### Response to Manuscript Reviewers' Comments

Title:

Baseline for ostracod-based northwestern Pacific and Indo-Pacific shallow-marine paleoenvironmental reconstructions: ecological modeling of species distributions

Dear Prof. Irizuki, Thank you all for your valuable comments on my manuscript. Please find the relevant excerpts from your report reproduced below, alongside their respective responses. Yours sincerely, Yuanyuan Hong (email: <u>oocirclr@gmail.com</u>)

1. When the relationship between ostracod distributions and environmental factors is studied, autochthonous ostracod data should be basically used. However, you did not discuss whether ostracod assemblages or specimens were autochthonous or allochthonous. For example, because Xestoleberis is phytal genus, it is basically allochthonous specimens in bottom sediments and transported from intertidal zones with Zostera beds or calcareous algae. You should add several sentences about this taphonomic problem.

We agree that a phytal genus like Xestoleberis is allochthonous, and its value in studying ostracod distribution and related environmental factors is limited. We added some sentences regarding taphonomic problems in the revised manuscript. Please see line 215–220 "A small percentage of specimens of phytal genera (e.g., Xestoleberis spp., Neonesidea spp.) were contained in each sample, which are basically allochthonous specimens in bottom sediments transported from surrounding phytal environments. The value of allochthonous species to environmental interpretation is limited, however most ostracod specimens in each sample are composed of benthic, muddy sediment dwellers which are considered autochthonous."

2. Total organic carbon content (TOC) in bottom sediment is very important for ostracod distribution (Irizuki et al., 2011, 2015a, 2018) and it is a good indicator to estimate eutrophication and dissolved oxygen (DO) in the past in case of studies based on core samples. Though you did not examine TOC in sediment, you had better discuss the importance of TOC as an environmental factor and that TOC is strongly related to eutrophication and DO. (Irizuki, T., Hirose, K., Ueda, Y., Fujihara, Y., Ishiga, H., Seto, K., 2018, Ecological shifts due to anthropogenic activities in the coastal seas of the Seto Inland Sea, Japan, since the 20th century. Marine Pollution Bulletin, 127, 637-653.

Yes, indeed, we did notice eutrophication and hypoxia can be important factors for ostracods. It's the reason why we used Chlorophyll-a and DO in our modeling. They are reliable proxy for eutrophication and hypoxia. We agree TOC is important for paleo studies, but this MS is on modern distribution, and so it's out of the scope of our MS.

3. Minor problems are directly highlighted and revised in the text. Please also note the supplement to this comment: <u>https://www.biogeosciences-discuss.net/bg-2018-405/bg-2018-405-RC1- supplement.pdf</u>

Please see the attached pdf file for replies. For other corrections, please see the revised manuscript.

# Response to Manuscript Reviewers' Comments

Title: Baseline for ostracod-based northwestern Pacific and Indo-Pacific shallow-marine paleoenvironmental reconstructions: ecological modeling of species distributions

Dear editor and reviewer, T. M. Cronin Thank you all for your valuable comments on my manuscript. Please find the relevant excerpts from your report reproduced below, alongside their respective responses. Yours sincerely, Yuanyuan Hong (email: oocirclr@gmail.com)

1. The results section however is awfully descriptive and redundant, each paragraph starting the same way: Relative abundance of SPECIES X was correlated only with ENVIRONMENTAL: : :. These data is given in the tables. So emphasize in discussions the key species of most utility in east Asia. The data in tables are fine, but I think the authors have to discuss the most obvious and useful species as indicators of natural [T, S DO] and human [toxics, metals] chemical and physical factors. Not just plot and chart all the data. A little variability in writing style would help too.

Thanks for pointing this out! To improve descriptive and redundant impression, we divided the discussion section into sub-sections of (a) Widespread Group, (b) Temperate Group, (c) Subtropical Group, (d) Tropical Group, and (e) Globally Distributed Group. We also revised fig 7 accordingly. We also add some variation to our writing style. We already selected potentially important species for this study and so would like to keep mentioning all the species. Regarding the most obvious and important species, we already mentioned S impressa and N delicata in the abstract.

# 2. Tropical not tropic?

Thanks! Now we revised the MS and consistently use "tropical" as an adjective and "tropics" as a noun.

3. Some might argue 150 microns and larger misses some smaller species.

As discussed in the method section, most specimens smaller than 150 um will be early juveniles that are rarely preserved or difficult to identify. More datailes are discussed in Yasuhara et al 2017 Journal of Biogeography. So, we revised the relevant sentence in the method section as follow: "The residue was dry-sieved over a 150  $\mu$ m mesh sieve, and ostracod specimens larger than 150  $\mu$ m were picked; smaller individuals are mostly early instar juveniles that are often not preserved (because their shells are usually thin and delicate) or difficult to identify (see Yasuhara et al., 2017 for more details)."

4. I wonder why most specimens were dead shells and living animals were so scarce?

We don't know why (perhaps low population density or loss of living specimens during sampling or both). But it's quite common in grab sample based studies. However, dead shells eventually become fossils, so usage of mostly dead shells for obtaining autoecological information for paleoenvironmental application is reasonable.

5. Line 289. Why if K. kloempritensis lives in deeper water is it useful for sea level reconstruction? Species that live at or mean SL are best.

We agree that species living at mean SL are very useful, but our samples don't cover intertidal environments. *K. kloempritensis* is useful for sea level reconstructions at least in qualitative sense, because it could be an indicator for deeper water and tropical species rarely have such detailed autoecological information. The presence or higher relative abundance indicates higher relative sea-level.

6. Figure 7 could be re-designed to show the distributions better, for example, in shallow water regions.

We revised Fig. 7 to address your comment 1 above. We rearranged the order of species according to their geographic distribution groups. We also vertically compressed the map a bit for better visual. But please note than primary aim of this fig is to visualize large scale geographic distributions approximately, and it's out of the scope to show detailed or fine scale distributions.

## Response to Manuscript Reviewers' Comments

# Title: Baseline for ostracod-based northwestern Pacific and Indo-Pacific shallow-marine paleoenvironmental reconstructions: ecological modeling of species distributions

Dear Dr Lazaro, Thank you all for your valuable comments on my manuscript. Please find the relevant excerpts from your report reproduced below, alongside their respective responses. Yours sincerely, Yuanyuan Hong (email: <u>oocirclr@gmail.com</u>)

1. In order to avoid the iterative descriptions of results for all species it could be useful to underline the stronger correlations of species with environmental parameters (as positive correlations) and on the other hand, the stronger un-correlations of species/parameters (as negative correlations) to evidence the most sensitive species to environmental alterations (anthropogenic, in particular).

To address a reviewer 2's comment and to reduce iterative impression, we divide the results and discussion section into subsections by grouping the species into Widespread, Temperate, Subtropical, Tropical, and Globally Distributed Groups. We hope this works. In addition, the Table 3 already highlights significant correlations in model averaging (that are similar to "stronger correlations" in your sense).

2. Taphonomic status of individuals must be clearly noted, since only autochthonous specimens are valid to ecological modelling. In particular apply this with estuarine species that can be found in deeper waters.

The samples are mostly muddy (indicating deposition under calm condition), and so we think the faunal is mostly autochthonous, except a small percentage of phytal species included in each sample. We added some sentences regarding taphonomic problems in the revised manuscript. Please see line 215–220 "A small percentage of specimens of phytal genera (e.g., Xestoleberis spp., Neonesidea spp.) were contained in each sample, which are basically allochthonous specimens in bottom sediments transported from surrounding phytal environments. The value of allochthonous species to environmental interpretation is limited, however most ostracod specimens in each sample are composed of benthic, muddy sediment dwellers which are considered autochthonous."

## 3. Minor problems:

# 212 was strongly correlated with salinity (negative) better: strongly uncorrelated

We think the word "uncorrelated" is a bit confusing, because it can mean nonsignificant correlation instead of significant negative correlation. We also changed "strongly" to "significantly" for better accuracy. Text might be somehow simplified by using: correlated (positive) as correlated, and correlated (negative) as uncorrelated.

Please refer to answer for 3.

233 Relative abundance of B. bisanensis s.l., better using the complete name of species (Bicornucythere bisanensis) at first mention, and then writing the contracted name (B.

bisanensis) in other mentions of this species. This can apply for all species.

We agree, that's why we mentioned the complete name at the beginning of **5**. **Results and discussions**. In addition, species names at the beginning of a sentence are not abbreviated.

240 (Bicornucythere bisanensis) we did not see a significant relation between relative abundance and metal concentration, productivity s.l., but in Table 2 it is uncorrelated with MD (-0.23; -0.29) and correlated with Pb (+0.18)

Table 2 shows the best three regression models for the relative abundance of each common species. However, Table 3 is model averaging results (of all regression models) and more conservative regarding significance. So, MD and Pb are significant in some models, but not so overall. Thus, our discussion is mostly based on Table 3 results.

419 to 426 Why all these references there? Deleted.

Fig. 7 Bicornucythere bisanensis s.l. (dot in "l") Revised.

Table 2. R is variable Region. How is it measured the correlation/uncorrelation of different species with this variable?

Categorical parameter like geographic region can be included in regression modeling. Correlation is based on species distribution and presence and absence of each region.

Copper (Cu) is included in the performed environmental analyses (Fig. 3; Table 1), but

after this it do not appear in any of the results and discussions. I wonder if there is not one correlation with the studied species; if so, please indicate.

We explored linear dependencies by computing variance inflation factors (VIF) (Legendre & Legendre, 1998) and pairwise correlations between predictor variables to assess whether multicollinearity was likely to influence regression results (Yasuhara et al., 2012b). The degree of freedom is more than one for the geographic region variable (see below), thus we computed generalized variance inflation factors (GVIF). For continuous variables, GVIF (Table 4) is the same as VIF, but for categorical variables, GVIF has degrees of freedom (Df) equal to the number of coefficients associated with it (Hendrickx et al., 2004). Thus, we used GVIF1/2df to make GVIF values comparable among those with different Df. VIF >20 is usually indicative of high collinearity (Legendre & Legendre, 1998). Thus we calculated an equivalent threshold of 4.47 (equal to  $\sqrt{20}$ ) for GVIF1/2df to assess collinearity. Also, adjusted R2 >0.8 indicates a strong correlation of variables (Hoffman, 2015). In all datasets, summer temperature (ST) and copper (Cu) were highly correlated

(R2=0.8217), and the GVIFs of ST and Cu are >20, indicating that these correlations may influence regression results. Thus, we re-ran the linear regression modeling without ST and Cu. In other words, ST and Cu were removed from our analyses and discussion.

Please also note the supplement to this comment: <u>https://www.biogeosciences-discuss.net/bg-2018-405/bg-2018-405-RC3-supplement.pdf</u> Manuscript has been revised, with the comments in the supplement.





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4	Baseline for ostracod-based northwestern Pacific and Indo-Pacific shallow-
5	marine paleoenvironmental reconstructions: ecological modeling of species
6	distributions
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8	Yuanyuan Hong <sup>1,2,*</sup> , Moriaki Yasuhara <sup>1,2,*</sup> , Hokuto Iwatani <sup>1,2</sup> , Briony Mamo <sup>1,2</sup>
9	
10	
11	<sup>1</sup> School of Biological Sciences, The University of Hong Kong, Pok Fu Lam Road,
12	Hong Kong SAR, China
13	<sup>2</sup> Swire Institute of Marine Science, The University of Hong Kong, Cape d'Aguilar
14	Road, Shek O, Hong Kong SAR, China
15	
16	*Corresponding authors: Hong, Y.Y. (oocirclr@gmail.com); Yasuhara, M.
17	(moriakiyasuhara@gmail.com).
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- 28 Abstract:

29 Fossil ostracods have been widely used for Quaternary paleoenvironmental 30 reconstructions especially in marginally marine environments (e.g. for water depth, 31 temperature, salinity, oxygen levels, pollution). But our knowledge of the autoecology 32 of indicator species, the base of paleoenvironmental reconstructions, remains limited 33 and commonly lacks robust statistical support and comprehensive comparison with 34 environmental data. We analysed marginally marine ostracod taxa at 52 sites in Hong 35 Kong for which comprehensive environmental data are available. We applied linear 36 regression models to reveal relationships between species distribution and 37 environmental factors, and identified indicator species of environmental parameters. 38 For example, Sinocytheridea impressa and Neomonoceratina delicata indicate 39 botttom-water hypoxia - eutrophication, and heavy-metal pollution - increased 40 turbidity, respectively. Many taxa are widespread throughout the northwestern Pacific 41 - Indo-Pacific regions, including temperate (South China Sea to Japan and Russia), 42 subtropical (i.e., Indo-Pacific to the East China Sea), and tropical (i.e., Indo-Pacific 43 and South China Sea) taxa. With statistical support from ecological modeling and 44 comprehensive environmental data, These results provide a robust baseline for 45 ostracod-based Quaternary-Anthropocene paleoenvironmental reconstructions in the 46 tropic-extratopic northwestern Pacific and Indo-Pacific.

47

48 Key words: Autoecology, Distribution modeling, Indicator species, Ostracoda,

- 49 Paleoenvironmental reconstruction, Proxy.
- 50





### 51 Key points

- 52 1. We provide a robust baseline for ostracod (microscopic Arthropods) based
- paleoenvironmental reconstructions from Quaternary and Anthropocene marginalmarine sediments.
- 55 2. The studied species have wide distributions over the tropics and extratropics of the
- 56 northwestern Pacific and Indo-Pacific.
- 57 3. Ecological modeling established reliable indicator ostracod species for58 paleoenvironmental reconstructions.
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- 60
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#### 62 1. Introduction

Because of their small size, high abundance and excellent fossil record, fossil 63 64 ostracods (microcrustaceans), have been widely used to reconstruct Quaternary 65 environmental conditions including water-depth, salinity, temperature, oxygen, and 66 pollution, especially in marginal marine sediments (Boomer & Eisenhauer, 2002; Cronin, 2015; Frenzel & Boomer, 2005; Horne et al., 2012; Ruiz et al., 2005). In the 67 68 northwestern Pacific and Indo-Pacific there are numerous, widely distributed deltas 69 (Woodroffe et al., 2006) hosting accumulated Holocene marine sediments. Many 70 studies have reconstructed the depositional environments of these sediments (Alberti 71 et al., 2013; Dong et al., 2012; Irizuki et al., 2015b; Tanaka et al., 2011; Yasuhara & 72 Seto, 2006; Yasuhara et al., 2005; Zhou et al., 2015). Due to high sedimentation rates 73 (> 1 cm per year), fossil ostracods allow high-resolution reconstructions of human-74 induced environmental changes (pollution, eutrophication, bottom oxygen depletion) 75 over the past century (Irizuki et al., 2011; Yasuhara et al., 2003).





77 Many have evaluated the autoecology of indicator species as the basis for the 78 paleoenvironmental reconstructions (Hazel, 1988; Irizuki et al., 2003; Ozawa et al., 79 2004; Stepanova et al., 2003; Wang et al., 1988; Yasuhara & Seto, 2006; Zhao, 1984; 80 Zhao & Wang, 1988a, 1988b). Yet these studies tend to focus on only one or few 81 targeted environmental factor(s) and lack rigorous statistical evaluation, particularly 82 statistical modeling, a common approach in contemporary ecology. This is probably 83 due to the facts that comprehensive environmental dataset are often unavailable and 84 an ecological modeling approach (especially regression modeling and model selection) 85 has not been common in the field of micropaleontology.

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87 Hong Kong is an ideal location for the marine ecological modeling approach 88 valid for the northwestern Pacific and Indo-Pacific, because of its extensive and 89 intensive marine environmental monitoring program, which provides robust datasets 90 for ecological modeling and its subtropical location, where tropical and temperate 91 species coexist, which allows investigations of species with different latitudinal and 92 geographical distributions. We employed regression modeling of Hong Kong 93 shallow-marine ostracod species to show statistical relationships between species 94 abundance, distribution and environmental factors. This study allows the autoecology 95 and statistical evaluation of common tropical and extratropical species, providing a 96 baseline for ostracod-based shallow-marine paleoenvironmental reconstructions of the 97 northwestern Pacific and Indo-Pacific regions.

98

99 2. Study area





100 Hong Kong is situated at the southeastern corner of the Pearl River (Zhujiang) Delta, and has an area of 2500 km<sup>2</sup> (Fig. 1), at 22° 12.021' to 22° 33.817' N latitude, 113° 101 102 53.388' to 114° 26.920' E longitude. It is an ideal location to study natural and/or 103 anthropogenic impacts on benthic communities due to its complex hydrology and 104 long history of human influence. Western Hong Kong is affected by input from the 105 Pearl River, particularly during the summer heavy rainfall (Morton & Wu, 1975), 106 when salinity of the surface waters is strongly influenced by rainfall. Eastern Hong 107 Kong waters are mainly marine and derived from the South China Sea. As one of the 108 most urbanized coastal areas in the world, human activities, including rapid 109 industrialization, sewage discharge, trawling, dredging and land reclamation have led 110 to a deteriorated marine benthic ecosystem (Blackmore, 1998; Hodgkiss & Yim, 1995; Hong et al., 2017; Hu et al., 2008; Morton, 1996; Morton & Blackmore, 2001; Owen 111 112 & Sandhu, 2000; Shin, 1977; Tanner et al., 2000).

113

#### 114 **3. Materials and Methods**

#### 115 **3.1. Samples and laboratory procedure**

116 In January and July of 2011 we used a Van Veen Grab to collect 100 ml of sediment 117 from the uppermost cm of the sea floor from 52 sites in Hong Kong marine waters 118 (Fig. 1; Supplement A), 41 of which are in open waters and 11 in typhoon shelter sites. 119 Typhoon shelters are semi-enclosed areas of water designed to protect moored vessels 120 in extreme weather (Environmental Protection Department, 2011). All sites are 121 included in the Hong Kong EPD marine water and sediment quality monitoring 122 program, which has been conducted monthly since 1986 (for water) and biannually 123 (for sediment), providing comprehensive environmental data for all stations (see 124 below).





125 Sediments were wet-sieved over a 63 µm mesh sieve and air dried or oven-126 dried at 40 °C. The residue was dry-sieved over a 150 µm mesh sieve, and ostracod 127 specimens larger than 150 μm were picked; smaller individuals were not included to 128 avoid problems of identification in small, early instar juveniles. In samples containing 129 fewer than 200 specimens, we picked all individuals. If there were more than 200 130 specimens, we picked ostracods from a split. We identified each counted specimen to 131 species level when possible. We considered both an entire carapace or a single valve 132 as one individual for counting.

133

### 134 **3.2** *ironmental Variables*

135 We selected parameters from the EPD monitoring program (Table 1) for our 136 regression modeling (see below), including surface productivity (Chlorophyll-a, Chl; 137 Fig. 2), water depth (D; Fig. 2), bottom water dissolved oxygen (DO; Fig. 2), bottom 138 water salinity (Sal; Fig. 2), turbidity (Tur; Fig. 2), summer bottom water temperature 139 (ST - June to September average; Fig. 2), winter bottom water temperature (WT -140 November to Feburary average; Fig. 2), mud content (MD; Fig. 2), and heavy metal 141 concentration (Cu, Zn, and Pb; Fig. 3). These parameters are known to control 142 ostracod faunal properties (Cronin, 2015; Cronin & Vann, 2003; Hazel, 1988; Ikeya 143 & Shiozaki, 1993; Irizuki et al., 2005; Ruiz et al., 2005; Yasuhara et al., 2007; 144 Yasuhara et al., 2012b). We used averages over the entire monitoring period (1986-145 2011), because the ostracods in this study were mostly dead shells, thus the samples 146 should be considered time averaged. Bottom water DO is the average of the summer 147 season (June-September), due to the likely importance of summer bottom water 148 oxygen depletion.

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### 150 **4. Regression modeling**

Multiple linear regression modeling was used to determine the relationship between common ostracod species (relative abundance of each species) and environmental parameters (Supplement B). All environmental parameters were log-transformed and zero centered. Salinity outliers (salinity <25: DS2 and DS3) and samples with low abundance (<50 specimens: ES5, MS7, VS21, VS5 & VS6) were removed from the models.

157 The best-fitting models were selected based on Akaike's Information Criterion 158 (AICc) for small sample size, in which the lower score indicates the better model 159 support considering both goodness-of-fit and model complexity (Anderson & 160 Burnham, 2002). Akaike weights were used to summarize proportional support for all candidate models (Anderson et al., 2000) (Table 2). We considered parameter 161 162 estimates averaged over models, proportional to the support that each model received 163 (Anderson et al., 2000) (Table 3). This approach accounts for the uncertainty in model 164 selection and thus leads to appropriately broader confidence intervals than obtained 165 by relying only on the single, best-supported model. The relative importance of 166 various predictor variables was measured by the sum of Akaike weights of models 167 that included the variables in question (Brunham & Anderson, 2002).

We explored linear dependencies by computing variance inflation factors (VIF) (Legendre & Legendre, 1998) and pairwise correlations between predictor variables to assess whether multicollinearity was likely to influence regression results (Yasuhara et al., 2012b). The degree of freedom is more than one for the geographic region variable (see below), thus we computed generalized variance inflation factors (GVIF). For continuous variables, GVIF (Table 4) is the same as VIF, but for categorical variables, GVIF has degrees of freedom (Df) equal to the number of





175 coefficients associated with it (Hendrickx et al., 2004). Thus, we used GVIF<sup>1/2df</sup> to 176 make GVIF values comparable among those with different Df. VIF >20 is usually 177 indicative of high collinearity (Legendre & Legendre, 1998). Thus we calculated an equivalent threshold of 4.47 (equal to  $\sqrt{20}$ ) for GVIF<sup>1/2df</sup> to assess conlinearity. Also, 178 adjusted  $R^2 > 0.8$  indicates a strong correlation of variables (Hoffman, 2015). In all 179 180 datasets, summer temperature (ST) and water depth (D) were highly correlated 181  $(R^2=0.8217)$ , and the GVIFs of ST and Cu are >20, indicating that these correlations 182 may influence regression results. Thus, we re-ran the linear regression modeling 183 without ST and Cu. The new GVIFs of all variables were under 4.47 (Table 4).

We considered the degree of spatial autocorrelation in model residuals by the calculation of Moran's *I* index for the five best models. The neighborhood size was set as 2, 5, 10, 20 and 50 km. We found significant spatial autocorrelation in model residuals for many cases, thus we forced the geographic region variable (R) (Water Control Zones defined by EPD) to be included in all models. After this treatment, spatial autocorrelation was detected only in a few models for *Propontocypris* spp., *Stigmatocythere roesmani*, and *Hemikrithe orientalis*.

191 The multiple linear regression model analyses were implemented in R 192 programming language (R Core Team, 2016). We used 'M<sub>U</sub>MI<sub>N</sub>' (Bartoń, 2013) for 193 model averaging and 'SPDEP' (Bivand & Piras, 2015) to measure spatial 194 autocorrelation.

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### 196 5. Results and discussions

197 The comprehensive ostracod dataset for the 52 sites and the environmental variables 198 enabled us to elucidate distribution patterns of common ostracod taxa and their related 199 environmental factor(s). We identified 151 species belonging to 76 genera





200 (Supplement A). Among them, 18 common taxa (mainly species, a few genera) of 201 Sinocytheridea impressa, Neomonoceratina delicata, Propontocypris spp., 202 Pistocythereis bradyi, Bicornucythere bisanensis s.l., Keijella kloempritensis, 203 Nipponocythere bicarinata, Spinileberis quadriaculeata, Xestoleberis spp., 204 Loxoconcha malayensis, Neonesidea spp., Neosinocythere elongata, Stigmatocythere 205 roesmani, Phlyctocythere japonica, Alocopocythere goujoni, Hemikrithe orientalis, 206 Loxoconcha epeterseni and Hemicytheridea reticulata (Supplement B) were used for 207 regression modelling, and their relative abundances (to the total ostracod abundance in a sample) show a significant relation with environmental parameters. The best three 208 209 regression models are presented in Table 2 and the model-averaged parameter 210 estimates in Table 3.

Relative abundance of S. impressa [=Sinocytheridea latiovata; see Whatley 211 212 and Zhao (1988a)] was strongly correlated with salinity (negative), dissolved oxygen 213 (negative), mud content (positive) and productivity (positive) (Tables 2 and 3). The 214 species is noticeably dominant in areas characterized by a muddy bottom including 215 northern Mirs Bay, Port Shelter and coastal Southern Waters (Fig. 4). This species is 216 also abundant in Tolo Harbour, an area known for its summer hypoxia and 217 eutrophication (Hu et al., 2001; Sin & Chau, 1992). These results are consistent with 218 previous studies indicating that S. impressa is dominant in low salinity, nutrient-rich 219 and turbid estuaries (Irizuki et al., 2005; Tanaka et al., 2011), but we did not see a 220 significant relation with turbidity (Tables 2 and 3). S. impressa is known as a 221 euryhaline species widely distributed throughout the East and South China Seas 222 [abundant in water depths of <20 m; Whatley and Zhao (1988a)], and the Indo-Pacific 223 (Fig. 7).





224 Relative abundance of N. delicata (=Neomonoceratina crispata; see Hou & 225 Gou, 2007) is significantly correlated with Zn (positive), salinity (positive) and 226 turbidity (positive) (Tables 2 and 3). N. delicata is a nearshore species, abundant at 227 depths less than 30 m, at relatively high salinities (>30; Zhao and Wang, 1988). N. 228 *delicata* prefers higher salinity waters in Hong Kong (Figs. 2 and 4; Tables 2 and 3), 229 and is likely tolerant to human-induced environmental stress such as pollution and 230 eutrophication, in view of its positive correlation with Zn and turbidity. This species 231 is widely known from nearshore and estuary environments in the East and South 232 China Seas, and the Indo-Pacific (Fig. 7).

233 Relative abundance of B. bisanensis s.l. was significantly correlated with 234 water depth (negative) (Tables 2 and 3) and this species prefers shallower 235 environments (Figs. 2 and 4). In Chinese and Japanese coastal areas, B. bisanensis s.l. 236 is abundant in brackish water (salinity: 20-30) at depths less than 10 m (Ikeya & 237 Shiozaki, 1993; Irizuki et al., 2006; Zhao et al., 1986). Our results confirm its 238 preference for shallow depths. Bicornucythere bisanensis is tolerant of anthropogenic 239 impacts, especially eutrophication and the resulting bottom water hypoxia in Japan (Irizuki et al., 2003; Yasuhara et al., 2003; Yasuhara et al., 2012a). We did not see a 240 241 significant relation between relative abundance and metal concentration, productivity, 242 or dissolved oxygen. Possibly, the more dominant presence of S. impressa and N. 243 delicata, that are neither dominant or distributed throughout most of Japan, could 244 explain this difference. These species may have a higher tolerance than B. bisanensis 245 s.l. Another explanation may be that different morphotypes have different ecological 246 preferences (Abe, 1988), and only (F) h A is known to be tolerant to eutrophication 247 and bottom-water oxygen depletion (Irizuki et al., 2011; Irizuki et al., 2015a; 248 Yasuhara & Yamazaki, 2005; Yasuhara et al., 2007). Form A is less abundant in





Hong Kong, and due to the difficulty of identification of juveniles, we did not divide *B. bisanensis* into morphotypes. *B. bisanensis* s.l. is widely distributed throughout
marginal marine environments around Japan and Russia, and the East and South
China Seas (Fig. 7).

253 Relative abundance of *P. bradyi* was highly correlated with salinity (positive), 254 water depth (negative) and Pb (negative) (Tables 2 and 3). This indicates the species 255 prefers relatively shallow environments with high salinity (Figs. 2 and 4). In the Pearl 256 River Delta and shallow South China Sea (Fig. 7), P. bradyi is dominant along the 257 inner continental shelf at water depths <100 m (mostly common between 10–50 m), 258 and at salinities from 30-40 (Li, 1985; Zhao & Wang, 1990; Zhao et al., 1986). 259 *Pistocythereis bradyi* is a typical middle muddy bay species in Japan (Irizuki et al., 260 2006; Yasuhara & Irizuki, 2001; Yasuhara & Seto, 2006), and known from open bays 261 such as Gamagyang Bay in Korea (Abe, 1988) and Malacca Strait (Whatley & Zhao, 262 1988b). In these studies, P. bradyi prefers relatively high salinity and deeper water in 263 the inner continental shelf (Tables 2 and 3). Our data agree as to the preference for 264 high salinity, but we find shallower depths, inconsistent with the literature. Maybe 265 salinity is more important than depth, but the restricted depth range of our sites ( $\leq$ 35) 266 m) may also be a reason for this inconsistency. Our results indicate that P. bradyi is 267 sensitive to metal pollution. This species is widely distributed throughout the 268 marginally marine environments of Japan, the East and South China Seas, and the 269 Indo-Pacific (Fig. 7).

270 Relative abundance of *N. bicarinata* was correlated with productivity
271 (negative) (Tables 2 and 3). This is a typical middle bay species in Japan (Irizuki et al.,
2006), abundant on muddy substrates at water depths > 10 m (Yasuhara & Seto, 2006;
273 Yasuhara et al., 2005). (V) found *N. bicarinata* to be sensitive to eutrophication,





274 prefering lower productivity (Figures 2, 4). This species is know from marginal

275 marine environments around Japan and the East and South China Seas (Fig. 7).

276 Relative abundance of S. *quadriaculeata* is correlated to productivity (positive) 277 and turbidity (negative). This is a typical inner muddy bay species in Japan (Irizuki et 278 al., 2006), which prefers silty substrates in brackish waters, at salinities from 20–30, 279 and water depths of 2–7 m (Ikeya and Shiozaki, 1993). This study shows a preference 280 for waters with higher productivity but relatively low turbidity (Tables 2 and 3), so 281 that the species is abundant in Tolo Harbour (higher productivity, lower turbidity) but 282 not in Deep Bay (higher turbidity) (Figs. 2 and 4). Spinileberis quadriaculeata is not 283 tolerant to seasonal anoxia or oxygen depletion (0-1 mg/L) in Uranouchi Bay, Japan 284 (Irizuki et al., 2008), but we do not find a significant correlation with dissolved 285 oxygen content, probably due to the relatively high bottom-water oxygen content 286 (2.96-6.84 mg/L) in Hong Kong (Fig. 2; Supplement B). S. quadriaculeata is widely 287 distributed in marginally marine environments around Japan and Russia, and the East 288 and South China Seas (Fig. 7).

289 Relative abundance of K. kloempritensis was correlated only with water depth 290 (positive) (Fig. 4; Tables 2 and 3). Keijella kloempritensis is widely known from the 291 tropical Indo-Pacific region, and abundant along the inner continental-shelf of the 292 South and East China Seas (Fig. 7), at water depths range from 20-50 m and salinity 293 is close to normal marine (Zhao & Wang, 1990). Our modelling results are consistent 294 with this showing a preference for relatively deeper water in this study (Tables 2 and 295 3). Thus, this species is probably useful for reconstructing past sea-level changes in 296 the broad tropical and subtropical Indo-Pacific and northwestern Pacific regions.

297 Relative abundance of *L. malayensis* was correlated with dissolved oxygen
298 (negative) and mud content (negative) (Tables 2 and 3). *Loxoconcha malayensis* is a





299	typical tropical species known from the Indo-Pacific and the South China Sea (Fig. 7).
300	We did not find a correlation to temperature, likely due to the small range of variation
301	of bottom water temperatures in Hong Kong (winter temperature: 19.10-21.49°C).
302	This species prefers coarse sediments and is resistant to low oxygen content (Table 2
303	and 3), as seen by its abundance in Victoria Harbour (Figs. 2 and 4).
304	Relative abundance of <i>N. elongata</i> was correlated only with turbidity (positive)
305	(Tables 2 and 3). Neosinocythere elongata occurs along the entire coast of China (Fig.
306	7) in marginal marine, especially estuarine, environments shallower than 20 m (Dong
307	et al., 2012; Hou & Gou, 2007; Liu et al., 2013; Liu et al., 2017; Zhao & Whatley,
308	1993) and is known from the Indo-Pacific region (Fig. 7). Our modeling results and
309	previous studies indicate consistently that N. elongata prefers shallow, turbid waters
310	like Deep Bay and the Pearl River Estuary (Figs 2 and 6).
311	Relative abundance of S. roesmani was correlated with Pb (negative) (Tables
312	2 and 3), thus it was sensitive to metal pollution (but note the significant
313	autocorrelation with the modeling result of this genus) and absent in areas with high
314	metal concentrations, e.g., Tolo and Victoria Harbours (Fig. 3, 6). This species occurs

315 in the East and South China Seas and the Indo-Pacific region (Dewi, 1997; Mostafawi,

316 1992; Whatley & Zhao, 1988a) (Fig. 7).

317 Relative abundance of *P. japonica* was correlated with water depth (positive) 318 (Tables 2 and 3). This species is known from relatively deeper waters (>40 m) in the 319 East China Sea (Ishizaki, 1981; Wang et al., 1988). At our sites, it has its greatest 320 abundance at the deeper southern sites (Fig. 5). Phlyctocythere japonica is distributed 321 around Japan (Yasuhara et al., 2002) and the East and South China Seas (Fig. 7). 322 Relative abundance of A. goujoni was correlated with salinity (positive)

323 (Tables 2 and 3). It occurs not only in Mirs Bay where the salinity is higher, but also





324 in Deep Bay and North Western Waters where the salinity is lower than in other areas 325 (Figs 2 and 6). The Deep Bay and North Western Waters are shallow and have 326 relatively low oxygen content. The modeling result of this species shows a marginally 327 insignificant but negative relationship to oxygen content and water depth with 328 moderately high relative importance (Table 3). We explain this inconsistency by 329 considering their preference of higher salinity and shallow water depths, and also their 330 resistance to low oxygen conditions, but further research is needed to know their 331 autoecology with better confidence. Alocopocythere goujoni is known from the South 332 China Sea and the Indo-Pacific (Fig. 7).

333 Relative abundance of *H. orientalis* was correlated with water depth (positive) 334 (Tables 2 and 3; but note the significant autocorrelation with the modeling result of 335 this genus), and it is more abundant in deeper waters including southern Mirs Bay 336 (Fig. 5). Hemikrithe orientalis is known from depths of 20-50 m in the South China 337 Sea (Zhao & Wang, 1988a), and reported from tropical Indo-Pacific marginal marine 338 environments (Fig. 7). Our regression modeling consistently shows a positive 339 relationship between the relative abundance and winter temperatures, with moderately high relative importance, although the correlation is marginally insignificant (Table 3). 340 341 Relative abundance of L. epeterseni was correlated with water depth (positive) 342 and turbidity (negative) (Tables 2 and 3), and its occurs in the southern and eastern, 343 deeper and less turbid parts of Hong Kong waters, but the trend is not very clear (Figs 344 2 and 6). This species is also known from the deeper parts of Osaka Bay, Japan 345 (Yasuhara & Irizuki, 2001) and from marginal marine environments around Japan 346 (Ishizaki, 1968), the East China Sea (Yang et al., 1982), and the South China Sea 347 (Cao, 1998) (Fig. 7). This species is reported as Loxoconcha modesta in Hou & Gou 348 (2007), and also has been misidentified as Loxoconcha viva and Loxoconcha sinensis





(Hou & Gou, 2007). Ishizaki (1968) described *Loxoconcha laeta* and *Loxoconcha* 

350 *modesta* but in our opinion, these are the females and males of the same species.

351 Ishizaki (1981) gave the new species names Loxoconcha epeterseni and Loxoconcha

352 *tosamodesta* for *Loxoconcha laeta* and *Loxoconcha modesta*, respectively, because

353 these names were junior homonyms. Since *Loxoconcha laeta* (= *epeterseni*) appears

354 earlier than *Loxoconcha modesta* (=tosamodesta) in the original description (Ishizaki,

355 (1968), we use the name *Loxoconcha epeterseni* for this species.

356 Relative abundance of H. reticulata was correlated with Pb (negative) and 357 water depth (negative) (Tables 2 and 3). This species is abundant in Tolo Harbour 358 and the inner part of Mirs Bay (Fig. 5), at shallow depths, and is also consistently 359 found in very shallow waters from the Indo-Pacific (Zhao & Whatley, 1989). Their 360 metal-pollution sensitivity is contradictory because they occur in Tolo and Victora 361 Harbours, both polluted regions of Hong Kong, and further research is needed to 362 better understand these results (Figs 2 and 6). Hemicytheridea reticulata is distributed 363 in the East China Sea (Gu et al., 2017), the South China Sea, and the Indo-Pacific (Fig. 364 7).

The relative abundance of the cosmopolitan *Neonesidea* spp. was correlated with dissolved oxygen (positive), as expected for a phytal species (Smith & Kamiya, 2002; Yamada, 2007) (Table 2 and 3; Fig 6).

The relative abundance of the cosmopolitan *Propontocypris* spp. was strongly correlated with productivity (negative) (Tables 2 and 3). This negative correlation with productivity (but note the significant autocorrelation with the modeling result of this genus) indicates that the genus prefers less eutrophic waters (Fig. 6). *Propontocypris* is a good swimmer (Maddocks, 1969), and thus may have an advantage in obtaining food in relatively food-limited environments.





- The relative abundance of the cosmopolitan phytal (Irizuki et al., 2008; Sato & Kamiya, 2007; Yasuhara et al., 2002) *Xestoleberis* spp. was correlated with turbidity (negative), mud content (negative), and dissolved oxygen (positive) (Table 2 and 3;
- 377 Fig. 6). The taxon's habitats including clear water, coarse sediment, and high oxygen
- 378 content are reflected in our modeling.
- 379

### 380 Summary

381 Benthic ostracods from Hong Kong marginal marine waters studied here include 382 widespread (i.e., distributed throughout the northwestern Pacific - Indo-Pacific region: 383 one species), temperate (i.e., distributed from the South China Sea to Japan and 384 Russia: five species), subtropical (i.e., distributed from the Indo-Pacific to the East 385 China Sea: six species), and tropical (i.e., distributed in the Indo-Paficic and South 386 China Sea: three species) species and three globally distributed genera (Fig. 7). We 387 provide a robust baseline of autoecology for these common ostracod taxa based on rigorous statistical modeling using comprehensive environmental data. We 388 389 established reliable indicator forms for water depth, mud content, salinity, turbidity, 390 dissolved oxygen, heavy metal pollution (Pb and Zn) and eutrophication (chlorophyll-391 a) (Table 5). Thus our results are applicable for future ostracod-based 392 paleoenvironmental studies in a wide range of localities from the tropics to the 393 extratropics, and from the Indian Ocean to the northwestern Pacific. We established 394 pollution and eutrophication indicator species in tropical environments for the first 395 time. Anthropocene paleoenvironmental and paleoecological studies in the tropics are 396 urgently needed because (1) the tropics are seriously under-studied (Wilkinson et al., 397 2014; Yasuhara et al., 2012a), (2) tropical environments and ecosystems are 398 vulnerable and sensitive to human influences (Jackson et al., 2001; Pandolfi et al.,





- 2003), and (3) Indo-Pacific tropical environments have been seriously degraded by
  the human activity of rapidly developing countries (Bellwood et al., 2004; Jackson,
  2008; Knowlton & Jackson, 2008). Our results provide useful and reliable tools for
  tropical Anthropocene research in the broad Indo-Pacific region.
- 403

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<mark>421</mark>	2007; Irizuki et al., 2009; Jie et al., 2013; Li, 1985; Tanaka et al., 2009; Wang & Zhao
422	1985; Wang & Zhang, 1987; Zhao, 1984; Zhao & Wang, 1988b; Zhao & Whatley,





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728 Captions





730 Fig. 1 Locality map showing the 52 sampling sites across Hong Kong, including 41 731 open water sites (blue dots) and 11 typhoon shelter sites (red open dots). From west to 732 east, DS: Deep Bay; NS: North Western waters; SS: Southern waters; VS: Victoria 733 Harbour; ES: Eastern Buffer; JS: Junk Bay; TS: Tolo Harbour; PS: Port Shelter; MS: 734 Mirs Bay. 735 736 Fig. 2 Spatial distribution of environmental parameters in Hong Kong. Mean surface-737 water chlorophyll-a concentration; water depth; summer (June to September) bottom-738 water dissolved oxygen content; mean bottom-water salinity; mean turbidity; mean 739 summer (June to September) bottom-water temperature; mean winter (November to 740 February) bottom-water temperature; and mean mud content. All are averaged values 741 of the data obtained during 1986–2013 (Table 1). 742 743 Fig. 3 Spatial distribution of environmental parameters in Hong Kong. Mean copper 744 (Cu) concentration, mean lead (Pb) concentration, and mean zinc (Zn) concentration 745 in surface sediments. All are averaged values of the data obtained during 1986-2013 746 (Table 1). 747 748 Fig. 4. Spatial distribution of the relative abundance of Sinocytheridea impressa, 749 Neomonoceratina delicata, Bicornucythere bisanensis s.l., Pistocythereis bradyi, 750 Nipponocythere bicarinata, Spinileberis quadriaculeata, Keijella kloempritensis, and 751 Loxoconcha malayensis in Hong Kong. See Figure 1 for sampling stations. 752 753 Fig. 5. Spatial distribution of the relative abundance of Neosinocythere elongata, 754 Stigmatocythere roesmani, Phlyctocythere japonica, Alocopocythere goujoni,





755 Hemikrithe orientalis, Loxoconcha epeterseni, Hemicytheridea reticulata and

- *Neonesidea* spp. in Hong Kong. See Figure 1 for sampling stations.
- 757
- Fig. 6. Spatial distribution of the relative abundance of *Propontocypris* spp., and *Xestoleberis* spp. in Hong Kong. See Figure 1 for sampling stations.
- 760

761 Fig. 7. Geographical distributions of the 18 taxa in the northwestern Pacific and Indo-762 Pacific regions, including Sinocytheridea impressa, Neomonoceratina delicata, 763 Pistocythereis bradyi, Bicornucythere bisanensis s.l., Keijella kloempritensis, 764 Nipponocythere bicarinata, Spinileberis quadriaculeata, Loxoconcha malayensis, 765 Neosinocythere elongata, Stigmatocythere roesmani, Phlyctocythere japonica, 766 Alocopocythere goujoni, Hemikrithe orientalis, Loxoconcha epeterseni, 767 Hemicytheridea reticulata, Neonesidea spp., Propontocypris spp., and Xestoleberis 768 spp. The following references were used mainly to determine the geographical 769 distributions of the species: Al Jumaily and Al-Sheikhly (1999); Dewi (1997); Dong 770 et al. (2012); Fauzielly et al. (2013); Hong et al. (2017); Hou and Gou (2007); 771 Hussain et al. (2004); Hussain et al. (2010); Hussain and Mohan (2000, 2001); Irizuki 772 et al. (2006); Irizuki et al. (2009); Iwatani et al. (2014); Jie et al. (2013); Li (1985); 773 Mostafawi (1992); Nishath et al. (2017); Noraswana et al. (2014); Pugliese et al. 774 (2006); Schornikov et al. (2014); Tanaka et al. (2009); Tanaka et al. (2011); Wang et 775 al. (1988); Wang and Zhang (1987); Wang and Zhao (1985); Zhao (1984); Zhao and 776 Wang (1988a, 1988b, 1990); Zhao and Whatley (1993); Zhou et al. (2015).

777

778 Table 1. Summary of marine water/sediment parameters. Note: 1. Summer: June,

July, August and September. 2. Winter: November, December, January and February.





# 780

781	Table 2. Best three regression models of the relative abundance of common species,
782	including Sinocytheridea impressa, Neomonoceratina delicata, Propontocypris spp.,
783	Pistocythereis bradyi, Bicornucythere bisanensis s.l., Keijella kloempritensis,
784	Nipponocythere bicarinata, Spinileberis quadriaculeata, Xestoleberis spp.,
785	Loxoconcha malayensis, Neonesidea spp., Neosinocythere elongata, Stigmatocythere
786	roesmani, Phlyctocythere japonica, Alocopocythere goujoni, Hemikrithe orientalis,
787	Loxoconcha epeterseni and Hemicytheridea reticulata. The table shows the
788	coefficient of each term, adjusted R <sup>2</sup> , the Akaike information criterion corrected for
789	small sample size (AICc), and the Akaike weight (AW). Bold denotes significance at
790	P < 0.05. Overall P is $< 0.05$ in all models. R: region. Other abbreviations are found in
791	Table 1.

792

793 Table 3. Model-averaged parameter estimates and CIs of the relative abundance of 794 common species, including Sinocytheridea impressa, Neomonoceratina delicata, 795 Propontocypris spp., Pistocythereis bradyi, Bicornucythere bisanensis s.l., Keijella 796 kloempritensis, Nipponocythere bicarinata, Spinileberis quadriaculeata, Xestoleberis 797 spp., Loxoconcha malayensis, Neonesidea spp., Neosinocythere elongata, 798 Stigmatocythere roesmani, Phlyctocythere japonica, Alocopocythere goujoni, 799 Hemikrithe orientalis, Loxoconcha epeterseni and Hemicytheridea reticulata. CIs, 800 confidence intervals; RI, relative importance (the sum of the Akaike weights of 801 models that include the variable in question; see Materials and Methods); R, region. 802 Other abbreviations are found in Table 1. Bold denotes CIs that exclude zero. For R, 803 coefficient, lower CI, and upper CI values shown are averages of those for geographic 804 regions.





805	
806	Table 4. GVIF value for Environmental Variables. Df, degree of freedom; R, region.
807	Other abbreviations are found in Table 1.
808	
809	Table 5. Summary of autoecology for common ostracod taxa. Chl: Chlorophyll-a; D:
810	Water Depth; DO: Dissolved Oxygen; MD: Mud Content; Sal: Salinity; Tur:
811	Turbidity; WT: Winter Temperature; Pb: Lead; Zn: Zinc; R: Region.
812	
813	
814	Supplement A. Ostracod faunal list.
815	
816	Supplement B. Dataset used for the regression modeling.











22'30°

22'2

22.50

22'30"

22'20°











114'20



































Fig. 4









Fig. 5













Fig. 7





Table 1.			
Parameter (Abbreviation)	Unit	Sampling Depth / Material	Season (AD. 1986-2013)
Chlorophyll-a (Chl)	μg/L	Surface water	All year
Water Depth (D)	m		All year
Dissolved Oxygen (DO)	mg/L	Bottom water	Summer <sup>1</sup>
Mud Content (MD)	%w/w (<63µm)	Bottom sediment	All year
Salinity (Sal)		Bottom water	All year
Turbidity (Tur)	NTU	Bottom water	All year
Summer Temperature (ST)	°C	Bottom water	Summer <sup>1</sup>
Winter Temperature (WT)	°C	Bottom water	Winter <sup>2</sup>
Copper (Cu)	mg/kg	Bottom sediment	All year
Lead (Pb)	mg/kg	Bottom sediment	All year
Zinc (Zn)	mg/kg	Bottom sediment	All year





Table 2.													
Model	Chl	D	DO	MD	Sal	Tur	WT	Pb	Zn	R	$\mathbb{R}^2$	AICc	AW
Sinocythe	eridea in	npressa	a										
1	0.33		-1.47	0.75	-9.13					0.34	0.55	-37.29	0.27
2	0.41		-1.48		-8.75					0.37	0.50	-35.24	0.10
3			-1.12	0.94	-10.30					0.44	0.49	-34.78	0.08
Neomono	ceratind	a delica	ata										
1					3.77	0.34			0.41	-0.13	0.48	-82.57	0.29
2			0.43		5.02	0.31			0.39	-0.20	0.50	-81.21	0.15
3					3.47	0.33		-0.20	0.55	-0.12	0.48	-79.32	0.06
Proponto	<i>cypris</i> s	pp.											
1	-0.28			0.46						0.04	0.20	-72.47	0.15
2	-0.24									0.07	0.13	-71.74	0.10
3	-0.24			0.49			-2.46			0.02	0.22	-70.76	0.06
Pistocyth	ereis br	adyi											
1		-0.12			2.67			-0.21		-0.06	0.61	-163.64	0.52
2		-0.13			2.87	0.04		-0.20		-0.05	0.61	-159.79	0.08
3		-0.12	0.07		2.83			-0.21		-0.07	0.60	-159.42	0.06
Bicornuc	vthere b	isanen.	<i>sis</i> s.l.										
1		-0.09		-0.23						0.02	0.60	-137.80	0.12
2		-0.08								-0.01	0.56	-136.77	0.07
3				-0.29				0.18		0.00	0.58	-136.77	0.05
Keijella k	loempri	itensis											
1		0.06						-0.06		-0.02	0.56	-202.12	0.12
2		0.08								-0.02	0.53	-201.51	0.09
3		0.06		0.09				-0.08		-0.02	0.58	-200.86	0.06
Nipponoc	ythere b	bicarin	ata										
1	-0.07		-0.12							0.03	0.43	-200.57	0.11
2	-0.09									0.03	0.39	-200.38	0.10
3	-0.09	-0.03	-0.16							0.04	0.45	-199.30	0.06
Spinilebe	ris quad	lriacule	eata										
1	0.06					-0.09				-0.04	0.63	-183.88	0.10
2		-0.05								0.02	0.60	-182.94	0.06
3	0.08					-0.09	-0.75			-0.04	0.65	-182.66	0.05
Xestolebe	eris spp.												
1	-	0.04	0.15	-0.11		-0.08		0.05		-0.02	0.62	-225.55	0.09
2		0.03	0.15	-0.09		-0.09				-0.02	0.59	-225.29	0.08
3				-0.09		-0.06				0.00	0.52	-224.60	0.06





Model	Chl	D	DO	MD	Sal	Tur	WT	Pb	Zn	R	R <sup>2</sup>	AICc	AW
Loxoconcha malayensis													
1		-0.03	-0.14	-0.12						0.03	0.55	-229.55	0.10
2	0.04		-0.13	-0.12						0.02	0.55	-229.42	0.09
3		-0.04	-0.14	-0.10				-0.04		0.03	0.57	-228.47	0.06
Neoneside	ea spp.												
1	-0.12			-0.25					0.19	0.05	0.28	-149.00	0.09
2	-0.11		0.33	-0.24			-1.13		0.20	0.05	0.31	-147.86	0.05
3			0.21							0.02	0.08	-147.40	0.04
Neosinocy	there e	longata	a										
1	-0.02					0.09				-0.03	0.76	-244.70	0.09
2				-0.06		0.08				-0.03	0.76	-244.42	0.08
3						0.09				-0.03	0.74	-244.15	0.07
Stigmatoc	ythere	roesma	ni										
1								-0.08		0.00	0.23	-225.23	0.07
2					0.36			-0.07		-0.02	0.25	-224.06	0.04
3			0.10		0.67			-0.07		0.30	0.30	-224.03	0.04
Phlyctocy	there ja	iponica	!										
1		0.04								0.00	0.28	-238.60	0.19
2		0.03			0.33					-0.02	0.30	-237.01	0.09
3		0.03						-0.02		0.00	0.27	-235.62	0.04
Alocopocy	vthere g	goujoni											
1	-	-			0.21					-0.04	0.68	-331.97	0.09
2		-0.01			0.28				-0.01	-0.04	0.71	-330.52	0.05
3		-0.01			0.27			-0.02		-0.04	0.71	-330.45	0.04
Hemikrith	e orien	talis											
1		0.03					0.46			0.00	0.19	-249.44	0.11
2		0.03	0.07							0.00	0.18	-248.67	0.07
3		0.04	0.06				0.42			0.00	0.23	-248.60	0.07
Loxoconci	ha epet	erseni											
1	-	0.03			-0.33	-0.03				0.01	0.49	-288.61	0.11
2	0.02	0.04		-0.04	-0.34	-0.04				0.00	0.56	-287.76	0.07
3	0.02	0.04			-0.34	-0.04				0.00	0.51	-287.31	0.06
Hemicythe	eridea 1	reticula	ta										
1		-0.03						-0.04		0.01	0.23	-270.79	0.14
2	0.02	-0.02						-0.04		0.01	0.26	-269.44	0.07
3	0.03							-0.03		0.00	0.19	-268.64	0.05





Table									
Term		Coeffiencient	Lower CI	Upper CI	Term		Coeffiencient	Lower CI	Upper CI
	theridea i		0.00	0.01		la kloempr		0.00	0.04
R	1.00	0.36	-0.09	0.81	R	1.00	-0.02	-0.09	0.04
Sal	0.99	-9.26	-14.61	-3.91	D	0.86	0.06	0.02	0.11
DO	0.91	-1.42	-2.48	-0.37	Pb	0.58	-0.08	-0.17	0.01
MD	0.75	0.82	0.07	1.57	Sal	0.35	0.68	-0.21	1.58
Chl	0.74	0.82	0.03	0.70	MD	0.25	0.08	-0.05	0.21
WT	0.20	0.82	-2.34	8.89	Tur	0.24	0.05	-0.03	0.14
Zn	0.13	0.82	-0.68	0.51	Chl	0.22	-0.04	-0.11	0.03
Tur	0.11	0.82	-0.61	0.30	Zn	0.17	0.02	-0.11	0.14
D	0.11	0.82	-0.29	0.41	WT	0.14	0.33	-0.55	1.22
Pb	0.10	0.82	-0.62	0.46	DO	0.11	0.03	-0.14	0.19
		a delicata					bicarinata		
R	1.00	-0.15	-0.42	0.12	R	1.00	0.02	-0.04	0.09
Zn	0.94	0.41	0.11	0.70	Chl	0.92	-0.08	-0.14	-0.02
Sal	0.93	4.06	1.00	7.13	DO	0.50	-0.14	-0.30	0.02
Tur	0.84	0.33	0.06	0.59	D	0.30	-0.03	-0.08	0.02
DO	0.33	0.45	-0.17	1.06	WT	0.25	-0.03	-0.08	0.02
Pb	0.17	-0.18	-0.67	0.30	Sal	0.24	0.51	-0.35	1.36
MD	0.14	0.25	-0.33	0.84	Tur	0.19	-0.04	-0.11	0.04
D	0.11	-0.01	-0.22	0.20	Zn	0.18	-0.04	-0.12	0.04
WT	0.11	-0.86	-4.32	2.60	Pb	0.13	-0.03	-0.11	0.06
Chl	0.09	0.00	-0.24	0.23	MD	0.10	0.00	-0.13	0.13
Propor	ntocypris s	spp.			Spinil	eberis qua	driaculeata		
R	1.00	0.05	-0.19	0.30	Ŕ	1	-0.01	-0.10	0.07
Chl	0.80	-0.26	-0.47	-0.04	Tur	0.66	-0.09	-0.17	0.00
MD	0.58	0.50	-0.03	1.03	Chl	0.54	0.06	0.00	0.13
WT	0.29	-2.60	-6.48	1.28	D	0.45	-0.05	-0.10	0.01
Pb	0.19	-0.18	-0.55	0.20	WT	0.32	-0.76	-1.82	0.31
Sal	0.17	-1.48	-4.88	1.92	DO	0.19	0.10	-0.10	0.30
DO	0.15	-0.27	-0.99	0.45	MD	0.17	-0.07	-0.23	0.09
Zn	0.14	-0.03	-0.48	0.41	Pb	0.17	-0.05	-0.16	0.07
D	0.13	0.04	-0.17	0.26	Zn	0.14	0.03	-0.09	0.15
Tur	0.10	0.01	-0.29	0.32	Sal	0.13	0.11	-1.03	1.26
Pistor	vthereis br	advi			Xestal	<i>eberis</i> spp			
R	1.00	-0.06	-0.15	0.04	R	1.00	• -0.01	-0.06	0.05
Sal	1.00	2.71	1.53	3.88	Tur	0.77	-0.07	-0.12	-0.01
D	1.00	-0.12	-0.19	-0.06	MD	0.66	-0.10	-0.19	0.00
Pb	0.97	-0.21	-0.32	-0.10	DO	0.63	0.13	0.00	0.26
Tur	0.12	0.04	-0.07	0.15	D	0.42	0.03	-0.01	0.07
Zn	0.11	-0.05	-0.23	0.13	Pb	0.33	0.04	-0.02	0.11
DO	0.10	0.06	-0.18	0.31	Sal	0.27	0.46	-0.24	1.15
WT	0.10	0.33	-0.98	1.64	WT	0.19	-0.37	-1.06	0.31
Chl	0.09	0.02	-0.08	0.11	Zn	0.14	0.00	-0.09	0.08
MD	0.08	-0.01	-0.20	0.18	Chl	0.10	0.00	-0.05	0.05
				0.10				0.00	0.00
Bicorn R	<i>ucythere</i> 1 1.00	bisanensis s.l. 0.01	-0.11	0.12	<i>Loxoc</i> R	oncha mai 1.00	layensis 0.02	-0.02	0.06
MD	0.63	-0.26	-0.11	0.12	DO	0.87	-0.14	-0.02 -0.25	-0.03
D D	0.03 0.62	-0.20 -0.08	-0.32 -0.16	0.00	MD	0.87	-0.14	-0.23	-0.03
D Pb	0.38	<b>-0.08</b> 0.14	-0.05	0.33	D	0.48	-0.03	-0.20	0.00
DO	0.38	0.14	-0.03	0.33	Chl	0.48	0.03	-0.00	0.00
Chl	0.20	0.17	-0.15	0.48	Chi Pb	0.40	-0.04	-0.01	0.08
Tur	0.19	0.08	-0.07	0.19	PD WT	0.29	-0.04 0.41	-0.10	1.03
	0.19	-0.01	-0.08	0.22	Zn	0.26	-0.03	-0.21	0.04
Zn Sal	0.16	-0.01			Zn Sal	0.20	-0.03	-0.10	0.04
			-1.86	1.82					
WT	0.10	0.06	-1.80	1.92	Tur	0.11	-0.01	-0.07	0.05





Term	RI	Coeffiencient	Lower CI	Upper CI	Term	RI	Coeffiencient	Lower CI	Upper CI
Neones	<i>idea</i> sp	р.			Alocop	ocyther	e goujoni		
R	1.00	0.02	-0.09	0.13	R	1.00	-0.03	-0.05	-0.02
DO	0.72	0.30	0.02	0.57	Sal	0.78	0.22	0.03	0.41
Zn	0.58	0.15	-0.01	0.31	D	0.46	-0.01	-0.02	0.00
MD	0.46	-0.23	-0.49	0.03	DO	0.43	-0.03	-0.07	0.01
Chl	0.42	-0.09	-0.21	0.02	Pb	0.31	-0.01	-0.03	0.01
WT	0.32	-1.13	-2.69	0.42	Zn	0.29	-0.01	-0.03	0.01
Tur	0.24	-0.09	-0.22	0.05	WT	0.24	0.13	-0.08	0.33
D	0.23	0.05	-0.04	0.15	Tur	0.18	0.01	-0.01	0.03
Pb	0.17	0.05	-0.13	0.24	MD	0.14	-0.01	-0.04	0.02
Sal	0.15	-0.60	-2.20	1.01	Chl	0.11	0.00	-0.01	0.01
Neosin	ocyther	e elongata			Hemik	rithe ori	ientalis		
R	1.00	-0.03	-0.07	0.00	R	1.00	0.00	-0.04	0.03
Tur	1.00	0.08	0.04	0.13	D	0.77	0.03	0.00	0.05
MD	0.33	-0.05	-0.13	0.02	WT	0.46	0.43	-0.07	0.93
Chl	0.30	-0.02	-0.05	0.01	DO	0.44	0.08	-0.02	0.17
WT	0.26	-0.33	-0.85	0.18	Sal	0.30	0.37	-0.17	0.90
Zn	0.21	-0.02	-0.06	0.02	Pb	0.22	-0.03	-0.08	0.02
Pb	0.19	-0.02	-0.07	0.02	Tur	0.17	0.02	-0.03	0.07
D	0.12	0.00	-0.03	0.03	Chl	0.14	-0.01	-0.05	0.03
DO	0.12	-0.02	-0.11	0.07	Zn	0.11	0.00	-0.05	0.05
Sal	0.10	0.04	-0.40	0.49	MD	0.10	-0.01	-0.08	0.07
Stigmat	tocythe	re roesmani			Loxoce	oncha ej	veterseni		
R	1.00	-0.01	-0.07	0.05	R	1.00	0.00	-0.02	0.03
Sal	0.61	0.62	-0.04	1.27	D	0.94	0.03	0.00	0.05
Pb	0.61	-0.06	-0.12	0.00	Tur	0.76	-0.03	-0.06	0.00
Tur	0.37	0.04	-0.01	0.10	Sal	0.53	-0.30	-0.62	0.02
Zn	0.31	-0.05	-0.11	0.02	MD	0.38	-0.04	-0.08	0.01
DO	0.31	0.09	-0.04	0.22	Chl	0.30	0.02	-0.01	0.04
MD	0.23	-0.06	-0.16	0.04	DO	0.26	0.04	-0.02	0.10
Chl	0.19	-0.02	-0.07	0.02	Pb	0.17	0.01	-0.02	0.05
WT	0.19	0.35	-0.33	1.02	WT	0.13	-0.13	-0.48	0.22
D	0.14	-0.01	-0.05	0.04	Zn	0.12	0.01	-0.03	0.04
Phlycto	cythere	e japonica			Hemic	vtheride	a reticulata		
R	1.00	-0.01	-0.05	0.03	R.	1.00	0.01	-0.02	0.03
D	0.80	0.03	0.01	0.06	Pb	0.67	-0.04	-0.07	0.00
Sal	0.42	0.46	-0.10	1.02	D	0.66	-0.02	-0.04	0.00
Pb	0.21	-0.03	-0.08	0.03	Chl	0.49	0.03	0.00	0.05
Zn	0.20	-0.02	-0.07	0.03	WT	0.24	-0.24	-0.64	0.16
WT	0.15	0.22	-0.38	0.81	MD	0.23	-0.03	-0.09	0.02
DO	0.14	0.03	-0.08	0.15	Zn	0.17	-0.01	-0.06	0.05
Tur	0.12	0.00	-0.05	0.05	DO	0.13	0.02	-0.05	0.10
Chl	0.12	0.00	-0.04	0.05	Tur	0.13	-0.01	-0.05	0.03
MD	0.11	0.00	-0.09	0.08	Sal	0.11	-0.05	-0.43	0.34





Table 4.			
Environmental Variables	GVIF	Df	GVIF <sup>1/2Df</sup>
Chl	7.40	1	2.72
D	6.41	1	2.53
DO	4.49	1	2.12
MD	3.72	1	1.93
Sal	9.43	1	3.07
Tur	6.67	1	2.58
Pb	9.98	1	3.16
Zn	10.05	1	3.17
WT	2.39	1	1.55
R	1266.30	9	1.49





Table 5										
Таха	Chl	D	DO	MD	Sal	Tur	WT	Pb	Zn	R
Sinocytheridea impressa	+		-	+	-					
Neomonoceratina delicata					+	+			+	
Pistocythereis bradyi		-			+			-		
Bicornucythere bisanensis s.l.		-								
Keijella kloempritensis		+								
Nipponocythere bicarinata	-									
Spinileberis quadriaculeata	+					-				
Loxoconcha malayensis			-	-						
Neosinocythere elongata						+				
Stigmatocythere roesmani								-		
Phlyctocythere japonica		+								
Alocopocythere goujoni					+					
Hemikrithe orientalis		+								
Loxoconcha epeterseni		+				-				
Hemicytheridea reticulata		-						-		
Neonesidea spp.			+							
Propontocypris spp.	-									
Xestoleberis spp.			+	-		-				

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      Biogeosciences
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      Research Paper
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      Baseline for ostracod-based northwestern Pacific and Indo-Pacific shallow-
      marine paleoenvironmental reconstructions: ecological modeling of species
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 6
      distributions
 7
      Yuanyuan Hong<sup>1,2,*</sup>, Moriaki Yasuhara<sup>1,2,*</sup>, Hokuto Iwatani<sup>1,2</sup>, Briony Mamo<sup>1,2</sup>
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      <sup>1</sup>School of Biological Sciences, The University of Hong Kong, Pok Fu Lam Road,
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      Hong Kong SAR, China
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      <sup>2</sup>Swire Institute of Marine Science, The University of Hong Kong, Cape d'Aguilar
14
      Road, Shek O, Hong Kong SAR, China
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      *Corresponding authors: Hong, Y.Y. (oocirclr@gmail.com); Yasuhara, M.
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      (moriakiyasuhara@gmail.com).
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28 Abstract:

29	Fossil ostracods have been widely used for Quaternary paleoenvironmental
30	reconstructions especially in marginal, marine environments (e.g. for water depth,
31	temperature, salinity, oxygen levels, pollution). But our knowledge of indicator
32	species, autoecology, the base of paleoenvironmental reconstructions, remains limited
33	and commonly lacks robust statistical support and comprehensive comparison with
34	environmental data. We analysed marginal, marine ostracod taxa at 52 sites in Hong
35	Kong for which comprehensive environmental data are available. We applied linear
36	regression models to reveal relationships between species distribution and
37	environmental factors for 18 common taxa (mainly species, a few genera) in our
38	Hong Kong dataset, and identified indicator species of environmental parameters. For
39	example, Sinocytheridea impressa, widely distributed euryhaline species throughout
40	the East and South China Seas and the Indo-Pacific, indicates eutrophication and
41	botttom-water hypoxia, Neomonoceratina delicata, widely known species from
42	nearshore and estuarine environments in the East and South China Seas, and the Indo-
43	Pacific, indicates heavy-metal pollution and increased turbidity, The 18 taxa used for
44	this study are widely distributed geographically and divided into Widespread
45	(throughout the northwestern Pacific and Indo-Pacific regions), Temperate [South
46	China Sea to Russia (Sea of Japan coast) and Japan], Subtropical (Indo-Pacific to the
47	East China Sea), Tropical (Indo-Pacific and South China Sea), and Globally
48	Distributed Groups. With statistical support from ecological modeling and
49	comprehensive environmental data, these results provide a robust baseline for

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69 ostracod-based Quaternary-Anthropocene paleoenvironmental reconstructions in the

70 tropical-extratropical northwestern Pacific and Indo-Pacific widely.

71

- 72 Key words: Autoecology, Distribution modeling, Indicator species, Ostracoda,
- 73 Paleoenvironmental reconstruction, Proxy.
- 74

#### 75 Key points

76 1. We provide a robust baseline for ostracod-based (microscopic Arthropods)

77 paleoenvironmental reconstructions from Quaternary and Anthropocene marginal

78 marine sediments.

- 79 2. The studied species have wide distributions over the tropics and extratropics of the
- 80 northwestern Pacific and Indo-Pacific.
- 81 3. Ecological modeling established reliable indicator ostracod species for82 paleoenvironmental reconstructions.
- 83
- 84
- 85

# 86 1. Introduction

Because of their small size, high abundance and excellent fossil record, fossil ostracods (microcrustaceans), have been widely used to reconstruct Quaternary environmental conditions including water-depth, salinity, temperature, oxygen, and pollution, especially in marginal marine sediments (Boomer & Eisenhauer, 2002; Cronin, 2015; Frenzel & Boomer, 2005; Horne et al., 2012; Ruiz et al., 2005). In the northwestern Pacific and Indo-Pacific there are numerous, deltas (Woodroffe et al., 2006) hosting accumulated Holocene marine sediments. Many studies have Reviewer 17/12/18 5:13 PM Deleted: (microscopic Arthropods) Reviewer 17/12/18 5:13 PM Deleted:

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**Comment [1]:** Do you want to call them microscopic arthropods or microcrustaceans? I realise both work but you use one term in your highlights and another in your introduction. Just pick one and keep it consistent either way. m o 19/12/18 7:26 PM

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97 reconstructed the depositional environments of these sediments (Alberti et al., 2013;
98 Dong et al., 2012; Irizuki et al., 2015b; Tanaka et al., 2011; Yasuhara & Seto, 2006;
99 Yasuhara et al., 2005; Zhou et al., 2015). Due to high sedimentation rates (> 1 cm per
100 year), fossil ostracods allow the high-resolution reconstruction, of human-induced
101 environmental changes (pollution, eutrophication, bottom oxygen depletion) over the
102 past century (Irizuki et al., 2011; Irizuki et al., 2015a; Irizuki et al., 2018; Yasuhara et al., 2007).

#### 104

114

105 Many have evaluated the autoecology of ostracod indicator species as the 106 basis for paleoenvironmental reconstructions (Hazel, 1988; Irizuki et al., 2003; Ozawa 107 et al., 2004; Stepanova et al., 2003; Wang et al., 1988; Yasuhara & Seto, 2006; Zhao, 108 1984; Zhao & Wang, 1988a, 1988b). Yet these studies tend to focus on only one or a 109 few targeted environmental factor(s) and lack rigorous statistical evaluation, 110 particularly statistical modeling, a common approach in contemporary ecology. This 111 is probably due to the fact that comprehensive environmental datasets are often 112 unavailable and an ecological modeling approach (especially regression modeling and 113 model selection) has not been common in this, field of micropaleontology.

Hong Kong <u>constitutes</u> an ideal location for <u>a</u> marine ecological modeling approach in the northwestern Pacific and Indo-Pacific regions because of extensive and intensive marine environmental monitoring program and subtropical location where tropical and temperate species coexist. This program provides robust datasets for ecological modeling, and the subtropical location allows the investigation of species with different latitudinal and geographical distributions. We employed regression modeling of Hong Kong shallow-marine ostracod species to show Reviewer 17/12/18 5:17 PM Deleted: s

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statistical relationships between species abundance, distribution and environmental factors. This study allows the autoecology and statistical evaluation of common tropical and extratropical species, providing a baseline for ostracod-based shallowmarine paleoenvironmental reconstructions of the northwestern Pacific and Indo-Pacific regions.

148

## 149 2. Study area

150 Hong Kong is situated at the southeastern corner of the Pearl River (Zhujiang) Delta, 151 and has an area of 2500 km<sup>2</sup> (Fig. 1), at 22° 12.021' to 22° 33.817' N latitude, 113° 152 53.388' to 114° 26.920' E longitude. It is an ideal location to study natural and/or 153 anthropogenic impacts on benthic communities due to its complex hydrology and 154 long history of human influence. Western Hong Kong is affected by input from the 155 Pearl River, particularly during the summer heavy rainfall (Morton & Wu, 1975), 156 when surface water salinity is strongly influenced by rainfall. Eastern Hong Kong 157 waters are mainly marine and derived from the South China Sea. As one of the most 158 urbanized coastal areas in the world, human activities including rapid industrialization, 159 sewage discharge, trawling, dredging and land reclamation have led to a deteriorated 160 marine benthic ecosystem (Blackmore, 1998; Hodgkiss & Yim, 1995; Hong et al., 161 2017; Hu et al., 2008; Morton, 1996; Morton & Blackmore, 2001; Owen & Sandhu, 162 2000; Shin, 1977; Tanner et al., 2000).

163

### 164 3. Materials and Methods

# 165 **3.1. Samples and laboratory procedure**

166 In January and July of 2011 we used a Van Veen Grab to collect 100 ml of sediment

167 from the uppermost <u>centimeter</u> of the sea floor from 52 sites in Hong Kong marine

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173 waters (Fig. 1; Supplement A), 41 of which are in open waters and 11 in typhoon 174 shelter sites. Typhoon shelters are semi-enclosed areas of water designed to protect 175 moored vessels in extreme weather (Environmental Protection Department, 2011). All 176 sites are included in the Hong Kong EPD marine water and sediment quality 177 monitoring program, which has been conducted monthly since 1986 (for water) and 178 biannually (for sediment), providing comprehensive environmental data for all 179 stations (see below).

180 Sediments were wet-sieved over a 63 µm mesh sieve and air dried or oven-181 dried at 40 °C. The residue was dry-sieved over a 150 µm mesh sieve, and ostracod 182 specimens larger than 150 µm were picked; smaller individuals are mostly early instar 183 juveniles that are often not preserved (because their shells are usually thin and 184 delicate) or difficult to identify (see Yasuhara et al., 2009 and Yasuhara et al., 2017 185 for more details). In samples containing fewer than 200 specimens, we picked all 186 individuals. If there were more than 200 specimens, we picked ostracods from a split. 187 We identified each counted specimen to species level when possible. We considered 188 both an entire carapace or a single valve as one individual for counting.

189

## 190 **3.2 Environmental Variables**

We selected parameters from the EPD monitoring program (Table 1) for our regression modeling (see below), including surface productivity (Chlorophyll-a, Chl; Fig. 2), water depth (D; Fig. 2), bottom water dissolved oxygen (DO; Fig. 2), bottom water salinity (Sal; Fig. 2), turbidity (Tur; Fig. 2), summer bottom water temperature (ST – June to September average; Fig. 2), winter bottom water temperature (WT – November to Feburary average; Fig. 2), mud content (MD; Fig. 2), and heavy metal concentration (Cu, Zn, and Pb; Fig. 3). These parameters are known to control

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**Comment [3]:** Yasuhara, M., Iwatani, H., Hunt, G., Okahashi, H., Kase, T., Hayashi, H., Irizuki, T., Aguilar, Y. M., Fernando, A. G. S. and Renema, W., 2017. Cenozoic dynamics of shallow-marine biodiversity in the Western Pacific. Journal of Biogeography: 44, 567–578. Added.

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ostracod faunal properties (Cronin, 2015; Cronin & Vann, 2003; Hazel, 1988; Ikeya
& Shiozaki, 1993; Irizuki et al., 2005; <u>Irizuki et al., 2015a; Irizuki et al., 2018;</u> Ruiz et al., 2005; Yasuhara et al., 2007; Yasuhara et al., 2012b). We used averages over the entire monitoring period (1986–2011), because the ostracods in this study were mostly dead shells, thus the samples should be considered time averaged. Bottom water DO is the average of the summer season (June–September), due to the likely importance of summer bottom water oxygen depletion.

209

# 210 4. Regression modeling

Multiple linear regression modeling was used to determine the relationship between common ostracod species (relative abundance of each species) and environmental parameters (Supplement B). All environmental parameters were log-transformed and zero centered. Salinity outliers (salinity <25: DS2 and DS3) and samples with low abundance (<50 specimens: ES5, MS7, VS21, VS5 & VS6) were removed from the models.

217 The best-fitting models were selected based on Akaike's Information Criterion 218 (AICc) for small sample size, in which the lower score indicates the better model 219 support considering both goodness-of-fit and model complexity (Anderson & 220 Burnham, 2002). Akaike weights were used to summarize proportional support for all 221 candidate models (Anderson et al., 2000) (Table 2). We considered parameter 222 estimates averaged over models, proportional to the support that each model received 223 (Anderson et al., 2000) (Table 3). This approach accounts for the uncertainty in model 224 selection and thus leads to appropriately broader confidence intervals than obtained 225 by relying only on the single, best-supported model. The relative importance of 226 various predictor variables was measured by the sum of Akaike weights of models

that included the variables in question (Brunham & Anderson, 2002).

228 We explored linear dependencies by computing variance inflation factors (VIF) 229 (Legendre & Legendre, 1998) and pairwise correlations between predictor variables 230 to assess whether multicollinearity was likely to influence regression results 231 (Yasuhara et al., 2012b). The degree of freedom is more than one for the geographic 232 region variable (see below), thus we computed generalized variance inflation factors 233 (GVIF). For continuous variables, GVIF (Table 4) is the same as VIF, but for 234 categorical variables, GVIF has degrees of freedom (Df) equal to the number of coefficients associated with it (Hendrickx et al., 2004). Thus, we used GVIF<sup>1/2df</sup> to 235 236 make GVIF values comparable among those with different Df. VIF >20 is usually 237 indicative of high collinearity (Legendre & Legendre, 1998). Thus we calculated an equivalent threshold of 4.47 (equal to  $\sqrt{20}$ ) for GVIF<sup>1/2df</sup> to assess conlinearity. Also, 238 239 adjusted  $R^2 > 0.8$  indicates a strong correlation of variables (Hoffman, 2015). In all 240 datasets, summer temperature (ST) and copper (Cu) were highly correlated 241  $(R^2=0.8217)$ , and the GVIFs of ST and Cu are >20, indicating that these correlations 242 may influence regression results. Thus, we re-ran the linear regression modeling 243 without ST and Cu. The new GVIFs of all variables were under 4.47 (Table 4).

We considered the degree of spatial autocorrelation in model residuals by the calculation of Moran's *I* index for the five best models. The neighborhood size was set as 2, 5, 10, 20 and 50 km. We found significant spatial autocorrelation in model residuals for many cases, thus we forced the geographic region variable (R) (Water Control Zones defined by EPD) to be included in all models. After this treatment, spatial autocorrelation was detected only in a few models for *Propontocypris* spp., *Stigmatocythere roesmani*, and *Hemikrithe orientalis*.

251 The multiple linear regression model analyses were implemented in R

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253 programming language (R Core Team, 2016). We used ' $M_UMI_N$ ' (Bartoń, 2013) for 254 model averaging and 'SPDEP' (Bivand & Piras, 2015) to measure spatial 255 autocorrelation.

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# 257 5. Results and discussions

258 The comprehensive ostracod dataset for the 52 sites and the environmental variables 259 enabled us to elucidate distribution patterns of common ostracod taxa and their related 260 environmental factor(s). We identified 151 species belonging to 76 genera 261 (Supplement A). Among them, 18 common taxa (mainly species, a few genera) of 262 Pistocythereis bradyi, Bicornucythere bisanensis s.l., Nipponocythere bicarinata, 263 Spinileberis quadriaculeata, Phlyctocythere japonica, Loxoconcha epeterseni, 264 Sinocytheridea impressa, Neomonoceratina delicata, Keijella kloempritensis, 265 Neosinocythere elongata, Stigmatocythere roesmani, Hemicytheridea reticulata Loxoconcha malayensis, Alocopocythere goujoni, Hemikrithe orientalis, 266 267 Propontocypris spp., Neonesidea spp. and Xestoleberis spp. (Supplement B) were 268 used for regression modelling, and their relative abundances (to the total ostracod 269 abundance in a sample) show a significant relation with environmental parameters. 270 The best three regression models are presented in Table 2 and the model-averaged 271 parameter estimates in Table 3. A small percentage of specimens of phytal genera 272 (e.g., Xestoleberis spp., Neonesidea spp.) were, contained in each sample, which are 273 basically allochthonous specimens in bottom sediments transported from surrounding 274 phytal environments. The value of allochthonous species to environmental 275 interpretation is limited, however, most ostracod specimens, in each sample are 276 composed of benthic, muddy sediment dwellers which are considered autochthonous, 277

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312	Ostracods were divided into four groups based on their geographic.
313	distributions including Widespread Group; Temperate Group; Subtropical Group;
314	and Tropical Group; and Globally distributed Group (Fig. 4).
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317	a. Widespread, Group,
318	Only one species <i>Pistocythereis bradyi</i> constitutes Widespread Group.
319	Pistocythereis bradyi is widely distributed throughout the marginal marine
320	environments of Japan, the East and South China Seas, and the Indo-Pacific (Fig. 4).
321	Relative abundance of <i>P. bradyi</i> was highly correlated with salinity (positive), water
322	depth (negative) and Pb (negative) (Tables 2 and 3). This indicates the species prefers
323	relatively shallow environments with high salinity (Figs. 2 and 5). In the Pearl River
324	Delta and shallow South China Sea (Fig. 4), P. bradyi is dominant along the inner
325	continental shelf at water depths <100 m (mostly common between 10-50 m), and at
326	salinities from 30-40 (Li, 1985; Zhao & Wang, 1990; Zhao et al., 1986).
327	Pistocythereis bradyi is a typical middle muddy bay species in Japan (Irizuki et al.,
328	2006; Yasuhara & Irizuki, 2001; Yasuhara & Seto, 2006), and known from open bays
329	such as Gamagyang Bay in Korea (Abe, 1988) and Malacca Strait (Whatley & Zhao,
330	1988b). In these studies, P. bradyi prefers relatively high salinity and deeper water in
331	the inner continental shelf (Tables 2 and 3). Our data agree as to the preference for
332	high salinity, but inconsistent with the literature regarding shallower water depths
333	Salinity may be more important than depth, but the restricted depth range of our sites
334	( $\leq$ 35 m) may also be a reason for this inconsistency. Our results indicate that <i>P</i> .
335	<i>bradyi</i> is sensitive to metal pollution.
336 337	b. Temperate Group

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519	Five species including Bicornucythere bisanensis s.l., Nipponocythere	
520	bicarinata, Spinileberis quadriaculeata, Phlyctocythere japonica and Loxoconcha	
521	epeterseni are distributed from Japan-Russian Coast to South China Sea.	
522	Bicornucythere, bisanensis s.l. is very common in most samples, the relative	Reviewer 18/12/18 2:12 PM
523	abundance of which was significantly correlated with water depth (negative) (Tables	Deleted: <i>B</i> Reviewer 18/12/18 2:12 PM
524	2 and 3) and this species prefers shallower environments (Figs. 2 and 5). In Chinese	Deleted: .
525	and Japanese coastal areas, B. bisanensis s.l. is abundant in brackish water (salinity:	
526	20-30) at depths less than 10 m (Ikeya & Shiozaki, 1993; Irizuki et al., 2006; Zhao et	
527	al., 1986). Our results confirm this preference for shallow depths. In Japan,	Reviewer 18/12/18 2:13 PM
528	Bicornucythere bisanensis is tolerant of anthropogenic impacts, especially	Deleted: its
529	eutrophication and the resulting bottom water hypoxia, (Irizuki et al., 2003; Irizuki et	Reviewer 18/12/18 2:13 PM
530	al., 2011; Irizuki et al., 2015a; Irizuki et al., 2018; Yasuhara et al., 2003; Yasuhara et	Deleted: in Japan
531	al., 2007; Yasuhara et al., 2012a). We did not see a significant relation between	
532	relative abundance and metal concentration, productivity, or dissolved oxygen.	
533	Possibly, the more dominant presence of S. impressa and N. delicata, that are neither	
534	dominant or distributed throughout most of Japan, could explain this difference.	
535	These species may have a higher tolerance than <i>B. bisanensis</i> s.l Another	
536	explanation may be that different morphotypes have different ecological preferences	
537	(Abe, 1988), and only Form A is known to be tolerant to eutrophication and bottom-	
538	water oxygen depletion (Irizuki et al., 2011; Irizuki et al., 2015a; Irizuki et al., 2018;	
539	Yasuhara & Yamazaki, 2005; Yasuhara et al., 2007). Form A is less abundant in	
540	Hong Kong, and due to the difficulty of juvenile identification, we did not divide B.	Reviewer 18/12/18 2:16 PM
541	bisanensis into morphotypes. Bicornucythere bisanensis s.l. is widely distributed	Deleted: of juveniles Reviewer 18/12/18 2:16 PM
542	throughout marginal marine environments around Japan, Russia (Sea of Japan coast),	<b>Deleted:</b> <i>B.</i> m o 19/12/18 11:47 PM
543	and the East and South China Seas (Fig. 4).	Deleted: and

551	Relative abundance of N. bicarinata correlated with productivity (negative)
552	(Tables 2 and 3). This is a typical middle bay species in Japan (Irizuki et al., 2006),
553	abundant on muddy substrates at water depths >10 m (Yasuhara & Seto, 2006;
554	Yasuhara et al., 2005). We found N. bicarinata to be sensitive to eutrophication,
555	prefering lower productivity (Figs 2 and 5). This species is know from marginal
556	marine environments around Japan and the East and South China Seas (Fig. 4).
557	Relative abundance of S. quadriaculeata correlated to productivity (positive),
558	and turbidity (negative) (Tables 2 and 3). This is a typical inner muddy bay species in
559	Japan (Irizuki et al., 2006), which prefers silty substrates in brackish waters, at
560	salinities from 20-30, and water depths of 2-7 m (Ikeya and Shiozaki, 1993). This
561	study shows a preference for waters with higher productivity but relatively low
562	turbidity (Tables 2 and 3), so that the species is abundant in Tolo Harbour (higher
563	productivity, lower turbidity) but not in Deep Bay (higher turbidity) (Figs. 2 and 5).
564	Spinileberis quadriaculeata is not tolerant to seasonal anoxia or oxygen depletion (0-
565	1 mg/L) in Uranouchi Bay, Japan (Irizuki et al., 2008), but we do not find a
566	significant correlation with dissolved oxygen content, probably due to the relatively
567	high bottom-water oxygen content (2.96-6.84 mg/L) in Hong Kong (Fig. 2;
568	Supplement B). Spinileberis quadriaculeata is widely distributed in marginal marine
569	environments around Japan, Russia (Sea of Japan coast), and the East and South
570	China Seas (Fig. 4).
571	Relative abundance of P. japonica correlated with water depth (positive)
572	(Tables 2 and 3). This species is known from relatively deeper waters (>40 m) in the
573	East China Sea (Ishizaki, 1981; Wang et al., 1988). At our sites, it has its greatest
574	abundance at the deeper southern sites (Fig. 5). Phlyctocythere japonica is distributed
575	around Japan (Yasuhara et al., 2002) and the East and South China Seas (Fig. 4).

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586	Similarly to P. japonica, relative abundance of L. epeterseni correlated with water		Deleted: as
587	danth (magitiva) and turbidity (magativa) (Tablas 2 and 2). It accurs in the coutham		Reviewer 18/12/18 2:20 PM
507	depth (positive), and turbidity (negative) (Tables 2 and 3). It occurs in the southern		Deleted: was
588	and eastern, deeper and less turbid regions of Hong Kong waters, but the trend is not		Reviewer 18/12/18 2:20 PM
500	and eastern, deeper and less turble regions of frong Kong waters, but the tiend is not		Deleted: also
589	very clear (Figs 2 and 5). This species is also known from the deeper parts of Osaka		Reviewer 18/12/18 2:41 PM Deleted:
007	very erear (1155 2 and e). This species is also known norm the deeper parts of osaka	$\langle \rangle \rangle$	Reviewer 18/12/18 2:41 PM
590	Bay (Yasuhara & Irizuki, 2001) and marginal marine environments around Japan	$\langle \rangle$	Deleted: and its
		( ) )	Reviewer 18/12/18 2:20 PM
591	(Ishizaki, 1968), the East China Sea (Yang et al., 1982), and the South China Sea		Deleted: parts
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592	(Cao, 1998) (Fig. 4). This species is reported as Loxoconcha modesta in Hou & Gou		Comment [7]: Not correct. Check all the
593	(2007), and also has been misidentified as Loxoconcha viva and Loxoconcha sinensis		figs correspondence in the main text, after
			rearrangement. Checked.
594	(Hou & Gou, 2007). Ishizaki (1968) described Loxoconcha laeta and Loxoconcha		Reviewer 18/12/18 2:42 PM
			Deleted: , Japan
595	modesta, but these are the females and males of the same species (Ikeya et al., 2003).	$ \rangle$	Reviewer 18/12/18 2:42 PM
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596	Ishizaki (1981) gave the new species names Loxoconcha epeterseni and Loxoconcha	$\mathbb{N}$	m o 22/12/18 9:32 PM
507		$( \ ) $	<b>Comment [8]:</b> Do not delete the sentence of Loxoconcha epeterseni. Instead add the
597	tosamodesta for Loxoconcha laeta and Loxoconcha modesta, respectively, because		reference Ikeya et al 2003 suggested by
<b>F</b> 00	these non-se ware innier homonyme. Since Longeougher leasts (= anotonyoui) annoor		Irizuki. It's worth to
598	these names were junior homonyms. Since Loxoconcha laeta (= epeterseni) appears		mention, no much people don't kno [35]
599	earlier than Loxoconcha modesta (=tosamodesta) in the original description (Ishizaki,	-	m o 22/12/18 11:40 PM
399	carrier than Loxoconcha modesta (-tosamodesta) in the original description (isinzaki,		<b>Deleted:</b> ; Ikeya et al., 2003 m o 22/12/18 11:40 PM
600	1968), we use the name Loxoconcha epeterseni for this species (e.g., see Ikeya et al.,	1	Deleted:
000	1900), we use the nume howeeners epicersen for this species (e.g., see hey' et al.,		m o 22/12/18 11:46 PM
601	2003).		<b>Deleted:</b> in our opinion,
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603			Deleted: East China Sea- to Ind [36]
604	c. Subtropical Group		17/12/18 1:15 PM
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605	Six species including Sinocytheridea impressa, Neomonoceratina delicata,		17/12/18 1:15 PM
		$\left( \right) \right)$	Formatted: Font:Bold
606	Keijella kloempritensis, Neosinocythere elongata, Stigmatocythere roesmani and		17/12/18 1:15 PM
6 <b>- -</b>			Formatted: Font:Bold
607	Hemicytheridea reticulata are reported from the East China Sea to Indo-Pacific area.		17/12/18 1:15 PM Formatted: Font:Bold
(00		$\langle \rangle \rangle$	m o 19/12/18 10:51 PM
608	Sinocytheridea impressa [=Sinocytheridea latiovata; see Whatley and Zhao		Deleted: Five
600	(10880)] is the most dominant species the relative shundance of which was		Reviewer 18/12/18 2:53 PM
609	(1988a)] is the most dominant species, the relative abundance of which was		Deleted: 1
610	significantly correlated with salinity (negative), dissolved oxygen (negative), mud		m o 19/12/18 11:52 PM
010	significantiy correlated with samily (negative), dissolved oxygen (negative), mud		Deleted:
611	content (positive) and productivity (positive) (Tables 2 and 3). This species is		Reviewer 22/12/18 9:32 PM
	content (postare) and producting (postare) (rubbe 2 and 5). This species is		Comment [9]: You can't start a se [37]

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()	figs correspondence in the main text, after
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	<b>Comment [8]:</b> Do not delete the sentence
	of Loxoconcha epeterseni. Instead add the
$\setminus$	reference Ikeya et al 2003 suggested by
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11	mention, no much people don't kno [35]
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629	noticeably dominant in areas characterized by a muddy bottom including northern
630	Mirs Bay, Port Shelter and coastal Southern Waters (Fig. 5). It is also abundant in
631	Tolo Harbour, an area known for its summer hypoxia and eutrophication (Hu et al.,
632	2001; Sin & Chau, 1992). These results are consistent with previous studies indicating
633	that S. impressa is dominant in low salinity, nutrient-rich and turbid estuaries (Irizuki
634	et al., 2005; Tanaka et al., 2011), but we did not see a significant relation with
635	turbidity (Tables 2 and 3). Sinocytheridea impressa is known as a euryhaline species
636	widely distributed throughout the East and South China Seas [abundant in water
637	depths of <20 m; Whatley and Zhao (1988a)], and the Indo-Pacific (Fig. 4).
638	<u>Neomonoceratina, delicata (=Neomonoceratina crispata; see Hou &amp; Gou,</u>
639	2007) is very common in most of the samples, and the relative abundance
640	significantly correlates, with Zn (positive), salinity (positive) and turbidity (positive)
641	(Tables 2 and 3). <i>Neomonoceratina delicata</i> is a nearshore species, abundant at depths
642	less than 30 m, at relatively high salinities (>30; Zhao and Wang, 1988). It prefers the
643	higher salinity waters in Hong Kong (Figs. 2 and 5; Tables 2 and 3), and in view of its
644	positive correlation with Zn and turbidity, is likely tolerant to human-induced
645	environmental stress such as pollution and eutrophication, This species is widely
646	known from nearshore and estuarine environments in the East and South China Seas,
647	and the Indo-Pacific (Fig. 4).
648	The relative abundance of K. kloempritensis correlated only with water depth
649	(positive) (Fig. 6; Tables 2 and 3). Widely known from the tropical Indo-Pacific
650	region, K. kloempritensis is abundant along the inner continental shelf of the South
651	and East China Seas (Fig. 4), at water depths ranging from 20-50 m and salinity, close
652	to normal marine (Zhao & Wang, 1990). Our modelling results are consistent with
653	this, showing a preference for the relatively deeper waters in our study (Tables 2 and

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674	3). Thus, this species is probably useful for reconstructing past sea-level changes in
675	the broad tropical and subtropical Indo-Pacific and northwestern Pacific regions as a
676	deeper water indicator.

677	Relative abundance of N. elongata correlated only with turbidity (positive)	
678	(Tables 2 and 3). This species occurs along the entire coast of China (Fig. 4) in	
679	marginal marine, especially estuarine, environments shallower than 20 m (Dong et al.,	
680	2012; Hou & Gou, 2007; Liu et al., 2013; Liu et al., 2017; Zhao & Whatley, 1993)	
681	(Fig. 4). Known from the Indo-Pacific region, our modeling results and previous	
682	studies indicate consistently that N. elongata prefers shallow, turbid waters like Deep	
683	Bay and the Pearl River Estuary (Figs 2 and 6).	
684	The relative abundance of both S. roesmani and, H. reticulata correlated with	
685	Pb (negative) (Tables 2 and 3), thus they are sensitive to metal pollution (but note the	
686	significant autocorrelation with the modeling result of S. roesmani) and absent in	
687	areas with high metal concentrations, e.g., Tolo and Victoria Harbours (Fig. 3, 6).	
688	Relative abundance of <i>H. reticulata</i> also correlated with water depth (negative)	
689	(Tables 2 and 3). This species is abundant in Tolo Harbour and the inner part of Mirs	
690	Bay (Fig. 6), at shallow depths, and is also consistently found in very shallow waters	
691	from the Indo-Pacific (Zhao & Whatley, 1989). Their metal-pollution sensitivity is	
692	contradictory because they occur in Tolo and Victora Harbours, both polluted regions	
693	of Hong Kong, and further research is needed to better understand these results (Figs	
694	2 and 6). They occur in the East and South China Seas and the Indo-Pacific region	
695	<u>(Fig. 4).</u>	
696		
697	d. <u>"Tropical Group</u>	

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717	Three species including Loxoconcha malayensis, Alocopocythere goujoni and
718	Hemikrithe orientalis are distributed from the South China Sea to the Indo-Pacific.
719	Relative abundance of L. malayensis correlated with dissolved oxygen
720	(negative) and mud content (negative) (Tables 2 and 3). It is a typical tropical species
721	known from the Indo-Pacific and the South China Sea (Fig. 4). We did not find a
722	correlation with temperature, likely due to the small range of variation of bottom
723	water temperatures in Hong Kong (winter temperature: 19.10-21.49°C). This species
724	prefers coarse sediments and is resistant to low oxygen content (Table 2 and 3), as
725	seen by its abundance in Victoria Harbour (Figs. 2 and 6).
726	Relative abundance of both A. goujoni and H. orientalis correlated with
727	natural, factors only, Alocopocythere goujoni correlated with salinity (positive)
728	(Tables 2 and 3) and occurs, not only in Mirs Bay where the salinity is higher, but also
729	in Deep Bay and North Western Waters where the salinity is lower than in other areas
730	(Figs 2 and 6). The Deep Bay and North Western Waters are shallow and have
731	relatively low oxygen content. The modeling result of this species shows a marginally
732	insignificant but negative relationship to oxygen content and water depth with
733	moderately high relative importance (Table 3). We explain this inconsistency by
734	considering their preference for higher salinity and shallow water depths, and also
735	their resistance to low oxygen conditions, but further research is needed to know their
736	autoecology with better confidence. Relative abundance of H. orientalis correlated
737	with water depth (positive) (Tables 2 and 3; but note the significant autocorrelation
738	with the modeling result of this genus), and it is more abundant in deeper waters
739	including southern Mirs Bay (Fig. 6). It is known from depths of 20-50 m in the
740	South China Sea (Zhao & Wang, 1988a), and reported from tropical Indo-Pacific
741	marginal marine environments (Fig. 4). Our regression modeling consistently shows a

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755	positive relationship between relative abundance and winter temperatures, with	Reviewer 18/12/18 3:36 PM
756	moderately high relative importance, although the correlation is marginally	Deleted: the
757	insignificant (Table 3).	
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759	e. Globally Distributed Group	
760	Propontocypris is known as a cosmopolitan genus. The relative abundance of	m o 22/12/18 6:50 PM <b>Comment [11]:</b> Justify to left. OK
761	Propontocypris spp. significantly correlated with productivity (negative) (Tables 2	m o 19/12/18 11:06 PM Formatted: Indent: First line: 1.27 cm
762	and 3). This negative correlation with productivity (but note a significant	
763	autocorrelation with the modeling result of this genus) indicates that the genus prefers	
764	less eutrophic waters (Fig. 6). Propontocypris is a good swimmer (Maddocks, 1969),	
765	and thus may have an advantage in obtaining food in relatively food-limited	
766	environments.	m o 20/12/18 12:39 AM
767	Phytal genera including Neonesidea spp. and Xestoleberis spp. have global	Formatted: Font:Italic
768	distribution and are correlated with various environmental factors. The relative	
769	abundance of Neonesidea spp. correlated with dissolved oxygen (positive), as	
770	expected for a phytal species (Smith & Kamiya, 2002; Yamada, 2007) (Table 2 and 3;	
771	Fig 7). Similarly, phytal (Irizuki et al., 2008; Sato & Kamiya, 2007; Yasuhara et al.,	23/12/18 12:00 AM
772	2002) Xestoleberis spp. correlated with dissolved oxygen (positive), turbidity	Deleted: 6
773	(negative) and mud content (negative) (Table 2 and 3; Fig. 7). This taxon's habitat	23/12/18 12:00 AM
774	preference including clear water, coarse sediment, and high oxygen content are	Deleted: 6
775	reflected in our modeling. As mentioned above, the value of allochthonous phytal	
776	species to environmental interpretation is limited, but they broadly reflect adjacent	
777	phytal environments.	
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779	Summary	Deleted:

785 Benthic ostracods from Hong Kong marginal marine waters studied here include 786 widespread (i.e., one species distributed throughout the northwestern Pacific-Indo-787 Pacific region), temperate (i.e., five species distributed from the South China Sea to 788 Japan and Russia), subtropical (i.e., six species distributed from the Indo-Pacific to 789 the East China Sea), and tropical (i.e., three species distributed in the Indo-Paficic and 790 South China Sea) species and three globally distributed genera (Fig. 4). We provide a 791 robust baseline of autoecology for these common ostracod taxa based on rigorous 792 statistical modeling using comprehensive environmental data. We established reliable 793 indicator forms for water depth, mud content, salinity, turbidity, dissolved oxygen, 794 heavy metal pollution (Pb and Zn) and eutrophication (chlorophyll-a) (Table 5). Thus 795 our results are applicable for future ostracod-based paleoenvironmental studies in a 796 wide range of localities from the tropics to the extratropics, and from the Indian 797 Ocean to the northwestern Pacific. We established pollution and eutrophication 798 indicator species in tropical environments for the first time. Anthropocene 799 paleoenvironmental and paleoecological studies in the tropics are urgently needed 800 because (1) the tropics are seriously under-studied (Wilkinson et al., 2014; Yasuhara 801 et al., 2012a), (2) tropical environments and ecosystems are vulnerable and sensitive 802 to human influences (Jackson et al., 2001; Pandolfi et al., 2003), and (3) Indo-Pacific 803 tropical environments have been seriously degraded by the human activity of rapidly 804 developing countries (Bellwood et al., 2004; Jackson, 2008; Knowlton & Jackson, 805 2008). Our results provide useful and reliable tools for tropical Anthropocene 806 research in the broad Indo-Pacific region.

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808 Acknowledgement

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816	Yung, for support; L. Wong, C. Law, M. Lo, and the staff of the Electronic	
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824	Research Grants Council of Hong Kong (project code: HKU 17303115), the Early	
825	Career Scheme of the Research Grants Council of Hong Kong (project code: HKU	
826	709413P), and the Seed Funding Programme for Basic Research of the University of	12/12/18 10:29 PM <b>Deleted:</b> Irizuki et al. (2006); Zhao and
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1343	Fig. 1 Locality map showing the 52 sampling sites across Hong Kong, including 41
1344	open water sites (blue dots) and 11 typhoon shelter sites (red open dots). From west to
1345	east, DS: Deep Bay; NS: North Western waters; SS: Southern waters; VS: Victoria
1346	Harbour; ES: Eastern Buffer; JS: Junk Bay; TS: Tolo Harbour; PS: Port Shelter; MS:
1347	Mirs Bay.
1348	
1349	Fig. 2 Spatial distribution of environmental parameters in Hong Kong. Mean surface-
1350	water chlorophyll-a concentration; water depth; summer (June to September) bottom-
1351	water dissolved oxygen content; mean bottom-water salinity; mean turbidity; mean
1352	summer (June to September) bottom-water temperature; mean winter (November to
1353	February) bottom-water temperature; and mean mud content. All are averaged values
1354	of the data obtained during 1986–2013 (Table 1).
1355	
1356	Fig. 3 Spatial distribution of environmental parameters in Hong Kong. Mean copper
1357	(Cu) concentration, mean lead (Pb) concentration, and mean zinc (Zn) concentration
1358	in surface sediments. All are averaged values of the data obtained during 1986-2013
1359	(Table 1).
1360	
1361	Fig. 4 Geographical distributions of the 18 taxa in the northwestern Pacific and Indo-
1362	Pacific regions, including Pistocythereis bradyi, Bicornucythere bisanensis s.l.,
1363	Nipponocythere bicarinata, Spinileberis quadriaculeata, Phlyctocythere japonica,
1364	Loxoconcha epeterseni, Sinocytheridea impressa, Neomonoceratina delicata, Keijella
1365	kloempritensis, Neosinocythere elongata, Stigmatocythere roesmani, Hemicytheridea
1366	reticulata Loxoconcha malayensis, Alocopocythere goujoni, Hemikrithe orientalis,
1367	Propontocypris spp., Neonesidea spp. and Xestoleberis spp The following references

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1368	were used mainly to determine the geographical distributions of the species: Al
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1375	(1988); Wang and Zhang (1987); Wang and Zhao (1985); Zhao (1984); Zhao and
1376	Wang (1988a, 1988b, 1990); Zhao and Whatley (1993); Zhou et al. (2015). Note that
1377	Sinocytheridea impressa is know to be distributed in Japan, but their Japanese
1378	distribution is very limited in certain areas of the southern part of Japan (Iwasaki
1379	1992; Tanaka et al. 2019). Thus, we did not indicate their Japanese-Russian coast
1380	distribution in this figure.
1381	
1382	Fig. <u>5</u> Spatial distribution of the relative abundance for <u>Pistocythereis bradyi</u> ,
1383	Bicornucythere bisanensis s.l., Nipponocythere bicarinata, Spinileberis
1384	quadriaculeata, Phlyctocythere japonica, Loxoconcha epeterseni, Sinocytheridea
1385	impressa, and Neomonoceratina delicata in Hong Kong. See Figure 1 for sampling
1386	stations.
1387	
1388	Fig. 6. Spatial distribution of the relative abundance for Keijella kloempritensis,
1389	Neosinocythere elongata, Stigmatocythere roesmani, Hemicytheridea reticulata
1390	Loxoconcha malayensis, Alocopocythere goujoni, Hemikrithe orientalis, and
1391	Propontocypris spp. in Hong Kong. See Figure 1 for sampling stations.
1392	

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1411	Fig 7	Spatial	distribution	of	the	relative	abundance	for	Neonesidea	spp	and
T 1 T T	I 16. 🚽	. opanai	uisuiouuon	U1	unc	relative	abundance	101	reonesided	spp.	and

1412 Xestoleberis spp, in Hong Kong. See Figure 1 for sampling stations.

#### 1413

## 1414

1417

1415 Table 1. Summary of marine water/sediment parameters. Note: 1. Summer: June,

1416 July, August and September. 2. Winter: November, December, January and February.

1418	Table 2. Best three regression models of the relative abundance of common species,
1419	including <u>Pistocythereis bradyi</u> , <u>Bicornucythere bisanensis s.l.</u> , <u>Nipponocythere</u>
1420	bicarinata, Spinileberis quadriaculeata, Phlyctocythere japonica, Loxoconcha
1421	epeterseni, Sinocytheridea impressa, Neomonoceratina delicata, Keijella
1422	kloempritensis, Neosinocythere elongata, Stigmatocythere roesmani, Hemicytheridea
1423	reticulata Loxoconcha malayensis, Alocopocythere goujoni, Hemikrithe orientalis,
1424	Propontocypris spp., Neonesidea spp. and Xestoleberis spp., The table shows the
1425	coefficient of each term, adjusted $R^2$ , the Akaike information criterion corrected for
1426	small sample size (AICc), and the Akaike weight (AW). Bold denotes significance at
1427	P < 0.05. Overall P is $< 0.05$ in all models. R: region. Other abbreviations are found in
1428	Table 1.
1429	•

# Table 3. Model-averaged parameter estimates and CIs of the relative abundance <u>for</u> common species, including <u>Pistocythereis bradyi</u>, <u>Bicornucythere bisanensis</u> s.l.,

- 1451 common species mendaring <u>ristocytnerets braayt, bicornacytnere bisanensis s.i.</u>
- 1432 <u>Nipponocythere bicarinata, Spinileberis quadriaculeata, Phlyctocythere japonica</u>,
- 1433 Loxoconcha epeterseni, Sinocytheridea impressa, Neomonoceratina delicata, Keijella
- 1434 kloempritensis, Neosinocythere elongata, Stigmatocythere roesmani, Hemicytheridea
- 1435 reticulata Loxoconcha malayensis, Alocopocythere goujoni, Hemikrithe orientalis,

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Deleted: Fig. 7. Geographical distributions of the 18 taxa in the northwestern Pacific and Indo-Pacific regions, including Sinocytheridea impressa, Neomonoceratina delicata, Pistocythereis bradyi, Bicornucythere bisanensis s.l., Keijella kloempritensis, Nipponocythere bicarinata, Spinileberis quadriaculeata, Loxoconcha malayensis, Neosinocythere elongata, Stigmatocythere roesmani, Phlyctocythere japonica, Alocopocythere goujoni, Hemikrithe orientalis, Loxoconcha epeterseni, Hemicytheridea reticulata, Neonesidea spp., Propontocypris spp., and Xestoleberis spp. The following references were used mainly to determine the geographical distributions of the species: Al Jumaily and Al-Sheikhly (1999); Dewi (1997); Dong et al. (2012); Fauzielly et al. (2013); Hong et al. (2017); Hou and Gou (2007); Hussain et al. (2004); Hussain et al. (2010); Hussain and Mohan (2000, 2001); Irizuki et al. (2006); Irizuki et al. (2009); Iwatani et al. (2014); Jie et al. (2013); Li (1985); M ... [40] m o 23/12/18 12:09 AM

Comment [18]: Change from "Season (AD. 1986-2013)" to just "Season". [.... [41] m o 23/12/18 12:09 AM

**Comment [19]:** Change the order here and in the table. Changed.

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1517	Propontocypris spp., Neonesidea spp. and Xestoleberis spp CIs, confidence	m o 22
1518	intervals; RI, relative importance (the sum of the Akaike weights of models that	m o 23/ Comm and in t
1519	include the variable in question; see Materials and Methods); R, region. Other	23/12/1 Delete
1520	abbreviations are found in Table 1. Bold denotes CIs that exclude zero. For R,	Neomon spp., Pis bisanen.
1521	coefficient, lower CI, and upper CI values shown are averages of those for geographic	Nippono quadria
1522	regions.	malayen elongata Phlyctod
1523		goujoni, epeterse
1524	Table 4. GVIF value for Environmental Variables. Df, degree of freedom; R, region.	
1525	Other abbreviations are found in Table 1.	
1526		
1527	Table 5. Summary of autoecology for common ostracod taxa. Chl: Chlorophyll-a; D:	
1528	Water Depth; DO: Dissolved Oxygen; MD: Mud Content; Sal: Salinity; Tur:	
1529	Turbidity; WT: Winter Temperature; Pb: Lead; Zn: Zinc; R: Region. + and - marks	
1530	indicate significant positive and negative corrlations, respectively.	
1531		
1532		
1533	Supplement A. Ostracod faunal list.	22/12/1
1534		Format
1535	Supplement B. Dataset used for the regression modeling.	
1536		

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