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A Biome Portfolio Analysis (BPA) of Integrated Coastal Zone Management in the West of Ireland

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Abstract

EU policy geared towards the sustainable development of European coastal areas has incorporated Integrated Coastal Zone Management (ICZM) as one of its primary mechanisms to achieve its goal. However, critical shortcomings in the ICZM paradigm have emerged. In particular, incoherence in the European Commission's ICZM principles with respect to local and strategic objectives remains an issue. Additionally, a lack of scientific certainty about environmental processes when determining the environmental pros and cons of alternative coastal-management decisions undermines environmentally protective decisions that may otherwise hinder local regional development. With these issues in mind, a Biodiversity Portfolio Analysis (BPA) is applied to Iarras Aithneach, a peninsula on the west coast of Ireland, to test its suitability as tool for ICZM. In addition, the paper uses the BPA methodology to explore the contrast between scientific/strategic and local attitudes towards the management of a coastal area of environmental importance. Pronounced differences between the two are found and the implications for both BPA and ICZM are discussed. The spatial and participatory nature of the BPA process and the explicit treatment of risk the framework exhibits suggest there is scope for it to become a useful tool for ICZM. It also has the potential to act as a routine way of quantifying the "attitude gap" between the scientific community and the local community when managing a unique coastal area.

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1. Introduction

Despite the initial incorporation of Integrated Coastal Zone Management (ICZM) as one of the primary mechanisms of environmental policy geared towards sustainable development of European coastal areas, further evaluations have lead to an awareness of the need for an updated ICZM initiative. In particular, the development of a Marine Strategy Framework Directive (MSFD) and an overarching Maritime Policy [1] [2] is likely to assist in the European adoption of ICZM, since they may well provide the medium through which ICZM is shaped, implemented, and brought into legislation. The MSFD [3] in particular recommends environmental and ecological indicators as a means of assessing current environmental status and to track effectiveness of the directives measures. The ability to update directive measures according to their performance across the marine regions is also outlined under the principles relating to adaptive management. As such, the MFSD and the nature of the EU Commission's maritime policy very much reflect developments in the existent literature on what form ICZM should take and how it should be implemented. In sum, what is emerging is the requirement of an integrated, spatially based form of coastal management which inherently addresses the issue of risk and uncertainty and is adaptive over time to allow for improvements which were not foreseeable in earlier versions of ICZM.

In this paper Biodiversity Portfolio Analysis (BPA) [4] is put forward as a management format which attempts to incorporate all of these requirements into its approach. To that end, a case study of the methodology is carried out, as the concept is new and in its infancy. BPA is derived from financial portfolio theory and is an ideally structured approach for coastal management situations. At first glance, it may seem unusual for a methodology stemming from the management of financial assets to have an application in the field of biodiversity conservation, but in recent years, researchers in that field have highlighted the suitability of the concept, due to its explicit trade-off between expected payoffs and exposure to potential risks/losses [5]. Markowitz [6] developed a quantitative definition of the relationship between the riskiness of an investment, and the expected return. Asset managers compose portfolios of assets such that both objectives (minimising risk but achieving a desired level of expected return) can be optimized. In a similar way, society must balance between two alternative decisions. One of these is to ensure healthy environmental status allowing society to consume the wide array of services that flow from healthy ecosystems. The other is allowing human activities which are economically necessary, to proceed. Limiting one to promote the other is at the heart of all environmental decision making. As Figge [5] points out, 'the expected benefit which society derives from species, genes or ecosystems is uncertain, but this risk can be partially diversified away by combining various species, genes or ecosystems in a biodiversity portfolio'. In this way, rather than making isolated environmental management decisions, society's decisions between the two alternatives would focus on aggregate values of services and risks, aiding the decision making process and allowing for optimality in the trade off between the two societal goals.

Aside from the need to update ICZM and tailor it to recent policy recommendations, more critical problems exist for the ICZM paradigm as a whole. Environmental problems that arise, not out of poor coordination, but out of entirely contradictory environmental and economic goals, may not be solvable by group discussion and consensus, but by prioritization of, in all likelihood, the strategic principles. This latter point is really the key stumbling block for ICZM. While integration may be desirable, deciding between strategically or locally based management decisions is not only a methodological issue, but a political, legislative and philosophical one. This paper therefore presents an example of an environmentally sensitive area of European coastline where local and strategic objectives may clash, the extent to which these objectives contrast, and the implications from a policy/management perspective.

BPA is employed as the format through which to explore some of these problems in this study. In this way the validity of BPA as a tool for ICZM is tested (given the updated status of European maritime policy) but it also serves as a medium for highlighting the extent of the implications of having contradictory ICZM principles in EU policy recommendations. Section 2 discusses the emergence of ICZM and some of the literature which identifies specific problems with the concept. Section 3 outlines the BPA methodology. Section 4 presents the background to the case study and section 5 presents the results. Section 6 includes a discussion and the conclusion of the paper.

2. Strategic versus local Principles in ICZM

The concept of ICZM emerged in the scientific community of the 1970s, developed through the 1980s and entered the international political scene during the Rio Earth Summit of 1992 [7]. The European Union Recommendation of 2002 outlined 8 core principles which a European adoption of ICZM should include [8]. McKenna et al. [9] divide these principles into three distinct groups, listed here as they appear in the paper:

1. Two ‘procedural’ principles: support and involvement of relevant administrative bodies and use of a combination of instruments that are focused on the attributes of the methods and procedures that might be used to best advance ICZM
2. Three ‘strategic’ principles: broad overall perspective, long-term perspective, and working with natural processes. These principles mainly focus attention on long-term goals, and fit easily into the sustainability ethos that dominates contemporary environmentalism.
3. Three essentially ‘local’ principles: local specificity, adaptive management during a gradual process, and involving all the parties concerned. These can be regarded as a balancing set to the second group, because they focus interest on specific areas and problems, encourage tailoring of management to local conditions and encourage the participation of the public in formulating management policy.

McKenna et al. [9] claim that because the principles are presented as a menu of free-standing options, with no prioritization either within or between groups, irreconcilable differences in strategy arise. Billé [7] also argues that the idea that all conflicts can be resolved with a consensus agreement is a simplistic belief which arises out of three flawed assumptions; firstly, that environmental management is a problem of coordination, secondly, that consultation is the solution to this lack of coordination and thirdly, that consultation is inseparable from consensus. Billé [7] also raises a further criticism of ICZM which he refers to as the positivist illusion. Many calls for improved management of coastal areas stress the need to develop the scientific understanding of marine and coastal ecosystem processes [10,11,12]. However, many natural processes are (and will remain) far beyond the reach of scientific understanding. For example Johannes [13] demonstrates theoretically that the inception of a rational management of Indonesian coral reefs alone would require at least 400 person-years to collect data only, a process which would have to be repeated annually.

Realistically, management of coastal areas involves making decisions under imperfect knowledge and uncertainty. Collating explanatory data about human and ecosystem processes until definite outcomes can be predicted (while something to be strived for) cannot realistically be the precursor to every management decision. The therefore subjective reality of management decisions, as opposed to the positivist illusion, can make management decisions affecting the economic, cultural and social goals of the local community controversial in nature. Examples of controversial environmental legislation are abundant; constraints on commercial fisheries such as catch quotas and marine protected areas have significant impacts on the livelihoods of fishing communities; input constraints on agricultural production, designed to attain set levels of environmental standards, reduce agricultural output; Hynes and Hanley [14] document the conflict between typical water use values and hydro-electric schemes on “wild” rivers. In any of these examples, scientific diagnosis about the environmentally damaging effect of the practice in question, and predictions about the subsequent benefits of said constraints, is subject to scientific uncertainty [15]. The reality then is that while scientific understanding about environmental processes is not up to the job of perfectly informing society and its policy makers on the optimal use of environmental resources, decisions still have to be made. The objective of any approach to environmental decision making then, must be to provide environmental manager’s with the best information possible, and a feasible way of making decisions that can optimise resource use [16]. Since deciding between management alternatives will unavoidably involve qualitative, as well as quantitative distinctions, the decision making process requires a modelling framework which assists in this. Such assertions support the basis of using BPA, given its integrated, qualitative and spatial framework and the next section examines how such a technique might be used in practice.

3. Methodology

The Biodiversity Portfolio Analysis (BPA) as developed by Hills et al. [4], is a spatially orientated framework which marries the input of the local and scientific communities, stakeholders and local agencies to form a broad overview of the contribution that various geographical biome types in the local area make to society. It is intended to assist coastal managers in deciding between alternative policy decisions by allowing for a qualitative assessment of their impacts on the cultural, social, economic and environmental services that the various biome types of an area provide. One of the attractive features of BPA is that it incorporates threats/risks to the biomes under study into the analysis, and uses this information when balancing between alternative management strategies. It is a derived from the financial portfolio theory of Markowitz [6] and therefore deals explicitly with optimal trade-offs between risk and return across diverse assets.

BPA requires the identification of geographical areas or “biomes” from which ecosystem services, and hence the value of their societal “returns”, are derived. Associated with each ecosystem service/return, and thus each biome, is a risk to the return in terms of the scale of the extent and seriousness of various threats. In this case then, the “assets” in question are environmentally sensitive biomes which derive their anthropocentric value from the multiple market and non-market services that their biogeographic features provide to society.

According to Hills et al. [4], once a basic understanding of biomes, risks and returns for a study area is built up, various scenarios can be developed based on possible management interventions; these scenarios can be assessed for their effect on the risk and return of the biodiversity portfolio. Four key sets of data are required for the framework to be operational; biome type, spatial area of biome, services arising out of each biome and threats to each biome’s functions. The degree of return for the study area's biodiversity portfolio can be defined as:

$$\sum_{i=1}^{n} esv_i * ba_i$$

and the degree of risk as:

$$\sum_{i=1}^{n} bt_i * ba_i$$

where esv_i is the ecosystem service value of biome i, ba_i is total area of biome i, and bt_i is the scale of threat on biome i. The method requires values be placed upon the overall return from each biome, the mean return of all biomes in the study area, the risk/threat to each biome and the mean of the biome risks in the study area. Risk and return values are evaluated on like scales allowing for direct comparison of the trade-offs between the two. Local stakeholders and/or scientists with knowledge of the study area provide the rankings on these scales for the alternative biomes. Typically, in a non-market valuation study, researchers attempt to estimate the monetary value of an environmental asset. BPA is not generally concerned with monetary values, but a scaling system which treats market and non-market services and risks with equal weight. This is a crucial strength of the BPA approach and what sets it apart from typical cost benefit analysis.

The attributed scale values allow for a comparison of the risks and returns derived from different biomes, the relative positioning of the biomes when plotted on a scatter gram plot (in terms of risk and return), and identification of the relationship between the risk and return of different biomes. The latter exercise, where correlations in the risk factors across all biomes are identified, is one of the potentially most useful tools of BPA. Correlations are identified by determining the extent to which biomes have a common response to threats. Biomes with a similar response to threats have positive correlation, biomes with an alternative response to threats have negative correlation and those showing neither alternative nor similar response are not significant. There are three terms for describing the extent of any relationship between biomes:

Independent: where correlation between any pair of biomes is not significant, then the threat factors for these biomes are not related, i.e. they respond in an independent fashion to threat factors;

Associated: where the correlation between risk factors for a pair of biomes is significant and positive, then the threat factors impact upon the biomes in very similar way;

Resilient: where the correlation between any pair of biomes is significant and negative, then threats that can greatly impact upon the ecosystem services in one biome tend to have little impact upon the other biome.

Hills et al. [4] also develop the notion of portfolio impact sensitivity (PIS) which they calculate by scoring all of the biome pairs as +1, -1 or 0 according to whether they are associated, resilient, or independent, respectively, and then sum the values to determine the biome portfolio's overall level of association/resilience. For example, a portfolio made up of biomes that are largely associated with each other in terms of responsiveness to threats will have very high PIS, whereas the opposite is true of a portfolio made up of resilient biomes. The lower the PIS of the biome portfolio, then the easier it will be for manager's to make decisions that yield highest possible biome returns while “containing” risks. A higher PIS value however will mean that a single or small number of threats could have a highly negative impact on the ecosystem services arising out of many of the biomes within the management area.

Integral to the methodology is the process of determining each biome in the study area as well as the ecosystem services provided by that biome and the risks/threats it is exposed to. As a starting point, this is achieved through reference to the relevant literature. However, given that BPA is

intended as an integrated and stakeholder engaged management format, this information is also compiled through the organisation of a locally based stakeholder workshop. Also during the workshop, values for the biome risks and services are assigned by the participants. The depiction of local attitudes is therefore captured by the results of the stakeholder analysis workshop.
One of the aims of this study was to identify the extent of the potential "attitude gap" between the scientific community and local inhabitants with respect to the question of how ecosystem services rank in terms of their anthropocentric value and to what extent risks, both manmade and environmental, threaten the provision of those services. In order to do this it was also necessary to attain a depiction of a scientific or strategically minded attitude towards the same biomes, services and risks, which featured in the stakeholder analysis. Therefore in addition to the stakeholder analysis, a second analysis was carried out, using the same survey, but valuing services and risks according to the opinions of marine scientists with in-depth knowledge of the study area.

Through the consultation with the stakeholder group, all ecosystem services and risks were rated on a scale of 0 to 3 where:

$$0: \quad \begin{cases} if\ service = neglible\ ecosystem\ service\ provided \\ if\ risk = threat\ factor\ has\ no\ impact \end{cases}$$

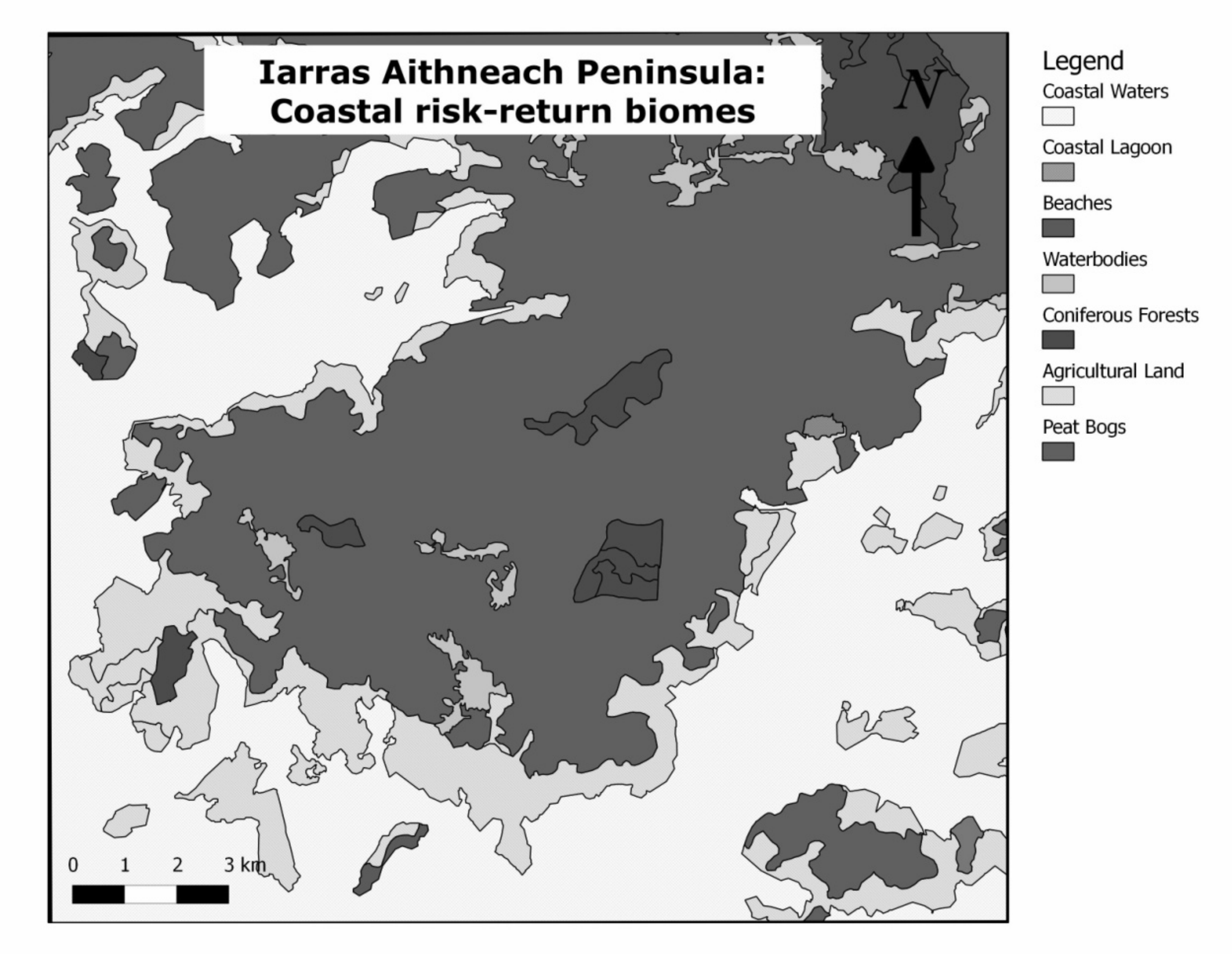
and:

$$3: \quad \begin{cases} if\ service = extensive\ to\ complete\ service\ provided \\ if\ risk = threat\ could\ destroy\ biome\ function \end{cases}$$

In later consultations with scientific opinion, the very same analysis was carried out, recording the values assigned to ecosystem services and threats to allow for comparison with the results of the stakeholder analysis.

4. Coastal Study Site and Selection of Biomes, Services and Threats

The study area in which the BPA was based was Iorras Aithneach on the western coast of Ireland. A map of the Iorras Aithneach study area and the associated biomes identified in the stakeholder analysis are shown in Fig. 1.



This area was specifically selected due to the diverse biogeographic features by which the peninsula is characterized. The coastal inlets around Iorras Aithneach are the location of previous, current or potential aquaculture projects which offer good economic and employment opportunities to the local community but are controversial from an environmental perspective [17,18,19]. Unique habitat types which Iorras Aithneach possesses warrant strategic conservation measures, but often these conservation measures can clash with local economic goals. For example the cutting of turf on local peat bogs is prohibited, which directly increases the costs of fuel consumption for the average household in Iorras Aithneach. Moreover, the harvesting of peat is a tradition in itself and has a cultural value for the community. Other areas amongst the diverse terrain types are of cultural importance in the area, such as the many small islands off the coast of Carna. Some of these islands were once inhabited by the same ancestors of those living in the community today, and islands such as Oileán Mhic Dara are part of an annual traditional religious pilgrimage. The economic, social, cultural and ecological tradeoffs that exist for the management of this area make it ideal for an assessment of potential incoherence in the local and strategic “free-standing” principles of the European Council recommendation on ICZM.

There were a total of eight biomes identified in the area for inclusion in the BPA. In some cases, biome types existed to only a negligible degree in the Iarras Aithneach study area, and sufficient data for their inclusion in the study did not exist to include them in the analysis. Removed biome types were salt marsh and shallow water. In other cases, biome types were grouped under one category. This was done when various classes of biome type were deemed to have the same resource use and exploitation patterns. Sand inlets, sand dunes, shingles and rock platforms were categorised as, ‘sand beaches’. Other biome types unique to the area were added to the list such as peat bogs, agricultural land (which also included pastures) and coniferous forest. From the stakeholder analysis it also emerged that coastal islands should constitute a separate biome type, due to their significant cultural and historical value to the local community. The water bodies biome accounted not just for the many fresh water Loughs of the area but also for the diverse network of rivers also. A definition of each biome is included in Appendix A.

All maps of the study area and biomes contained within it were created using ArcGIS and Corine Land Cover data which is a digital map of the European environmental landscape. Corine Land Cover 2006 is the third dataset in a series, the previous datasets corresponding to base years of 1990 and 2000. The ecosystem services included in the study were identified through a combination of stakeholder analysis and referral to relevant literature. They are agriculture, fishing, aquaculture, intertidal gathering, sand/grave/rock/peat extraction, conservation interest, recreation and tourism, cultural/educational, flood protection/coastal defence, nutrient/waste absorption, renewable energy generation and land-take (car-parks/range/causeways).
Risks/threats to the biomes were identified through a combination of stakeholder analysis and referral to relevant literature. These included: climate change, erosion, flooding (including sea level rise), saline intrusion, tourism and recreation impact, new causeways and other infrastructure, agricultural change, pollution (including oil spills), invasive species, marine and terrestrial litter/dumping, over-gathering of shellfish/overfishing, over-regulation and salt damage.

5. Results and Analysis

The list of identified biome types, related ecosystem services, and the values assigned to them from the stakeholder workshop are displayed in table 1(a) and 1(b). Each value that the stakeholder group attributed to an ecosystem service is shown in part (a) of table 1, but in part (b) it is scaled to the spatial area of the biome type it arises out of. For example, the ecosystem service “fishing” derived from the biome type “coastal water” received an ecosystem service value of 3 from the workshop participants. Scaling this to the spatial area of the biome, which is 10,490 square kms, means a return of 31,470 is generated from fishing in the sea and ocean. For any biome type, the total of all ecosystem service values arising out of that biome are scaled and then summed to determine the total return of the biome. Continuing the example then, coastal water also receives a non-zero value for the ecosystem services aquaculture, conservation interest, recreation and tourism, cultural/recreational and nutrient/waste absorption. In total, stakeholders gave all of the services provided by coastal water a value of 17, meaning that once spatially scaled, the coastal water contributes 178,338 credits to the total return of the localities biome portfolio.

Biome return, or ecosystem service value for each biome, prior to spatial scale being considered, can be viewed in the penultimate row of Table 1(a). At this stage, coastal water provides the greatest return, followed by sand beaches and coastal islands, with peat bogs and agricultural land also receiving a high valuation. The lowest valued biome returns were coniferous forest, coastal lagoons and water bodies, respectively.
The penultimate row of Table 1(b) shows biome return when scaled according to biome area. The result is a substantial shift in the ranking of returns in the biome portfolio. For larger values, it is

useful to view biome returns in terms of their proportionate contribution to the total biome portfolio return. The final row of table 1(b) gives the normative value of all biome returns. This is simply the return of an individual biome divided by the sum of total biome portfolio return. The coastal water biome remains the biome providing the greatest return, since in addition to its high valuation in the stakeholder analysis, it constitutes a large part of the study area. However the next greatest contribution to portfolio returns come from peat bogs. Agricultural land, coastal islands, water bodies and coniferous forest make the subsequent, descending contributions to biome portfolio return. Coastal lagoons and sand beaches make less than a 1% contribution to portfolio return which appears as zero due to rounding error.

Clearly, the inclusion of biome's spatial areas in the calculation of return alters the rankings of biome returns considerably. The peat bog biome has an area of 13,500 square kms, dominating Iarras Aithneach landscape. This compares to biomes like agricultural land and coastal islands, which have an area of 3,293 square kms and 2044 square kms respectively. As a result, they are overtaken by the peat bog biome in the ranking of return provision. On one level this is a legitimate re-ranking of biome returns; if there is a greater supply of a biome then there is a greater provision of its services. The flip side is the impact this has on the valuation of returns from very small biomes. For example, despite the fact that sand beaches received the second highest return through the stakeholder analysis, its contribution to portfolio return is less than 1% due to its extremely small (just 37 square kms) spatial area[1].

Coastal managers may also want to observe the value of an ecosystem service across *all* biomes, not only its contribution within *one*. For this reason the penultimate *column* of table 1(b) shows the values an ecosystem service is given relative to, and scaled to, the biomes from which the service is provided, summed across all biomes. The last column in table 1(b) gives the proportionate contribution of each service to the total portfolio return.

The format for valuing biome risks, shown in Table 2(a) and 2(b), follows that for valuing ecosystem services; once a risk is identified, its threat to each individual biome is valued by the workshop participants and then scaled according to biome areas. Total threat to each biome and the proportional contribution of that biome to total biome portfolio risk is shown in the last 2 rows of Table 2(b). The total value of each threat type across all biomes and the proportional contribution of that threat to total biome portfolio risk is shown in the last 2 *columns* of table 2(b). An immediate glance at the data collected on biome risks shows that risk was given far lower values than services from equivalent biomes. While the coastal water biome is valued as that with the greatest exposure to risk, once areas are included in the calculation of biome risk, peat bogs becomes the most at risk biome. The least at risk biomes, are coastal lagoons and sand beaches, both before and after spatial scale has been included in the calculation. Interestingly, the greatest threat across all biomes is over-regulation, one of the risks identified during the stakeholder workshop. The identification of this threat and high value it received in the stakeholder analysis, coupled with the low values given to most other environmental risks, represents a subtle indication of the divide that exists between local and strategic mindsets in coastal development,

[1] While it is desirable from a spatially orientated perspective to relate the value of a biome's services to its area, it can also mean that highly valued services from small biomes all but disappear from overall contribution percentages. This is a concerning feature of BPA. Suppose for example that a rare and endangered species exists in the coastal lagoon biome. A non-market value may produce a very high existence value for the species, which is completely reliant on the coastal lagoon biome for survival. However, because the biome contributes so little to total portfolio return, BPA, in this case, could be used to justify decisions which threaten the biome, for example, land-take development. In reality, society cannot afford to be so blasé with important highly scarce biomes; small biomes should have a much higher substitution value than larger biomes, simply because there is less of them. This issue is further discussed in the discussion section of the paper.

and the feelings that exist amongst stakeholders about the implications of environmental protection and its impact on local livelihoods.

The relationship between the normative risk and return for each value is shown in Fig. 2. A high return relative to risk ratio in a biome can be considered more desirable since is provides the returns related to the biome with less threat of loss of those returns. The ratio acts as an indicator as to which biomes coastal managers can focus on in order to maximize the biome portfolio return relative to risk. Policies and management decisions that can lower the exposure of biomes to risk or increase services without affecting risk exposure, improves the return relative to risk profile of the portfolio. Coastal waters and peat bogs provide the greatest return and are associated with the greatest risk. If risks affecting coastal water and peat bogs were addressed and reduced, this would lead to a substantial increase in the return relative to risk ratio of the Iarras Aithneach biome portfolio. For example risks to the coastal water biome which received a positive value in the stakeholder analysis were pollution, invasive species, marine dumping and over-gathering of shellfish and overfishing. Policy steps which successfully reduced these risks would constitute a positive contribution to the risk return profile of the areas biomes. The same can be said for any risk amongst any of the biomes; however, the impact would be most noticeable for large biomes.

The spatial magnitude of some biomes means that they dominate the Iarras Aithneach peninsula's landscape, and therefore the results, since calculations are spatially based. For this reason, the risk return profiles of the biomes are also depicted *before* spatial area has been included in the calculations of risk and return. The extent of the transformation brought about by inclusion of biome area in the final calculation of biome risk or return warrants this. Fig. 3 shows the risk return relationship for each biome prior to being scaled according to area. The result of depicting biome risk-return relationships in this way is a much more in-depth and diversified portrayal of which ecosystem services local stakeholders attach value to.

One of the potentially most useful tools of BPA is its ability to assign a risk correlation to two biomes, indeed, the risk correlations amongst all biomes in the portfolio. Since any threat can relate to multiple biomes, understanding the common sensitivity of these biomes to risk informs coastal managers about the responsiveness of portfolio risk to various hypothetical scenarios. The risk correlation is categorised using Pearson's r statistic[2] and depending on the value of this calculation, biomes can be associated, resilient or independent. If two biomes tend to score highly for the same types of risks, then they will have a significantly positive pairwise correlation (associated). If many biomes within the portfolio are associated, the portfolio will have high portfolio impact sensitivity (PIS). For such an area, biome portfolio risk can be reduced most efficiently by tackling those risks which are common to the majority of biomes, as this will lead to the greatest reduction of portfolio risk, and therefore the greatest improvement of the biome portfolio's risk return profile.

If portfolio biomes tend to score highly for alternative risks (are resilient), significantly negative pairwise correlation will dominate the portfolio, which will therefore have a negative PIS value. In this case, decisions which further expose an individual biome to risk will not expose other biomes in the portfolio to the same risk. This suggests that overall biome portfolio return can be increased by developing biomes productivity, (for example through agriculture, fishing and resource extraction) to derive more returns to the community (since the associated risks are

[2] The Pearson R correlation indicates the magnitude and direction of the association between two variables that are on an interval or ratio scale.

confined to individual biomes). It is important to note that such development should not overly exacerbate exposure to risk in a single biome either, confined as it may be to a single or small number of biomes.

Table 3 shows the pairwise correlations for the threat factors of each biome in the Iarras Aithneach area when the calculation is carried out using the risk and return values recorded during the stakeholder analysis. Only 2 biomes display a statistically significant pairwise correlation with each other (at the .01 threshold), namely, agricultural land and coniferous forest. At a threshold level of .05, the coastal lagoon and waterbodies biomes can also be deemed as associated. This means that the biome portfolio, according to the risk and returns values given by local stakeholders has a low, but not negative, PIS value. This indicates that from a coastal management perspective, the return of the biome portfolio is resilient to development of most of the major biomes, without systemic risks affecting other biomes in the portfolio.

The analysis now turns to the scientific consultations and the resulting data and management connotations. As previously mentioned a group of marine scientists were also presented with the same scale risk return tables as the local stakeholder group. These individuals were based at a university operated shell and fin fish research laboratory (aquaculture) in the study area. As such they also had an in-depth knowledge of the marine and coastal biomes in the area through their research work. Table 4(a) and 4(b) show the values attributed to biome returns during this scientific consultation. For every biome the overall value given to total return exceeded that of the stakeholder analysis. The greatest difference was in the coastal lagoon biome, receiving a value of 18 from scientific consultations and 4 through the stakeholder analysis. The least differently valued biomes were sand beaches (22:16), coastal waters (20:17) and peat bogs (19:12).

The reasoning behind similar valuations of these biomes is not as close to consensus as it appears however. Scientists and local stakeholders may be relating the value of returns from these biomes to different ecosystem services. The coastal water biome has a significant status in Iarras Aithneach; it has provided substantial economic opportunity in the area through fisheries, aquaculture, intertidal gathering, tourism and as a result of these naturally has a strong cultural and historical significance to the community. However, it received zero return values for services like nutrient/waste absorption and renewable energy generation. Contrastingly, these services received positive values during the scientific consultations and services like “conservation interest” received maximum return value (3). This situation is true also for the peat bog biome. While the biome scored highly in the stakeholder analysis for services such as peat extraction, conservation received a low scale value (1). Contrastingly, conservation was given a value of 3 during the scientific consultations. The picture of similarly rated biome returns can therefore be misleading[3].

Table 5(a) and 5(b) show the values attributed to biome risks during the scientific consultations. In all cases the values are far higher than in the stakeholder analysis. Fig. 4 depicts the risk return relationship for each biome in Iarras Aithneach based on the scientific consultations and also

[3] This is a positive feature of the BPA framework. BPA allows not only for a valuation of the biome returns, but even in cases where values seem to converge, it allows the analyst to observe where attitudes differ about *where* that return is coming from. This example shows the importance of properly reflecting on the results in order to avoid misinterpretation.

those from the stakeholder analysis to allow for comparison. The difference between the strategic and local survey results appears less pronounced when spatial area is included in the depiction of the risk return profile of the biomes. The contrast is starker when comparing total values alone, before spatial area is included in the calculations.
Because the true contrast in values given from both viewpoints is concealed when spatial area plays such a large role in risk-return calculations, the contrast in risk return profiles *before* spatial area is brought into the equation is shown in Fig. 5. This is a much fairer depiction of the biomes which local stakeholders valued highly for both risks and returns. Biome portfolio return in a local stakeholder context is largely made up of returns from peat bog, coastal water, agricultural land and coastal islands. In contrast, the biome portfolio under the scientific context exhibits more evenly proportioned sources of biome risk and return[4].

Table 6 shows the pairwise correlations between biomes when using the values attained from the scientific consultation. There are a total of 7 biomes which have a statistically significant positive pairwise correlation at the .01 threshold level of statistical significance. At the .05 threshold level of statistical significance, there is a total of 11. Clearly, the scientific consultations result in a far higher PIS value for the biome portfolio. The implication of this from a coastal management perspective, is that a management decision affecting one biome, which may appear to pose no threat to other biomes in the area (based on the values attained through the stakeholder analysis), could affect the return from other biomes according to more scientifically informed points of view and analyses.

6. Discussion and Conclusion

One of the major weaknesses of the European ICZM initiative described by McKenna et al. [9] was that the strategic principles, which require management to take a wide view of spatial and temporal factors, are incompatible with local principles which focus on the "specific needs of specific people in specific places". This incoherency, arising out of two conflicting objectives, will affect any coastal management initiative so long as the issue is not resolved at the policy level. Indeed, BPA generally requires that a panel of various stakeholders and scientific experts, representing diverse interest groups, reach consensus about the value of each ecosystem service in a biome, as well as the scale of any threats to that biome's function. Yet Billé [7] suggests that the idea that all conflicts can be resolved with a consensus agreement is a simplistic belief and that "such misconceptions are partly responsible for the inability of numerous participatory processes to adequately take charge of the environmental problems that justified their inception".

This raises a question: If Billé is right, is BPA not then redundant? From this analysis, it appears not. While the Hills et al. [4] vision of BPA was that of a tool which could arrive at consensus values across a diverse groups, this analysis supports a variation of their theme. Rather than grouping scientists with local stakeholders and struggling to attain some form of consensus about things, the methodology could be used to evaluate the perspectives of both groups separately, after which, the data can be used to draw distinctions and understand where attitude gaps and similarities lie. This would appear to be a far more arming process for coastal managers, for as the literature clearly indicates, the real challenge for the future of European coastal management will be balancing the various objectives of multiple interests. To do this, coastal manager's need

[4] This is because the scientific consultations lead to upper *and therefore similar* valuations of each biome's services, despite the fact that the scientific valuations were higher than local valuations in every case. This seems justified since a scientific understanding precedes a greater awareness of biome functions and ecosystem services, and correspondingly higher values. For further comparison of the risk-return results of the survey, see Fig. 5.

to understand what those interest groups are and how their attitudes toward biome use and management compare.

Despite the proposition that defining an “attitude gap” is a more useful function for BPA, there is still scope for it to assist in deciding between alternative management decisions on a qualitative basis when sufficient quantitative data to do so does not exist. This scope is limited however by the incoherent nature of the ICZM principles at present and until such incoherency is resolved, any management format based on participation and consensus is undermined. This weakness is a feature of ICZM policy as opposed to management frameworks like BPA, which are framed by the policy context they are applied to. A further point is worth noting. The entire process of categorizing a management area by biome types, risks and returns plays the role of informing policy makers about the *diversity* of environmentally important spaces an area possesses (as well as the derivative ecosystem services and environmental and man-made risks to those services).

An additional point to note from the results presented in this paper is that *apparently* similar biome valuations from both the scientific and local survey participants acquired value from contradicting services, for example, conservation and peat extraction. While commonality in the value assigned to biomes’ total return may indicate convergence (which is attractive from a management perspective since it suggests that strategic and local objectives are aligned), similar total biome return values may not reflect consensus at all. In fact, they can represent the very opposite; a completely opposite point of view on the value of the services delivered by the biome, and as a consequence, a completely opposite point of view on how that biome should be managed into the future. It is recommended that BPA always be carried out by defining categorical groups such as local, strategic, stakeholder, relevant interest group etc, so that the risk-return values of each group for each biome can be compared and assessed, and the sources of biome value can be identified.

The contribution of a service to biome portfolio return was also found to be heavily affected by the size of the biome it arose out of. Certain ecosystem services, for example carbon sequestration, need to arise out of large spatial areas to provide a meaningful service. In such a case, considering biome size is highly relevant when calculating which biome best provides that service. However, there are many cases where ecosystem services, in particular biodiversity and existence value, are of priority, yet are linked to relatively small biomes. It is not ideal that a methodology designed to evaluate risks and services relating to sensitive ecological areas should understate these risks and services when a biome is small relative to other biomes in the study area. If anything, small biomes are more responsive to threat factors and this should be represented in the methodology.
One way of factoring heterogeneity in risk sensitivity (due to biome size differences) into the BPA methodology would be to structure area dependent risk elasticities into the methodology. In this case, the greater the supply of any biome, i.e. the larger it is, the less responsive it would be to risk exposure. Diminishing the size of any biome, or dealing with a biome which is in lesser supply than other biomes, would mean increasing its responsiveness to any threat in the modelling procedure. This adaption of the methodology would be in keeping with economic theory related to the increasing substitution price effect of any good as it diminishes in supply. Such an adaption may be justified on the basis that if a biome is decreased in size, its potential to absorb negative impacts is reduced and the costs of damaging the biome’s function (to supply ecosystem services) is likely to be higher, hence risks are higher. The key to structuring risk elasticity into the methodology would be to correctly associate various risk sensitivity levels to particular categories of biome size. This is an important avenue for future research in the area of BPA.

Finally, the PIS of the biome portfolio was highly dependent on which study group the data was based upon; the scientific group providing data which lead to a far higher PIS value. While BPA can only highlight where the two domains differ, the incoherence in local and strategic objectives in EU policy is a problem that coastal manager's face. Because there has been no prioritisation of either set of principles, there is no guidance or legislation off of which coastal managers can base their decisions.

During the stakeholder analysis the negative attitude of stakeholders towards the perceived risk of over-regulation became evident. It is likely that this attitude contributed to the low values assigned by the stakeholder analysis participants for risks across all biomes. In recent decades, regulation, especially with respect to coastal livelihoods like fishing, aquaculture, and shellfish harvesting have reduced the capacity of local stakeholders to harvest, profit or gain employment from such local economic activity. Recently, prohibitive regulation on peat extraction in peat bogs has also been brought into legislation. Over-regulation is a very real concern for local inhabitants of coastal areas of environmental importance and tackling the development of such negative perceptions is an important part of an integrated approach to coastal management. A vital part of tackling such negative perceptions must be the identification of areas where the negative impact of regulation on regional economic development can be mitigated and sustainable enterprise and development is promoted at the policy level.

It is clear that the nature of the irreconcilable differences in EU ICZM objectives will require some controversial decisions to be made regarding prioritisation of principles. With respect to BPA, one possibility for consideration is that coastal manager's would base decisions off data from local participatory stakeholder groups *and* data from scientific consultations. Because locally based data will be likely to have lower risk values and therefore a lower PIS value, any management decisions based on achieving local objectives would first have to be analysed through the scientific consultation data. Where no predetermined "red lights" with respect to the scientifically based PIS values were set off, local development orientated decisions could be proceeded with. Further case studies demonstrating this type of analysis are needed.

There is a wider debate taking place on this topic about the justification of basing environmental management decisions on the value assessments of consumer preferences when many individuals do not understand the various environmental and ecosystem processes which provide the services society consumes. If non-market values are to be used within cost-benefit analysis (CBA) to inform public policy choice and the management of environmental assets, then the main tenet of welfare economics on which CBA is based – namely, the primacy of consumer preferences – creates problems for many when these preferences are based on very incomplete understanding of how ecosystems work, of the importance of ecosystem services to well-being, and of the importance of different aspects of biodiversity. As Atkinson and Mourato [20] point out, 'to the extent that groups or individuals are poorly informed about the environment, there are too many risks to allowing uninformed views to hold sway over decisions'.

In this study, the "attitude gap" between scientific and local views was pronounced. Of the various reasons why this may be so, a disparity in the level of knowledge of participants about ecosystem processes, benefits and biodiversity in general, is likely to account for much of this. The assessments indicate that BPA may be a useful format for helping environmental manager's and policy makers understand where local views stray from scientific views about ecosystem services and risks and how the coastline should be managed. Such a procedure could be an ideal "first step" in any coastal management initiative. Clearly, there are two states of thought regarding environmental decision making; one favouring consumer preferences (local), the other preferring reliance on expert opinion for strategic development. Be it for the purposes of attempting to make optimal tradeoffs between coastal development, conservation, risk and return, or simply to categorise the differences in outlook between local and strategic views, there is scope for development and application of BPA. In situations where strategic and local objectives are closely aligned, BPA is especially suitable for application. There is also scope in future applications of the BPA framework to apply non-market values from the literature to biomes as a measure of return in a benefit type transfer type exercise.

Table 1 (a) Estimated ecosystem service values of biomes based on stakeholder analysis

Service	Biome Type							
	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs
Agriculture	0	0	3	2	2	1	3	3
Fishing	3	1	3	0	3	0	0	0
Aquaculture	3	0	1	0	0	0	0	0
Intertidal Gathering	3	0	0	3	0	0	0	0
Sand/gravel/rock/peat extraction	0	0	0	0	0	0	3	3
Conservation interest	2	2	0	3	3	2	1	1
Recreation and tourism	3	0	1	3	2	0	1	2
Cultural/educational	3	0	0	2	3	0	2	3
Flood protection /coastal defence	0	0	0	3	2	0	0	0
Nutrient/waste absorption	0	0	0	0	0	0	0	0
Re. Energy generation	0	0	1	0	0	0	0	0
Landtake (carparks/range/causeways)	0	1	0	0	0	0	2	0
Total Service	17	4	9	16	15	3	12	12
Area of each biome (sq km)	10490	31	1306	37	2044	1171	3293	13380

Table 1 (b) Product of biome spatial areas and estimated ecosystem service values based on stakeholder analysis

Service	Biome Type									
	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs	Total value for each service	Norm. Value for each service
Agriculture	0	0	3918	74	4088	1171	9879	40140	**59270**	**13.94%**
Fishing	31470	31	3918	0	6132	0	0	0	**41551**	**9.78%**
Aquaculture	31470	0	1306	0	0	0	0	0	**32776**	**7.71%**
Intertidal Gathering	31470	0	0	111	0	0	0	0	**31581**	**7.43%**
Sand/gravel/rock/peat extraction	0	0	0	0	0	0	9879	40140	**50019**	**11.77%**
Conservation interest	20980	62	0	111	6132	2342	3293	13380	**46300**	**10.89%**
Recreation and tourism	31470	0	1306	111	4088	0	3293	26760	**67028**	**15.77%**
Cultural/educational	31470	0	0	74	6132	0	6586	40140	**84402**	**19.86%**
Flood protection /coastal defence	0	0	0	111	4088	0	0	0	**4199**	**0.99%**
Nutrient/waste absorption	0	0	0	0	0	0	0	0	**0**	**0.00%**
Re. Energy generation	0	0	1306	0	0	0	0	0	**1306**	**0.31%**
Landtake (carparks/range/causeways)	0	31	0	0	0	0	6586	0	**6617**	**1.56%**
Total Service Value S for each biome	**178330**	**124**	**11754**	**592**	**30660**	**3513**	**39516**	**160560**	**369184**	**100%**
Normalised value for each biome (% scale)	**42%**	**0%**	**3%**	**0%**	**7%**	**1%**	**9%**	**38%**	**100%**	

Table 2 (a) Estimated risk value to ecosystem biomes based on stakeholder analysis

Risk/Threat	Biome Type							
	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs

Climate Change	0	0	0	0	0	0	0	0
Erosion	0	0	0	1	1	0	0	0
Flooding (inc. Sea level rise)	0	1	1	0	1	0	0	0
Saline intrusion	0	1	0	0	0	0	0	0
Tourism and recreation impact	0	0	0	0	0	0	0	0
New causeways and other infrastructure	0	0	0	0	0	0	0	0
Agricultural change	0	0	0	0	0	1	3	1
Pollution inc. oil spills	1	0	0	0	2	0	0	0
Invasive species	2	0	0	0	0	0	1	1
Marine and terrestrial litter/dumping	1	0	0	0	0	0	0	0
Overgathering of shellfish/overfishing	1	0	0	0	0	0	0	0
Other 1 (Over-regulation)	0	0	0	0	0	0	0	3
Other 2 (Salt damage)	0	0	0	0	0	0	0	0
Total Risk	5	2	1	1	4	1	4	5
Area of each biome (sq km)	10490	31	1306	37	2044	1171	3293	13380

Table 2 (b) Product of biome spatial area and estimated risk value to each biome based on stakeholder analysis

Risk/Threat	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs	Total value for each risk	Norm. Value for each risk
Climate Change	0	0	0	0	0	0	0	0	**0**	**0.00%**
Erosion	0	0	0	37	2044	0	0	0	**2081**	**1.45%**
Flooding (inc. Sea level rise)	0	31	1306	0	2044	0	0	0	**3381**	**2.36%**
Saline intrusion	0	31	0	0	0	0	0	0	**31**	**0.02%**
Tourism and recreation impact	0	0	0	0	0	0	0	0	**0**	**0.00%**
New causeways and other infrastructure	0	0	0	0	0	0	0	0	**0**	**0.00%**
Agricultural change	0	0	0	0	0	1171	9879	13380	**24430**	**17.05%**
Pollution inc. oil spills	10490	0	0	0	4088	0	0	0	**14578**	**10.17%**
Invasive species	20980	0	0	0	0	0	3293	13380	**37653**	**26.28%**
Marine and terrestrial litter/dumping	10490	0	0	0	0	0	0	0	**10490**	**7.32%**
Overgathering of shellfish/overfishing	10490	0	0	0	0	0	0	0	**10490**	**7.32%**
Other 1 (Over-regulation)	0	0	0	0	0	0	0	40140	**40140**	**28.02%**
Other 2 (Salt damage)	0	0	0	0	0	0	0	0	**0**	**0.00%**
Total Threat Value R for each biome	**52450**	**62**	**1306**	**37**	**8176**	**1171**	**13172**	**66900**	**121,281.00**	**100%**
Normalised value for each biome (% scale)	**37%**	**0%**	**1%**	**0%**	**6%**	**1%**	**9%**	**47%**	**100%**	

Table 3 Pairwise correlation (Pearson's r) of the threat factors for each of the biomes based on stakeholder analysis data

	Coastal Water	Coastal lagoons	Water bodies (inc. fresh lochs and rivers)	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs

Coastal Water	1							
Coastal lagoons	-0.262	1						
Water bodies (inc. fresh lochs and rivers)	-0.178	0.677*	1					
Sand Beaches	-0.178	-0.123	-0.083	1				
Coastal Islands	0.094	0.135	0.330	0.330	1			
Coniferous forest	-0.178	-0.123	-0.083	-0.083	-0.147	1		
Agricultural land	0.069	-0.160	-0.108	-0.108	-0.190	0.946**	1	
Peat bogs	0.011	-0.196	-0.133	-0.133	-0.234	0.213	0.276	1

** Highly significant at 0.01 threshold
* Significant at the .05 threshold

Table 4 (a) Estimated ecosystem service values of biomes based on scientific consultation

Service	Biome Type							
	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs
Agriculture	0	0	3	0	3	3	3	2
Fishing	3	2	3	0	3	0	0	0
Aquaculture	3	0	3	1	3	1	0	0
Intertidal Gathering	1	1	0	3	3	0	0	0
Sand/gravel/rock/peat extraction	3	1	0	3	1	0	3	3
Conservation interest	3	3	3	3	3	1	2	3
Recreation and tourism	2	2	2	3	3	3	1	1
Cultural/educational	3	2	3	2	3	2	2	2
Flood protection /coastal defence	1	3	3	3	2	1	2	3
Nutrient/waste absorption	3	1	2	1	1	2	2	2
Re. Energy generation	2	0	2	0	2	1	2	0
Landtake (carparks/range/causeways)	0	3	0	3	1	1	3	3
Total Service	**24**	**18**	**24**	**22**	**28**	**15**	**20**	**19**
Area of each biome (ha)	**10490**	**31**	**1306**	**37**	**2044**	**1171**	**3293**	**13380**

Table 4 (b) Product of biome spatial areas and estimated ecosystem service values based on scientific consultation

Service	Biomes									
	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs	Total value for each service	Norm. Value for each service
Agriculture	0	0	3918	0	6132	3513	9879	26760	**50202**	**7%**
Fishing	31470	62	3918	0	6132	0	0	0	**41582**	**6%**
Aquaculture	31470	0	3918	37	6132	1171	0	0	**42728**	**6%**
Intertidal Gathering	10490	31	0	111	6132	0	0	0	**16764**	**2%**
Sand/gravel/rock/peat extraction	31470	31	0	111	2044	0	9879	40140	**83675**	**12%**
Conservation interest	31470	93	3918	111	6132	1171	6586	40140	**89621**	**13%**
Recreation and tourism	20980	62	2612	111	6132	3513	3293	13380	**50083**	**7%**
Cultural/educational	31470	62	3918	74	6132	2342	6586	26760	**77344**	**11%**
Flood protection /coastal defence	10490	93	3918	111	4088	1171	6586	40140	**66597**	**10%**
Nutrient/waste absorption	31470	31	2612	37	2044	2342	6586	26760	**71882**	**11%**
Re. Energy generation	20980	0	2612	0	4088	1171	6586	0	**35437**	**5%**
Landtake (carparks/range/causeways)	0	93	0	111	2044	1171	9879	40140	**53438**	**8%**
Total Service Value S for each biome	**251760**	**558**	**31344**	**814**	**57232**	**17565**	**65860**	**254220**	**688486**	**100%**
Normalised value for each biome (% scale)	**37%**	**0%**	**5%**	**0%**	**8%**	**3%**	**10%**	**37%**	**100%**	

Table 5 (a) Estimated risk value to ecosystem biomes based on scientific consultation

Risk/Threat	Biome Type Sea and ocean	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs
Climate Change	3	2	3	3	3	2	3	3
Erosion	1	3	3	3	3	3	3	3
Flooding (inc. Sea level rise)	3	3	3	3	3	1	3	2
Saline intrusion	0	1	1	0	2	2	3	3
Tourism and recreation impact	2	2	3	3	3	2	2	2
New causeways and other infrastructure	1	3	1	2	2	2	3	3
Agricultural change	3	3	3	2	3	2	3	3
Pollution inc. oil spills	3	3	3	3	3	3	3	3
Invasive species	1	3	3	2	2	0	0	0
Marine and terrestrial litter/dumping	2	3	2	3	2	1	1	2
Overgathering of shellfish/overfishing	3	2	3	3	3	0	0	0
Other 1 (Over-regulation)	1	1	1	1	1	0	1	1
Other 2 (Salt damage)	2	2	1	1	1	0	2	2
Total Risk	**25**	**31**	**30**	**29**	**31**	**18**	**27**	**27**
Area of each biome (ha)	**10490**	**31**	**1306**	**37**	**2044**	**1171**	**3293**	**13380**

Table 5 (b) Product of biome spatial area and estimated risk value to each biome based on scientific consultation

Risk/Threat	Sea and ocean	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs	Total value for each risk	Norm. Value for each risk
Climate Change	31470	62	3918	111	6132	2342	9879	40140	**94054**	**11%**
Erosion	10490	93	3918	111	6132	3513	9879	40140	**74276**	**9%**
Flooding (inc. Sea level rise)	31470	93	3918	111	6132	1171	9879	26760	**79534**	**9%**
Saline intrusion	0	31	1306	0	4088	2342	9879	40140	**57786**	**7%**
Tourism and recreation impact	20980	62	3918	111	6132	2342	6586	26760	**66891**	**8%**
New causeways and other infrastructure	10490	93	1306	74	4088	2342	9879	40140	**68412**	**8%**
Agricultural change	31470	93	3918	74	6132	2342	9879	40140	**94048**	**11%**
Pollution inc. oil spills	31470	93	3918	111	6132	3513	9879	40140	**95256**	**11%**
Invasive species	10490	93	3918	74	4088	0	0	0	**18663**	**2%**
Marine and terrestrial litter/dumping	20980	93	2612	111	4088	1171	3293	26760	**59108**	**7%**
Overgathering of shellfish/overfishing	31470	62	3918	111	6132	0	0	0	**41693**	**5%**
Other 1 (Over-regulation)	10490	31	1306	37	2044	0	3293	13380	**30581**	**4%**
Other 2 (Salt damage)	20980	62	1306	37	2044	0	6586	26760	**57775**	**7%**
Total Threat Value R for each biome	**262250**	**961**	**39180**	**1073**	**63364**	**21078**	**88911**	**361260**	**974833**	**100%**
Normalised risk for each biome (% scale)	**31%**	**0%**	**5%**	**0%**	**8%**	**3%**	**11%**	**43%**	**100%**	

Table 6 Pairwise correlation (Pearson's r) of the threat factors for each of the biomes based on scientific consultation data

	Coastal Water	Coastal lagoons	Water bodies (inc. fresh lochs and rivers)	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs
Coastal Water	1.000							
Coastal lagoons	0.354	1.000						
Water bodies (inc. fresh lochs and rivers)	0.619*	0.511*	1.000					
Sand Beaches	0.653*	0.626*	0.788**	1.000				
Coastal Islands	0.563	0.435	0.855**	0.733**	1.000			
Coniferous forest	0.028	0.298	0.272	0.282	0.588*	1.000		
Agricultural land	0.072**	0.148	-0.023	-0.016	0.330	0.789**	1.000	
Peat bogs	0.006	0.157	-0.103	-0.017	0.254	0.841**	0.939**	1.000

** Highly significant at 0.01 threshold
* Significant at the .05 threshold

Fig. 2: Normalised risk-return profiles of all portfolio biomes relative to spatial area of each biome

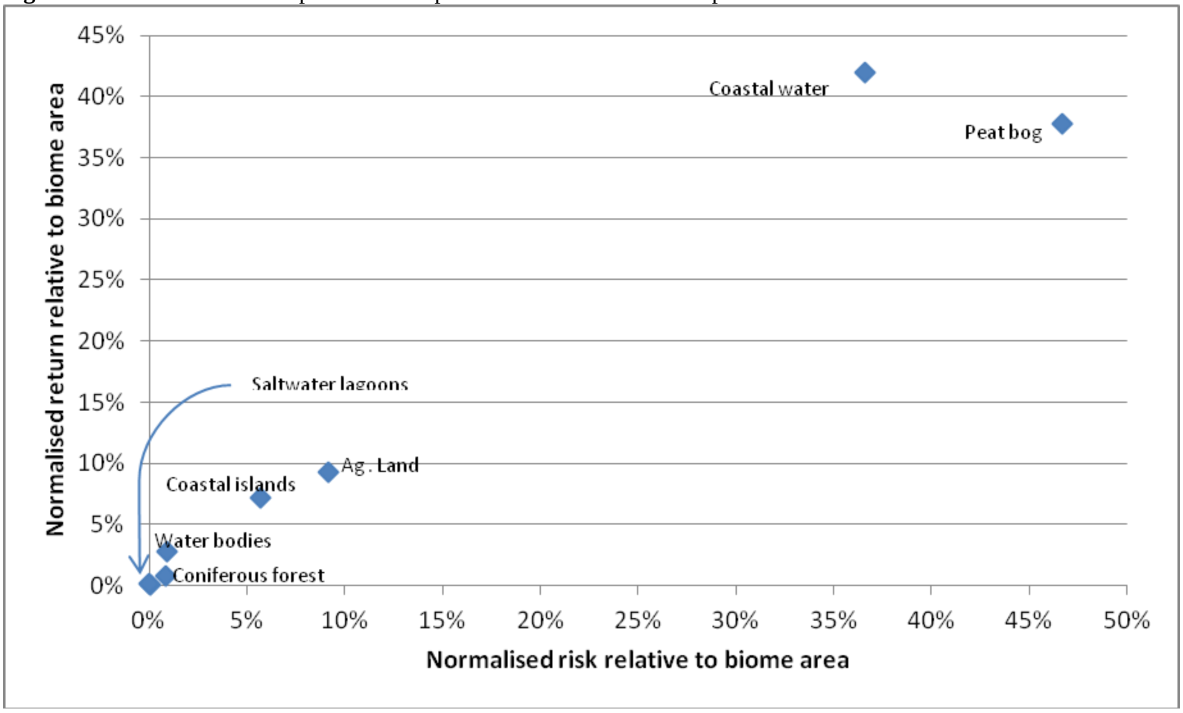


Fig. 3: Normalised risk-return profiles of all portfolio biomes regardless of spatial area of each biome

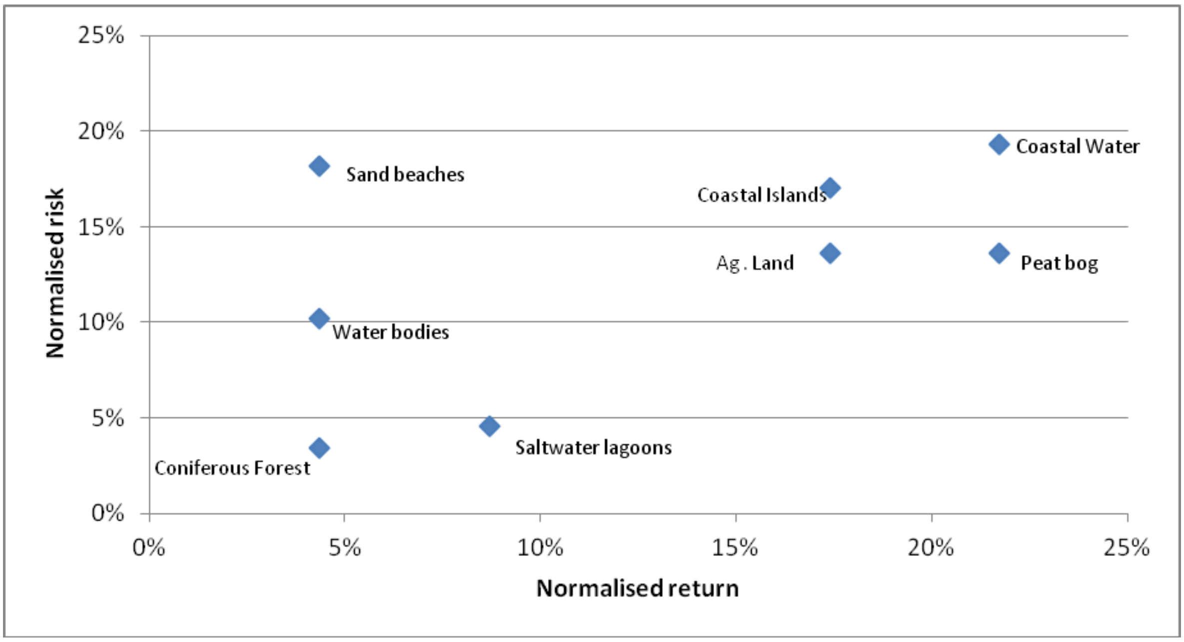


Fig. 4. Normalised and risk-return profiles of all portfolio biomes for both local stakeholder analysis and scientific consultations (biome service and risk values * biome area)

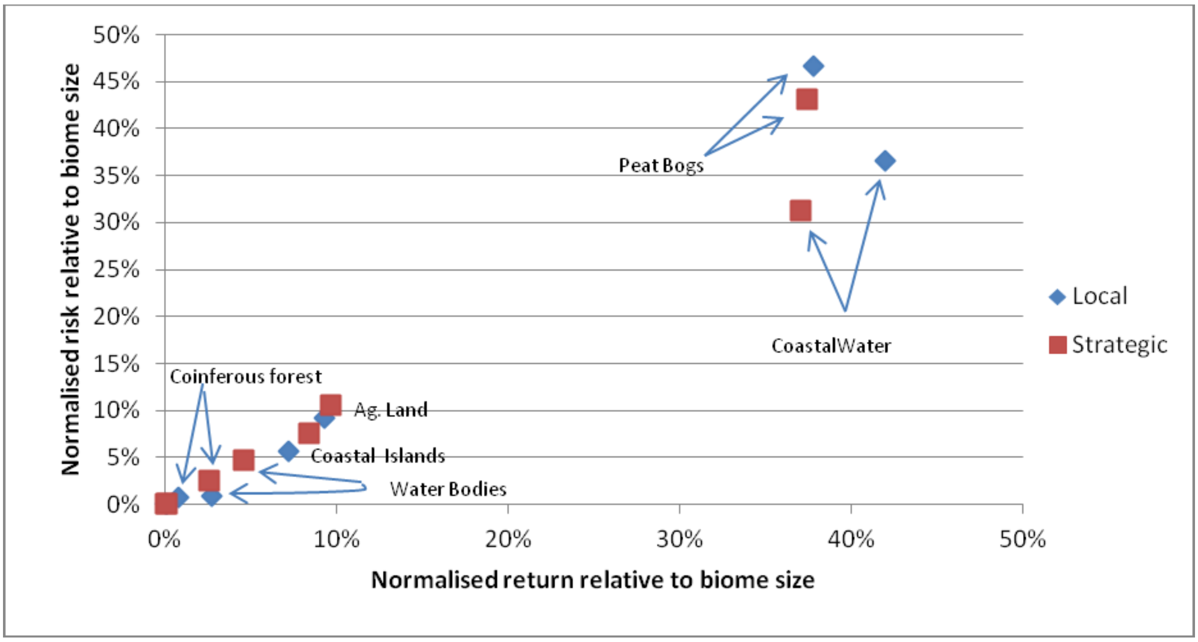
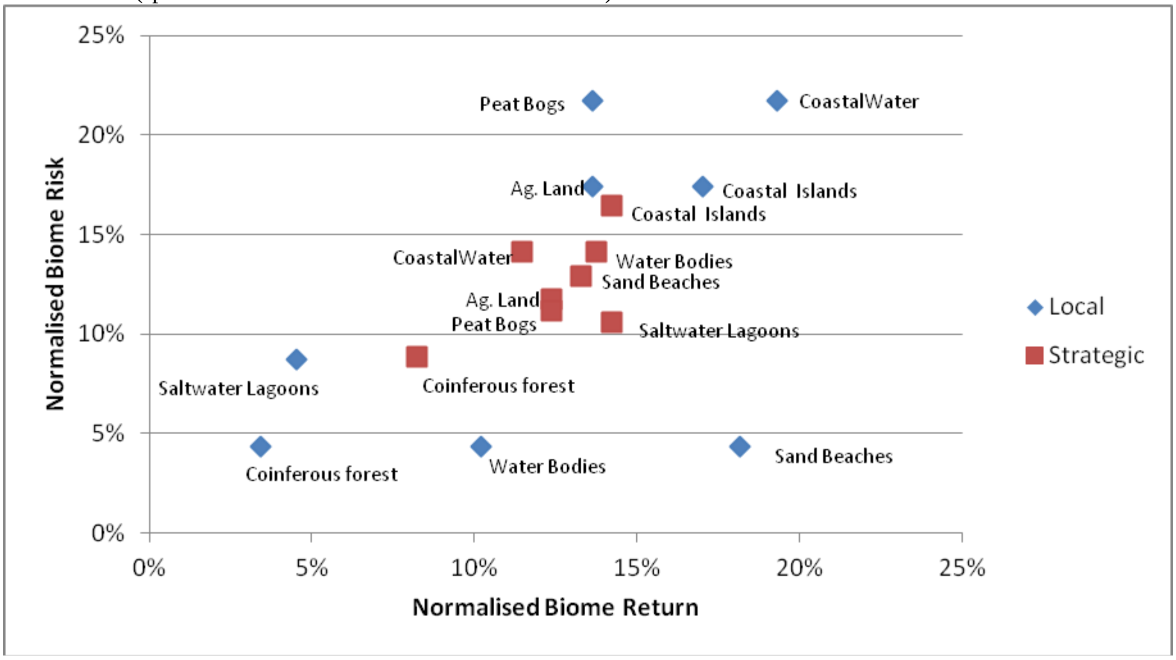


Fig. 5. Normalised and risk-return profiles of all portfolio biomes for both local stakeholder analysis and scientific consultations (spatial area of biome not included in calculation)



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Appendix

1. **Coastal Water:** The zone of maximum interaction between humans and critical biological resources ; the intertidal zone to four meters below Mean Low Water.
2. **Sand open beach:** A beach is a geological landform along the shoreline of an ocean, sea, lake or river. It usually consists of loose particles which are often composed of rock, such as sand, gravel, shingle, pebbles or cobblestones. The particles of which the beach is composed can sometimes instead primarily be of biological origins, such as whole or fragmentary mollusc shells or fragments of coralline algae. In this study it also encompasses
   - 2.1. *Sand inlet:* A recess, such as a bay or cove made up of sand, along the coast)
   - 2.2. *Shingles:* A beach which is armoured with pebbles or small- to medium-sized cobbles. Typically, the stone composition may grade from characteristic sizes ranging from two to 200 mm
   - 2.3. *Rock Platform:* The ancient, stable, interior layer of a continental craton composed of igneous or metamorphic rocks covered by a thin layer of sedimentary rock. Rock platforms are flat, expansive eroded regions that lie at the base of rocky headlands. They are important habitats, as they contain a huge variey of plants and animals that cope with unique physical stresses of waves, fluctuating weather conditions and two complete tide cycles per day. Rock platforms are the most accessible of all marine habitats and an important resource for recreation and education
   - 2.4. *Sand Dunes:* a ridge of sand created by the wind; found in deserts or near lakes and oceans
3. **Coastal/Saltwater Lagoons:** Natural saline lagoons are areas of typically (but not exclusively) shallow coastal saline water, wholly or partially separated from the sea by sandbanks, shingle rock or other barrier such as hard substrata. They retain some sea water at low tide and vary in salinity from slightly saltier than fresh water (brackish) to saltier than sea water (hyper-saline). Sea water exchange can occur through a natural or artificial channel or by percolation either through or over the barrier. More diffuse freshwater inputs (e.g. percolation, groundwater seepage) can affect the lagoon's salinity. Lagoons that are highly modified or are of artificial origin, such as those that occur behind a seawall, can still provide a similar habitat to that of natural lagoons, with a comparable range of specialised species.
4. **Water Bodies:** Natural or artificial stretches of water including rivers.
5. **Coastal Islands:** Any substantial land masses on the coast of Iarras Aithneach coast captured by the boundaries of the study site

6. **Coniferous Forest:** Vegetation formation composed principally of trees, including shrub and bush understories, where coniferous species predominate. Also included the catgeories:
7. **Agricultural land:** Areas principally occupied by agriculture, interspersed with significant natural areas. Also included the category:

   7.1. *Pastures*: Dense, predominantly graminoid grass cover, of floral composition, not under a rotation system. Mainly used for grazing, but the fodder may be harvested mechanically. Includes areas with hedges (bocage).
8. **Peat Bogs:** Peatland consisting mainly of decomposed moss and vegetable matter. May or may not be exploited.

Table 1 (a) Estimated ecosystem service values of biomes based on stakeholder analysis

Service	Biome Type							
	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs
Agriculture	0	0	3	2	2	1	3	3
Fishing	3	1	3	0	3	0	0	0
Aquaculture	3	0	1	0	0	0	0	0
Intertidal Gathering	3	0	0	3	0	0	0	0
Sand/gravel/rock/peat extraction	0	0	0	0	0	0	3	3
Conservation interest	2	2	0	3	3	2	1	1
Recreation and tourism	3	0	1	3	2	0	1	2
Cultural/educational	3	0	0	2	3	0	2	3
Flood protection /coastal defence	0	0	0	3	2	0	0	0
Nutrient/waste absorption	0	0	0	0	0	0	0	0
Re. Energy generation	0	0	1	0	0	0	0	0
Landtake (carparks/range/causeways)	0	1	0	0	0	0	2	0
Total Service	17	4	9	16	15	3	12	12
Area of each biome (sq km)	10490	31	1306	37	2044	1171	3293	13380

Table 1 (b) Product of biome spatial areas and estimated ecosystem service values based on stakeholder analysis

Service	Biome Type									
	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs	Total value for each service	Norm. Value for each service
Agriculture	0	0	3918	74	4088	1171	9879	40140	**59270**	**13.94%**
Fishing	31470	31	3918	0	6132	0	0	0	**41551**	**9.78%**
Aquaculture	31470	0	1306	0	0	0	0	0	**32776**	**7.71%**
Intertidal Gathering	31470	0	0	111	0	0	0	0	**31581**	**7.43%**
Sand/gravel/rock/peat extraction	0	0	0	0	0	0	9879	40140	**50019**	**11.77%**
Conservation interest	20980	62	0	111	6132	2342	3293	13380	**46300**	**10.89%**
Recreation and tourism	31470	0	1306	111	4088	0	3293	26760	**67028**	**15.77%**
Cultural/educational	31470	0	0	74	6132	0	6586	40140	**84402**	**19.86%**
Flood protection /coastal defence	0	0	0	111	4088	0	0	0	**4199**	**0.99%**
Nutrient/waste absorption	0	0	0	0	0	0	0	0	**0**	**0.00%**
Re. Energy generation	0	0	1306	0	0	0	0	0	**1306**	**0.31%**
Landtake (carparks/range/causeways)	0	31	0	0	0	0	6586	0	**6617**	**1.56%**
Total Service Value S for each biome	**178330**	**124**	**11754**	**592**	**30660**	**3513**	**39516**	**160560**	**369184**	**100%**
Normalised value for each biome (% scale)	**42%**	**0%**	**3%**	**0%**	**7%**	**1%**	**9%**	**38%**	**100%**	

Table 2 (a) Estimated risk value to ecosystem biomes based on stakeholder analysis

Risk/Threat	Biome Type							
	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs

Climate Change	0	0	0	0	0	0	0	0
Erosion	0	0	0	1	1	0	0	0
Flooding (inc. Sea level rise)	0	1	1	0	1	0	0	0
Saline intrusion	0	1	0	0	0	0	0	0
Tourism and recreation impact	0	0	0	0	0	0	0	0
New causeways and other infrastructure	0	0	0	0	0	0	0	0
Agricultural change	0	0	0	0	0	1	3	1
Pollution inc. oil spills	1	0	0	0	2	0	0	0
Invasive species	2	0	0	0	0	0	1	1
Marine and terrestrial litter/dumping	1	0	0	0	0	0	0	0
Overgathering of shellfish/overfishing	1	0	0	0	0	0	0	0
Other 1 (Over-regulation)	0	0	0	0	0	0	0	3
Other 2 (Salt damage)	0	0	0	0	0	0	0	0
Total Risk	5	2	1	1	4	1	4	5
Area of each biome (sq km)	10490	31	1306	37	2044	1171	3293	13380

Table 2 (b) Product of biome spatial area and estimated risk value to each biome based on stakeholder analysis

Risk/Threat	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs	Total value for each risk	Norm. Value for each risk
Climate Change	0	0	0	0	0	0	0	0	**0**	**0.00%**
Erosion	0	0	0	37	2044	0	0	0	**2081**	**1.45%**
Flooding (inc. Sea level rise)	0	31	1306	0	2044	0	0	0	**3381**	**2.36%**
Saline intrusion	0	31	0	0	0	0	0	0	**31**	**0.02%**
Tourism and recreation impact	0	0	0	0	0	0	0	0	**0**	**0.00%**
New causeways and other infrastructure	0	0	0	0	0	0	0	0	**0**	**0.00%**
Agricultural change	0	0	0	0	0	1171	9879	13380	**24430**	**17.05%**
Pollution inc. oil spills	10490	0	0	0	4088	0	0	0	**14578**	**10.17%**
Invasive species	20980	0	0	0	0	0	3293	13380	**37653**	**26.28%**
Marine and terrestrial litter/dumping	10490	0	0	0	0	0	0	0	**10490**	**7.32%**
Overgathering of shellfish/overfishing	10490	0	0	0	0	0	0	0	**10490**	**7.32%**
Other 1 (Over-regulation)	0	0	0	0	0	0	0	40140	**40140**	**28.02%**
Other 2 (Salt damage)	0	0	0	0	0	0	0	0	**0**	**0.00%**
Total Threat Value R for each biome	**52450**	**62**	**1306**	**37**	**8176**	**1171**	**13172**	**66900**	**121,281.00**	**100%**
Normalised value for each biome (% scale)	**37%**	**0%**	**1%**	**0%**	**6%**	**1%**	**9%**	**47%**	**100%**	

Table 3 Pairwise correlation (Pearson's r) of the threat factors for each of the biomes based on stakeholder analysis data

	Coastal Water	Coastal lagoons	Water bodies (inc. fresh lochs and rivers)	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs

Coastal Water	1							
Coastal lagoons	-0.262	1						
Water bodies (inc. fresh lochs and rivers)	-0.178	0.677*	1					
Sand Beaches	-0.178	-0.123	-0.083	1				
Coastal Islands	0.094	0.135	0.330	0.330	1			
Coniferous forest	-0.178	-0.123	-0.083	-0.083	-0.147	1		
Agricultural land	0.069	-0.160	-0.108	-0.108	-0.190	0.946**	1	
Peat bogs	0.011	-0.196	-0.133	-0.133	-0.234	0.213	0.276	1

** Highly significant at 0.01 threshold
* Significant at the .05 threshold

Table 4 (a) Estimated ecosystem service values of biomes based on scientific consultation

Service	Biome Type							
	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs
Agriculture	0	0	3	0	3	3	3	2
Fishing	3	2	3	0	3	0	0	0
Aquaculture	3	0	3	1	3	1	0	0
Intertidal Gathering	1	1	0	3	3	0	0	0
Sand/gravel/rock/peat extraction	3	1	0	3	1	0	3	3
Conservation interest	3	3	3	3	3	1	2	3
Recreation and tourism	2	2	2	3	3	3	1	1
Cultural/educational	3	2	3	2	3	2	2	2
Flood protection /coastal defence	1	3	3	3	2	1	2	3
Nutrient/waste absorption	3	1	2	1	1	2	2	2
Re. Energy generation	2	0	2	0	2	1	2	0
Landtake (carparks/range/causeways)	0	3	0	3	1	1	3	3
Total Service	**24**	**18**	**24**	**22**	**28**	**15**	**20**	**19**
Area of each biome (ha)	**10490**	**31**	**1306**	**37**	**2044**	**1171**	**3293**	**13380**

Table 4 (b) Product of biome spatial areas and estimated ecosystem service values based on scientific consultation

Service	Biomes									
	Coastal Waters	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs	Total value for each service	Norm. Value for each service
Agriculture	0	0	3918	0	6132	3513	9879	26760	**50202**	**7%**
Fishing	31470	62	3918	0	6132	0	0	0	**41582**	**6%**
Aquaculture	31470	0	3918	37	6132	1171	0	0	**42728**	**6%**
Intertidal Gathering	10490	31	0	111	6132	0	0	0	**16764**	**2%**
Sand/gravel/rock/peat extraction	31470	31	0	111	2044	0	9879	40140	**83675**	**12%**
Conservation interest	31470	93	3918	111	6132	1171	6586	40140	**89621**	**13%**
Recreation and tourism	20980	62	2612	111	6132	3513	3293	13380	**50083**	**7%**
Cultural/educational	31470	62	3918	74	6132	2342	6586	26760	**77344**	**11%**
Flood protection /coastal defence	10490	93	3918	111	4088	1171	6586	40140	**66597**	**10%**
Nutrient/waste absorption	31470	31	2612	37	2044	2342	6586	26760	**71882**	**11%**
Re. Energy generation	20980	0	2612	0	4088	1171	6586	0	**35437**	**5%**
Landtake (carparks/range/causeways)	0	93	0	111	2044	1171	9879	40140	**53438**	**8%**
Total Service Value S for each biome	**251760**	**558**	**31344**	**814**	**57232**	**17565**	**65860**	**254220**	**688486**	**100%**
Normalised value for each biome (% scale)	**37%**	**0%**	**5%**	**0%**	**8%**	**3%**	**10%**	**37%**	**100%**	

Table 5 (a) Estimated risk value to ecosystem biomes based on scientific consultation

Risk/Threat	Biome Type Sea and ocean	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land
Climate Change	3	2	3	3	3	2	
Erosion	1	3	3	3	3	3	
Flooding (inc. Sea level rise)	3	3	3	3	3	1	
Saline intrusion	0	1	1	0	2	2	
Tourism and recreation impact	2	2	3	3	3	2	
New causeways and other infrastructure	1	3	1	2	2	2	
Agricultural change	3	3	3	2	3	2	
Pollution inc. oil spills	3	3	3	3	3	3	
Invasive species	1	3	3	2	2	0	
Marine and terrestrial litter/dumping	2	3	2	3	2	1	
Overgathering of shellfish/overfishing	3	2	3	3	3	0	
Other 1 (Over-regulation)	1	1	1	1	1	0	
Other 2 (Salt damage)	2	2	1	1	1	0	
Total Risk	**25**	**31**	**30**	**29**	**31**	**18**	
Area of each biome (ha)	**10490**	**31**	**1306**	**37**	**2044**	**1171**	

Table 5 (b) Product of biome spatial area and estimated risk value to each biome based on scientific consultation

Risk/Threat	Sea and ocean	Coastal lagoons	Water bodies	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land
Climate Change	31470	62	3918	111	6132	2342	9879
Erosion	10490	93	3918	111	6132	3513	9879
Flooding (inc. Sea level rise)	31470	93	3918	111	6132	1171	9879
Saline intrusion	0	31	1306	0	4088	2342	9879
Tourism and recreation impact	20980	62	3918	111	6132	2342	6586
New causeways and other infrastructure	10490	93	1306	74	4088	2342	9879
Agricultural change	31470	93	3918	74	6132	2342	9879
Pollution inc. oil spills	31470	93	3918	111	6132	3513	9879
Invasive species	10490	93	3918	74	4088	0	0
Marine and terrestrial litter/dumping	20980	93	2612	111	4088	1171	3293
Overgathering of shellfish/overfishing	31470	62	3918	111	6132	0	0
Other 1 (Over-regulation)	10490	31	1306	37	2044	0	3293
Other 2 (Salt damage)	20980	62	1306	37	2044	0	6586
Total Threat Value R for each biome	**262250**	**961**	**39180**	**1073**	**63364**	**21078**	**88911**
Normalised risk for each biome (% scale)	**31%**	**0%**	**5%**	**0%**	**8%**	**3%**	**11%**

Table 6 Pairwise correlation (Pearson's r) of the threat factors for each of the biomes based on scientific consultation data

	Coastal Water	Coastal lagoons	Water bodies (inc. fresh lochs and rivers)	Sand Beaches	Coastal Islands	Coniferous forest	Agricultural land	Peat bogs
Coastal Water	1.000							
Coastal lagoons	0.354	1.000						
Water bodies (inc. fresh lochs and rivers)	0.619*	0.511*	1.000					
Sand Beaches	0.653*	0.626*	0.788**	1.000				
Coastal Islands	0.563	0.435	0.855**	0.733**	1.000			
Coniferous forest	0.028	0.298	0.272	0.282	0.588*	1.000		
Agricultural land	0.072**	0.148	-0.023	-0.016	0.330	0.789**	1.000	
Peat bogs	0.006	0.157	-0.103	-0.017	0.254	0.841**	0.939**	1.00[illegible]

** Highly significant at 0.01 threshold
* Significant at the .05 threshold

Fig. 2: Normalised risk-return profiles of all portfolio biomes relative to spatial area of each biome

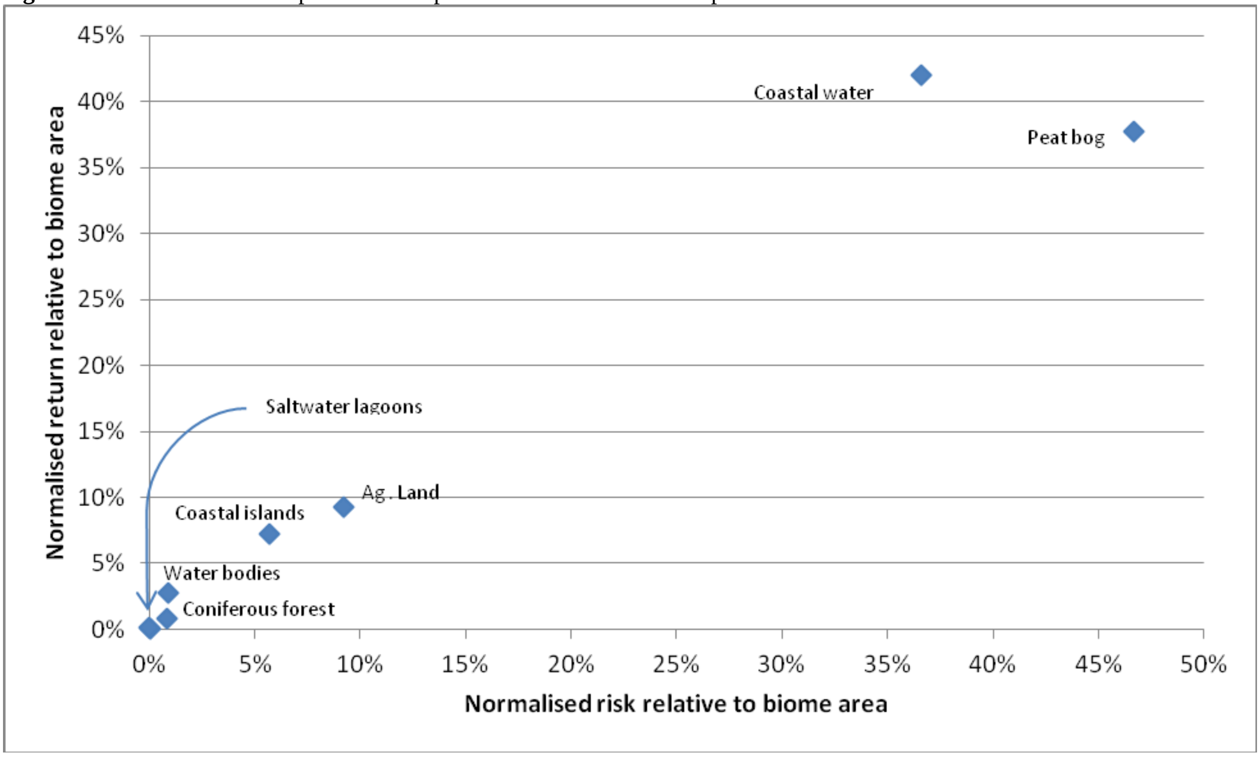


Fig. 3: Normalised risk-return profiles of all portfolio biomes regardless of spatial area of each biome

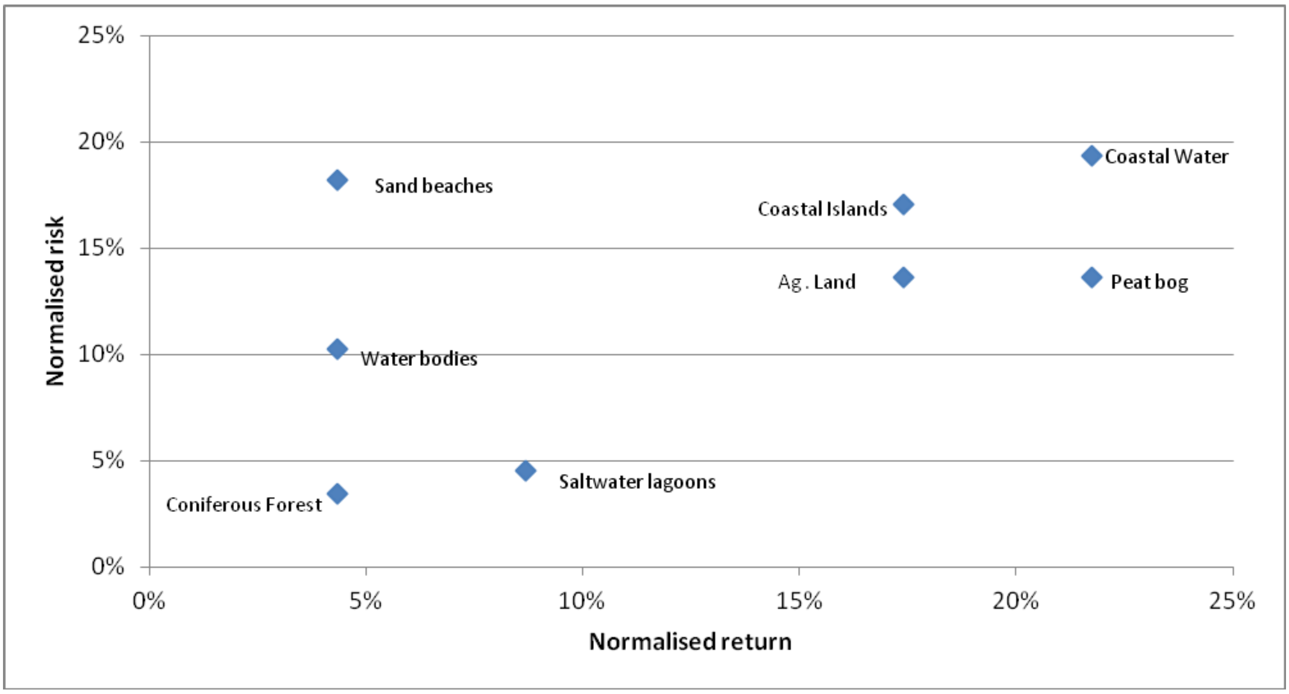


Fig. 4. Normalised and risk-return profiles of all portfolio biomes for both local stakeholder analysis and scientific consultations (biome service and risk values * biome area)

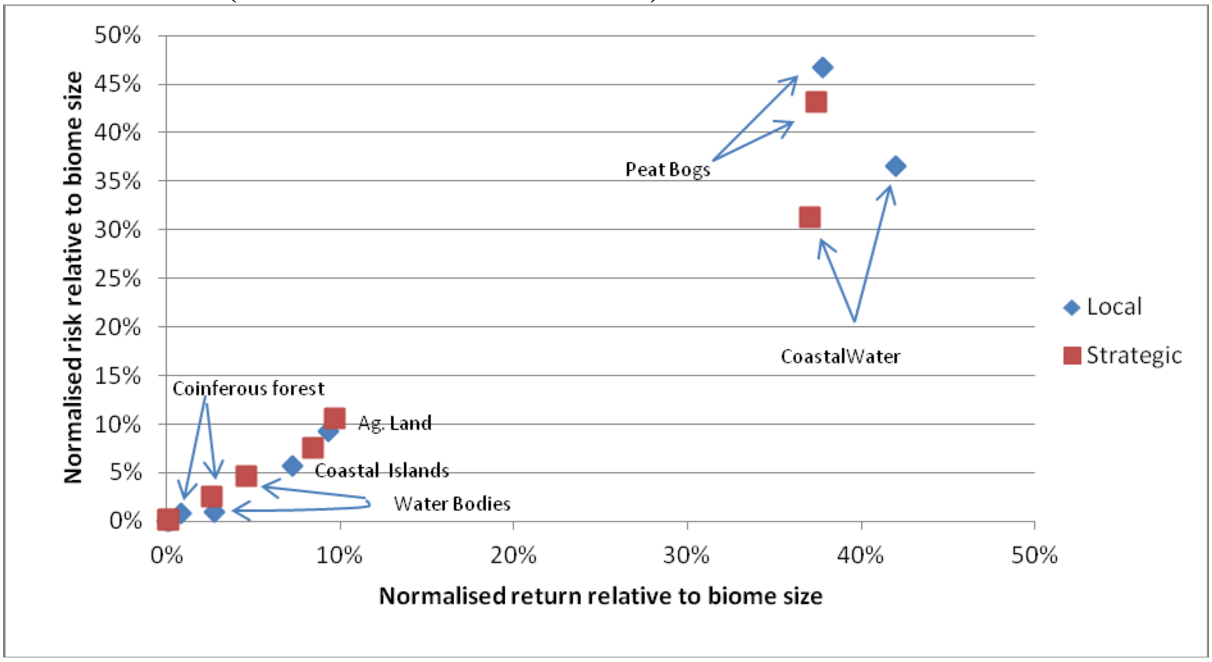
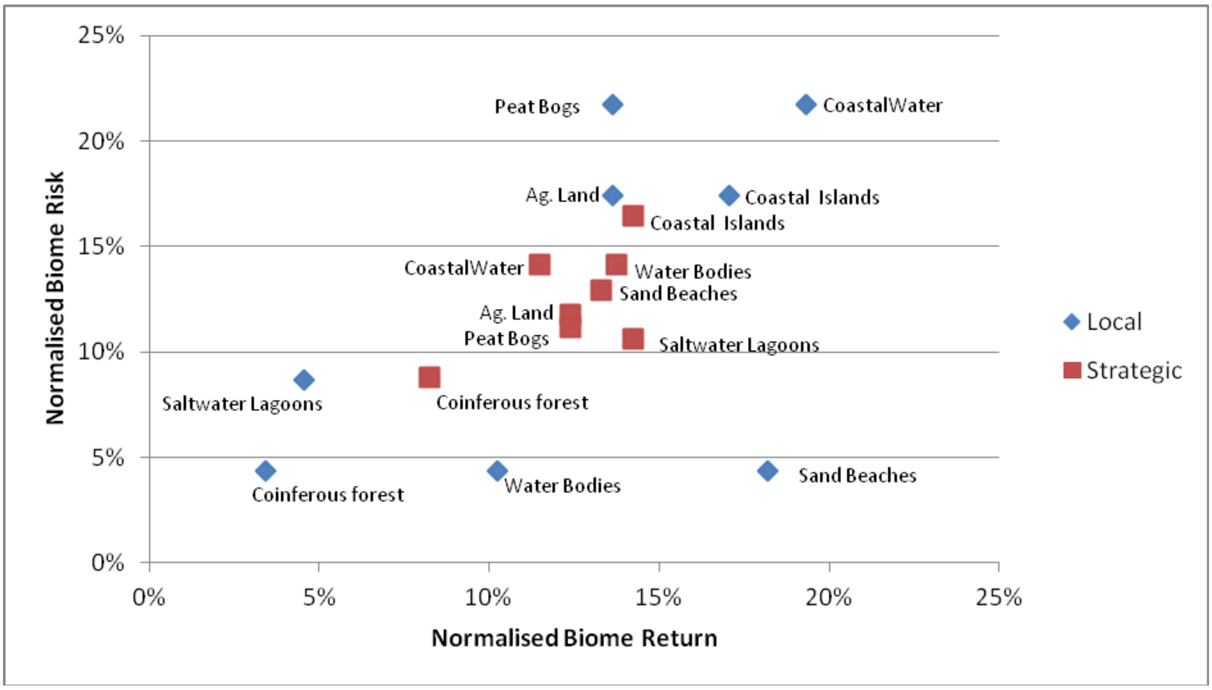


Fig. 5. Normalised and risk-return profiles of all portfolio biomes for both local stakeholder analysis and scientific consultations (spatial area of biome not included in calculation)



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