

Lesions on the jaws of an adult male orca (*Orcinus orca*) from Punta Norte, Argentina

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Abstract

The Punta Norte Patagonia orca (*Orcinus orca*) population/ecotype exhibits a unique foraging strategy that involves intentionally stranding onto beaches to capture pinnipeds, primarily Southern sea lions (*Otaria byronia*, formerly *Otaria flavescens*). One adult male orca from this population was a prolific hunter. Between 1 February and 30 April, each year from 2006 to 2011, he conducted a total of 319 attacks and 173 successful captures. The highest number of attacks (n = 122) and captures (n = 76) in a single season both occurred in 2008. During that same period, he intermittently presented with multiple bilateral lesions on his maxillae and mandibles. We present milestone images (n = 6) and paired same-day images (n = 16; 8 pairs) documenting the progression of these lesions.

Keywords:

ecotype, foraging behaviour, injury, intentional stranding, killer whale, wound healing

Using standardised descriptive criteria, we compared lesion characteristics across time, between left and right sides, and between the maxillae and mandibles. We developed the Lesion-Eye-patch Ratio (LER) to quantify lesion area relative to the corresponding eye patch area using ImageJ software. The highest paired image LER was 2.02 (recorded in 2009), indicating lesions more than twice the size of the eye patch, whilst the lowest was 0.16 (recorded in 2007). This unique dataset provides evidence of what we believe to be the longest documented duration of persistent lesions in a free-ranging orca. We speculate that the most likely contributing factor was temporary mandibular misalignment associated with beach egress during intentional stranding events. Such misalignment may have caused teeth to puncture soft tissues of the mouth, leading to infection and the development of externally visible lesions. A possible genetic predisposition cannot be excluded, as there is evidence (albeit limited) that this adult male's presumed older brother exhibited smaller but similar lesions. The survival and continued hunting success of this individual demonstrates that orca with significant lesions can forage effectively. These observations support a reassessment of the management framework concerning the rescue and release of injured orca whose lesions might otherwise be considered debilitating, as this male not only hunted for himself, but he also captured prey and provisioned other orca in the population.

Introduction

Since 1975, the orca (*Orcinus orca*, also known as killer whale) population known as the Punta Norte Patagonia population/ecotype (Copello et al., 2019) has been documented intentionally stranding to hunt pinnipeds at Punta Norte (42°04' S, 063°46' W), Argentina (e.g., López & López, 1985; Hoelzel, 1989; Ford, 1992; Iñiguez, 1993; Iñiguez et al., 2002; Copello et al., 2019). Punta Norte is located at the northeasternmost point of the anchor-shaped

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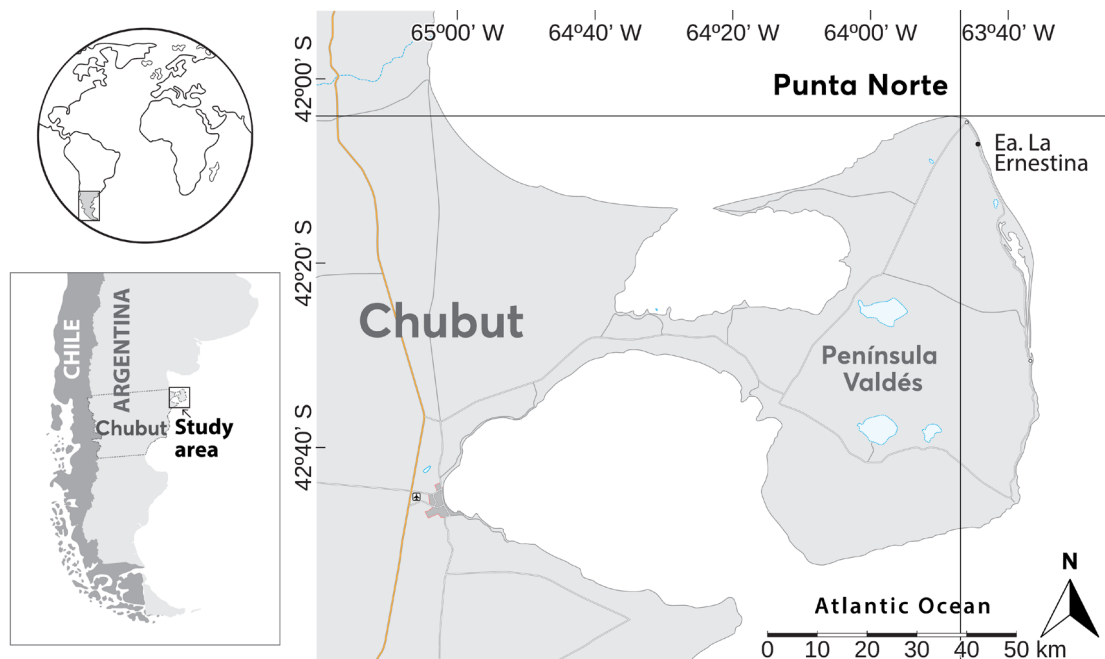


Figure 1. Site location of Punta Norte (42°04'S, 063°46'W), at the northeasternmost point of the anchor-shaped isthmus of Península Valdés, on the east coast of Patagonia, Chubut, Argentina and within Estancia La Ernestina. Map by Gabriela Bellazzi.

isthmus of Península Valdés, on the east coast of Patagonia, Chubut, Argentina (Fig. 1).

Intentional stranding is a learned foraging strategy which requires skill acquisition and is not always successful (Hoelzel, 1991; Iñíguez et al., 2002). It is also a high-risk hunting method: individuals may become unintentionally stranded and remain on the beach (López, 2000), which can sometimes be fatal (Enarson et al., 2024). Moreover, their prey, primarily Southern sea lions (*Otaria byronia*, formerly *Otaria flavescens*), but occasionally Southern elephant seals (*Mirounga leonina*) or South American fur seals (*Arctocephalus australis*), have the potential to inflict wounds during capture attempts.

Such hunting behaviour has been well described for this population (e.g., López & López, 1985) and extensively documented through both video (e.g., Attenborough, 1990) and photographic records (e.g., Enarson et al., 2024). During stranding events, the orca may be 80-100% out of the water (Fig. 2), allowing individuals to be documented and identified based on congenital and acquired dorsal fin shape, scars, pigmentation patterns of the saddle and eye patches (e.g., López & López, 1985; Bigg et al., 1987; Visser & Mäkeläinen, 2000; Mäkeläinen et al., 2025) and injuries (Copello et al., 2019; Visser et al., 2021). Occasionally, both sides of an individual can be photographed during a single foray onto the beach (Enarson et al., 2024; PNOR, 2025).

During a successful hunt, an orca grasps its prey using its teeth and, once secured, vigorously egresses from the beach through coordinated movements of the head, tail, pectoral fins, and the whole body (Enarson et al., 2024), involving axial muscles typically used for swimming (e.g., *musculus longissimus* and *m. multifidus*, see Pabst, 1990) and muscles from the neck, jaw, and flippers not usually involved in propulsion (e.g., *m. sternohyoid*, *m. sternocephalicus*, *m. deltoides*, and *m. scalenus*, among others; see Cozzi et al., 2017). The immense physical forces applied during



Figure 2. The adult male orca (*Orcinus orca*) known as Mel (catalogue number PTN-001) intentionally stranding whilst attempting to capture South American sea lion (*Otaria byronia*) pups. During such foraging behaviour, at times an orca may be 80-100% out of the water. Note the position of the pectoral fins, with his left fin flat and his right slightly rotated with the posterior edge approximately 45° upwards. An area of white *Depigmentation* is visible on Mel's right maxilla and an area of slight grey *Discolouration* is visible on his right mandible (see text for details). Photo 20080410-PTN-JMC-D1-013 © Juan M. Copello.

these manoeuvres may exert significant pressure on the cranial structures, including the jaws and teeth.

In this species, the dentition typically comprises 10-14 teeth per quadrant (Rapp, 1837; Eschricht, 1866). The teeth are generally elliptical in shape, with crowns comprising approximately one-third of the total tooth size (Heyning & Dahlheim, 1988; Dahlheim & Heyning, 1999). Tooth size varies along each row, with the largest teeth located centrally and the smallest at the anterior and posterior ends (Loch et al., 2025). Several authors have noted that the condition of an orca's dentition may contribute to or exacerbate lesions; for example, abscesses may form when

Table 1. Criteria used to classify the lesions observed on the adult male orca (*Orcinus orca*) (PTN-001, Mel) documented at Punta Norte, Argentina between 2006 and 2011. The classifications are listed in an approximate order of escalation, however multiple classifications may apply at any given moment, e.g., a zone of *Discolouration* may surround an *Open (raw)* lesion.

Lesion Classification	Lesion Description
No lesion	No visible <i>Discolouration</i> or <i>Open lesions</i> visible. No <i>Depigmentation</i> (see separate classification for <i>Depigmentation scar</i>).
Discoloured	The epidermis is not depigmented (see separate classification), instead it is a different colour to the surrounding affected and nonaffected area(s). Affected area(s) may include hyper-pigmented, or non-white darker zones (e.g., grey), be tinted red or pink or have a yellow/mustard colour, particularly on the areas which would normally be white in the species.
Abscess	A localised area of infection which the body has attempted to control and isolate from surrounding normal/non-infected tissue. This may result in a pocket of pus, surrounded by a fibrous tissue capsule and/or an open lesion which may or may not be suppurative, pyogenic, or purulent. [§]
Open (raw)	An open lesion which looks 'fresh'/'raw', is typically red, and has clean margins. Does not appear to be bleeding.
Open (granulated)	An open lesion which has a coarse surface/various textures (i.e., not smooth), although sections of the lesion may have tissue that is loose, necrotic and/or layered, perhaps as part of the healing process. The colour may be variable, or predominantly pale pink, red, grey, and/or discoloured. There may be indistinct margins.
Open (bleeding)	An open lesion from which blood is being discharged.
Depigmentation scar	No open lesions are visible, but as a result of a lesion, a depigmented scar remains. Previously, if the area was black, it would now typically be white. Such a scar would be considered a 'healed' lesion, although subsequent lesion(s) may occur at the same (or adjacent) location(s).

[§] (after Vlasman & Campbell, 2003).

teeth become infected (Tomes, 1873; Harmer, 1927; Colyer, 1938; Wellings, 1944; Mead, 1961; Mitchell & Baker, 1980; Gormley, 1990). However, such reports are typically isolated observations documented over short periods (days). To our knowledge, no published records describe lesions associated with dentition in this species that have been documented over an extended period.

Here, we report on the multi-year status of intermittent lesions on an adult male orca from the Punta Norte Patagonia population/ecotype. We examine the potential aetiology of these lesions, which were found bilaterally on the maxillae and mandibles and postulated that the development and persistence of these lesions included mechanisms related to the foraging behaviour, temporal jaw misalignment, dentition, and to potential genetic predisposition.

Materials and Methods

Site and Season

For this study, data were collected from four sites in the Punta Norte region: (1) Medina Bay, (2) Faro Bay, (3) Attack Channel, and (4) Mel's Bay. Medina Bay and Mel's Bay are approximately 5 km apart, located on the west and south side of Punta Norte, respectively (Fig. 3). Medina Bay has the steepest beach gradient (approximately 15°) whereas Mel's Bay has the shallowest (< 10°). Medina Bay is the only site not immediately adjacent to, or bordered by, rocky/sandstone reefs (locally termed *restingas*).

Annual observations were carried out between 1 February and 30 April from 2005 through 2026, except when winds were from the north and the sea state was at Beaufort Scale 6 or higher. Although at-sea observations of cetaceans are typically conducted when the sea state is Beaufort Scale 3 or less (e.g., Hupman et al., 2015), as this study was shore-based it was possible to conduct research with higher sea states. However, shore breaking waves do impact the ability to collect relevant images. Based on 20 years of sighting data (PNOR, unpub. data),

this three-month period coincided with South America sea lion pupping and the subsequent phase when pups begin entering the water (Campagna, 1985).

Orca Identification and Observations

During each season, individual orca were confirmed as present using two methods: (1) photographic confirmation ('proof of presence') or (2) visual confirmation ('sighted'). In both cases, identification was verified against the most current identification catalogue (e.g., PNOR, 2025). Collectively, these records are referred to here as 'observations'. From these observations, we documented the milestones for each individual.

Foraging behaviour was categorized as 'intentional stranding', whereby an individual actively came onto the beach in the pursuit of prey (i.e., an attack, successful or not), or 'practice stranding', whereby an individual actively came onto the beach in the absence of prey.

Images

We selected images that were illustrative of (i) key milestones including first and last observation of an orca, occurrences of foraging behaviour, and when lesions were visible; (ii) classification criteria (Table 1); (iii) physical movements during intentional stranding and egress; and (iv) paired left-right images from the same date.

Each image was referenced using the Punta Norte Orca Research (PNOR) archival code, which includes the date (yyyymmdd), site code (PTN), photographers' initials (e.g., JMC), and unique daily image number. This coding system allows cross-referencing with the complete PNOR database.

For the paired comparisons, images were selected when the animal was approximately perpendicular (between 80-90°) to the camera. When such angles were not available, the closest approximation was used. Please see Supplementary Material 1 for details regarding image selection and equipment used.

Case Studies

This study focuses on one adult male orca (catalogue number PTN-001, “Mel”), selected due to the recurrence and persistence of facial lesions over multiple years. We therefore extracted all data relating to this individual for focused analysis. Within this subset, we identified images that included visible maxilla(e) and/or mandible(s) for lesion assessment. A historical overview of this male is presented, including representative images illustrating lesion persistence over multiple years. For contextual comparison, we also reviewed other adult males from the same population to evaluate potential lesion aetiology.

Lesions: Placement, Classification, and Measurements

Lesions encompass the range of externally visible anomalies such as *Discolouration*, wounds and scars. Using the animal's perspective for orientation, we recorded whether lesions were present on the left and/or right side and whether they involved the maxilla(e) and/or mandible(s). We developed a classification of the lesions which were ordered according to presumed escalation severity, with definitions informed by descriptions of abscesses and related lesions in marine mammals (e.g., Vlasman & Campbell, 2003).

Image analysis was conducted using the open-source software ImageJ (Ferreira & Rasband, 2012; Schneider et al., 2012) on each image (Supplementary Material 1). The ratio of lesion area to the corresponding eye patch area was calculated for each image, generating a Lesion-Eye-patch Ratio (LER). LER values could exceed 1 if the lesion area was larger than the eye patch (Supplementary Material 1).

$$LER = \frac{\text{Lesion area}}{\text{Eye patch area}}$$

LER values were then compared across paired images: (a) left and right sides; (b) maxillae and mandibles; (c) lesion classification categories; and (d) over time and tested if the lesions and their locations were statistically different. As the dataset was all from the same individual (i.e., the data was correlated) we used the paired t-test to account for this. The comparisons were then used to assess the lesions as they developed chronologically, to ascertain if there were any predictable sequences.

We noted key/significant milestones, including first appearance and first depigmentation of the lesions. We also used Mel's estimated age during the study, as age-related factors may have influenced lesion prevalence.

Hypotheses for Lesion Aetiology

We postulated hypotheses to explain the development and persistence of the lesions, including mechanisms related to foraging behaviour, jaw alignment, dentition, and potential genetic predisposition. Each hypothesis was evaluated against available observational and photographic evidence, and those considered most plausible are presented in the Discussion.

Results

Orca - Historical Context

In 2004, an adult male orca was catalogued as PTN-001 (named Mel). Previous studies had catalogued him as B2/“Mel” (Hoelzel, 1991) and as PNB2/“Mel” (Iñíguez, 2001; Iñíguez et al., 2005). These earlier alpha-numerical designations were not retained in the PNOR catalogue because the original group-based classifications were no longer applicable following fission-fusion dynamics along matriline and mixing among previously identified



Figure 3. The two main sites (Medina Bay, Attack Channel) and two additional sites (Faro Bay, Mel's Bay) in the Punta Norte region where photographs of the adult male orca (*Orcinus orca*) were collected; Medina Bay and the Attack Channel are situated approximately 5 km apart on the west and south side of Punta Norte, respectively. The reefs (*restingas*) and the channels are visible along the coastline. Image extracted from Google Earth on 02 February 2026 and adapted by Ingrid N. Visser.

groups (PNOR, unpub. data, 2026). All individuals were therefore reassigned sequential identification numbers independent of group affiliation (Copello et al., 2021; Enarson et al., 2024).

Mel was estimated to have been born *circa* 1960 and was observed intentionally stranding to hunt from 1975 onwards (JCL. data). By 1976, he had acquired the characteristic dorsal fin morphology of an adult male (Hoelzel, 1991). Age and sex classification were based on these milestone dates and established characteristics of adult male orca, including total length > 6 m, sexual maturity at approximately 13-18 years of age (Christensen, 1984; Olesiuk et al., 2005), dorsal fin height > 1.5 m (Olesiuk et al., 2005), pectoral fins up to 1.5 m in length (Visser, unpub. data), and overall body robustness (see Ford, 2018).

Although Mel was observed between 1975 and 2011, systematic lesion assessment was only possible from 2007 onward due to limitations in early record-keeping (e.g., incomplete date records and lack of same-day paired images). Nonetheless, unpublished records describe lesions as early as 1986 (Lopez & PNOR, unpub. data) and a reference to facial lesions, albeit minimal, appeared in a published account from 1999 (Whooley, 1999).

Three previously unpublished images of Mel from 1993, 2000, and 2001 were available (Supplementary Material 2, Fig. 2.1-2.3). During this eight-year period, there was no white *Depigmentation Scar* (Table 1) area on his left maxilla. The LER values for *Open* lesion(s) (*raw*, *granulated*, *bleeding*) on the left maxilla had increased by a factor of 5.5 from 1993 to 2000 (LER for all *Open* lesions was 0.10 to 0.54 respectively, see details in Supplementary Material 2, Fig. 2.1 to 2.3 and Tables 2.1-2.3). A 2001 image of the right jaw shows a lesion of similar size to that observed on his left jaw in 2000, classified as *Discoloured*, *Open* (*raw*) (Supplementary Material 2, Fig. 2.3).

Additionally, from when first photographed in the 1980s, Mel exhibited a pronounced malocclusion ('overbite'), with the maxillae/rostrum protruding beyond the mandibles more than is typically observed in adult male orca (e.g., Supplementary Material 2, Fig. 2.1-2.3 and compare to orca images widely available online and in the literature). Despite this, he remained a successful hunter; during the study period Mel was observed

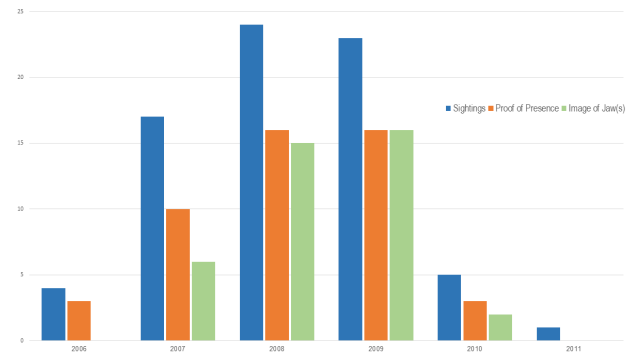


Figure 4. Number of days within each year when there were sightings (*i.e.*, no photos) and proof of presence (*i.e.*, confirmed identification using photographs) of the adult male orca (*Orcinus orca*) known as Mel, between 2006 and 2011. The total number of days of observations for each year were ascertained by adding sightings + proof of presence, whilst the photos of the jaw(s) were a subset of the latter and did not impact the total number of days of observations (sightings + days with photographs).

capturing sea lion pups and carrying them offshore to provision an adult female orca (PTN-014, "Sol"), who was of an unknown lineage and was never documented intentionally stranding.

Current Study – Lesion Classification and Milestones

Between 2006 and 2011, Mel was observed on 122 days (Table 2). The highest seasonal presence occurred in 2008 ($n = 40$ days), declining thereafter until 2011, when a single sighting was recorded without photographic confirmation (Fig. 4). Images were obtained on 48 days between 2006 and 2011 (Fig. 4), of which 39 included his left and/or right jaws. All such images were acquired during intentional stranding events; no practice strandings were documented. The highest number of attacks in a year occurred in 2008 ($n = 122$), which also corresponded to the highest number of successful captures ($n = 76$) (Table 2). Daily intentional strandings ranged from one to 21, with a maximum of successful captures ($n = 13$) occurring in a single day in both 2008 and 2009 (Table 2).

Table 2. Data for the adult male orca (*Orcinus orca*) Mel (PTN-001) with the highest number of each aspect indicated within a shaded cell. The aspects considered were: the number of days of observations (sightings + proof of presence), attacks (with and without captures), the number of successful captures in each sea lion season (by year), the highest number of attacks and successful captures within each year, together with the date of occurrence and the number of pairs of photographs available for assessment from that year.

Season (by year)	# days observed*	Attacks	Captures	Highest # attacks on 1 day & date	Highest # of captures on 1 day & date	Days with photo pairs
2006	7	10	5	($n = 7$) 05 Mar 2006	($n = 5$) 05 Mar 2006	0
2007	27	65	37	($n = 20$) 26 Mar 2007	($n = 9$) 03 Apr 2007	1
2008	40	122	76	($n = 18$) 17 Mar 2008	($n = 13$) 17 Mar 2008	2
2009	39	102	48	($n = 21$) 25 Mar 2009	($n = 13$) 25 Mar 2009	5
2010	8	20	7	($n = 11$) 08 Apr 2010	($n = 4$) 08 Apr 2010	0
2011	1	0	0	($n = 0$)	($n = 0$)	0
Total	122	319	173	Highest ($n = 21$)	Highest ($n = 13$)	8

* Days observed included sightings (no photographs) + proof of presence (photographs confirming identification).



Figure 5a. On 01 March 2009, the lesions on the orca (*Orcinus orca*) Mel's left side include *Discolouration* on the maxilla, which covers nearly all the *Depigmented* area. There are also *Open (granulated)* lesions on both the maxilla and mandible with a significant area of *Discolouration* surrounding the lesion on the latter. The total LER for the left lesions was 0.76. Note the apparent debridging of dermal tissue between the *Discolouration* and the open lesion on his mandible. The malocclusion ('overbite') is clearly visible. LER = Lesion-Eye-patch Ratio. Photo 20090301-PTN-JMC-D1-008 © Juan M. Copello.



Figure 5b. The lesions on the orca (*Orcinus orca*) Mel's right side at the start of this season (*i.e.*, taken 01 March 2009) were *Open (raw)* and they were not too dissimilar in size and location to those documented from the previous season (Supplementary Material 2, Figs 2.5b and 2.6b). There was also a slight *Depigmentation* on the maxilla. The total LER for the right lesions was 0.74. LER = Lesion-Eye-patch Ratio. Photo 20090301-PTN-JMC-D1-020 © Juan M. Copello.

A total of eight same-day left-right pairs (*i.e.*, 16 images) were obtained (Figs 5 and 6, Table 2, and see Supplementary Material 2, Figs 2.4-2.9 and Tables 2.1 and 2.2) between 19 March 2007 (Supplementary Material 2, Fig. 2.4a-b) and 30 March 2009 (Supplementary Material 2, Fig. 2.9a-b), *i.e.*, 1,097 days (three years and one day) between first and last pairs. The greatest number of paired images was five, which occurred on a day with the highest number of attacks ($n = 21$, Table 2). In contrast, the year with the highest number of attacks (2008, $n = 122$) yielded only two same-day images in a year was (Table 2). In the first paired image (19 March 2007), a distinct curve on the left maxilla near the gape was visible (Supplementary Material 2, Fig. 2.4a), contrasting with earlier straight jawlines observed in 1993 (Supplementary Material 2, Fig. 2.1) and 2000 (Supplementary Material, Fig. 2.2).

Lesion Classification

On any given day, we documented a range of lesion categories and LERs across sides (left and right) and jaw regions (maxillae and/or mandibles). For example, on 04 April 2008 (Supplementary Material 2, Fig. 2.5), his left side showed no lesions nor *Discoloured* areas but a *Depigmentation scar* from previous lesions was visible. In contrast, on 01 March 2009 (Fig. 5), Mel's left side lesions were classified as *Open (granulated)* with noticeable *Discolouration* and a *Depigmentation scar* was also visible. Across all milestone

and paired images (1993-2009) no Abscess type lesions were observed.

The highest total LER (*i.e.*, including all lesion categories) was 2.47 (milestone image, 2000), indicating lesions nearly 2.5 times larger than the size of the eye patch (Supplementary Material 1, Fig. 1.4). Within the paired images, the highest total LER was 2.02 (recorded on 08 March 2009), whilst the lowest was 0.16 (recorded on 19 March 2007).

Within all the milestone and paired images, the highest single-category of a LER was 1.93 (*Discoloured*; (Supplementary Material 1, Fig. 1.4), from the 2000 milestone image. The lowest single-category LER was 0.01 (a *Depigmentation scar* from the 2001 milestone image).

Within the paired images, the highest single category LER was 1.12 (*Discoloured*, left mandible, on 08 March 2009; Fig. 5), whilst the lowest single category LER was 0.02 (*Open (granulated)* left maxilla, on 01 March 2009). *Open (granulated)* and *Depigmentation Scar* lesions were the most frequent ($n = 7$ days). *Open (bleeding)* lesions were not observed in paired images (Table 3).

Mandible of Maxilla

Average LER values were significantly larger on the mandible compared to the maxilla on both sides (L maxilla vs L mandible: $t = 2.458$, $p = 0.0492$; R maxilla vs R mandible: $t = 2.515$, $p = 0.0456$). There was no significant difference between left

Table 3. Number of days each lesion type was present, by location on the jaws, within the 16 paired images (*i.e.*, $n = 8$ pairs) of orca (*Orcinus orca*) Mel, between 2007 and 2009. Note that *Open (bleeding)* was only documented in a single photo (*i.e.*, non-paired image).

Jaw	Lesion Classification				
	<i>Discoloured</i>	<i>Open (raw)</i>	<i>Open (granulated)</i>	<i>Open (bleeding)</i>	<i>Depigmentation scar</i>
L maxilla	5	1	5	0	7
L mandible	6	1	5	0	0
R maxilla	5	1	6	0	3
R mandible	6	1	7	0	0

and right maxillae ($t = -0.103$, $p = 0.9215$) or between left and right mandibles ($t = 1.623$, $p = 0.1557$). There was a significant difference between the maxilla (both sides) and the mandible (both sides) ($t = 3.999$, $p = 0.0012$). In other words, the statistical analysis indicated that the LER was dependent on jaw location, with the mandible exhibiting significantly larger lesions than the maxilla. Overall, the distribution of those lesions was symmetrical between the left and right sides of Mel, with no significant difference in the LER.

Temporal Patterns

Open (bleeding) lesions were documented on only one day between 1993 and 2009 (17 March 2008; Supplementary Material 2, Fig. 2.10a) and appeared to have stopped bleeding within two hours (Supplementary Material 2, Fig. 2.10b).

No complete healing was observed between 1993 and 2010. The shortest documented progression from *Open* to *Discoloured* was one year and 17 days (see Supplementary Material 2, Fig. 2.4a on 19 March 2007 and Fig. 2.5a on 04 April 2008).

The last *Open* lesion was recorded on 07 April 2009, when only a left side image was obtained (Fig. 9). In that image there was an *Open (raw)* lesion on Mel's left maxilla anterior to his eye and another directly inferior to his eye, and an *Open (raw)* lesion with a *Discoloured* area extending over more than half of the jaw.

The last day that either of Mel's jaws were photographed (regardless of lesion status) was on 15 April 2010 (Supplementary Material 2, Fig. 2.11) and only an image of his left side was obtained. His jaws were only partially visible, and no lesions were evident on his maxilla although a very small area that could be classified as *Discoloured* was discernible on the mandible just below the mandibular arch. The pre-existing *Depigmented* areas below his eye patch and in front of his eye remained.

Within only the paired images, no cyclic nature was evident (Fig. 10). However, rapid fluctuation in lesion size was documented on the left mandible in March 2009: the total LER increased from 0.67 (01 March 2009) to 2.02 (09 March 2009), over a period of

just seven days and then decreased by more than half to 0.56 in the next nine days (17 March 2009) (Fig. 10, and Table 2.2).

Age and Status of Mel

We could find no clear correlation between the lesions and Mel's age. He was estimated to be approximately 50 years old at his last sighting in 2011 (PNOR, 2023; 2024). He has not been resighted during 14 subsequent seasons (through April 2026, PNOR, unpub. data). Based on his age and prolonged absence (Olesiuk et al., 2005), he is now presumed dead. For comparison, the longest documented absence in this population is four seasons; 25 April 2018 until 01 May 2022 by the female orca PTN-012 ("Antu") (PNOR, 2023; Enarson et al., 2024). In other orca populations individuals have been absent for extended periods before resighting, such as the male T2A from the Pacific Northwest Transient/Bigg's (8 years, Ford & Ellis, 1999) and the female NZ1 (A1) (13 years, Visser & Cooper, 2020). If his age estimate is accurate, Mel would be approximately 65 years old in 2026, within the documented maximum longevity (60-70 years) for males of the fish-eating Pacific Northwest population (Olesiuk et al., 2005). However, there are no published parameters for mammal-eating populations.

Other Case Studies

Among intentionally stranding orca at Península Valdés, only five adult males (including Mel) have been documented with more than 50% of their body out of the water when stranding (other males only partially strand in shallow waters, or patrol just off the beach and do not strand or are not yet fully mature). Three adult male orca are illustrated in Supplementary Material 3 (two of which have lesions, one of which was determined to be closely related to related to Mel; Hoezel, 1989). A male (known



Figure 6a. On 15 March 2009, the *Open (granulated)* lesions on the orca (*Orcinus orca*) Mel's left side were almost entirely encompassed by areas of *Discolouration*. The total LER for the left lesions was 0.93. Note the position of the sea lion pup near the apex of his jaws. LER = Lesion-Eye-patch Ratio. 20090315-PTN-JMC-D1-036 © Juan M. Copello.



Figure 6b. There were *Discoloured* lesions present on the maxilla and mandible of the orca (*Orcinus orca*) known as Mel. The *Open (granulated)* lesions on Mel's right side were very similar, in size and classification on 15 March 2009, to those documented seven days prior (Supplementary Material 2, Fig. 2.7b). The total LER for the right lesions was also 0.93. Note the piece of seaweed in his mouth. LER = Lesion-Eye-patch Ratio. 20090315-PTN-INV-D1-121 © Ingrid N. Visser.

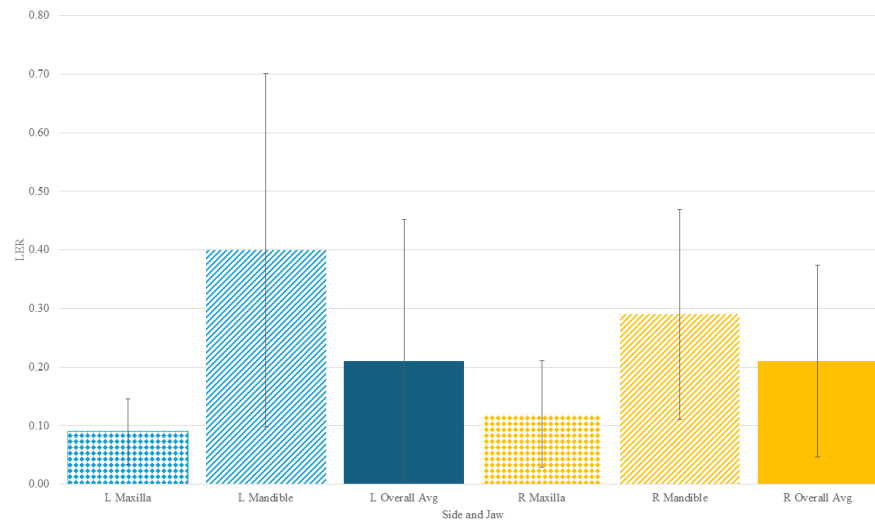


Figure 7. Average LER (Lesion-Eye-patch Ratio) comparing sides and jaws of the orca (*Orcinus orca*) known as Mel from (n = 8) paired images (2007-2009), for all lesion classifications. Bars represent the mean, whiskers the standard deviation. Paired t-test values were significantly larger on the mandible compared to the maxilla on both sides (L mandible vs L maxilla: $t = 2.456$, $p = 0.0495$; R mandible vs R maxilla: $t = 2.515$, $p = 0.0456$). However, there was no statistically significant difference when comparing the left to the right maxillae nor for the left to the right mandibles. L = left; R = right.

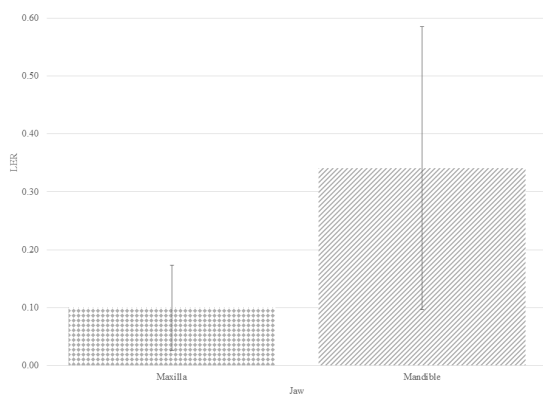


Figure 8. Average LER (Lesion-Eye-patch Ratio) comparing maxilla and mandible lesions (2007-2009) of all lesion classifications and both sides, of orca (*Orcinus orca*) known as Mel. Bars represent the mean, whiskers the standard deviation. A paired t-test showed a statistically significant difference between the combined maxilla and mandible lesions ($t = 3.999$, $p = 0.0012$).

as Mel) was documented intentionally stranding between 1975 and 1986 but he was never photographed and did not exhibit visible lesions (JCL, unpub. data).

Discussion

The intentional stranding behaviour of the adult male Punta Norte Patagonia orca during foraging provided a rare opportunity to collect long-term data on facial lesions in a free-ranging individual. We documented reoccurring lesions on both sides of his head, on both the maxillae and mandibles. These lesions were recorded over a period of years, representing the longest duration

for which lesions have been documented on a free-ranging orca.

The underlying aetiology and pathogenesis of the lesions could not be definitively established from photographic and observational data. Regardless of aetiology, the biomechanics of any orca — let alone an adult male — getting off the beach are remarkable. Their sheer weight (Heyning & Dahlheim, 1988), up to three fused cervical vertebrae (Cozzi et al., 2016) and fusiform shape (Bell, 1837), preclude easy egress. Their pectoral fins, used for lift-based swimming (Huggenberger et al., 2019), along with their scapular and associated musculature, are not adapted for the extreme actions observed during intentional stranding and subsequent egress. In this context, their use during egress may be considered an example of exaptation (an anatomical feature acquiring a function for which it was not originally selected or adapted, Gould & Vrba, 1982; Sol, 2015) as they are used to manoeuvre the front part of the animal's body off the beach.

We speculated that there could be several non-exclusive explanations as to the aetiology of the lesions on Mel. Six of these were eliminated with a reasonably high degree of confidence (Supplementary Material 4). Of the remaining postulated explanations, three hypotheses appeared most plausible and likely linked: Hypothesis One (misalignment of the jaws due to the egressing method), Hypothesis Two (teeth involvement), and Hypothesis Three (genetic predisposition). Of these, the clearest supporting evidence relates to Hypothesis One, and when combined with Hypothesis Two, these provide the most logical explanation. However, given that only one other adult male in the population exhibited similar lesions and was related to Mel, we cannot rule out some degree of genetic influence.

Hypothesis One: Biomechanical Stress and Mandibular Misalignment

Hypothesis One proposes that the body motions required to egress from the beach after intentional stranding create atypical



Figure 9. The last photo of the orca (*Orcinus orca*) known as Mel in our dataset which showed lesions was taken 07 April 2009, i.e., eight days after the last same-day pair of photos (Supplementary Material 2, Fig. 2.9a, b). There were *Open (raw)* lesions and *Depigmented scars* on his left maxilla. On his mandible the lesion was *Open (raw)* with a *Discoloured* area extending over more than half of the jaw. The total LER (Lesion-Eye-patch Ratio) was 1.03. There was no image for the right side for this day. Photo 20090407-PTN-JMC-D1-008 © Juan M. Copello.

physical stresses that lead to jaw misalignment, resulting in either direct damage to jaw bones and/or soft tissues, or secondary puncturing by misaligned teeth (see Hypothesis Two for this latter aspect).

The biomechanics involved in egress are complex (see videos in Supplementary Material 5). When on the beach, each pectoral fin may be forced into lateral elevation approaching 90° from the body (Fig. 11), contrasting with the natural ~45° downward “hanging” position in water (Visser et al., 2021, see their Fig. 3). Although rigid overall, the pectoral fins articulate with a shoulder joint and scapular complex containing interconnected muscles, fascia, and ligaments (Felts & Spurrell, 2005; see also our Figs 12 and 13). This atypical positioning may place loading and pressure on these structures, potentially causing distortion or misalignment of soft tissues and skeletal components.

During egress, significant movements occur, including lateral bending and arching of the body, upward lifting and lateral movements of the thorax and head, tail elevation (sometimes clear of the water), and “hunching” motions. The pectoral fins are flexed, twisted, elevated and used as pivot points. Movements may be synchronous or independent (e.g., both fins used in a “push-up” motion, head swung laterally, or one fin elevated while the other pushes against pebbles, Fig. 11a, b). Although some examples in the video in Supplementary Material 5 involve females, the actions are similar between the sexes but may be exacerbated in adult males due to their larger pectoral fins and heavier body weight.

Recognising the interconnectedness of the scapular, skull, and mandibular soft tissues (Figs 12 and 13), such gross movements likely place strain on the thoracic-head region, potentially resulting in mandibular misalignment. Hyperextension of the pectoral fin may stress the shoulder joint capsule, possibly leading to rupture or ligament laxity. Strain may transmit to muscles connected to the maxilla and mandible via the *sternomastoideus*, *omohyoideus*, *sternohyoideus*, *deltoideus*, and *supraspinatus* muscles (see Figs 12

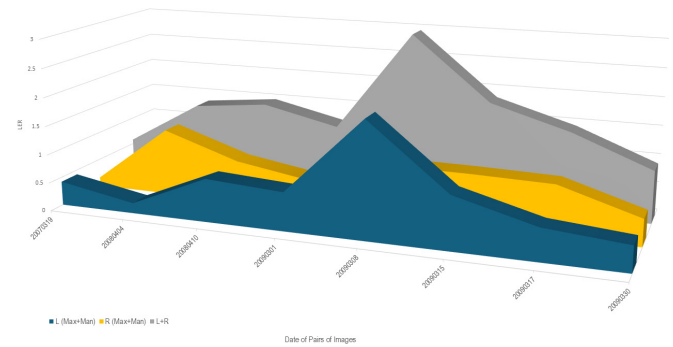


Figure 10. The Lesion-Eye-patch Ratio (LER) for the (n = 8) pairs of images on the left, right maxillae and mandibles of the orca (*Orcinus orca*) Mel, and combined, between 2007 and 2009. A LER of 1 = the same size as the eye patch. There was no cyclic nature of the lesions from this dataset, however the rapid change in size over a 16-day period (01 - 17 March 2009) is apparent on the left mandible; see text for details. Note that the X axis (Date of Pairs of Images) is not to scale. L = left; R = right; Max = maxilla; Man = Mandible

and 13 for approximate placement of these muscles and Galliano et al., 1966; Strickler, 1978; Reidenberg & Laitman, 1994; Cozzi et al., 2017; and Huggenberger et al., 2019 for additional anatomical detailed information on other cetacean species). Hyperextension is at times visible in the scapula-complex region (Figs 2 and 11a). Combined with beach attack velocities exceeding 20 km per hour (PNOR, unpub. data; and see video Supplementary Material 5) and vigorous egress movements, these stresses could plausibly twist the mandible out of alignment (Ulmer, 1941).

The mandibular symphysis in orca is typically partially fused with interlocking rugosities, resulting in an effectively immobile joint (Strauch et al., 2024). Consequently, stress would likely be concentrated at the coronoid process, mandibular condyle, and angular process (Fig. 14). Adjacent to these is the mandibular fossa (or ‘pan’/‘mandibular canal’), a relatively thin-walled structure housing the lipid-rich mandibular fat pad (MFP), integral to hearing. The MFP may contain immune-related markers (Takeuchi et al., 2024). Histological examination following localized injury has shown diffuse congestion and hemorrhaging (Fernández et al., 2005). The higher prevalence of lesions on Mel’s mandibles may relate to this anatomical vulnerability, although confirmation would require necropsy.

Adult male orca weigh 4,000–9,000 kg (Sleptsov, 1965; Wada, 1981; Heyning & Dahlheim, 1988; Clark et al., 2000), with much of this mass concentrated anteriorly (Heyning & Dahlheim, 1988; Williams, 2009). During egress, this mass must be lifted or repositioned using body motion and the pectoral fins. Additionally, although sea lion pups weigh 3–15 kg at birth (Ridgway & Harrison, 1981; King, 1983), they can exceed 30 kg. When positioned at the apex of the mouth (e.g., Fig. 6a) and twisting dynamically and/or when being violently shaken (see examples in Supplementary Material 5 video), they may impose additional pressure on the temporo-mandibular joints, potentially leading to subluxation or dislocation.

Hypothesis Two: Teeth and Soft Tissue Trauma

Hypothesis Two considers dental involvement. Either dental pathology created infection pathways, or intact but misaligned teeth punctured soft tissues.



Figure 11a. The adult female orca (*Orcinus orca*) Valen (PTN-009) as she egressed from the beach. Note that the angle of each of her pectoral fins is different. The right pectoral fin elevates the thorax and head while directing momentum to the left (see Fig. 22b). Her head is raised high in an atypical 'push-up' position. 20090320-PTN-JMC-D1-249

Jaw misalignment is associated with malocclusion and extreme tooth wear in orca (Tomes, 1873; Ulmer, 1941), and dental pathology can lead to infection (Graham & Dow, 2005). Only two images of Mel's teeth were available (Supplementary Material 2, Fig. 5a), taken less than one second apart and showing the anterior left mandibular quadrant. Three visible teeth (#1 – #3) exhibited negligible coronal wear (< 10%), each scoring 0 following Jett et al. (2017). No additional pathology was observed.

Given that anterior teeth typically exhibit greater wear (Ford et al., 2011; Jett et al., 2017; Loch et al., 2025), it is reasonable to infer that most of Mel's teeth were likely undamaged. However, intact teeth could increase the likelihood of injury to soft tissues if malocclusion occurred due to mandibular misalignment. Even temporary craniomandibular dysfunction could cause teeth to protrude unevenly, puncturing soft tissue and forming abscesses that subsequently suppurate and manifest externally as visible lesions.

Hypothesis Three: Genetic Predisposition

Hypothesis Three proposes a genetic predisposition. Hoelzel (1989) identified two adult male orca (Mel and Bernardo) in this population as closely related. Both developed lesions in similar anatomical locations within a few years. This raises the possibility of inherited susceptibility, potentially exacerbated by similar hunting methods.

Over approximately 20 years of monitoring, no other male or female within this population has shown maxillary or mandibular lesions (though one individual exhibited some *Discolouration*; Supplementary Material 3). It is unclear how related Mel and Bernardo were to the current individuals in the population. Thus, if genetic predisposition existed, it may have interacted with behavioural intensity or mechanical loading. Mel conducted 319 attacks during the six-year period we documented him, including 21 in a single day. These intentional strandings potentially exacerbated any genetic vulnerability he had. We do not have comparative data for Bernardo (Mel's presumed older brother



Figure 11b. The adult female orca (*Orcinus orca*) Valen, one second after Fig. 11a, illustrating how she has now swung her body to her left and has lifted her right pectoral fin(s) clear of the beach and the water. Note that her body is now also flexed to her left. The sequential time was extracted from metadata of the RAW images. 20090320-PTN-JMC-D1-250

who also exhibited facial lesions). Two other males, "Jaluel" (PTN-19, presumed to have been born in 1998) and "Pao" (PTN-006, born in 2005) also intentionally strand (the most attacks they have conducted in a single day were 11 and 9, respectively, PNOR, unpub. data). Jaluel has never been a prolific hunter and has never been documented with any lesions (SM3). Only Pao has shown any signs of lesions; a *Discoloured* area on this left mandible in April 2016 (Supplementary Material 3). Since that date, he has not exhibited any lesions, despite the number of attacks increasing over time and as he has matured (SM3).

Context and Implications

Although a wide range of publications document cetacean lesions from sunburn (e.g., Bossley & Woolfall, 2014), boat strike (e.g., Dwyer et al., 2014; Raverty et al., 2020; Visser et al., 2021), entanglement (e.g., Moore et al., 2013), rake marks (e.g., Visser, 1998; Grimes et al., 2023;), and cookie cutter shark bites (e.g., Dwyer & Visser, 2011; Visser et al., 2020), only one publication has presented long-term lesion data in orca (Visser et al., 2021). Comprehensive case studies remain rare, including within captivity where aggression-related lesions occur (e.g., Zimmerman, 2011; 2012; Marino et al., 2019; Visser, 2019) and the animals can be observed daily.

To facilitate comparisons and quantify changes between the sides of the head, the upper and lower jaws, and the variations over time we developed a classification system and 'Lesion- Eye-Patch Ratio'. Rapid size fluctuations were observed, including doubling and halving within just over two weeks. Similar rapid lesion healing has been documented in other contexts (Visser & Fertl, 2000; Dwyer & Visser, 2011). In Mel's case, hydro-debriding during swimming may have reduced bacterial load, analogous to irrigation debridement in humans (Saeg et al., 2021).

Despite substantial lesions, Mel continued to hunt successfully and provision conspecifics, such as the female Sol. In the past, injured orca have at times been slated for euthanasia based on their wounds. For example, in New Zealand the standard operating

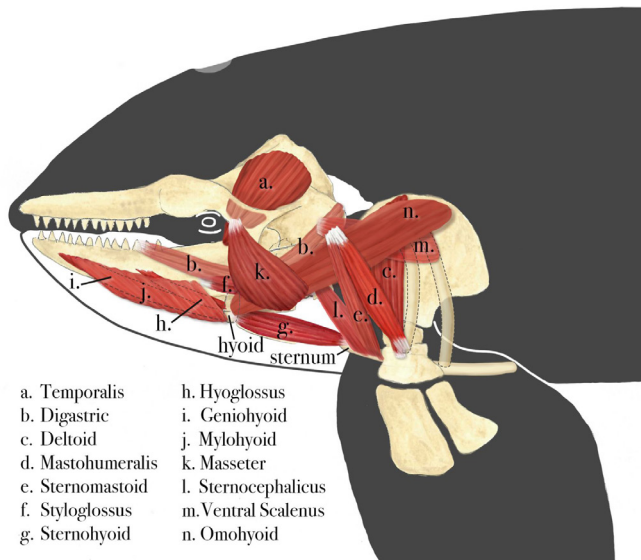


Figure 12. Sagittal view of the musculature of the shoulder complex, skull, and mandibular process which were potentially implicated during the position of the pectoral fin(s) of orca (*Orcinus orca*) during egress from the beach. Note that not all muscles of this region are depicted. The musculature depicted is based on the known orca skeleton and reference data from related dolphin musculature. Illustration by Lydia Trom © Lydia Trom & Orca Research Trust.

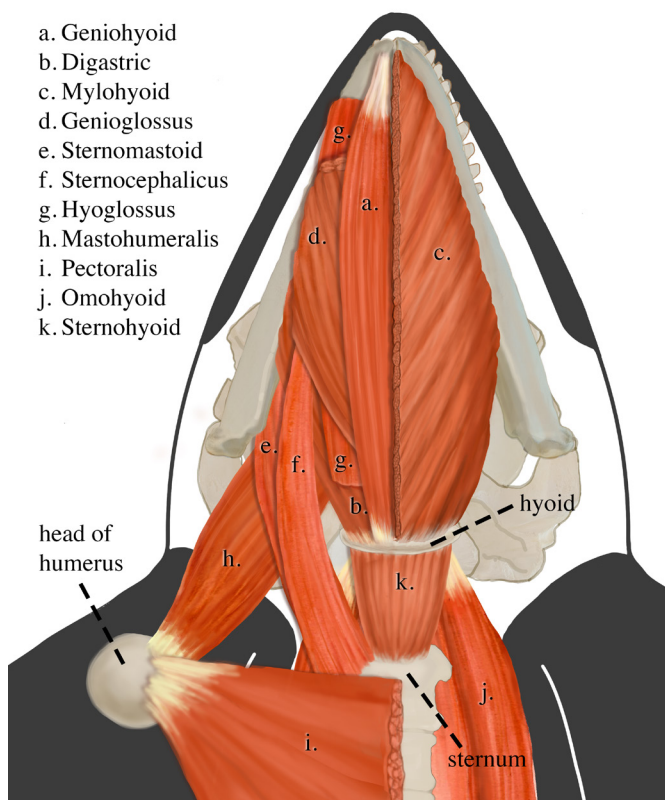


Figure 13. Ventral view of the musculature potentially implicated during egress of orca (*Orcinus orca*) from the beach. Note that not all muscles of this region are depicted, such as the tongue muscles (e.g., the styloglossus). The musculature depicted is based on the known orca skeleton and reference data from related dolphin musculature. The outline of the skull is visible and the position of the hyoid and sternum are indicated. Illustration by Lydia Trom © Lydia Trom & Orca Research Trust.

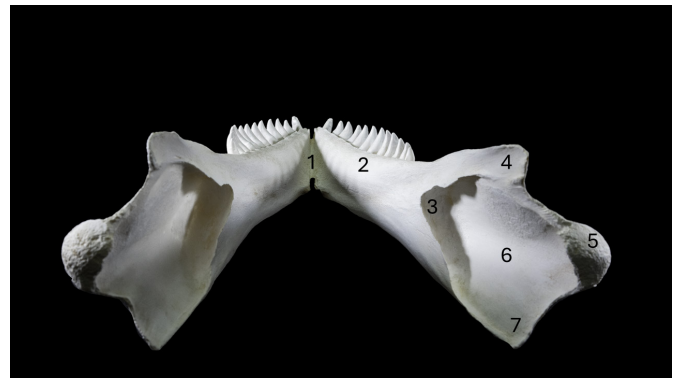


Figure 14. Mandibles of a museum-quality replica orca (*Orcinus orca*), with replica teeth in situ. 1 = mandibular symphysis, 2 = dentate zone of mandible, 3 = mandibular foramen, 4 = coronoid process, 5 = mandibular condyle, 6 = mandibular fossa, 7 = angular process. Note the relatively thin bone of the zones 3, 6 and 7 which, in a live specimen, would be filled with the mandibular fat pad. Composition by Ingrid N. Visser.

procedures for cetacean rescues do not cater for rehabilitation in captivity as there are no suitable facilities (Visser & Fertl, 2020). As such, when a young male orca stranded, with a bleeding cut in the tissue surrounding the left pectoral fin joint along the thorax, the Department of Conservation (the New Zealand Government Department legally mandated to protect cetaceans) stated that the bleeding cut was reason enough to warrant shooting him. However, the onsite rescue team managed to convince the local Government rangers to allow a rescue attempt, which was successful and the orca was subsequently documented for more than 23 years (Visser et al., 2021). Orca (and other cetaceans) have a remarkable capacity for recovery and abilities to cope with injuries, such as when they have been struck by boat propellers or lost limbs to entanglements (Visser, 1999; Copello et al., 2021; Visser et al., 2021; Urbán et al., 2024). These examples illustrate that lesions should factor into the assessment criteria for a rescue, by taking into consideration the ability of these animals to heal. The current case study further supports the framework for rescuing and releasing any injured orca whose lesions might otherwise be considered debilitating. Mel not only hunted for himself, but he also captured prey and provisioned other orca in the population despite his graphic and extensive lesions that prevailed over a period of years. Such a framework is important when dealing with small populations of orca and particularly given the small number of intentional stranders at Punta Norte (e.g., $n = 6$ in 2007; $n = 21$ in 2025; PNOR, unpub. data).

Finally, these findings underscore the importance of carcass recovery, necropsy, and retention of skeletal material—including teeth—to assess ossification of mandibular joints and dentition wear. Such material would allow future evaluation of the anatomical and potentially genetic underpinnings of these lesions.

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Supplementary Material

Supplementary Material 1. Lesions on the jaws of an adult male orca. Figs 1.1-1.6 and Table 1.1.

Supplementary Material 2. Comparison of milestone and paired images. Figs 2.1-2.12.

Supplementary Material 3. Other adult male orca documented intentionally stranding at Punta Norte. Figs 3.1-3.8 and Table 3.1-3.2

Supplementary Material 4. Six rejected hypotheses, and some of the reasonings as to why we believe these are less likely

to have been the cause of the lesions on the adult male orca (*Orcinus orca*) known as Mel.

Supplementary Material 5. Video of beach attack by orca and egress behavior back into the water.
