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# IRON ORE PARTICLES ON FOUR SEAWEED SPECIES FROM CAMBURI BEACH (ESPÍRITO SANTO STATE, BRAZIL)*

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## ABSTRACT

The present study estimated the iron-ore concentration found on four species of seaweed. The species tested grow on a site heavily contaminated by this ore, in the city of Vitória, state of Espírito Santo, Brazil. Under natural conditions, the iron ore reached a temperature 5.0ºC higher than the sand on a sunny day. All the species had iron ore adhered to their fronds. *Udotea cyathiformis* was the species with the highest iron-ore concentration varing from 0.07 to 0.90 g wet weight, followed by *Lobophora variegata* (from 0.07 to 0.62 g wet weight), *Padina gymnospora* (from 0.08 to 0.55 g wet weight) and *Ulva fasciata* (from 0.05 to 0.25 g wet weight). Even after four changes of water over a 12-hour period, the fronds still had particles adhered to their outside cell wall. All the species showed similar tendencies to release the iron, with the highest percentage of particles (40 to 60%) released in the first change of water.

## RESUMO

Minério de ferro particulado sobre quatro macroalgas da Praia de Camburi (Estado do Espírito Santo-Brasil). O presente trabalho determinou a concentração de minério de ferro presente em quatro macroalgas. As espécies testadas ocorrem em um local extremamente contaminado por este particulado, na cidade de Vitória, Estado do Espírito Santo, Brasil. Sob condições naturais, o minério de ferro alcançou um temperatura de até 5,0ºC acima da temperatura da areia em um dia ensolarado.Todas as espécies estudadas apresentavam minério em suas paredes externas. A espécie *Udotea cyathiformis* apresentou a maior concentração de minério em sua fronde variando de 0,07 a 0,90 g massa úmida, seguida por *Lobophora variegata* (de 0,07 a 0,62 g massa úmida), *Padina gymnospora* (de 0,08 a 0,55 g massa úmida) e *Ulva fasciata* (de 0,05 a 0,25 g massa úmida). Mesmo após sucessivas trocas de água, as frondes ainda apresentavam partículas aderidas às suas paredes celulares externas. As espécies apresentaram a mesma tendência de liberação de minério, sendo a maior percentagem do particulado liberada na primeira troca de água (40 a 60%).

Key words: Macroalgae, Iron ore, Camburi Beach.
Palavras chave: Macroalgas, Minério de ferro, Praia de Camburi.

## INTRODUCTION

For over 20 years, an iron-ore processing complex discharged the water used during the pelleting process onto Camburi Beach, which is located in the inner part of Espírito Santo Bay. As a result, tons of iron in the form of "Pellet Synter Fines" (hematite) accumulated on the beach and on the bottom of the bay. Discharge was halted in 1991, when settling ponds began to operate.

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Coating of seaweeds by particulate matter of different origins and sizes (Burrows & Pybus, 1971; Devinny & Volse, 1978), including iron-ore dust (Boney, 1980a; Nassar *et al.*, 2002) can affect the survival rate and the growth of seaweeds, especially during the early stages of development.

Even though iron ore is not toxic in seawater, because it occurs in its reduced form (Boney, 1978), it can damage organisms because of its physical properties. Iron ore can change the sand temperature up to 50ºC during a sunny day (Mac Lachlan, 1977). Eramus & De Villiers (1982), studying intertidal animals, observed that iron-ore dust affects the heat absorption and the reflecting characteristics of the surfaces of the animals, thus decreasing their environmental fitness on rocky shores. The development of larvae and eggs from marine organisms can be affected when covered by particulate matter (Bamber, 1980; Kline & Stekoll, 2001). Also, different chains in the food web could be affected, because herbivores such as fish and invertebrates may find it hard to feed on seaweeds covered by this particulate matter (Burrows & Pybus, 1971; Moss *et al.,* 1973).

The covering of fronds by iron ore affects the photosynthetic performance under low irradiance of *S. vulgare* C. Agardh*, U. lactuca* Delile*, Padina gymnospora* (Küetz.) Sond*., Asparagopsis taxiformis* (Delile) Trevis and *Galaxaura marginata* (J. Ellis & Sol.) J. V. Lamour (Nassar & Yoneshigue-Valentin, 2005). The ore also affects the development of *Sargassum vulgare* embryos and germlings, although no visible influence was demonstrated on gamete discharge and fertilization (Nassar *et al*., 2002).

Depending on the organization of their thalli, seaweeds tend to retain significant amounts of iron ore, even after many hours suspended in clean seawater (Boney, 1978; Wong *et al*., 1979; Nassar & Yoneshigue-Valentin, 2005).

The goal of this investigation was to estimate the concentration of iron ore released from the frond surfaces of four, foliaceous seaweeds: *Ulva lactuca* Delile, *Padina gymnospora* (Küetz.) Sond., *Lobophora variegata* (Lamouroux) Womersley ex E.C. Oliveira and *Udotea cyathiformis* Decne., found at Camburi Beach, a location highly contaminated by this ore.

## Material and Methods

Four species with different internal morphology but similar, expanded fronds were selected (Joly, 1965). The selected species have high biomasses at Camburi Beach (20º16`S and 40º15`W), state of Espírito Santo (Mitchell *et al.,* 1990):

- *Udotea cyathiformis* (thallus formed by calcified filaments, terete stalk and a funnel-shaped flabellum);
- *Ulva fasciata* (foliaceous ribbon-like thallus);
- *Padina gymnospora* (fanlike blades with curved apical margin, moderately calcified) and
- *Lobophora variegata* (fanlike blades without curved apical margin, not calcified).

The species were distributed in patches over an area of 500 $m^2$. Twenty replicates were randomly collected for each species, in different patches, in March 2001. All samples were collected by hand in the shallow subtidal zone (50 cm depth), and were individually bagged and frozen. In the laboratory, each sample was placed in a conical flask (250 mL) with 100 mL of filtered seawater (Millipore, 0.45 µm pore size).

The samples were kept in an orbital shaker for 12 hours at constant speed. Every three hours, the seaweeds were transferred to flasks with clean seawater (adapted from Boney, 1978). The water loaded with ore was filtered through a previously weighed, quantitative paper filter (Whatman 1). Each filter was inspected under a stereoscopic microscope, and large particles of shell fragments or sand retained with the iron ore were removed. The filters were then dried and weighed. The difference between the final and initial weights was considered as the amount of iron ore released into the water by the fronds.

The temperatures of the iron ore and fine sand samples were compared for three hours on a sunny day (10 replicates). Temperature was estimated with a mercury thermometer (0 to 100 $^{o}$C).

The statistical significance of the differences of iron-ore concentration between the species and changes of water were tested by the Kruskal-Wallis test, because the data did not show a normal distribution. One-way Anova tested the difference between sand and iron-ore temperature.

## Results

All the species collected on Camburi Beach had iron ore adhered to their fronds. *Udotea cyathiformis* was the species with the highest iron-ore concentration varing from 0.07 to 0.90 g wet weight, followed by *Lobophora variegata* (from 0.07 to 0.62 g wet weight), *Padina gymnospora* (from 0.08 to 0.55 g wet weight) and *Ulva fasciata* (from 0.05 to 0.25 g wet weight). There was no significant difference between the iron ore released by the four species ($H = 0.93$; $p = 0.62$).

The filaments of *U. cyathiformis* tend to form a cup-shaped frond, which is extremely favorable to deposition of particles, as was easily observed during the sampling and laboratory procedures. On *U. lactuca*, the particles tend to accumulate on the undulations of the frond, and on *P. gymnospora* they are imprisoned by the mucilage and $CaO_3$ impregnation. In the case of *L. variegata*, the iron was observed mostly on the portions adhered to the substrate.

Figure 1 demonstrates that when in contact with clean seawater, most of the iron ore, from 40.0 to 60.0 %, was released in the first change of water, with smaller amounts released in the subsequent changes.

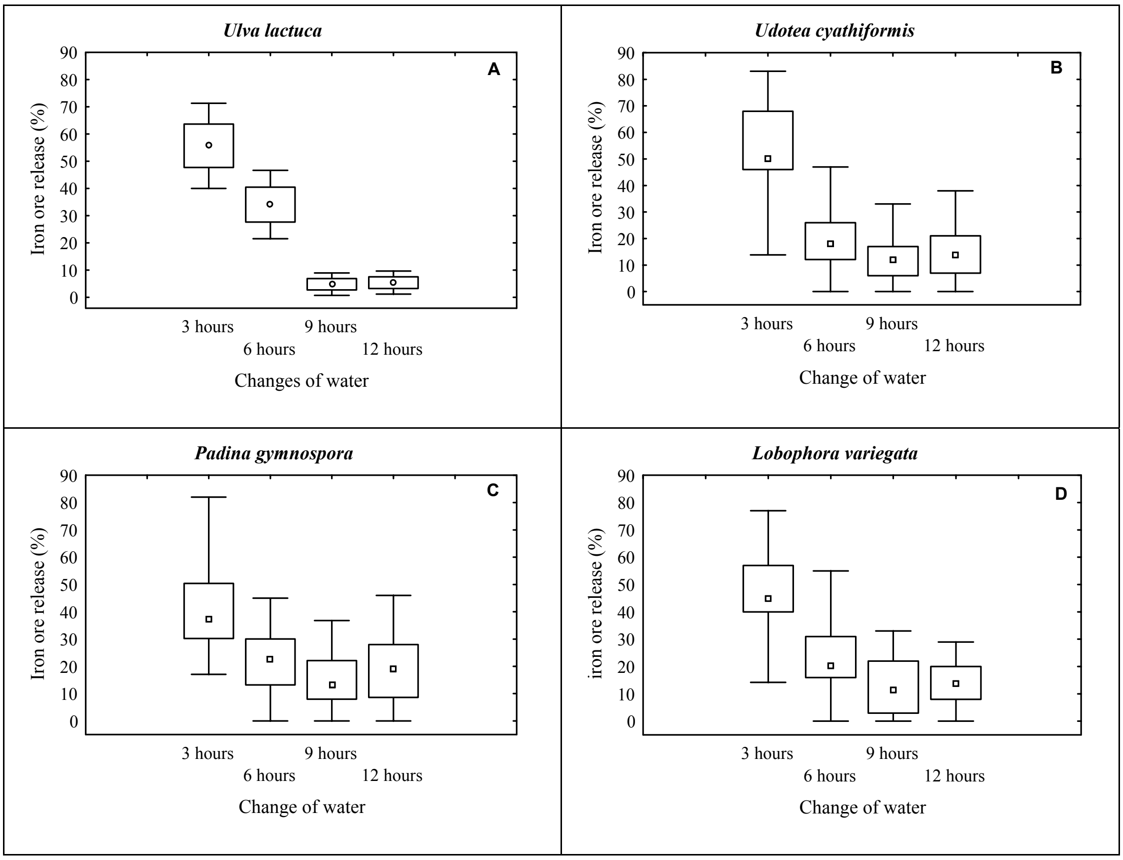


Fig. 1. Percentage of iron ore released after consecutive changes of water. A. *Ulva lactuca*. B. *Udotea cyathifomis*. C. *Padina gymnospora*. D. *Lobophora variegata*. (Vertical lines = reange of measurements; central box = inter-quartile ranges; central horizontal circles = median values).

The comparison between the percentage of iron released in each change did not show significant differences between the species: first change ($H = 7.41$; $p = 0.06$), second change ($H = 2.43$; $p = 0.29$), third change ($H = 0.92$; $p = 0.63$) and fourth change ($H = 0.92$; $p = 0.63$). The lack of difference indicates that all the species have a similar tendency to release the iron ore during the 12 hours that they were kept in filtered seawater.

The iron ore when exposed to the sun at air temperatures of 36.7 ± 3.8°C (mean ± standard deviation) reached 45.1 ± 9.4°C, and the sand reached 41.6 ± 4.0°C during the same period of time. The difference between the values was significant ($F = 16.50$, $P < 0.05$).

## Discussion

Even after 12 hours in clean water, some iron still adhered to the fronds, confirming the observation of Wong *et al*. (1977) about the difficulty of obtaining species free of iron particles at locations where this mineral is abundant. Tissue compromised by iron-ore particles can affect studies of heavy metals. Nassar *et al*. (2003) found on *Padina gymnospora* from Camburi Beach, a direct relationship between heavy-metal content and the amount of iron particles adhered to the fronds, especially iron, aluminum and manganese.

The single observation of the iron temperature under natural conditions indicated a difference of nearly 10.0 °C from the air. The temperature of the iron was about 5.0 °C higher than that the sand. Algae from tropical areas can tolerate wide temperature oscillations (Díaz-Pifferer, 1967), but it is possible that the increase of substrate temperature due to the ore also increases the desiccation of the fronds during air exposure, affecting the photosynthesis of the algae (Dring & Brown, 1982).

Even though it was not possible to obtain fronds totally free of the ore, the ore tended to be released when the fronds were exposed to clean water. In Espírito Santo Bay, part of the seabed is covered by a thick layer of iron ore, which is frequently suspended and redeposited over the benthic organisms by waves, storms or tidal movements (personal observation). Note that the iron-ore values mentioned here, correspond to the iron released by the seaweed fronds only. The iron located in the substrate where the algae were fixed was not taken into account; for instance, the dense basal mass of rhizoids of *U. cyathiformis* was buried deep into the iron ore itself.

Some algae, eventually, tolerate being covered and uncovered by natural sediments (Gibbons, 1988). The timing of this cycle is probably an important factor in the composition of the regional flora. Species must have features that provide some advantage in this kind of environment, such as apical growth and a basal portion adapted to resist burying and abrasion (Stewart, 1983). Therefore, it was not unexpected to find some species thriving at Camburi Beach.

Boney (1980b) observed a seasonal pattern in the deposition of particulate matter (colliery) over tufts of *Audouinella purpurea* (Lightf.) Woelkerling, with no evidence of cell damage. This indicates that certain algae in the intertidal zone are efficient collectors of particle suspended in the water. Nevertheless, we must be cautious in relating natural, periodic phenomena to catastrophic events, such as an incident where a large amount of particulate matter (e.g., iron ore) arrives suddenly in the marine environment.

Obviously, there must be a difference between the effects of the iron ore on algae never previously exposed to it (acute accident), and the effect on algae growing in an environment where this ore is abundant and lasting (chronic accident). Nassar *et al*. (2002) demonstrated that one-month-old plantlets of *Sargassum vulgare* were more susceptible to the acute introduction of iron ore than were embryos fertilized in the presence of this particulate.

As they grow, some algae tend to incorporate the iron ore into their outer cell wall. This is the case in *P. gymnospora,* where the iron is adsorbed into the cell wall and bound by the mucilage or $CaO_3$ (Nassar *et al*., 2003). In other cases, the particles are captured at the base of branches or in cavities and depressions, with no effect on photosynthesis, as in *Centroceras clavulatum* (C. Agardh *in* Kunth) Mont. in Durieu de Maisonneuve, *Caulerpa racemosa* (Forsskal) J.Agardh, *Hypnea musciformis* (Wulfen *in* Jacqu.) J.V. Lamouroux, *Codium decorticatum* (Wood.) M. Howe and *Acanthophora spicifera* (Vahl) Boergesen (Nassar & Yoneshigue-Valentin, 2005).

Despite the large amount of iron on the substrate and covering the seaweed fronds at Camburi Beach, the species still survive, even though their abundances fluctuate from year to year. It is obvious that we cannot attribute to the iron ore alone the species composition of this beach. Another factor surely affecting the community is the input of sewage from different origins to the bay.

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