Photographer-guided attributes for underwater image aesthetics

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Abstract

Automated aesthetic assessment of photographs is an active research area with applications in image editing and retrieval. There are many suggestions on the various factors of importance in making an image 'good' or 'aesthetically pleasing'. However, there is no consensus in the literature on a definitive set of attributes that contribute to image aesthetics for underwater images, which include features specific to an aquatic environment. In this research we interview underwater photographers and apply thematic analysis to their responses with the aim of determining which attributes are important for an aesthetically-pleasing underwater image. The results define a set of nine key attributes (i.e. *Aesthetics*, *Aquatic features*, *Colour*, *Composition*, *Image precision*, *Lighting*, *Novelty*, *Subject(s)*, and *Technical competence*). These findings will guide future work in automated assessment of underwater image aesthetics.

Keywords Aesthetic attributes · Image aesthetics · Underwater imagery

Introduction

Aesthetics, in relation to the idea of beauty, has long been a field of study with experiments into the psychological mechanisms underlying aesthetics dating back to the nineteenth Century [7]. More recently the field of Neuroaesthetics, which attempts to understand the physiological basis underlying aesthetic experiences [5], has found that beautiful visual stimuli activates specific regions of the visual cortex [15] triggering the reward circuitry in the brain to produce a feeling of pleasure [18].

Computational image aesthetic assessment of photographs is an active research area [6, 25] where the aim is to categorise images based on their aesthetic appeal. There are many suggestions into the various factors that may contribute towards making an image 'good' or 'aesthetically pleasing' including subjective elements [14], the absence of distortions (e.g. Gaussian noise, image compression) [13], and even interestingness [10] and memorability [16].

However, there is a lack of consensus within the community on a defined set of attributes that contribute to image aesthetics.

Whilst the discipline of underwater images shares some common ground with terrestrial images, due to the differences in lighting, environment, subjects, and associated challenges underwater there may be different factors which contribute towards the definition of a good image. Research into underwater image quality assessment focuses on the impact of the underwater medium in regards to image quality with commonly used metrics assessing the colourfulness, contrast and sharpness of an image [27]. In contrast, the aesthetic assessment of underwater images has received little attention.

In this work we seek to answer the following research question:

- RQ: What are the attributes of a good underwater image?

To investigate this we interview underwater photographers and apply thematic analysis to their responses with the aim of determining which attributes are important for an aesthetically-pleasing underwater image.

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Literature review

In this section we review the datasets and methods for image aesthetics assessment, look in more depth at work focusing on image aesthetic attributes and review the literature on underwater image aesthetics.

Image aesthetics

The automated assessment of image aesthetics is an active research area with applications in image editing and retrieval [6, 25]. Deep learning-based aesthetic assessment methods have achieved remarkable results in comparison to previous approaches [24, 12]. These methods require training on large datasets of images with corresponding ground truth scores collated through subjective evaluation experiments with human participants. Previous datasets (see Table 1) have provided, together with each image, a mean aesthetic score or a distribution of aesthetic scores. Some datasets allow further insights into why an image might be aesthetically pleasing with scores for a variety of aesthetic attributes (e.g. colour & lighting, composition, subject of photo etc) [17, 14] and even photographer-written captions [28, 4].

Aesthetic attributes

Table 2 shows the attributes and scales used by three aesthetic image datasets [17, 4, 14]. The variety in types of attributes and scales used shows that there is little consensus in the literature. However, there are a number of repeating themes occurring with all three datasets containing attributes for light and colour. Composition or compositional elements such as rule of thirds and symmetry are also found in all of the datasets.

The attributes were also chosen in a variety of different ways. For the Aesthetics & Attributes Database (AADB) [17] the attributes were selected by consulting professional photographers. For the Photo Critique Captioning Dataset (PCCD) [4] the attributes were defined by a website set up for photography challenges where the images were collected from [2]. Finally for the Explainable Visual Aesthetics (EVA) dataset [14] the authors chose attributes that had been used in previous studies and that were likely to be easy

Table 2 Aesthetic image datasets with attributes

Dataset	Attribute	Scale
AADB [17]	Overall aesthetics	1–5
	Interesting content	0 or 1
	Object emphasis	0 or 1
	Good lighting	0 or 1
	Color harmony	0 or 1
	Vivid color	0 or 1
	Shallow depth of field	0 or 1
	Motion blur	0 or 1
	Rule of thirds	0 or 1
	Balancing elements	0 or 1
	Repetition	0 or 1
	Symmetry	0 or 1
PCCD [4]	General impression	1–10
	Subject of photo	1–10
	Composition & perspective	1–10
	Use of camera, exposure & speed	1–10
	Depth of field	1–10
	Color & lighting	1–10
	Focus	1–10
EVA [14]	Overall aesthetics	0–10
	Difficulty in rating aesthetics	1–4
	Light & color	1–4
	Composition & depth	1–4
	Quality	1–4
	Semantics	1–4

to understand by naive subjects. Across all of these datasets no specific methodology was used in the selection of the attributes, perhaps this indicates that a more rigorous methodology such as grounded theory could beneficially be applied to the attribute selection process.

There is a large variety in the scales used for the attributes with AADB using a binary scale to indicate the presence or absence of an attribute, PCCD using a 10-point scale and EVA using a 4-point scale (i.e. very bad, bad, good, very good) as well as binary scales to indicate which of the attributes influenced the aesthetic decision. Previous work has found that an 11-point scale has a lower standard deviation around the mean opinion score in comparison to a 5-point

Table 1 Aesthetic image datasets

Dataset	Year	Size	Scale	Ratings	Attributes	Tags	Captions
AVA	2012	255,000	11-point (0–10)	78–549	0	✓	AVA-comments
AADB	2016	10,000	5-point (1–5)	5	11	✗	✗
PCCD	2017	4235	10-point (1–10)	1	7	✗	✓
EVA	2020	4070	11-point (0–10)	30+	4	✗	✗

AVA [20], AADB [17], PCCD [4], EVA [14], AVA-Comments [28]

scale [26], although in these datasets an 11-point scale was only used for overall aesthetics in EVA.

Underwater aesthetic attributes

In terrestrial image aesthetic assessment it has been found that the relative importance of aesthetic attributes changes between different image content categories [14]. As underwater images are distinctly different from terrestrial images it is highly likely that the attributes that influence the assessment of aesthetics will also be different. Another challenge for underwater aesthetic assessment is that within underwater photography that are a variety of distinct image content categories (e.g. macro, wide-angle etc) and the relative importance of aesthetic attributes will also likely be different within each of these.

Previous research into underwater image quality assessment predominantly focused on objective metrics to measure the image degradation caused by the aquatic environment such as colour distortion, reduced contrast and blurring [27, 9]. Underwater image aesthetics has received some attention with a number of underwater image datasets providing mean opinion scores only [27, 9]. However, none have attempted to define aesthetic attributes for underwater images. To help address this gap this paper seeks to determine which attributes are important in the assessment of underwater image aesthetics.

Methodology

In this section we describe the methods that we used to address the research question. We investigated underwater image aesthetics by means of discussions with underwater photographers during face-to-face interviews. We chose face-to-face interviews rather than online ones, believing that the former would create a more relaxed setting for participants to open up about their experiences.

We considered the characteristics and number of participants that might be appropriate for our study. We selected our sample frame by inviting underwater photographers from an underwater photography interest group [1] who, as a group, possessed a certain degree of expertise with the domain of enquiry, i.e. underwater photography. Considering [8, 19], we conjectured that such a sample frame presented a relatively homogeneous population which was appropriate for the fairly narrow objectives for our study. We also speculated that the interview dialogue would be rich and dense in order to enable data saturation. We aimed to interview ten underwater photographers.

All face-to-face interviews were conducted in the United Kingdom (UK), between July and December 2019. The interview protocols were approved by the Faculty Research Ethics Committee of the University of the West of England and subsequently carried out in accordance with the relevant guidelines and regulations. Interviewees received a small honorarium for attending interviews (i.e., Amazon vouchers worth 20 GB pounds). They were also reimbursed for their travel expenses.

For ethical reasons, we obtained informed consent from each participant before conducting an interview. Before the interviews were conducted, each participant was requested to bring with them three of their personal favourite underwater images. Where underwater images were displayed to participants, the same Apple iMac workstation with a 27 inch screen of resolution 5120 x 2880 pixels was used in all instances. The interview was structured around three tasks, i.e. (i) establishing information about the participant, (ii) ranking five underwater images in terms of image aesthetics, and (iii) discussing the three favourite underwater images that the participants brought with them. The images used in tasks (ii) and (iii) were to act as prompts to encourage the participants to describe why an underwater image might or might not be aesthetically pleasing. Specifically, the motivation for task (ii) was to encourage participant insights by use of iterative comparative ranking of pairs of images to see which was the 'better' image aesthetically. The motivation for task (iii) was also to prompt insights from participants, but rather by asking participants to reflect at their leisure on what might be an aesthetically pleasing image before the interview, and bring the results of that reflection to the interviews.

Task 1: about the participants

Interviews were conducted with each participant separately, and each began with a series of questions relating to the participant's age, gender and experience as an underwater photographer, i.e.

Q1.   What is your age?

Q2.   What is your gender?

Q3.   Where '1' is 'novice/amateur' and '5' is 'expert/professional', how would you rate your level of experience in underwater photography?

Task 2: ranking five underwater images

Each participant was presented with five underwater images, see Fig. 1. We were motivated to carefully select the five images. Firstly, each of these images had been displayed

Fig. 1 Five underwater images [1]
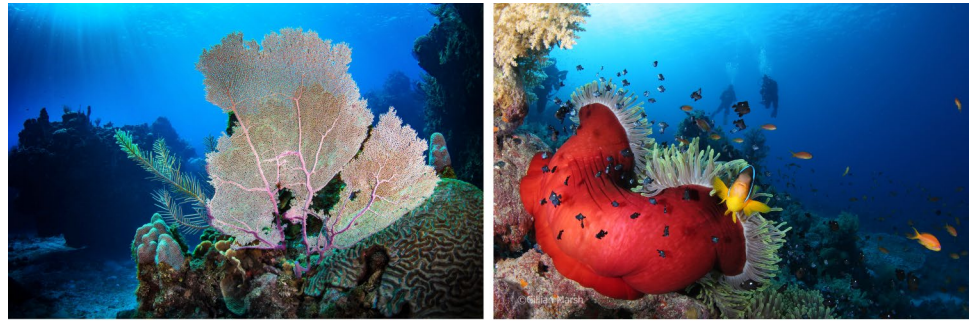
(a) Image A (Mark Drayton)

(b) Image B (Gillian Marsh)

(c) Image C (Gillian Marsh)

(d) Image D (Jim Drake) (e) Image E (Mark Drayton)

previously in July 2016 at a monthly image competition at the underwater photography interest group [1], so we reasoned that the images would likely present some aesthetically pleasing aspects for the participants to explore. Secondly, the five images are all of the underwater landscape 'genre', to provide some meaningful comparability. (Hence we excluded other image genres, such as 'macro', or 'abstract', because it can be difficult and not particularly meaningful to compare an underwater landscape image with, say, an underwater close-up macro image.) Next, we wanted to provide an element of stimulation for the participants, so we chose three landscape and two portrait mode

images. However, we were also mindful of cognitive load. We wished to avoid overloading the participants with an excess of pair-wise comparisons which could lead to fatigue and loss of focus on the task at hand. Hence, we reasoned that five images within a single underwater image genre struck a reasonable balance between these competing motivations. At interview, each participant was asked to rank the underwater images from best to worst, and the ranking was recorded. The interview then continued with the following open question:

Q4. Can you explain your ranking?

This was followed by a semi-structured interview segment consisting of open-ended questions. This encouraged participants to describe their experiences of judging underwater image aesthetics from their own viewpoint and afforded opportunities for more probing follow-up questions from researchers. For example, follow-up questions might ask the participant to expand or explain their answer in more depth. Follow-up questions helped to elicit a better understanding of underlying participant values, views and experiences of judging underwater image aesthetics.

Task 3: discussing favourite images

Each participant was asked to discuss their three favourite underwater images that they had previously been requested to bring to the interview. Some of these images can be seen in Fig. 2. Discussions were semi structured and facilitated by the following open-form questions:

*Q5.* Can you describe your favourite images?

Q6. Can you explain why these are your favourites?

Q7. Can you describe what makes a good image?

Q8. Can you describe why an image might not be good?

Q9. What specific criteria do you use when judging an image?

These open-form questions provided opportunities for participants to describe their point of view on image aesthetics and allowed researchers to ask follow-up questions.

Analytical approach

The interviews were audio recorded, transcribed verbatim, and the transcripts were then imported into NVivo software [3]. We then applied qualitative grounded theory to explore ideas and concepts in the transcript data. We tagged emerging ideas and concepts in the data with codes to record their

Fig. 2 Favourite Underwater Images
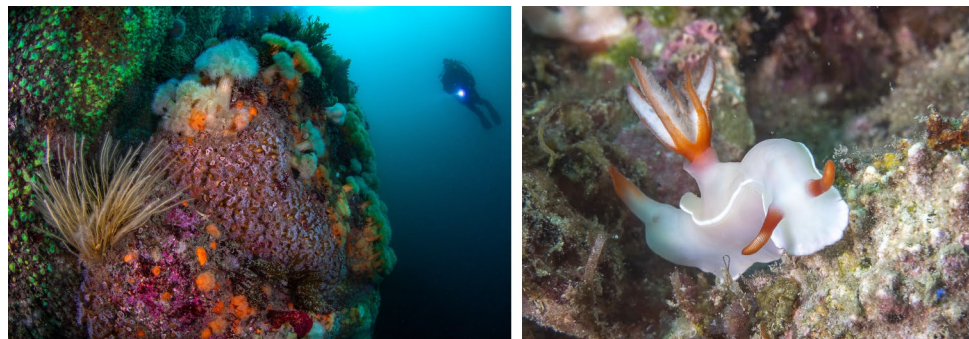
(a) Wide-angle (Robert Bailey)

(b) Nudibranch

(c) Cardinal fish (Richard Ayrton)

(d) Whale shark (Robert Bailey)

occurrence(s) and succinctly summarise them [21–23]. We used no preconceived conceptual coding frameworks to structure the analysis.

Both authors independently analysed the transcripts, identifying emerging themes and ideas which were then tagged with codes from the viewpoint of underwater image aesthetics. The authors conducted three rounds of coding, with joint discussions on the definitions of the codes to ensure that they were being appropriately and consistently assigned. As part of evaluating the codes on each round, they discussed whether to use code hierarchies as a means of providing additional insights into the data. Results and analysis of the transcripts are described in Sect. 4.

Results

Task 1 results: about the participants

Participant responses to interview questions 1, 2 and 3 are given in Table 3. Although we extended invitations to conduct face-to-face interviews with ten underwater photographers, seven individuals accepted. The average age of the study participants is 63.2 years, and six are male. The average experience rating is 3.7. In calculating the average experience rating of the participants, we took the midpoint value for participants who described their experience between one value and another; for example, we took "3 to 4" as 3.5 in calculation. Although interview participants were invited to rate their underwater photography experience on a scale of '1' (novice/amateur) to '5' (expert/professional), four participants responded with an answer between two values, e.g. "3 to 4", and two participants responded with an answer exactly in the middle of two values, i.e. "4.5". The average age of study participants may suggest a high level of experience, although the reported underwater photography experience ratings range from '2' to '4.5'. The interview participants are all based in the UK and while this may indicate that the majority of their images are captured in UK waters, many participants mentioned taking frequent international trips for underwater photography.

Task 2 results: ranking five underwater images

Results for participant responses of ranking the five underwater images A, B, C, D and E are given in Table 4, wherein a variety of rank values can be seen for the interview participants. To determine the most highly ranked image, and then the second, third, fourth and fifth ranked images, we awarded a score of five for a best ranked image, a score of four for a second best ranked image, and so on. Results of image rankings are shown in Table 5. The column labelled '1st' gives the count of best rankings for the image, the column labelled '2nd' gives the count of second best rankings for the image, and so on. The column labelled '**Score**' shows the overall score for an image. Image C has the highest score, and so is the highest ranked image with respect to all participants' rankings.

Regarding Interview Question 4, "Can you explain your ranking?", we now provide an overview of participants' responses with some illustrative quotations. Further detailed qualitative analysis of participant responses is provided in Sect. 4.4. In overview, we note that the participants (i) used multiple attributes as criteria to explain their rankings, (ii) iterated over many pairwise comparisons, and (iii) some participants drew upon their previous experience as competition judges.

- *Use of multiple attributes as criteria:* For instance, participants discussed underwater image lighting (e.g. highlights and shadows, ambient versus artificial lighting). Participants also discussed image colour (e.g. saturation), and image composition (e.g. rule of thirds and foreground/background) and subject interest (e.g. some interesting aspect of animal behaviour). In addition, participants discussed the technical production of the underwater images (e.g. image depth of field, and the focus and sharpness of the image). Some participants also explained that some image attributes could be objec-

Table 3 Participant responses to interview questions 1, 2 and 3

Participant	Q1, Age	Q2, Gender	Q3, Experience rating
1	55	M	4.5
2	61	M	4.5
3	61	M	3
4	71	M	3–4
5	68	M	4–5
6	69	M	3–4
7	64	F	2–3

Table 4 Participant responses ranking five underwater images A, B, C, D and E

Participant	1st	2nd	3rd	4th	5th
1	B	C	A	D	E
2	C	A	D	B	E
3	C	D	A	B	E
4	B	E	D	A	D
5	B	C	A	D	E
6	C	B	E	A	D
7	A	C	B	E	D

Table 5 Rankings for five underwater images A, B, C, D and E

Image	1st	2nd	3rd	4th	5th	Score
A	1	1	3	2	0	22
B	3	1	1	2	0	26
C	3	3	1	0	0	30
D	0	1	1	2	3	14
E	0	1	1	1	4	13

tively evaluated (e.g. how sharp or in focus the subject of an image appeared), or subjectively evaluated (e.g. some aspects of composition). For example, Participant 1 remarked when reflecting on his overall ranking of the five images:

> "Then I'm gonna start getting a bit more nit-picky, and now we're getting into the subjective zone, we're talking about composition, well the thirds you know, and this is very very subjective." (P1)

We speculate that subjectivity may play a part in explaining the variety in participant rankings of the five images. Some participants noted that the use of multiple attributes as criteria contributed to the extent to which an image was deemed pleasing and had visual impact in an underwater context. When asked what he meant by an underwater image with visual impact, Participant 5 replied that:

> "It's one that [...] stands out, that you jump to in your mind." (P5)

- *Iterative pair-wise comparison:* As participants performed ranking of the five images, we noted that participants approached the task by comparing one image against the other four in a pair-wise fashion. We speculate that given the cognitive load of using multiple attributes as criteria to evaluate images, iterative pair-wise comparison emerged as a pragmatic and effective strategy.
- *Previous experience of judging in competitions:* We noted that participants' explanations of image rankings frequently drew upon past experience, not least in underwater photographic competitions. As Participant 1 explains:

> "I've judged a few competitions in BC [British Columbia, Canada] before and some fairly prolific ones like the open portfolio. I've judged and I've sat with a lot of certified judges in the UK at another photo club, Leamington Spa Photographic Society, which has been going for nearly a century and there's a lot of talented landscape and topside photographers there I'm the only underwater photographer in the group." (P1)

Regarding the five underwater images, Participant 1 also explained that:

> "None of them are perfect in my opinion, not one of these images would win a competition in my books because I can find flaws with all of them." (P1)

Task 3 results: discussing favourite images

Regarding Interview Question 5, "Can you describe your favourite images?", participants described at some length the story of their favourite images in terms of how they (i) planned and captured their images, (ii) enhanced the resulting raw image with 'post-processing' via image enhancement tools, and (iii) took pleasure with the final result, especially the aesthetic and visual impact.

- *Planning and capturing an image:* Participants described how rather than being spontaneous, images were often planned, particularly with respect to the subject of the image. For example, Participant 2 described how they had planned an image of an interesting biological phenomenon (see Fig. 2c):

> "This is a male cardinal fish which is looking after the eggs so its mouth is full of eggs, which makes this an interesting subject." (P2)

Participant 2 also described planning to dive and capture underwater images of a deep ship wreck:

> "The Britannic is the sister ship of the Titanic okay so this is this deep wreck. You won't find another image like that. It is a unique one." (P2)

- *Enhancing the raw image:* Participants described how they used multiple attributes as criteria (see Sect. 4.2) for aesthetic enhancement of their favourite images. One participant also recognised that image enhancement (a.k.a. *post-processing*) could be an emotional activity:

> "I'm emotionally involved with this picture. What I try and do is, having taken them, leave them for a while because you lose quite, quite that emotional attachment and you could be far more objective about what are you doing." (P6)

- *Taking pleasure in the final result:* Participants described taking great aesthetic satisfaction in their favourite underwater images. For example, Participant 1 reported:

"So you know all the criteria that I talked about, it ticks all those boxes." (P1)

Other participants also described taking pleasure in achieving an aesthetically pleasing image that had visual impact. For example:

"There's just something about that, is just the patterns and the randomness but it's the light, it feels alive, there's not flat colours." (P3)

"I like the pose on it, it coming out the eye contact there, there's a bit of curve in it a bit of movement in it. I'm quite pleased with that one." (P3)

"It's just there, it just brings it up, it just pops." (P4)

"Impact, it's that word." (P5)

Regarding Interview Question 6, "Can you explain why these are your favourites?", participants 1, 3, 4 and 5 replied that their answer to this question was covered by their answer to the previous question. On the other hand, Participant 2 replied that it was difficult to say why an image is a favourite or not. Participant 2 then went on to indicate that if as a photographer, he had expended much effort in difficult diving circumstances to capture an image, he was likely to have a different aesthetic evaluation of the image compared to an individual who sees the image for the first time. He stated that:

"There's a certain amount of emotional baggage that goes with an image like that, rightly or wrongly." (P2)

Participant 6 also explained that he admired the technical production quality of his favourite images, as well as the image aesthetics. He described the technical production quality of an image (i.e. its exposure, sharpness of focus etc.) as its *"technical competence"*. He explained that when he was evaluating his own images after raw image capture:

"It is ones that obviously mean something to me, but they do need to be at least reasonably technically competent. If I've done enough to identify it's not competent, like...I delete them." (P6)

Regarding Interview Question 7, "Can you describe what makes a good image?", many of the participants described detailed lists of criteria. Participants mentioned criteria that were specific to the underwater environment as well as noting that the criteria could change depending on the category of underwater photography (e.g. wide-angle and macro). Themes that repeated came up within the participants responses were that a good underwater image (i) tells a story, (ii) is aesthetically pleasurable and engaging, and (iii) is technically competent.

- *Tells a story:* Good images are those that tell a story and engage the viewer with a narrative. Participant 2 stated:

  "It definitely has to tell a story." (P2)

  Participant 5 also underlined the importance of storytelling:

  "It's a method, you're telling your audience something about what you saw and what was going on." (P5)

  Participant 5 then went on to say while referring to one of the images they brought with them to the interview:

  "I think there's a story there so I think that makes a picture more engaging more interesting." (P5)

- *Aesthetically pleasurable and engaging:* Participants highlighted the importance of images being aesthetically pleasurable and engaging. In particular the idea that an image will draw you in and make you want to look at it:

  "It has to make you look twice. It has to capture you because it has to draw you in." (P2)

  "There's just something that draws you to it and makes you want to look at it." (P3)

  Participants also mentioned that good images are immediately engaging and used words to describe this such as images with "impact" or the "wow factor":

  "The wow factor is generally what makes that image stand out." (P4)

  Participant 4 then went on to report criteria that would give an image the wow factor:

  "You know things that have never been shot before like you've never seen before yeah novelty rarity, would be it, and peak of the action, you know that would be one, and erm...you know unusual animal behaviour perhaps." (P4)

- *Technically competent:* Participants emphasised the value of technical competence (w.r.t. objective metrics such as exposure and focus) towards making a good image:

  "It's got to be technically perfect as near can." (P4)

  "A technically competent picture. That's what appeals to me really." (P6)

Regarding Interview Question 8, "Can you describe why an image might not be good?", many of the participants provided detailed reasons outlining why an image might not be good. The main themes that were present throughout the participants responses for an underwater image not being good were (i) poor exposure and lighting, (ii) being out of

focus or blurred, (iii) messy or distracting elements, (iv) poor composition, and (v) lack of subject engagement and separation from the background.

- *Poor exposure and lighting:* Underwater images are not good if they are poorly exposed and lit, unevenly lit or are inappropriately lit for the subject matter. Participant 5 stated:

    "Poorly lit if you haven't got even lighting or an appropriate lighting for your subject." (P5)

- *Out of focus or blurred:* There were frequent accounts of technical aspects of underwater images that could lead to a negative opinion such as if an image is out of focus, blurred, unsharp or lacking in contrast. Participant 2 explained:

    "It goes without saying that anything that's out of focus or blurred when you're not wanting it to be blurred that's obviously a bad image so one of the first things I do when I when I look at my images is that I'll reject any that are obviously out of focus or blurred." (P2)

- *Messy or distracting elements:* Participants mentioned that messy or distracting elements can detract from the aesthetic appeal of an image. These elements include the untidy pose of a subject, unclean edges around the image or backscatter in the water column. Participant 2 stated:

    "The typical example is that you've got a series of shots with a diver in and in one of them the diver's fins are both nice and flat and straight and that's the image you'll choose and the others where the fins are like this and that and all over the place you'll reject because as a whole the image works best when the divers looking trim and neat as opposed to being untidy." (P2)

- *Poor composition:* An image might not be good if compositional elements were lacking such as breaking the rule of thirds. Participant 3 mentioned that squint horizons and horizon lines being at wrong level in regards to image and subject could negatively affect an image:

    "Horizons being squint, horizon lines being at the wrong level, they don't fit with the subject so yeah if that horizon line is on the lower third it would be odd if it was higher up and there was only a bit of sky." (P3)

    Participant 3 also said that poor composition could lead a viewer out of a picture rather than into it:

    "Photographs where you are led out of the picture by the shape of the subject so a wreck where your eyes are drawn out of the picture rather than into it or eyes which are taking you out a bit like those on the anthias in the corner that makes you want to be looking out of the picture rather than into it." (P3)

- *Lack of subject engagement and separation:* Poor underwater images lack either eye contact or engagement with the subject. The subject may also be poorly separated from the background leading to a flat image with no depth. Commonly captured subjects was also cited as a reason why an image might not be good. Participant 4 described a lack of subject engagement:

    "You haven't got the fish staring straight into the lens of the camera you know both eyes and a good eye contact." (P4)

    In regards to subject separation Participant 3 explained:

    "Images which are flat where there's no separation, I've got loads of those. Sea lions which sort of merge into the rocks behind and it just feels there's no depth to it where there should be depth." (P3)

Regarding Interview Question 9, "What specific criteria do you use when judging an image?", we provide an overview of participants' responses. In should be noted that Interview Question 9 was added after the first interview so for this question there are only responses from participants 2–7. The participants highlighted the importance of both (i) subjective and (ii) technical criteria when judging underwater images. (iii) Novelty is also an important criteria. A few of the participants described (iv) the process they went through when judging underwater images.

- *Subjective criteria:* Here participants referred to images that had the "wow factor" or "grabs you in some way":

    "The wow factor, everyone talks about the wow factor. The wow factor is when you open an image and you go wow." (P2)

    "Does that grab me or not does that mean anything to me is that am I interested having another look or looking at it for longer." (P5)

    "It's just whatever is an aesthetically pleasing one to you and that is subjective." (P7)

    It would also appear that the subjective or emotional aspects outweigh more technical criteria:

    "I think quite a lot of competitions are won by on the basis of emotion. I like that picture not it is a good picture." (P3)

- *Technical criteria:* Participants stated that good images needed to be technically competent (e.g. well exposed, in focus etc):

    "In the judging sense I think it's rare if it's not technically good that it's going to get through my filter to the next stage." (P5)

    "Am I going to be distracted by the technical shortcomings of it to the point where I can't be bothered to look at it." (P3)

- *Novelty:* Image and subject novelty as well as the difficulty in capturing an image can influence how an image might be judged. Participant 1 explained:

    "I have to look at was the photographer innovative have they captured something novel a creature that's not normally photographed have they done something you know completely different than any other photographers done." (P1)

- *Judging process:* Participants described some of the processes they followed when judging an image for a competition:

    "I tend to go through all the images and as I go through them I basically, one two three I give them a score, you know one or two or three." (P4)

    "I'll view them several times and some will get moved up or move down." (P4)

    "I never do it in one day because actually your reaction to images does change over time and I might get a preliminary shortlist but then go back and totally reorder them." (P5)

Analysis

In this section we report the results of the thematic analysis of the interview transcripts. We noted that although ten underwater photographers had been invited to attend for interview, seven accepted and participated. Nevertheless, the scale and richness of the transcripts resulted in a total of 623 sections of text being coded. The authors conducted three independent rounds of coding, with detailed joint discussions of the definitions and meanings of codes to ensure consistency. The rounds of coding were not completed until the range of common thematic issues had been identified and defined, and the NVivo codebook had stabilized. We judged that at this point, the number of codings was ample, all relevant codes had been identified (i.e. code saturation had been achieved [11]) and understood in a meaningful way with respect to the domain of enquiry (i.e. information saturation had also been achieved [19]). The coding and thematic discussions confirmed our initial conjecture that the aim of the study was focused and narrow, and the participants showed a range of expertise in the domain. In addition, the quality of the interview dialogue was rich and dense which was subsequently reflected in the domain-specific analysis of interview transcripts.

We identified nine distinct codes (i.e. *Aesthetics*, *Aquatic features*, *Colour*, *Composition*, *Image precision*, *Lighting*, *Novelty*, *Subject(s)*, and *Technical competence*) and within seven of those codes we also identified specific sub-codes. Brief descriptions of each of the codes and sub-codes can be found in Table 6.

Table 7 shows the frequencies of coded responses in regards to the attributes which determine a good underwater image. The first and second most frequently occurring codes were *Subject(s)* (26.5%) and *Composition* (24.2%) suggesting that these aspects are very important in determining a good underwater image. Examples, both referring to Fig. 1c (Image C), of participant responses coded as *Subject(s)* and *Composition* respectively include:

"We've got two lovely subjects that are very engaging they're looking right at me they're coming left to right there's space on this side." (P1)

"This is a lovely lovely composition of how these animals are arranged here it's absolutely perfect." (P1)

The third, fourth and fifth most frequently occurring codes were *Lighting* (12.7%), *Aesthetics* (10.8%) and *Colour* (7.9%). This suggests that these aspects are also important factors that contribute to underwater image aesthetics. A coded response for the *Lighting* code is provided by Participant 1 while discussing Fig. 1b (Image B):

"I mean as I'm looking at this photograph it's perfectly exposed." (P1)

A coded response for *Aesthetics* is given by Participant 1 while discussing Fig. 2a which illustrates an example where aesthetics can be confirmed by approval from the crowd:

"This image won Underwater Photographer of the Year for British Wide-Angle [...] so that's a very good accolade." (P1)

Participant 4 provides an example of a coded response for *Colour* while discussing Fig. 1e (Image E):

"I love the, the colour palette used here, the blue against the red, the yellow, really does work very well and there's a bit of red there as well." (P4)

Other participant coded responses that occurred less frequently were *Image precision* (5.8%), *Aquatic features* (5.5%), *Technical competence* (4.0%) and *Novelty* (2.7%) suggesting that although these factors contribute towards making a good image they are of lesser importance than

Table 6 Codes and sub-codes for reports of underwater image aesthetic attributes with brief descriptions

Code	Sub-code	Brief description
Aesthetics		In relation to the idea of beauty
	Crowd influence	E.g. competition prize, group consensus
	Impact	An image that grabs you and stands out
	Individual preferences	Varying preferences between individuals
	Subjectivity	An emotional response to an image
Aquatic features		Features specific to the underwater environment
	Backscatter	Illuminated particles in the water column
	Bubbles	E.g. from the exhalation of a diver
	Snell's window	Scene above surface appears circular
	Sunbeams	Rays of sunlight
	Surface effect	Surface reflections, textures
Colour		Surface quality w.r.t. light reflected by surface
	Appropriate colour	Realistic colours for the subject
	Beautiful colour	Nice or strong colour
	Colour palette	Colour contrast, balance and range of colours
	Colourful	Bright, vibrant, saturated colours
	Muted tones	Flat, dull colours
Composition		Arrangement of visual elements within an image
	Image depth	Layers in an image e.g. foreground, background
	Negative space	Space around the subject
	Photography rules	E.g. symmetry, rule of thirds
Image precision		E.g. focus, sharpness, texture
	Focus	Area where detail is located in an image
	Sharpness	Degree of detail in an image
	Texture	Visual quality of the surface of an object
Lighting		How a scene is illuminated by a light source
	Contrast	Relation bet. different tones in an image
	Exposure	Amount of light that reaches the camera sensor
	Highlights	Lightest areas in an image
	Shadows	Darkest areas in an image
Novelty		Quality of being new, original, or unusual
Subject(s)		In regards to the subject(s) in an image
	Relation bet. subjects	Harmony amongst image elements
	Subject engagement	Subject engagement with photographer
	Subject separation	Subject separation from background
	Subject story	Narrative, context
	Subject strength	Rare, unique subject of interest
Technical competence		W.r.t. objective metrics e.g. lighting, focus

the previously mentioned codes. An example of a coded response for *Image precision* is provided by Participant 3 when discussing an image of a tiny nudibranch (see Fig. 2b) (rhinophores are the horn-like structures which protrude from their front):

"I like the fact that I've got the rhinophores in focus." (P3)

A coded response from Participant 5 while discussing Fig. 1a (Image A) describes one of the *Aquatic features*:

"I like sun beams and you get the impression although it's a false impression that the Sun is illuminating that fan from behind." (P5)

An illustration of a response for the code of *Technical competence* is given by Participant 2 while discussing an image of a cardinal fish (see Fig. 2c):

"It has to be well exposed, it has to be in focus or at least and that's where perhaps this one is a good example." (P2)

Table 7 Codes and sub-codes for reports of underwater image aesthetic attributes with frequencies ($N = 623$)

Code	Sub-code	Freq. (%)	Freq. (%)
Aesthetics		10.8	
	Crowd influence		2.7
	Impact		4.0
	Individual preferences		1.1
	Subjectivity		2.9
Aquatic features		5.5	
	Backscatter		2.1
	Bubbles		0.6
	Snell's window		0.3
	Sunbeams		1.0
	Surface effect		1.4
Colour		7.9	
	Appropriate colour		0.3
	Beautiful colour		2.7
	Colour palette		1.9
	Colourful		1.3
	Muted tones		1.6
Composition		24.2	
	Image depth		6.3
	Negative space		8.3
	Photography rules		9.6
Image precision		5.8	
	Focus		1.6
	Sharpness		1.9
	Texture		2.2
Lighting		12.7	
	Contrast		1.9
	Exposure		5.5
	Highlights		2.4
	Shadows		2.9
Novelty		2.7	
Subject(s)		26.5	
	Relationship between subjects		1.4
	Subject engagement		8.7
	Subject separation		5.0
	Subject story		3.2
	Subject strength		8.2
Technical competence		4.0	

Finally, Participant 1 provides an example of a response for the *Novelty* code while discussing an image of a whale shark (see Fig. 2d):

> "It's an unusual image because you've got a whale shark which is the biggest fish in the sea." (P5)

In the following subsections we discuss each of the seven codes that contain sub-codes and provide example quotes for each of the sub-codes.

Aesthetics

Within the *Aesthetics* code we identify four distinct sub-codes. The most frequently occurring sub-code is *Aesthetics - Impact* (4.0%). Participants described images as having "impact" or the "wow factor" to indicate those which stand out and demand your attention:

"The wow factor, everyone talks about the wow factor. The wow factor is when you open an image and you go wow." (P2)

Aesthetics - Subjectivity (2.9%), which encompasses an individual's emotional response to an image, is the second most commonly occurring sub-code:

"Some people like one picture and some people will pick a completely different one, it's just whatever is an aesthetically pleasing one to you and that is subjective." (P7)

Aesthetics - Crowd influence (2.7%) is the third most commonly reported *Aesthetics* sub-code. This sub-code refers to aesthetics being influenced by others for example due to an image winning a reputable underwater photography competition.

"It's a competition winner, it appeals to me." (P6)

In contrast the least most frequently reported sub-code *Aesthetics - Individual preferences* (1.1%) refers to varying aesthetic preferences amongst individuals.

"I was never that keen on this image but that's partly a built in prejudice because I like tropical waters." (P5)

Aquatic features

The most frequently occurring sub-code within the *Aquatic features* code is *Aquatic features - Backscatter* (2.1%). Underwater photographers aim to capture images that are free from backscatter (i.e. illuminated particles in the water column) and often remove unwanted backscatter from images in post-processing software.

"Things that are inherent in the underwater photographic process but but usually detract from the image and I don't mind seeing a little bit backscatter but I don't like to notice the backscatter in the image." (P5)

The next most commonly occurring sub-code is *Aquatic features - Surface effect* (1.4%). An example of a participant response for this sub-code is:

"It's an unusual image because you've got a whale shark which is the biggest fish in the sea but you've also got a lovely surface reflection." (P1)

The following most frequently appearing sub-code is *Aquatic features - Sunbeams* (1.0%) which are a common feature of underwater images captured near the surface of the water.

"This is one of a series I've which have got the dappled light and the sunbeams." (P5)

Another common feature of underwater images is captured in the *Aquatic features - Bubbles* (0.6%) sub-code. These refer to bubbles that are usually produced by an exhalation from a diver and are often undesirable as articulated by Participant 1:

"I'd like to see those bubbles cloned out of the way." (P1)

The least frequently coded sub-code, within the *Aquatic features* code, is *Aquatic features - Snell's window* (0.3%). This refers to a phenomenon whereby the scene above the surface appears circular due to refraction at the air/water boundary. Participant 3 states that it is a desirable feature to capture in an underwater image:

"Nice to have Snell's window in the background." (P3)

Colour

Colour - Beautiful colour (2.7%) is the most frequently appearing sub-code within the *Colour* code. This sub-code represents participant responses which describe colour as positive using words such as "nice" and "strong":

"It's a nice green as opposed to a horrible green." (P3)

The second most commonly occurring sub-code is *Colour - Colour palette* (2.7%) which contains coded responses which discuss colour contrast, balance and range of colours. An example is provided by Participant 5:

"What I like about it is the contrast between the pink and the blue." (P5)

Colour - Muted tones (1.6%) is the third most frequently reported sub-code which includes coded responses which describe colour negatively using terms such as "flat" and "dull":

"Then that one I think feels to me to be quite some way below the others, it just feels very flat and sort of insipid." (P3)

The next most commonly occurring sub-code is *Colour - Colourful* (1.3%) which includes coded responses where colour is described as "bright", "vibrant" or "saturated":

"I tend to go for more saturation or vibrance in my pictures." (P5)

Finally, the least frequently appearing sub-code, within the *Colour* code, is *Colour - Appropriate colour* (0.3%). Participant 5 mentioned that it is important that colours in an image are realistic and appropriate for the subject:

"If your colour balance and your colour palette aren't appropriate for the subject, don't display the subject to its best advantage then that doesn't work for me." (P5)

Composition

The most commonly appearing sub-code within the *Composition* code is *Composition - Photography rules* (9.6%). This sub-code refers to responses on the subject of compositional photography rules such as symmetry and rule of thirds:

> "Compositional rules you know rule of thirds we say the subject should be intersecting on the third line here you've got a subject in one third you got nothing really in the middle this is probably intersecting on the line again I kind of follow loosely follow those rules they don't have to be perfect." (P1)

The second most frequently occurring sub-code is *Composition - Negative space* (8.3%) which describes the space in an image around a subject. Participant 1 articulates the benefits of negative space in an image:

> "It's nice in some ways and in other ways it's a little too crowded to me I'd like to see some more negative space on here so I'm looking for space from my subjects to breathe a bit." (P1)

The third most commonly occurring sub-code is *Composition - Image depth* (6.3%) which depicts the layers in an image such as foreground, middle ground and background:

> "When I'm looking at a wide-angle picture I want to see layers in an image I want to be able to walk through the image just like looking at a path." (P1)

Image precision

Image precision - Texture (2.2%) is the first most commonly occurring sub-code within the *Image precision* code. This sub-code refers to participant responses which describe the visual quality of the surface of an object i.e. variances in shape, tone and colour depth. An example of a participant response is provided by Participant 6:

> "A lovely texture of the fan coral, lovely texture on the surface of the water." (P6)

Image precision - Sharpness (1.9%) is the second most frequently appearing sub-code and describes the degree of detail in an image:

> "The eyes are nice and sharp but because of the depth of field of the lens we're losing a bit of the sharpness sort of at the front of the lips and some of the bits here." (P2)

Finally, the third most commonly found sub-code is *Image precision - Focus* (1.6%). This sub-code represents responses on the subject of focus or blur (i.e. lack of focus). Focus refers to the area where detail is located in an image and an example response is provided by Participant 2:

> "It goes without saying that anything that's out of focus or blurred when you're not wanting it to be blurred that's obviously a bad image so one of the first things I do when I look at my images is that I'll reject any that are obviously out of focus or blurred." (P2)

Lighting

The most frequently appearing sub-code in the *Lighting* code is *Lighting - Exposure* (5.5%). Exposure refers to the amount of light that reaches the camera sensor. An example of this sub-code is provided by Participant 1:

> "This an anemone skirt and this has exposed lovely it's a great bit of the image." (P1)

The second and third most commonly occurring sub-codes are *Lighting - Shadows* (2.9%) and *Lighting - Highlights* (2.4%), respectively. These sub-codes describe the darkest and lightest areas in an image. An example quote for *Lighting - Shadows* is contributed by Participant 1:

> "I've got a big mass of black shadow here where there's no detail at all that I can see here so I'd want to bring this out." (P1)

In an example of a response for the sub-code *Lighting - Highlights* Participant 5 describes a part of the image being "blown out" which means that it is so overexposed it appears completely white with no captured details:

> "If you have a big area which is just totally blown out I find that ugly and distracting so mostly I try to adjust the tonal range of the image so that I get a true black somewhere mostly you know it depends on the image but I get a just touching on the true white I try and adjust the tones within an image so that the histogram stretches across there are exceptions to every rule and not every picture benefits from that but, that one has been adjusted so it gives a nice good black in there and a good white there with a full range of tones in between." (P5)

The fourth and least frequently appearing sub-code is *Lighting - Contrast* (1.9%). Contrast describes the relationship between different tones in an image e.g. lightest and darkest areas. Participant 1 illustrates the important of contrast in underwater photography:

> "An underwater image has to have contrast so we need to be close to the subject in the foreground or you need to be in clear enough water so there's con-

trast in the image you don't want muted colors and you want some definition in there." (P1)

Subject(s)

The first and second most frequently occurring sub-codes for the *Subject(s)* code are *Subject(s) - Subject engagement* (8.7%) and *Subject(s) - Subject strength* (8.2%), respectively. *Subject(s) - Subject engagement* refers to how the subject engages with the photographer for example with interesting behaviour or the attractiveness of the subject:

> "One of the things I do with my own photography is, I find you know when you're taking fish and animals that the eye is critically important to engage and I find those eyes difficult to see." (P5)

Subject(s) - Subject strength refers to how unique or rare the subject of interest is:

> "It draws you in because of the subject matter. Who doesn't like a dolphin? Dolphins and seals so it's good subject material." (P5)

The third most commonly appearing sub-code is *Subject(s) - Subject separation* (5.0%) which describes the subject's completeness and separation/contrast from the background:

> "It's not only the subject being in the right position and in the right attitude, it's being separated from its background so you can focus on the subject itself." (P6)

Subject(s) - Subject story (3.2%) is the fourth most frequently found sub-code and describes the narrative and/or context of an image. An example quote is provided by Participant 2:

> "The cardinal fish makes that one interesting is that, yes it's a nice portrait of a fish but then you start thinking what's all this funny stuff in here and then if you zoom in, if I can, you can start to see that there are funny little dots there which are the eyes of the fish developing in the eggs which sort of makes it interesting in its own right." (P2)

Finally, the least commonly appearing sub-code, within the *Subject(s)* code, is *Subject(s) - Relationship between subjects* (1.4%) which describes the relationship between subjects or elements in an image with an example response from Participant 5:

> "The subject material is nicely arranged the diver balances the dolphins quite well so I think that is why I like that." (P5)

Discussion

The scale and richness of our rigorous analysis of participant transcripts as outlined in Sect. 4.4 resulted in a total of 623 sections of text being coded. In response to our original research question (i.e. What are the attributes of a good underwater image?), nine key attributes of a good underwater image emerged (i.e. *Aesthetics*, *Aquatic features*, *Colour*, *Composition*, *Image precision*, *Lighting*, *Novelty*, *Subject(s)*, and *Technical competence*). We also provide insightful sub-codes to gain further understanding within seven of the key attributes.

The two most frequent attributes in terms of participant responses are *Subject(s)* (26.5%) and *Composition* (24.2%). This suggests underwater photographers should place a particular emphasis on the subjects they capture and compositional elements in an image. Within *Subject(s)* the sub-codes of importance with respect to underwater images are *Subject(s) - Subject engagement* (8.7%), *Subject(s) - Subject strength* (8.2%) and *Subject(s) - Subject separation* (5.0%). Many of the image subjects described in the sub-codes were underwater specific, e.g. relating to aspects of underwater marine life, or ship wrecks. Within *Composition* all of the sub-codes (i.e. *Composition - Photography rules* (9.6%), *Composition - Negative space* (8.3%) and *Composition - Image depth* (6.3%)) received a large number of coded responses. Other notable sub-codes were *Lighting - Exposure* (5.5%) and *Aesthetics - Impact* (4.0%).

Subjective attributes (e.g. *Subject(s)*, *Composition* and *Aesthetics*) are deemed more important than technical production aspects (e.g. *Image precision* and *Technical competence*). However, these findings may be the result of underwater photographers self filtering their images and only presenting to the public those of a technically high standard so that technical production aspects are not often called in to question.

Aquatic features are attributes unique to underwater images. However, aquatic features of the marine environment can provide both challenges and opportunities for the underwater photographer. For example, backscatter (*Aquatic features - Backscatter*) can challenge the underwater photographer who might wish to remove the presence of any particulate matter in the water from an image to increase image clarity. On the other hand, opportunities for a unique and interesting aesthetically pleasing underwater image can arise from recording the effect of looking up at the surface from underwater (*Aquatic features - Surface effect*), sunbeams streaming through the marine environment when disturbed by surface waves (*Aquatic features - Sunbeams*), and diver exhalation bubbles (*Aquatic features - Bubbles*) rising to the surface from deep underwater.

Limitations

This research contributes original insights into underwater image aesthetics. Further study with a larger sample size could enhance the results by providing the opportunity to interview a wider demographic of photographers. A potential limitation is that both the researchers and the interview participants were UK-based; future studies should consider samples from other countries.

Conclusions and future work

In this work we set out to determine the attributes of importance for underwater image aesthetics. Nine attributes were identified (i.e. *Aesthetics*, *Aquatic features*, *Colour*, *Composition*, *Image precision*, *Lighting*, *Novelty*, *Subject(s)*, and *Technical competence*), where *Composition* and *Subject(s)* are of particular importance. To provide more detailed understanding of the key attributes, we identified sub-codes within seven of them.

Appreciation of underwater-specific aesthetic attributes (*Aquatic features*) affords the underwater photographer opportunities for recording interesting aesthetically pleasing images underwater. The nine identified aesthetic attributes can also be used as a framework from which to assess underwater image aesthetics with wider benefit to underwater photographers and the underwater imaging research community.

Future work will aim to collate an underwater image aesthetics dataset where each image has corresponding scores for aesthetic attributes. This dataset will be used to train an AI-based auto-judge for underwater images and contribute towards advancing research in the domain of underwater image aesthetics.

Supplementary information

Interview transcripts and analysis of qualitative data in NVivo 1.6.2 format are openly available from http://researchdata.uwe.ac.uk/682. [Accessed 10 January 2023].

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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