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NOTE

Seal-mounted cameras detect invertebrate fauna on the underside of an Antarctic ice shelf

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ABSTRACT: While modern sampling techniques, such as autonomous underwater vehicles, are increasing our knowledge of the fauna beneath Antarctic sea ice of only a few meters in depth, greater sampling difficulties mean that little is known about the marine life underneath Antarctic ice shelves over 100 m thick. In this study, we present underwater images showing the underside of an Antarctic ice shelf covered by aggregated invertebrate communities, most likely cnidarians and isopods. These images, taken at an average depth of 145 m, were obtained with a digital still camera system attached to Weddell seals *Leptonychotes weddellii* foraging just beneath the ice shelf. Our observations indicate that, similar to the sea floor, ice shelves serve as an important habitat for a remarkable amount of marine invertebrate fauna in Antarctica.

KEY WORDS: Ice shelf · Fauna · Antarctica · Camera · Diving · Weddell seal · *Leptonychotes weddellii*

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INTRODUCTION

The under-ice environment has long been considered to be an important habitat for marine organisms, but sampling difficulties have previously prevented their direct observation. A recent study using an autonomous underwater vehicle (AUV) revealed that Antarctic krill *Euphausia superba* are concentrated under Antarctic sea ice that is a few meters thick (Brierley et al. 2002). However, since it is much more difficult to make AUV observations beneath the ice shelves, which can be more than a hundred meters thick, little is known about the marine life there.

The recent development of image recording systems that can be attached to animals has allowed direct observations of diving animals' foraging behavior and of the surrounding environment (Davis et al. 1999, 2003, Ponganis et al. 2000, Hooker et al. 2002, Sato et al. 2002, Watanabe et al. 2003, 2004, Mitani et al. 2004, Takahashi et al. 2004). This development has lead to the concept of using marine predators as autonomous samplers for investigating marine organisms otherwise difficult to observe in their natural environment (Fuiman et al. 2002). We deployed a digital camera system on Weddell seals *Leptonychotes weddellii* inhabiting an inlet surrounded by the Riiser Larsen Ice Shelf to obtain images of marine organisms that were encountered by the seals during their dives.

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MATERIALS AND METHODS

Field experiments were conducted from December 4 2003 to January 3 2004 at Drescher Inlet, Antarctica (72.87° S, 19.43° W). The inlet is a crack 25 km long and up to 2 km wide in the Riiser Larsen Ice Shelf. The depth of the ice shelf surrounding the inlet ranges from 80 m at the mouth to 160 m in the inner section of the inlet, and the water depth inside the inlet ranges from 380 to 520 m. Sea ice still covered the inlet during our investigations in the late austral spring.

We attached a camera system (DSL-1000DV, Little Leonardo) to 4 adult female Weddell seals, using the immobilization and deployment techniques described in Bornemann et al. (1998). The camera system consisted of 2 cylindrical housings, each 230 mm in length and 52 mm in diameter. One housing contained a flash (guide number 32) and the other a color digital still camera (angle of view 45°, effective resolution 510 × 492 pixels), a depth sensor (maximum depth of 1000 m, resolution of 1 m, absolute accuracy of ±5 m) and an onboard microcomputer with 64 MB flash memory. It provided depth data at 1 s intervals, and underwater images at 30 s intervals below a pressure-sensed depth threshold of 5 m. It weighed 3.4 kg in air (approximately 1% of a seal's body mass) and 1.6 kg in water (for further details, see Watanabe et al. 2003).

A previous study on Weddell seals' diving behavior at Drescher Inlet showed that a mode exists in the distribution of maximum dive depth for dives ≤50 m (Fig. 2 in Plötz et al. 2001). We therefore assumed that the majority of foraging activity occurs during dives with a maximum depth >50 m and thus considered all dives >50 m to be foraging dives. The criterion of 50 m was also used in Sato et al. (2002). Means (±1 SD) are reported.

RESULTS

A total of 66 dives with a maximum depth >50 m were logged for the 4 seals, during recording periods ranging from 8.4 to 38.6 h. During the dives, 2282 underwater images were obtained. The images allowed us to classify all the 66 dives into 3 groups: 12 dives (18.2%) were at the underside of the ice shelf (mean maximum dive depth 152.9 ± 23.6 m) (Fig. 1), 19 dives (28.8%) were at the sea bottom (mean maximum dive depth 413.4 ± 13.4 m) and 35 dives (53.9%) were in the pelagial (mean maximum dive depth 117.0 ± 47.4 m). Of the 4 Weddell seals, 2 made dives just below the ice shelf; for one seal these represented 3 out of a total of 23 deep dives (>50 m) (13.0%), for the other 9 out of 15 (60.0%). Images (235) taken at a mean depth of 145 ± 18 m during these particular dives showed the surface structure underneath the ice shelf. Of these 235 images, 203 (86.4%) showed patchy aggregations of invertebrate communities, most likely cnidarians and isopods (Fig. 1b,c,d), while the rest of the images (13.6%) showed no organisms. A total of 29 images (12.3%) showed the seals stretching their necks towards the ice shelf surface, possibly to catch prey (Fig. 1e).

DISCUSSION

To our knowledge, this is the first direct observation of invertebrate fauna on the underside of an Antarctic ice shelf. While rich seafloor fauna in Antarctica have been previously reported (Arntz et al. 1994), our images indicate that Antarctic ice shelves also serve as a substrate for a remarkable amount of invertebrate fauna. Two of the 4 seals dived and foraged just below the ice shelf, suggesting that the area below the ice is also an important habitat for fishes such as *Pleuragramma antarcticum*, the predominant prey of Weddell seals in the study area (Plötz et al. 2001). This is supported by Fuiman et al. (2002), who observed *P. antarcticum* under an ice shelf in McMurdo Sound, Antarctica, by means of a video camera attached to Weddell seals.

Our new approach of utilizing diving animals to explore otherwise inaccessible regions, such as the underside of ice shelves, is currently limited to descriptive use, primarily because of the relatively low camera resolution (0.25 mega pixels). In addition to capturing higher resolution images, simultaneous ambient data (e.g. salinity, temperature; Hooker & Boyd 2003) and more precise information on seals' behavior (e.g. swim speed, 3D dive paths; Davis et al. 2003, Mitani et al. 2003, 2004) should allow a more quantitative assessment of the sub-ice shelf invertebrate fauna and the surrounding environment in future studies.

Ice shelves fringe most of the Antarctic continent and constitute 11% of the total area of Antarctica (Swithinbank 1988). Gradual retreat of ice shelves, punctuated by periods of rapid collapse in response to the regional atmospheric warming over the last few decades (Doake & Vaughan 1991, Rott et al. 1996, Vaughan & Doake 1996, Shepherd et al. 2003), could reduce the number and diversity of animals inhabiting these icy substrates and, consequently, may influence the Antarctic marine ecosystem. Therefore, observations such as those made in this study are important in helping to understand the ecology of this unusual ecosystem.

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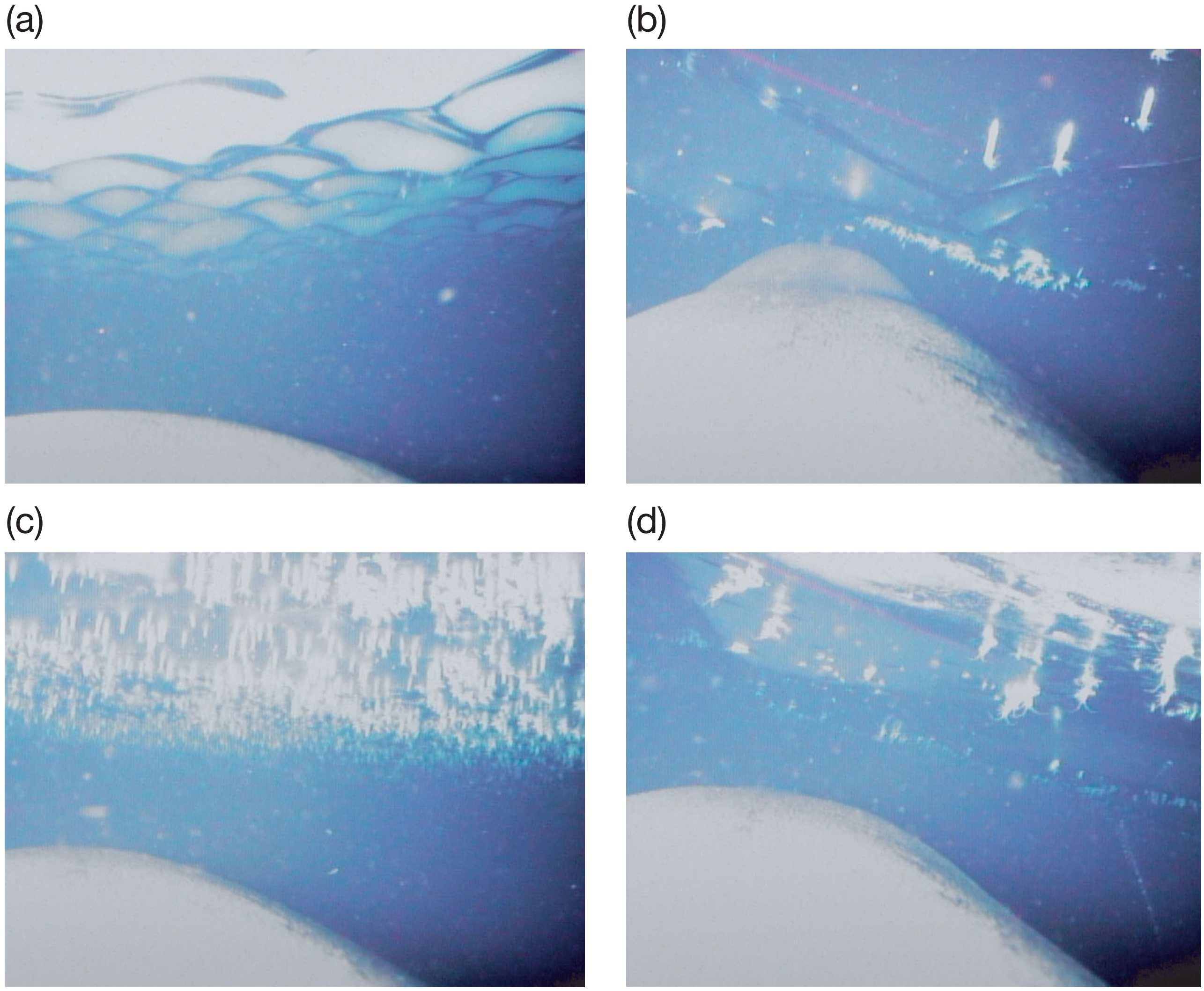

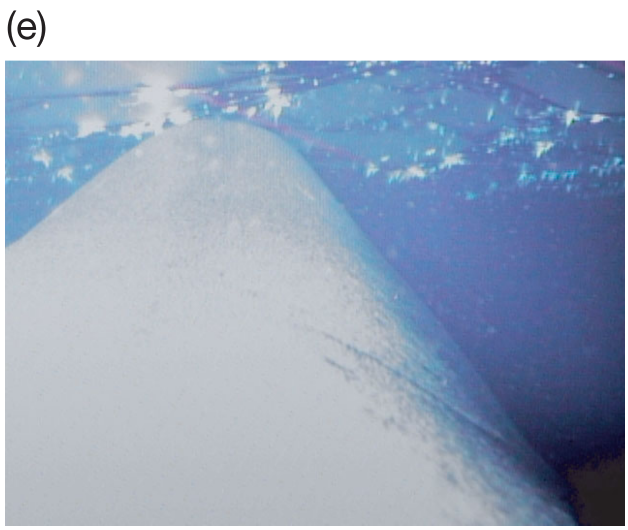

Fig. 1. Images taken with the seal borne, digital still camera system, showing the underwater surface-structure of an Antarctic ice shelf (looking forward over the seal's back). (a) Surface of the ice shelf edge, along which the seal was descending. Depth: 97 m. (b) Invertebrates on the underside of the ice shelf, possibly cnidarians with tubular bodies ending in a crown of tentacles. Depth: 150 m. (c) Dense aggregation of the invertebrates shown in (b). Depth: 148 m. (d) Crustaceans, possibly isopods (*Antarcturus* sp.), hanging down from the ice shelf, with long paired antennae and what appear to be legs in filter-feeding mode. Depth: 161 m. (e) A seal stretching its neck towards the ice shelf, possibly to capture prey. Depth: 151 m

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