Preliminary image analysis of acute and chronic injuries, parasites, and skin conditions in the Okhotsk Bowhead whale (*Balaena mysticetus*) stock in the western Okhotsk Sea

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Abstract

Causes of morbidity and mortality of the endangered Okhotsk Sea population of the bowhead (OSB) whale are not well known. We present findings from a preliminary image analysis (n=110) of free-ranging OSB whales on evidence of acute and chronic injuries, parasites, and various skin conditions in the western Okhotsk Sea. No evidence of serious injuries as defined as "an injury that is more likely than not to result in mortality" were observed. Based on the limited analysis, OSB whales are exposed to similar threats as Bering-Chukchi-Beaufort (BCB) bowhead whale stock as evidenced by scars caused by line entanglement and killer whale predation attacks. Killer whale injuries are more severe (i.e. degree of damage) and include amputations of fluke tips and flipper tips. Observed molting related skin conditions were unique to the OSB as was the apparent greater body burden of whale lice. The unusual skin molting conditions could possibly reflect the different marine habitat that OSB whales occupy (i.e. water temperature, salinity, turbidity, anthropogenic and mining run-off). Given the limited number of individual whales that were examined, our findings and conclusions are preliminary and will be revisited with the completion of a comprehensive image analysis of OSB whales. The available images of OSB whales that use the Western Sea of Okhotsk (Shpak unpubl.data) serve as foundation for an ID catalogue and future mark-recapture work. Scars, active wounds, belly and chin patch pigmentation, and age-related greying of flukes and eye area are suitable external features in bowhead whales to be used for identifying individuals.

Introduction

Shpak et al. (2014, 2015, 2016) recently provided updated information on the endangered Okhotsk Sea Bowhead (OSB) Whale subpopulation. Based on recent genetic mark–recapture data (2011-2013) the total population size is estimated at ~300 animals, while pooling the data with the earlier sample (1995-2001) rises the number to ~500 whales (Shpak et al. 2014). During the summer, OSB stock inhabits mostly ice-free waters in the western Okhotsk Sea (Shantar region), but some individuals may spend summer in Shelikhov Bay in the north. There is limited knowledge about the ecology of these whales and not much is known about their natural morbidity and mortality factors (Reilly et al. 2012). Based on our observations, communication with local residents, and open-source information, a variety of risk factors/threats including killer whale (*Orcinus orca*) predation, by-catch from local salmon fishing, adventure tourism have been identified. Oil resource development and mining operations may also impact the marine habitat and bowhead whales. A variety of tools including stranding information, post mortem examination of aboriginal subsistence-harvested bowhead whales, and image analysis from photo catalogues have been successfully used to better understand the ecology and causes of natural morbidity and mortality of BCB bowhead and North Atlantic right whales (for example, Philo et al. 1993; George et al. 1994, 2017; Knowlton et al. 2012; Stimmelmayr 2015). Similar type of work has not been done for the OSB whale stock, which is exempt from aboriginal-subsistence whaling. We present our findings from an image analysis of a subset of photographs collected from 2011 to 2013 on evidence of acute and chronic injuries, parasites, and various skin conditions in OSB stock in the western Okhotsk Sea.

Materials and Methods

We conducted a manual image analysis of a representative subset of high resolution photos of OSB whales taken during July-August from a small motorized inflatable boat (2011-2013) in the western Sea of Okhotsk (Shpak et al. 2014; 2015). A total of 110 photos including 2011 (n=54), 2012 (n=36), 2013 (n=32) of free-ranging OSB whales were first categorized by whale surface behavior (i.e. type of display). Photos were subsequently evaluated by body region for evidence of acute and chronic injuries including scars, presence/absence of whale lice (cyamids), diatoms, and various skin conditions. Prior to analysis all images underwent quality assurance control whereby photos of low quality (i.e. too distant) or duplicate shots were excluded. The basic criteria for assigning a scar type (i.e. line entanglement, killer whale wounds, ship strike) were as described by George et al. (2017). Appearance of other wounds (i.e. acute and healing) that did not fit these criteria were recorded and described as observed. Cyamid presence/absence was recorded as previously described by Von Duyke et al. (2016). Known skin conditions associated with diatoms, *molting* and of unknown etiology were recorded and macroscopic characteristics of these skin conditions described as observed.

Results and Discussion

No photogrammatic measurements were taken to ascertain absolute size, but based on estimated size and markings the majority of photo images were from immature including one calf to mature whales. Mature older whales were characterized by characteristic "greying" of the eye, peduncle, flipper insertion, and fluke body.

Surface Behavior: Photo documented surface behavior of OSB whales included *blows, spy hop (syn. head rise), head lunge, flipper slapping, tailing and tail slapping, tree log play , actual logging, and surface feeding.* Similar surface behaviors have been previously reported for the BCB bowhead whale stock (Wursig and Clark 1993).

External Markings: A summary of observed external markings are provided in Table A to C. Examples of photographs depicting described markings are provided as photo compilations (Fig.1, a-e). No evidence of serious injuries as defined as "an injury that is more likely than not to result in mortality" were observed (Anderson et al. 2008). Diatom films i.e. yellow stains on non-pigmented skin (white) and muddy brownish film on pigmented skin were observed. Diatom staining is observed in BCB bowheads but incidence has not been quantitatively evaluated (Haldiman et al. 1985). Whale lice (cyamid) infestation was present on OSB whales. Individual and clusters of *cyamids* (orange color) were noted in and around the blowhole, neck, rostrum, and occasionally flipper and flukes. Only a few were associated with scars. The observed intensity of cyamid infestation of individual whales appears markedly greater than previously reported for BCB bowhead whales (< 10 per whale see Von Duyke et al. 2016). Evidence for *ship-strike injury* i.e. propeller cuts was scarce with one animal having scars consistent with a propeller contact. This is consistent with findings for BCB whales where "scars associated with vessel strikes are infrequent and occur on ~2% of all harvested whales" as discussed by George et al (2017). Wrapping linear scars at the base of the peduncle consistent with *line entanglement* were present on several whales. In comparison to BCB bowhead whale scars associated with line entanglement were of delicate and precise nature. Width of these peduncle scars suggests different gear is involved than what is known for BCB bowhead whales.

Scars from *killer whale* attacks (i.e. rake marks; tip amputation) were present on flukes and flippers. It is noteworthy that the extent of tissue damage from bites to the appendages was more severe than previously observed for BCB bowhead whales. Similar extensive killer whale related injuries have been observed in found dead immature gray whales on the North Slope, Alaska (R. Stimmelmayr, unpubl. data). A variety of fresh linear skin defects i.e. gauges, scratches, lacerations not associated with scaring were noted mostly on the body of mid and large size whales. These types of injuries have not been commonly observed in BCB whales.

Presumed *molting skin conditions* such as the square shaped raised marks along the body -axis squares ~ 10-20 cm diameter (aka the *coco chanel print or houndstooth pattern*), and parallel evenly spaced *grooves and welts* perpendicular to the body axis alongside the main body as seen for the OSB, have previously not been appreciated for the BCB stock. The *coco chanel print* and the parallel *welts/grooves* observed on several whales are strikingly similar to the external appearance of postnatal ecdysis stages in southern right whale calves (see Reeb et al. 2005 and our photo compilation), while tree-bark skin (i.e. shingles) observed on a few whales is more similar to the appearance of molting BCB calves as described by Haldiman and Tarpley (1993). The high incidence of molting (i.e. shedding of thin and thick plates of skin) in OSB bowhead whales has been previously described by Chernova et al. (2016) and is thought to be driven by the warm water temperatures in the shallow bays of Sea of Okhotsk. Whitehead et al. (1990) similarly discussed the more frequent sloughing of sperm whales (*Physeter macrocephalus*), humpback whales (*Megaptera novaeangliae*), and gray whales (*Eschrichtius robustus*) observed in warmer compared with colder waters. Ecophysiological function of observed shedding/sloughing of skin in calves may accommodate the rapid body growth rate of post natal calves during their transition to a yearling whale, and for older baleen whales – a thermoregulatory response to ambient water temperature, as well as a seasonal skin cleanse for parasites and skin microbiome. The latter has been proposed for amphibians and Antarctic killer whales (Cramp et al. 2014; Durban and Pitman 2012). Breaching and tail slapping in whales may facilitate removal of skin and attached lice as noted by Rowntree (1983). Although we believe molting may play a certain role in parasite removal, from the photos available to us it is evident that whale lice manage to move to areas of younger skin.

In conclusion, OSB whales are exposed to similar anthropogenic and natural threats as BCB whales as evidenced by line entanglement and killer whale scars. Observed molting related skin conditions are unique to the OSB as is the greater body burden of whale lice. The high prevalence of summer skin molting as discussed by Chernova et al. (2016) could reflect the different marine habitat that OSB whales occupy (i.e. water temperature, salinity, turbidity etc.), Similarly the high whale lice burden observed on individual whales may reflect suitable environmental conditions for successful whale lice reproduction and growth. Given the limited number of individual whales that were examined by this image analysis our findings and conclusions are by nature general and need to be revisited with the completion of a comprehensive image analysis of OSB whales. The available images of OSB whales that use the Western Sea of Okhotsk (Shpak, unpubl. data) will serve as foundation for an ID catalogue and future mark-recapture based population size assessments as several of the whales have very distinct markings. Scars, wounds, and chin patch pigmentation are suitable external features in bowhead whales to be used for identifying individuals.

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Table 1a. A summary of grossly visible external markings (scars and injuries) from the image analysis of 110 photos of OSB bowhead whales taken during 2011-2013.

Injury type	Description	Body Location	Comment
Line Entanglement	linear or curvilinear cuts or scars into the skin;	Leading edge of flukes; peduncle region; flipper insertion	Few in comparison to BCB Bowhead; also more delicate appearance suggesting different strength and diameter of line entanglements (George et al. 2017); one bowhead had a tissue defect at flipper insertion consistent with line entanglement there
Killer whale wounds	Multiple short parallel linear or zig zag scars (tooth rake marks) of variable length approximately 2–4 cm apart; amputation of fluke or flipper tips.	Leading and trailing edge of the flukes, fluke tips, flipper tip	Extent of tissue damage from bites to the appendages was more severe than previously observed for BCB bowhead whales. Similar extensive killer whale related injuries have been observed in found dead immature gray whales on the North Slope, Alaska (R. Stimmelmayr, unpubl. data)
Ship strike injuries	Lacerations or incising wounds associated with contact with the spinning propeller or a boat or ship hull; typically ship propeller wounds are recognized as a series of parallel concave scars or cuts.	Blow hole crown	Shape and size suggests small boat propeller contact
Scars of unknown etiology	broad stroked linear short white marks; point scars;	Blowhole ridges/ crown; rostrum, neck,	BCB whales also exhibit a variety of unique scars that have been variably attributed to walrus tusk, ice seal, polar bear claw marks, beluga whales, ice scouring (Philo et al. 1993; George et al 1994); No quantitative analysis has been done on these type of scars in BCB bowhead whales.
Gauges	Deep tissue defects	Rostrum	Similar defects and subsequent scars have been occasionally seen in BCB bowhead whales
Lacerations and scratches	zig zag irregular shaped lacerations; brushstroke like superficial scrapes of the epidermis	Body	Bottom scraping and contact with tree logs are possible causes for observed injuries in OSB (O. Shpak, unpubl. data); Fresh zigzag shaped longitudinal lacerations have been observed on 2016 landed whales that came into contact with floating sea ice (R. Stimmelmayr, unpubl. data).

Table 1b. A summary of grossly visible ectoparasites from the image analysis of 110 photos of OSB bowhead whales taken during 2011-2013.

Ectoparasites	Description	Body Location	Comment
Diatom films	Yellow to ochre staining of epidermis mostly noticeable on non-pigmented white skin	Rostrum, mandible especially chin patch	Occasionally observed in BCB bowhead whales, but no quantitative data available (Haldiman et al. 1985)
Whale lice	Single to clusters of red whale lice (Cyamid spp.) associated with natural openings and between shingles/patches of thick proliferated epidermis	Blowhole; neck; flipper	Higher cyamid burden per individual whale than BCB stock (Von Duyke et al. 2016); lice in OSB whales mostly not associated with obvious wounds/scars (only one case) but with natural openings. and edges/crevices of skin shingles
Sea Lamprey scars	Pin point scars arranged in a circle	Head	Confirmed lamprey dentition scars have been observed on common minke whales in Icelandic waters (Olafsdottir and Shinn 2013). This would be the first observation in a bowhead whale.

Table 1c. A summary of grossly visible external markings of molting and other skin conditions from the image analysis of 110 photos of OSB bowhead whales taken during 2011-2013.

Molting Skin Conditions	**Description**	**Body Location**	**Comment**
Tree bark skin	Patches of thickened skin;	Jaw, neck	Usually seen in calves and yearling BCB bowhead whales " so called "baby skin" by Alaskan indigenous whalers- but can occur in immature whales (Haldiman and Tarpley 1993)
Grooves	Multiple evenly spaced parallel narrow depressions of the epidermis without evidence of scarring	Body	Uncommon for BCB bowhead whales but has been observed (Gay Sheffield pers. commun.)
Welts	Multiple linear raised evenly spaced marks perpendicular to the body axis ; spacing 10-20 cm wide giving the skin a loose appearance	Body	Not observed in BCB bowhead whales
Coco chanel print or houndstooth print	Square shaped raised marks along the body – axis squares ~ 10-20 cm diameter	Body	Not observed in BCB whales; A similar pattern has been observed in Southern right whale calves preceding their postnatal ecdysis (Reeb et al. 2005)
Skin Peeling/Shedding	Shedding top layer of epidermis ; areas were skin has been shed is grey in color versus deep jet black of the remainder of the skin	Anywhere on the whale	Not uncommon among BCB bowhead whales harvested for subsistence purposes
Miscellaneous			
White Belly	Patch of unpigmented skin	Ventrum; lateral body	A white "Belly patch" similar to Right whale markings are occasionally observed in BCB whales. One OSB whale with similar markings was observed
Age related greying and pigmentation loss	A "salt / pepper" coloration to solid white ; loss of black pigmentation	Eye region, medial flipper at insertion; fluke table ; peduncle,	Usually seen in older large whales; used as an external marking by Alaskan indigenous whalers to identify "old" whales.

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Figure 1. A . Composite of photos of acute and chronic injuries from line entanglement, possible ship strike, and scars of unknown etiology in OSB stock (2011-2013) in the western Okhotsk Sea.

Figure. 1 B . Composite of examples of acute and chronic injuries from killer whale predation attacks in OSB stock (2011-2013) in the western Okhotsk Sea.

Figure 1.C. Composite of photos of whale lice (cyamids) and diatoms in OSB stock (2011-2013) in the western Okhotsk Sea.

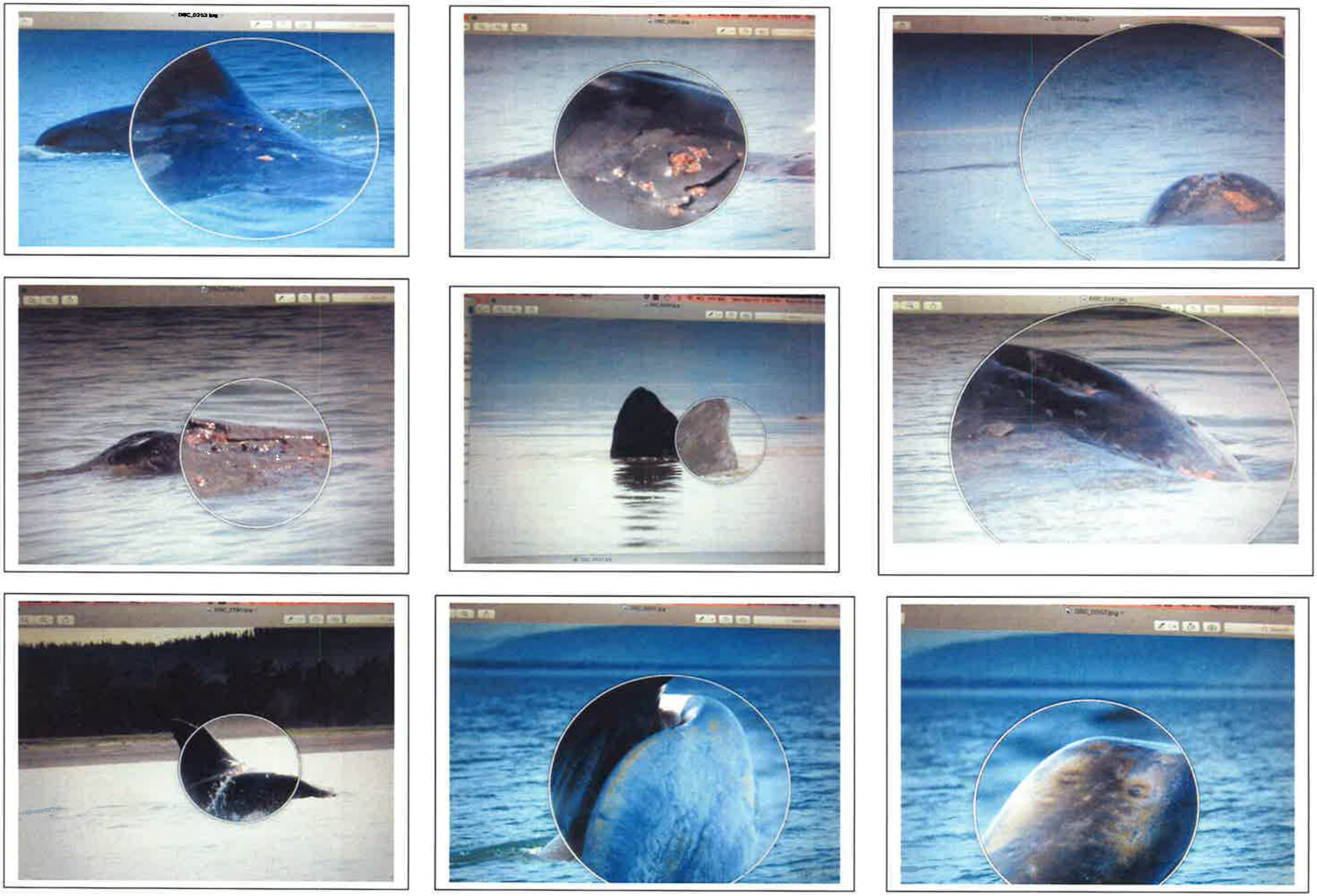

Figure 1. D. Composite of photos of signs of ageing in OSB stock (2011-2013) in the western Okhotsk Sea.

Figure 1 E . Composite of photos of molting and other skin conditions in OSB stock (2011-2013) in the western Okhotsk Sea.