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Note

Offshore iron sand extraction in New Zealand: Potential trace metal exposure of benthic and pelagic biota

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ABSTRACT

Plans to exploit an offshore source of iron sand in South Taranaki Bight (STB), New Zealand, caused concerns that such exploitation may expose benthic and pelagic biota to elevated trace metal concentrations. We conducted dilute-acid extractions and standard elutriate tests to investigate the potential of this exploitation to (1) create a new seafloor with elevated trace metal content, (2) mobilise trace metals during iron sand extraction and, (3) enrich the returning process seawater, which feeds iron sand through mills, with trace metals. We found that recruits of freshly uncovered sediment may encounter higher-than-natural concentrations of cadmium, nickel and chromium (but not of copper, lead, and zinc) and propose to investigate the bioavailability of these metals. Elutriate test with raw and milled iron sand revealed that, for nickel and copper, dilution of the process seawater may be required to meet the local water quality guideline. We argue that this dilution can be achieved by adjustment of the mass and seawater balance of the offshore extraction process.

Placer mining—the mining of minerals that have been concentrated in the marine environment by physical processes such as waves and currents—is a relatively small industry that currently exploits only a fraction of the known deposits (Murton, 2002; Rona, 2008). Pressure on land-based resources, however, has spurred technological developments and the interest in hitherto unexplored resources (Baker et al., 2016). For example, Trans-Tasman Resources Limited (hereafter, TTR; www.ttrl.co.nz) seeks to exploit a large offshore source of iron sand in South Taranaki Bight (STB), North Island, New Zealand (Fig. 1, http://www.epa.govt.nz). Iron sand is a general term for sand-sized grains (62–2000 μm) of iron-rich minerals mainly magnetite (Fe_3O_4), titanomagnetite (Fe_2TiO_3) and ilmenite ($FeTiO_3$). The offshore iron sands in STB, which are mainly derived from Taranaki volcano andesite are the largest known resource of metalliferous ore in New Zealand. They originated as crystals in volcanic rocks and ash deposits, washed down and eroded by rivers, largely from Mount Taranaki but also from the Central Plateau of the North Island, to Taranaki Bight (Carter, 1980). To source iron sand from STB, TTR proposes to extract ~50 million tonnes per year of seafloor sediment from a permitted area of approximately 66 km^2, located 22–33 km offshore in waters between 20 and 42 m deep, with a 450-t remotely controlled seabed crawler and a floating metallurgical processing plant—a 345 m-long vessel for the recovery and processing of iron sand. The crawler pumps a slurry of sediment from an average depth below the seafloor of 5 m up to the offshore beneficiation plant, which screens the slurry to remove > 3.5 mm particles and then extracts and concentrates the iron ore with alternating steps of magnetic separation and low-intensity milling. TTR will return the de-ored sand, including particles > 3.5 mm, suspended in seawater to STB and transfer the dewatered, concentrated iron ore to a storage vessel. This ore will eventually be transhipped to a cape-size vessel for export to customers who use it to manufacture steel. This operation, like harbour dredging, mobilises large volumes of sediment over an extended time and, among other potentially adverse effects, such as increased seawater turbidity, altered sediment grain size composition, and excess underwater noise, may expose pelagic and benthic biota to sediment-bound trace metals—contaminants commonly found in concentrations toxic to marine biota (Govindasamy et al., 1998; Gorski and Nugegoda, 2006; Rouchon and Phillips, 2016). Mobilisation of such sediment, however, does not necessarily result in contaminated seawater (Wasserman et al., 2016; Tiquio et al., 2017) and the potential for metal contamination may vary spatially and temporally depending on geochemical sediment properties, the hydrological regime, and the mass balance of the iron sand extraction and processing procedures.

In the case of TTR's proposed exploitation, exposure of biota to trace metals may occur due to three effects: (1) sub-seafloor iron sand will be uncovered and so, over time, colonised by invertebrates. The trace metal content of this iron sand may exceed that of natural surface sediment and, if so, and if such metals are in fact bioavailable, interfere with the colonisation of the new seafloor. (2) The extraction and processing of iron sand involves rapid mixing of this sand with fully

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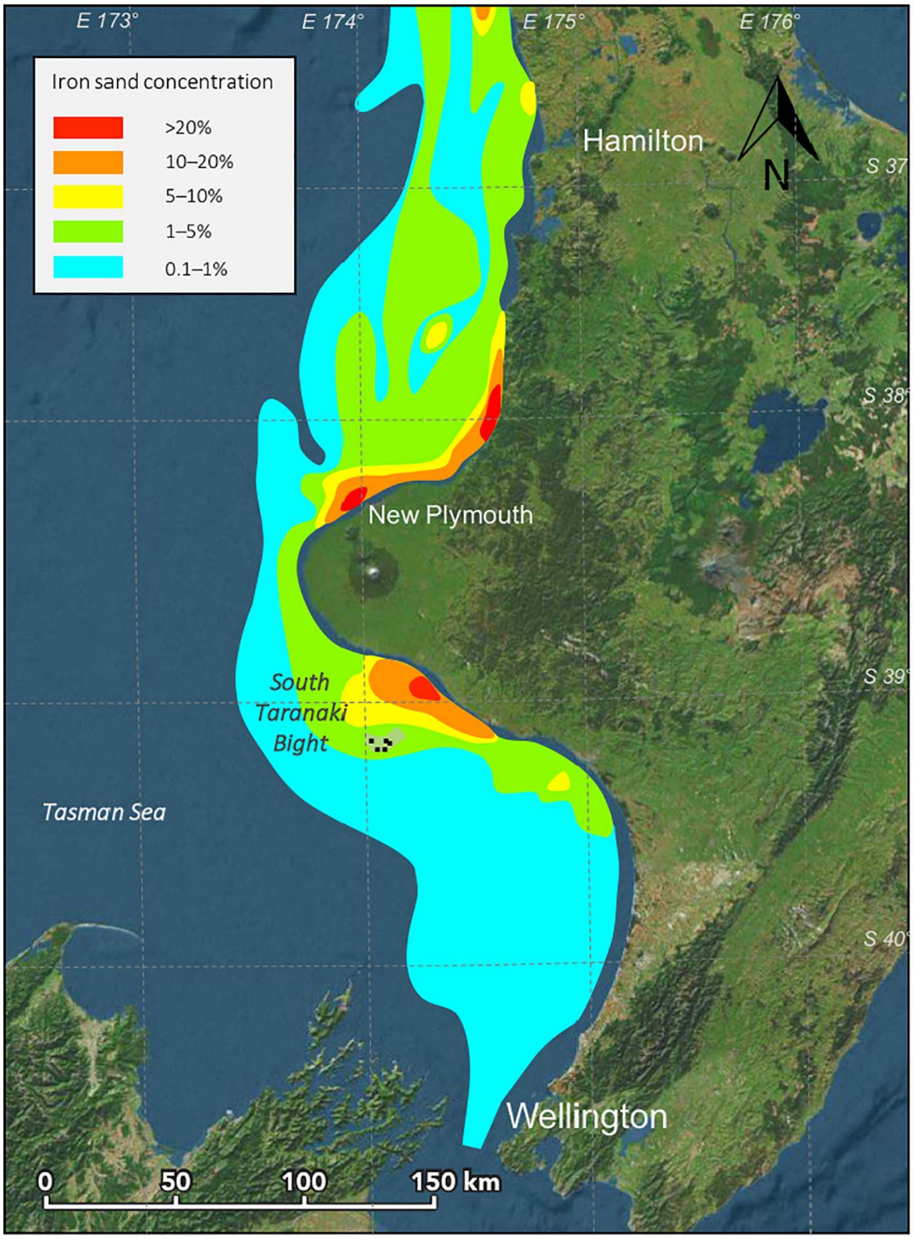

Fig. 1. Map showing the distribution of iron sand along the southwest coast of New Zealand's North Island. Contour values are percent iron sand by weight. Black dots in the grey area indicate five sediment core sampling sites within the proposed mining area. Adapted from Carter (1980).

oxygenated seawater. This mixing may mobilise trace metals via oxidation of metal sulfides and metal-adsorbing pyrite and iron monosulfides (Morse, 1995; Simpson et al., 1998). (3) Grinding of iron sand aboard the floating metallurgical processing plan increases the specific surface area of iron sand particles and potentially the release of trace metals into the process seawater. Because this seawater is returned to STB, its trace metal load can affect pelagic biota.

Here, on request of the New Zealand Environmental Protection Authority and TTR, we contribute to an assessment of the potential of the proposed operation to expose benthic and pelagic biota to potentially harmful concentrations of six trace metals: cadmium, chromium, copper, lead, nickel, and zinc. First, we compare the concentrations of these metals in dilute-acid extracts from deep iron sand with that in extracts from surface sediment. We argue that colonisation of the freshly exposed, deep iron sand is unlikely affected by these metals if the dilute-acid soluble metal concentration in the deep sediment does not differ from that in the surface sediment. We then evaluate trace metal concentrations in seawater suspensions (standard elutriation) of sub-seafloor iron sand and consider dilution aboard the processing vessel and after release into STB to assess the risk for pelagic biota. Finally, we investigate whether grinding of magnetically enriched iron sand increases the potential of the iron sand to enrich the process seawater with trace metals.

Sample collection and preparation—On the 12th and 13th of June 2012, we used an electrical vibrocorer (Model P-5b, Rossfelder Corporation) to collect one iron sand core at each of five sites (Table 1) located ~32 km offshore, in STB, within an area of ~3.5 km diameter in 32–43 m deep water (Fig. 1). We used these cores to assess, as a

Table 1

Geographic coordinates and water depth (m) of five sampling sites. PD, recorded penetration depth of the coring tube; CL, length of the retrieved sediment core.

Site	Latitude	Longitude	Water depth (m)	PD (m)	CL (m)
1	S 39° 53.637′	E 174° 6.696′	38	4.3	3.6
2	S 39° 53.560′	E 174° 4.565′	40	5.0	4.1
3	S 39° 52.128′	E 174° 3.268′	43	3.0	2.2
4	S 39° 52.636′	E 174° 7.744′	32	3.2	2.2
5	S 39° 52.003′	E 174° 6.775′	37	5.0	4.0