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RUST-COLORED BEARDED (*ERIGNATHUS BARBATUS*) AND RINGED (*PHOCA HISPIDA*) SEALS FROM SVALBARD, NORWAY

Christian Lydersen,* Kit M. Kovacs, and Espen Lydersen

Norwegian Polar Institute, N-9296, Tromsø, Norway (CL, KMK)
Norwegian Institute for Water Research, Box 179 Kjelsås, N-0411, Oslo, Norway (EL)

Bearded and ringed seals from Svalbard, Norway, often have strongly rust-colored faces; the fore-flippers also are rust-colored in some animals. Element analyses of fur from normally colored and rust-colored seals of both species showed that high concentrations of iron were present in the colored fur, indicating that iron oxides are probably the main reason for the unnatural coloration. High concentrations of vanadium and manganese also were found in samples of colored fur. Oxides of these elements also may contribute to the discoloration. We suggest that seals acquire elements responsible for the coloration while feeding in soft-bottom sediments. Their faces and flippers make contact with rich deposits of iron monosulfide in a reducing environment. When this sediment is brought up into the water column by the seals, the iron monosulfide is oxidized to form iron oxides that precipitate onto the hair shafts of the seals. The higher incidence of rust-colored bearded seals, compared with ringed seals, is explained by the greater dependence of the former species on benthic prey items.

Key words: bearded seal, benthic feeding, iron oxides, ringed seal, rust

During studies of bearded seals (*Erignathus barbatus*) in Svalbard, Norway, in recent years (Hammill et al. 1994; Kovacs et al. 1996; Lydersen et al. 1994, 1996), we have noted a high frequency of animals with strongly rust-colored faces (Fig. 1). The discoloration often extends beyond the head, down onto the shoulders and sometimes includes parts of the fore-flippers. Ringed seals (*Phoca hispida*) also have been studied for many years in this area (Lydersen 1998), and animals with rust-colored faces also have been observed in this species (Fig. 1), although in much lower frequency than for bearded seals.

Red-coloration of pinnipeds has been described previously for harbor seals (*Phoca vitulina*) from the San Francisco Bay area, California (Allen et al. 1993). These seals also were mainly discolored in the head and shoulder areas, and element analyses of hair samples from these animals showed that the color was derived from depositions of iron oxide on hair shafts (Allen et al. 1993). San Francisco Bay includes large shallow water areas with strong summer winds that may resuspend sediments containing ferrous iron into the water column. Allen et al. (1993) suggested that resuspended material in the water column was the principal source of iron oxide deposited on pelage of seals.

Studies of bearded and ringed seals in Svalbard have, for the most part, been conducted in relatively deep fjord areas on the west coast of Spitsbergen where wind is unlikely to cause resuspension of bottom sediments. Our objectives were to perform element analyses of fur samples from bearded and ringed seals with and without rust-colored fur to find the reason for the discoloration, and investigate possible explanations for its occurrence.

* *Correspondent: lydersen@npolar.no*

FIG. 1.—Bearded seals (upper panels) and ringed seals (lower panels) from Svalbard, Norway, with rust-colored (left panels) and normal (right panels) pelage.

MATERIALS AND METHODS

Samples of pelage were collected from 4 seals shot for other purposes in Kongsfjorden (78°55′N, 12°30′W), Svalbard, Norway, during May 1997. Study animals included 2 bearded seals and 2 ringed seals, 1 of each species with and 1 without rust-colored pelage. Normally, the facial area is where the rust color is the most intense. However, samples of skin were not collected from this area because many species of seals, including ringed seals, excrete various odorous substances from this area during rut (Ryg et al. 1992), which may affect chemical analyses. Instead, a 10-cm^2 sample of skin with attached hair was taken from the ventral part of the neck and kept frozen until analyses.

Samples of skin were thawed for analyses, and about 1 cm^2 from each sample was transferred into an acid-cleaned glass bottle and leached with 0.5 N nitric acid (HNO_3) for 10 min. The leachate subsequently was analyzed for sodium using inductively coupled plasma emission spectroscopy. All other elements examined were analyzed using inductively coupled plasma mass spectroscopy (Elan 6000, Perkin Elmer, Norwalk, Connecticut) at the Norwegian Institute for Water Research, according to accredited procedures (Steinnes et al. 1993).

RESULTS AND DISCUSSION

Samples of fur were analyzed for 41 different elements (Table 1). High concentrations of sodium and magnesium primarily were due to their high concentrations in seawater. To exclude those and other sea-

TABLE 1.—Element analysis (μg/l) of samples of rust-colored and normal fur from bearded and ringed seals collected in Svalbard, Norway, during spring 1997. Concentration of elements in seawater (Weast 1990) also is included.

		Rust-colored pelage		Normal pelage		
Element	Symbol	Bearded	Ringed	Bearded	Ringed	Seawater
Aluminum	Al	408.00	444.00	94.00	44.00	10.00
Antimony	Sb	0.40	0.40	0.90	2.80	0.33
Arsenic	As	40.00	15.00	4.10	7.40	3.00
Barium	Ba	12.00	4.20	4.60	1.10	30.00
Beryllium	Be	0.30	0.20	<0.05	<0.05	0.00
Boron	B	306.00	301.00	540.00	745.00	4,600.00
Cadmium	Cd	6.40	6.60	16.00	21.00	0.11
Cerium	Ce	12.00	3.10	0.29	0.18	0.40
Cesium	Cs	0.20	0.80	0.92	0.49	0.50
Cobalt	Co	3.00	3.10	0.88	0.89	0.27
Copper	Cu	105.00	90.00	50.00	51.00	3.00
Dysprosium	Dy	1.30	0.36	0.03	0.03	
Erbium	Er	0.62	0.17	0.02	0.02	
Europium	Eu	0.42	0.13	0.01	0.02	
Gadolinium	Gd	1.70	0.51	0.04	0.04	
Gallium	Ga	0.21	0.19	0.13	0.06	0.03
Holmium	Ho	0.25	0.09	0.01	0.01	
Iron	Fe	35,000.00	6,900.00	1,010.00	1,190.00	10.00
Lanthanum	La	7.00	1.80	0.18	0.13	0.01
Lead	Pb	118.00	36.00	93.00	590.00	0.03
Lithium	Li	1.50	1.70	9.00	<5.00	180.00
Lutetium	Lu	0.10	0.05	0.00	0.01	
Magnesium	Mg	11,800.00	12,000.00	21,200.00	25,300.00	1,350.00
Manganese	Mn	74.00	36.00	11.00	7.80	2.00
Molybdenum	Mo	1.00	0.40	0.50	<0.50	10.00
Neodymium	Nd	7.00	1.90	0.19	0.13	
Nickel	Ni	39.00	36.00	61.00	51.00	5.40
Rubidium	Rb	12.00	12.00	29.00	19.00	120.00
Samarium	Sm	1.60	0.50	0.04	0.04	
Selenium	Se	3.50	2.20	8.70	4.50	0.09
Sodium	Na	57,400.00	43,500.00	110,000.00	154,000.00	10,500,000.00
Strontium	Sr	221.00	161.00	219.00	179.00	8,100.00
Terbium	Tb	0.24	0.09	0.01	0.01	
Tin	Sn	1.10	1.40	1.00	0.60	3.00
Titanium	Ti	25.00	25.00	28.00	24.00	1.00
Tungsten	W	0.30	0.20	<0.30	<0.30	0.10
Uranium	U	0.29	0.11	0.07	0.11	3.00
Vanadium	V	372.00	104.00	8.30	9.90	2.00
Ytterbium	Yb	0.43	0.13	0.00	0.02	
Yttrium	Y	6.10	1.60	0.24	0.23	0.30
Zinc	Zn	782.00	916.00	1,270.00	1,100.00	10.00

water sources, we used the ratio between sodium (assuming that seawater was the total source of this element) and the other elements in seawater (Table 1) to calculate the amount of each respective element in our analyses that had originated from seawater. That amount of each material was subtracted from total amounts found in our analyses of fur samples. After exclusion of the contribution of different elements from seawater itself, the element with the largest difference in concentration between samples of rust-colored and normal fur was iron for both species (Table 2). The 2 species of

TABLE 2.—Elements with the largest differences in concentration between rust-colored and normal fur that may be responsible for the discoloration of bearded and ringed seals collected in Svalbard, Norway, spring 1997.

Element	Δ rust-colored fur − normal fur (μg/l)	
	Bearded seals	Ringed seals
Arsenic	35.9	7.6
Manganese	63.0	28.2
Copper	55.0	39
Vanadium	363.7	94.1
Iron	33,990.0	5,710

seals haul out only on 1st-year sea ice in the study area; this substrate was assumed not to contribute to the acquisition of the rust-coloration.

Based on results from analyses of samples from bearded and ringed seals in Svalbard, it is reasonable to assume that iron oxide (Fe_2O_3) is the primary cause of coloration of the pelage, as was the case for harbor seals (Allen et al. 1993). Fresh precipitate of Fe_2O_3 normally is yellowish, but it changes successively to brown, red, and finally to black as the precipitate ages (Weast 1990). High concentrations of vanadium and manganese in colored pelage in seals from Svalbard (Table 2) also may contribute to the color. Vanadium oxide (V_2O_5) is red-orange, whereas manganese oxide (MnO_2) is dark brown to black. Vanadium and manganese are likely present in these forms in seawater. Precipitates of Fe_2O_3 commonly are positively charged and known to adsorb strongly to negatively charged clay particles, organic colloids, and other suspended solids (Wetzel 1975). These aggregates join to form a rapidly settling precipitate. Other metals may also coprecipitate. So, in addition to vanadium and manganese, other metals such as copper (Wetzel 1975) may contribute to the color.

Allen et al. (1993) suggested that resuspended sediments, particularly in wind-exposed, shallow-water areas, bring sufficient quantities of ferrous (Fe(II)) iron from sediments into the water column to serve as a principal source of the ferric oxide (Fe(III)) deposited on the pelage of seals. If this were the case, we would expect the entire body of all seals in the area to be stained red, especially for species such as harbor seals that haul out on a regular basis. We suggest that discoloration of fur actually is connected to feeding in soft bottom sediments, where seals put their head and sometimes their fore-flippers in direct contact with the sediment.

Sediments in fjords of western Svalbard contain high concentrations of various heavy metals, including iron (Sikora et al. 1996). In Kongsfjorden, large amounts of organic matter are produced in water masses during spring while the fiord is still covered by ice (Elverhøi et al. 1980). This organic matter is comprised of diatoms, larval bivalves and gastropods, copepods, and considerable amounts of amorphous organic matter that consists largely of algae tissue (Elverhøi et al. 1980). Thus, spring and early summer favor accumulation and subsequent formation of organic-rich borderlines called varves in sediments. Sedimentation and subsequent degradation of organic matter will cause significant lowering of the redox potential (Eh) to a level ($Eh < 100$ mV) where both Fe^{3+} and SO_4^{2-} will be reduced to Fe^{2+} and H_2S, respectively. Under these conditions, iron monosulfide (FeS) and iron disulfide (FeS_2) form. Sulfate reduction rarely is complete, and only small changes in redox potential may effect the $SO_4^{2-}:H_2S$ ratio. This is the reason why a distinct black line often occurs in sediments that are rich in organic matter. Iron monosulfide, which seems to be a predominantly iron-containing compound in the black organic varves of Kongsfjorden sediments, is likely the main cause of the rust-colored pelage in resident seals.

When seals feed on fauna that live in the sediment, such as many gastropods and bivalves, they probably use vibrissae to detect prey in a manner similar to that described for walruses (*Odobenus rosmarus*—Kastelein and Mosterd 1989). They likely dig with their fore-flippers or stick their heads into the sediment during retrieval of these sorts of prey organisms. During this process, they make direct contact with the sediment. We have observed bearded seals surfacing with their heads soiled with soft bottom sediments. The iron monosulfide in sediments oxidizes to Fe_2O_3 when Eh increases, as is the case when seals bring it up through the water column.

No systematic surveying has been conducted to quantify frequency of occurrence of rust-colored bearded and ringed seals in the Svalbard area. However, based on field notes from the past 5 years and opportunistic observations in the study area during the past 2 spring field seasons, >50% of bearded seals (115 of 212) and <1% of ringed seals (3 of 324) had rust-colored faces. The reason for the higher incidence of rust-colored bearded seals compared with ringed seals ($\chi^2 = 219$, $P < 0.05$) probably can be explained by differences in feeding habits. In the Svalbard area, as in other Arctic areas, bearded seals mainly prey on benthic food organisms, whereas ringed seals generally take more pelagic and ice-associated prey (Gjertz and Lydersen 1986; Hjelset et al. 1999; Lydersen et al. 1989; Weslawski et al. 1994). Many of the gastropods and bivalves commonly found in stomachs of bearded seal are soft-bottom species that live in the sediment. Our small sample could explain why the rust-colored bearded seal in this study had much higher concentration of iron compared with the ringed seal (Table 1). The difference in iron concentrations also could occur because bearded seals feed more often on soft-bottom areas than do ringed seals. Because iron oxides on pelage adhere to the surface of hair shafts (Allen et al. 1993), different physicochemical properties of hairs of the 2 species also could explain differences.

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