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Note

Discovery of a recent, natural whale fall on the continental slope off Anvers Island, western Antarctic Peninsula

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ABSTRACT

Whale falls provide a substantial, nutrient-rich resource for species in areas of the ocean that may otherwise be largely devoid of food. We report the discovery of a natural whale fall at 1430 m depth in the cold waters of the continental slope off the western Antarctic Peninsula. This is the highest-latitude whale fall reported to date. The section of the carcass we observed—the tail fluke—was more complete than any previously reported natural whale fall from the deep sea and in the early stages of decomposition. We estimate the entire cetacean to measure 5–8 m in length. The flesh remained almost intact on the carcass but the skin was missing from the entire section except for the end of the fluke, clearly exposing blubber and soft tissue. The absence of skin indicates rapid and Homogeneous loss. The dominant macrofauna present were crustaceans, including most prominently the lithodid crab *Paralomis birsteini*, and zoarcid fish typical of the 'mobile-scavenger' successional stage. The density of mobile macrofauna was greatest on the carcass and declined to background levels within 100 m, indicating that they were attracted to the whale fall. This whale fall offers an important opportunity to examine the decomposition of a carcass under deep-sea conditions at polar latitudes.

1. Introduction

When a whale carcass falls to the seafloor it delivers a sudden and enormous input of organic carbon. Such food falls constitute an important source of energy and nutrients to otherwise oligotrophic environments, which include large areas of the deep sea (Baco and Smith, 2003; Smith and Baco, 2003; Glover et al., 2010; Amon et al., 2013). The longevity of a whale fall may vary from less than 10 years in oxygen-rich environments to 50 years or more in oxygen-poor environments (Smith and Baco, 2003; Fujiwara et al., 2007; Glover et al., 2010; Lundsten et al., 2010b). During its lifetime, the food, habitat, and shelter that a whale fall provides attract a diverse and dense faunal assemblage that changes through succession over time. The species richness on a single whale fall can exceed 200 species across the various successional stages of decay; the diversity of associated taxa may include food-fall specialists, and species associated with hydrothermal-vent and cold-seep environments (Smith et al., 1989; Bennett et al., 1994; Baco and Smith, 2003; Smith and Baco, 2003; Lundsten et al., 2010a; Amon et al., 2013).

The decomposition of a whale fall varies substantially between carcasses and is affected by factors including carcass size, associated faunal assemblage, water depth and water temperature (Allison et al., 1991; Smith and Baco, 2003; Fujiwara et al., 2007; Lundsten et al., 2010b). Four successional stages have been proposed: (1) a 'mobile-scavenger' stage usually lasting approximately four months to two years, in which scavengers remove the soft tissue from the carcass; (2) an 'enrichment-opportunist' stage, also typically lasting months to years, in which opportunistic polychaetes and crustaceans densely colonize organically enriched sediments and exposed bones; (3) a 'sulfophilic' stage typically lasting decades, in which a species-rich, sulfur-loving assemblage thrives on the skeleton as sulfide is produced from the anaerobic breakdown of bone lipids; and (4) a 'reef' stage in which suspension feeders opportunistically settle on the remaining hard

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substrate after nutrients have been depleted (Smith et al., 1989; Smith and Baco, 2003; Goffredi et al., 2004; Lundsten et al., 2010a, 2010b). The presence and duration of each successional stage is case-dependent; under some conditions each stage can progress slowly, while under other conditions, the rate of decomposition can be so rapid that particular stages are short or absent (Smith, 2006; Goffredi et al., 2004; Braby et al., 2007; Lundsten et al., 2010a, 2010b).

Today, more than 850,000 whale carcasses are estimated to be scattered on the seafloor globally at various stages of decomposition (Smith and Baco, 2003). Despite their abundance, their discovery is rare and only six natural whale falls have been studied *in situ* (Table 1). Of these, five were discovered in the sulphofilic stage (Smith et al., 1989, Fujioka et al., 1993; Smith and Baco, 2003; Lundsten et al., 2010a; Amon et al., 2013) and one predominantly in the enrichment-opportunist stage (Goffredi et al., 2004).

In this paper, we report the discovery of a seventh natural whale fall, located off the western Antarctic Peninsula (WAP), close to the United States Antarctic Program's Palmer Station. We describe the condition of this largely intact carcass and the associated faunal assemblage. The carcass is the southernmost (and highest-latitude) natural whale fall reported to date and is also in an earlier stage of decomposition than any other natural whale fall previously described.

2. Methods and study site

The whale fall was discovered on the continental slope off Anvers Island, Antarctica, on 24 November 2013, during cruise NBP13-10 of the *RV Nathaniel B. Palmer*. The carcass is located at 64°07.09′S, 66°34.94′W, lying in a north–south orientation perpendicular to the shallow gradient of the continental slope at a depth of 1430 m (Fig. 1). Water temperature at the observation site was 0.82 °C. In this area the continental slope is relatively uniform and lacks the gullies caused by post-glacial ice retreat, which characterize some shelf areas along the WAP. The substrate consists of fine sediment scattered with occasional glacial dropstones (Fig. 2a).

Images of the whale fall were obtained using SeaSled, a towed-camera vehicle (see Singh et al., 2007; Eastman et al., 2013 for descriptions) during photography of a 10-km transect of the seafloor running north-to-south along the continental slope in a depth range of 1300–1470 m. Images were taken every 6 s, providing an imaged corridor 2 m wide along the sea floor. SeaSled was equipped with two cameras (both 1.4-megapixel, or 1360 × 1024 pixels), two strobes (150 w-s), an acoustic-doppler current profiler (ADCP; 1200 kHz Teledyne RD Instruments), a Paroscientific depth sensor, and a CTD (Seabird SBE-49 Fast CAT 16-Hz CTD).

All mobile macrofauna visible on the whale fall, and 10 m north and south of its location along the imaged corridor, were recorded and identified to the lowest possible taxonomic level. Densities were established for macrofauna in direct contact with the carcass, within 2 m of the carcass, and 2–10 m from the carcass. Fish and crustaceans were also recorded at 50-m intervals, extending 300 m north and south of the whale fall, in order to calculate densities.

3. Results

3.1. Description of carcass

The image mosaic shows a 2.25-m tail-section of a small cetacean (Fig. 2a). The section observed appears to be roughly one third of the whole carcass, and from this we estimate the entire animal to measure 5–8 m in length. The carcass was in the early stages of decomposition and in the 'mobile-scavenger' successional stage. The skin was missing from the entire section, clearly exposing the blubber and soft tissue, except at the very end of the fluke (Figs. 2a and d). The flesh remained almost intact with the exception of the fluke, and the right side of the tail-section where the tissue appears to have been torn into strips (Fig. 2a). Small pieces of flesh also appeared to be scattered on the sediment surrounding the carcass.

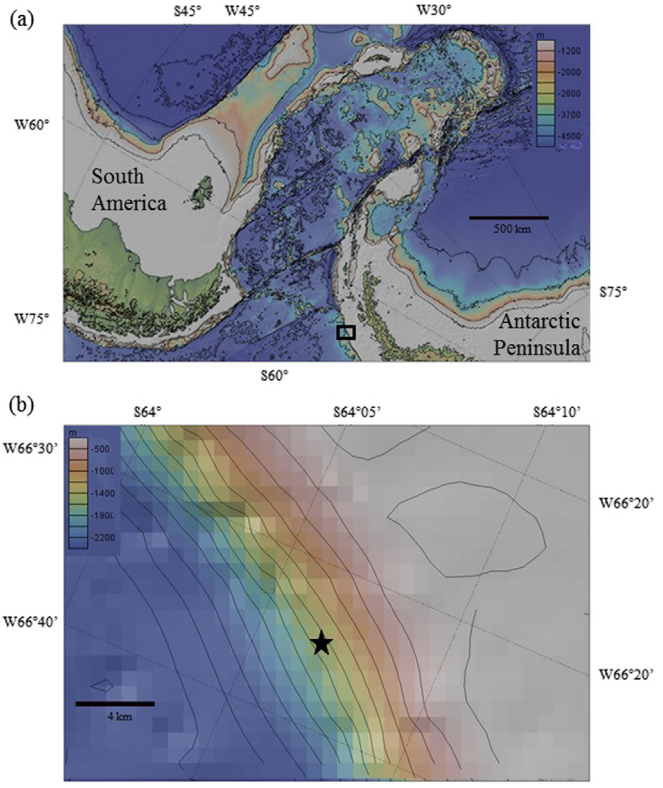

Fig. 1. Location of whale fall. (a) Bathymetry of the surrounding region. Contour lines are 1000 m. (b) Local bathymetry of the area surrounding the whale fall. Exact location of whale fall denoted by ★. Contour lines are 200 m. Location of (b) is marked in (a) by open black rectangle. Bathymetry constructed in GeoMapApp. Bathymetry data from Smith and Sandwell (1997).

Table 1
Natural whale falls reported in literature. NR indicates information not reported in study.

Depth (m)	Geographic region	Latitude	Longitude	Temperature	Dominant stage at discovery	Estimated age at discovery	Reference
1444	Southern Ocean	59°41′ S	28°21′ W	NR	Sulfophilic	4–64 yr	Amon et al. (2013)
960	Northeast Pacific Ocean	33°20′ N	119°59′ W	NR	Sulfophilic	5–15 yr	Smith and Baco (2003)
1240	Northeast Pacific Ocean	33°12′ N	118°30′ W	4.1 °C	Sulfophilic	3–34 yr	Smith et al. (1989)
1288	Northeast Pacific Ocean	48°40′ N	126°50′ W	NR	Sulfophilic	< 10 yr	Lundsten et al. (2010a)
4037	Northwestern Pacific Ocean	30°55′ N	141°49′ E	NR	Sulfophilic	NR	Fujioka et al. (1993)
2891	Northeast Pacific Ocean	36°36′ N	122°26′ W	1.67 °C	Enrichment-opportunist	< 1 yr	Goffredi et al. (2004)
1430	**Southern Ocean**	**64°07′ S**	**66°35′ W**	**0.8 °C**	**Mobile-scavenger**	**< 2 month**	**Present study**