Memo 675
For: JBS&G/HanRoy
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Salinity tolerance of stygofauna at Mulga Downs Iron Ore Mine

Introduction

The Mulga Downs Iron Ore Mine (MDIOM) project proposed by Hancock Prospecting Pty Ltd (HPPL) consists of a series of above and below-water table, open mine pits and associated infrastructure to support the production of up to 12 million tonnes of iron ore per annum over a 30 year period. Dewatering will be required to support the open pit mining. It is proposed that when the volume of dewatering exceeds operational water demands, excess water will be disposed of by the injection of groundwater into deeper aquifers at the MDIOM, a process referred to as managed aquifer recharge (MAR). Groundwater reinjection usually results in a rise in the watertable around the sites of injection, even when injecting into deep aquifers. This is referred to as 'groundwater mounding'. The process usually also increases salinity in the surficial aquifer where the mounding occurs. For the purpose of this memo, groundwater mounding is considered to occur where there has been a rise of >1m in the water table and groundwater drawdown to occur where there has been a decline due to abstraction of >2m.

This memo considers the likely upper salinity tolerances of the nine stygofauna species known only from the areas of expected groundwater mounding of >1m at the two planned areas of MAR (Table 1). One of the MAR areas is mostly to the west of the proposed mine pits and the other is at the eastern end of the MDIOM Development. Three sections of the MAR areas are expected to have significant increase in salinity. These are named Murray's West MAR, Valley Near Murray's Hill and DB1 Far East in Figure 1. All three areas contain potentially restricted species (Table 1).

Over the total life of the MDIOM, there is substantial overlap of the areas of MAR and groundwater drawdown (Figure 1) as a result of sequential project development. The groundwater to be reinjected in MAR areas will come from nearby parts of the MDIOM as mine pits are dewatered during mining. All nine species being considered in relation to MAR will also experience groundwater drawdown. Some of the species also occur at sites where they will experience only drawdown (Table 1). The surveys during which the species were collected are described in Bennelongia (2023).

Current Groundwater Salinity

The depth to water table across the MDIOM varies from approximately 3 m to10 m below ground level (mbgl). Mapping of current salinities in the first metre below the water table is provided in Figure 1. Within the mapped area, salinity ranges from 60 mg/L to approximately 10,800 mg/L total dissolved solids (TDS). Salinities are highest in the valley areas of the MDIOM, with a mound of saline groundwater originating from the overlying claypans and fresher groundwater occurring on the valley sides. As such, on the edges of the saline mound, there is a halocline, usually at a depth between 40 mbgl and 80 mbgl, with salinities usually being 20,000-30,000 mg/L at 120 mbgl (Figure 2).

Table 1. Numbers of sites where 'restricted 'species from drawdown areas were recorded.

Species	Murray's West	Near Murray's Hill	DB1_Far East	Central Drawdown
Oligochaeta				
Achaeta sp.		1	1	1
Hydracarina				
Guineaxonopsis sp. B03	1		1	
Ostracoda				
Areacandona 'BOS1381'		1		1
Syncarida				
*Pilbaranell*a 'MH1'		2	1	
Pilbaranella 'MH2'		1		
Pilbaranella 'sp. B18		1		
Atopobathynella sp. B09			2	
nr *Billibathynella* 'MH2'		3	2	
Parabathynellidae 'MH3'		1		

Note that in text and tables, salinity is expressed in mg/L total dissolved solids (TDS) while Figure 1 and Appendix 2 use electrical conductivity (µS/cm) as the unit of salinity. Units of µS/cm can be multiplied by 0.6 for approximate conversion to mg/L TDS (see Williams 1986).

Stygofauna Salinity Tolerance

Salinity classification for aquatic invertebrates generally recognizes three broad classes of salinity tolerance, with two freshwater categories (Williams 1964; Hammer 1986):

- 'freshwater' species in salinity<3,000 mg/L TDS,
    - true freshwater species in salinity <500 mg/L (uncommon in Western Australia except perhaps the Kimberley),
    - oligohaline species in salinity of 500 – 3,000 mg/L (typical of most 'freshwater' species in Western Australia),
- hyposaline species in salinity 3,000-20,000 mg/L (many are much less tolerant), and
- saline species in salinity >20,000 mg/L.

These salinity categories are an attempt to characterize species according to physiology but they are approximate and many species will have occurrences in the salinity ranges of more than one category

Information on salinity tolerances of Pilbara stygofauna species is provided below. Using Bennelongia's database of stygofauna collected since 2007 and the results of the Pilbara Biological Survey (Halse *et al*. 2014), the mean, minimum and maximum salinity of occurrence was extracted for all Pilbara stygofauna having at least four records of occurrence accompanied by salinity measurements. As a general summary, apart from worms for which there is quite a lot of ecological uncertainty, approximately 83% of species have mean salinity occurrences of <1,800 mg/L. A further 7% have mean salinity tolerances below 3,000 mg/L.

The potentially restricted worm species, *Achaeta* sp., belongs to the family Enchytraeidae and is conventionally regarded as aquatic (or stygofauna if below ground) but may be more correctly treated as amphibious. All three records at the MDIOM were collected in troglofauna scrapes. The salinity tolerance of the species is not considered further.

Eighty-nine of the 110 ostracod species with at least four occurrences associated with salinity values belong to the family Candonidae. All but seven species have mean salinity occurrences of <1,800 mg/L, with the other seven having mean occurrence of <5,500 mg/L. All but four of the 21 non-candonid ostracods have mean salinity occurrences of <1,800 mg/L, with the remaining species having mean occurrences of <2,500 mg/L. The median ratio of maximum salinity to mean salinity for ostracods is 1.8 (range 1.0-7.3).

Many species of syncarid have been collected from the Pilbara but they are usually represented by few records and only 27 species (belonging to the families Bathynellidae and Parabathynellidae) have at least four salinity records. Syncarids also mostly have small ranges and six of the nine potentially restricted species at the MDIOM are syncarids. All have mean salinity occurrences of <1,800 mg/L. The median ratio of maximum salinity to mean salinity for syncarids is 1.4 (range1.1-14.0), which suggests that even small numbers of records probably provide a reasonably accurate guide to the upper salinity tolerance of syncarids.

Only five species of Hydracina have at least four occurrences associated with salinity values. Four of these have mean salinity occurrences of <1,800 mg/L. The other species has a mean salinity occurrence of 2,500 mg/L. The median ratio of maximum salinity to mean salinity for Hydracina, for which there are few records, is 1.8 (range 1.5-2.8).

Stygofauna at MDIOM

The likely salinity tolerances for eight potentially restricted species of stygofauna (excluding *Achaeta* sp.) were calculated by multiplying the mean observed salinity of each species by the median ratio of maximum salinity to mean salinity for the appropriate taxonomic group (e.g. syncarids).

Based on sampling results, three of the potentially restricted species at the MDIOM (all syncarids) are inferred to be true freshwater species with upper salinity tolerances of <500 mg/L (Table 2), four species (three syncarids and the water mite) are inferred to have upper salinity tolerances of 500-1500 mg/L, and the single potentially restricted ostracod species has an inferred upper salinity tolerance (3,101 mg/L) just beyond the 'freshwater' range.

Table 2. Observed salinity occurrence and inferred salinity tolerance, together with types of impact, for 'restricted' stygofauna species.

Salinity values mg/L TDS. *, Inferred upper salinity tolerance (see text). ‡, used maximum observed.

Species	Mean salinity	Maximum salinity	Minimum salinity	*Inferred upper salinity tolerance
Oligochaeta				
Achaeta sp.	-	-	-	-
Hydracarina				
Guineaxonopsis sp. B03	406	719	92	731
Ostracoda				
Areacandona 'BOS1381'	1723	2394	1052	3101
Syncarida				
*Pilbaranell*a 'MH1'	197	257	110	276
Pilbaranella 'MH2'	1066	-	-	1492
Pilbaranella sp. B18	155	-	-	217
Atopobathynella sp. B09	73	92	54	102
nr *Billibathynella* 'MH2'	589	1049	110	1049‡
Parabathynellidae 'MH3'	632	-	-	885

Discussion

The inferred upper salinity tolerances of the eight potentially restricted stygofauna species were estimated using a formal methodology that is likely to be accurate for most species collected from a large number of sites. However, the species in Table 2 were collected from few sites (1-5) and in such circumstances the inferred upper salinity tolerance of species may be underestimated for some species. At the same time, in agreement with values in Table 2, there is broad-based information suggesting more than 80% of Pilbara stygofauna species have mean occurrence of <1,800 mg/L.

Implications

AQ2 (*in litt*.) predicts that the weighted average salinity of groundwater abstracted at the MDIOM will periodically reach 3,000 mg/L through the life of the mine. Under one porosity scenario, it will reach 4,200 mg/L during the first half of mine life.

It is also predicted that most of the MAR area will, on average, experience relatively small salinity increases of approximately 500 mg/L (AQ2 *in litt*.). However, at Murray's West (which supports only one record of *Guineaxonopsis* sp. B03 (S01 group) salinity is expected to increase by 2,550 mg/L. to 3,800 mg/L. The resultant salinity exceeds the inferred upper salinity tolerance of *Guineaxonopsis* sp. B03 (S01 group).

At Valley Near Murray's Hill, salinity is predicted to increase 1000 mg/L from 3,600 to 4,600 mg/L, although the salinity contours and the salinities at which species were recorded show that current salinity in most of the area, except to the south, is considerably lower than 3,600 mg/L,. Even *Areacandona* 'BOS1831', the most salt tolerant of the eight restricted species with an estimated upper tolerance of 3101, is unlikely to tolerate the predicted salinity increase at Valley Near Murray's Hill, although salinity at particular sites may remain lower than suggested by the broad salinity predictions available. The other six species recorded at Valley Near Murray's Hill have inferred salinity tolerances of 217-1,492 mg/L.

At DB1 Far East, salinity is expected to increase by 1,300 mg/L from 1,400 to 2,700 mg/L. The one species collected only from DB1 Far East, *Atopobathynella* sp. B09, has an inferred upper salinity tolerance of 102 mg/L and is highly unlikely to persist at 2,700 mg/L. One of the other species occurring at DB1 Far East (as well as Velley Near Murray's Hill) is also unlikely to persist, with the inferred upper salinity tolerance of *Pilbaranella* 'MH1' being 276 mg/L. The second species, nr *Billibathynella* 'MH2' with an upper salinity tolerance of 1,049 mg/L will probably also not persist, although it is not a robust prediction.

References

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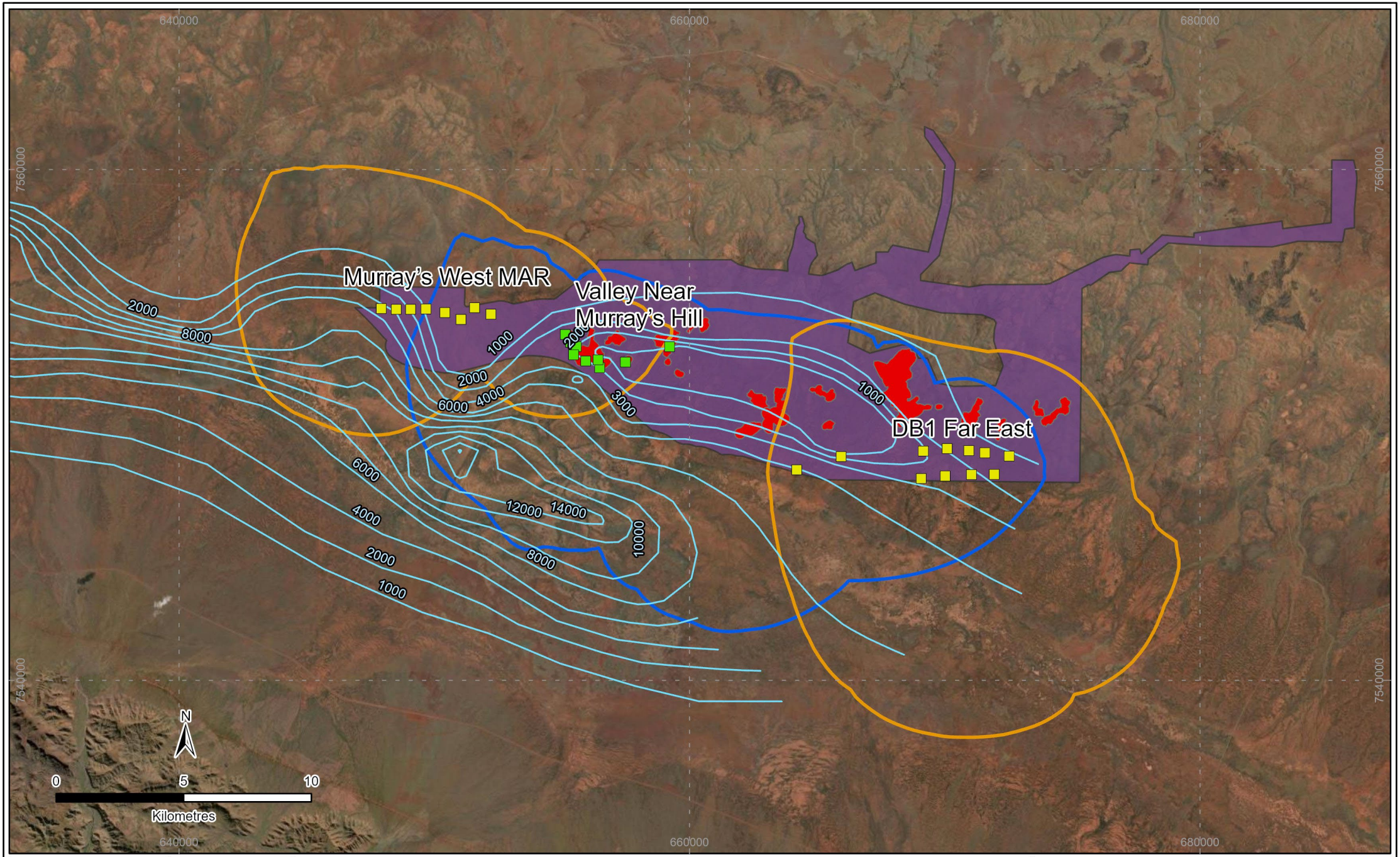

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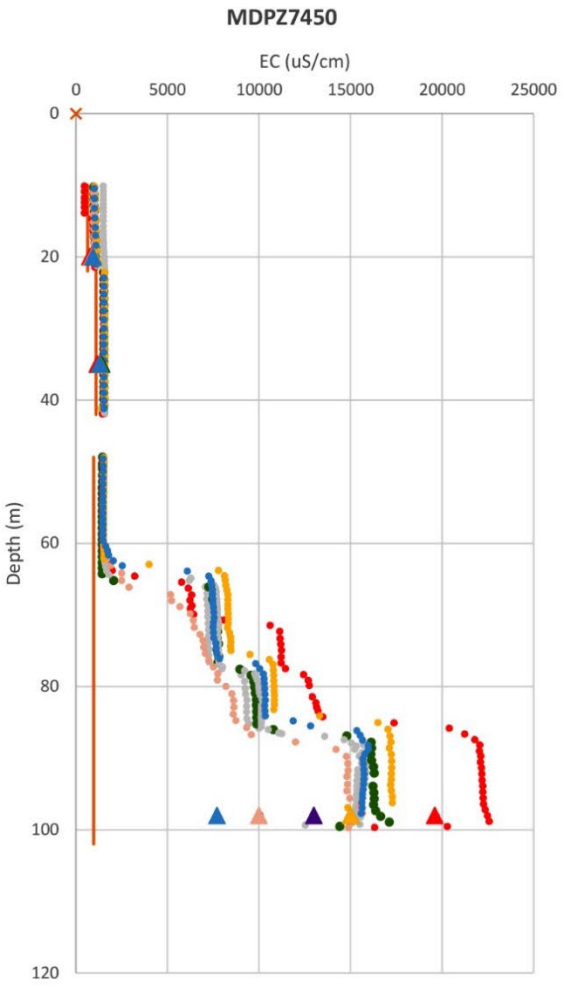
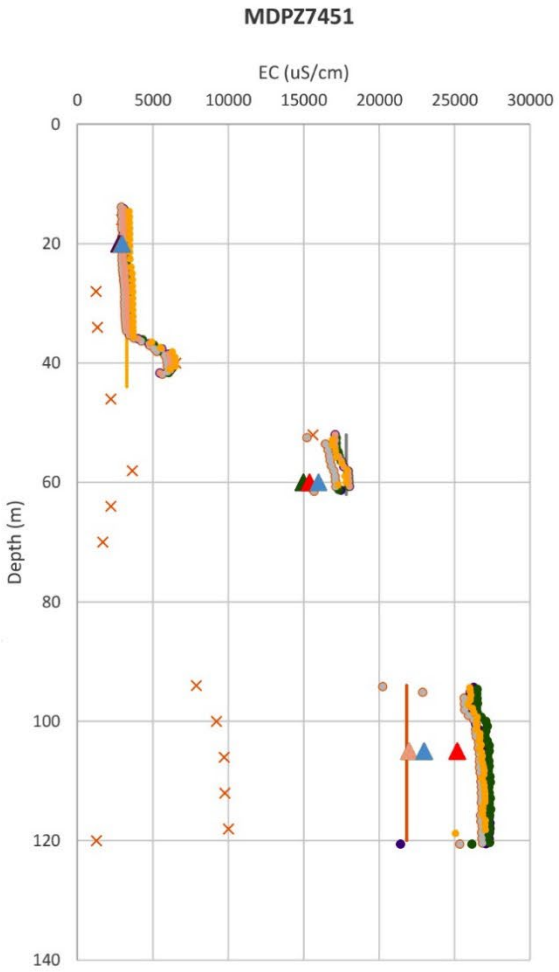
GDA2020 MGA Zone 50
Scale: 1:185,000
Author: VMarques
Date: 11/10/2024

Legend

- Project location (inset)
- Development Envelope
- Proposed pits
- Cumulative 1m Mounding Contours
- Cumulative 2m Drawdown Contour
- PT51-MAR Bores
- PT51-Dewatering Bores Converted to MAR Bores
- EC contours (µS/cm)

Figure 1. Existent salinity contours at Mulga Downs Iron Ore Mine





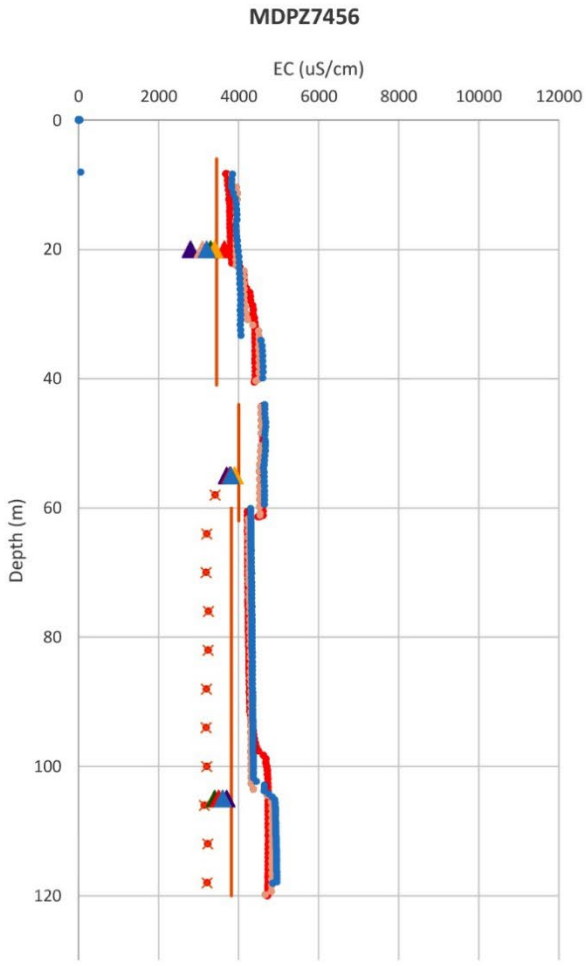


Figure 2. Salinity profiles (µS/cm) of three MDIOM bores (data from AQ2).

AQ2

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Appendix 2. Locations and salinity (as µS/cm EC) records for the nine potentially restricted species and associated salinity contours (µS/cm).

Note that some species names shortened from database versions (this has been done in text as well)..

Bore	Latitude	Longitude	Species	EC	Contours
MD2971	-22.14915	118.54551	Achaeta sp.	-	-
MD3394	-22.1489	118.65496	Achaeta sp.		-
MD0901	-22.10535	118.5048	Achaeta sp.	-	-
Robinsons Well	-22.1646	118.56882	Areacandona `BOS1381`	3990	4000-6000
MD0462	-22.12218	118.51367	Areacandona `BOS1381`	1754	1000-2000
md_kar7	-22.1366	118.6353	Atopobathynella sp. B09 (Para'`MH1`)	89.4	1000-2000
MD0429	-22.1593	118.6515	Atopobathynella sp. B09 (Para'`MH1`)	153.2	2000-3000
MD0429	-22.1593	118.6515	Guineaxonopsis sp. B03 (S01 group)	153.2	2000-3000
Hesters Bore	-22.1059	118.4670	Guineaxonopsis sp. B03 (S01 group)	1158	<1000
Hesters Bore	-22.1059	118.4670	Guineaxonopsis sp. B03 (S01 group)	1199	<1000
Hesters Bore	-22.1059	118.4670	Guineaxonopsis sp. B03 (S01 group)	1242	<1000
md_kar6	-22.1489	118.6534	nr Billibathynella `MH2` (Para'`MH2`)	183.4	1000-2000
MD0509	-22.1190	118.5256	nr Billibathynella `MH2` (Para'`MH2`)	485.7	1000-2000
MD0533	-22.1176	118.5266	nr Billibathynella `MH2` (Para'`MH2`)	796	1000-2000
MD0533	-22.1176	118.5266	nr Billibathynella `MH2` (Para'`MH2`)	812	1000-2000
MD0509	-22.1190	118.5256	nr Billibathynella `MH2` (Para'`MH2`)	1006	1000-2000
MD0562	-22.1252	118.5079	nr Billibathynella `MH2` (Para'`MH2`)	1163	2000-3000
MD0396	-22.1612	118.6785	nr Billibathynella `MH2` (Para'`MH2`)	1720	1000-2000
MD0396	-22.1612	118.6785	nr Billibathynella `MH2` (Para'`MH2`)	1748	1000-2000
MD0525	-22.11422	118.51489	Parabathynellidae `MH3`	1054	1000-2000
md_kar6	-22.1489	118.6534	Pilbaranella `MH1`	183.4	1000-2000
MD0499	-22.1154	118.5046	Pilbaranella `MH1`	371.9	2000-3000
MD0499	-22.1154	118.5046	Pilbaranella `MH1`	376.2	2000-3000
MD0577	-22.1048	118.5074	Pilbaranella `MH1`	428.7	<1000
MD0577	-22.1048	118.5074	Pilbaranella `MH1`	1555	<1000
MD0462	-22.12218	118.51367	Pilbaranella `MH2`	1776	1000-2000
MD0974	-22.11325	118.53701	Pilbaranella sp. B18	258	1000-2000