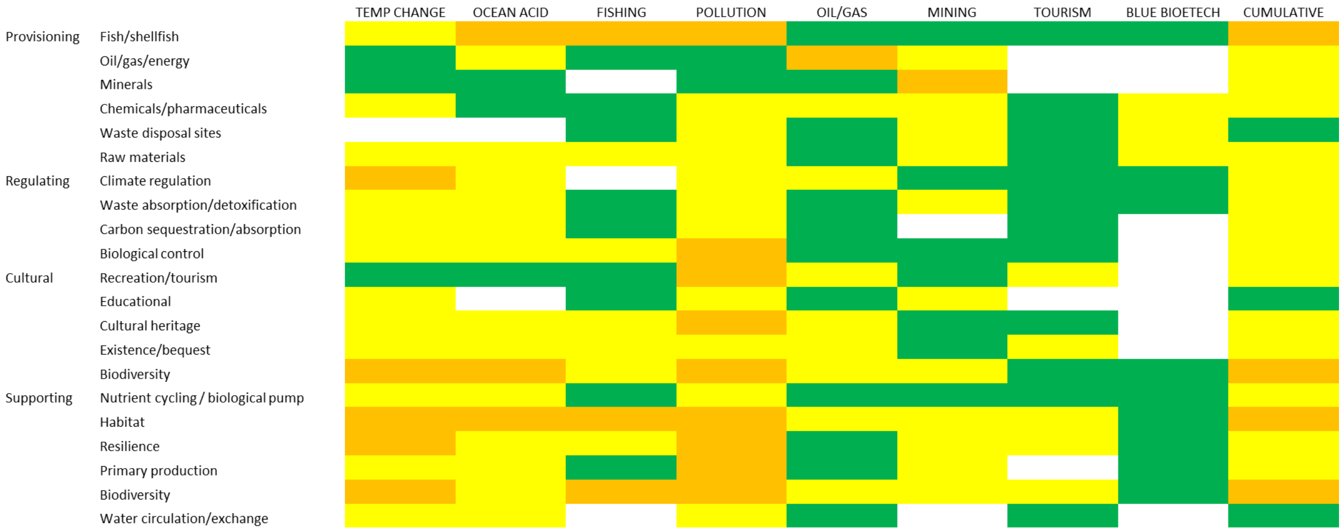
Appendix 4. Example page of SurveyMonkey 2nd Delphi survey


Identifying Ecosystem Services and associate risks in the North Atlantic – ATLAS Delphi Survey Round 2

4. Impact of **Ocean Acidification** on the following ecosystem services

	NA	Positive Effect	Likelihood of Positive Effect	Negative Effect	Likelihood of Negative Effect
Fish / shellfish *(Provisioning service)*					
Oil/gas/energy *(Provisioning service)*					
Minerals *(Provisioning service)*					
Chemicals / pharmaceuticals *(Provisioning service)*					
Waste disposal sites *(Provisioning service)*					
Raw materials *(Provisioning service)*					
Climate regulation *(Regulating service)*					
Waste absorption / detoxification *(Regulating service)*					
Carbon sequestration / absorption *(Regulating service)*					
Biological control *(Regulating service)*					
Recreation / tourism *(Cultural service)*					
Educational *(Cultural service)*					
Cultural heritage *(Cultural service)*					
Existence / bequest *(Cultural service)*					
Biodiversity *(Cultural service)*					

Appendix 5. Figures from the 2nd Delphi survey, equivalent to those presented from the first survey (in Appendix 3).



Classes	Effect/Likelihood	Colour
Very low	1.0 - 1.7	
Low	greater than 1.7 - 2.5	
Medium	greater than 2.5 - 3.3	
High	greater than 3.3 - 4.1	
Very high	greater than 4.1 - 5.0	

Figure 1. Negative effects of human drivers on ecosystem services

Classes	Effect/Likelihood	Colour
Very low	1.0 - 1.7	
Low	greater than 1.7 - 2.5	
Medium	greater than 2.5 - 3.3	
High	greater than 3.3 - 4.1	
Very high	greater than 4.1 - 5.0	

Figure 2. Likelihood of negative effects of human drivers on ecosystem services

..

		TEMP CHANGE		OCEAN ACID		FISHING		POLLUTION	
		Effect	Likelihood	Effect	Likelihood	Effect	Likelihood	Effect	Likelihood
Provisioning	Fish/shellfish	3	4	4	4	4	4	4	4
	Oil/gas/energy	2	3	2,5	2,5	2	3	2	2
	Minerals	2	3	2	3	1	2	2	2
	Chemicals/pharmaceuticals	3	3	2	3	2	3	3	3
	Waste disposal sites	1	2,5	1	2	2	2	3	3
	Raw materials	3	3	3	3	3	2	3	3
Regulating	Climate regulation	4	4	3	3,5	1	2	3	3
	Waste absorption/detoxification	3	3	3	3	2	3	3	3
	Carbon sequestration/absorption	3	3	3	3	2	2	3	3
	Biological control	3	3	3	3	3	3	4	3
Cultural	Recreation/tourism	2	3	2	3	2	3	4	4
	Educational	3	3	1	3	2	3	3	3
	Cultural heritage	3	3	3	3	3	3	3,5	3
	Existence/bequest	2,5	3	3	3	3	3	3	3
	Biodiversity	4	4	4	4	3	4	4	4
Supporting	Nutrient cycling / biological pump	3	3	3	3	2	3	3	3,5
	Habitat	3,5	4	4	4	4	4	4	4
	Resilience	4	4	3	3	3	3	4	3
	Primary production	3	3	3	3	2	3	4	3
	Biodiversity	4	4	3	4	4	4	4	4
	Water circulation/exchange	3	3	3	3			2,5	2

		OIL/GAS		MINING		TOURISM		BLUE BIOETECH		CUMULATIVE	
		Effect	Likelihood	Effect	Likelihood	Effect	Likelihood	Effect	Likelihood	Effect	Likelihood
Provisioning	Fish/shellfish	2	3	2	3	2	2	2	2	4	4
	Oil/gas/energy	4	4	2,5	2,5	1	1	1,5	1	3	3
	Minerals	2	2	4	4	1	1	1,5	1	2,5	3
	Chemicals/pharmaceuticals	2,5	2	3	3	2	3	3	3,5	3	3
	Waste disposal sites	2	3	3	3	2	2,5	3	3	2	3
	Raw materials	2	2	3	3	2	2	2,5	2,5	3	3
Regulating	Climate regulation	3	3	2	3	2	2	2	2	3	3
	Waste absorption/detoxification	2	2	2,5	3	2	1,5	2	2	3	3
	Carbon sequestration/absorption	2	2,5	1,5	2,5	2	2	1,5	2	3	3
	Biological control	2	2	2	2	2	2	1	3	3	3
Cultural	Recreation/tourism	3	3	2	2,5	3	3	1	1	3	3
	Educational	2	2	2,5	2,5	1,5	1,5	1,5	1,5	2	3
	Cultural heritage	3	3	2	2	2	2	1	1	3	3
	Existence/bequest	3	3	2	2	2,5	2	1,5	2	3	3
	Biodiversity	3	3	3	3	2	3	2	3	4	4
Supporting	Nutrient cycling / biological pump	2	3	2	3	2	2	2	2	3	3
	Habitat	3	3	3	4	3	3	2	2	4	4
	Resilience	2	3	2,5	3	2,5	3	2	2	3	3
	Primary production	2	1,5	2,5	2	1	1	2	2	3	3
	Biodiversity	3	3	3	4	3	3	2	2	4	4
	Water circulation/exchange	2	2	1	2	2	2	1	2	2	2

Figure 3. Negative effects of human drivers on ecosystem services, and their likelihoods. Cases where both likelihood and effect are level 4 is marked as red.

Appendix: Document Information

EU Project N°	678760	Acronym	ATLAS
Full Title	A trans-Atlantic assessment and deep-water ecosystem-based spatial management plan for Europe		
Project website	www.eu-atlas.org		

Deliverable	N°	5.2	Title	Risks and pressures to ecosystem services
Work Package	N°	5	Title	Valuing Ecosystem Services

Date of delivery	Contractual
Dissemination level	Public

Authors (Partner)	UiT			
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Version log	1		
Issue Date	Revision N°	Author	Change