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MEASUREMENT OF TRACE METALS IN SHELLFISH IN SUPPORT OF THE *JAMBO* MONITORING PROGRAMME

Supplement to FSA (Scotland) Project Code: SO2023

A D McIntosh, S Devalla, C D Robinson and I M Davies

June 2005

Fisheries Research Services
Marine Laboratory
375 Victoria Road
Aberdeen AB11 9DB

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SUMMARY

As part of the monitoring programme following the cessation of the recovery of the zinc sulphide cargo from the MV *Jambo*, samples of scallops (*Pecten maximus*) and the edible crab (*Cancer pagurus*), from sites near to (Black Rock and Tanera Beag) and remote from (Sgeirean Glasa and Horse Island) the wreck site (En a' Char) in the Summer Isles, were collected in February 2005 by the Fisheries Research Services Marine Laboratory (FRS ML) on behalf of the Food Standards Agency (Scotland) (FSA(S)). Trace metal concentrations were determined separately and individually in whole tissue and gonad in scallops and the white and brown meat from crabs.

Zinc concentrations determined in whole scallop tissue were similar at sites within the Summer Isles near to, and remote from, the *Jambo* location. Combined Summer Isles concentrations in whole scallops were similar to those found in an offshore reference location, NM12. These data are consistent with no zinc contamination from the MV *Jambo*..

Notwithstanding the above, concentrations seen in whole scallops (near and remote sites combined) were significantly lower in 2005 than in 2004.

There was no significant difference between the zinc concentrations determined in scallop gonad tissue at the near and remote sites and the zinc concentrations determined in scallop gonad tissue from NM12 in January and February 2005. In addition, there was no difference in concentrations seen in scallop gonad tissues (near and remote sites combined) between 2005 and 2004.

There were no significant differences in zinc concentrations determined in white or brown crab meats from sites in the vicinity of the wreck. Concentrations were not significantly different from those found in the previous monitoring period.

There was no significant difference between the cadmium concentration determined in whole scallop tissue from the near and remote sites and the cadmium concentration determined in equivalent tissue from the offshore reference NM12 in January and February 2005. Cadmium concentrations in scallop gonad tissue from both near and remote sites showed a marked reduction in February 2005 compared to the previous monitoring period but the cadmium concentrations in scallop gonad tissue at the near sites remain greater than the scallop gonad cadmium concentrations from the offshore reference station, NM12.

Concentrations of cadmium in whole scallop tissue from all sampling locations exceeded the EC Regulation (221/2002/EC) limit of 1.0 mg kg^{-1}. Concentrations in scallop gonad tissue did not exceed this limit.

Cadmium was barely detectable in crab white meat but was higher in crab brown meat. The EC Regulation (221/2002/EC) does not apply to the brown meat of crab.

There was no significant difference between the lead concentration determined in whole scallop tissue from the near and remote sites and the lead concentration determined in equivalent tissue from the offshore reference NM12 sample station in January and February 2005.

The lead concentration in scallop gonad tissue from the near sites in February 2005 was significantly greater than equivalent tissue from the remote sites.

The concentrations of lead in both whole scallop and gonad tissues showed a significantly marked reduction at both near sites in February 2005 compared to those sampled over the previous monitoring period.

Concentrations of lead in scallops were all less then the EC Regulation limit of 1.5 mg kg^{-1}.

Lead concentrations in crab white and brown meat were, with one exception, below the limit of analytical detection (0.087 mg kg^{-1} wet weight tissue).

The concentrations of arsenic determined in whole scallops sampled in February 2005 were significantly lower at all sites compared to the previous monitoring period, except at Horse Island. The arsenic concentration in scallop gonad tissue in February 2005 was significantly lower than over the previous monitoring period, October 2003 to January 2004, at the Horse Island location only.

No spatial or temporal differences in arsenic concentrations were seen in the crab meats.

BACKGROUND

The MV *Jambo*, on passage from Dublin to Odda in Norway, grounded on rocks on the west side of En a' Char, in the Summer Isles, on the morning of 29 June 2003. The vessel was carrying 3300 tonnes of zinc concentrate (sphalerite), a zinc sulphide mineral.

Because it was thought possible that adverse weather conditions over winter might redistribute the remaining cargo, with possible food chain related concerns, the Food Standards Agency (Scotland) (FSA(S)) contracted the Fisheries Research Services Marine Laboratory (FRS ML) to conduct monitoring of biota potentially available for human consumption.

Samples of scallops (*Pecten maximus*) and edible crabs (*Cancer pagurus*) had been collected immediately after the grounding of the vessel, prior to the loss of any cargo. These provided baseline values against which subsequent samples could be compared. A monthly sampling programme for scallops and crabs was initiated in mid October 2003 and continued until January 2004. The results of trace metals determined in crabs, up to December 2003, and scallops, to January 2004, were presented to FSA(S) (SO02023); FRS Contract Report No 09/04. This survey included analyses of scallops collected in the vicinity of the wreck (Fig. 1a) and also scallops collected at an offshore reference station in the North Minch; Fishing Box NM12 (Fig. 1b).

In continuation of the *Jambo* monitoring programme, FSA(S) commissioned the present survey which comprised the collection of samples of scallops from sites near to (Black Rock and Tanera Beag) and remote from (Sgeirean Glasa and Horse Island) the wreck site on En a'

Char in the Summer Isles in February 2005. Edible crabs were collected from near, north and south of the wreck site and from Sgeirean Glasa, as a reference site.

MATERIALS AND METHODS

Samples of scallops and crabs were collected from the same locations used in the previous study (October 2003 to January 2004) (Fig. 1a). It had originally been intended to collect samples in both January and February 2005. Sampling was not possible during January due to adverse weather precluding access to the sampling locations.

FSA(S) had also commissioned FRS to determine the trace metal concentrations in scallops taken from an offshore fishing box in the North Minch (NM12) (Fig. 1b) to the east of Lewis in the winter period November 2004 to March 2005. Six scallop samples were obtained during January and February, and this enabled additional comparisons to be made.

Sample processing and analytical methods were as described previously (FRS Contract Report No 09/04). Trace metal methods are accredited by UKAS to ISO 17025.

For the purpose of statistical analysis, the scallop data from the sampling sites nearest to the wreck site (Black Rock and Tanera Beag) were combined and defined as ‘near’. The data from the two reference sites (Sgeirean Glasa and Horse Island) were combined and defined as ‘remote’. This procedure was not applied to the crab data because of the more diverse sampling locations.

Analytical results which were less than the limit of detection (<LoD) of the determinand, were assigned a value of half the detection limit for the purpose of statistical analysis, one way ANOVA (Minitab™ V14).

RESULTS AND DISCUSSION

The full analytical data sets for the trace metals determined in the tissues from the scallops and crabs are presented in the following tables:

Table 1: Concentrations of zinc, cadmium, lead and arsenic determined in whole scallop and scallop gonad tissue sampled near to and remote from the wreck site in February 2005.

Table 2: Concentrations of zinc, cadmium, lead and arsenic determined in crab white and brown meat sampled near to and north and south of the wreck and remote from the wreck site in February 2005.

When interpreting the results, it is necessary to bear in mind “nuisance” factors which may have affected the analytical results. These will include possible differences in the measured trace metal concentrations arising from differences in the local geology between the wreck area and the reference area in the west of the Minch. Seasonal factors may influence comparisons between “Time zero” samples collected in July 2003, and data from subsequent sampling which was carried out during winter months.

Zinc

Scallops

Zinc concentrations in whole scallop tissue at the near sites in February 2005, a total of six samples, ranged from 16.1 to 28.7 mg kg^{-1} wet weight tissue (mean 22.3 mg kg^{-1}; SD 4.6) and

18.7 to 33.8 mg kg^{-1} (mean 24.9 mg kg^{-1}; SD 5.5) at the remote sites (Table 1). There was no significant difference ($p \geq 0.05$) in whole scallop zinc concentrations (Fig. 2a) between the 'near' and 'remote' sites in February 2005. The zinc concentration determined in whole scallop tissue from the offshore reference station NM12 in January and February 2005 (FSA(S) Report SPIN030) ranged from 21.4 to 27.9 mg kg^{-1} wet weight (mean 23.6 mg kg^{-1}; SD 2.7). The mean zinc concentrations determined in whole scallop tissue in February 2005 were not significantly different to the mean zinc concentrations determined in whole scallop tissue from the offshore reference station NM12 in January and February 2005.

The mean zinc concentration (23.6 mg kg^{-1}; SD 5.0) in whole scallops at the Summer Isle sites in February 2005 was significantly lower ($p \leq 0.05$) than the mean (36.4 mg kg^{-1}; SD 9.1) derived during the previous monitoring period (October 2003 to January 2004).

Zinc concentrations in scallop gonad tissue at the near sites ranged from 20.3 to 31.8 mg kg^{-1} wet weight tissue (mean 26.9 mg kg^{-1}; SD 3.8) and 27.3 to 32.9 mg kg^{-1} (mean 29.0 mg kg^{-1}; SD 2.0) at the remote sites (Table 1). There was no significant difference ($p \geq 0.05$) in scallop gonad zinc concentrations (Fig. 2b) between the 'near' and 'remote' sites in February 2005. There was no significant difference ($p \geq 0.05$) in scallop gonad zinc concentrations between the February 2005 samples and the zinc concentrations determined in scallop gonad tissue from the offshore reference station NM12 in January and February 2005 or the zinc concentrations determined in scallop gonad tissue from the previous occasions (October 2003 to January 2004).

Crabs

The mean zinc concentrations in crab white meat were 67.3 mg kg^{-1} (near to wreck), 58.4 mg kg^{-1} wet weight tissue (north of wreck), and 80.5 mg kg^{-1} (south of wreck) (Table 2). The mean zinc concentration at the 'remote' site was 82.5 mg kg^{-1}. There was no significant difference ($p \geq 0.05$) in zinc concentrations between the four sites sampled in February 2005.

There was no significant difference in white meat zinc concentration between the February 2005 and December 2003 samples taken from the wreck site and south of the wreck (Fig. 2c). The white meat zinc concentration was significantly lower ($p \leq 0.05$) in the sample from north of the wreck site in February 2005 compared to the December 2003 sample. There was no significant difference ($p \geq 0.05$) in white meat zinc concentration at the Sgeirean Glasa, reference site between October/November 2003 and February 2005.

The mean zinc concentrations in crab white meat were consistently higher than the concentrations in crab brown meat (Fig. 2d). There were no significant temporal or spatial differences in crab brown meat zinc concentrations.

The Commission Regulation 466/2001/EEC (as amended by Regulation 221/2002/EC) that applies to trace metals in bivalve molluscs provides maximum concentrations for cadmium, lead and mercury in certain fishery products to maintain a high level of consumer health protection. There are currently no applicable European standards for zinc in shellfish. The Shellfish Growing Waters Directive (79/923/EEC) provides Guideline and Imperative standards for shellfish flesh. The concentrations of zinc determined in whole scallop and gonad tissue were less than the Guideline and Imperative values of 50 and 100 mg kg^{-1} respectively for Standards for Shellfish (Henderson and Davies, 2001). The Commission Regulation 466/2001/EEC also applies to crustaceans, excluding the brown meat of crabs. The UK Reference Nutrient Intake (RNI) ranges for zinc, set by COMA, are 5.5–9.5 mg day^{-1} for males and 4.0–7.0 mg day^{-1} for females.

The Co-associated Contaminants

Cadmium

The Commission Regulation (221/2002/EC), setting maximum levels for certain contaminants in foodstuffs, is 1.0 mg kg^{-1} for cadmium in bivalve molluscs. Cadmium concentrations determined in whole scallop tissue exceeded this concentration. The mean cadmium concentrations in gonad tissue in February 2005 were below the 1.0 mg kg^{-1} wet weight Commission Regulation (221/2002/EC).

Cadmium concentrations in whole scallop tissue at the near sites in February 2005 ranged from 2.5 to 4.2 mg kg^{-1} wet weight tissue (mean 3.6 mg kg^{-1}; SD 0.62) and 1.8 to 4.0 mg kg^{-1} (mean 2.5 mg kg^{-1}; SD 0.84) at the remote sites (Table 1). The cadmium concentration determined in whole scallop tissue from the 'near' sites in February 2005 was significantly ($p \leq 0.05$) greater than the cadmium concentrations determined in whole scallop from the 'remote' sites (Fig. 3a) but not significantly different from that seen in equivalent tissue from the offshore reference station NM12. There was no significant difference in cadmium concentration in whole scallop tissue between the 'remote' sites in February 2005 and the offshore reference station in January and February 2005.

Cadmium concentrations in scallop gonad tissue at the near sites in February 2005 ranged from 0.11 to 0.28 mg kg^{-1} wet weight tissue (mean 0.22 mg kg^{-1}; SD 0.07) and 0.12 to 0.34 mg kg^{-1} (mean 0.20 mg kg^{-1}; SD 0.08) at the remote sites (Table 1). The cadmium concentrations in scallop gonad tissue from February 2005 were consistently and significantly lower ($p \leq 0.05$) than the cadmium concentrations determined in gonad tissues sampled over the period October 2003 to January 2004 (Fig. 3b). Although there has been a reduction in cadmium concentration at the 'near' sites, these values remain significantly greater than the cadmium concentration determined in scallop gonad tissue from the offshore reference station NM12 in January and February 2005 (mean 0.12 mg kg^{-1}; SD 0.03). There was no significant difference between cadmium concentrations in scallop gonad tissue from the 'remote' sites and the offshore reference station NM12 in January and February 2005.

The mean concentrations of cadmium in scallop gonad found in this study are below the Commission Regulatory (221/2002/EC) 1.0 mg kg^{-1} wet weight level.

The cadmium concentrations in crab white meat were all below the limit of detection (<0.075 mg kg^{-1}) (Table 2). The cadmium concentrations in crab brown meat (Fig. 3c) were higher than those determined for white meat. The Commission Regulation (221/2002/EC) setting maximum levels for certain contaminants in foodstuffs, puts the limit for cadmium in crustaceans at 0.5 mg kg^{-1}, excluding the brown meat of crab.

Lead

The Commission Regulation (221/2002/EC), setting maximum levels for certain contaminants in foodstuffs, puts the limit for lead in bivalve molluscs at 1.5 mg kg^{-1}.

Lead concentrations in whole scallop tissue at the near sites in February 2005 ranged from 0.11 to 0.30 mg kg^{-1} wet weight tissue (mean 0.18 mg kg^{-1}; SD 0.07) and <LoD to 0.21 mg kg^{-1} (mean 0.12 mg kg^{-1}; SD 0.06) at the remote sites (Table 1).

Lead concentrations in scallop gonad tissue at the near sites in February 2005 ranged from 0.05 to 0.30 mg kg^{-1} wet weight tissue (mean 0.11 mg kg^{-1}; SD 0.08) and <LoD to 0.06 mg kg^{-1} (mean 0.03 mg kg^{-1}; SD 0.01) at the 'remote' sites (Table 1).

The concentrations of lead in both whole scallop and gonad tissues were significantly lower ($p \leq 0.05$) at both near sites in February 2005 compared to those sampled previously, but were not significantly different either from the 'remote' Summer Isle sites or from the offshore reference station NM12 (Figs 4a and 4b).

Lead concentrations in crab white meat were only detectable in one sample, 0.09 mg kg^{-1} and below the limit of detection (0.087 mg kg^{-1} wet weight) in brown meat (Table 2). The Commission Regulation (466/2001/EC) setting maximum levels for certain contaminants in foodstuffs, puts the limit for lead in crustaceans at 0.5 mg kg^{-1}, excluding the brown meat of crab.

Arsenic

Arsenic concentrations in whole scallop tissue at the near sites in February 2005 ranged from 1.4 to 1.7 mg kg^{-1} wet weight tissue (mean 1.6 mg kg^{-1}; SD 0.1) and 1.5 to 1.9 mg kg-^{1} wet weight (mean 1.7 mg kg^{-1}; SD 0.12) at the remote sites (Table 1). Arsenic concentrations in whole scallop were significantly lower ($p \leq 0.05$) at the 'near' sites and Sgeirean Glasa than the equivalent January 2004 samples but there was no significant difference ($p \geq 0.05$) between the combined near and combined remote arsenic concentrations determined in whole scallop tissue in February 2005 (Fig. 5a).

Arsenic concentrations in whole scallop tissue from both the combined near and combined remote Summer Isle sites were significantly lower than the arsenic concentrations determined in whole scallop tissues from the offshore reference station NM12 in January and February 2005.

Arsenic concentrations in scallop gonad tissue at the near sites in February 2005 ranged from 1.5 to 2.8 mg kg^{-1} wet weight tissue (mean 2.2 mg kg^{-1}; SD 0.5) and 0.9 to 2.2 mg kg^{-1} wet weight (mean 1.5 mg kg^{-1}; SD 0.5) at the remote sites (Table 1). There was no significant difference ($p \geq 0.05$) in arsenic concentration in scallop gonad tissue at the combined near or combined remote sites but the arsenic concentrations in scallop gonad tissue from the 'near' sites were significantly greater ($p \leq 0.05$) than at the 'remote' sites in February 2005 (Fig. 5b).

There was no significant difference ($p \geq 0.05$) in arsenic concentration in scallop gonad tissue from the 'near' sites and the offshore reference station NM12 in January and February 2005 but the arsenic concentration in scallop gonad tissue from the 'remote' sites was significantly ($p \leq 0.05$) lower than in equivalent tissues from the offshore reference station NM12 in January and February 2005.

There was no significant difference in crab white and brown meat arsenic concentrations in samples taken in February 2005 with those sampled previously (Table 2) (Figs 5c and 5d).

There are currently no limits for total arsenic that apply to shellfish foodstuffs.

CONCLUSIONS

The local ('near' versus 'remote'), and regional (Summer Isles versus the offshore reference site NM12) similarity in whole scallop zinc concentrations was seen in both the 2004 and 2005 surveys. This implies no *Jambo* related increase in zinc burdens. Notwithstanding this general picture, a reduction in zinc concentration in whole scallops was seen in the Summer Isles sites between 2004 and 2005. It is thought this is more a reflection of the intrinsic variability of the data than indicative of a true reduction in zinc concentrations through depuration of elevated levels seen as a consequence of the *Jambo* release.

The apparent reductions which were seen in cadmium, lead and arsenic concentrations in some, but not all tissues, at some but not all ‘near’ versus ‘remote’ sites between the 2004 and 2005 surveys, invite a *Jambo* related explanation. But it is difficult to ascribe these findings to a *Jambo* related ‘recovery’ process since reductions of a similar scale were not seen in zinc concentrations, this being the major constituent of the cargo. The co-associated contaminants are presumed to be intrinsically bound up in the ore crystal matrix such that their release to the marine environment would be conditioned by the solubility of zinc sulphide. It is possible that, following some dissolution of ore particles, the differences of uptake and excretion kinetics of zinc and other metals in scallops may have resulted in differences in the magnitudes and rates of change of observed concentrations in tissue samples. The higher concentrations of trace metals seen in whole scallops are assumed to reflect particulate material adhering to membranes which are included in the analysis. The primary edible portions of scallops are the adductor muscle and the gonad. Concentrations in adductor muscle are commonly lower than those seen in gonad.

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Table 1

Concentrations of zinc, cadmium, lead and arsenic (mg kg^{-1} wet weight) determined in whole scallop tissue and scallop gonad tissue from close to and remote from the wreck site sampled in February 2005

whole scallop tissue

	'close' sites		'remote' sites	
ZINC	Black Rock	Tanera Beag	Sgeirean Glasa	Horse Island
	24.00	28.70	26.54	33.78
	18.28	22.12	27.53	20.46
	24.72	16.09	18.69	22.47
mean	22.33	22.30	24.25	25.57
S.D.	3.53	6.31	4.84	7.18
CADMIUM	Black Rock	Tanera Beag	Sgeirean Glasa	Horse Island
	2.48	3.24	4.00	1.81
	4.20	4.04	2.07	2.39
	3.76	3.59	2.89	1.78
mean	3.48	3.63	2.98	2.00
S.D.	0.89	0.40	0.97	0.34
LEAD	Black Rock	Tanera Beag	Sgeirean Glasa	Horse Island
	0.23	0.30	0.16	0.21
	0.15	0.13	0.13	0.10
	0.16	0.11	<LoD	0.09
mean	0.18	0.18	0.15	0.13
S.D.	0.04	0.11		0.07
ARSENIC	Black Rock	Tanera Beag	Sgeirean Glasa	Horse Island
	1.62	1.62	1.52	1.78
	1.44	1.74	1.70	1.85
	1.70	1.57	1.77	1.83
mean	1.59	1.64	1.67	1.82
S.D.	0.13	0.09	0.13	0.04

scallop gonad tissue

	'close' sites		'remote' sites	
ZINC	Black Rock	Tanera Beag	Sgeirean Glasa	Horse Island
	28.50	20.29	27.28	29.66
	31.79	25.50	28.43	27.64
	27.37	27.86	32.85	28.37
mean	29.22	24.55	29.52	28.56
S.D.	2.29	3.87	2.94	1.02
CADMIUM	Black Rock	Tanera Beag	Sgeirean Glasa	Horse Island
	0.13	0.27	0.23	0.14
	0.11	0.28	0.22	0.12
	0.22	0.27	0.34	0.13
mean	0.16	0.27	0.26	0.13
S.D.	0.06	0.01	0.07	0.01
LEAD	Black Rock	Tanera Beag	Sgeirean Glasa	Horse Island
	0.10	<LoD	<LoD	<LoD
	0.10	<LoD	<LoD	<LoD
	0.27	0.10	<LoD	<LoD
mean	0.16	0.10		
S.D.	0.10			
ARSENIC	Black Rock	Tanera Beag	Sgeirean Glasa	Horse Island
	1.88	1.47	0.92	1.43
	2.09	2.47	2.19	1.20
	2.63	2.79	1.84	1.52
mean	2.20	2.24	1.65	1.38
S.D.	0.39	0.69	0.66	0.17

S.D. = Standard Deviation

<LoD = Below Limit of Detection

Detection Limits for Zn = 0.517 mg kg^{-1}
Cd = 0.075 mg kg^{-1}
Pb = 0.087 mg kg^{-1}
As = 0.080 mg kg^{-1}

Table 2

Concentrations of zinc, cadmium, lead and arsenic (mg kg^{-1} wet weight) determined in crab white and brown meat from close to and remote from the wreck site in February 2005

crab white meat

				'remote' from wreck site
ZINC	Near wreck	North of wreck	South of wreck	Sgeirean Glasa
	68.75	39.40	58.46	84.17
	67.73	67.37	86.32	79.00
	65.35	68.46	96.79	84.44
mean	67.28	58.41	80.52	82.54
S.D.	1.75	16.47	19.81	3.07
CADMIUM	Near wreck	North of wreck	South of wreck	Sgeirean Glasa
	<LoD	<LoD	<LoD	<LoD
	<LoD	<LoD	<LoD	<LoD
	<LoD	<LoD	<LoD	<LoD
mean	<LoD	<LoD	<LoD	<LoD
S.D.				
LEAD	Near wreck	North of wreck	South of wreck	Sgeirean Glasa
	<LoD	<LoD	0.09	<LoD
	<LoD	<LoD	<LoD	<LoD
	<LoD	<LoD	<LoD	<LoD
mean	<LoD	<LoD	0.09	<LoD
S.D.				
ARSENIC	Near wreck	North of wreck	South of wreck	Sgeirean Glasa
	7.70	4.45	8.72	19.34
	7.66	10.17	15.96	17.14
	7.22	10.27	17.47	13.85
mean	7.53	8.30	14.05	16.78
S.D.	0.27	3.34	4.68	2.76

crab brown meat

				'remote' from wreck site
ZINC	Near wreck	North of wreck	South of wreck	Sgeirean Glasa
	17.57	11.57	18.31	17.34
	15.83	28.13	17.51	22.05
	13.62	18.54	22.13	23.29
mean	15.67	19.41	19.32	20.89
S.D.	1.98	8.31	2.47	3.14
CADMIUM	Near wreck	North of wreck	South of wreck	Sgeirean Glasa
	1.95	0.87	0.24	4.40
	2.80	4.29	0.79	0.84
	<LoD	0.21	1.44	0.67
mean	2.38	1.79	0.82	1.97
S.D.		2.19	0.60	2.11
LEAD	Near wreck	North of wreck	South of wreck	Sgeirean Glasa
	<LoD	<LoD	<LoD	<LoD
	<LoD	<LoD	<LoD	<LoD
	<LoD	<LoD	<LoD	<LoD
mean	<LoD	<LoD	<LoD	<LoD
S.D.				
ARSENIC	Near wreck	North of wreck	South of wreck	Sgeirean Glasa
	5.70	4.08	4.21	7.97
	5.83	8.02	8.40	7.40
	2.64	5.32	7.39	7.23
mean	4.72	5.81	6.67	7.53
S.D.	1.81	2.01	2.19	0.39

S.D. = Standard Deviation

<LoD = Below Limit of Detection

Detection Limits for Zn = 0.517 mg kg^{-1}
Cd = 0.075 mg kg^{-1}
Pb = 0.087 mg kg^{-1}
As = 0.080 mg kg^{-1}

FIGURE LEGENDS

1 Map showing location of wreck site and locations from where scallops and crabs were sampled around the Summer Isles a) over period October 2003 to January 2004 and in February 2005 and b) location of offshore reference site North Minch Fishing Box NM12.

2. Mean zinc concentrations (mg kg^{-1} wet weight) determined in a) whole scallop tissue and b) scallop gonad tissue from near to and remote from the wreck site in February 2005, including the period October 2003 to January 2004 together with the time zero sample from 29 June 2003, the day the *Jambo* grounded in the Summer Isles.

   Mean zinc concentrations (mg kg^{-1} wet weight) determined in c) crab white and d) brown meat in February 2005, including the period October 2003 to December 2004 and from the reference site in January 2004 together with the time zero sample from 29 June 2003.

3. Mean cadmium concentrations (mg kg^{-1} wet weight) determined in a) whole scallop tissue and b) scallop gonad tissue from near to and remote from the wreck site February 2005, including the period October 2003 to January 2004 together with the time zero sample from 29 June 2003.

   Mean cadmium concentrations (mg kg^{-1} wet weight) determined in c) crab white meat and d) crab brown meat in February 2005, including the period October 2003 to December 2004 and from the reference site in January 2004 together with the time zero sample from 29 June 2003.

4. Mean lead concentrations (mg kg^{-1} wet weight) determined in a) whole scallop tissue and b) scallop gonad tissue from near to and remote from the wreck site in February 2005, including the period October 2003 to January 2004 together with the time zero sample from 29 June 2003.

5. Mean arsenic concentrations (mg kg^{-1} wet weight) determined in a) whole scallop tissue and b) scallop gonad tissue from near to and remote from the wreck site in February 2005, including the period October 2003 to January 2004 together with the time zero sample from 29 June 2003.

   Mean arsenic concentrations (mg kg^{-1} wet weight) determined in crab c) white meat and d) crab brown meat in February 2005, including the period October 2003 to December 2004 and from the reference site in January 2004 together with the time zero sample from 29 June 2003.

Figure 1a

Scallop and crab sampling locations in the Summer Isles - February 2005

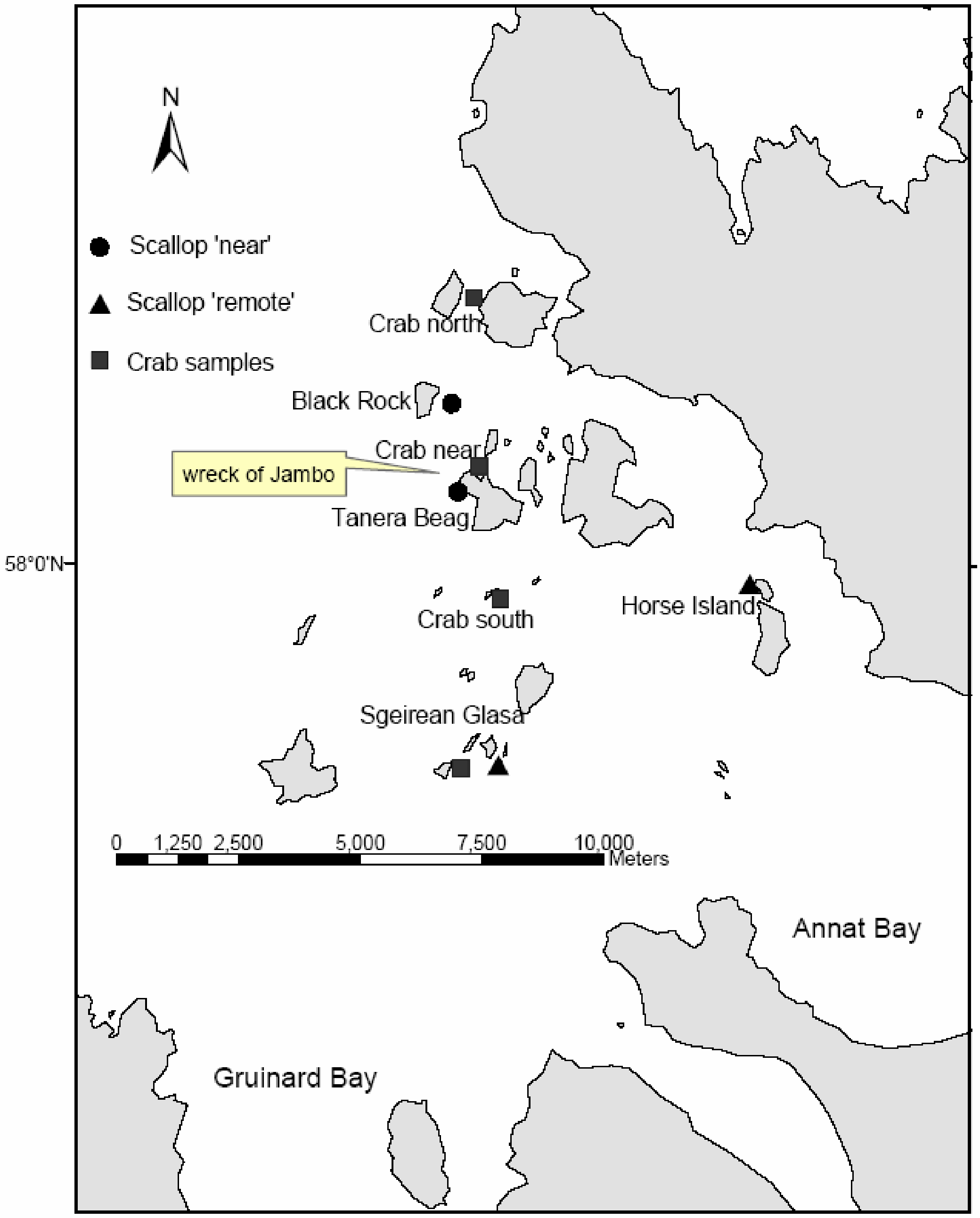


Figure 1b

Location of North Minch Fishing Box NM 12
for scallop sampling in January and February 2005

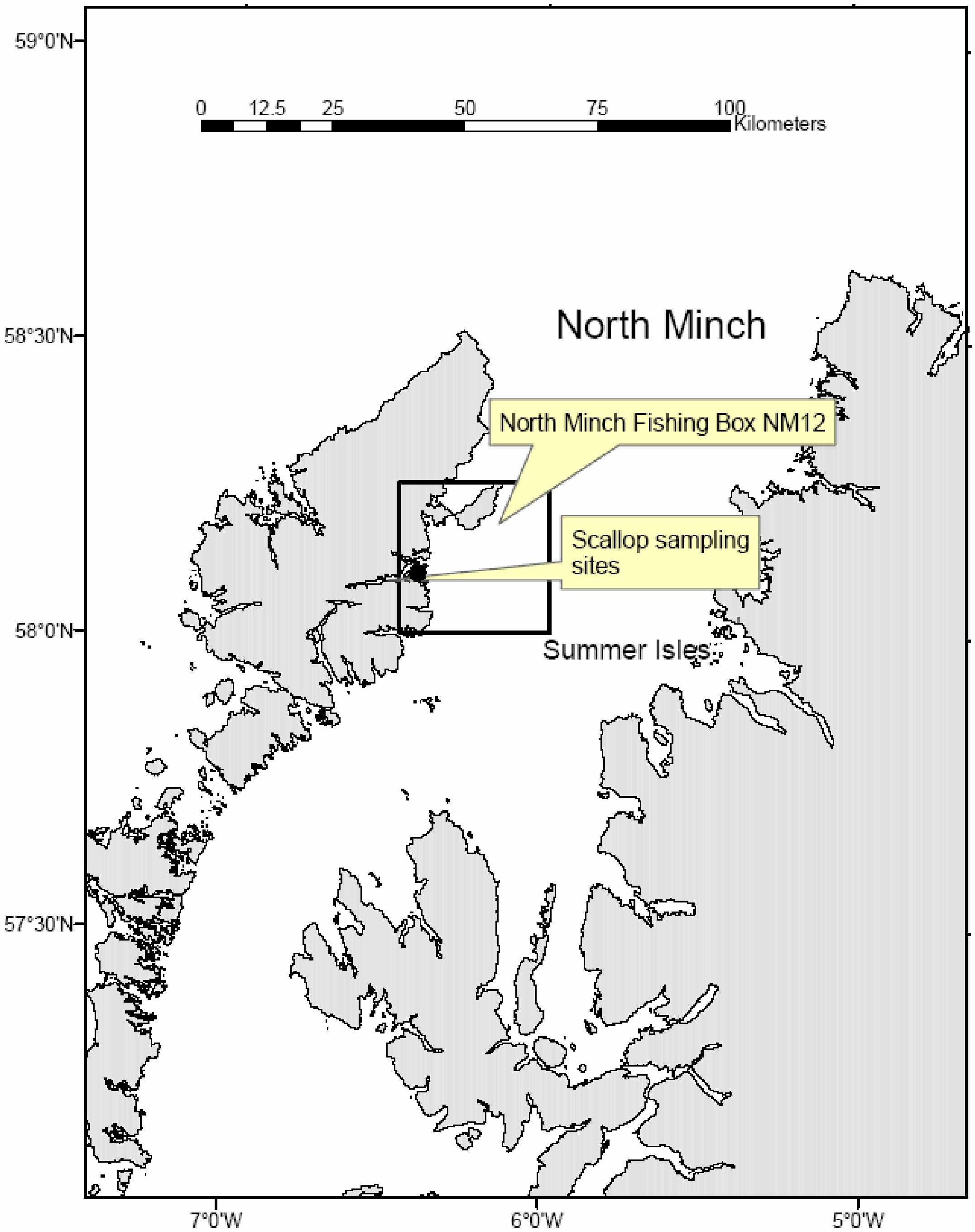
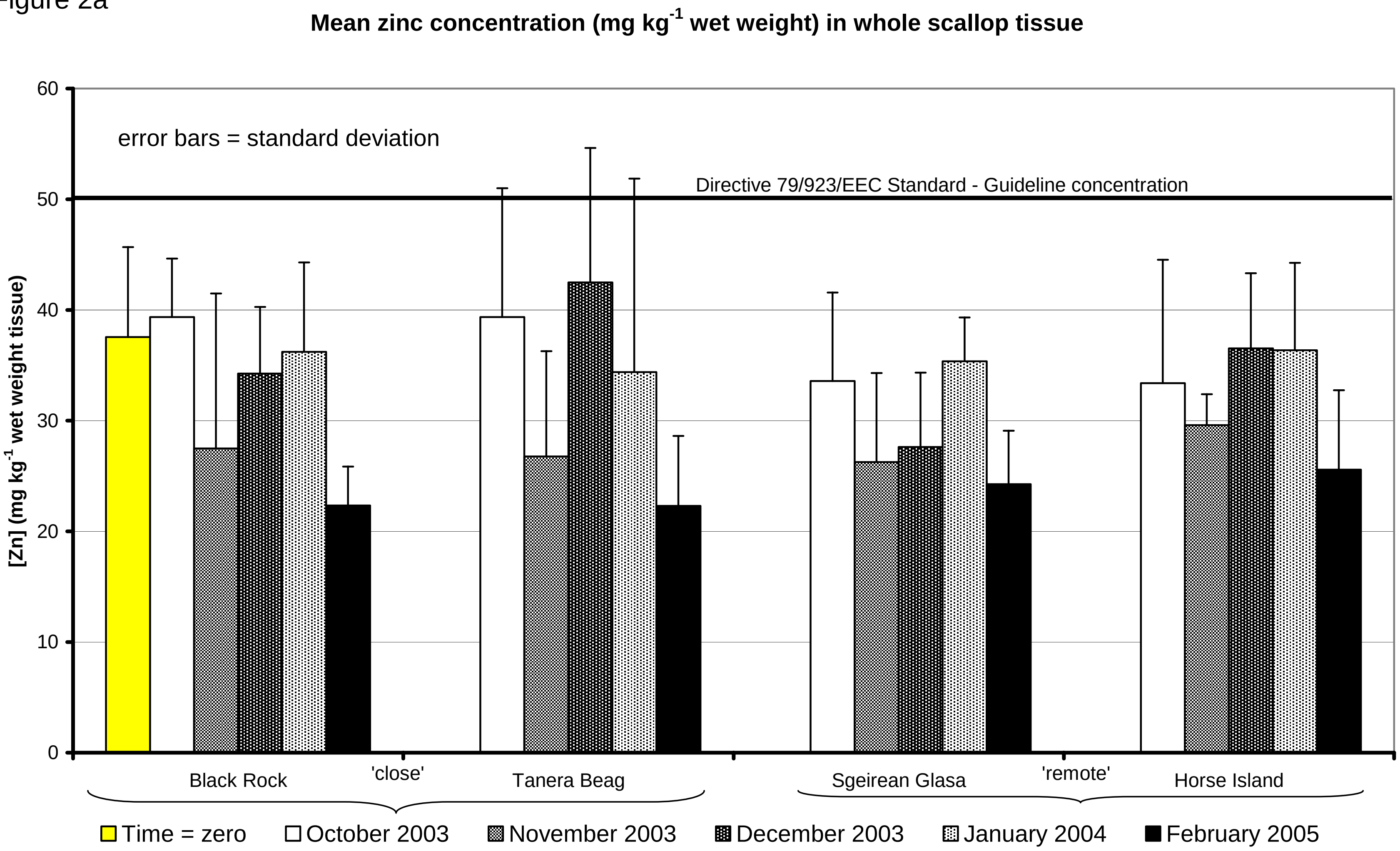


Figure 2a



Mean zinc concentration (mg kg-1 wet weight) in whole scallop tissue
60
50
40
30
20
10
0
[Zn] (mg kg-1 wet weight tissue)
error bars = standard deviation
Directive 79/923/EEC Standard - Guideline concentration
Black Rock
'close'
Tanera Beag
Sgeirean Glasa
'remote'
Horse Island
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 2b

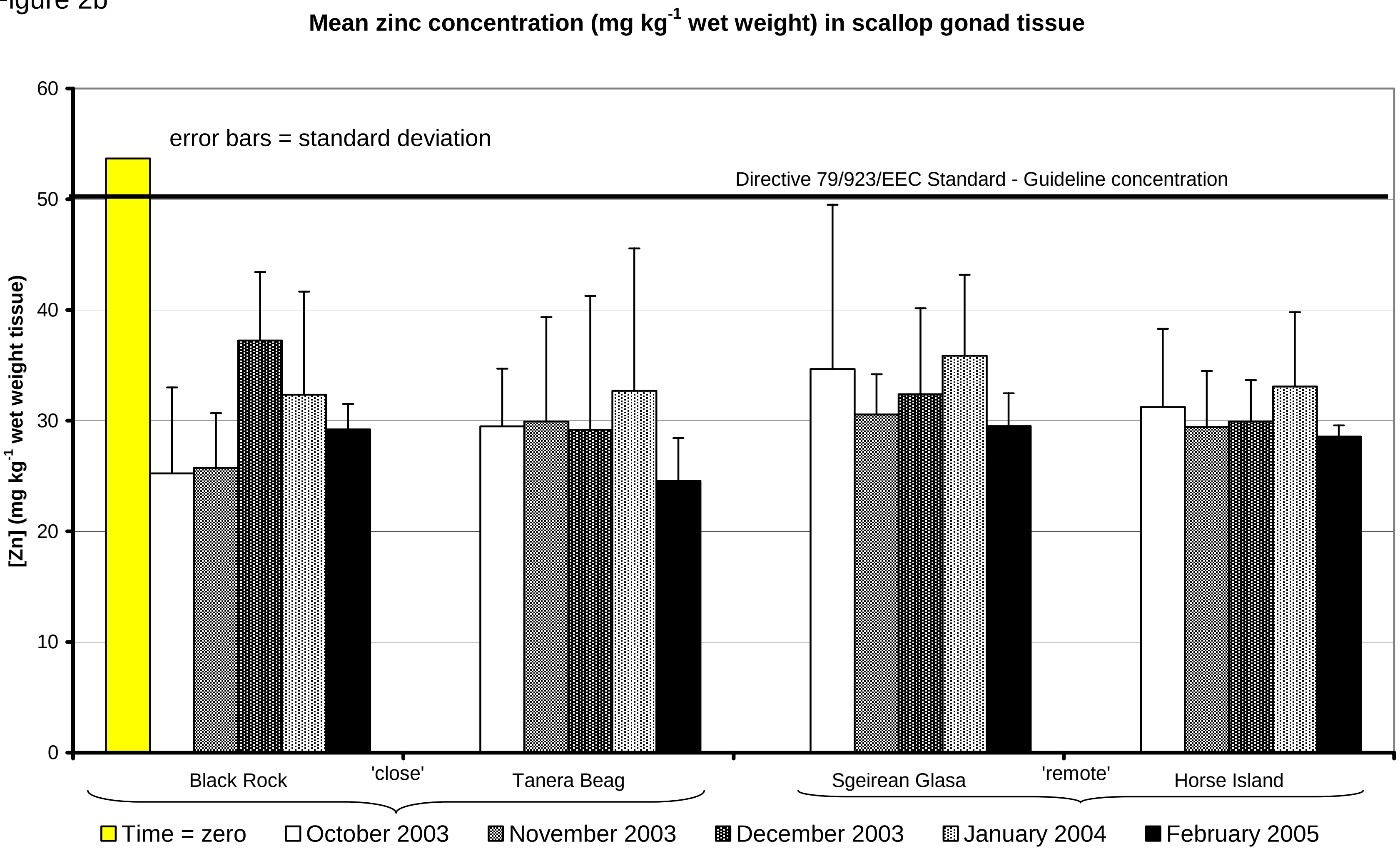
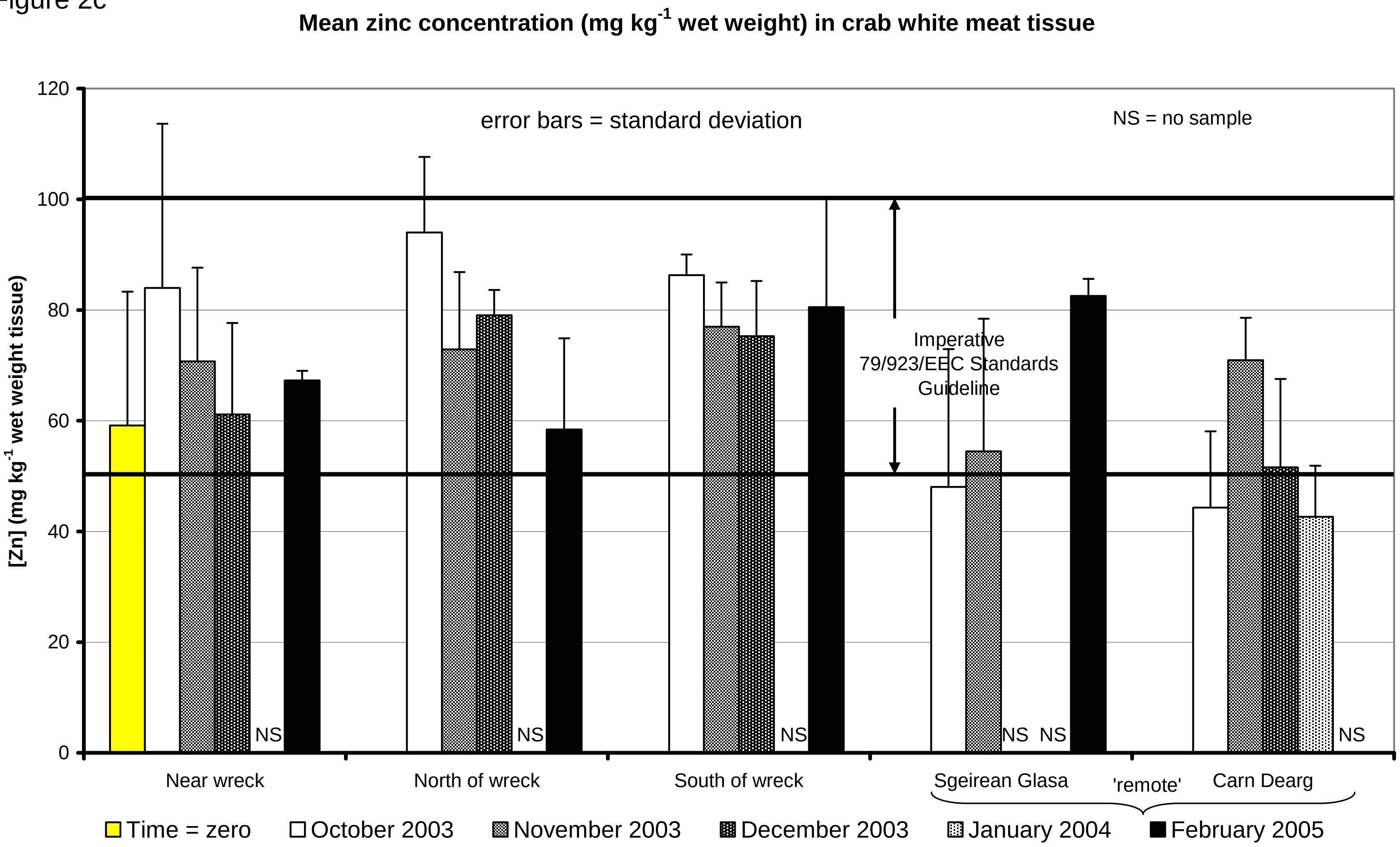

Mean zinc concentration (mg kg-1 wet weight) in scallop gonad tissue
[Zn] (mg kg-1 wet weight tissue)
60
50
40
30
20
10
0
error bars = standard deviation
Directive 79/923/EEC Standard - Guideline concentration
Black Rock
'close'
Tanera Beag
Sgeirean Glasa
'remote'
Horse Island
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 2c



Mean zinc concentration (mg kg-1 wet weight) in crab white meat tissue
error bars = standard deviation
NS = no sample
[Zn] (mg kg-1 wet weight tissue)
120
100
80
60
40
20
0
Imperative
79/923/EEC Standards
Guideline
NS
NS
NS
NS NS
NS
Near wreck
North of wreck
South of wreck
Sgeirean Glasa
'remote'
Carn Dearg
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 2d

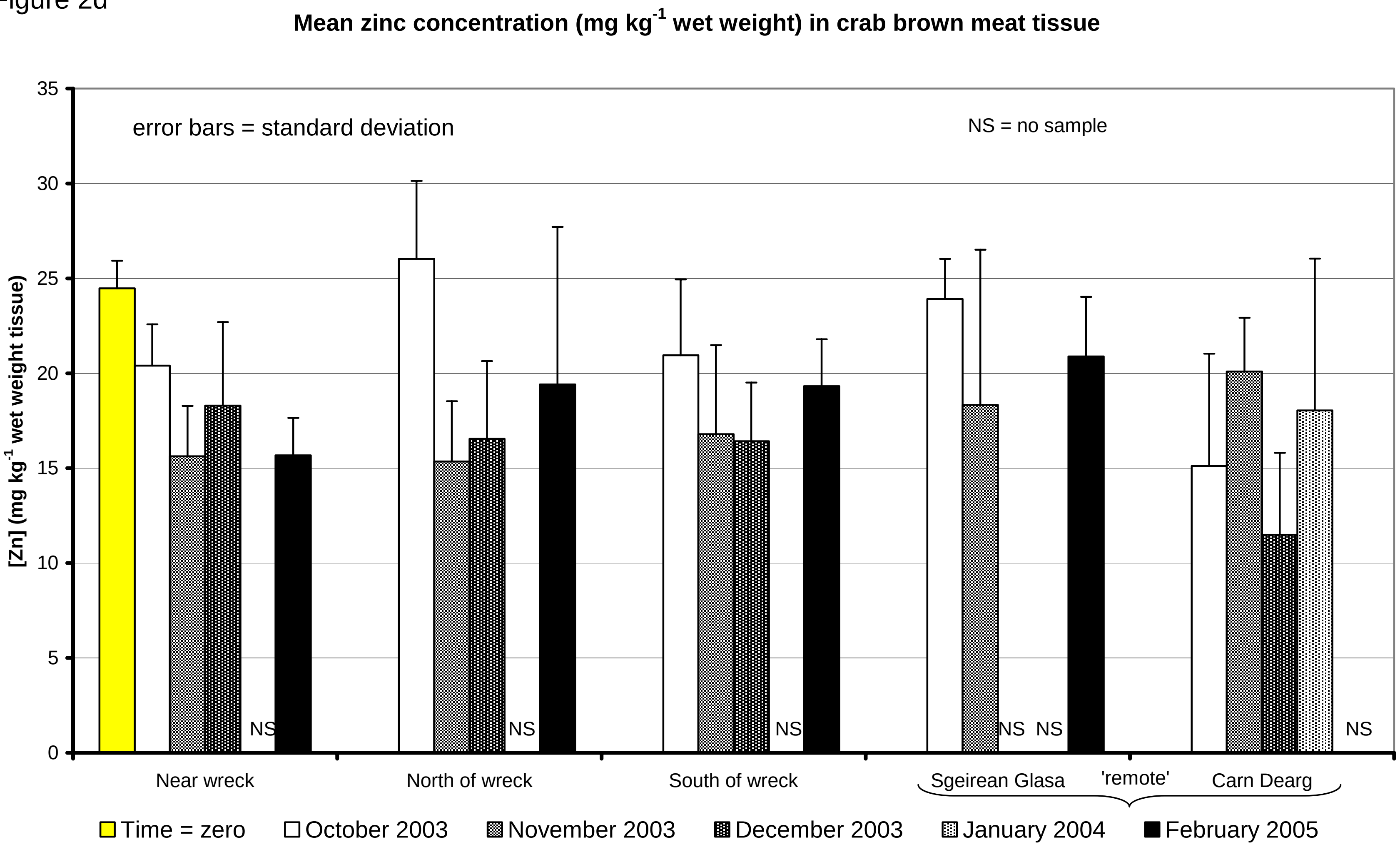
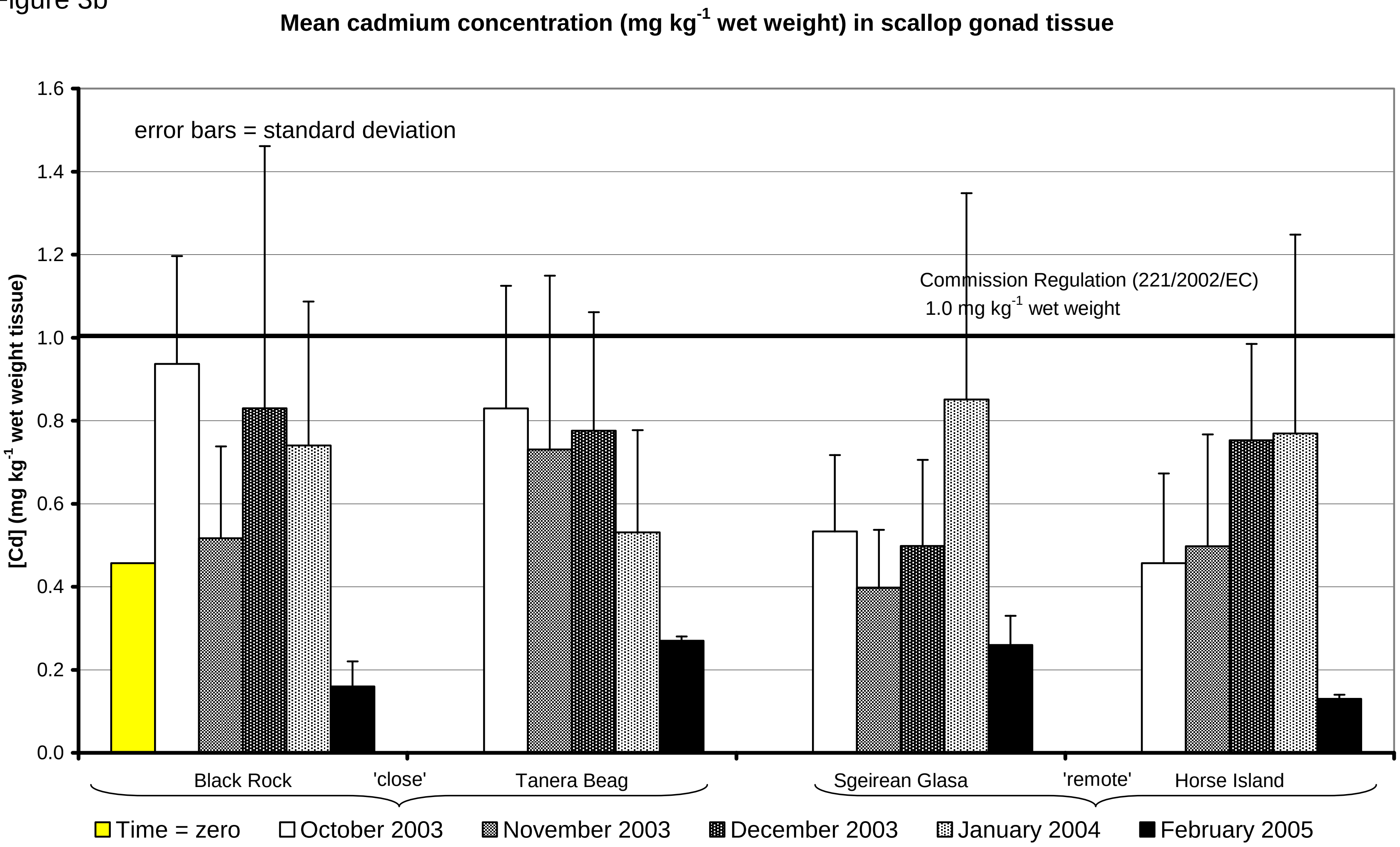

Mean zinc concentration (mg kg-1 wet weight) in crab brown meat tissue
error bars = standard deviation
NS = no sample
[Zn] (mg kg-1 wet weight tissue)
35
30
25
20
15
10
5
0
NS
NS
NS
NS
NS
NS
Near wreck
North of wreck
South of wreck
Sgeirean Glasa
'remote'
Carn Dearg
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 3a

Mean cadmium concentration (mg kg-1 wet weight) in whole scallop tissue
error bars = standard deviation
Commission Regulation (221/2002/EC)
1.0 mg kg-1 wet weight
[Cd] (mg kg-1 wet weight tissue)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Black Rock
'close'
Tanera Beag
Sgeirean Glasa
'remote'
Horse Island
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 3b



Mean cadmium concentration (mg kg-1 wet weight) in scallop gonad tissue
error bars = standard deviation
Commission Regulation (221/2002/EC)
1.0 mg kg-1 wet weight
[Cd] (mg kg-1 wet weight tissue)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Black Rock
'close'
Tanera Beag
Sgeirean Glasa
'remote'
Horse Island
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 3c

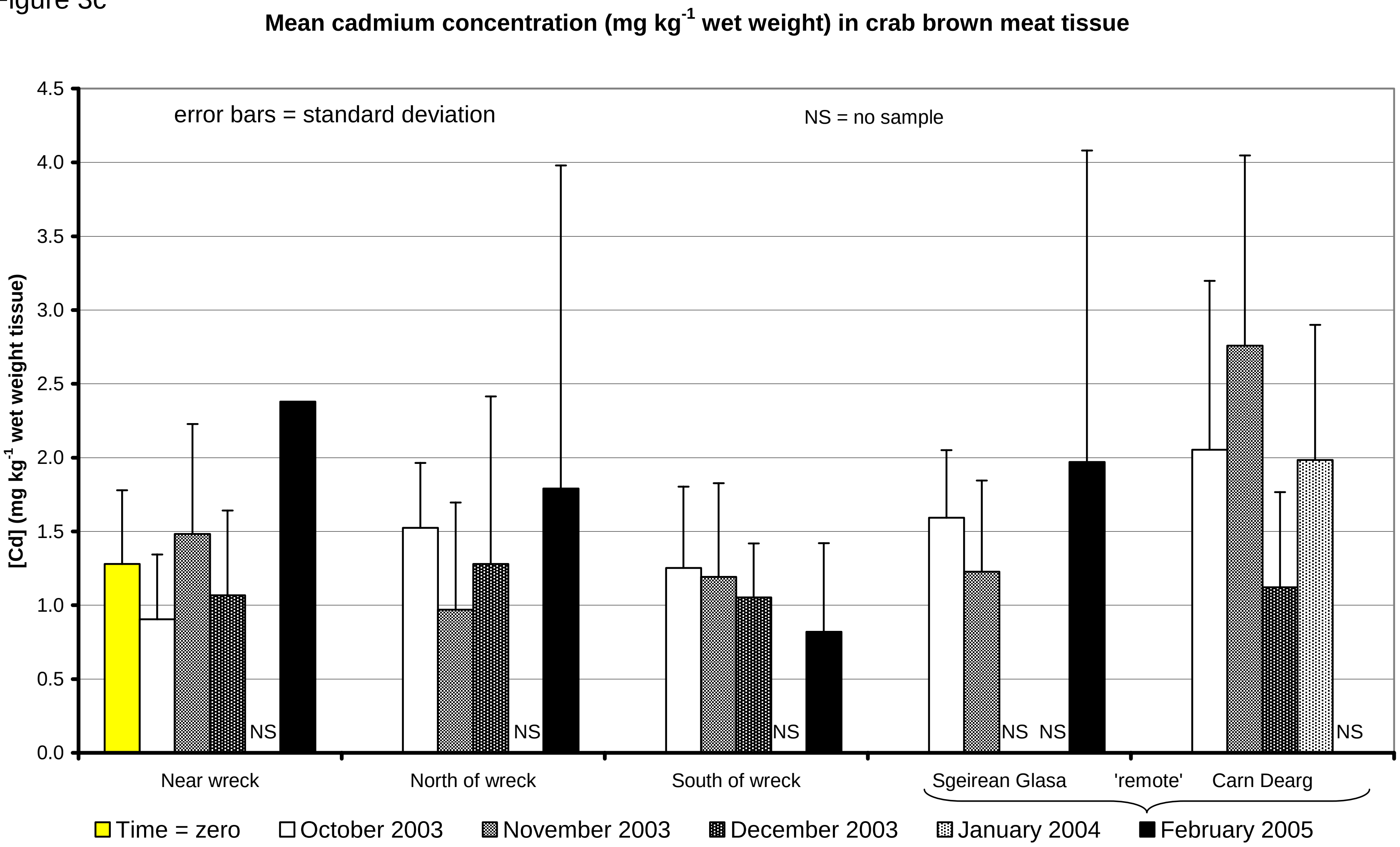

Mean cadmium concentration (mg kg-1 wet weight) in crab brown meat tissue
error bars = standard deviation
NS = no sample
[Cd] (mg kg-1 wet weight tissue)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
NS
NS
NS
NS NS
NS
Near wreck
North of wreck
South of wreck
Sgeirean Glasa
'remote'
Carn Dearg
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 4a

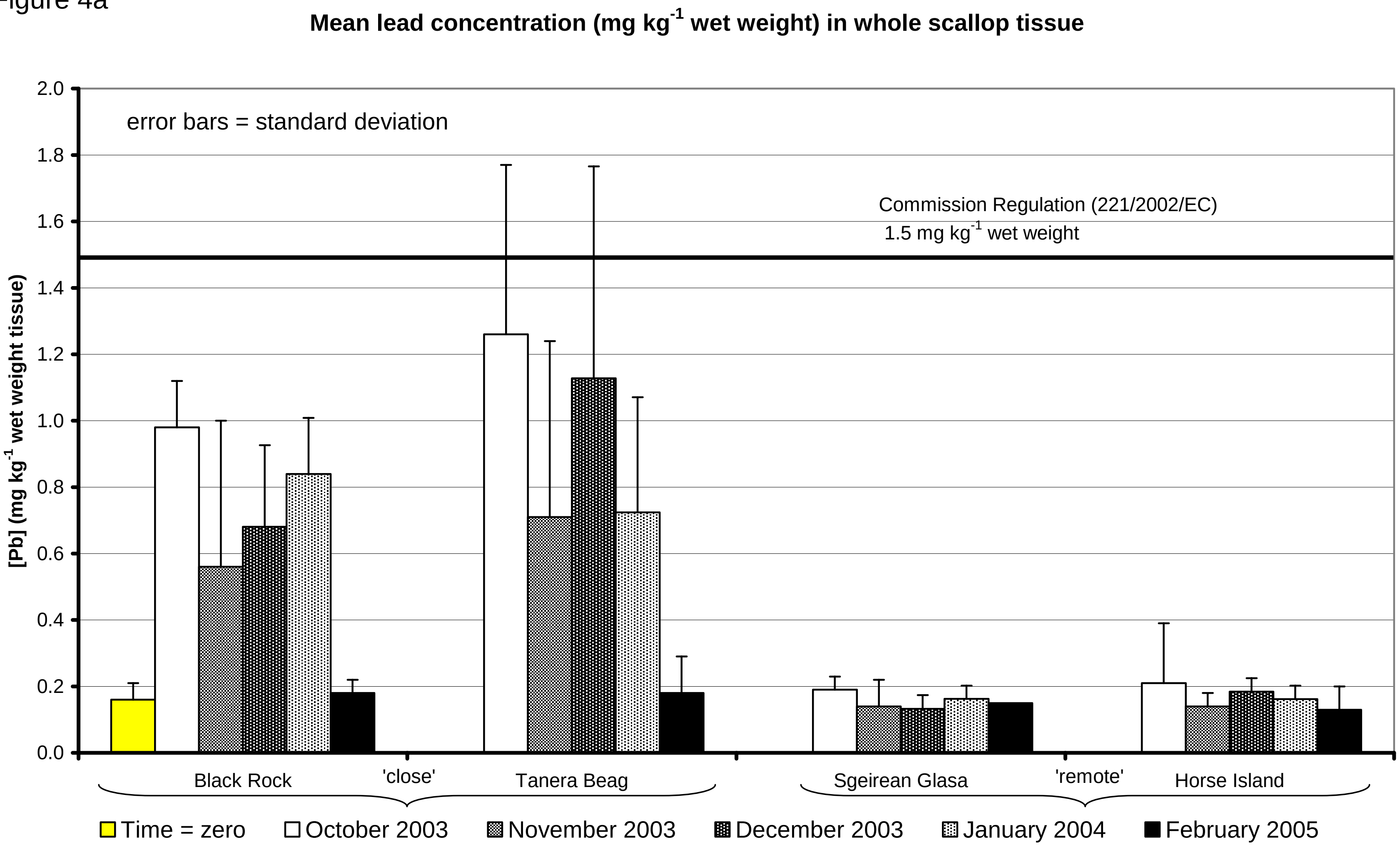

Mean lead concentration (mg kg-1 wet weight) in whole scallop tissue
error bars = standard deviation
Commission Regulation (221/2002/EC)
1.5 mg kg-1 wet weight
[Pb] (mg kg-1 wet weight tissue)
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
Black Rock
'close'
Tanera Beag
Sgeirean Glasa
'remote'
Horse Island
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 4b

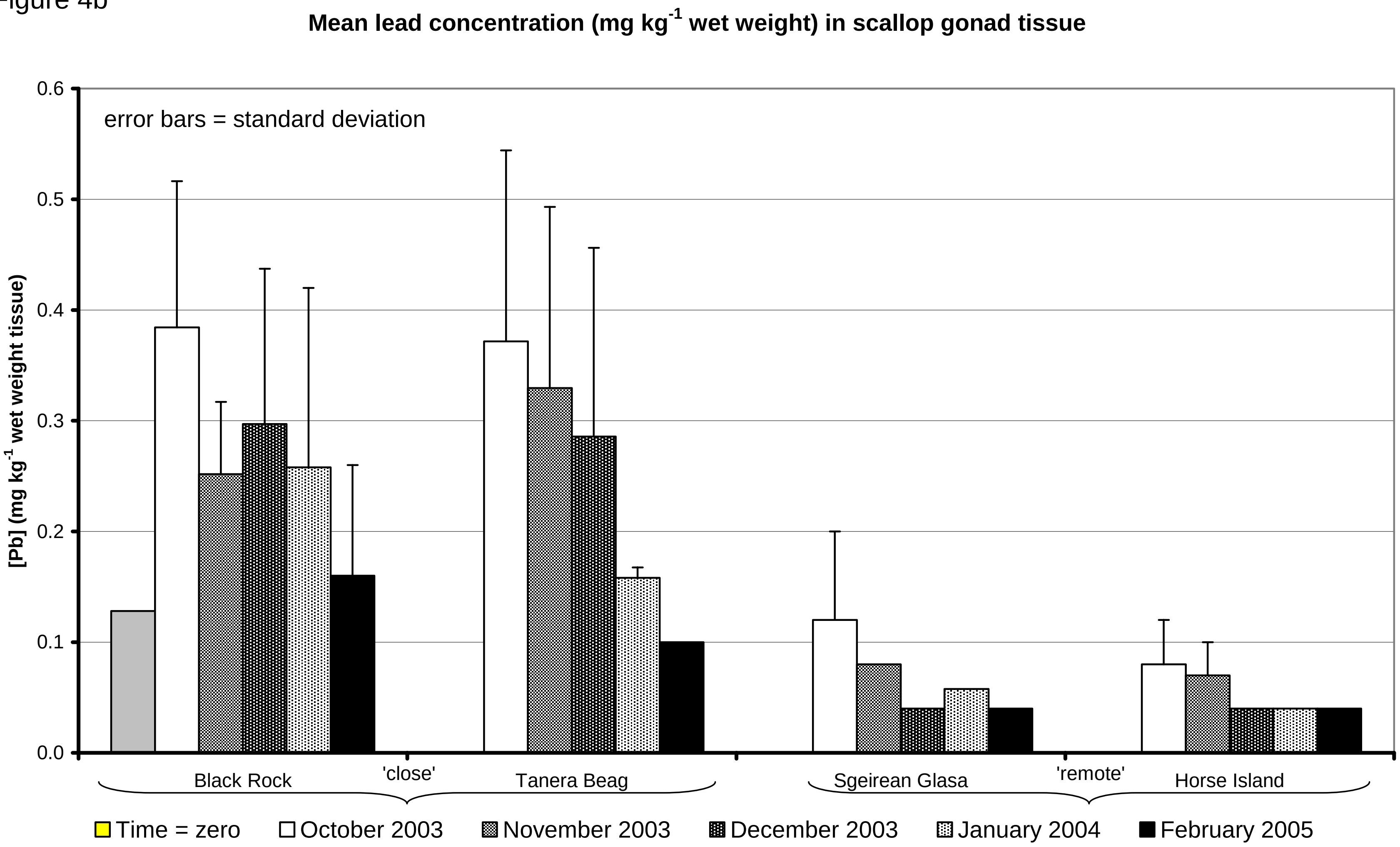

Mean lead concentration (mg kg-1 wet weight) in scallop gonad tissue
error bars = standard deviation
[Pb] (mg kg-1 wet weight tissue)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Black Rock
'close'
Tanera Beag
Sgeirean Glasa
'remote'
Horse Island
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 5a

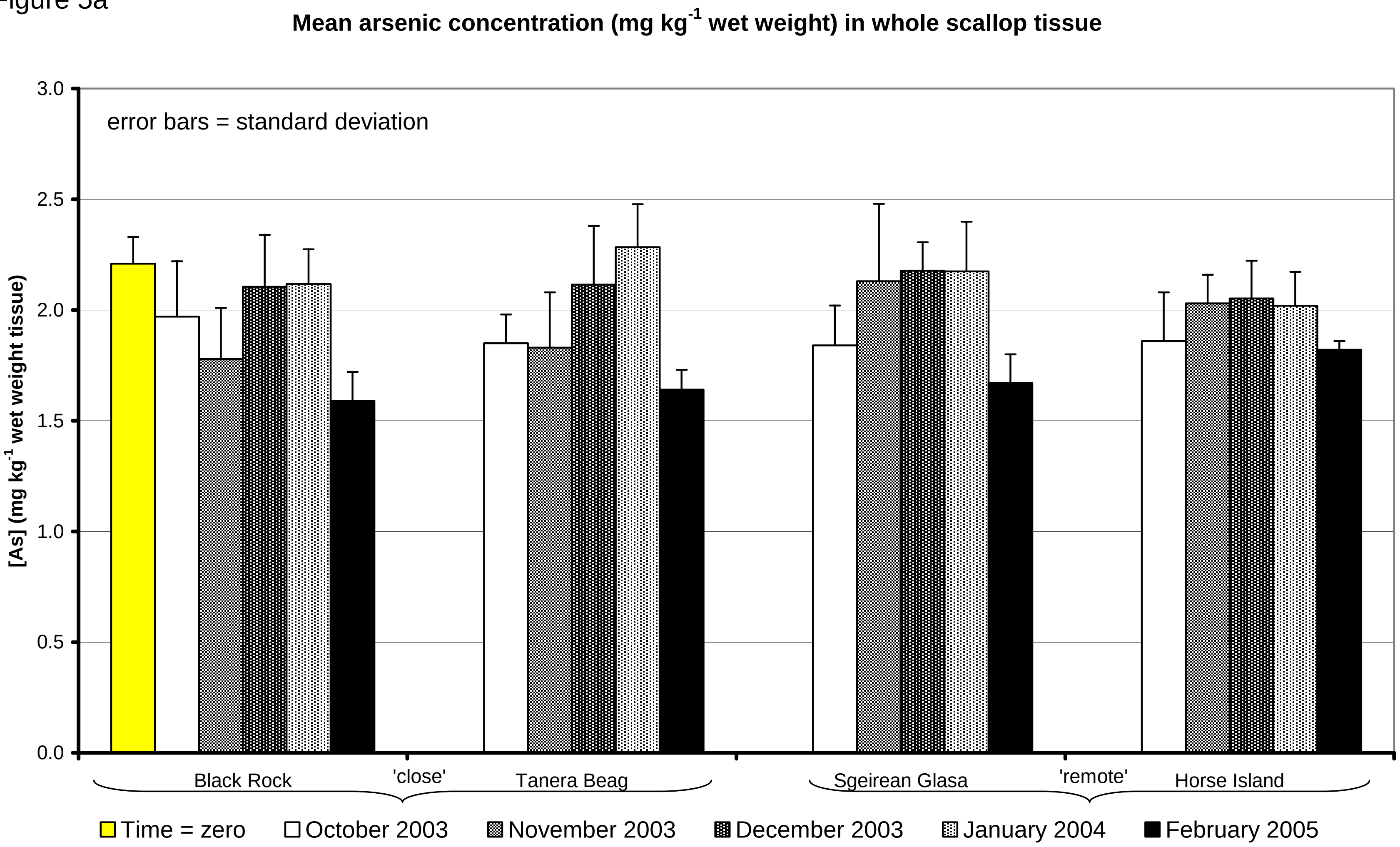

Mean arsenic concentration (mg kg-1 wet weight) in whole scallop tissue
3.0
2.5
2.0
1.5
1.0
0.5
0.0
error bars = standard deviation
[As] (mg kg-1 wet weight tissue)
Black Rock
'close'
Tanera Beag
Sgeirean Glasa
'remote'
Horse Island
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 5b

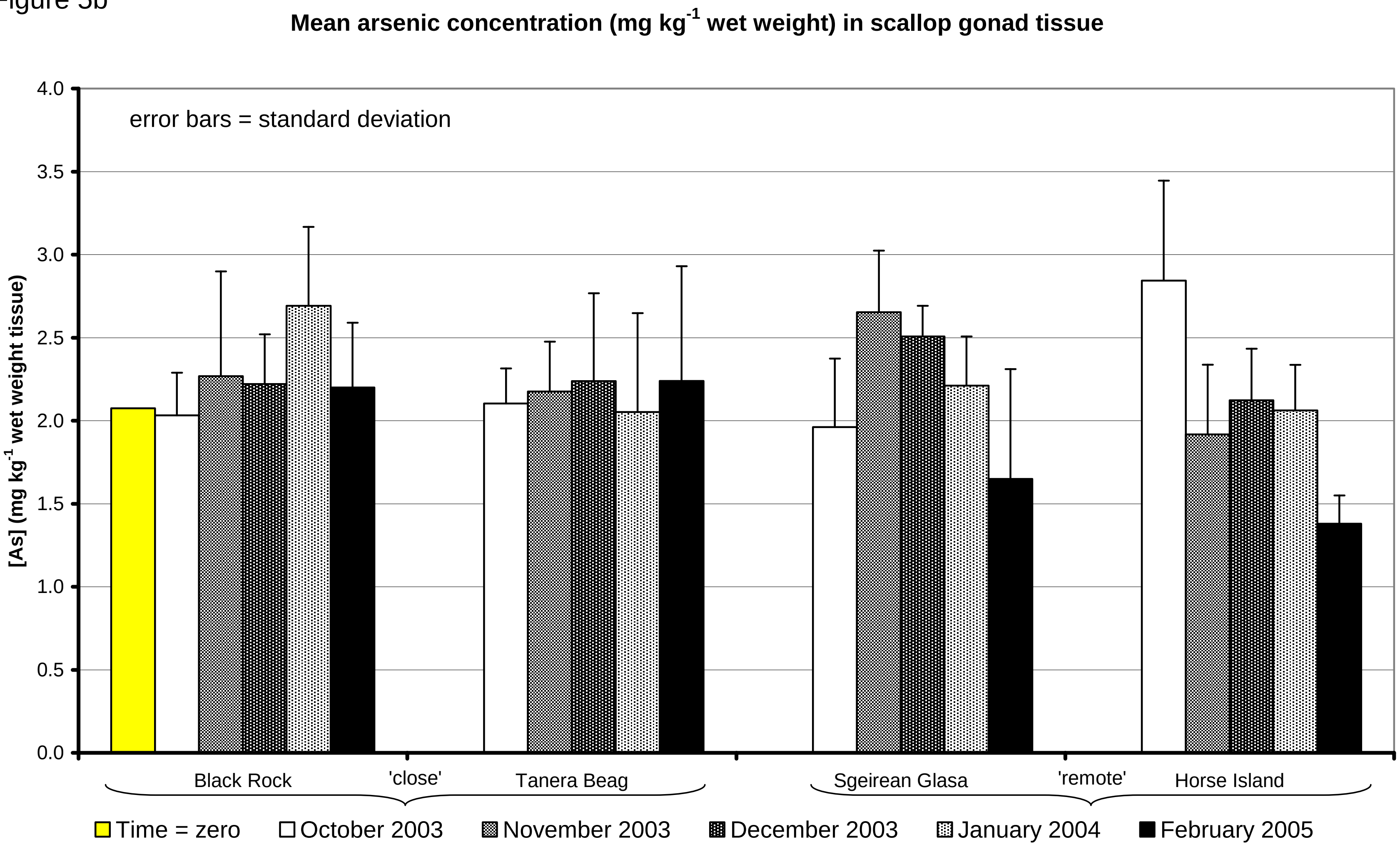
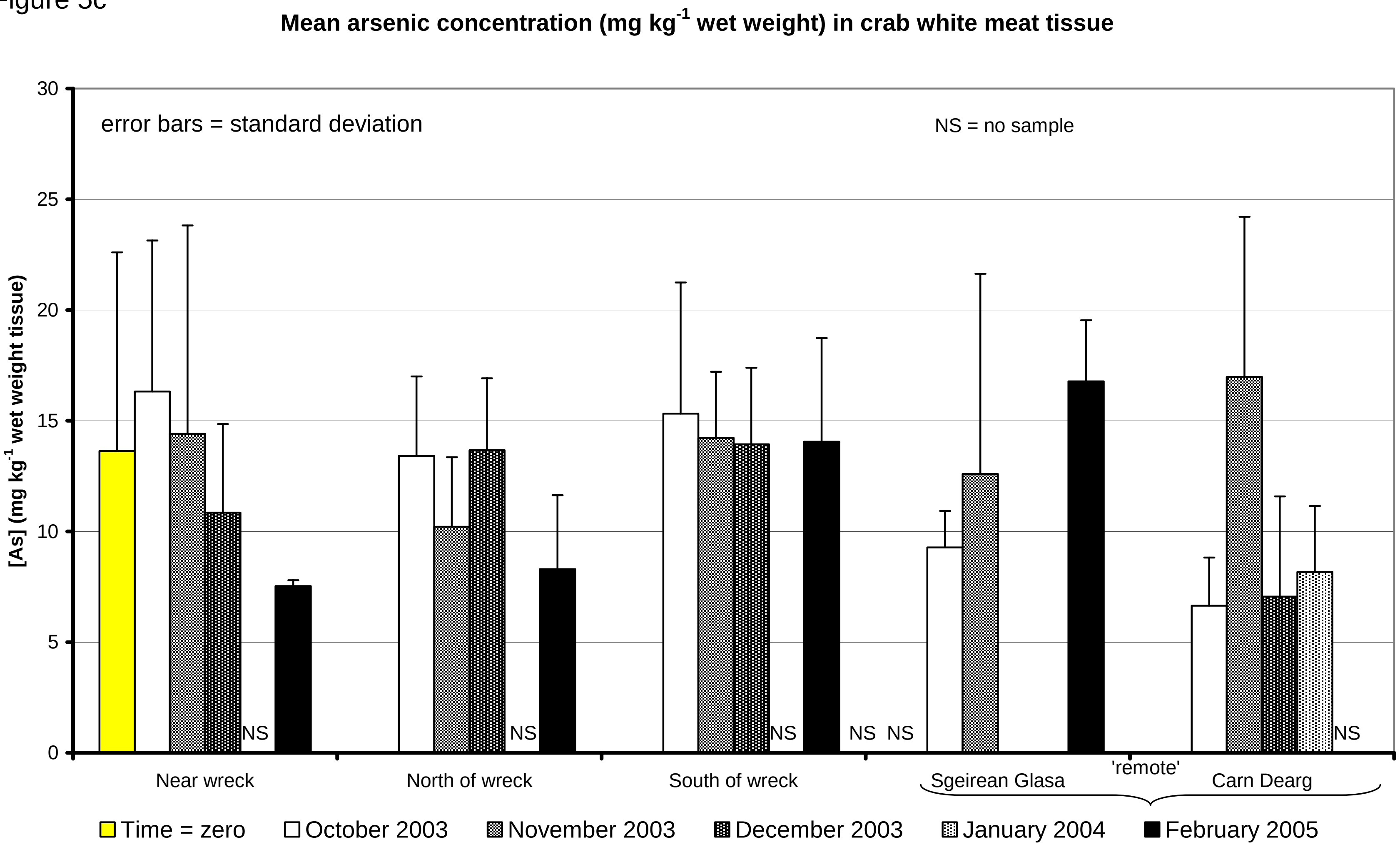
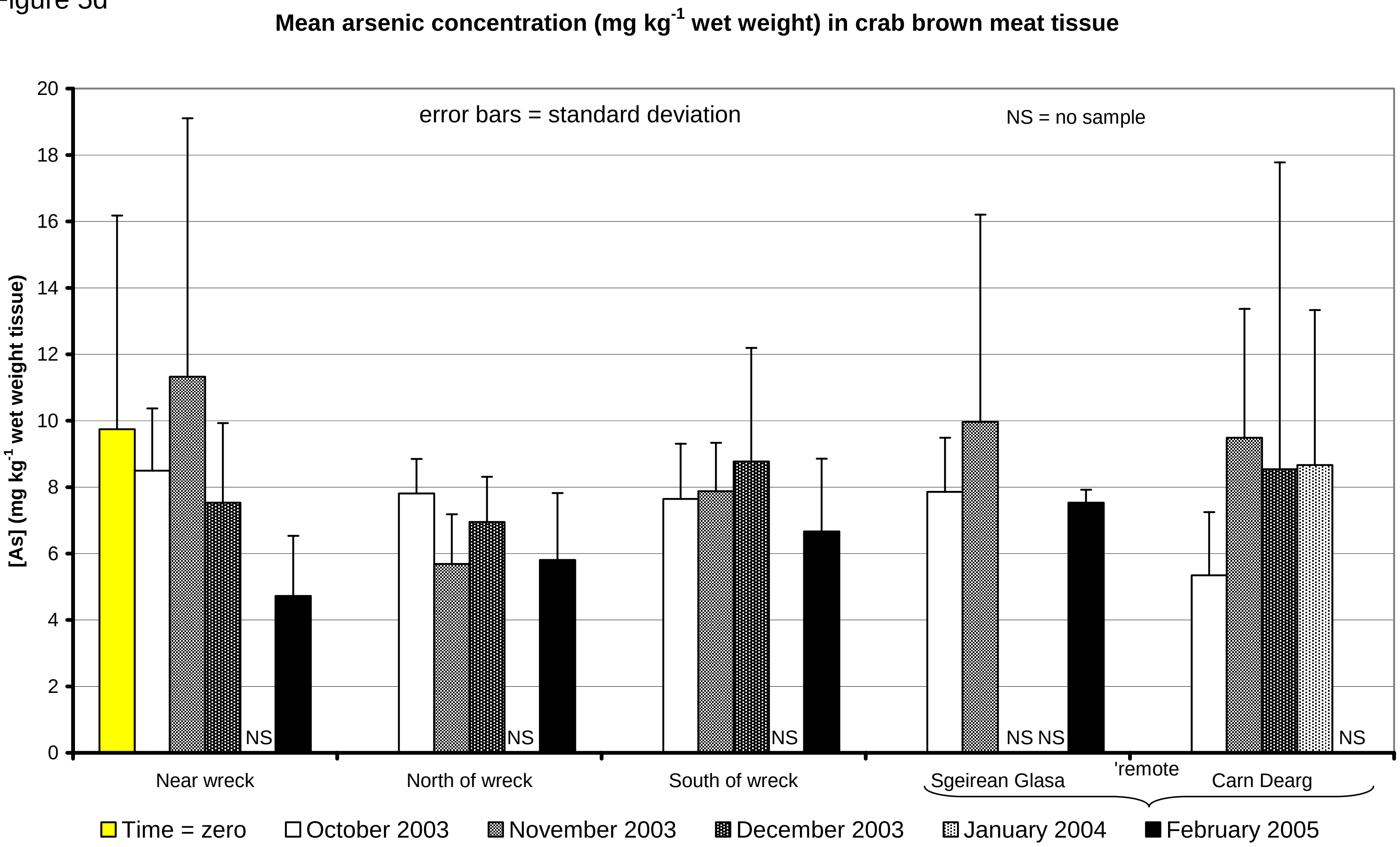

Mean arsenic concentration (mg kg-1 wet weight) in scallop gonad tissue
error bars = standard deviation
[As] (mg kg-1 wet weight tissue)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Black Rock
'close'
Tanera Beag
Sgeirean Glasa
'remote'
Horse Island
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 5c



Mean arsenic concentration (mg kg-1 wet weight) in crab white meat tissue
error bars = standard deviation
NS = no sample
[As] (mg kg-1 wet weight tissue)
30
25
20
15
10
5
0
NS
NS
NS
NS
NS
NS
Near wreck
North of wreck
South of wreck
Sgeirean Glasa
'remote'
Carn Dearg
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005

Figure 5d


Mean arsenic concentration (mg kg-1 wet weight) in crab brown meat tissue
error bars = standard deviation
NS = no sample
[As] (mg kg-1 wet weight tissue)
20
18
16
14
12
10
8
6
4
2
0
NS
NS
NS
NS NS
NS
Near wreck
North of wreck
South of wreck
Sgeirean Glasa
'remote
Carn Dearg
Time = zero
October 2003
November 2003
December 2003
January 2004
February 2005