Macro and microelements in soft tissues and shells of South African mussels: from consumption risks to regional patterns

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Mussels as objects are important, because they are…

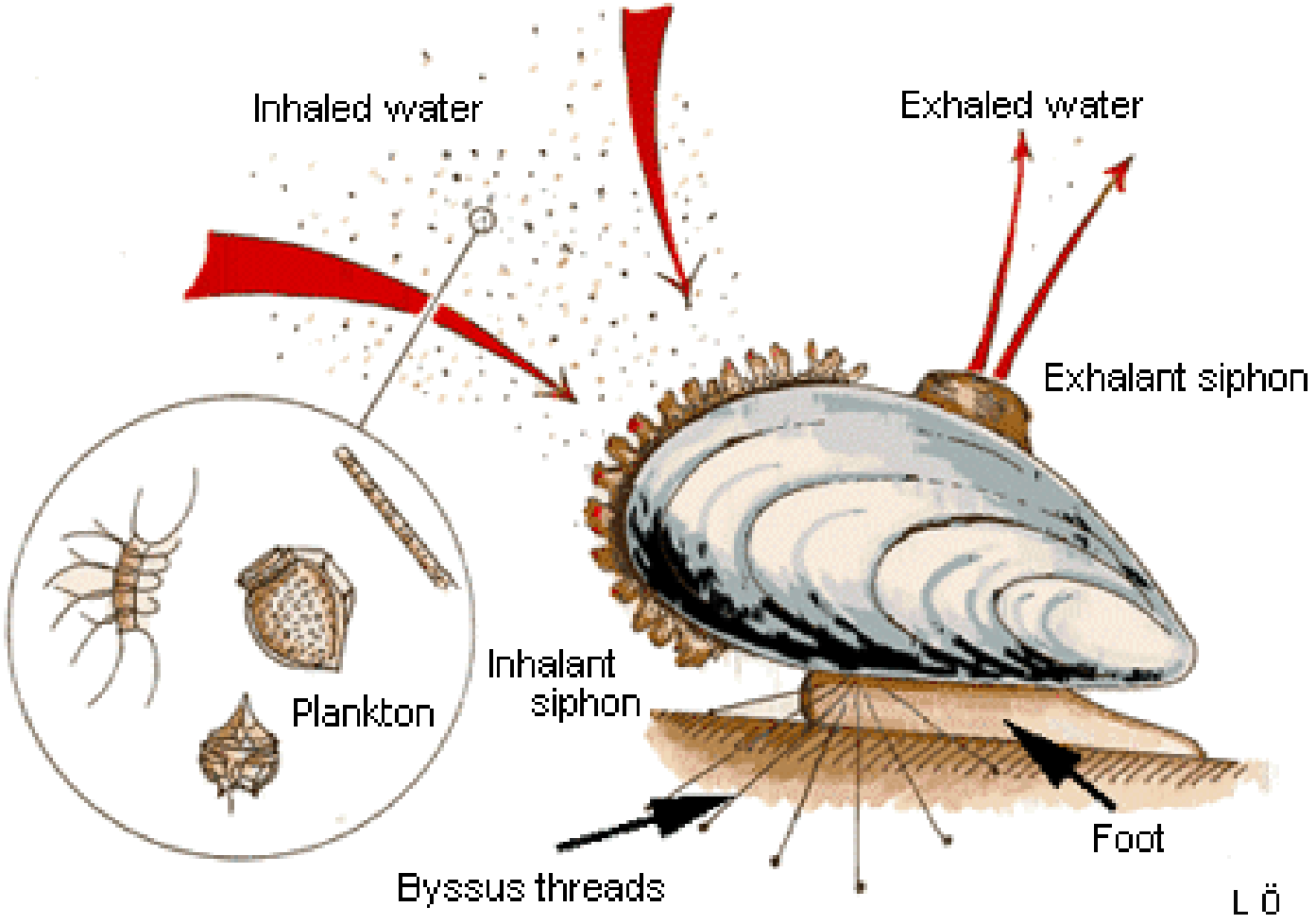
- widely distributed and easily to collect
- good biomonitors of pollution
- edible, so the accumulation of elements at threshold concentrations can be dangerous for our health
- farmed – important to know the levels of trace elements in the product

Mussels

Water (soluble ions)

Phytoplankton (biogenic elements)

Suspended matter (biogenic and terrigenous elements)



Soft tissues (soft organs)

Shells

Sampling sites

Material and methods: neutron activation analysis

- 10-12 individuals (*Mytilus galloprovincialis,* 50-70 mm length*)* were sampled from each site (14) – 166 of independent specimens
- NAA REGATA facility at the reactor IBR-2 (FLNP JINR)
- 4 HPGe detectors (Canberra) with a resolution of 1.9 keV for the total- absorption peak of 1332 keV of ^{60}Co.
- After Shapiro-Wilk and Levene's tests the nonparametric Kruskal-Wallis test was applied to examine the significance of differences among stations ($p<0.05$)

Neutron activation analysis at the REGATA

Determined elements	Packaging	Irradiation	Time of decay	Measurement	Standard reference materials
Mg, Al, S, Cl, Ca, Ti, V, Mn, I	Plastic bags	3 min	2 min	15 min	NIST1633c (coal fly ash), NIST1547 (peach leaves), NIST1632c (trace elements in coal), IRMM690cc (calcareous soil), NIST2710, NIST2710a (Montana soil), NIST2709 (trace elements in soil), NIST1572 (citrus leaves), NIST1566b (oyster tissue)
Na, K, As, Br, U	Aluminum cups	3 days	3 days	30 min	
Sc, Cr, Fe, Co, Ni, Zn, Se, Rb, Sr, Sb, Cs, Th			20 days	90 min	

Soft tissue

Factor analysis:

Factor 1 (*Terrigenous*)

Al, Sc, Mn, Fe, Co, Ni, Rb, Cs, Th

Factor 2 (*Anthropogenic*)

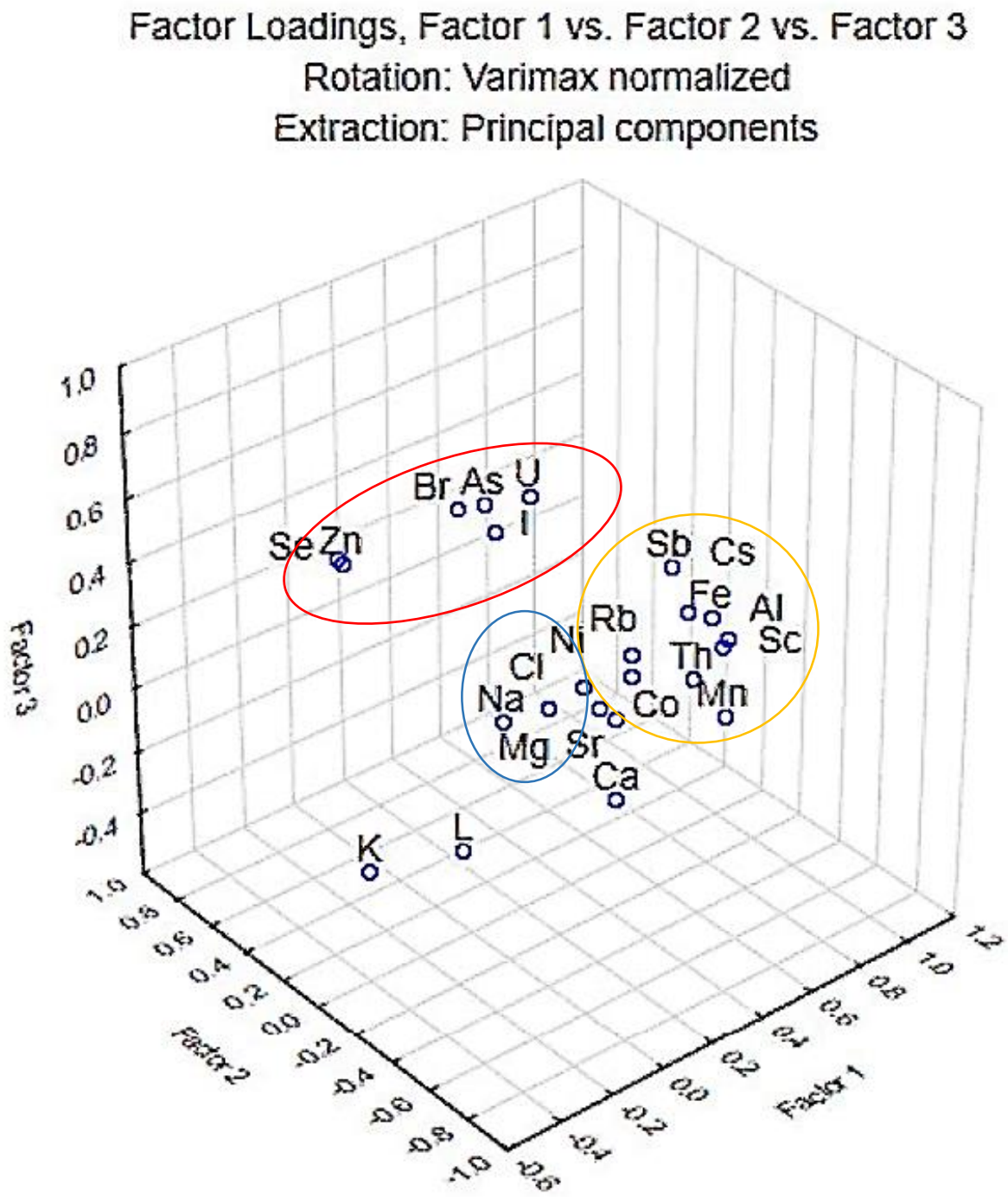
Zn, As, Br, I, U

Factor 3 (*Salinity, biogenic*)

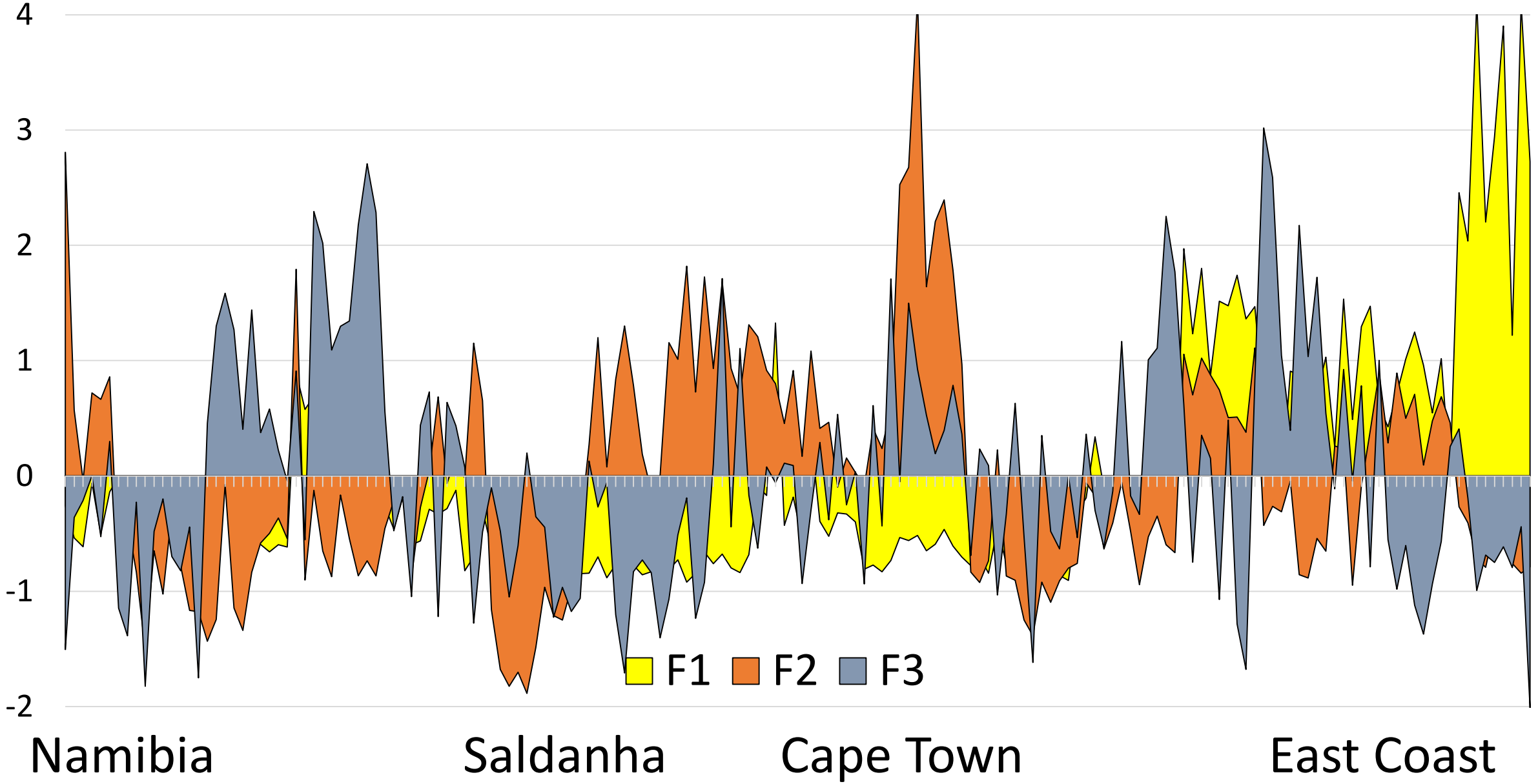
Na, Mg, Cl, Br

Factor 4 (*Biogenic*)

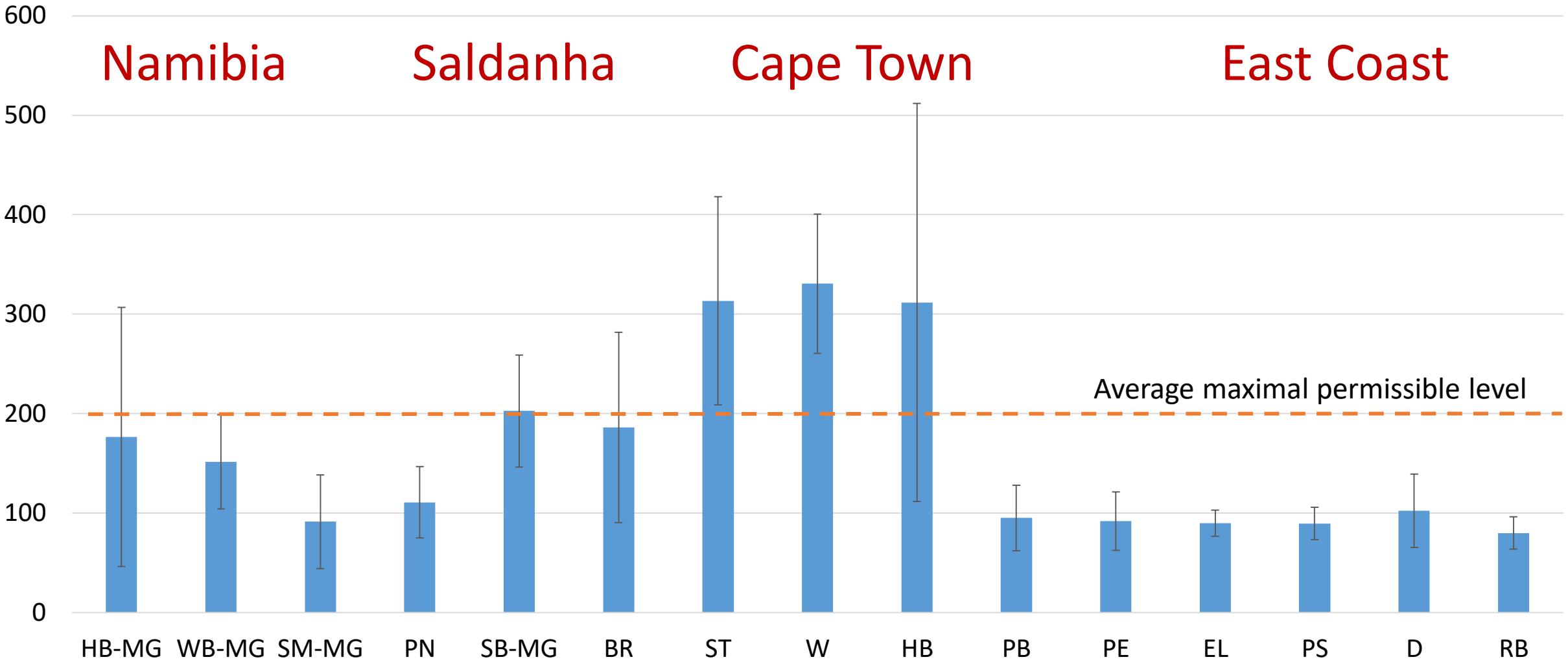
Ca, **Se**, Sr



Factor scores



Zinc (ppm, wet weight)



Zinc, ppm, wet weight basis

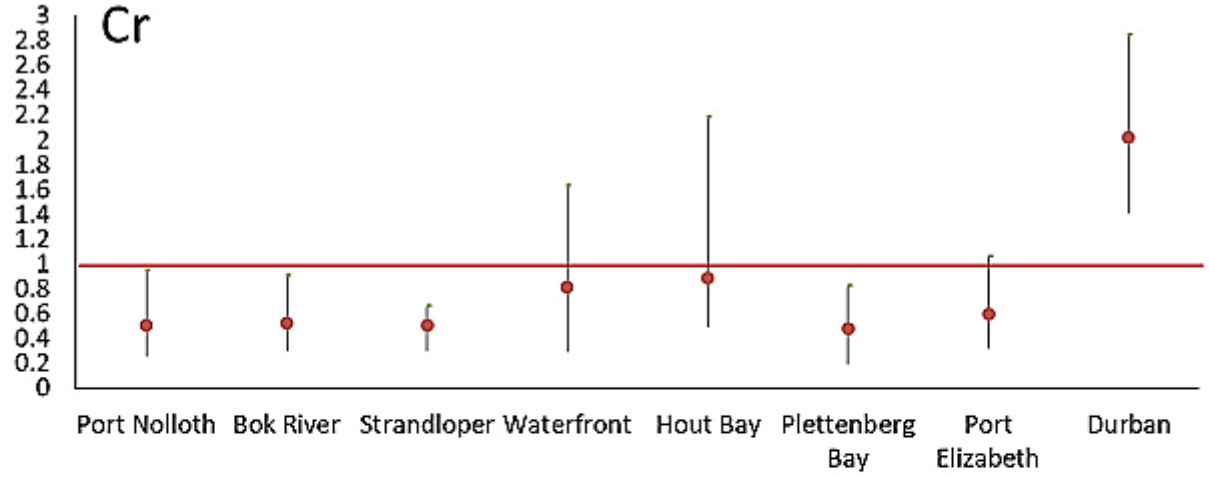
MPL (wet weight)	Our data (range min-max)			Richir et a., 2014 (max) Farmed mussels	Leblanc et al., 2005 Table mussels
	Polluted stations	Pristine areas	Wild mussels		
150-300	230-479	66-297	108-231	224	195

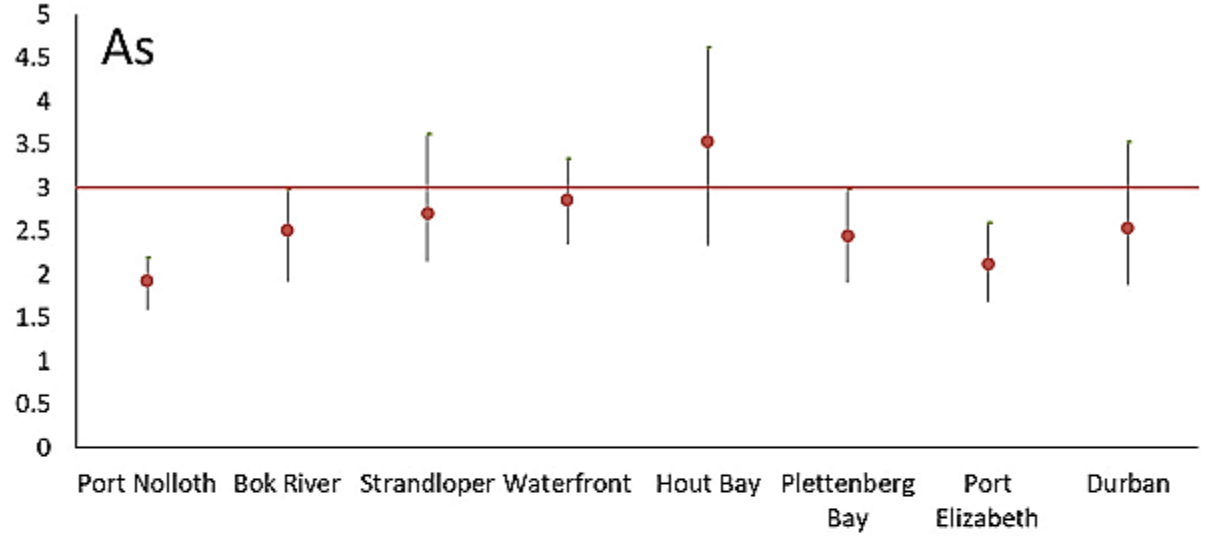
Outliers were excluded

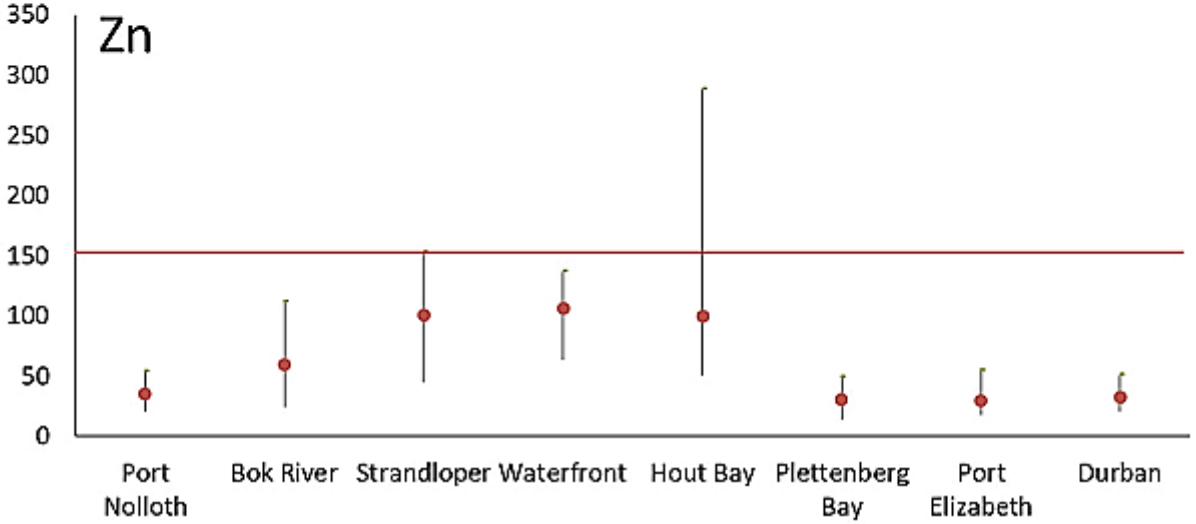
Evaluation of risks in consumption of soft tissues (meat)

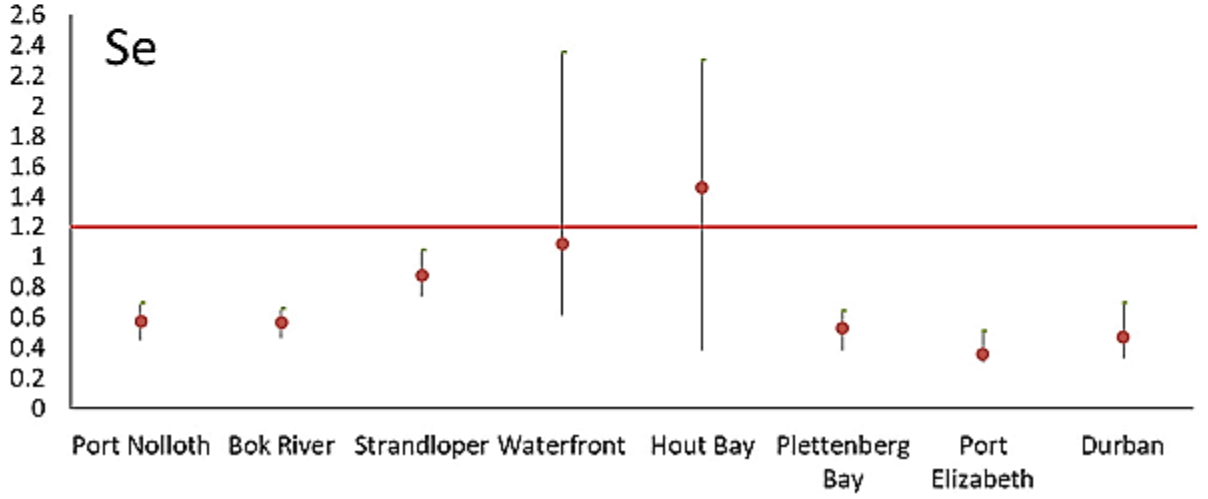
- 1- direct comparison of concentrations in soft tissues (wet weight basis) with seafood maximum permissible limits (**MPL**s);
- 2- characterization of the amount of mussels (maximal provisional consumption rate **MPCR**, kg/week) that would need to be consumed per week by a 70-kg average adult to reach the provisional tolerable weekly intake (PTWI) established by the Joint FAO/WHO Expert Committee on Food Additives (JECFA);
- 3- estimation of risk quotient (**RQ**), which corresponded to ratio between estimated weekly intakes (**EWI**) and prescribed PTWI values of element;
- 4- estimation of target hazard quotient (**THQ**) and total hazard index (**HI**) which corresponded to sum of all quotients from elements as its combinations for each station for local coastal population

Means, maximum and minimum concentrations (wet weight) and average MPLs









Red lines corresponded to average maximum permissible levels (Nekhoroshkov et al., 2021)

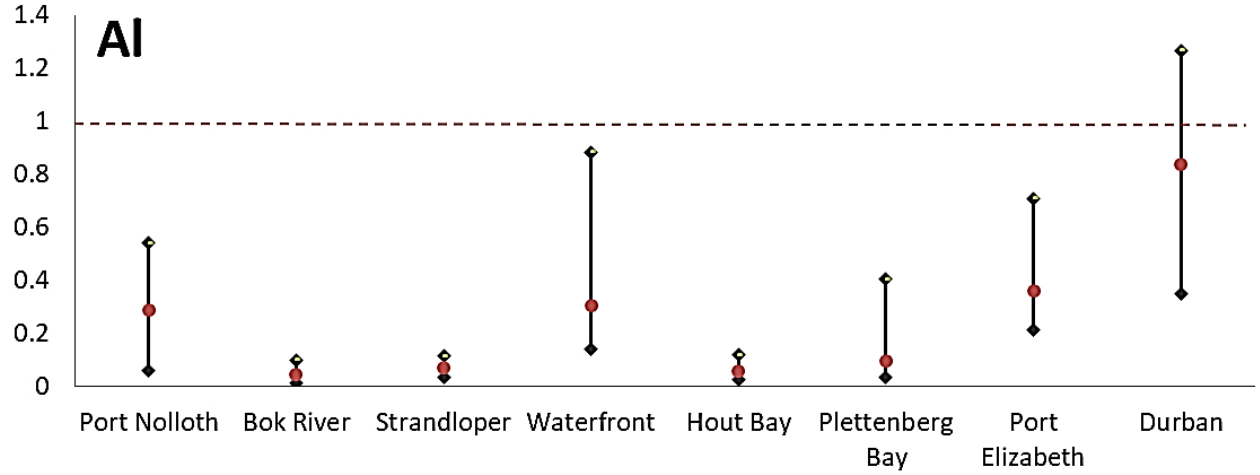
Consumption risks – how much you can eat per week?

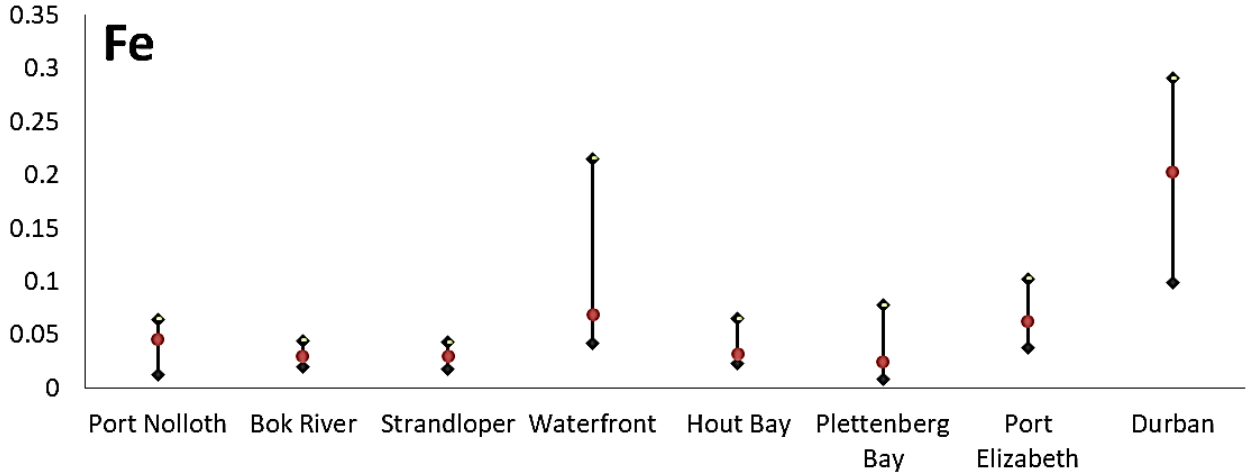
wet weight	PTWI	RfD	EWI	MPCR
	µg/kg bw/week	µg/kg bw/day	µg/kg bw/week	kg/week
Na	24500000 [a]		39600	123
Al	2000		1230	0.3
Cl	1050 [a]	100[e]	680	-
Cr	5-20 [b]	3 (Cr^{+6}) 1500 (salts Cr^{+3})	3.95	0.25-1.0
Mn	980 [a]	140	24.2	8.1
Fe	5600 [a]	700[f]	630	1.8
Co	700 [a]	300[f]	0.53	265
Ni	35	20	2.46	2.8
Zn	7000 [a]	300	320	4.4
As	15 [a] (withdrawn)	0.3 (inorganic)	9.22	0.77
Se	35 [c]	5	3.18	2.2
Br	28 [c]	4 (bromate)	390	-
Sr	4200 [c]	600	140	6.1
Sb	2.8 [c]	0.4	0.042	13.2
I	119 [a]		49	0.49
U	21 [c]	3 (soluble salts)	0.42	10.1
	JECFA FAO/WHO	**IRIS EPA USA**		

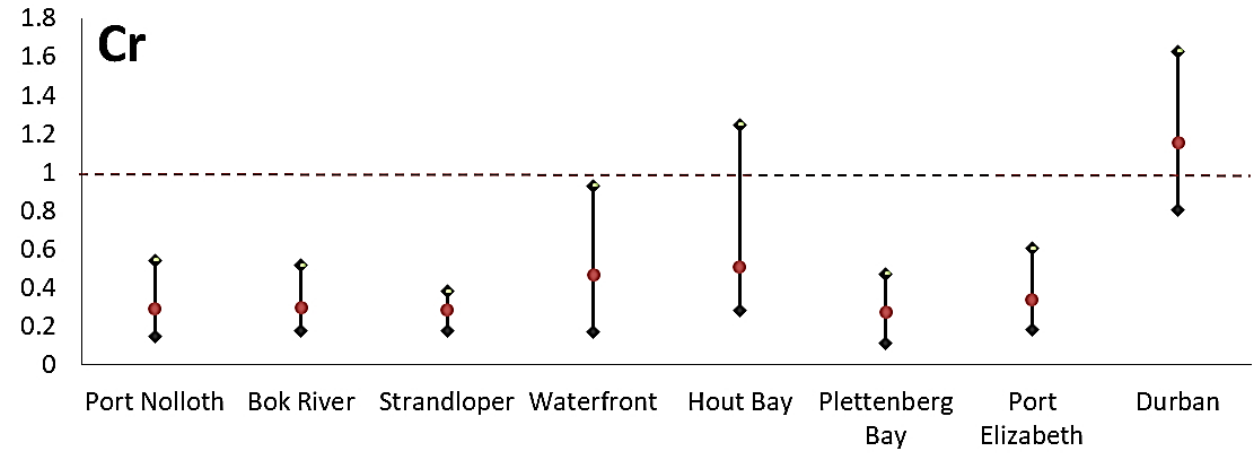
lower than 250 g/week

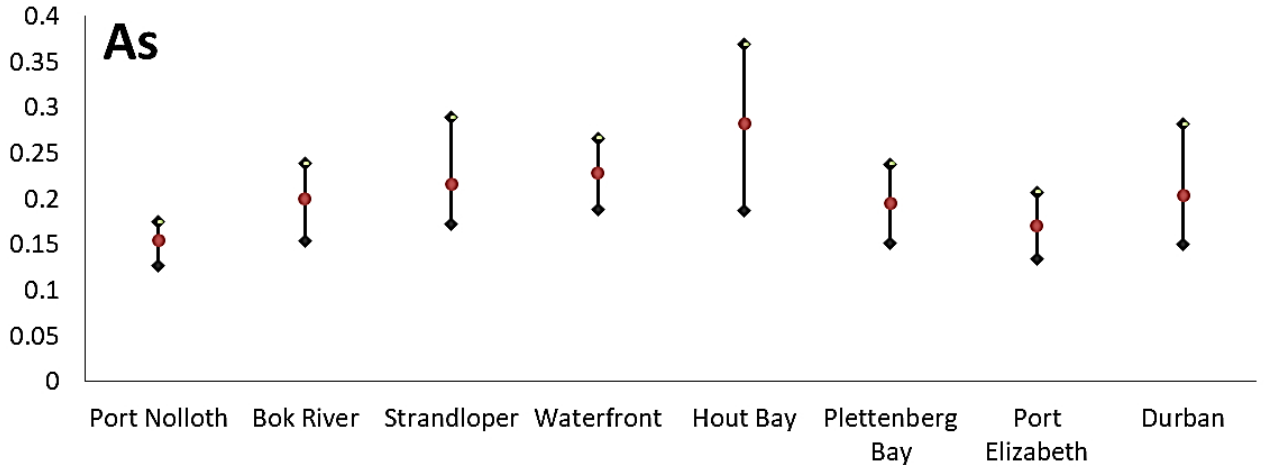
Nekhoroshkov et al., 2021

Risk quotients (EWI/PTWI)

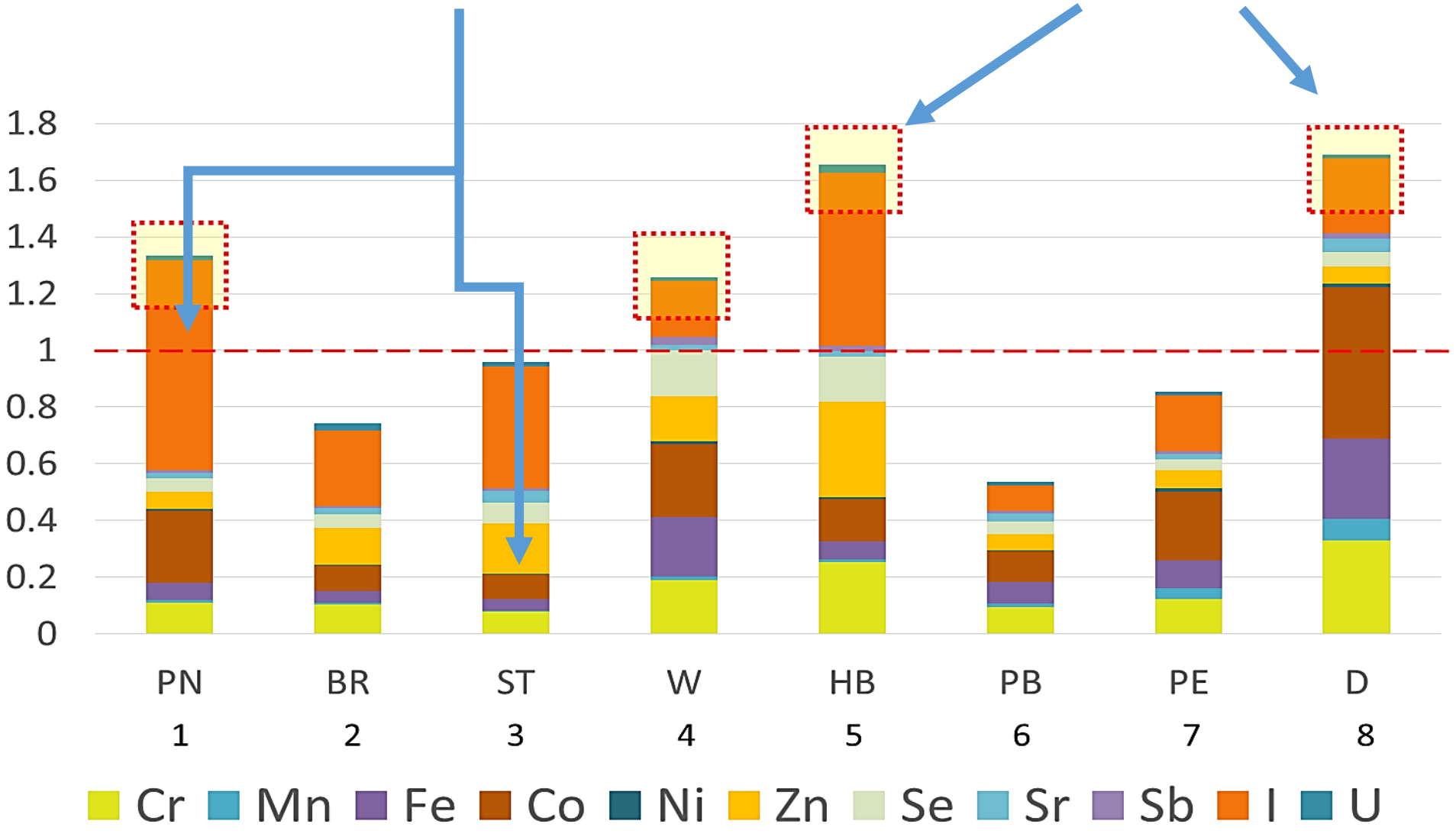








Target hazard quotient and Hazard indices



Elements with risk for consumption according to 4 approaches

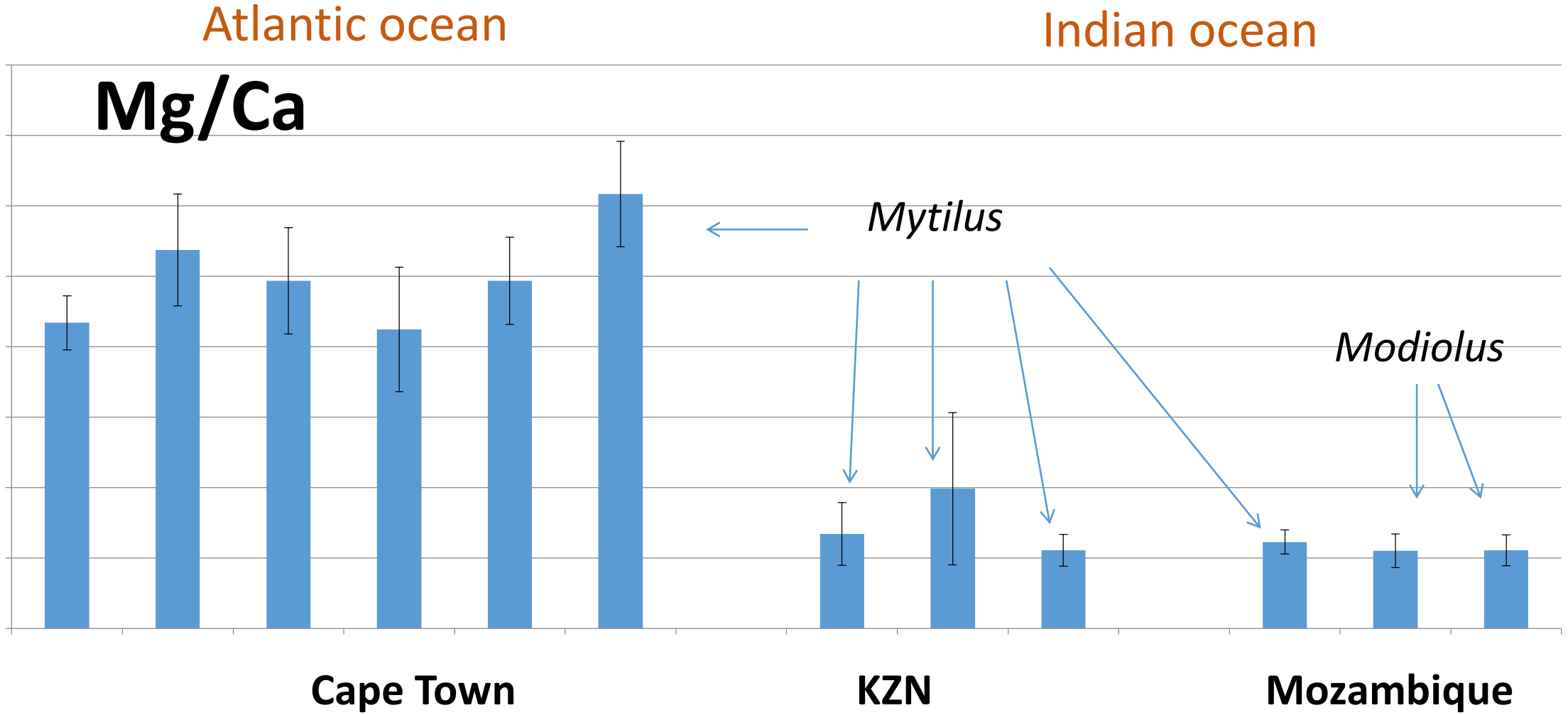
- Safe group: Na, Mn, Fe, Ni, Se, Sr, Sb, U
- Risk group: Al, Cr, Co, Zn, As, and I

All in all:
<250
g/week

Shells

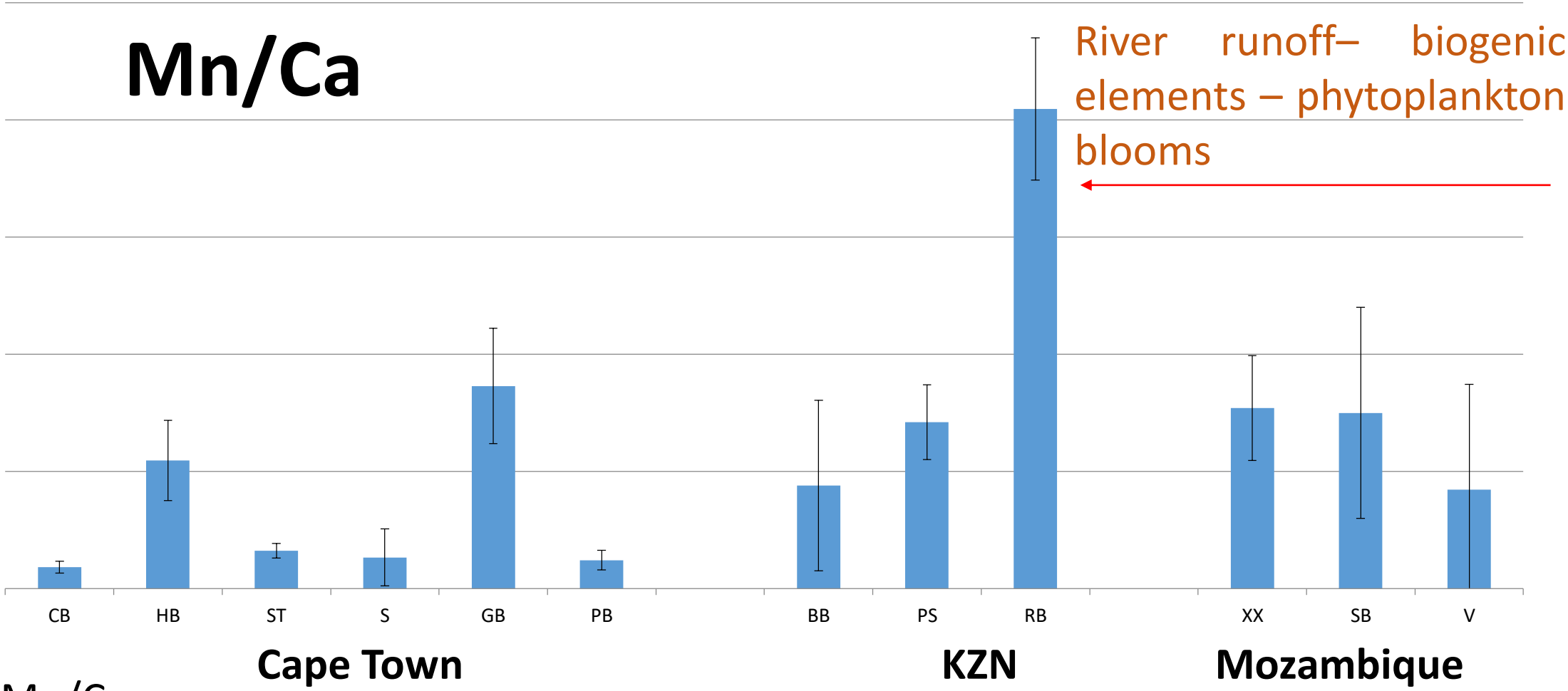
- Sc, Cr, Mn, Sb, Cs, Th reached close levels in comparison with soft tissue
- Ca and Sr were accumulated to 10 times higher levels than in soft tissues
- Cl and Zn were accumulated to 10-100 times lower concentrations than in soft tissues
- In polluted zones V, Fe, Co, Ni, Br, Ag, U were accumulated to close levels in shells and in soft tissues

El/Ca ratios in shells



- Regional features (salinity and temperature) despite the species

Mn/Ca



Mn/Ca

- exhibited increases to riverine discharge and associated phytoplankton blooms (Lazareth et al., 2003)
- shell Mn/Ca ratios related to seasonal variations in primary production (Vander Putten et al., 2000).

Publications

- Bezuidenhout, J., Nekhoroshkov, P., Zinicovscaia, I., Yushin, N. and Frontasyeva, M., 2020. Accumulation Features of Micro and Macroelements in Indigenous and Alien Molluscs in Saldanha Bay, South Africa. Ecological Chemistry and Engineering S, 27(4), pp.495-508.
- Nekhoroshkov, P.S., Bezuidenhout, J., Frontasyeva, M.V., Zinicovscaia, I.I., Yushin, N.S., Vergel, K.N. and Petrik, L., 2021. Trace elements risk assessment for consumption of wild mussels along South Africa coastline. Journal of Food Composition and Analysis, 98, p.103825.


Thank you for your attention!