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Global, standardised southern right whale qualitative visual health assessment protoco

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Introduction

Recent fluctuations in southern right whale (SRW, *Eubalaena australis*) counts and elongation of calving intervals (e.g. Marón et al. 2015, Charlton 2017, Vermeulen et al. 2018, 2019) across the main wintering grounds have lead to the creation of the International Whaling Commission Southern Ocean Research Partnership (IWC-SORP) Theme 6: "The right sentinel for climate change: linking foraging ground variability to population recovery in the southern right whale", in 2018 (SC67B). This Theme aims to leverage the existing long-term datasets from main wintering grounds with new knowledge on foraging areas and linkages between migratory habitats to investigate the impact of past and future climate variation on right whale recovery. Subsequently, the SRW workshop held at the World Marine Mammal Conference in Barcelona in 2019 identified regional visual health assessments as a high priority within IWC-SORP Theme 6, to better understand the links between health, reproduction and climate (SC/68B/SH07).

Visual health assessments are repeatable methods and have been conducted for terrestrial and marine mammals (e.g. Lowman et al. 1976; Bradford et al. 2008; Joblon et al. 2014; Morfeld et al. 2014). The visual health assessment method for North Atlantic right whales (*Eubalaena glacialis*) was established by Pettis et al. (2004) using selected physical variables from archived photographs, showing changes in body condition of females in calving and non-calving years. This suggests that changes in body condition and overall health can be detected visually and assessed qualitatively from photographs, and can be related to reproductive success through photo identification matching. As health assessments are most effectively conducted in a standardised manner across regions (Christansen et al. 2020), the IWC Scientific Committee (SC) encouraged the development of a global, standardised IWC-endorsed visual health assessment protocol for southern right whales (IWCSC SH68B Report).

Aerial photogrammetry and the use of unmanned aerial vehicles (UAVs) enable a quantitative assessment of body condtion (Christiansen et al. 2018 & 2020). However, qualitative visual health assessments allow for whale health to be assessed using multiple indices and provide a metric for assessing historical and contemporary images taken from various angles and platforms.

In view of the above, this paper aims to provide a global, standardised southern right whale visual health assessment protocol for endorsement by the IWC SC Southern Hemisphere sub-committee at the 2021 meeting (SC/68C). The protocol builds on the visual health assessment completed by Pettis et al. (2004) for North Atlantic right whales, and Hörbst et al. 2018 (SC/68A/SH/13) for adult southern right whales. Visual health assessments leverage from long-term photo-identification catalogues of SRWs in their wintering grounds to be able to assess the health of known individuals over time, which can be evaluated in relation to their reproductive success.

Methods

Image Grading

In this protocol, a set of images is defined as aerial and lateral images of an individual adult whale taken during annual surveys, that are no more than 19 days appart if the individual was encountered multiple times based on Christiansen et al. (2018) who found that a minimum of 20 days between sightings was needed to detect a measureable change in body condition.

Prior to a visual health assessment of an individual whale, a set of images of this individual is graded and evaluated based on: 1) quality of images (scored 1-3); 2) water visibility (scored 1-3), and 3) proportion of the whale's dorsal side visible in the entire set of images, measured from the tip of the rostrum to the median notch of the fluke, to allow for the appropriate evaluation of the health indices caudal to the blow holes. A minimum acceptance criteria is set at ≥ 45% of the dorsal side of the animal (measured from the tip of the rostrum) which could be in one image or achieved through the sum of multiple images. Table 1 summarizes the scoring criteria of image quality and water visibility. Figure 1 shows the minimum proportion of the dorsal side of the body needed for a visual health assessment based in body percentages described in Christiansen et al. (2018). The health indices can be found in Table 2.

Only a set of photographs scored 1-2 in both image quality and water visibility, ánd in which ≥ 45% of the dorsal side of the animal is visible is qualified to be included in the visual health assessment. It is acknowledged that some images provide valuable perspectives and data for scoring even though they may not be of the highest quality. Therefore, a set of images is used and must meet the minimum quality standards for inclusion.

Table 1: The proposed grading indices (and their subsequent scoring categories) to evaluate the quality of a set of images of an individual southern right whale, to perform a qualitative visual health assessment.

Scores			
	1	**2**	**3**
Image quality	Photographs are sharp and the 'to be scored features' are clearly visible	Some photographs are blurry and the 'to be scored features' are only partially visible	Most/all photographs are of bad quality and/or blurry and the 'to be scored features' are difficult to see or not visible at all
Water visibility	Water is clear and 'to be scored features' that are underwater can be seen through the water	Water is slightly murky and the 'to be scored features' that are under water are not clearly visible, but those above the water are and can be scored	Water is murky and the 'to be scored features' that are underwater are not visible

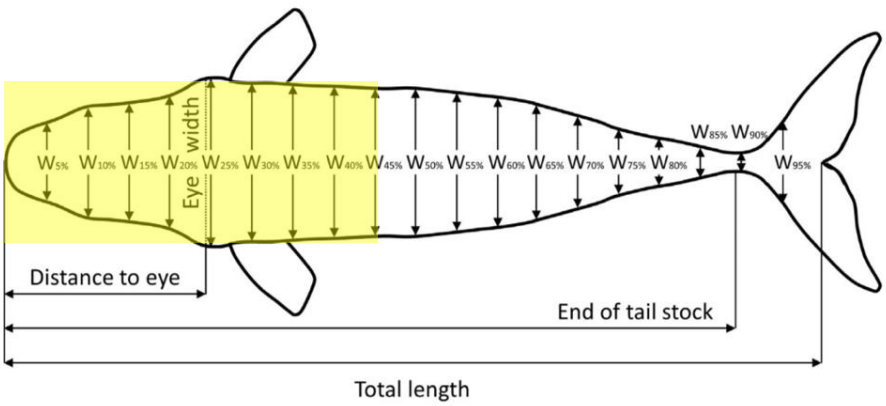

Figure 1: Graphic representation of a southern right whale with body sections (each representing 5% of the body length of the animal) marked from the tip of the rostrum to the median notch of the fluke, used to determine the body length of the dorsal side seen in images. Yellow shading indicates the minimum proportion (**≥** 45%) of the surface area that needs to be visible for viable qualitative health assessment. Source: Christiansen et al. (2018).

Table 2: The four health indices and their subsequent scoring categories for the visual health assessment of southern right whales.

Health index	Detail	1 (Good)	2 (Medium)	3 (Poor)
Body condition – qualitative (deposited fat reserve post-blowhole)	Lateral view	Flat or rounded neck roll, convexity	Slight to moderate concavity	Severe concavity, dip
	Aerial view	Thicker behind the eyes and rectangular shaped body	Thicker behind the eyes and cone shaped body	Thinner behind the eyes and cone shaped body
Skin lesions	Predatory rake marks	Absent	Healed or present on ≤20% of body surface area affected	Fresh or present on >20% body surface area, parts of fluke/flipper missing
	Gull harassment	Absent	Healed or present on ≤20% of body surface area affected	Fresh or present on >20% body surface area
	Entanglement	Absent	Healed or present on ≤20% of body surface area affected	New or present on >20% body surface area, Fishing gear attached
	Ship strikes	Absent	Healed or present on ≤20% of body surface area affected	Fresh or present on >20% body surface area, Amputation
	Others	Absent	Healed or present on ≤20% of body surface area affected	Present on >20% body surface area
Skin condition (average of the 2 variables)	Skin sloughing (peeling)	Sloughing present on <20% body	Sloughing present on <45% body surface area	Sloughing present on ≥45% body surface area
	C. erraticus aggregations on body/head	Absent	Evidence of cyamids	Substantial aggregation of cyamids
Cyamids around blowholes	*C. erraticus* aggregations around blowholes	Absent	Evidence of cyamids	Substantial aggregation of cyamids

Health index and scoring

Four visual health indices and scoring criteria were adapted from Pettis et al. (2004): 1) body condition, 2) skin lesions, 3) skin condition (skin sloughing and presence of *Cyamus erraticus* (orange in colour) on body/head), and 4) *C. erraticus* around blowholes. These are all scored on a numerical scale with lower values indicating poorer health, as outlined below and in Table 2.

1. *Body condition*

The score for body condition is based on the estimation of the relative amount of subcutaneous fat (Pettis et al. 2004). This was examined based on the prominence of accumulated fat in the neck area ('neck roll') posterior to the blowholes, as described by Rowntree (1999). The score is based on dorsal convexity or concavity of this area. When viewed laterally, a right whale in "good" condition will have a flat or slightly rounded convex shape or fat roll posterior to the blowholes and would be given a score 1 (Figure 2 top). Individuals in "medium" or average condition show only slight to moderate concavity and are given a score of 2 (Figure 2 middle). Whales considered to be in "poor" body condition show concavity in the same area posterior to the blowholes, and in extreme cases show a dip behind a 'hump' posterior to the blowholes and are given a score of 3 (Pettis et al. 2004) (Figure 2 bottom).

For aerial images, a score of 1 (good) is given when the whale has a rectangular body shape and appears broader behind the eyes (Figure 3 top). A score of 2 (medium) if the whale presents a cone-shaped body and is still broader behind the eyes (Figure 3 middle). A score of 3 (poor) is given when a cone-shaped body is observed and the whale appears thinner behind the eyes (Table 2, Figure 3 bottom).

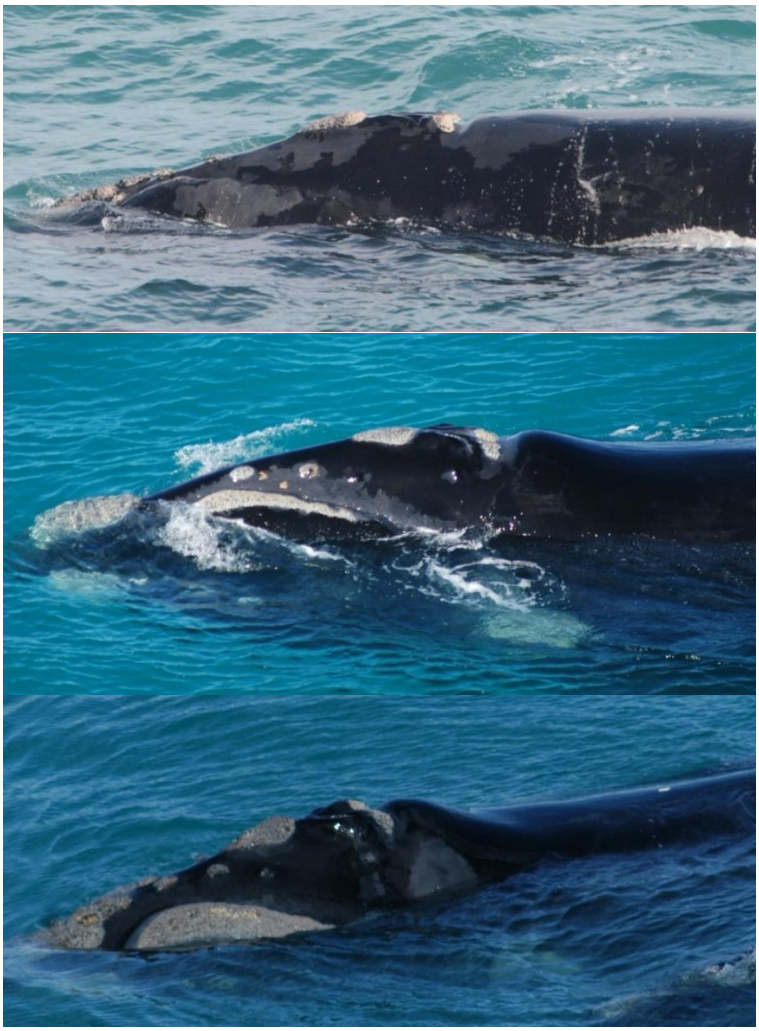

Figure 2: Cliff based photographs of southern right whales exemplifying scoring of the lateral view based on the prominence of subcutaneous blubber in the cervical area immediately caudal to the blowholes, of the three categories; top) 1 (good), flat or

rounded neck fat roll, middle) 2 (medium), slight to moderate convexity, and bottom) 3 (poor), severe concavity or a dip present posterior to the blowholes. Images from Eubalaena Pty. Ltd. and Curtin University.

Figure 3: Unmanned aerial vehicle images of right whales exemplifying scoring of the aerial view based on the prominence of subcutaneous blubber in the cervical area immediately caudal to the blowholes, of the three categories; left) 1 (good), rectangular shape body condition and broader behind the eyes, middle) 2 (medium), cone-shaped body condition and braoder behind the eyes, and right) 3 (poor), cone-shaped body condition and thinner behind the eyes. Image adapted from Christiansen et al. 2020. Image credits: left New Zealand (Steve Dawson), middle Australia (Fredrik Christiansen), right North Atlantic (John W. Durban/Holly Fearnbach).

2. Skin lesions

Skin lesions (from predatory rake marks, gull harassment, entanglement, ship strike, other), are assessed under three categories (1= 'absent', 2= 'healed or present on ≤20% body surface area',and 3=' Fresh or present on >20% body body surface area') (Table 2; Figure 4). The percentage of the affected body surface area is qualitatevly estimated in proportion to the total body surface area of the whale.

The cause or source of lesions present on the skin of right whales is often unknown. However, common appearance of lesions are areas of broken skin, with white or grey colouration or ulcer formations resulting in cratering to the outer layer of the skin (Pettis et al. 2004). Such lesions may not always result in long-term effects on body condition or accumulation of subcutaneous fat, but the underlying cause (e.g. entanglement, ship strike, gull harassment, other) may delay parous females from reaching energetic levels needed for reproduction (e.g. van der Hoop et al. 2016). Lesions from gull harassment has increased in southern right whales in Argentina and is known to cause mortality and impact nursing behaviour (Marón et al., 2015). Whilst lesions from gull harassment are qualified into three categories, the data can be made available for further assessment of other factors such as wound size, and percent of body affected (see Marón et al., 2015).

Figure 4: Aerial photographs of southern right whales exemplifying the scoring of skin condition based on the prevalence of lesions, of the three categories; left) 1 (absent) and middle) 3 (present). Images from Aarhus University. Kelp gull wounds on an adult southern right whale female (top right) and a severe case of kelp gull wounds on a calf (bottom right). Images from Mariano Sironi, Instituto de Conservación de Ballenas, Argentina.

The term 'rake mark' describes scarring resulting from a bite or tooth scraping injury. These injuries are most commonly a predatory wound, for example from a killer whale (*Orcinus orca*) or shark bite (George et al.1994). Although evidence of killer whale teeth markings on the skin are frequently reported (Weller et al. 2018) they are rarely lethal events on large adult whales (Mehta et al. 2007; Steiger et al. 2008) and do not necessarily result in long-term effects on health. It is important to note that this definition of rake marks is different from the definition used by Pettis et al. (2004), who defined rake marks as the presence of an injury (in this protocol defined as skin lesion), and not as a bite or tooth marks from predation events.

Figure 5: Photographs of southern right whales exemplifying scoring based on the prevalence of rake marks or bites, of the two categories; top) 1 (absent or few), no rake markings or predatory bites present, Bottom) 3 (present), evidence of rake markings or predatory bites. Images from Aarhus University and Curtin University.

The possible sources/causes of skin lesions are listed separately in the protocol so that the data can be further integregated to assess causal factors of health condition. However, these categories are grouped for the overall analysis of skin lesions as a visual health indice.

3. Skin Condition

Skin condition was evaluated based on i) skin sloughing and ii) cyamids (*C. erraticus*) on the body or on the soft skin between the callosity tissue, and given a total score based on the average score of these two categories.

Each category is detailed below:

i. The percent presence of skin sloughing (partially peeling or completely detached skin), within three categories ('good', 'medium' or 'poor') (Table 2; Figure 5).

   Although skin sloughing is often a natural process, periodically renewing itself and water temperature (Pitman et. al. 2019), extensive shedding of the skin may alter the whales' daily activity cost increasing the time resting (Fortune et al. 2017; Reeb et al. 2007). Additionally, extensive sloughing is a sign of poor health (Pettis et al. 2004). Whales that exhibit skin areas with presence of sloughing on less than 20% of the body surface area are considered to be in "good" health (score 1), with sloughing on less than 45% are considered to be in "medium" health (score 2) and with sloughing on 45% or more of the body surface area are considered to be in "poor" health (score 3). The percentage of the affected body surface area is qualitateivly estimated.

Figure 5: Aerial photographs of southern right whales exemplifying the scoring of skin condition based on the severity of skin sloughing of the three categories; left) 1 (good), clean skin with < 20% sloughing, middle) 2 (medium) sloughing present on < 50% of the body, and right) 3 (poor) sloughing present on > 50% of the body. Images from Aarhus University, University of Pretoria and Instituto de Conservación de Ballenas Argentina.

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ii. Presence of cyamids (*Cyamus erraticus)* on the body, in wounds or severely damaged areas of skin, within three categories ('good', 'medium' or 'poor') (Table 2; Figure 6).

   Right whales carry three species of whale lice, two are restricted to the callosities and make them appear white (*Cyamus gracilis* and *Cyamus ovalis*). The third species *Cyamis erraticus* is orange and aggregates in the genital slits but also in damaged or wounded skin areas

(Kaliszewska et al. 2005), and whales with poor skin condition are likely to have larger aggregations of these amphipods and are therefore considered to be in poorer health (Rowntree 1996). Whales considered to be in “good” health (score 1) exhibit minor or no presence of *C. erraticus* on the body or soft skin between the callosity tissue (*C. ovalis and C. gracilis* colonise the hardened, elevated callosity tissue and are not considered a sign of ill health) (Rowntree 1996, Kaliszewska et al. 2005). Adult whales in “medium” health (score 2) exhibit some evidence of aggregations of *C. erraticus* on the body or soft skin between the callosity tissue and whales in “poor” health (score 3) exhibit substantial aggregations of *C. erraticus* on the body or soft skin between the callosity tissue.

Figure 6: Imagery of southern right whales exemplifying the scoring of skin condition based on the severity of cyamid coverage on the skin of the three categories; left) 1 (good), clean skin with no cyamids (*Cyamus erraticus)* on the body, middle) 2 (medium), evidence of cyamids on the body, and below) 3 (poor), substantial aggregations of cyamids on the body. Images from Eubalaena Pty. Ltd., Curtin University, and John Totterdale, respectively.

4. Cyamids around blowholes

The prevalence of cyamids (*C. erraticus*) aggregating around the opening of the blowholes were evaluated within three categories; ‘Absent’ (score 1), ‘Evidence of cyamids'’ (score 2) and 'Substantial aggregation of cyamids' (score 3). A reliable evaluation of presence of cyamids required a minimum of 50% of the blowhole being visible. The amount or covering of cyamid aggregation directly in and around the blowholes is assumed to be dependent on the severity of injury, swimming speed or stress to the individual whale (Osmond and Kaufman 1998; Table 2; Figure 7).

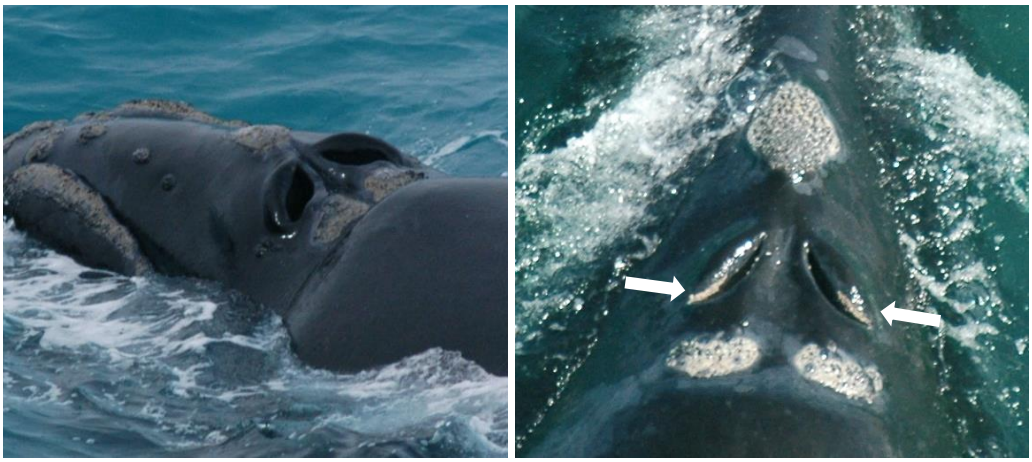

Figure 7: Imagery of southern right whales exemplifying scoring based on the prevalence of cyamids (*Cyamus erraticus*) aggregating directly in or around the opening of the blowholes, of the two categories; left) 1 (absent or few), with no or few cyamids present around or in the blowholes, right) 2 (present), evidence of cyamids aggregating around or in the blowholes. Images from Curtin University.

Consistency Analysis

Weighting of scores

Upon discerning the quality of images and scoring the health indices of suitable imagery, a Total Score (TS) of visual health can be calculated. However, as the different health indices have different impacts on the whales' health, it is proposed to apply a weighing to the scores as follows: 40% for body condition, 30% for skin lesions, 20% for skin condition (inclusive of sloughing and cyamids on body), and 10% for cyamids around blowholes. Body condition was weighted more heavily than all other health variables, as subcutaneous fat is the most important contributor to the reproductive health of right whales (based on e.g. Christiansen et al. 2018, Lockyer 2007, 2011, Miller et al. 2011, Williams et al. 2013). A principal component analysis (PCA) can be performed to visualise the relation in variation among the four health indices.

Randomised control trial

A randomised control trial (double-blind approach) is proposed to assess inter-research consistency when scoring health variables.This involves at least four experienced SRW researchers individually re-scoring 100 individuals randomly selected from the study period using a routine in R (Core version 3.5.1; RStudio Team 2018). A Fleiss' Kappa test for agreement and assessment of percentage agreement would then allow comparison in the consistency of health indices scoring from four total alternate researchers (Conger, 1980; Fleiss, 1971; Fleiss et al. 2003).

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