



A comparative assessment of fatty acids in Antarctic organisms from the Ross Sea: Occurrence and distribution



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HIGHLIGHTS

- SFAs, PUFAs and MUFAs differed in the species and tissues.
- Unsaturated fatty acids prevailed (>74%) in fish due to extreme cold conditions.
- C22:6n3 was highest in fish and penguin tissues respect to invertebrates.
- EPA was high in all organisms and DHA was low in invertebrates.
- No correlations were found between FAMES and PCBs, PBDEs, DDTs.

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ABSTRACT

Lipids are important energy source and structural component for cellular membranes and tissues, involved in the osmoregulation and immune response, and are very important in the bioaccumulation of lipophilic chemicals too. Among lipids, fatty acids (FAs) give information on diet of organisms, since FA of consumer lipids can be related to those of diet; plants and animals vary in their FA signature because of differences in the synthesis of lipids.

In this study, lipid content and FA composition in tissues of Antarctic organisms from the Ross Sea (*Odontaster validus*, *Sterechinus neumayeri*, *Chionodraco hamatus*, *Trematomus bernacchii*, *Pygoscelis adèlieae*) were assessed. Differences in lipid characterisation were found between both species and tissues. The lipid content was highest in *C. hamatus* liver (3.51%), and lowest in *T. bernacchii* muscle (0.16%). The polyunsaturated fatty acids (PUFAs) prevailed in the *C. hamatus* muscle, and among FAs, the docosahexaenoic acid (DHA; C22:6n3) was the most abundant (20.93%). The C22:6n3 accumulated more in fish and penguin tissues than in invertebrate species. The high contribution of unsaturated fatty acids (>74%) in fish tissues was related to the low environmental temperature. The fatty acid profile and the essential fatty acids occurrence were also discussed in the light of physiological adaptations and feeding habits of organisms; the relationships with contaminant bioaccumulation were also assessed.

To the best of our knowledge, this is the first report of fatty acid composition and fingerprint in a Ross Sea trophic web and their correlation with contaminant concentration.

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1. Introduction

Antarctica is an extreme environment, often described as the coldest, driest and windiest continent on the Earth. It is encircled by the Southern Ocean, that is one of the largest, oldest and coldest deep-water marine system. Ice covers the sea for much of the year; waters have temperatures near the freezing point (about $-1.9\text{ }^{\circ}\text{C}$)

and in many areas of the ocean they never exceed $0\text{ }^{\circ}\text{C}$ throughout the year (Bargagli, 2005). The Southern Ocean is characterized by extremely low temperatures, a strong seasonal light regime creating monocyclic primary productivity, minimal thermal stratification, and only small seasonal variations in salinity and inorganic nitrate concentrations. Organisms inhabiting seas in Antarctic region, where they are constantly exposed to these extreme conditions, have developed special physiological and biochemical adaptations to survive in this area.

Lipids are important for organisms growth because they are concentrated source of energy and are involved in many

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physiological function (Chapkin, 1992; Hwang, 1992). They are also important as energy reserves and function also as structural component for cellular membrane production. In addition, certain lipids can serve as vitamins, hormones, pigments and as precursors to essential substances such as eicosanoids, which function in internal processes such as osmoregulation and immune response (Hwang, 1992). Given the importance of lipid as energy source and biomembrane components, lipid composition in Antarctic organisms is affected by extreme conditions, especially low temperatures, where metabolic rates may be reduced and membrane structure and function altered (Parrish et al., 1997). Lipids provide long-term energy reserves necessary for survival during overwintering by many Antarctic species. For example, Antarctic phytoplankton communities incorporate as much as 80% of fixed carbon into lipid compared to 20% lipid in temperate communities (Smith and Morris, 1980). The fatty acid (FAs) constituents of lipids also change in response to temperature, with lower temperature leading to an increase in fatty acid unsaturation and alteration of carbon chain length (Lewis, 1962; Farkas and Herodek, 1964).

Previous studies clarified that great evolutionary changes have occurred in several enzymatic and structural proteins allowing Antarctic fish to sustain metabolic activities substantially comparable to those found in fish with higher cell temperature (Somero and Hochachka, 1976; Detrich, 1991). At low temperatures, the rates of molecular diffusion and enzyme reactions can slow down considerably, so organisms exhibit a diversity in lipid structures to fashion membranes to prevailing ambient temperatures in such a manner that they become more fluid in a cold-acclimatized than in a warm-acclimatized state (Carey and Hazel, 1989; Gibbs and Somero, 1990). Higher amounts of unsaturated phospholipid classes increase the fluidity and the functionality of biomembrane. Moreover, higher proportions of polyunsaturated fatty acids (PUFAs) as well as alterations in the composition of gangliosides may contribute to a proper functioning of the nervous system and brain at low temperatures (Cossins, 1994).

Moreover, Antarctic fish produce freezing-point depressing molecule (antifreeze molecules), either peptides or glycopeptides, which are put in the body fluids and can protect the organism from ice crystal formation (DeVries, 1988). The concentration and composition of antifreeze compounds depend on the ambient water temperature, the depth of the habitat, level of activity and mode of life of specimen. In addition, haematocrit of the blood is either reduced or, as in Channichthyidae, erythrocytes and haemoglobin are absent. In this way they can counteract the temperature-induced viscosity increase of the blood and facilitate the cardiac work (Hemmingsen and Douglas, 1970; Wells et al., 1980). Moreover, the more pelagic notothenioid species tend to reduce heavy components, such as bones and scales, and to accumulate lipids (Eastman, 1990). These modifications are important adaptations towards neutral buoyancy since all notothenioids lack swim-bladder. Lipids deposits may be subcutaneous, muscular,

hepatic or mesenteric; only the first two locations are extensively utilized in the neutrally buoyant species and in notothenioids store lipids primarily in the form of triacylglycerols. Unlike some other species, notothenioids not store great amounts of wax esters or other less dense lipids, because lipids in these organisms are important also for the gonad development and as energy reserves (Eastman, 1993). In contrast to pelagic species, benthic invertebrates usually do not have extensive lipid stores and tend to have a sluggish life of low-energy throughput (Greave et al., 1997).

The aim of this study was to determine and compare the lipid content and the fatty acid composition in tissues of the following Antarctic organisms: two species of echinoderms, the *Odontaster validus* and *Sterechninus neumayeri*; two species of fish, the *Chionodraco hamatus* and *Trematomus bernacchii*, and one seabird, the *Pygoscelis adeliae*. These species are representative of different trophic levels of a Ross Sea coastal environment, occupy different ecological niches in the Antarctic marine food web, and show different habits. Implication of their lipid biochemistry with respect to feeding, buoyancy and energetics are discussed, together with other factors that may influence the biochemical composition of organism lipids. Understanding the structure and functioning of marine ecosystems requires information on the trophic relationships between the key species. Because of their great variety and high levels, fatty acids would appear to be particularly suitable as trophic tracers in marine organisms (Sargent, 1976; Iverson, 1993). In fact, fatty acids analysis could yield information on diet and prey, since fatty acids of consumer lipids can be related to those of diet, and plants and animals differ in their fatty acid-signature because of differences in their lipid-synthesis pathways (Sargent, 1976).

The evidence of a relationship between some lipids, in particular the mono-unsaturated and n-3 poly-unsaturated fatty acids (MUFAs and PUFAs) and the bioaccumulation of lipophilic contaminants, was already reported for humans (AMAP, 1998; Deutch et al., 2007). Here the correlation between fatty acid classes and the bioaccumulation of certain contaminants was calculated in order to assess if the content of lipophilic contaminants may be associated with the amount of FAMES in the studied species.

To the best of our knowledge, this is the first report of fatty acid composition and fingerprint in a Ross Sea trophic web and their correlation with contaminant concentration.

2. Materials and methods

2.1. Collection of samples

During the XX Italian Antarctic Expedition (January–February 2005) some species of Antarctic organisms were collected in the Ross Sea, south of the Italian Mario Zucchelli scientific station (74°42′00″S 164°08′40″E), inside the Antarctic Specially Protected Area (ASP) No. 161, Terra Nova Bay (Antarctica) (Fig. 1). In particular, they were two species of echinoderms: *Odontaster validus*

Table 1
Available biometric information of organisms.

	site	n	length (cm)	height (cm)	wt (g)
<i>Sterechninus neumayeri</i>	N of ASPA	3	3.35 ± 0.27 (3–3.6)	1.76 ± 0.16 (1.4–1.9)	6.7 ± 3.38 (4.4–10.6)
	ASPA	12	4.05 ± 0.92 (2.5–6.3)	2 ± 0.51 (1.1–3.1)	9.85 ± 4.26 (3.5–14.8)
	S of ASPA	9	3.74 ± 0.76 (2.3–5.2)	1.95 ± 0.53 (1.1–3)	5.88 ± 3.13 (1.4–10.83)
<i>Odontaster validus</i>	N of ASPA	5	2.97 ± 0.26 (2.75–3.4)		7.64 ± 1.61 (5.7–9.7)
	ASPA	10	4.6 ± 0.47 (3.95–5.3)		23.47 ± 7.17 (16.6–38)
	S of ASPA	15	4.09 ± 0.46 (3.1–4.7)		15.92 ± 4.53 (10.5–25.4)
<i>Chionodraco hamatus</i>	N of ASPA	15	38.17 ± 2.77 (34–43)	452.06 ± 38.167 (280–681)	
	ASPA	6	35.08 ± 1.74 (33–38)	405.33 ± 95.44 (301–582)	
	S of ASPA	6	34.92 ± 1.62 (33–37.5)	339.83 ± 50.32 (282–399)	
<i>Trematomus bernacchii</i>	N of ASPA	6	28.75 ± 8.63 (22–41)	246.67 ± 108.61 (135–390)	
<i>Pygoscelis adeliae</i>	N of ASPA	1			

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