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# Seascape Visual Characterization: Combining Viewing Geometry and Physical Features to Quantify the Perception of Seascape

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**Abstract:** The visual impacts of marine-based economic activities on seascape quality and its inherent value for different user groups are considered to be a highly contentious issue and difficult to quantify. In recent years, with the growth of the blue economy, the need to better understand the visual perceptions of seascapes has become essential when seeking societal support for new development. This article presents a unique method for assessing and quantifying seascape perception by characterizing a person viewing the geometry of seascape views both from the land and the sea. The method first utilizes a geographic information system (GIS) model to deconstruct the viewing geometry of a seascape view into five geometric elements, including (1) area of viewshed, (2) length of the visible coastline, (3) horizontal extent of the view, (4) vertical extent of the view, and (5) distance to the view. These geometric elements in the second step were reconstructed through an analytical hierarchical process (AHP) to determine the visual quality perception of participants. The results showed a significant improvement in the visual characterization of the seascape and its visual quality perception in comparison with conventional visual characterization methods. The findings indicate that the model promotes multiple perceptual perspectives by facilitating constructive discussions about social acceptance of the visual impact of a specific marine-based development.

**Keywords:** seascape character assessment; visual character assessment; GIS modeling; spatial planning; visual geometry; spatiovisual analysis; visual quality



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## 1. Introduction

In many parts of the world, coastal and marine landscapes (or seascapes) are considered essential elements in people's sense of identity and culture [1]. The significant growth of the blue economy in recent decades [2,3] however, has created varying degrees of visual impacts on the quality of people's seascape experience and its inherent value in different user groups [4,5]. This has resulted in new onshore and offshore developments becoming highly contentious and a major source of conflict between those who value economic activities as a source of income and livelihood, and those who wish to keep the seascape unchanged [6].

To assess the likely impact of changes to the seascape, from the type of ocean and coastal-based economic activity being evaluated, seascape impact assessments in recent decades have become a required element of the environmental impact assessment (EIA) [7,8]. This process of the seascape visual sensitivity analysis is used to determine the degree to which a seascape could accommodate the predicted change [9,10]. However, in order to fully analyze seascape's visual sensitivity, it is necessary to compare the visual impacts of any development against a visual baseline [9,11]. This visual baseline is established by evaluating the visual characteristics of a seascape based on their qualities or values [12,13].

Seascape visual characterization is defined as a process of mapping and describing the seascape to demonstrate how one area is visually distinct from another [1,9]. The level of information gathered at this stage for defining a meaningful characterization often depends on how the seascape is visually understood. In the literature, the visual definition of seascape is sometimes simply treated as an extension of the landscape [1]. However, according to Miller and Morrice [14], the visual definition of a seascape should include three important components: (a) visual characteristics of the conjunction of the land and the sea, (b) visual characteristics of the land viewed from the sea, and (c) visual characteristics of the sea viewed from the land. The compartmentalized seascape is therefore seen as a discrete area within which there is shared intervisibility between land and sea (within a single visual envelope).

The developed methodologies for visual characterization of the seascape in comparison with the terrestrial landscape are less advanced. One of the main reasons for this might be that the visual characterization of landscapes relies on a variety of physical features that are frequently found on the surface of the land. For example, Tveit [15,16] identified nine key concepts, including coherence, complexity, and ephemera, to describe the visual characteristics of landscape. However, such physical features either do not exist in the marine environment or they tend to be dynamic and temporary (e.g., the visual characteristics of the sea surface may change due to weather and light conditions), which precludes them from being mapped [1,10,12].

In most recent studies, visual characteristics of seascapes are often collected through two complementary approaches: on the one hand, by using desk or GIS map-based analysis, and on the other, by direct observations [11,12]. The first approach usually takes advantage of a digital terrain model (DTM) within a geographic information system to map the degree of intervisibility between the land and the sea [5,17–21]. The output map is often designed to reflect the visual significance (or exposure) of a location by showing the number of likely viewpoints with overlapping visual envelopes. While this might characterize a specific location, in terms of the proportion of visual receptors, it does not provide any additional information about the other visual characteristics of a seascape. This gap is usually filled by the second approach, which requires extensive site-based activities including photography, drawing sketches, and annotations defining the important visual characteristic [1,9].

Although these approaches may be applicable within a local scale EIA, they are rarely applicable to a regional scale strategic environmental impact assessment (SEIA). This is because the extensive reliance on direct observations as a method to collect visual characteristics of a seascape has several limitations. Firstly, site-based activities (e.g., photography) reflect a static representation of the seascape, whereas the seascape is dynamic and continuously changing through both natural processes and cultural changes. As a result, repeating and updating observations, particularly at regional and national scales (strategic scale) can be a never-ending expensive and difficult task. Secondly, selecting a suitable location to record the visual details of a scene, considering potential limited access to remote areas and poor visibility due to weather and light conditions, can sometimes become a time-consuming, expensive, or impractical exercise [22–24]. Thirdly, direct observations, unlike a map-based approach, rely on expert judgment and are therefore not an objective method of data collection [25]. Kaplan [26] argues that experts also perceive the visual environment rather differently from other people, and expert evaluation is therefore “a dubious source of objective judgment” on behalf of other people. Additionally, the visual preference of an individual observer may also vary, depending on light conditions, weather, and even socioeconomic circumstances [27]. Lastly, photography may poorly represent the visual characteristics of a seascape, as a single or even panoramic photograph may not capture the diversity of potential views [28,29].

Supporting the sustainable development of blue economy activities requires ecosystem-based maritime spatial planning (EBMSP), with the challenge of applying SEIA in the context of policy development and setting up marine spatial plans at strategic scales [30]. The main focus of this article is to develop a GIS map-based approach for visual characterization of the seascape at a strategic scale. The method uses commonly available tools in GIS software (e.g., viewshed analysis, line of sight, skyline) [31–33] to deconstruct the viewing geometry of a seascape view into several geometric elements for seascape characterization using a case study from Tasmania, Australia. The visually characterized seascape is then used to describe the visual quality perception in the study region to demonstrate how this might potentially be used to prioritize seascapes in an EBMSP context.

## 2. Study Region

The study region (Figure 1) is in the southeast of the island state of Tasmania, Australia. It lies between 42°30′ and 43°45′ south latitude and between 146°45′ and 148°00′ east longitude. Tasmania is internationally recognized for its high-quality aquaculture and wild fishery products. Species that are commercially farmed in Tasmania include abalone, Atlantic salmon, blue mussels, ocean trout, Pacific oysters, and seahorses [34]. In this analysis the contributions made by the land and the sea were limited to two geographical extents. The geographical extent of the sea was selected to include Storm Bay and the adjacent Tasman Sea (approximately 4880 km$^2$). The geographic extent of the land was selected by applying a 20-km band or buffer on the landward side of the geographical extent of the sea (approximately 6535 km$^2$). The study region is home to 175 individual aquaculture farms where 45 of them are classified as finfish aquaculture.

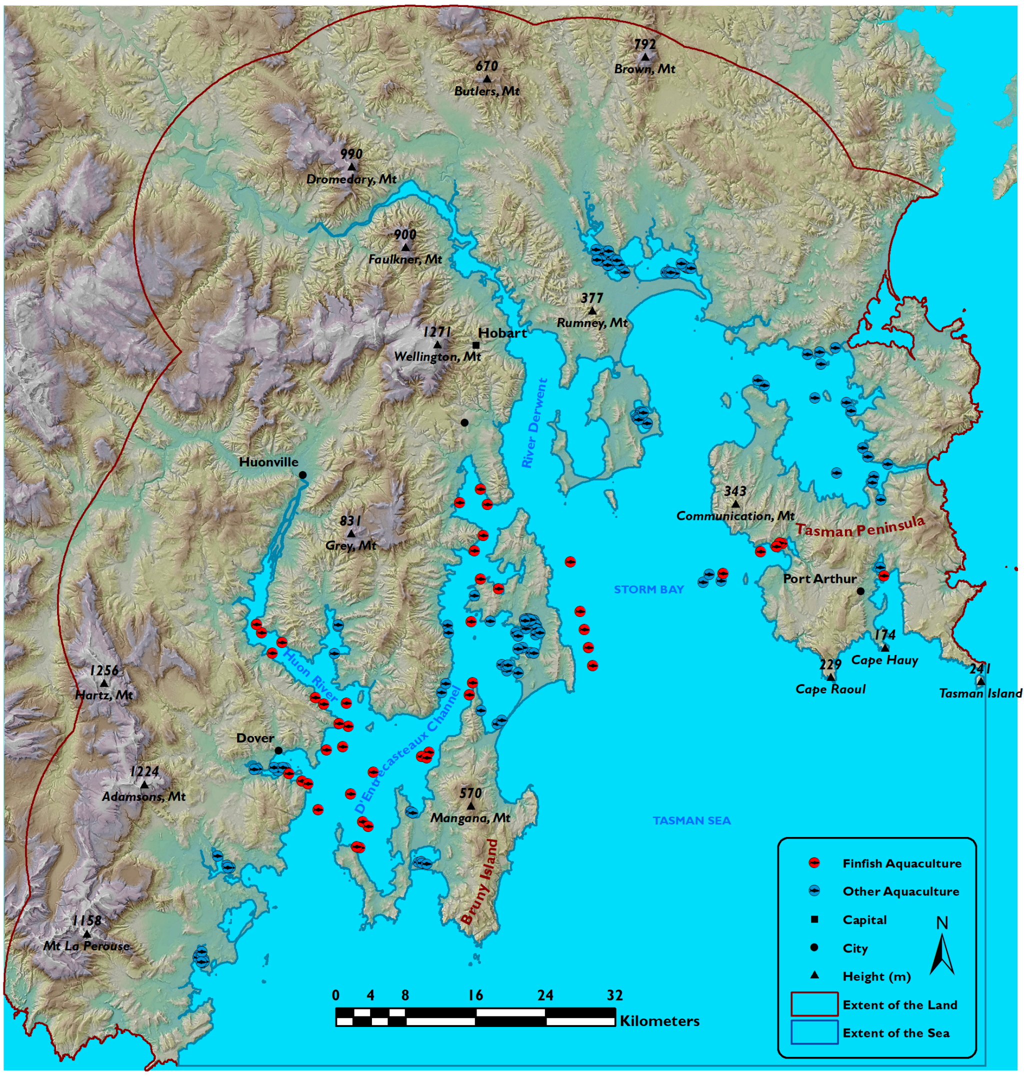



**Figure 1.** The study region is in southeastern Tasmania and includes Storm Bay, a region of active marine development for Blue Economy initiatives. Currently, there are 175 individual aquaculture farms within the study area where 45 of them are classified as finfish aquaculture (red points).

## 3. Model Components and Development

A three-stage model was developed to represent a visual baseline for the study area (Figure 2). Stage one implements a seascape visual character model where several submodels are developed to extract and describe the viewing geometry and physical features of the seascape, viewed from both viewpoints on the land and the sea. Stage two uses the key features from stage one to develop a perceptual model based on simple factors of visual environmental perception and preferences within an analytical hierarchical process (AHP). This model allocates appropriate weights for the outputs of the seascape visual character model. The allocated weights obtained for each of the five visual characters are multiplied with their respective calculated values to get a visual quality score for every viewpoint on land and sea. In the third and last stage of the model, the quality scores derived from both sets of viewpoints on the land and the sea are used in a series of extrapolation and interpolation processes to create two spatial raster layers: (1) visual quality score and (2) visual significance for the landward and seaward extents of the study area.

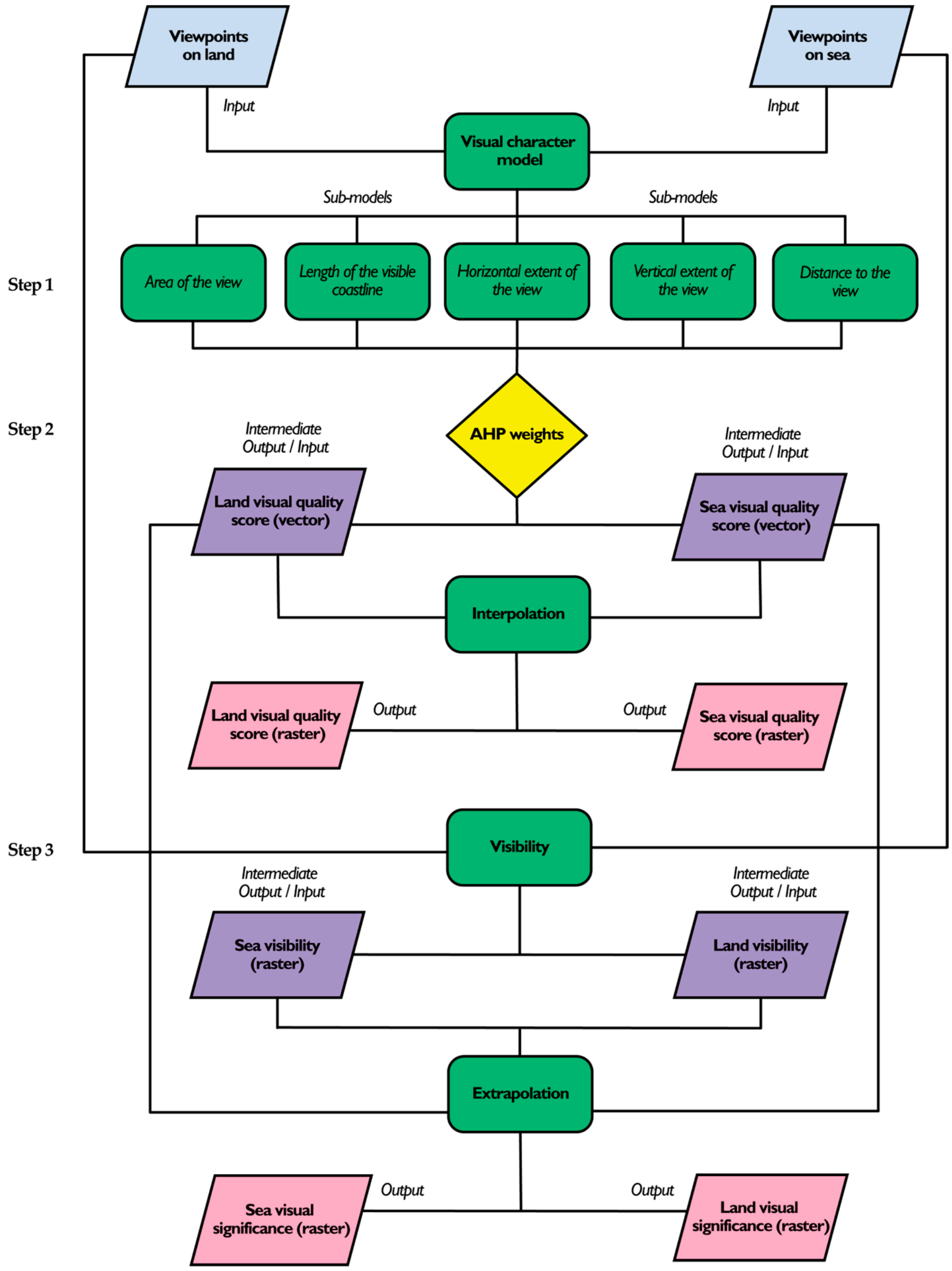


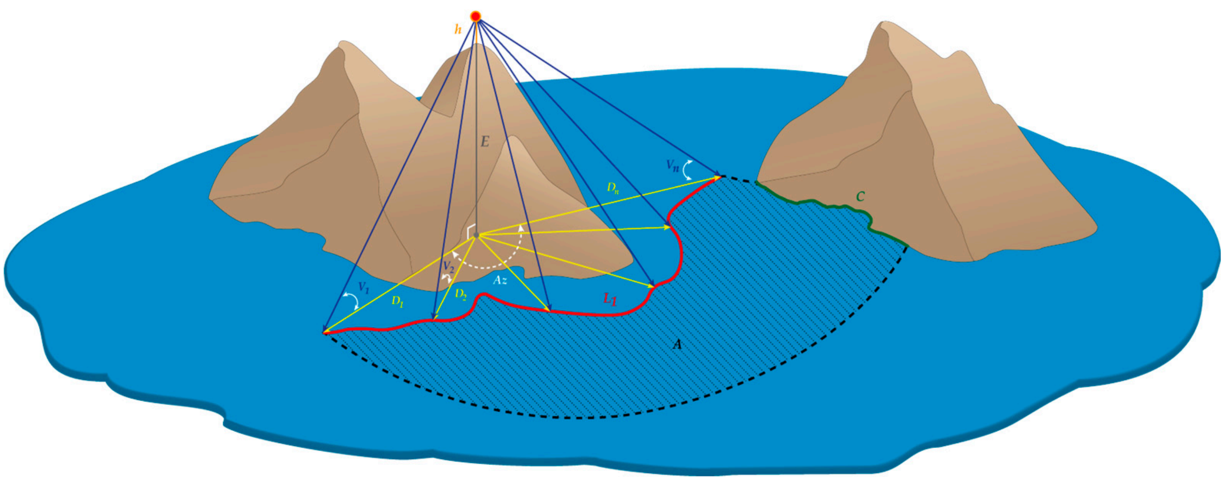

**Figure 2.** Conceptual structure of the visual character model.

### *3.1. Establishing the Visual Character Model Environment*

The primary model input was a hydrologically conditioned digital terrain model (DTM) sourced from the Land Information System Tasmania [35]. It is a 1:25,000 scale of terrain height data with ±5 m vertical accuracy at a 1-m vertical resolution and a 25-m horizontal resolution. The DTM was resampled to a 50-m horizontal resolution in order to reduce the computing overhead for our analysis. A vector representation of the coastline used in this model was reconstructed from the boundary between the resampled DTM and the marine areas. To represent the viewpoints from both land and sea, two sets of regular grid vector points, spaced at one-kilometer intervals, were generated across the landward and seaward extents of the study area. These viewpoints were then vertically modified to reflect an effective baseline visual height of 1.8 m, representing the height of an average person, above the DTM. That is to say, all the other visual height possibilities, such as a viewer being on top of a manmade surface (e.g., a viewer on a ferry, ship, or building), were not considered in this study. The data processing and model development were conducted within ArcGIS software (ESRI), and prior to our analysis, the input data and the generated proxy data were all projected to the Geocentric Datum of Australia 1994 (GDA94)/Map Grid of Australia (MGA) Zone 55 georeferenced system.

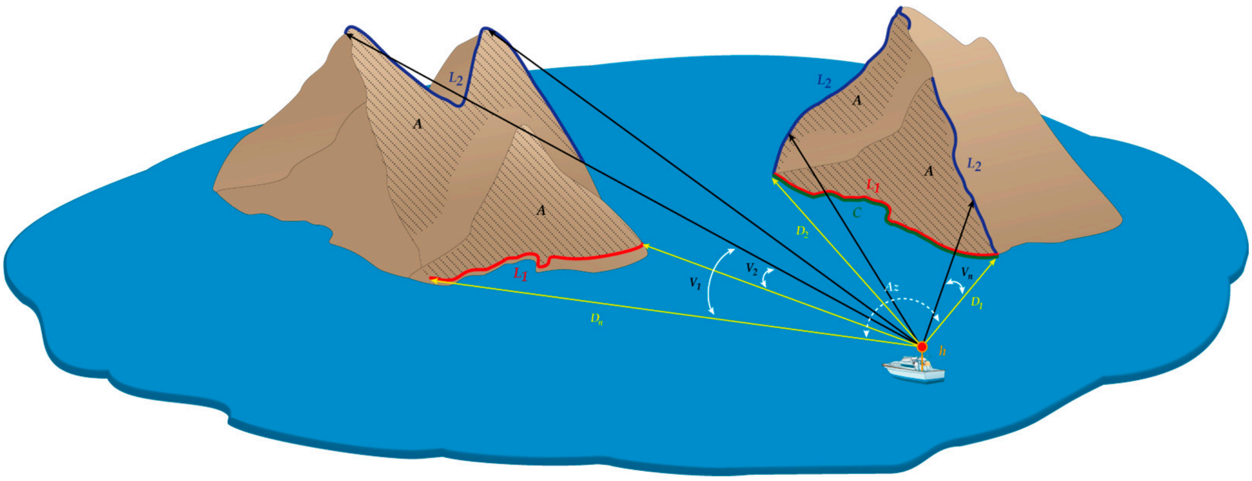
### *3.2. Stage One: Seascape Visual Character Model*

The first stage was the development of a seascape visual character model based on the viewing geometry of the seascape to explain the spatial relationships between the viewpoint and the *object of view* (i.e., the potential view that can be seen from a location). Where the *object of view* for viewpoints on the land was limited to the visible portion of the sea (sea view), and conversely, the *object of view* for viewpoints on the sea was limited to the visible portion of the land (land view). Viewing geometry relations, including perceived extents and perceived angles of view, were used to describe five seascape visual characters: (1) *area of the visibility*, (2) *length of the visible coastline*, (3) *horizontal extent of the view*, (4) *vertical extent of the view*, and (5) *distance to the view*. Figure 3 shows these five seascape visual characters from the viewpoint of the land and the sea, respectively. The visibility toolset within the '3D Analyst' extension of ArcGIS software was used to develop five submodels reconstructing and measuring the seascape visual characters. Two separate workflows were developed using ArcGIS's visual programming language (ModelBuilder) to enable batch processing functionality in running these submodels for multiple viewpoints on land and sea.




(**a**)

**Figure 3.** *Cont.*




(**b**)

**Figure 3.** Shows the geometric depictions of five seascape visual characters for a viewpoint on the land (**a**) and the sea (**b**). These depictions are denoted as follows: area of the visibility (*A*), length of the visible coastline (*C*), horizontal extent of the view (*Az*), vertical extent of the view ($V_i$), distance to the view ($D_i$), the line separating the land from the sea ($L_1$), the line separating land from sky ($L_2$), the height of observer (*h*), and elevation above the sea level (E).

### 3.2.1. Area of Visibility

The *Area of visibility (A)* refers to the total geographical area that can be seen from a viewpoint, also known as the viewshed. This submodel characterizes the perceptual experience of the openness of an environment [16]. The area of the visibility from each viewpoint depends on several factors, including the height of the viewpoint above sea level to offset the influence of the curvature of the earth, the level of interruption by promontories of land (lines of cliffs, frequent headlands, shallow sloping terrain, or local terrain), and atmospheric refraction. In this submodel, the 3D Analyst's 'visibility tool' was used to calculate visible and nonvisible areas for a given viewpoint while considering the earth's curvature. However, it should be noted that the visibility calculation did not account for the following: (1) the effect of vegetation covers, building, and other manmade objects; and (2) the effect of atmospheric refraction under the average atmospheric conditions of the study region. The visibility analysis output (raster format) uses binary classification to assign one to all visible cells and zero to all nonvisible cells across the landward and seaward extents of the study area. The resulting Boolean visibility layer for any viewpoint on the land was intersected with the sea to exclude visible parts of the land (the *object of view* is the sea); and for any viewpoint on the sea, the visibility layer was intersected with the land to exclude visible parts of the sea (the *object of view* is the land). If a viewpoint had more than one visible area, they were summed to represent the total *area of the visibility*.

### 3.2.2. Length of the Visible Coastline

The *length of the visible coastline (C)* refers to the total length of the coastline that falls within the visible areas. This submodel characterizes one of the most visually sensitive lines in the seascape that affects the focus of an observer's attention by creating a strong contrast between land and sea and also provides a strong feature to enable orientation. The presence of coastline, therefore, makes the seascape's visual character distinctive and increases the perceived 'quality' of a view [36]. The proportion of the visible coastline for any of the viewpoints on the land or the sea was identified by intersecting the coastline with the *area of visibility (A)*. The visible segments of the coastline were summed to represent the total *length of the visible coastline*.

#### 3.2.3. Horizontal Extent of the View

The *horizontal extent of the view (Az)* refers to the proportion of the azimuth angle or compass direction of the view in the horizontal plane (0–360 degrees) from a viewpoint that subtends the area occupied by the *object of view*. The *horizontal extent of the view* is particularly important for seascape characterization because the width of the view is expected to be greater for viewpoints with a wide horizontal angle of view than it is for viewpoints with a narrow angle of view [1,14]. The output of this submodel can therefore help to characterize whether the extent of view from a viewpoint is 'glimpsed' (e.g., a view from the end of a narrow inlet on the land) or 'panoramic' (e.g., a view from a headland). The output is also linked to the sea/sky or land/sky horizon lines in the view, depending on whether the viewpoint is on land or the sea. Similar to the coastline, these lines create a sharp contrast and are therefore known to be visually sensitive [13] and, as such, play a key role in characterizing the seascape. In this submodel, the 3D Analyst's 'skyline' tool, which identifies a vector line separating the sky from a surface (e.g., DTM) surrounding a viewpoint (skyline), was used to reconstruct the line that goes along the horizontal extent of view. However, there are a number of important considerations that need to be noted about the use of the 'skyline' tool in this submodel. Since the tool searches for the skyline above the horizon (inclination: 0 to +90 degrees) with respect to the viewpoint position, it could only be used for the viewpoints on the sea where the *object of view* lies above the horizon. In order to adopt the tool for the viewpoints on the land where the *object of view* lies below the horizon (depression: 0 to −90 degrees), the input DTM surface and the viewpoint height above sea level were multiplied by minus one. This line was then used within the 3D Analyst's 'skyline graph' tool to count the units of azimuth angle representing the proportion of azimuth angle.

#### 3.2.4. Vertical Extent of the View

The *vertical extent of the view* refers to the average of the maximum vertical angle of view ($V_i$) along the horizontal plane from a viewpoint that subtends the area occupied by the *object of view*. The output of this submodel is particularly important for seascape characterization because visual stimulus is expected to be greater for viewpoints where the direction of view is not completely horizontal or level. In this submodel, depending on the position of a viewpoint on the land or the sea, its relationship with the *object of view* differed. The *vertical extent of the view* for viewpoints on the land is a function of the viewpoint's elevation ($E$) in relation to the sea as the *object of view*. For instance, a viewpoint on high terrain (i.e., a vantage point) can be described as having a superior viewing angle overlooking the sea (the viewer looking downward) because it has the potential to see a greater percentage of the sea, as the viewpoint's elevation offsets the influence of the curvature of the earth. On the other hand, the *vertical extent of the view* from viewpoints on the sea explains its relationship with the height of the land. For example, a viewpoint on the sea with close visual proximity to a headland or steep sea cliff of considerable size (viewer looking upward) can be described as having a large vertical scale landmark. The output of this submodel can therefore help to characterize whether an observer from a viewpoint is relatively looking down or up (−90 to +90 degrees) to see the *object of view*. In this submodel, the 3D Analyst's 'skyline' tool was used to reconstruct the horizontal line that maximized the vertical angle. However, depending on the position of a viewpoint on the land or the sea environment, the horizontal line that maximizes the vertical angle is different. The horizontal line that maximized the vertical angle for viewpoints on the land was the line separating land from the sea ($L_1$); and the horizontal line that maximized the vertical angle for viewpoints on the sea was the line separating land from the sky ($L_2$). This line ($L_1$ *or* $L_2$) was then used within the 3D Analyst's 'construct line sights' tool to reconstruct multiple lines of sight from a viewpoint. The number of lines of sight ($i$) from a viewpoint to the horizontal line that maximized the vertical angle ($L_1$ *or* $L_2$) was limited by sampling at a certain interval. The resulting vertical angles measured for each line of sight from a viewpoint were averaged to represent the *vertical extent of the view*.

#### 3.2.5. Distance to the View

The distance to the view refers to the average of the minimum Euclidian distances from a viewpoint to the object of view ($D_i$) along the horizontal plane. The output of this submodel describes the relative distance from a viewpoint to the *object of view*. This is extremely important for seascape characterization in a number of ways. The *distance to the view* influences the degree of perceived visual contrast, scale dominance of the *object of view*, which in turn affects the perception of the environment, level of detail, and focus of the viewer. In this submodel, the horizontal line that minimizes the Euclidian distance to the object of view from the viewpoint of land and the sea ($L_1$) is reconstructed using the previous submodels. The 'line of sight' ($i$) from the vertical extent of the view submodel was used to calculate the Euclidian distances, and they were averaged to represent the *distance to the view*.

### *3.3. Second Stage: Seascape Visual Perceptual Quality Score*

In this analysis, the AHP approach was used to allocate appropriate weights for each of the seascape visual character models. The AHP approach is a multicriteria decision-making tool developed by [37] that builds a hierarchy for decision-making by establishing priorities by using pairwise comparisons. The use of pairwise comparison makes the judgment relatively easy and allows us to mathematically check the consistency of the judgment. The AHP procedure in this study is composed of two primary steps: (1) to create two separate pairwise comparisons of the five visual submodels for viewpoints on land and at sea; and (2) to specify a relative weight for each submodel by forming priority vectors.

The relative weights of submodels in AHP are determined based on pairwise comparison. Saaty [37] suggested a scale of 1–9 when comparing two components (Table 1). The score of 1 represents equal importance of two components, and 9 represents extreme importance/preference. The numerical values that represent the pairwise comparison of objectives are placed into matrix A. The entry in the $i^{th}$ row and the $j^{th}$ column of matrix A is the importance of objective i compared to that of objective j. It follows the entries in the diagonal of matrix A, which are equal to 1, for example $a_{ii} = 1$. The score of $a_{ij}$ in the pairwise comparison matrix represents the relative importance of the objective on the row i over the objective on the column j, for example $a_{ij} = w_i/w_j$. The reciprocal value of the expression $a_{ij} = 1/a_{ij}$ is used when objective j is more important than objective i. Hence, the pairwise comparison matrix for a decision maker with n objectives is an $n \times n$ matrix $A = \left[a_{ij}\right]$ such that:

$$a_{ij} > 0 \quad \text{for } i, j = 1, \ldots, n, \ (\text{called 'positive matrix'}), \tag{1}$$

$$a_{ij} = 1/a_{ij} \quad \text{for } i, j = 1, \ldots, n \ (\text{called 'reciprocal matrix'}). \tag{2}$$

**Table 1.** Proposed scale for pairwise comparison suggested by Saaty [37].

| Scale | Definition of Scale |
|---|---|
| 1 | Equally Important Preferred |
| 2 | Equally to Moderately Important Preferred |
| 3 | Moderately Important Preferred |
| 4 | Moderately to Strongly Important Preferred |
| 5 | Strongly Important Preferred |
| 6 | Strongly to Very Strongly Important Preferred |
| 7 | Very Strongly Important Preferred |
| 8 | Very Strongly to Extremely Important Preferred |
| 9 | Extremely Important Preferred |

The following eigenvector equation was used to calculate the priority weight vector after all pairwise comparisons were completed:

$$Aw = \lambda_{max} w, \tag{3}$$

The greatest eigenvalue in matrix A is denoted by the symbol $\lambda_{max}$. The normalization of the priority weight vector $wi > 0$ was performed by $\alpha = \sum_i^n wi = 1$.

Consistency is measured by the consistency index (CI) and the consistency ratio (CR). The CI is defined by:

$$CI = \lambda_{max} - n/n - 1, \tag{4}$$

If the pairwise evaluations do not contain any discrepancies, then $\lambda_{max} = n$. The pairwise evaluations' coherence is measured by the CR as follows:

$$CR = \frac{CI}{RI}, \tag{5}$$

where RI is the average CI of a collection of a randomly generated comparison values. Generally, a CR value of 10% or higher indicates a significant inconsistency and encourages the user to reconsider their judgment of the relative importance of the submodels or criteria.

### 3.4. Stage Three: Synthesis

In the last stage of the model, the normalized values of the visual character model outputs from both viewpoints on the landward and seaward components of the study area were multiplied by their respective weights. The weighted average of the visual character model outputs for each viewpoint underpins the visual perceptual quality scores. Interpolating these perceptual quality scores separately enabled the creation of two raster layers (one from viewpoints on land and the other from viewpoints at sea) that provide visual perceptual quality scores at locations where the viewpoints were not directly sampled. While these two raster layers describe the quality of the view from a potential viewpoint, they can also describe what can be seen in the opposite environment to where the viewpoint is located (e.g., a viewpoint on land can describe the quality of the visible area of sea as a whole). The calculated visual perceptual quality score from each viewpoint was then multiplied by its respective Boolean raster visibility layer to extrapolate its value to the *object of view* in the opposite environment (e.g., the land is the *object of view* for the viewpoint on the sea and vice versa). These extrapolated raster layers were summed together to represent the quality and visual significance of both the landward and seaward components of the study area. Finally, the raster outputs of the interpolation and extrapolation processes for the landward and seaward components of the study area were added together to generate the overall visual perceptual quality scores.

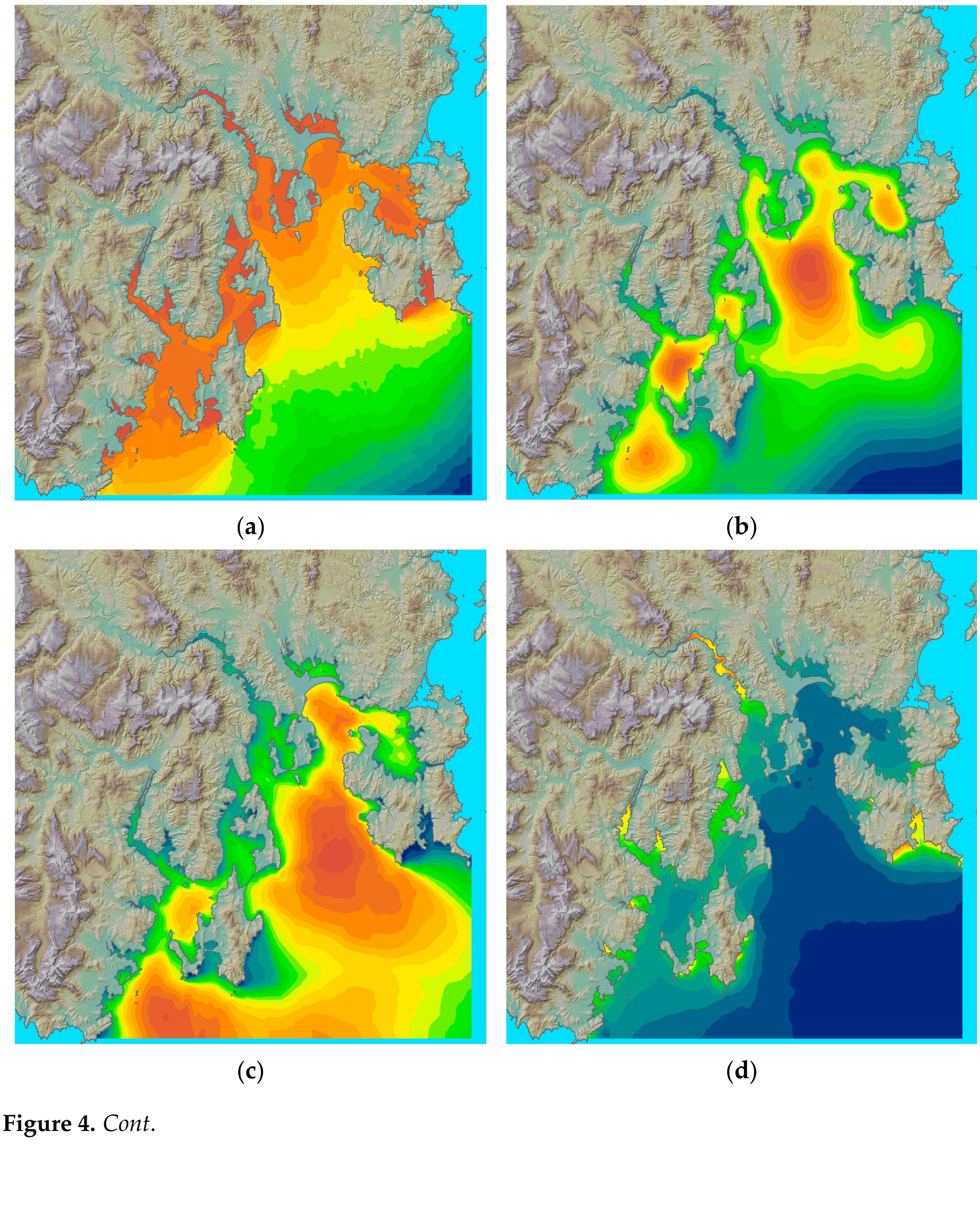
## 4. Results

The outputs from the five submodels of the visual character model in stage one include: (1) *area of visibility*, (2) *length of the visible coastline*, (3) *horizontal extent of the view*, (4) *vertical extent of the view*, *and* (5) *distance to the view*, which are normalized on a scale between 0 and 1 for both viewpoints on the land (total number of 6567 viewpoints) and the sea (total number of 4875 viewpoints). The normalized values from each submodel are then interpolated using the Kriging technique, which is an advanced geostatistical procedure that generates an estimated surface from a set of points.

The interpolated surfaces from the five submodels of the visual character model for viewpoints on the sea are shown in Figure 4. The seas from which the widest horizontal angle of the *land view* is available are predominantly located around the coastal region, but particularly in bays, narrow waterways (e.g., Huon River and River Derwent), and the D'Entrecasteaux Channel. The sea areas from which the average of the vertical angles of the *land view* is high are mostly located near Port Arthur, the upper course of the Huon and Derwent rivers, and southeast of Bruny Island. The sea areas from which the average

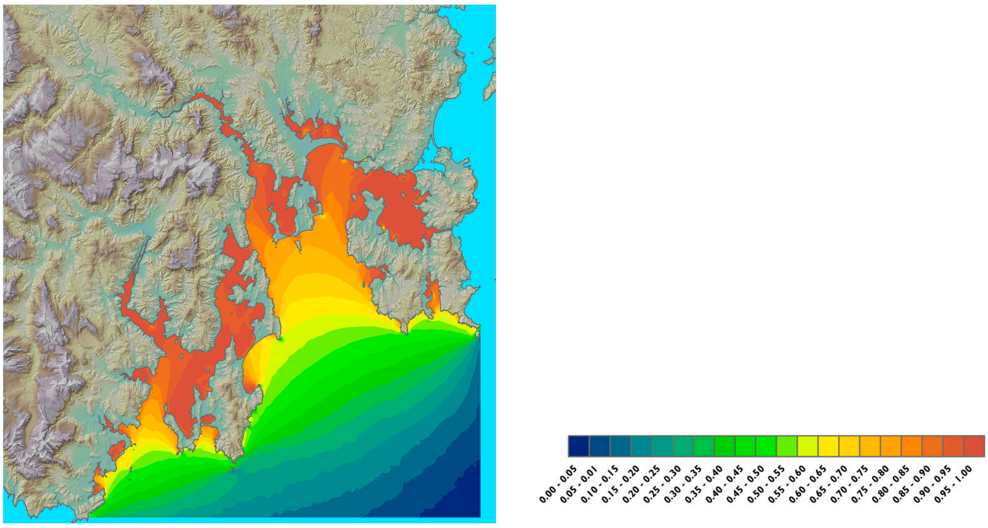
Euclidian distance to the *land view* is short follow the coast but peak in bays and other semi-enclosed waterways. The sea from which the greatest length of the coastline is visible is mostly located outside of the coastal zone, but particularly in Storm Bay and the southern part of the D'Entrecasteaux Channel. Finally, the sea from which most areas of *land view* are available is similar to that of the visible length of coastline, except that it extends further offshore onto the continental shelf.

The interpolated surfaces from the five submodels of the visual character model for the viewpoints on the land are shown in Figure 5. The land from which the majority of the wide horizontal angle of the *sea view* is available, is predominantly located in the highlands near the coastal region but particularly on headlands, some small islands, and the narrow land strip that connects the north and south parts of Bruny Island. The land from which the average of the vertical angles to the *sea view* is greater is mostly located around the unobstructed highlands near the sea, but particularly a high mountain in the vicinity of Hobart (Mount Wellington), southern parts of Bruny Island, and the Tasman Peninsula. Those locations in which the average Euclidian distance to the *sea view* is short are mostly located in coastal regions, as expected. Finally, the land from which the most *area of visibility* and *length of the visible coastline* can be seen is limited to the high mountains near Hobart and the southern part of Bruny Island.



(**a**) (**b**) (**c**) (**d**)

**Figure 4.** *Cont.*




(**e**)

**Figure 4.** Raw outputs of the five submodels of visual character model for viewpoints on the land. The outputs are normalized and shown on a categorical scale (20 equal parts) after interpolation: 0, low score; 1, high score. (**a**) horizontal extent of the view, (**b**) vertical extent of the view, (**c**) distance to the view, (**d**) length of the visible coastline, (**e**) area of the visibility.

The AHP model is used as a multicriteria evaluation approach to give two separate preference weights to the five submodels of the visual character model, one for the viewpoints on land and the other for the viewpoints at sea. In this study, the authors' own visual preferences (Table 2) were used in the pairwise comparison matrix for the five submodels of the visual character model. It should be noted that interviewing the community was not possible under COVID-19 restrictions at the time when this study was conducted, and therefore the authors preference rankings were used to demonstrate the approach. The calculated CR values for the pairwise comparison matrices of the viewpoints on land and sea are presented in Table 3. The two CR values are both less than 7%, indicating that the allocated weights are mathematically reliable. The two top priority submodels for viewpoints on land are *distance to the view* (50.5%) and *vertical extent of the view* (26.5%), whereas the order is reversed for viewpoints on the sea, where the top priority is the *vertical extent of the view* (47.3%) followed by the *distance to the view* (28.1%). The other three submodels, including *length of the visible coastline*, *horizontal extent of the view*, and *area of the visible area*, have the same respective priority order for land and sea viewpoints.

The calculated weights of the five submodels for the viewpoints on land and sea (Table 3) were multiplied by their respective normalized values for each viewpoint, and the results were summed to obtain a single visual geometric score. The visual geometric score for the viewpoints on land and the sea is interpolated using the Kriging technique, and the interpolated surfaces are presented in Figure 6. Most of the coastal land and sea areas have moderate to high-quality scores. The land areas with the highest scores are steep headlands (or capes) where they suddenly rise from the sea or land, such as those near Port Arthur (e.g., cape Raoul). These headlands tend to have high values in all five submodels of the visual character model. The sea areas with the highest score are mostly located in bay areas or narrow waterways surrounded by highlands (e.g., Port Arthur and the upper River Derwent).

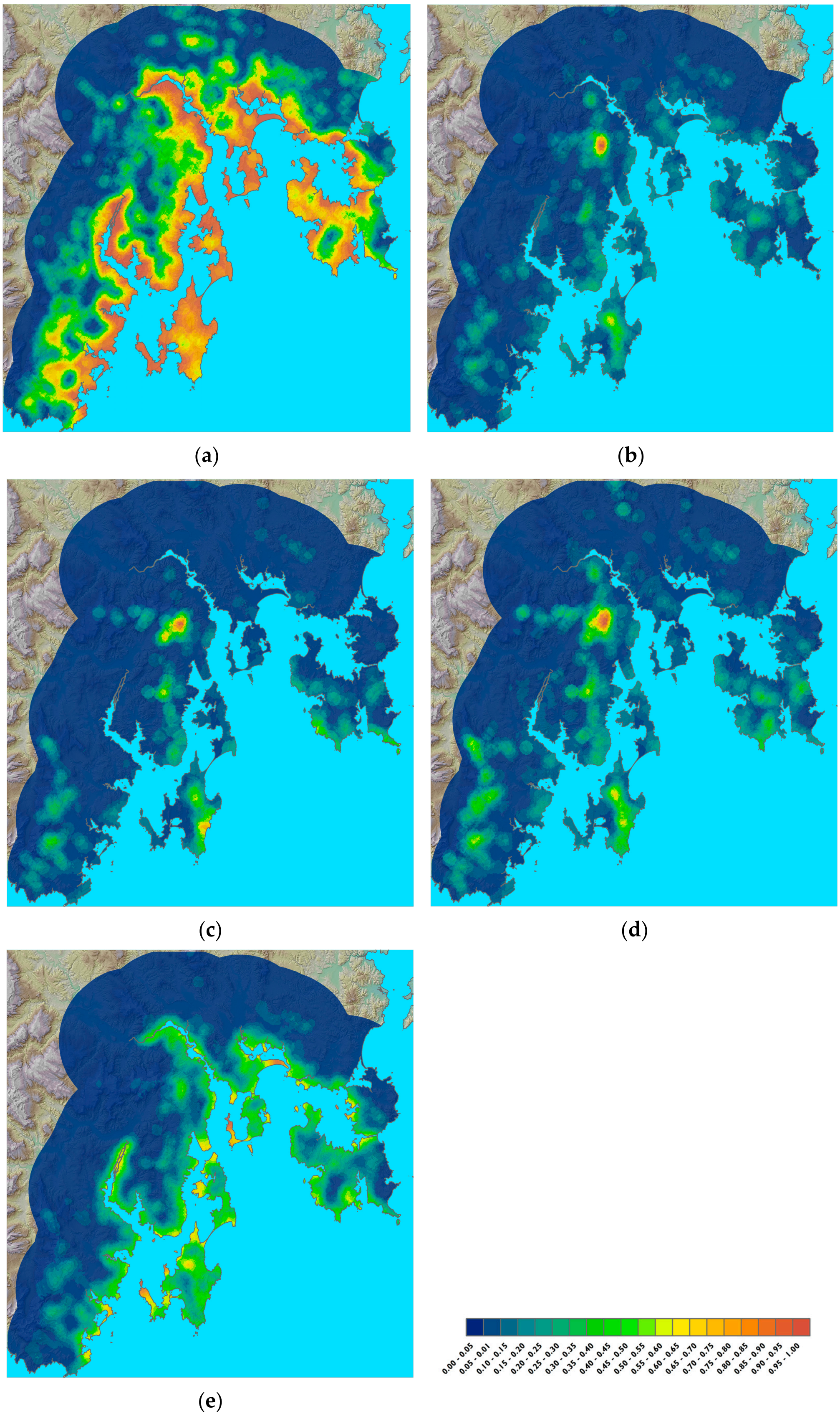



**Figure 5.** Raw outputs of the five submodels of visual character model for viewpoints on the sea. The outputs are normalized and shown on a categorical scale (20 equal parts) after interpolation: 0, low score; 1, high score. (**a**) horizontal extent of the view, (**b**) vertical extent of the view, (**c**) distance to the view, (**d**) length of the visible coastline, (**e**) area of the visibility.

**Table 2.** The top chart presents the pairwise comparison matrix for viewpoints on land and the bottom chart presents the pairwise comparison matrix for viewpoints on the sea. The scale ranges from one to nine, where one implies that the two elements are equally important. Hor: horizontal extent of the view, Ver: vertical extent of the view, Dis: distance to the view, Coa) length of the visible coastline, Are: area of the visibility.

**Pairwise Comparison Matrix for Viewpoints on the Land**

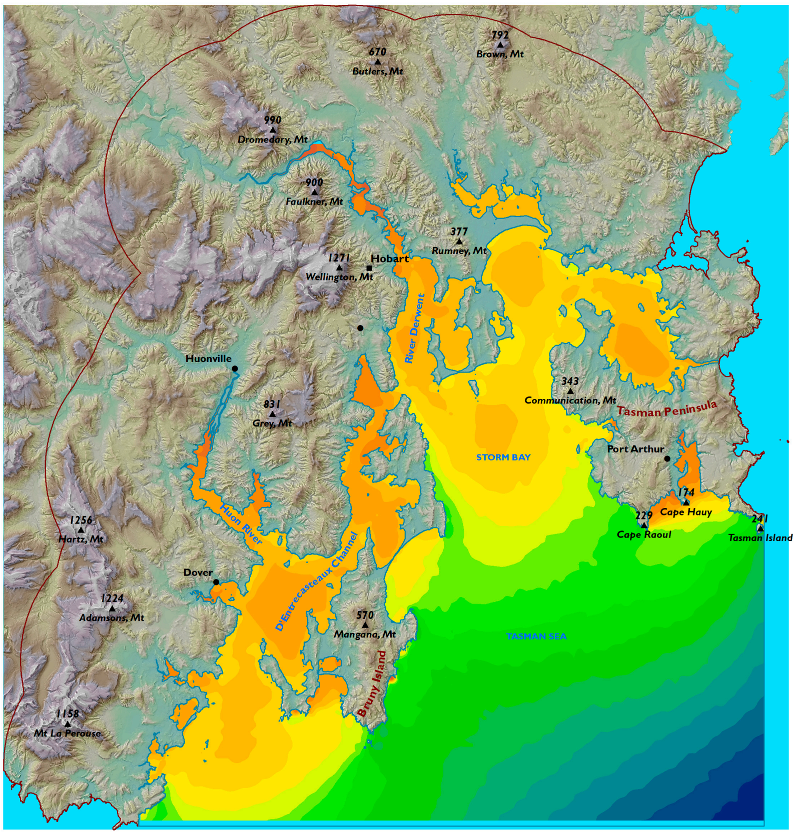
| No | Criteria | Scale Range | | | | | | | | | | | | | | | | | Criteria |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Dis | 9 | 8 | 7 | 6 | **5** | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Hor |
| 2 | Dis | 9 | 8 | 7 | 6 | 5 | 4 | **3** | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Ver |
| 3 | Dis | 9 | **8** | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Are |
| 4 | Dis | 9 | 8 | 7 | **6** | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Coa |
| 5 | Hor | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | **5** | 6 | 7 | 8 | 9 | Ver |
| 6 | Hor | 9 | 8 | 7 | 6 | 5 | 4 | **3** | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Are |
| 7 | Hor | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | **3** | 4 | 5 | 6 | 7 | 8 | 9 | Coa |
| 8 | Ver | 9 | 8 | **7** | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Are |
| 9 | Ver | 9 | 8 | 7 | 6 | 5 | 4 | **3** | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Coa |
| 10 | Are | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | **4** | 5 | 6 | 7 | 8 | 9 | Coa |

**Pairwise Comparison Matrix for Viewpoints on the Sea**

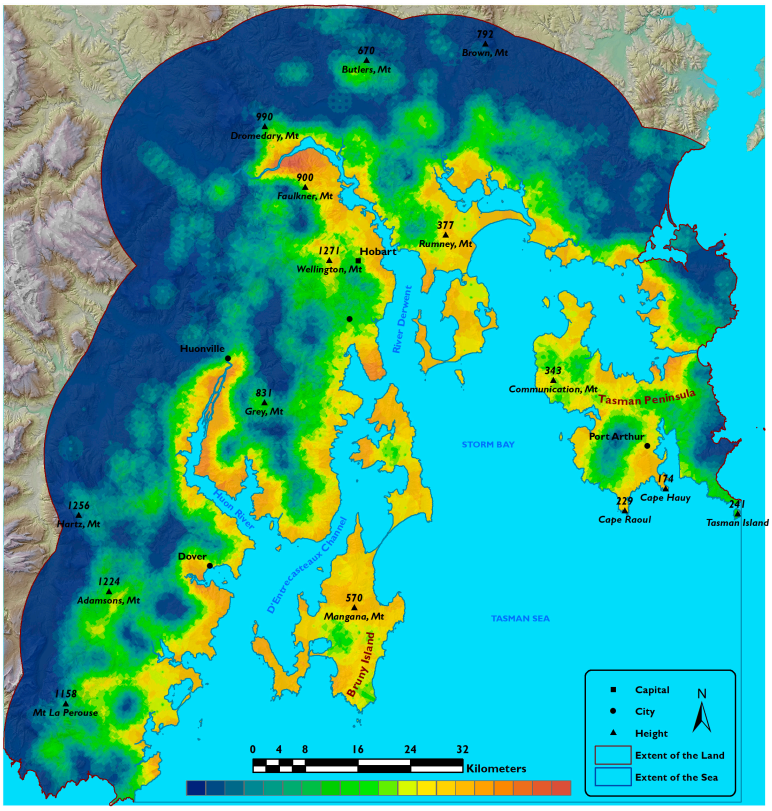
| No | Criteria | Scale Range | | | | | | | | | | | | | | | | | Criteria |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Dis | 9 | 8 | 7 | 6 | **5** | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Hor |
| 2 | Dis | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | **3** | 4 | 5 | 6 | 7 | 8 | 9 | Ver |
| 3 | Dis | 9 | 8 | **7** | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Are |
| 4 | Dis | 9 | 8 | 7 | 6 | 5 | 4 | **3** | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Coa |
| 5 | Hor | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | **7** | 8 | 9 | Ver |
| 6 | Hor | 9 | 8 | 7 | 6 | 5 | 4 | **3** | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Are |
| 7 | Hor | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | **3** | 4 | 5 | 6 | 7 | 8 | 9 | Coa |
| 8 | Ver | 9 | 8 | **7** | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Are |
| 9 | Ver | 9 | 8 | 7 | 6 | 5 | 4 | **3** | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | Coa |
| 10 | Are | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | **3** | 4 | 5 | 6 | 7 | 8 | 9 | Coa |

**Table 3.** The consistency ratio (CR) matrix for viewpoints on land and sea. Hor: horizontal extent of the view, Ver: vertical extent of the view, Dis: distance to the view, Coa: length of the visible coastline, Are: area of the visibility.

| **Viewpoint on the Land** | | | |
|---|---|---|---|
| **Rank** | **Criteria** | **Weight** | **Priority** |
| 1 | Dis | 0.50525 | 50.5% |
| 2 | Ver | 0.26537 | 26.5% |
| 3 | Coa | 0.12281 | 12.3% |
| 4 | Hor | 0.07049 | 7.0% |
| 5 | Are | 0.03608 | 1.4% |
| | CR | 0.06763 | 6.7% |
| **Viewpoint on the Sea** | | | |
| **Rank** | **Criteria** | **Weight** | **Priority** |
| 1 | Dis | 0.47328 | 47.3% |
| 2 | Ver | 0.28073 | 28.1% |
| 3 | Coa | 0.13613 | 13.6% |
| 4 | Hor | 0.06863 | 6.9% |
| 5 | Are | 0.04124 | 4.1% |
| | CR | 0.05966 | 5.9% |



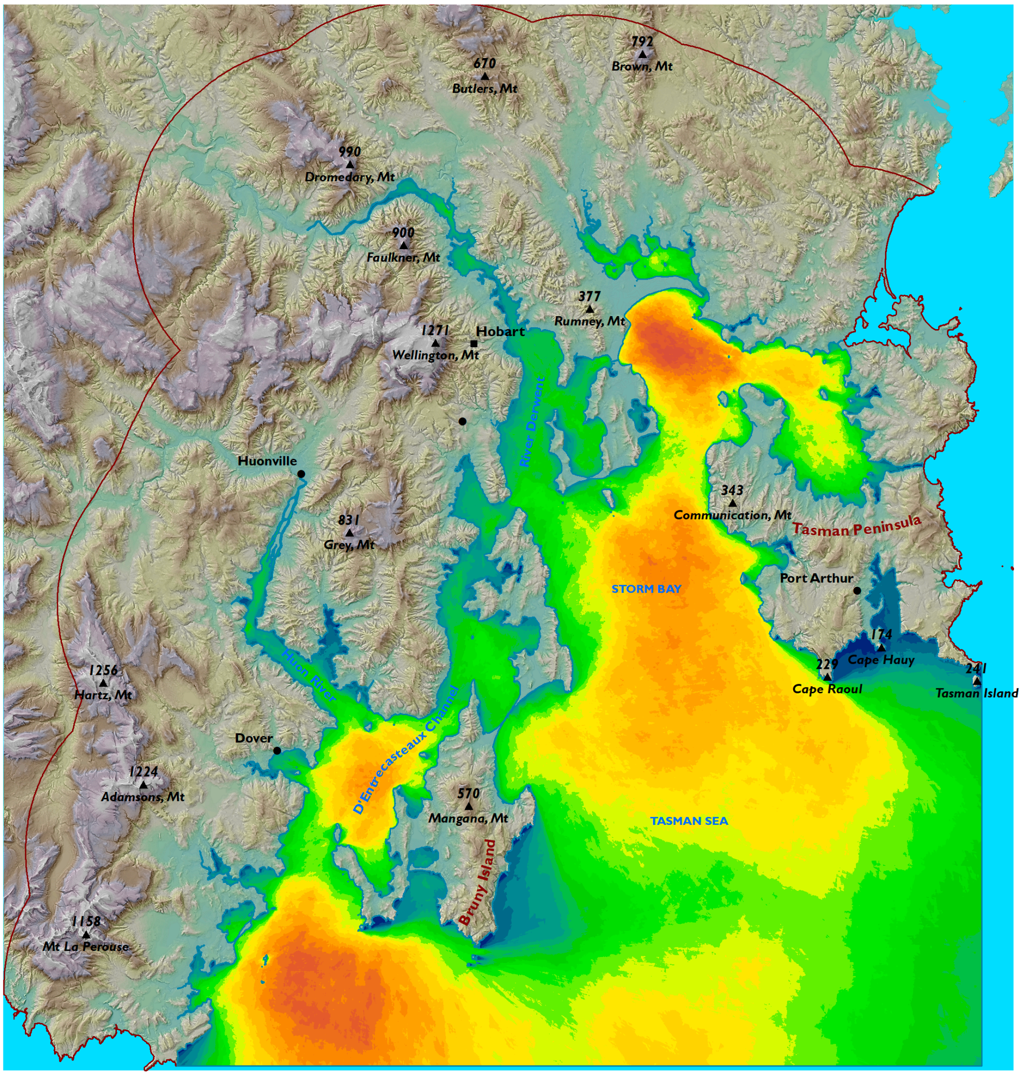

(**a**)




(**b**)

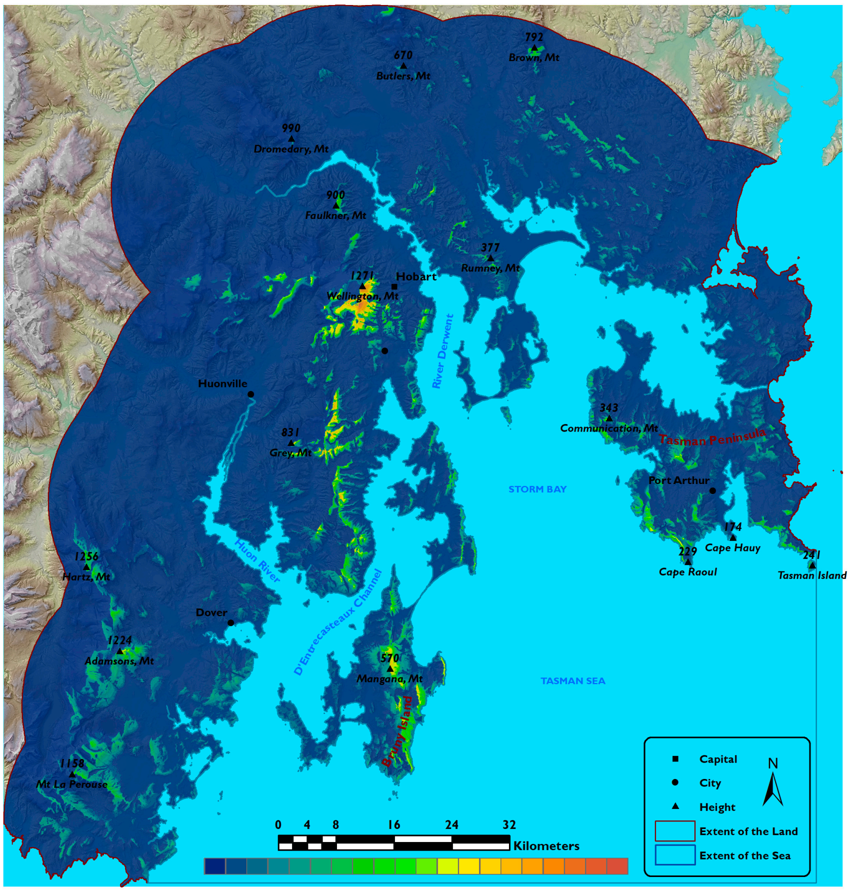
**Figure 6.** Interpolated surfaces from visual quality scores calculated for viewpoints on the sea (top (**a**)) and the land (bottom (**b**)). The outputs are normalized and shown on a categorical scale (20 equal parts): 0, low score; 1, high score.

The last stage focused on the visual significance (or exposure) of the land areas viewed from the viewpoints on the sea and the visual significance of the sea areas viewed from the viewpoints on the land (Figure 7). The calculated visual significance surfaces are influenced by their respective AHP scores for each viewpoint in stage two. The most visible land areas from all the viewpoints on the sea are highlands near the water, although the most visible area is Mount Wellington (1271 m) near Hobart. The elevation of these highlands counters the effect of the earth's curvature. The less visible sea areas from all viewpoints on the land are located near the southeast of Bruny Island and Port Arthur.




(**a**)

**Figure 7.** *Cont.*




(**b**)

**Figure 7.** Visual significance surfaces extrapolated from visual quality scores calculated for viewpoints on the sea (top (**a**)) and the land (bottom (**b**)). The outputs are normalized and shown on a categorical scale (20 equal parts): 0, low score; 1, high score.

## 5. Discussion

Seascapes can be adversely affected by human activities on land and the sea [1]. Concerns have been raised in Tasmania in regard to the visual impacts of proposed marine aquaculture developments (e.g., adverse impacts to natural scenery and loss of undisturbed views of the ocean). This is particularly important where the seascape and its view are highly valued by local people and the tourism industry. As a result, visual impact assessment is usually included within the EIA and local scale (e.g., site selection) studies. However, a robust and objective method of seascape visual assessment at a strategic scale (e.g., regional, national) is required for ecosystem-based marine spatial planning, with existing local-scale methods being either impractical to implement at a larger scale or overly subjective.

This study developed a three-stage GIS-based model that can be used to consistently assess the visual impacts of marine and land-based development at a strategic scale (e.g., regional or national). The first stage successfully developed an objective method of visual characterization of the seascape by using five submodels describing the viewing geometry of the viewpoints on land and sea. The main object of the first stage was to provide judgment-free descriptions of some of the key perceptual elements of the seascape. The second stage used AHP methods to allocate two different preference weightings to each of the five submodels for the viewpoints on land and sea. The last stage of the model used the preference weightings in combination with the actual values obtained from the submodels in the first stage, to generate an individual visual quality score (sometimes referred to as the strength of characters) for each viewpoint across the entire study area (multiple viewpoints). The visual quality scores were then utilized in a series of interpolation and extrapolation processes to create baseline map layers that reflect the visual quality and visual significance of both the landward and seaward extents of the study area.

Outputs of the seascape visual characterization in the first stage can be used in at least three different ways: (1) to evaluate the seascape according to its *perceived quality*, (2) to evaluate the seascape according to its *perceived value*, and (3) to evaluate the seascape according to its *capacity to accommodate change* (sensitivity analysis). In this study, however, the seascape was only evaluated according to its *perceptual quality*, which reflects how a seascape may be experienced or perceived by observers. As a result, a poor-quality score for a viewpoint does not, in itself, indicate low value. For example, a high-quality view may not be easily accessible and therefore may be classified as a low-value seascape, or vice versa. However, the outcomes of this model can be used in combination with a comprehensive set of value-laden judgments to reflect the relative degree of importance attached to seascapes. For example, buildings in urban areas can be considered as stationary viewpoints that have a permanent sea view, whereas road networks or ferry routes can be considered as dynamic viewpoints that have a temporary view and therefore a lower value (or weight). Alternatively, the outcomes of this model can be used to evaluate the degree to which a seascape can accommodate the changes that a marine (e.g., aquaculture, wind energy) development will impose without unacceptably reducing its quality or value.

Currently, research on the subject of visual characteristics of a seascape through map-based methodologies has been mostly limited to the use of visibility or viewshed analysis [5,17–21]. Despite using sound methodologies, the fundamental application of these methods for informing perceptual visual characteristics is rather weak, as the Boolean output only determines the visible and nonvisible locations from either single or multiple viewpoints [38,39]. The GIS-based model presented here demonstrates how viewshed analysis can be modified to facilitate the extraction of the viewing geometry of seascape views that is known to affect the visual perception of a viewer [40,41]. As a result, the model can be used both quantitatively and qualitatively to combine and rank visual characteristics in a way that is consistent, adaptable, and repeatable. This would allow SEIA to incorporate strategic policy and management decisions when evaluating regions proposed for development.

The visibility calculation in this model did not account for the effect of removing natural or unnatural obstructions on the surface of DTM, such as vegetation cover or buildings. As a result, in situations where an observer is very close to a dense forest or building, the view from the sea toward the land or, similarly, the view from the land toward the sea can be reduced significantly (e.g., the vertical angle of the view to the sea). This issue could be resolved by utilizing light detection and ranging (LIDAR) data, where the height of vegetation cover or buildings can be extracted and used as obstacles in the visibility calculation. Nevertheless, the growth and loss of vegetation cover over time, and urban expansion also need to be taken into account in terms of blocking or opening up new views of the sea or land.

The scale, resolution, and vertical accuracy of the input DTM data were the most important constraints in the model, and the interpretation of the results should recognize the limited details and variation in the terrain surface, including vertical accuracy ($\pm$5 m) that can be represented by 50 $\times$ 50 m cells at 1:25,000 scale. The use of LIDAR data can provide a very accurate, fine-resolution, and small-scale DTM, which can be exploited in locations where the complexity of terrain is important for visibility calculations. The resolution of the input viewpoints was another important constraint in the model, and similarly, the interpretation of the results should recognize the limited variation of sea or land views that can be observed from sample viewpoints on a 1 $\times$ 1 km regular grid. This problem can be resolved by increasing the number of sample viewpoints on a finer grid. However, the use of a finer-resolution DTM and larger numbers of sample viewpoints will significantly increase the processing time and the required computing power. The height of the sea level was assumed to be zero with respect to the land surface, whereas actual the sea level may rise and fall by several meters due to tidal movements or swell. Although this effect is temporary, it can be important for visibility calculations when the frequency of such effects is high (e.g., tidal estuary).

In this model, the effect of land cover such as vegetation or buildings was not taken into account in the quality evaluation. This could be significant when considering the contribution that features such as trees or views of historic buildings (e.g., Port Arthur Historic Site) make to the types of views that people may perceive as enhancing the quality of the view. On the other hand, views of industrial development (e.g., aquaculture facilities or an oil refinery) may also reduce the expectation that people may have for the quality of a view. More generally, seascape characterization can be expanded to include many additional characteristics that will increase the number of the key characteristics of seascape and consequently increase the level of qualitative assessment of seascape. For example, the nine key concepts of Tveit, Ode, and Fry [16] describing visual landscape character include stewardship, coherence, disturbance, visual scale, historicity, imageability, naturalness, complexity, and ephemera.

It is important to keep in mind the possible bias that might exist in the second stage of this model. This is because the AHP approach assumes that all the submodels (or criteria) are considered to be independent from each other. That is to say, all five submodels in this model have no interdependencies among them. However, in reality, this cannot be stated with absolute certainty. For example, an increase or decrease in the value obtained from one submodel may affect how the other submodels are perceived, and this, of course, is not an easy matter to convey for an interviewee or an individual to imagine. Nevertheless, if such relationships can be established, then the more general form of the AHP method known as the analytical network process (ANP) can be used for this purpose. The ANP, unlike the AHP method, is designed to overcome the problem of dependency and feedback among criteria and therefore remove the restrictions imposed by the hierarchical relationships among the criteria [42].

The AHP approach is proven to be an effective method of multiple criteria decision-making (MCDM) when all the submodels (or criteria) are considered to be independent from each other. In this study, the authors own preference rankings were used in the AHP's pairwise comparison to define the perceived quality weightings for the viewpoints on both land and sea, demonstrating this method. In future studies, this might be better achieved by interviewing both experts and stakeholders to derive the weightings for each submodel. Nevertheless, the interpolated results of each submodel can also be used as a visual aid for an individual in answering the pairwise comparison questionnaires.

## 6. Conclusions

The outcome of this multi-stage approach presented areas of similar, distinct, and recognizable characteristics and described the visual qualities of a place from a value-neutral perspective to create a visual baseline against which the effects of a development can be assessed. This process can aid in decision-making, as well as, design processes where the effects on key views are considered. The outcome of this study will focus a decision-maker's attention on determining mechanisms that can be deployed to guide positive decision-making and action to protect, manage, plan, and promote seascape character into the future. This decision-making tool is therefore likely to appeal to a range of organizations and individuals for strategic marine spatial planning in support of new developments within the blue economy. These outputs can also be used by stakeholders, including the tourism industry and real-estate marketers, to inform and facilitate discussions regarding the quality of the seascape from different perspectives.

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## References

1. Hill, M.; Briggs, J.; Minto, P.; Bagnall, D.; Foley, K.; Williams, A. *Guide to Best Practice in Seascape Assessment*; Marine Institute: Rinville, Ireland, 2001.
2. Eikeset, A.M.; Mazzarella, A.B.; Davíðsdóttir, B.; Klinger, D.H.; Levin, S.A.; Rovenskaya, E.; Stenseth, N.C. What is blue growth? The semantics of "Sustainable Development" of marine environments. *Mar. Policy* **2018**, *87*, 177–179. [CrossRef]
3. Hoerterer, C.; Schupp, M.F.; Benkens, A.; Nickiewicz, D.; Krause, G.; Buck, B.H. Stakeholder Perspectives on Opportunities and Challenges in Achieving Sustainable Growth of the Blue Economy in a Changing Climate. *Front. Mar. Sci.* **2020**, *6*, 795. [CrossRef]
4. Maslov, N.; Claramunt, C.; Wang, T.; Tang, T. Evaluating the Visual Impact of an Offshore Wind Farm. *Energy Procedia* **2017**, *105*, 3095–3100. [CrossRef]
5. Falconer, L.; Hunter, D.-C.; Telfer, T.C.; Ross, L.G. Visual, seascape and landscape analysis to support coastal aquaculture site selection. *Land Use Policy* **2013**, *34*, 1–10. [CrossRef]
6. Devine-Wright, P.; Howes, Y. Disruption to place attachment and the protection of restorative environments: A wind energy case study. *J. Environ. Psychol.* **2010**, *30*, 271–280. [CrossRef]
7. Depellegrin, D.; Blazauskas, N.; Egarter-Vigl, L. An integrated visual impact assessment model for offshore windfarm development. *Ocean Coast Manag.* **2014**, *98*, 95–110. [CrossRef]
8. Morris, P.; Therivel, R. *Methods of Environmental Impact Assessment*, 3rd ed.; Routledge: London, UK, 2009. [CrossRef]
9. Natural England. An Approach to Seascape Character Assessment; NECR105; Bristol, UK, 2012. Available online: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/396177/seascape-character-assessment.pdf (accessed on 13 March 2023).
10. Briggs, J.; White, S. *Welsh Seascapes and Their Sensitivity to Offshore Developments: Method Report*; Countryside Council for Wales (CCW): Bangor, UK, 2009.
11. Parker, S.K.A.; Grant, A.; Ahern, K. National Seascape Assessment for Wales; NRW Evidence Report 80; Wales, UK, 2015. Available online: https://naturalresources.wales/media/682028/mca-00-technical-report-summary-method-appendix.pdf (accessed on 13 March 2023).
12. MMO. *Seascape Assessment for the South Marine Plan Areas: Technical Report*; MMO 1037; Marine Management Organisation: Newcastle, UK, 2014; p. 88.
13. DTI. Guidance on the Assessment of the Impact of Offshore Wind Farms: Seascape and Visual Impact Report; 806666; UK, 2005. Available online: http://www.dti.gov.uk/renewables/pdfs/seascape_rep.pdf (accessed on 13 March 2023).
14. Miller, D.R.; Morrice, J.G. A Geographical Analysis of the Intervisibility of the Coastal Areas of Wales for Characterizing Seascapes; INTERREG 1994–1999; UK, 2001. Available online: https://www.hutton.ac.uk/sites/default/files/files/Geographic%20Analysis%20of%20Seascapes%20of%20Wales%20Miller%20and%20Morrice%20April%202002.pdf (accessed on 13 March 2023).
15. Fry, G.; Tveit, M.S.; Ode, A.; Velarde, M.D. The ecology of visual landscapes: Exploring the conceptual common ground of visual and ecological landscape indicators. *Ecol. Indic.* **2009**, *9*, 933–947. [CrossRef]
16. Tveit, M.; Ode, A.; Fry, G. Key concepts in a framework for analysing visual landscape character. *Landsc. Res.* **2006**, *31*, 229–255. [CrossRef]
17. Gkoltsiou, A.; Mougiakou, E. The use of Islandscape character assessment and participatory spatial SWOT analysis to the strategic planning and sustainable development of small islands. The case of Gavdos. *Land Use Policy* **2021**, *103*, 105277. [CrossRef]
18. Tsilimigkas, G.; Rempis, N.; Derdemezi, E.T. Marine Zoning and Landscape Management on Crete Island, Greece. *J. Coast. Conserv.* **2020**, *24*, 43. [CrossRef]
19. López-Sánchez, N.; Niveau-de-Villedary y Mariñas, A.M.; Gómez-González, J.I. The Shrines of Gadir (Cadiz, Spain) as References for Navigation. *GIS Visibility Anal.* **2019**, *5*, 284–308. [CrossRef]
20. Taofiqurohman, A.; Radjawane, I.M.; Dhahiyat, Y. Aesthetic quality assessment in Santolo Beach, West Java Province, Indonesia. *IOP Conf. Ser. Earth Environ. Sci.* **2018**, *162*, 012029. [CrossRef]
21. Depellegrin, D. Assessing cumulative visual impacts in coastal areas of the Baltic Sea. *Ocean. Coast Manag.* **2016**, *119*, 184–198. [CrossRef]
22. Kaplan, S. An informal model for the prediction of preference. In *Landscape Asessment: Values, Perception and Resources*; Zube, E.H., Brush, R.O., Fabos, J.G., Eds.; Dowden, Hutchinson and Ross: Stroudsburg, PA, USA, 1975; pp. 92–101.

23. Martin, B.; Ortega, E.; Otero, I.; Arce, R.M. Landscape character assessment with GIS using map-based indicators and photographs in the relationship between landscape and roads. *J. Env. Manag.* **2016**, *180*, 324–334. [CrossRef]
24. Sullivan, R.; Kirchler, L.; Lahti, T.; Roché, S.; Beckman, K.; Cantwell, B.; Richmond, P. Wind Turbine Visibility and Visual Impact Threshold Distances in Western Landscapes. In Proceedings of the National Association of Environmental Professionals 37th Annual Conference, Portland, OR, USA, 21–24 May 2012.
25. Mouflis, G.D.; Gitas, I.Z.; Iliadou, S.; Mitri, G.H. Assessment of the visual impact of marble quarry expansion (1984–2000) on the landscape of Thasos island, NE Greece. *Landsc. Urban Plan.* **2008**, *86*, 92–102. [CrossRef]
26. Kaplan, S. Perception and landscape: Conceptions and misconceptions. In *Environmental Aesthetics: Theory, Research, and Application*; Nasar, J.L., Ed.; Cambridge University Press: Cambridge, UK, 1988; pp. 45–55. [CrossRef]
27. Cakci, I. Landscape Perception. *Landsc. Plan.* **2012**, 251–276. [CrossRef]
28. Sevenant, M.; Antrop, M. Landscape Representation Validity: A Comparison between On-site Observations and Photographs with Different Angles of View. *Landsc. Res.* **2011**, *36*, 363–385. [CrossRef]
29. ASH design + assessment. *Landscape/Seascape Capacity for Aquaculture: Outer Hebrides Pilot Study*; No. 460; Scottish Natural Heritage Commissioned: Inverness, UK, 2011.
30. Pinkau, A.; Schiele, K.S. Strategic Environmental Assessment in marine spatial planning of the North Sea and the Baltic Sea–An implementation tool for an ecosystem-based approach? *Mar. Policy* **2021**, *130*, 104547. [CrossRef]
31. ESRI. Viewshed (Spatial Analyst). Available online: https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/viewshed.htm (accessed on 10 April 2023).
32. ESRI. Line Of Sight (3D Analyst). Available online: https://pro.arcgis.com/en/pro-app/latest/tool-reference/3d-analyst/line-of-sight.htm (accessed on 10 April 2023).
33. ESRI. Skyline (3D Analyst). Available online: https://pro.arcgis.com/en/pro-app/latest/tool-reference/3d-analyst/skyline.htm (accessed on 10 April 2023).
34. Tasmanian Government. The Perfect Environment for an Innovative and Successful Aquaculture Industry. Available online: www.cg.tas.gov.au (accessed on 1 October 2022).
35. Land Information System Tasmania. *LIST Tasmania 25 Metre Digital Elevation Model*; LIST, Ed.; Land Information System Tasmania (LIST): Tasmania, Australia, 2010.
36. Bourassa, S.C.; Hoesli, M.; Sun, J. What's in a View? *Environ. Plan. A Econ. Space* **2004**, *36*, 1427–1450. [CrossRef]
37. Saaty, T.L. *The Analytic Hierarchy Process*; McGraw-Hill: New York, NY, USA, 1980. [CrossRef]
38. Tandy, C. The isovist method of landscape survey. *Methods Landsc. Anal.* **1967**, *10*, 9–10.
39. Wu, Z.; Wang, Y.; Gan, W.; Zou, Y.; Dong, W.; Zhou, S.; Wang, M. A Survey of the Landscape Visibility Analysis Tools and Technical Improvements. *Int. J. Environ. Res. Public Health* **2023**, *20*, 1788. [CrossRef] [PubMed]
40. Sullivan, R.G. Assessment of Seascape, Landscape, and Visual Impacts of Offshore Wind Energy Developments on the Outer Continental Shelf of the United States. In *OCS Study BOEM 2021-032*; Department of the Interior Bureau of Ocean Energy Management Office of Renewable Energy Programs: Washington, DC, USA, 2021; p. 78.
41. Ogmen, H.; Herzog, M.H. The Geometry of Visual Perception: Retinotopic and Nonretinotopic Representations in the Human Visual System. *Proc. IEEE* **2010**, *98*, 479–492. [CrossRef] [PubMed]
42. Saaty, T.L. Fundamentals of the analytic network process—Dependence and feedback in decision-making with a single network. *J. Syst. Sci. Syst. Eng.* **2004**, *13*, 129–157. [CrossRef]