Supplementary Materials

Anthropogenic effects on the marine environment adjacent to Palmer Station, Antarctica

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Supplementary Protocols

Protocol S1. Additional laboratory contaminant analysis details

Organochlorine and hydrocarbon compound concentrations were determined by gas chromatography/mass spectrometry (GC-MS). Mercury concentrations were determined by cold vapor atomic absorption spectroscopy (CVAAS), while other metal concentrations were determined using inductively coupled plasma mass spectrometry (ICP-MS).

Metals

Instrumental analysis of metals (excluding mercury) was performed using a NexION 300D ICP-MS (PerkinElmer, Waltham, MA) after freeze-dried sediment samples were first digested in nitric acid and then hydrogen peroxide. The ICP-MS was optimized and calibrated each day of operation using one analytical blank (methylene chloride) and trace metals standard I (#C809J26, Thomas Scientific, Swedesboro, NJ).

Samples for mercury analyses were first digested with nitric acid-permanganate of the dried sediment or tissue followed by stannous chloride reduction to Hg metal. Detection was by CVAAS using a flow injection mercury system (Model FIMS-400, Perkin Elmer) using GERG standards (Aly et al., 2021).

PCBs, hydrocarbons, and pesticides

Samples were analyzed for organochlorine pesticides (OCs), PCB, PAHs and aliphatic hydrocarbons following GERG's Standard Operating Procedures (SOPs). The samples were thawed and homogenized, freeze dried and extracted in automated accelerated solvent extractor (ASE) cells together with a drying agent (Hydro matrix) to remove any water prior to analysis. More details regarding these methods can be found elsewhere (e.g., Yogui & Sericano. 2009; Aly et al, 2021).

Briefly, samples and associated QA/QC samples (i.e., blank, matrix spike, duplicate and Standard Reference material, if available) were spiked with the appropriate surrogate standards [d_{10}-naphthalene,d_{10}-acenaphthene,d_{10}-phenanthrene,and d_{12}-chrysene, for PAHs; d_{26}-nC_{12}, d_{42}-nC_{20}, d_{50}-nC_{24}, and d_{62}-nC_{30}, for aliphatic hydrocarbons; PCB congeners 103 and 198 and 4,4-dibromooctafluorobiphenyl (DBOFB), for PCBs and organochlorine pesticides before extraction.

Following the ASE extraction, the sample extracts were purified by partially deactivated silica/alumina column chromatography to eliminate the interfering materials and treated with acid washed copper beads to eliminate potential interference from sulfur compounds.

PAH, PCB, and OC analyses were performed by gas chromatography/mass spectrometry (GC/MS, Agilent Technologies 6890N GC System/5975C inert MSD) in the selective ion mode (SIM) after the addition of the appropriate internal standards [i.e., d_{10}-Fluorene, $d1_2$-Benzo(a)pyrene), for PAHs, and 2,4,5,6-tetrachloro-*m*-xylene (TCMX), for PCBs and OCs, used to evaluate the efficiency of the analytical methods. The sample extracts were splitless-injected into a 30m× 0.25mm i.d. (0.25 μm film thickness) DB-5MS fused silica capillary column (J&W Scientific, Inc. or similar) at an initial temperature of 60 °C, held for 3 min, and temperature was then programmed at 12°C min^{-1} to 300 °C with a hold of 6 min at the final temperature, for PAHs; for PCBs the initial temperature was set at 75 °C, held for 3 min, and then ramped to 150, 260, and 300 °C at 15, 2, and 20 °C min^{-1}, respectively, with a final hold of for 3 min; for PCBs, the initial temperature was programed from 130 °C, after a hold of 1 min, to 154, 210, and 300 °C at 12, 2, and 3 °C min^{-1}, respectively, with a final holding time of 5 min. Aliphatic hydrocarbons were analyzed by GC-FID, after the addition of d_{54}-nC_{26} as internal standard, using a DB-5MS fused silica capillary column and an oven-temperature program starting at 40 °C, held for 2 min and ramped up to 320 °C at a rate of 6 °C per min and a final hold of 15 min. The GC/MS and GC-FID were calibrated by injections of standards at five different concentrations. Identification of target analytes was based on the retention time of their respective peaks (Aliphatic hydrocarbons) or the respective quantitation ions and a series of confirmation ions (PAHs, PCBs, OCs).

Carbon Content

Carbon concentrations (TOC and TIC) were determined using a LECO Model 523-300 induction furnace with a Horiba PIR-2000 infrared (IR) detector, and quantified using an integrator (Sweet & Wade 1998). Total carbon (TC) was determined on an unmodified dry sample, while total organic carbon (TOC) was determined after sample acidification. Total inorganic carbon (TIC) was calculated as the difference between total carbon and total organic carbon.

Quality Assurance/ Quality Control

Each batch of up to 20 samples (all analyses) was accompanied by a duplicate of one of the samples (to test sample homogeneity and analytical variability), a procedural blank (to test for laboratory contamination) , a spiked blank (to determine matrix interferences), a matrix spike (to determine any matrix-dependent interferences), and standard reference material (SRM) with certified concentrations (to verify our data is comparable to analytical results from other laboratories around the world. Acceptance criteria for these QA/QC measures are listed below:

Element	Control Limit Criteria	Frequency
Instrument Calibration	Minimum of 5 standards; Response factor % RSD within ± 15% for all target compounds.	Initial and after any failures of continuing calibrations.
Instrument Blank	Instrument free of interfering contamination or perform necessary maintenance.	Prior to analysis of all analytical batches.
GERG Standard Check	Analytes within ± 25% or average of lab certified concentration with no analytes > 35% or recalibrate.	Prior to analysis of all analytical batches.
Continuing Calibration Verification (CCV)	Percent difference for all response factors within ± 15% or average of initial calibration; no single analyte greater than 25% or recalibrate and reanalyze back to last passing CCV.	After initial calibration, after 8-10 extracts during the analytical sequence, and at end of analytical sequence.
Surrogate Recovery	Recovery of 40 to 120% for all surrogates. See Section 3 for corrective actions.	All samples.
Method Blank	No analytes > 3x MDL. See Section 3 for exceptions to need for re-extraction.	One per QC batch.
Duplicates (if applicable)	RPD $\leq$ 25% for all analytes > 10 x MDL. See Section 3 for corrective action.	One per QC batch.
Matrix Spike, Matrix Spike Duplicate (if applicable)	% recovery within 40 to 120%. RPD for the spike recoveries should be $\leq$ 25% for all analytes. See Sections 3 for corrective actions.	One per QC batch.
Standard Reference Material (if applicable)	Recovery of 80% of certified or non-certified compounds within 30% of certified range for those analytes > 10x MDL. See Section 3 for corrective action.	One per QC batch.

References

Yogui, G.T. & Sericano, J.L. 2009. Levels and pattern of polybrominated diphenyl ethers in eggs of Antarctic seabirds: Endemic versus migratory species. *Environmental Pollution*, 157, 975-980, 10.1016/j.envpol.2008.10.016

Aly, N.A., Casillas, G., Luo, Y-S., McDonald, T.J., Wade, T.L., Zhu, R., Newman, G., Lloyd, D., Wright, F.A., Chiu, W.A. & Rusyn I. 2021 Environmental impacts of Hurricane Florence flooding in eastern North Carolina: temporal analysis of contaminant distribution and potential human health risks. *Journal of Exposure Science & Environmental Epidemiology*, 10.1038/s41307-021-00325-5

Supplementary Tables

Table S1. Summary statistics of sediment chemistry and grain size. N = 24.

Variable	Units	Mean	Std Dev	Median	Minimum	Maximum
TOC	%	0.29	0.18	0.285	0.02	0.75
TIC	%	0.08	0.07	0.08	0	0.2
TPH	ppm	2.75	2.37	2.21	0	8.91
PCB	ng/g	14.69	71.99	0	0	352.66
DDT	ng/g	1.18	5.17	0	0	25.26
PAH	ng/g	89.76	167.06	34.63	6.23	815.55
Gravel	%	7.91	9.74	4.27	0	31.86
Sand	%	43.32	24.46	39.59	11.17	83.73
Silt	%	42.06	28.04	49.29	3.72	77.69
Clay	%	6.72	4.77	5.13	1.03	15.13
Mud	%	48.77	31.96	56.95	5.16	88.83

Table S2. Abundances (n m^{-2}) of each species at each station. Cum = cumulative.

Species	Family	Class	Intake		North Palmer		Outfall		Pier		Mean	Mean	Cum.
			18 m	24 m	18 m	24 m	18 m	24 m	18 m	24 m	(n m^{-2})	(%)	(%)
Nematoda (unidentified)	Nematoda	Nematoda	3309	34226	4255	4255	15978	24109	37630	15127	17361	24.8	24.8
Podoceropsis sp.	Photidae	Amphipoda	0	473	1891	662	0	29026	9455	40655	10270	14.6	39.4
Oligochaeta (unidentified)	Oligochaeta	Oligochaeta	1891	27229	0	1796	32146	945	5106	1324	8805	12.6	52.0
Eudorella splendida	Leuconidae	Cumacea	0	0	5484	4822	0	12575	9360	12007	5531	7.9	59.9
Onoba subantarctica	Rissoidae	Gastropoda	5295	0	0	0	3025	662	5295	5767	2505	3.6	63.4
Ophelina syringopyge	Opheliidae	Polychaeta	1229	3687	4255	189	3309	2269	2458	378	2222	3.2	66.6
Maldanidae (unidentified)	Maldanidae	Polychaeta	95	95	0	0	0	95	189	16073	2068	2.9	69.5
Oriopsis sp.	Sabellidae	Polychaeta	95	15789	0	0	0	0	0	0	1985	2.8	72.4
Haplocheira plumosa	Aoridae	Amphipoda	0	95	0	95	0	5673	1891	5862	1702	2.4	74.8
Monoculodes scabriculosus	Oedicerotidae	Amphipoda	95	2647	0	0	0	2553	5484	2836	1702	2.4	77.2
Dispio sp.	Spionidae	Polychaeta	0	0	11062	0	0	0	0	0	1383	2.0	79.2
Apistobranchus glacierae	Apistobranchidae	Polychaeta	662	9549	0	0	662	0	0	0	1359	1.9	81.1
Mysella sp.	Lasaeidae	Bivalvia	7942	378	0	189	1040	0	567	95	1276	1.8	83.0
Rhodine antarctica	Maldanidae	Polychaeta	0	1891	1324	1324	1229	0	473	378	827	1.2	84.1
Heterophoxus videns	Phoxocephalidae	Amphipoda	284	945	0	0	567	1229	2269	1135	804	1.1	85.3
Nemertea (unidentified)	Nemertea	Nemertea	95	756	473	756	2836	189	378	473	745	1.1	86.3
Aphelochaeta sp.	Cirratulidae	Polychaeta	1135	2080	567	1702	0	0	0	0	685	1.0	87.3
Amphipoda (unidentified)	Amphipoda	Amphipoda	0	95	0	0	0	0	4160	189	555	0.8	88.1
Hippomedon kergueleni	Lysianassidae	Amphipoda	0	0	1607	0	1891	0	284	473	532	0.8	88.9
Heterophoxus sp.	Phoxocephalidae	Amphipoda	0	0	2836	1229	0	0	0	0	508	0.7	89.6
Spiophanes tcherniai	Spionidae	Polychaeta	1796	1796	0	0	0	0	0	0	449	0.6	90.2
Leitoscoloplos kergulensis	Orbiniidae	Polychaeta	473	1702	95	189	851	95	95	0	437	0.6	90.9
Capitella perarmata	Capitellidae	Polychaeta	0	189	945	1796	95	95	0	95	402	0.6	91.4
Gromia oviformis	Allogromiidae	Foraminifera	0	851	0	0	945	1040	95	95	378	0.5	92.0
Munna sp.	Munnidae	Isopoda	0	1324	0	0	189	0	189	662	295	0.4	92.4
Monoculodes sp.	Oedicerotidae	Amphipoda	95	0	0	1796	378	0	0	0	284	0.4	92.8
Ophryotrocha claparedei	Dorvilleidae	Polychaeta	0	1229	473	0	284	0	0	0	248	0.4	93.2
Brania sp.	Syllidae	Polychaeta	0	756	0	95	0	0	284	756	236	0.3	93.5
Axiothella sp.	Maldanidae	Polychaeta	0	473	0	1229	0	0	0	189	236	0.3	93.8
Paradoneis lyra	Paraonidae	Polychaeta	189	0	0	0	1040	0	473	0	213	0.3	94.1

Species	Family	Class	Intake		North Palmer		Outfall		Pier		Mean	Mean	Cum.
			18 m	24 m	18 m	24 m	18 m	24 m	18 m	24 m	(n m^{-2})	(%)	(%)
Amphicteis antarctica	Ampharetidae	Polychaeta	0	473	0	0	662	0	284	189	201	0.3	94.4
Campylaspis sp.	Nannastacidae	Cumacea	95	1324	0	0	0	0	95	0	189	0.3	94.7
Austrosignum grande	Paramunnidae	Isopoda	0	189	95	95	0	0	945	189	189	0.3	95.0
Gastropoda (larvae)	Gastropoda	Gastropoda	0	1418	0	0	0	0	0	0	177	0.3	95.2
Melita sp.	Melitidae	Amphipoda	95	95	0	0	0	0	284	945	177	0.3	95.5
Tharyx sp.	Cirratulidae	Polychaeta	0	0	0	0	1418	0	0	0	177	0.3	95.7
Bivalvia (juvenile)	Bivalvia	Bivalvia	0	945	473	0	0	0	0	0	177	0.3	96.0
Neverita sp.	Naticidae	Gastropoda	189	0	0	0	0	0	1040	0	154	0.2	96.2
Dorvillea furcata	Dorvilleidae	Polychaeta	0	567	0	0	567	0	0	0	142	0.2	96.4
Vaunthompsonia inermis	Bodotriidae	Cumacea	0	0	0	95	0	284	378	378	142	0.2	96.6
Arcturus sp.	Arcturidae	Isopoda	0	567	95	189	0	0	95	95	130	0.2	96.8
Bivalvia (unidentified)	Bivalvia	Bivalvia	0	0	95	0	473	473	0	0	130	0.2	97.0
Podocopida (unidentified)	Podocopida	Ostracoda	0	378	95	0	189	0	95	284	130	0.2	97.1
Leodora sp.	Serpulidae	Polychaeta	945	0	0	0	0	0	0	0	118	0.2	97.3
Monoculodes curtipediculus	Oedicerotidae	Amphipoda	0	0	851	0	0	0	0	0	106	0.2	97.5
Polychaeta (juvenile)	Polychaeta	Polychaeta	0	0	0	851	0	0	0	0	106	0.2	97.6
Golfingia sp.	Golfingiidae	Sipunculidea	0	473	0	378	0	0	0	0	106	0.2	97.8
Gastropoda (unidentified)	Gastropoda	Gastropoda	0	0	95	95	284	95	0	189	95	0.1	97.9
Laternula elliptica	Laternulidae	Bivalvia	95	0	189	0	473	0	0	0	95	0.1	98.0
Diastylis enigmatica	Diastylidae	Cumacea	0	0	0	95	0	95	473	95	95	0.1	98.2
Antatelson sp,.	Stenothoidae	Amphipoda	95	378	0	0	0	0	95	95	83	0.1	98.3
Paramunna rostrata	Paramunnidae	Isopoda	0	378	0	95	0	0	0	95	71	0.1	98.4
Sphaerodoropsis parva	Sphaerodoridae	Polychaeta	0	95	0	0	378	0	0	0	59	0.1	98.5
Scolelepis sp.	Spionidae	Polychaeta	0	0	378	95	0	0	0	0	59	0.1	98.6
Paraonis gracilis	Paraonidae	Polychaeta	0	378	0	95	0	0	0	0	59	0.1	98.6
Myodocopida (unidentified)	Myodocopida	Ostracoda	189	0	0	0	0	284	0	0	59	0.1	98.7
Orchomenella pinguis	Lysianassidae	Amphipoda	0	0	0	0	0	473	0	0	59	0.1	98.8
Eteone sp.	Phyllodocidae	Polychaeta	0	473	0	0	0	0	0	0	59	0.1	98.9
Halacaridae (unidentified)	Halacaridae	Arachnida	0	0	0	0	378	0	0	0	47	0.1	99.0
Coralliotrocha composita	Dorvilleidae	Polychaeta	0	0	0	0	378	0	0	0	47	0.1	99.0
Hauchiella tribullata	Terebellidae	Polychaeta	0	284	0	0	0	0	0	0	35	0.0	99.1
Axiothella antarctica	Maldanidae	Polychaeta	0	0	284	0	0	0	0	0	35	0.0	99.1

Species	Family	Class	Intake		North Palmer		Outfall		Pier		Mean	Mean	Cum.
			18 m	24 m	18 m	24 m	18 m	24 m	18 m	24 m	(n m^{-2})	(%)	(%)
Helicosiphon biscoeensis	Serpulidae	Polychaeta	0	0	0	0	189	0	95	0	35	0.0	99.2
Nototanais antarcticus	Nototanaidae	Tanaidacea	0	0	0	189	0	0	0	95	35	0.0	99.2
Trypanosyllis sp.	Syllidae	Polychaeta	0	0	0	0	284	0	0	0	35	0.0	99.3
Micromaldane ornithochaeta	Maldanidae	Polychaeta	0	0	0	0	0	284	0	0	35	0.0	99.3
Aricidea belgicae	Paraonidae	Polychaeta	0	284	0	0	0	0	0	0	35	0.0	99.4
Ampelisca dallenei	Ampeliscidae	Amphipoda	0	0	95	95	0	0	95	0	35	0.0	99.4
Cumacea (unidentified)	Cumacea	Cumacea	0	0	0	0	0	0	0	284	35	0.0	99.5
Syllis sp.	Syllidae	Polychaeta	0	284	0	0	0	0	0	0	35	0.0	99.5
Yoldia eightsi	Yoldiidae	Bivalvia	0	0	0	0	0	0	189	0	24	0.0	99.6
Nototanais dimorphus	Nototanaidae	Tanaidacea	95	95	0	0	0	0	0	0	24	0.0	99.6
Sipunculidae (unidentified)	Sipunculidae	Sipunculidea	0	0	0	0	95	0	95	0	24	0.0	99.6
Actiniaria (unidentified)	Actiniaria	Anthozoa	0	0	95	0	95	0	0	0	24	0.0	99.7
Lumbriclymenella sp.	Maldanidae	Polychaeta	0	0	0	0	95	0	95	0	24	0.0	99.7
Sabella sp.	Sabellidae	Polychaeta	0	0	0	0	189	0	0	0	24	0.0	99.7
Lysilla macintoshi	Terebellidae	Polychaeta	95	0	0	0	0	0	0	0	12	0.0	99.8
Sphaerosyllis perspicax	Syllidae	Polychaeta	0	0	0	0	95	0	0	0	12	0.0	99.8
Porifera (unidentified)	Porifera	Porifera	0	0	0	0	95	0	0	0	12	0.0	99.8
Ampharetidae (unidentified)	Ampharetidae	Polychaeta	95	0	0	0	0	0	0	0	12	0.0	99.8
Seriolis sp.	Seriolidae	Isopoda	0	0	0	95	0	0	0	0	12	0.0	99.8
Leaena antarctica	Terebellidae	Polychaeta	0	95	0	0	0	0	0	0	12	0.0	99.8
Pherusa kerguelarum	Flabelligeridae	Polychaeta	0	0	0	0	95	0	0	0	12	0.0	99.9
Flabelligera sp.	Flabelligeridae	Polychaeta	0	0	0	0	0	0	95	0	12	0.0	99.9
Parmaphorella sp.	Fissurellidae	Gastropoda	0	95	0	0	0	0	0	0	12	0.0	99.9
Boccardia sp.	Spionidae	Polychaeta	95	0	0	0	0	0	0	0	12	0.0	99.9
Boremysis sp.	Mysidae	Mysida	0	0	0	0	0	0	0	95	12	0.0	99.9
Phyllodocidae (unidentified)	Phyllodocidae	Polychaeta	0	95	0	0	0	0	0	0	12	0.0	99.9
Sabellidae (unidentified)	Sabellidae	Polychaeta	0	0	0	0	0	0	95	0	12	0.0	100.0
Terebellides stroemii	Trichobranchidae	Polychaeta	0	95	0	0	0	0	0	0	12	0.0	100.0
Amphilochidae (unidentified)	Amphilochidae	Amphipoda	0	0	0	0	0	0	0	95	12	0.0	100.0
			26757	117711	38102	24582	72895	82539	90670	107689	70118	100.0	

Table S3. Abundances (n m^{-2}) of each family at each station. Cum = cumulative.

Family	Order	Class	Intake		North Palmer		Outfall		Pier		Mean	Mean	Cum.
			18 m	24 m	18 m	24 m	18 m	24 m	18 m	24 m	(n m^{-2})	(%)	(%)
Nematoda	Nematoda	Nematoda	3309	34226	4255	4255	15978	24109	37630	15127	17361	24.8	24.8
Photidae	Amphipoda	Malacostraca	0	473	1891	662	0	29026	9455	40655	10270	14.6	39.4
Oligochaeta	Oligochaeta	Oligochaeta	1891	27229	0	1796	32146	945	5106	1324	8805	12.6	52.0
Leuconidae	Cumacea	Malacostraca	0	0	5484	4822	0	12575	9360	12007	5531	7.9	59.9
Maldanidae	Order Not Assigned	Polychaeta	95	2458	1607	2553	1324	378	756	16640	3226	4.6	64.5
Rissoidae	Neotaeniogloassa	Gastropoda	5295	0	0	0	3025	662	5295	5767	2505	3.6	68.0
Opheliidae	Order Not Assigned	Polychaeta	1229	3687	4255	189	3309	2269	2458	378	2222	3.2	71.2
Oedicerotidae	Amphipoda	Malacostraca	189	2647	851	1796	378	2553	5484	2836	2092	3.0	74.2
Sabellidae	Canalipalpata	Polychaeta	95	15789	0	0	189	0	95	0	2021	2.9	77.1
Spionidae	Canalipalpata	Polychaeta	1891	1796	11440	95	0	0	0	0	1903	2.7	79.8
Aoridae	Amphipoda	Malacostraca	0	95	0	95	0	5673	1891	5862	1702	2.4	82.2
Apistobranchidae	Canalipalpata	Polychaeta	662	9549	0	0	662	0	0	0	1359	1.9	84.1
Phoxocephalidae	Amphipoda	Malacostraca	284	945	2836	1229	567	1229	2269	1135	1312	1.9	86.0
Lasaeidae	Veneroida	Bivalvia	7942	378	0	189	1040	0	567	95	1276	1.8	87.8
Cirratulidae	Canalipalpata	Polychaeta	1135	2080	567	1702	1418	0	0	0	863	1.2	89.1
Nemertea	Nemertea	Nemertea	95	756	473	756	2836	189	378	473	745	1.1	90.1
Lysianassidae	Amphipoda	Malacostraca	0	0	1607	0	1891	473	284	473	591	0.8	91.0
Amphipoda	Amphipoda	Malacostraca	0	95	0	0	0	0	4160	189	555	0.8	91.8
Dorvilleidae	Errantia	Polychaeta	0	1796	473	0	1229	0	0	0	437	0.6	92.4
Orbiniidae	Order Not Assigned	Polychaeta	473	1702	95	189	851	95	95	0	437	0.6	93.0
Capitellidae	Order Not Assigned	Polychaeta	0	189	945	1796	95	95	0	95	402	0.6	93.6
Allogromiidae	Allogromiida	Monothalamea	0	851	0	0	945	1040	95	95	378	0.5	94.1
Syllidae	Errantia	Polychaeta	0	1040	0	95	378	0	284	756	319	0.5	94.6
Bivalvia	Bivalvia	Bivalvia	0	945	567	0	473	473	0	0	307	0.4	95.0
Paraonidae	Order Not Assigned	Polychaeta	189	662	0	95	1040	0	473	0	307	0.4	95.4
Munnidae	Isopoda	Malacostraca	0	1324	0	0	189	0	189	662	295	0.4	95.9
Gastropoda	Gastropoda	Gastropoda	0	1418	95	95	284	95	0	189	272	0.4	96.3
Paramunnidae	Isopoda	Malacostraca	0	567	95	189	0	0	945	284	260	0.4	96.6
Ampharetidae	Canalipalpata	Polychaeta	95	473	0	0	662	0	284	189	213	0.3	96.9
Nannastacidae	Cumacea	Malacostraca	95	1324	0	0	0	0	95	0	189	0.3	97.2

Family	Order	Class	Intake		North Palmer		Outfall		Pier		Mean	Mean	Cum.
			18 m	24 m	18 m	24 m	18 m	24 m	18 m	24 m	(n m^{-2})	(%)	(%)
Melitidae	Amphipoda	Malacostraca	95	95	0	0	0	0	284	945	177	0.3	97.5
Naticidae	Neotaeniogloassa	Gastropoda	189	0	0	0	0	0	1040	0	154	0.2	97.7
Serpulidae	Canalipalpata	Polychaeta	945	0	0	0	189	0	95	0	154	0.2	97.9
Bodotriidae	Cumacea	Malacostraca	0	0	0	95	0	284	378	378	142	0.2	98.1
Arcturidae	Isopoda	Malacostraca	0	567	95	189	0	0	95	95	130	0.2	98.3
Podocopida	Podocopida	Ostracoda	0	378	95	0	189	0	95	284	130	0.2	98.5
Golfingiidae	Golfingiida	Sipunculidea	0	473	0	378	0	0	0	0	106	0.2	98.6
Polychaeta	Polychaeta	Polychaeta	0	0	0	851	0	0	0	0	106	0.2	98.8
Diastylidae	Cumacea	Malacostraca	0	0	0	95	0	95	473	95	95	0.1	98.9
Laternulidae	Pholadomyoida	Bivalvia	95	0	189	0	473	0	0	0	95	0.1	99.0
Stenothoidae	Amphipoda	Malacostraca	95	378	0	0	0	0	95	95	83	0.1	99.2
Phyllodocidae	Errantia	Polychaeta	0	567	0	0	0	0	0	0	71	0.1	99.3
Myodocopida	Myodocopida	Ostracoda	189	0	0	0	0	284	0	0	59	0.1	99.3
Nototanaidae	Tanaidacea	Malacostraca	95	95	0	189	0	0	0	95	59	0.1	99.4
Sphaerodoridae	Errantia	Polychaeta	0	95	0	0	378	0	0	0	59	0.1	99.5
Terebellidae	Canalipalpata	Polychaeta	95	378	0	0	0	0	0	0	59	0.1	99.6
Halacaridae	Trombidiformes	Arachnida	0	0	0	0	378	0	0	0	47	0.1	99.7
Ampeliscidae	Amphipoda	Malacostraca	0	0	95	95	0	0	95	0	35	0.1	99.7
Cumacea	Cumacea	Malacostraca	0	0	0	0	0	0	0	284	35	0.1	99.8
Actiniaria	Actiniaria	Anthozoa	0	0	95	0	95	0	0	0	24	0.0	99.8
Flabelligeridae	Canalipalpata	Polychaeta	0	0	0	0	95	0	95	0	24	0.0	99.8
Sipunculidae	Golfingiida	Sipunculidea	0	0	0	0	95	0	95	0	24	0.0	99.9
Yoldiidae	Nuculoida	Bivalvia	0	0	0	0	0	0	189	0	24	0.0	99.9
Amphilochidae	Amphipoda	Malacostraca	0	0	0	0	0	0	0	95	12	0.0	99.9
Fissurellidae	Archaeogastropoda	Gastropoda	0	95	0	0	0	0	0	0	12	0.0	99.9
Mysidae	Mysida	Malacostraca	0	0	0	0	0	0	0	95	12	0.0	99.9
Porifera	Porifera	Porifera	0	0	0	0	95	0	0	0	12	0.0	100.0
Seriolidae	Isopoda	Malacostraca	0	0	0	95	0	0	0	0	12	0.0	100.0
Trichobranchidae	Canalipalpata	Polychaeta	0	95	0	0	0	0	0	0	12	0.0	100.0
		Sum	26757	117711	38102	24582	72895	82539	90670	107689	70118	100.0	

Table S4. Abundances of major taxa groups (n m^{-2})

Major taxa group	Intake		North Palmer		Outfall		Pier		Mean	Mean
	18 m	24 m	18 m	24 m	18 m	24 m	18 m	24 m	(n m^{-2})	(%)
Nematoda	3309	34226	4255	4255	15978	24109	37630	15127	17361	24.76
Amphipoda	662	4727	7280	3876	2836	38953	24015	52284	16829	24.00
Polychaeta	6902	42357	19382	7564	11818	2836	4633	18058	14194	20.24
Oligochaeta	1891	27229	0	1796	32146	945	5106	1324	8805	12.56
Cumacea	95	1324	5484	5011	0	12953	10306	12764	5992	8.55
Gastropoda	5484	1513	95	95	3309	756	6335	5956	2943	4.20
Bivalvia	8036	1324	756	189	1985	473	756	95	1702	2.43
Nemertea	95	756	473	756	2836	189	378	473	745	1.06
Isopoda	0	2458	189	473	189	0	1229	1040	697	0.99
Foraminifera	0	851	0	0	945	1040	95	95	378	0.54
Ostracoda	189	378	95	0	189	284	95	284	189	0.27
Sipunculidea	0	473	0	378	95	0	95	0	130	0.19
Tanaidacea	95	95	0	189	0	0	0	95	59	0.08
Arachnida	0	0	0	0	378	0	0	0	47	0.07
Anthozoa	0	0	95	0	95	0	0	0	24	0.03
Mysida	0	0	0	0	0	0	0	95	12	0.02
Porifera	0	0	0	0	95	0	0	0	12	0.02
Total	26757	117711	38102	24582	72895	82539	90670	107689	70118	100.00

Table S5. Mean biomass of major taxa groups at each station (g m^{-2}). Mean biomass of the bivalve, *Laternula elliptica* at Intake1 (164 g m^{-2}) and Outfall1 (1010 g m^{-2}) are not included in the table.

Taxa	Intake		North Palmer		Outfall		Pier		Mean	Mean	Cum.
	18 m	24 m	18 m	24 m	18 m	24 m	18 m	24 m	(n m^{-2})	(%)	(%)
Polychaeta	4.102	17.308	13.958	17.108	17.643	1.707	30.900	5.395	13.515	46.1	46.1
Mollusca	12.886	0.729	38.306	3.916	0.662	0.109	14.237	0.639	8.935	30.5	76.5
Crustacea	0.093	1.654	3.018	3.332	6.724	7.861	8.665	12.556	5.488	18.7	95.2
Oligochaeta	0.068	2.897	0.000	0.090	2.227	0.214	1.347	0.188	0.879	3.0	98.2
Sipuncula	0	0.028	0.000	1.061	0.059	0	0.007	0	0.144	0.5	98.7
Nemertea	0.001	0.111	0.057	0.264	0.177	0.044	0.164	0.205	0.128	0.4	99.2
Nematoda	0.006	0.301	0.029	0.030	0.094	0.094	0.109	0.085	0.093	0.3	99.5
Cnidaria	0	0	0.235	0	0.324	0	0	0	0.070	0.2	99.7
Formanifera	0	0.048	0	0	0.199	0.079	0.014	0.018	0.045	0.2	99.9
Copepod	0	0.081	0.006	0.004	0.004	0.072	0.036	0.049	0.031	0.1	100.0
Porifera	0	0	0	0	0.044	0	0	0	0.005	0.0	100.0
Halacaridae	0	0	0	0	0.002	0	0	0	0.000	0.0	100.0
Total	17.156	23.156	55.608	25.805	28.157	10.178	55.478	19.135	29.334	100.0	

Table S6. Highest correlations of sediment variables with macrobenthic community composition for combinations of one to five trial variables. TOC= total organic content, TIC = total inorganic carbon, TPH = total petroleum hydrocarbons.

Correlation method: Spearman rank Method: BIOENV Maximum number of variables: 5 Analyse between: Samples Resemblance measure: D1 Euclidean distance VARIABLES: TOC, TIC, Gravel, Sand, Silt, Clay, Mud, TPH, PCB, DDT, PAH
Best result for each number of variables No. Vars Corr. Selections 1 0.704 Mud 2 0.839 TOC, Silt 3 0.837 TOC, Sand, Silt 4 0.834 TOC, TIC, Silt, Mud 5 0.854 TOC, TIC, Gravel, Silt, Mud
Global Test Sample statistic (Rho): 0.854 Significance level of sample statistic: 0.3% Number of permutations: 9999 (Random sample) Number of permuted statistics greater than or equal to Rho: 32
Best results No. Vars Corr. Selections 5 0.854 TOC, TIC, Gravel, Silt, Mud 2 0.839 TOC, Silt 3 0.837 TOC, Sand, Silt 3 0.836 TOC, Sand, Mud 5 0.835 TOC, TIC, Sand, Silt, Mud 5 0.834 TOC, TIC, Gravel, Sand, Silt 5 0.834 TOC, Sand, Silt, Mud, TPH 4 0.834 TOC, TIC, Silt, Mud 5 0.834 TOC, TIC, Gravel, Sand, Mud 4 0.833 TOC, Sand, Silt, TPH
Global Test Sample statistic (Rho): 0.702 Significance level of sample statistic: 0.8% Number of permutations: 9999 (Random sample) Number of permuted statistics greater than or equal to Rho: 79 Best result for each number of variables No. Vars Corr. Selections 1 0.704 Mud 1 0.693 Silt 1 0.674 TOC

Table S7. Pearson correlations among sediment variables and univariate macrofauna variables. First row = correlation coefficient (rho), second row = p value. Rho > |0.7| and > |0.5| are bolded and italicized, respectively. N = 8.

	Abundance	Biomass	S	H'	J'	N1
PC1	0.043	0.153	-0.379	-0.208	-0.001	-0.191
	0.9198	0.7182	0.3543	0.6207	0.9972	0.6499
PC2	0.240	0.056	0.019	-0.499	*-0.622*	*-0.519*
	0.5663	0.8957	0.964	0.2077	*0.0995*	*0.1877*
TOC	0.370	0.162	0.131	0.095	-0.012	0.142
(%)	0.3671	0.7008	0.7576	0.8227	0.9772	0.737
TIC	0.420	0.010	0.042	-0.503	-0.643	*-0.508*
(%)	0.3005	0.9811	0.9217	0.2041	0.0854	*0.1988*
Gravel	0.104	-0.137	0.592	0.366	0.029	0.364
(%)	0.8069	0.7463	0.1223	0.3725	0.9452	0.3751
Sand	0.015	-0.100	0.417	0.164	-0.086	0.143
(%)	0.9714	0.8141	0.3034	0.6984	0.8402	0.7353
Silt	0.003	0.080	-0.479	-0.282	-0.005	-0.265
(%)	0.9952	0.8511	0.2302	0.4978	0.9899	0.5254
Clay	-0.294	0.287	-0.332	0.206	0.427	0.210
(%)	0.4798	0.4906	0.4223	0.6244	0.2908	0.6169
Mud	-0.039	0.111	-0.469	-0.220	0.056	-0.204
(%)	0.9264	0.7938	0.2411	0.6005	0.896	0.6275
TPH	0.249	-0.117	-0.408	-0.635	-0.456	*-0.617*
($\mu g\ g^{-1}$)	0.5525	0.783	0.3152	0.0908	0.2564	*0.1033*
PCB	0.039	-0.026	0.108	-0.258	-0.390	-0.280
($\mu g\ g^{-1}$)	0.9274	0.951	0.799	0.5376	0.3394	0.5023
DDT	0.039	-0.026	0.108	-0.258	-0.390	-0.280
($\mu g\ g^{-1}$)	0.9274	0.951	0.799	0.5376	0.3394	0.5023
PAH	-0.173	**0.747**	-0.162	-0.014	0.054	-0.072
($\mu g\ g^{-1}$)	0.6829	**0.0332**	0.7018	0.9739	0.8983	0.8656

Table S8 PAH content of marine sediments collected adjacent to Palmer Station. Data from 1991 is from Kennicutt *et al.* (1992a). All 2015 data are means of three replicates at each location and depth except * = replicate 1 and ^ = mean of replicates 2 and 3. Minimum detection limit (MDL) in 1991 = 10 ng g^{-1}. All units are ng g^{-1} unless otherwise specified.

Location	NE Palmer						Water Intake				Sewage Outfall			Pier		
Transect name	D-11	D-11	D-11	NP	NP	NP	D-1	D-1	Intake	Intake	D-2	Outfall	Outfall	D-13	Pier	Pier
Year sampled	1991	1991	1991	2015	2015	2015	1991	1991	2015	2015	1991	2015	2015	1991	2015	2015
Depth (m)	5	9	16	18*	18^	24	9	18	20	24	18	18	24	19	18	24
Total PAHs	MDL	4858	313	816	18	25	201	643	13	16	427	151	51	510	113	66
Group A PAHs																
Total Naphthalenes	MDL	3241	181	52	5	5	104	150	5	4	169	12	8	128	11	6
Total Fluorenes	MDL	802	63	28	3	3	56	194	3	2	58	4	4	103	6	5
Total Phenanthrenes	MDL	602	45	122	3	3	41	201	1	2	100	18	8	171	15	9
Total Chrysenes	MDL	MDL	MDL	142	1	6	MDL	MDL	1	2	MDL	14	7	MDL	11	10
Total DBTs	MDL	202	24	8	0	1	MDL	99	0	1	46	2	2	88	3	2
Group B PAHs																
Fluoranthene + Pyrene + C_1-Py-Fl	MDL	11	0	154	1	1	MDL	MDL	0	1	30	38	7	21	26	13
Benzofluoranthenes + Benzopyrenes	MDL	0	0	130	1	1	MDL	MDL	0	1	24	34	5	MDL	18	9
lndenopyrene + Dibenzanthracene + Benzoperylene	MDL	0	0	52	0	0	MDL	MDL	0	0	MDL	8	1	MDL	5	1
Group B/Total PAHs (%)	0.0	0.1	0.0	41.1	9.7	10.2	0.0	0.0	5.0	14.3	12.6	49.0	25.6	4.9	40.8	32.6
Total Phenanthrenes / Total DBTs (ratio)	MDL	2.97	1.85	15.18	25.47	5.08	0.00	2.02	3.23	2.81	2.18	10.15	4.47	1.95	4.45	4.88
Phenanthrenes / Total Phenanthrenes (%)	0.0	30.7	27.4	36.1	21.1	23.0	24.8	22.4	31.8	45.3	20.4	63.2	35.0	14.5	44.3	49.4
Total Naphthalenes / Total PAHs (%)	0.0	66.7	57.7	6.4	28.9	18.4	51.7	23.3	34.0	27.3	39.7	8.0	15.8	25.1	10.2	10.3
Easting	449958	449958	449956	449947	449947	449942	449836	449819	449767	449726	449807	449795	449788	449827	449828	449828
Northing	2816363	2816377	2816421	2816411	2816411	2816435	2816370	2816405	2816423	2816479	2816215	2816224	2816201	2816201	2816207	2816191

Supplementary Figures

2014 sediment metal concentrations

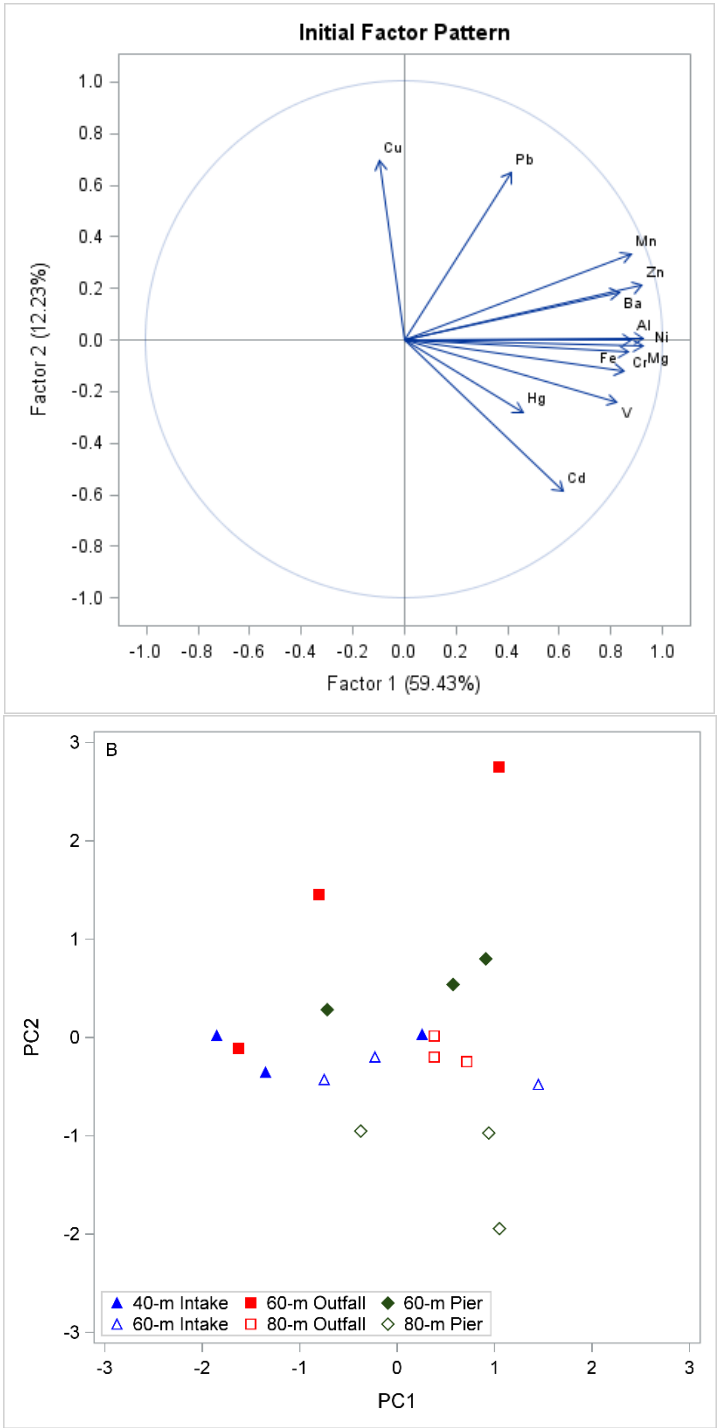

Fig. S1. Chemical Loads (A) and station scores (B) from Principal Components Analysis of 2014 metals data. 2014 sites were in similar locations to 2015 sites.

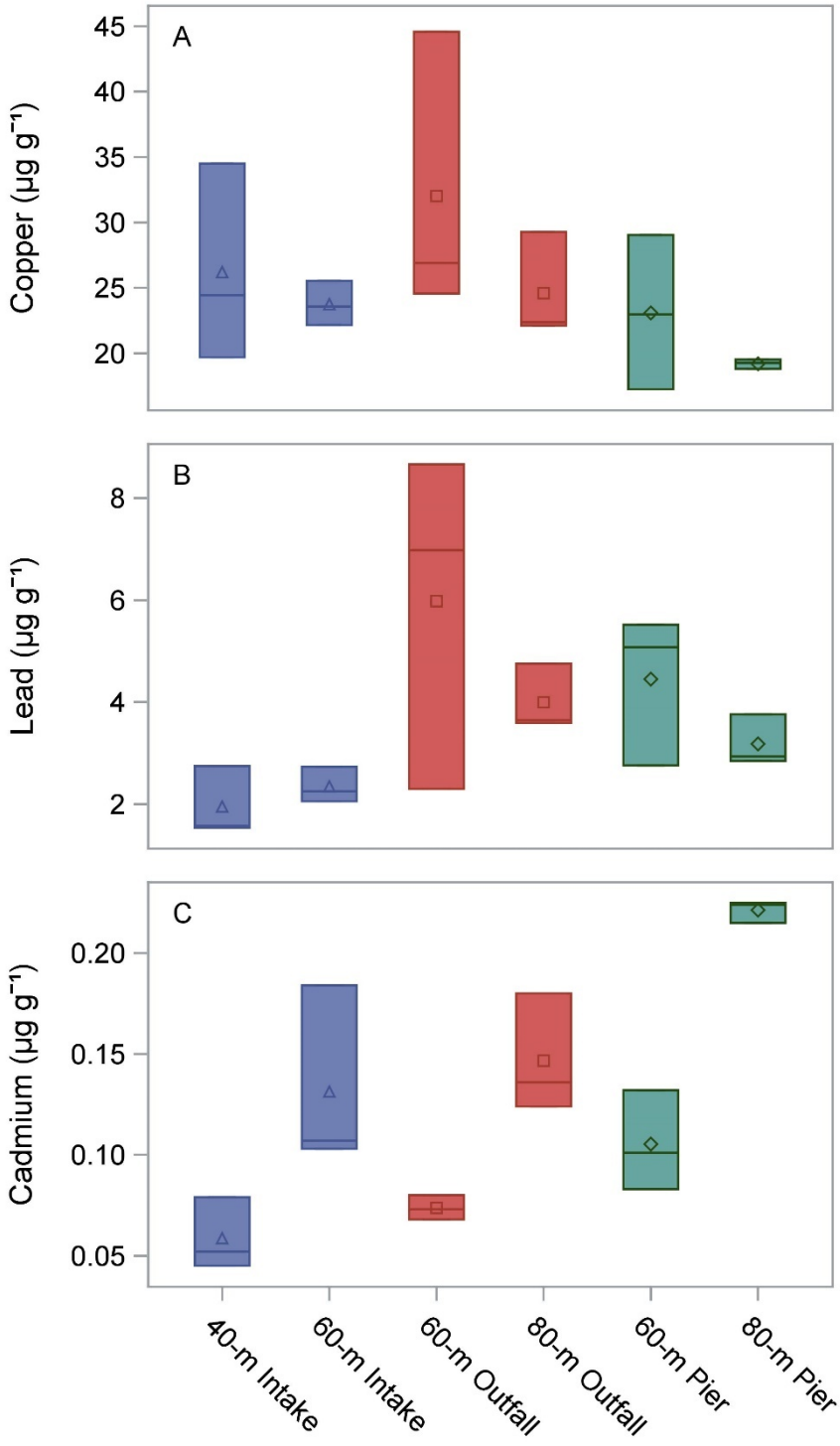

Fig. S2. Sediment copper (A), lead (B), and cadmium (C) concentrations adjacent to Palmer Station in 2014. Effects Range Low and Effects Range Medians are 34 and 270 µg g^{-1} for copper, 46.7 and 218 µg g^{-1} for lead, and 1.2 and 9.6 µg g^{-1} for cadmium (Long *et al.* 1995).

Comparisons of sediment characteristics among sites (2015)

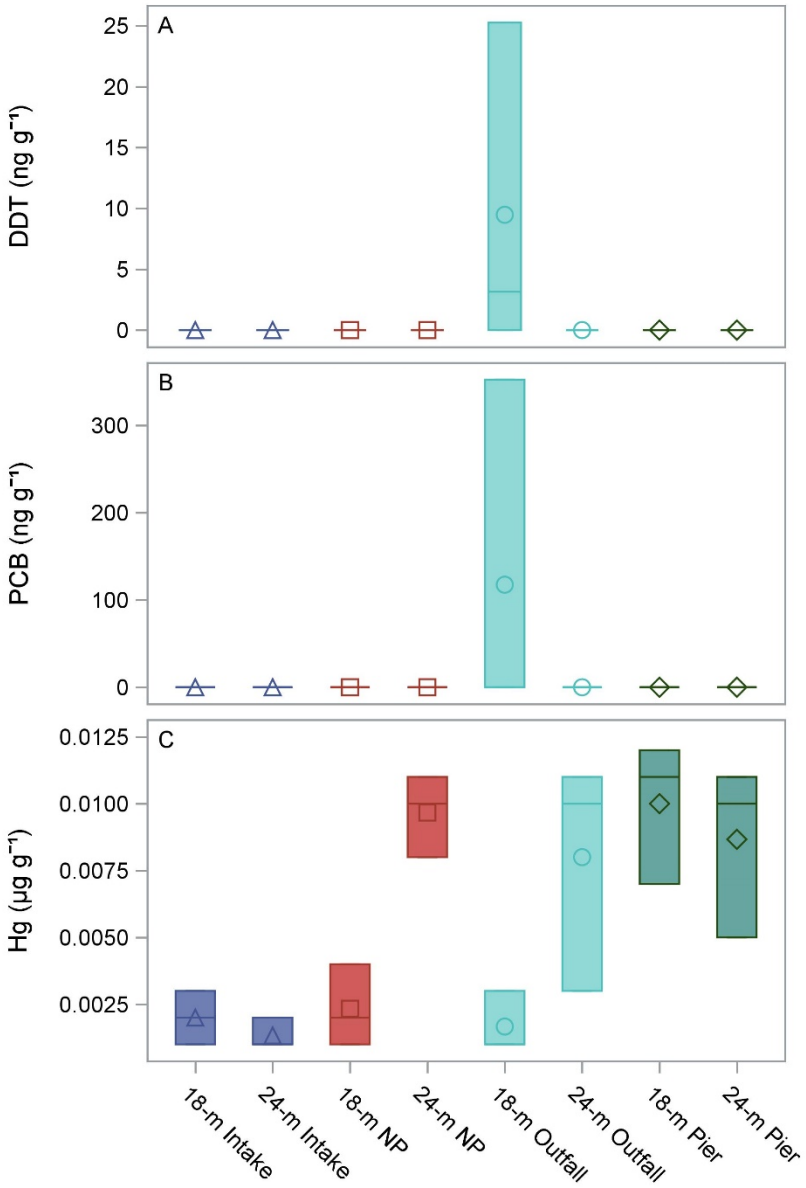

Fig. S3. DDT (A), PCB (B), and mercury (C) concentrations in sediments adjacent to Palmer Station. Symbols represent mean concentrations. Horizontal lines represent concentrations in each replicate sample.

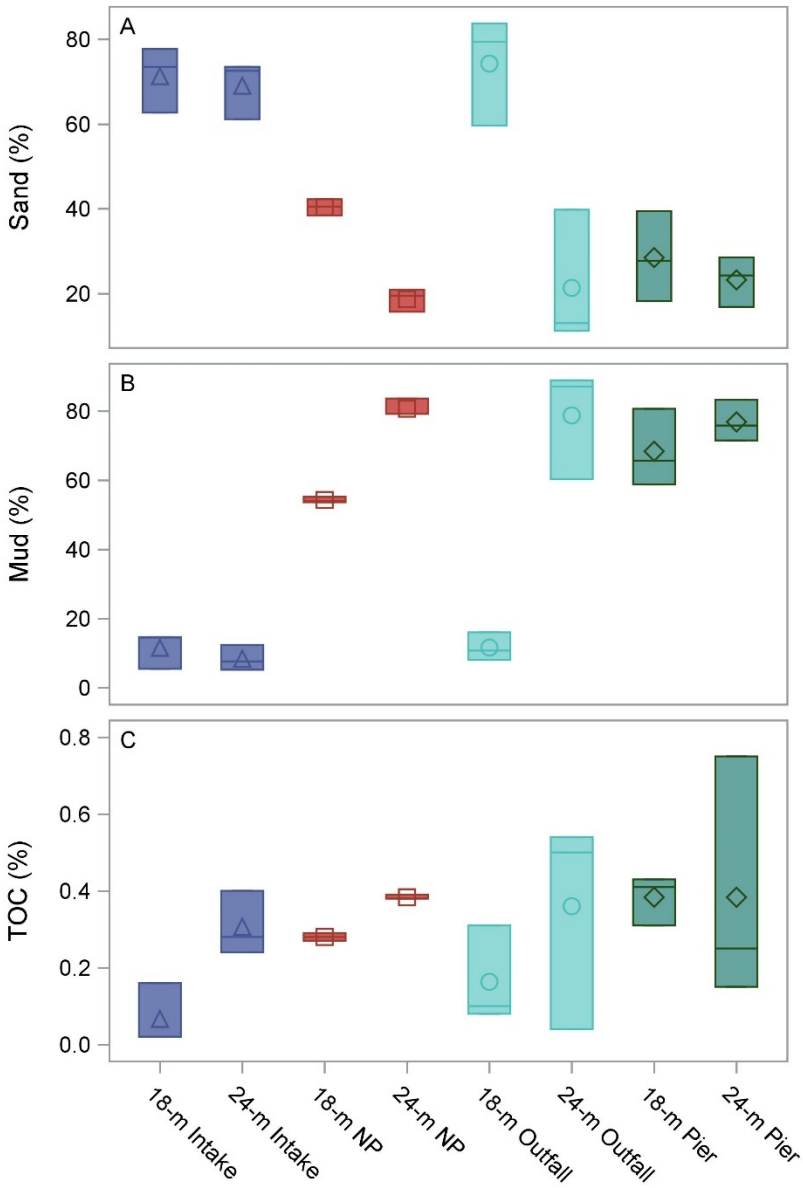

Fig. S4. Sand (A), mud (B; silt + clay), and TOC (C) content in sediments adjacent to Palmer Station. Symbols represent mean concentrations. Horizontal lines represent concentrations in each replicate sample.

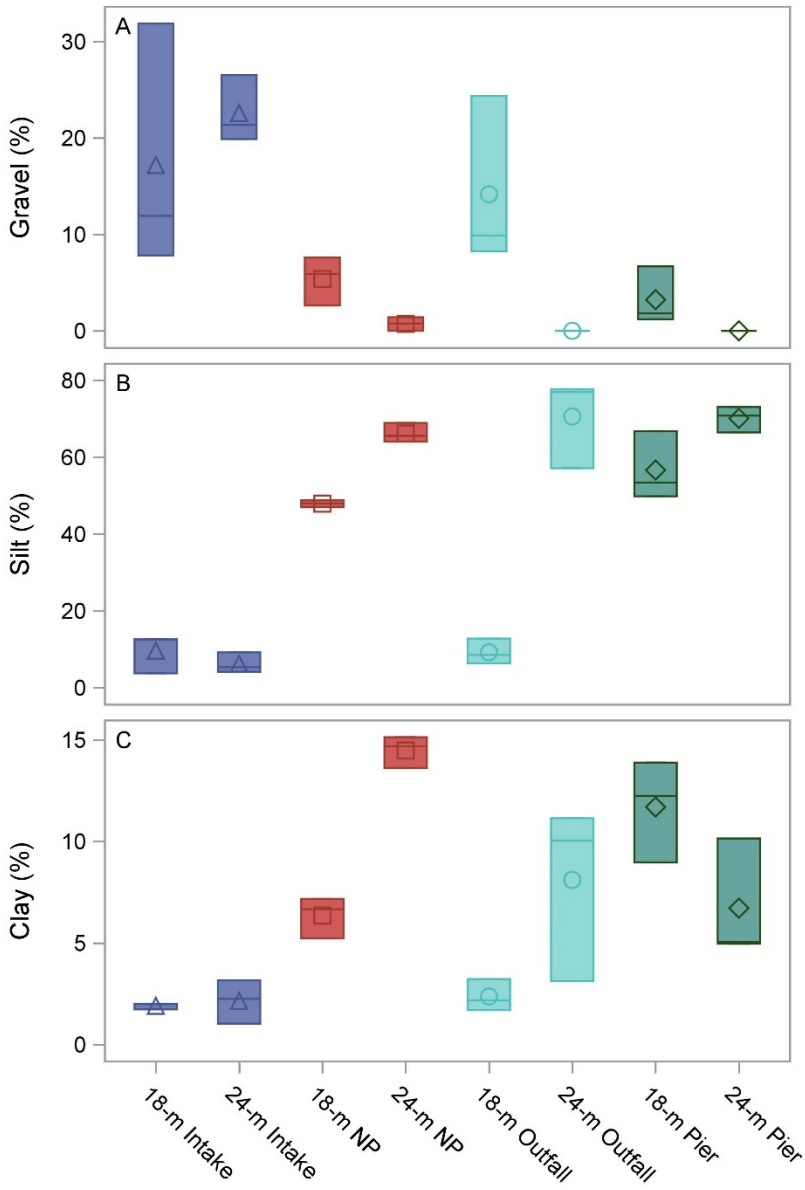

Fig. S5. Gravel (A), silt (B), and clay (C) content in sediments adjacent to Palmer Station. Symbols represent mean concentrations. Horizontal lines represent concentrations in each replicate sample.

Comparisons of univariate macrofauna descriptors among sites

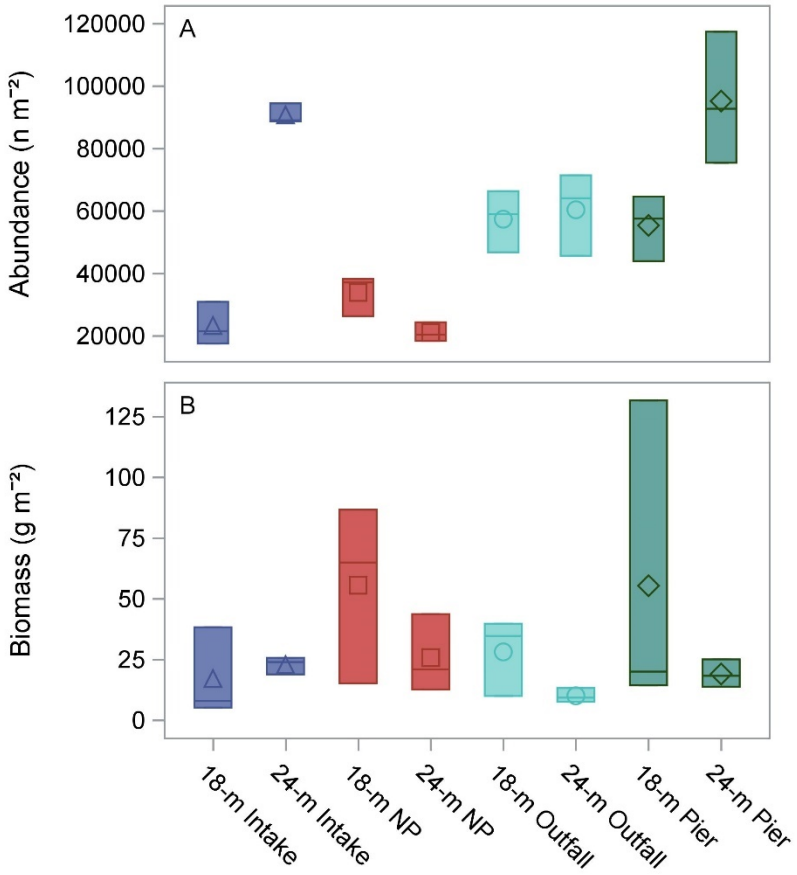

Fig. S6. Benthic macrofauna abundance (A), and biomass (B) adjacent to Palmer Station. Symbols represent mean concentrations. Horizontal lines represent concentrations in each replicate sample.

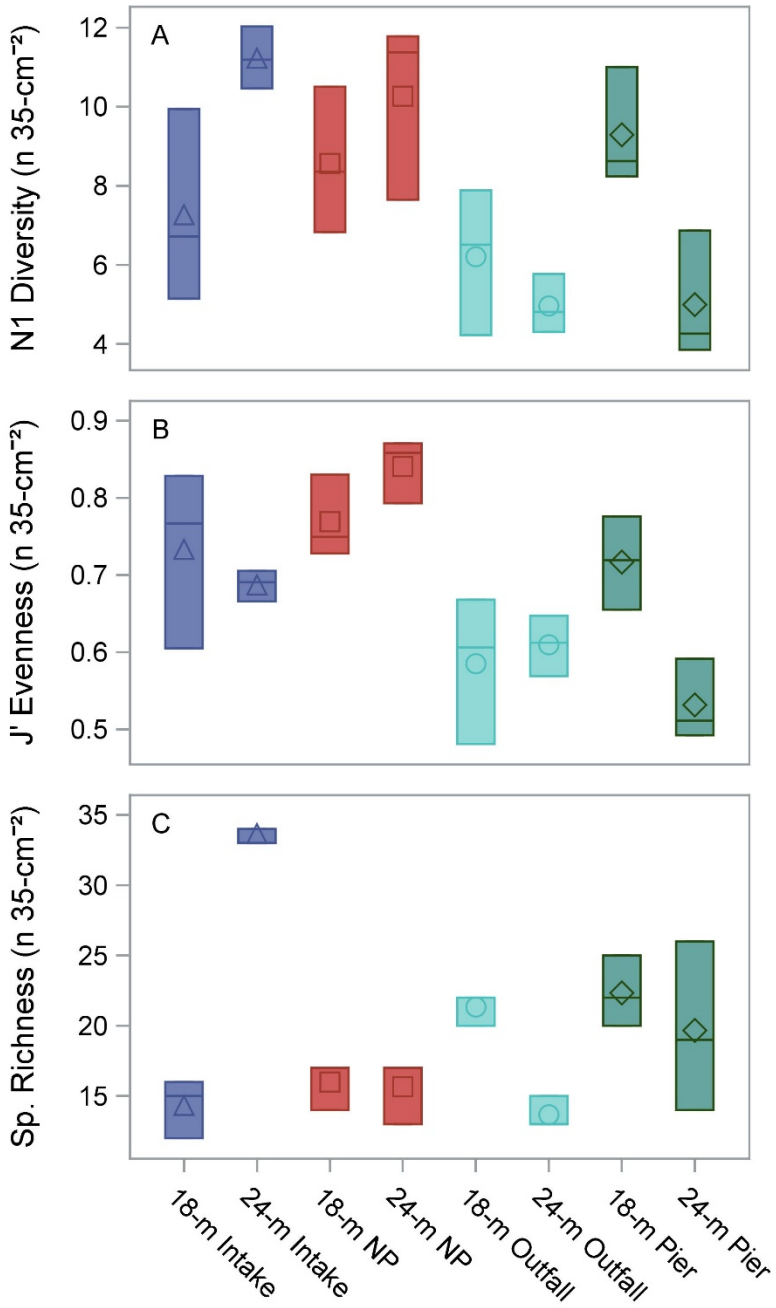

Fig. S7. Hill's N1 diversity (A), Pielou's evenness (B) and species richness (C) of benthic macrofauna adjacent to Palmer Station. Symbols represent mean concentrations. Horizontal lines represent concentrations in each replicate sample.

Limpet tissue chemistry among sites

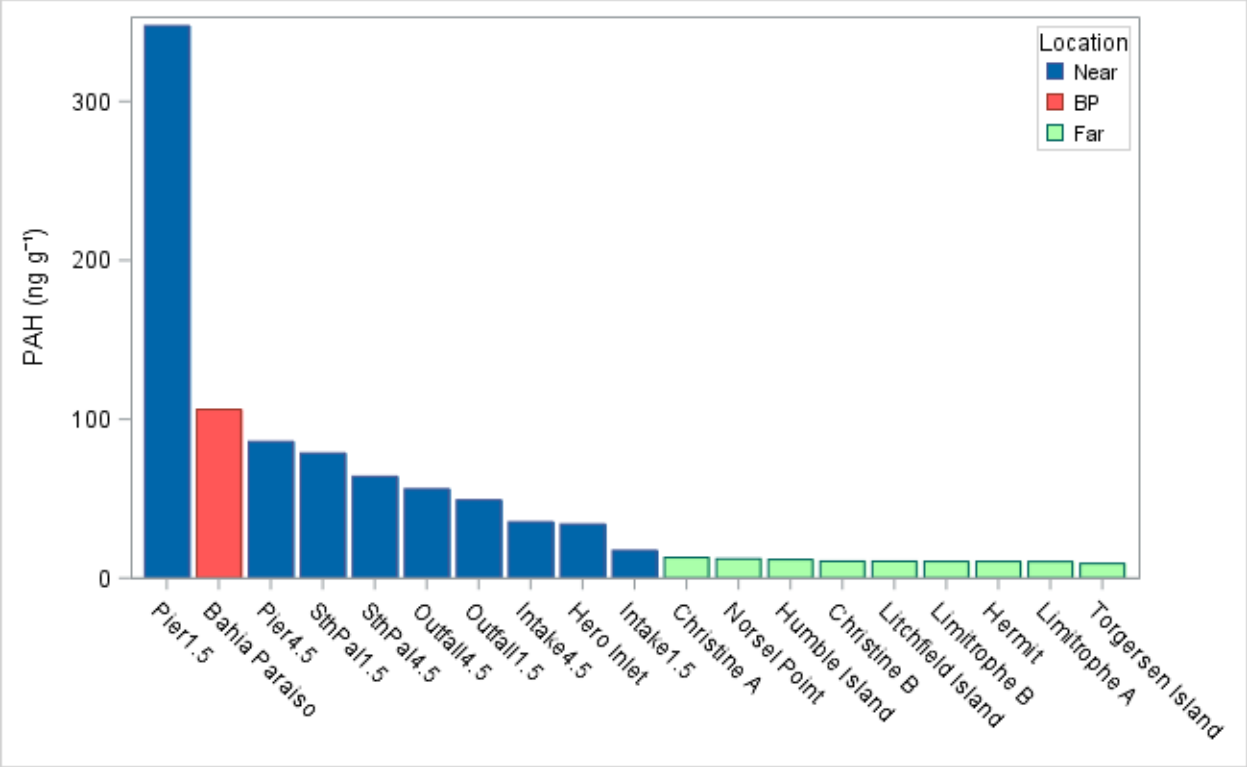

Fig. S8. Total polycyclic aromatic hydrocarbon (PAH) concentrations in limpet tissues in Arthur Harbor. BP = *Bahía Paraíso* wreck. Near = adjacent to Palmer Station. Far = outlying islands in Arthur Harbor

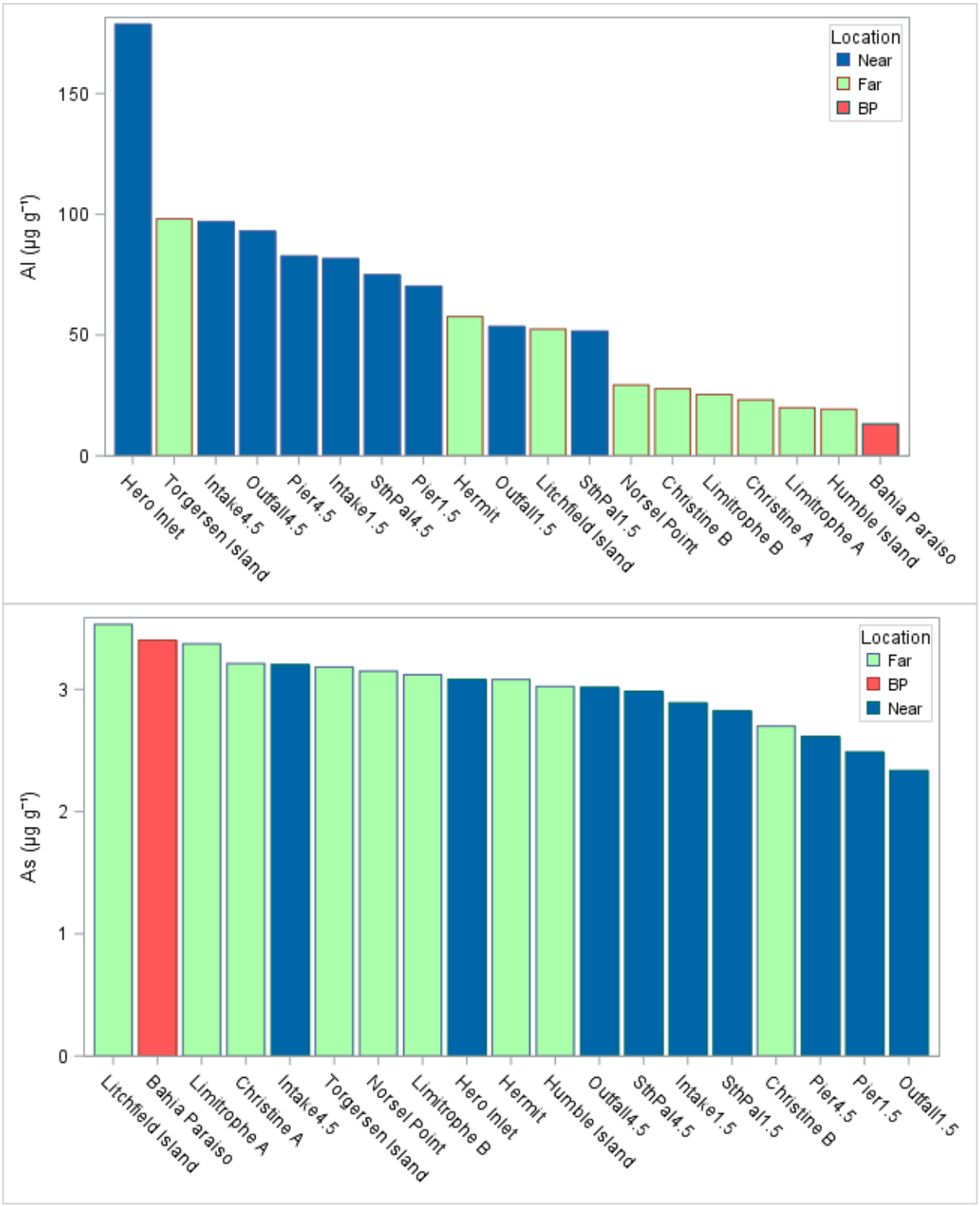

Fig. S9. Aluminum and Arsenic concentrations in limpet tissues in Arthur Harbor. BP = *Bahía Paraíso* wreck. Near = adjacent to Palmer Station. Far = outlying islands in Arthur Harbor

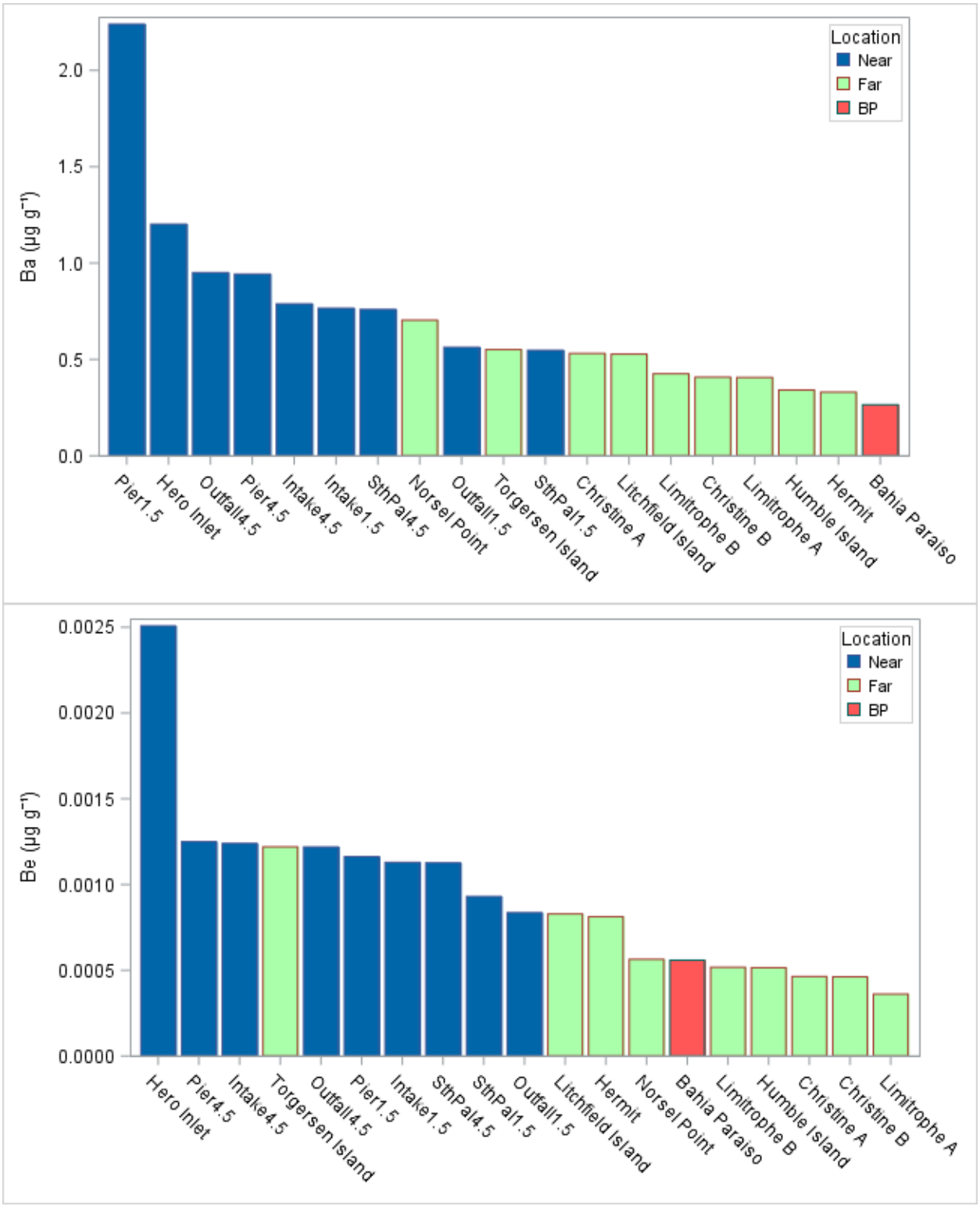

Fig. S10. Barium and Beryllium concentrations in limpet tissues in Arthur Harbor. BP = *Bahía Paraíso* wreck. Near = adjacent to Palmer Station. Far = outlying islands in Arthur Harbor

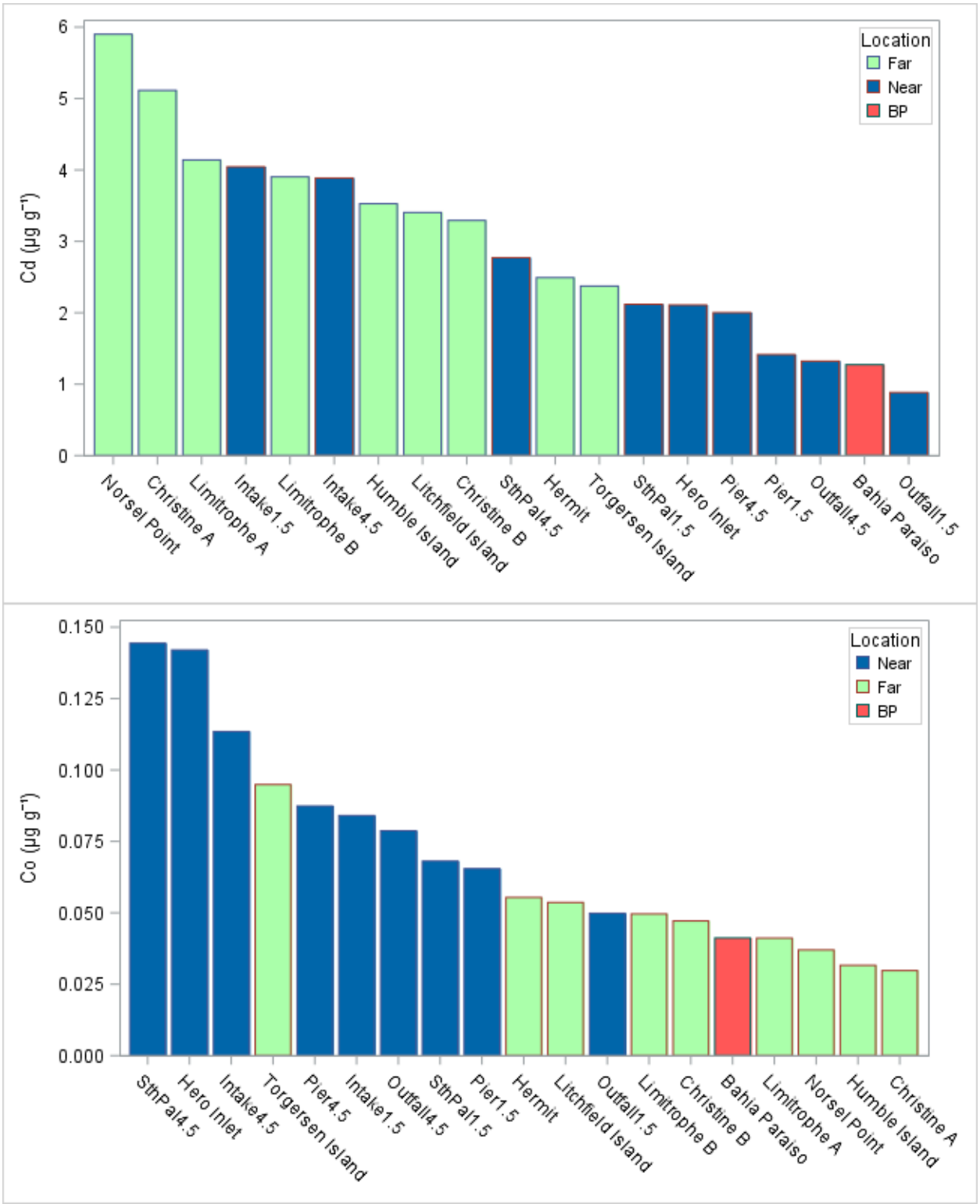

Fig. S11. Cadmium and cobalt concentrations in limpet tissues in Arthur Harbor. BP = *Bahía Paraíso* wreck. Near = adjacent to Palmer Station. Far = outlying islands in Arthur Harbor

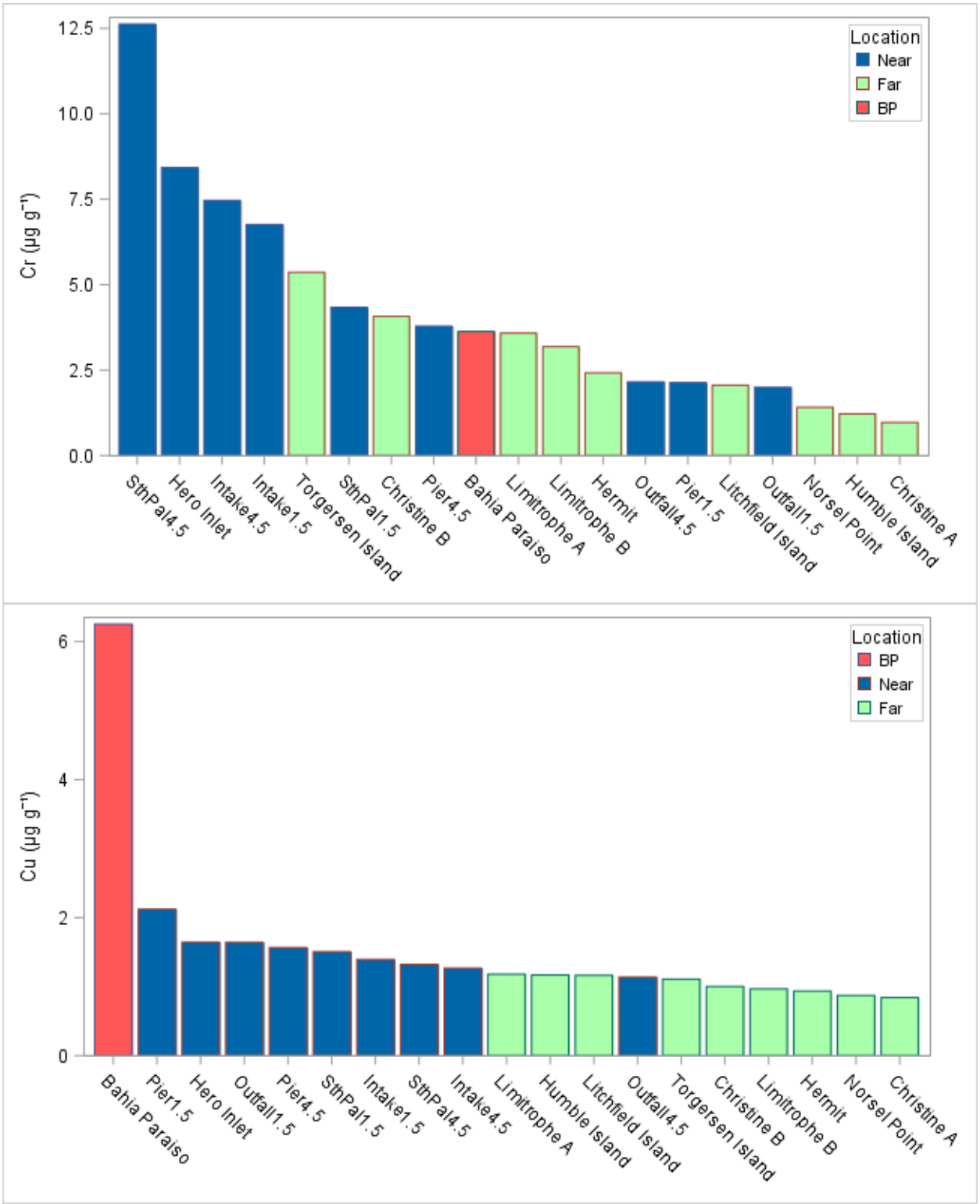

Fig. S12. Chromium and copper concentrations in limpet tissues in Arthur Harbor. BP = *Bahía Paraíso* wreck. Near = adjacent to Palmer Station. Far = outlying islands in Arthur Harbor

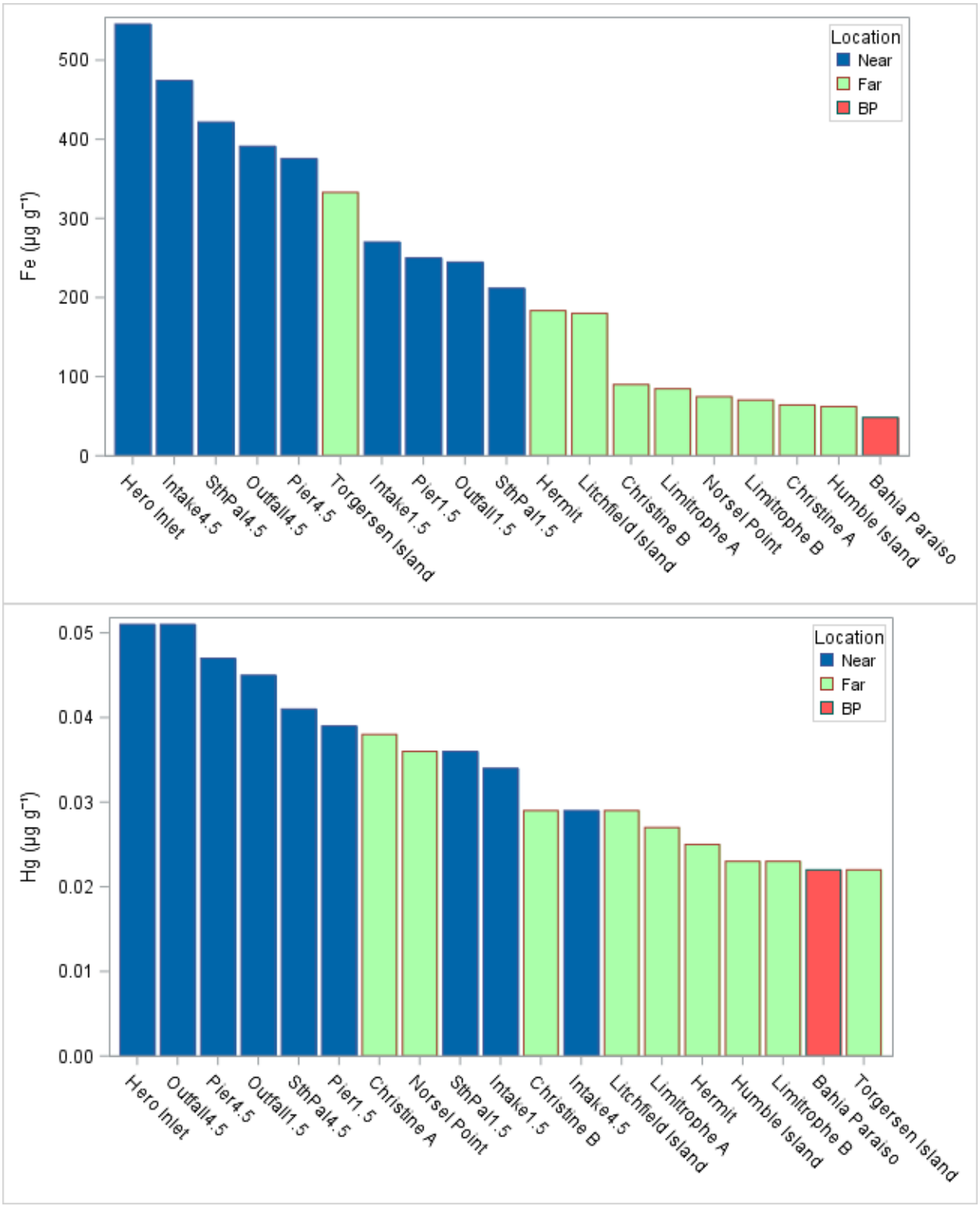

Fig. S13. Iron and mercury concentrations in limpet tissues in Arthur Harbor. BP = *Bahía Paraíso* wreck. Near = adjacent to Palmer Station. Far = outlying islands in Arthur Harbor

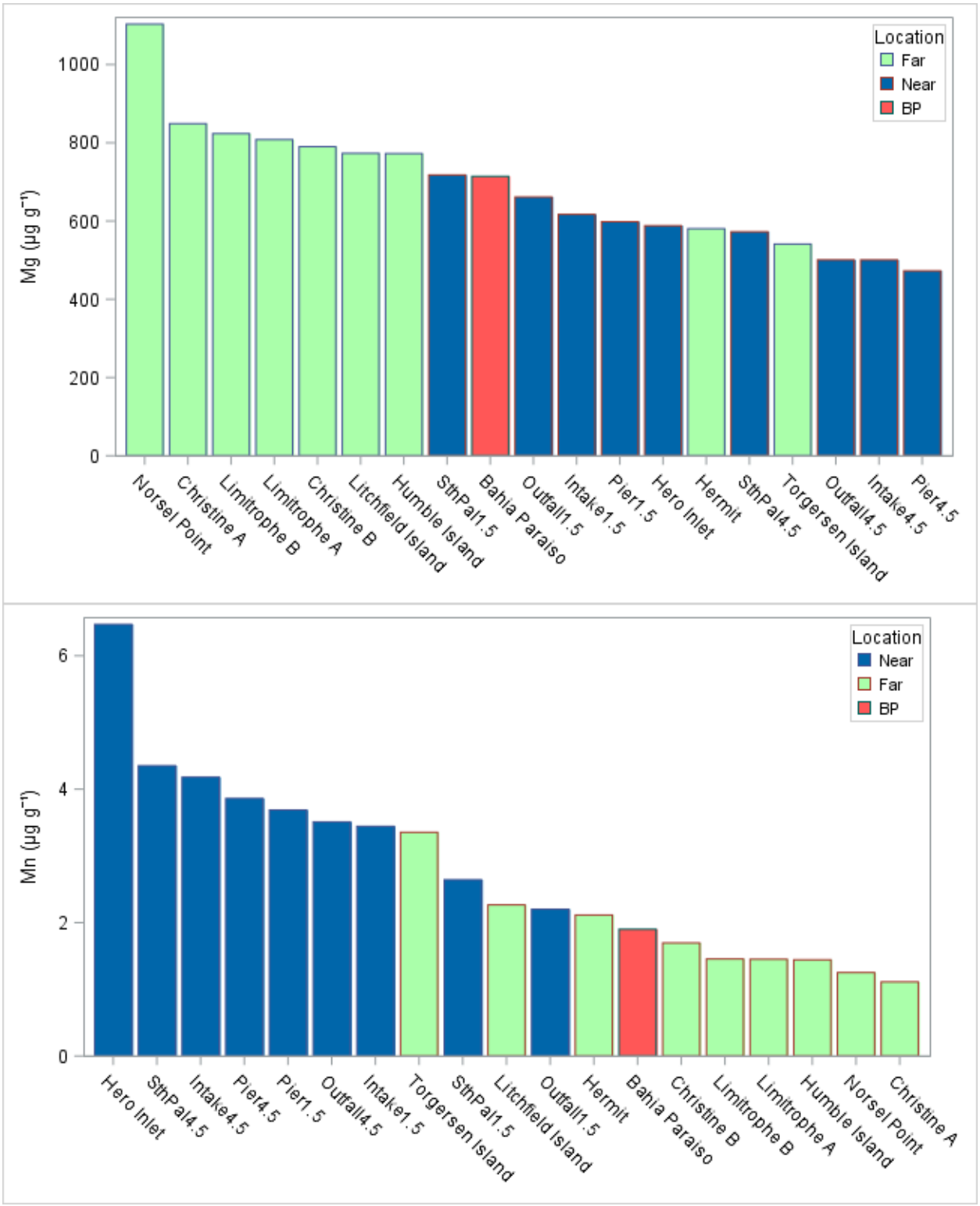

Fig. S14. Magnesium and manganese concentrations in limpet tissues in Arthur Harbor. BP = *Bahía Paraíso* wreck. Near = adjacent to Palmer Station. Far = outlying islands in Arthur Harbor

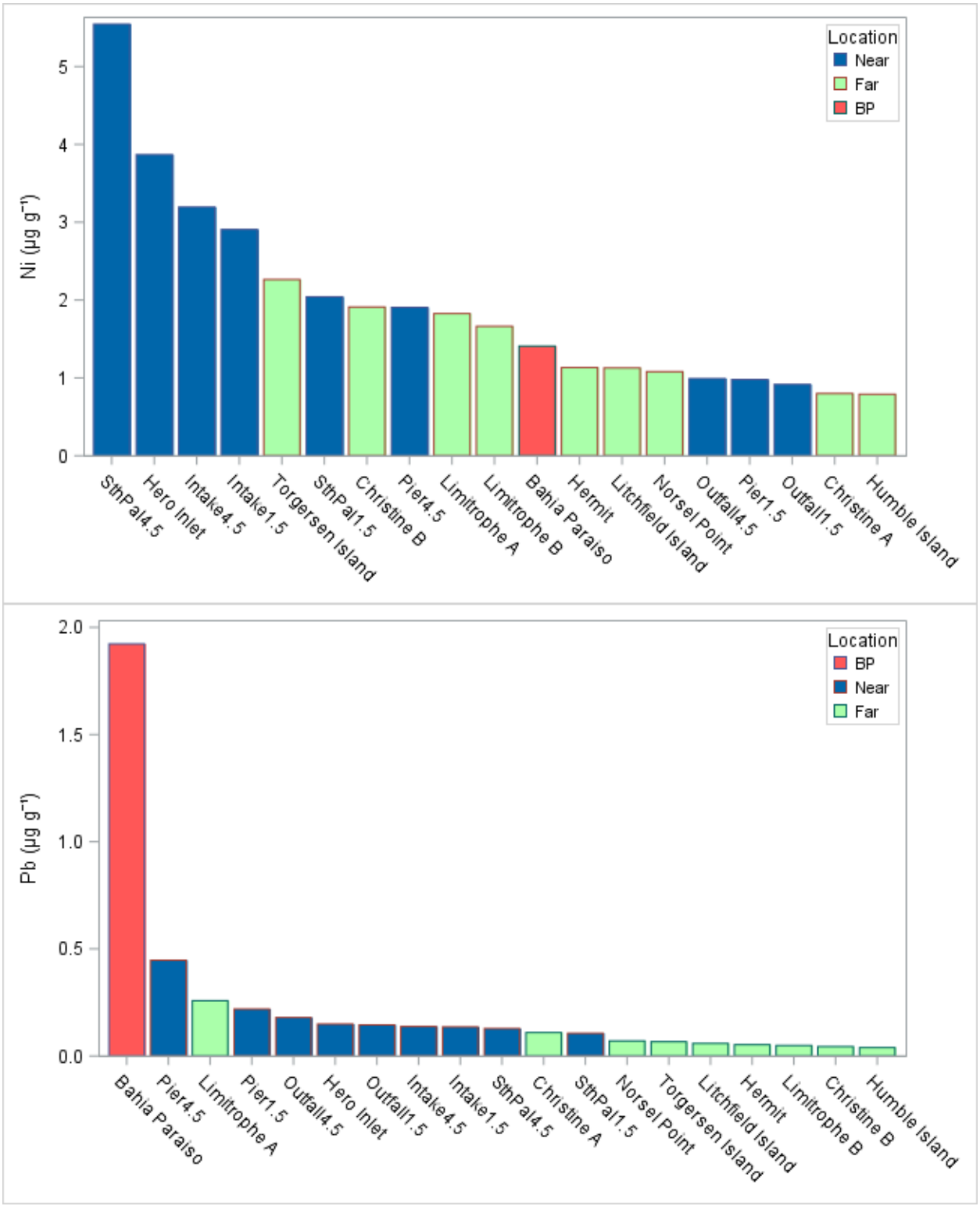

Fig. S15. Nickel and lead concentrations in limpet tissues in Arthur Harbor. BP = *Bahía Paraíso* wreck. Near = adjacent to Palmer Station. Far = outlying islands in Arthur Harbor

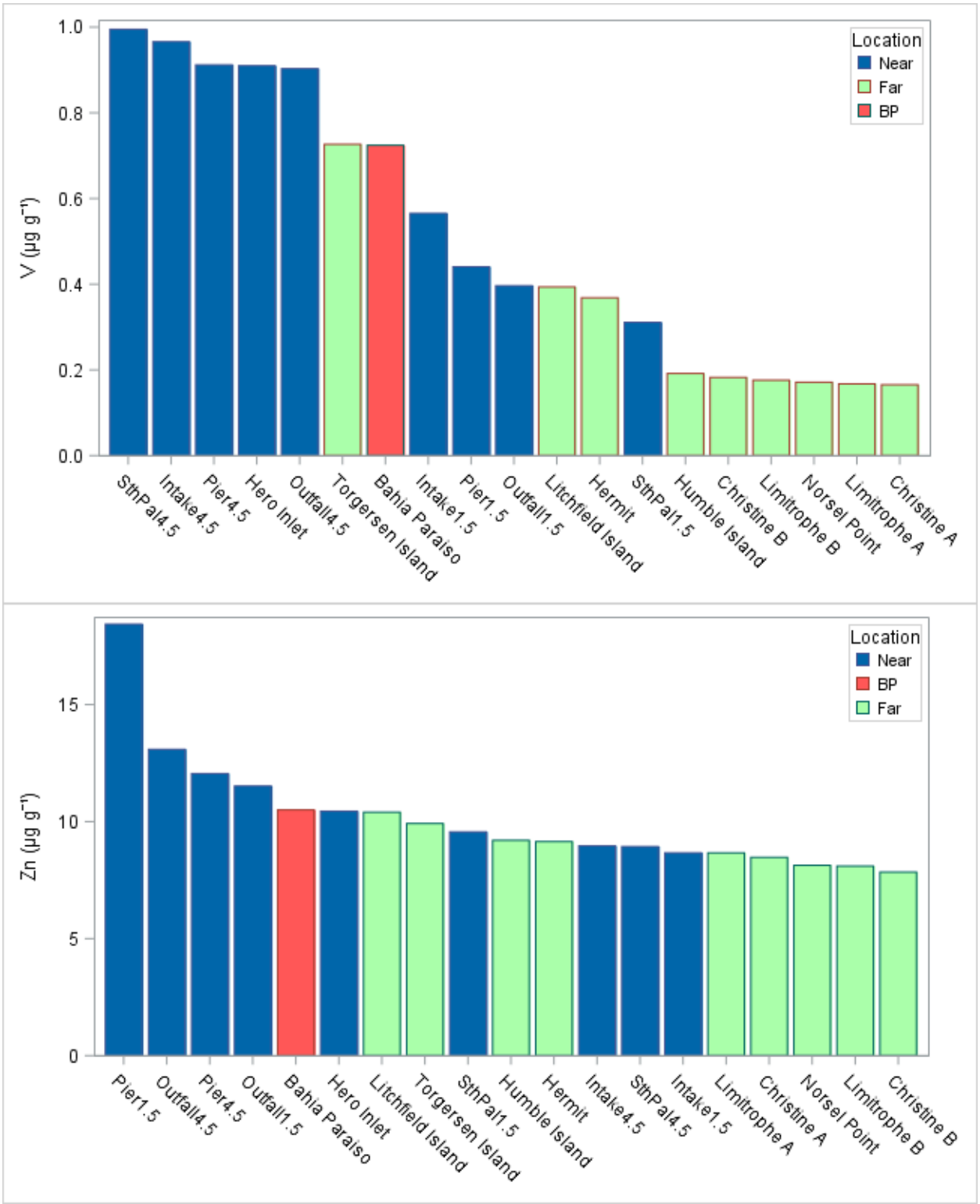

Fig. S16. Vanadium and zinc concentrations in limpet tissues in Arthur Harbor. BP = *Bahía Paraíso* wreck. Near = adjacent to Palmer Station. Far = outlying islands in Arthur Harbor