SCHOOL OF BIOLOGICAL SCIENCES
THE UNIVERSITY OF HONG KONG
香港大學生物科學學院

HKU Science

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24 January 2023

Dear MEEF Committee,

Re: Final report MEEF2021001

Here I would like to submit our completion report for the period from 1st of July to 30th June 2022.

(i) Executive summary (1-2 pages)

Whilst Hong Kong has a long history of coastal development and degradation, there is no study showing the impact of these activities in the fauna composition predating the 70s. Lantau Island is an important biogeographical region in Hong Kong and had been through intense coastal development. The northwestern side of the island is under influence of the Pearl River delta, which receive wastewater from households and industrial facilities, while the southeastern side of the island is less impacted by anthropogenic activities. Here, using radiocarbon dating of dead mollusc's shells, booth gastropods and bivalves, we investigated how human induced coastal degradation affected the subtidal fauna of northwestern and southeastern Lantau waters through time.

To obtain the mollusc shells, trawling sampling was performed at four sites around Lantau, two at southeastern and two at northwestern waters. The trawling sampling was conducted twice at each site, once in July and again in August 2018, with exception of one of the transects in the northwest, which was sampled only in August. The mollusc shells obtained were identified, quantified, and had their length measured. Time series data for bottom water and sediment quality was obtained for the interval between1986 to 2020 to better understand the environmental conditions the fauna experiences, and how environmental conditions changed through time in southeastern and northeastern Lantau waters.

The environmental data showed higher concentration of metals in the sediments on northwestern compared to southeastern Lantal during most of the recorded period, except for the late 90s and early 2000s, when the concentration of metals was similar between the two sites. Furthermore, the northwestern side showed signs of more intense eutrophication,

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with consistently higher organic and inorganic nitrogen, NO_2 -, NO_3 -, orthophosphate, Faecal coliforms and *E. coli* compared to southeastern Lantau waters.

A total of 1938 shells were identified into 118 morphospecies. The southeastern Lantau samples had a more diverse shell composition, with a total of 103 morphospecies compared to 64 in northeastern side. A size comparison between representative morphospecies showed similar length between shells from northwestern and southeastern Lantau, except for *Turritella bacillum*. This species is considered opportunist and resistant to environmental degradation, and we found that in the more eutrophic northwestern Lantau waters, individuals of this morphospecies are slightly larger than in the southeastern side.

From the identified specimens, shells from representative morphospecies, based on their abundance and representativity in the samples, were selected for 14C dating. The dates show that the opportunistic bivalve *Ruditapes philippinarum* is presently abundant in the impacted northwestern Lantau waters. The morphospecies, however, has less shells in the southwest side. In the other hand, the gastropod *Nassarius siquijorensis*, a scavenger considered resistant to environmental degradation, had both modern and older shells, predating the 2000s. The oldest shells of *N. siquijorensis* are present in southeastern Lantau. This species, thus, was present around Lantau in baseline conditions and now thrive in impacted environments. The bivalve *Paratapes undulatus* has mixed age distribution, with larger number of older shells, indicating this species has been consistently present around Lantau through time, but with evidence for decline in abundance. The morphospecies *Turricula nelliae*, considered a specialist and more sensitive species, had small number of individuals in the samples. The shells from this morphospecies were modern, indicating that, although not abundant, the morphospecies is present in contemporary times around Lantau. Lastly, the abundant gastropod *Turritella bacillum* had both old and new shells, showing the species was also present at baseline conditions, and is now very abundant at Lantau impacted waters.

The results in this report show that the more degraded northwestern and the less impacted southesastern Lantau waters have differences in their molluscan shell composition, with the more pristine southeastern side having higher diversity of shell morphospecies. Additionally, our radiocarbon dating analyses indicate faunal changes in Lantau subtidal community through time, with increase of opportunistic species and decrease of sensitive species. The shell radiocarbon dating analyses brought insights on the past ecosystem in

Lantau coastal waters and provided information on the impact of anthropogenic activities on the subtidal fauna.

(ii) Project title and brief description of the Project;

Shells for understanding Lantau subtidal ecosystem history: a conservation baseline

Whilst studies have shown a turnover and distributional shift in Hong Kong's subtidal macrofauna in 1970-1980s; there are no study records to document the changes in Hong Kong's subtidal ecosystem in the 1960s and before. It is likely, however, that substantial human-induced degradation of marine biota already has started by the early 20th Century or even before but given the limited biological information available and the lack of comprehensive descriptions of historic changes, we are unable to determine what a pre-disturbance faunal distribution would look like. Lantau is a key place to understand the past marine ecosystem and biogeographical distribution because it is the major distributional boundary of key marine organisms. For example, the Chinese White Dolphin mainly occurs in the northwestern side of Lantau and is much less common in the southeastern side. Finless porpoise and corals show opposite trends and are found almost exclusively in the southeastern side. To determine the natural baseline of this marine ecosystem difference between the northwestern and southeastern sides of Lantau, we are performing Accelerator Mass Spectrometry (AMS) radiocarbon dating of dead shells of selected molluscan morphospecies from surface sediments around Lantau to piece together changes in their distributions with time. Age distributions of these shells will tell us about the natural baseline information of where they were distributed before human impacts, and the subsequent human-induced ecosystem/distributional changes. From this information we will illustrate and map the past distributional changes of key species in Lantau, illustrating the natural baseline and quantifying anthropogenic impacts on subtidal macrobenthic distributions.

(iii) Progress against the proposed Work Schedule;

We conducted morphospecies selection and specimen inspection as well as size measurements. We also conducted analyses on size and age differences among the shells.

Specifics regarding the tasks in the schedule in the section 9c:

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Recruitment a senior research assistant: Done.
Planning and morphospecies selection: Done.
Specimen inspection: Done.
Size measurement: Done.
Radiocarbon dating: Done.
Data analyses: Done as detailed below Section iv.
Paper writing: in progress. Now we are conducted the continuation of this project, MEEF2022009, the paper will most likely come after finishing this continuous project. We will send you the paper when available.
Project wrapping up: Done as detailed below Section iv.

(iv) Results/descriptions on the completed activities with appropriate analyses, with the support of photos, videos, social media platform, etc., if any;

Shells were collected by trawling sampling performed at four transects, two at southeastern and two at northwestern Lantau waters (Table 1, Figure 1A). Sampling occurred twice at each transect, once in July and again in August 2018, with the exception of WT3, which was only sampled in August 2018. Surveyed sites correspond those presented by (Tao, Lau, et al. 2020; Tao, Lui, et al. 2020) for south and west Lantau (here classified as southeast and northwest Lantau, respectively). The trawler had both outriggers of 15 meters in length, towing ten nets of stretched mesh size 2 cm along the sea floor, each horizontally propped open by a metal bean of 2 m. For each transect, a trawl was conducted for 30 min at a speed of 5 to 7 km h^{-1}, surveying an area between 0.05 to 0.07 km^2. The obtained catch was sorted on board and the dead mollusk shells were transported to laboratory. The shells were cleaned and dried in a dry oven at 40°C. A total of 1936 shell were obtained. These shells were subsequently identified into 118 morphospecies, based on morphological characteristics and depictions on the books of Okutani (2017) and Zhang et al. (2016), and quantified (Table 2). Sixty-four of these morphospecies were present in northwestern and a hundred and three in southeastern Lantau. The shells had their length measured with a dial calliper (0.1 mm) and were photographed. The photographs were taken by a Nikon D760 camera, using a Nikkor macro lens 60mm F/2.8 ED, mounted on a Cognisys Inc. Stackshot automated focus stacking rail, which was mounted in a copy stand (Figure 2). Photos of representative mollusc species are in Figure *3*.

We selected shells from six representative morphospecies for radiocarbon dating, the gastropod species *Nassarius siquijorensis*, *Turricula nelliae* and *Turritella bacillum*; and the bivalve species were *Anadara globosa*, *Paratapes undulatus* and *Ruditapes philippinarum*. The radiocarbon dating of the shells was performed by a single-stage accelerator mass spectrometer (YS-AMS) at the Atmosphere and Ocean research Institute, the university of Tokyo, Japan (Yokoyama et al. 2019). The shell ages were calibrated to BC/AC with the software OxCal version 4.4 (Bronk Ramsey 2009). Shells with positive radiocarbon ages, i.e., dating before the present (BP, shells older than 1950 AD), were dated using the calibration curve marine20 (Heaton et al. 2020). Shells with negative radiocarbon ages (shells younger than 1950 AD) were dated using the post-bomb calibration curve nh3 (Hua et al. 2021; Reimer et al. 2020).

To assess the northwestern and southeastern Lantau benthonic habitats, historical data for bottom water and surface sediment quality ware retrieved for the areas near the trawling transects. The data was obtained from the Hong Kong Environmental Protection Department (EPD) (https://cd.epic.epd.gov.hk/EPICRIVER/marine/). The EPD sampling stations for water and sediment quality were NM6 and NS6 (both at 22°20.366'N, 113°53.908'E), respectively, for northwestern Lantau, and SM13 and SS6 (both at 22°12.957'N, 113°57.724'E), respectively, for southwestern Lantau (Figure 1B). The data time interval obtained ranged from 1986, time period when the EPD was created and started monitoring the water quality, up to 2020. The parameters used to assess water quality were: visibility, turbidity, suspended solids, total nitrogen, total inorganic nitrogen, NO_2^-, NO_3^-, NH_3, NH_4^+, phosphorus, orthophosphate, dissolved oxygen (DO), faecal coliforms, *Escherichia coli* and Biochemical Oxygen Demand (BOD). For the sediment quality, low and high molecular weight polycyclic aromatic hydrocarbon (LPAH and HPAH respectively), polychlorinated biphenyls (PCB), the metalloid arsenic and the metals cadmium, chromium, copper, lead, mercury, nickel, silver and zinc concentration data was retrieved.

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Table 1. GPS coordinates and water depth at the trawling transects.

Region	Transect	Water depth (m)	Latitude (N)	Longitude (E)
Southeastern	WT1	7.4 - 19.9	22°11.259' - 22°12.285'	113°55.232' - 113°59.086'
	WT2	4.0 - 11.6	22°11.264' - 22°12.926'	113°51.358' - 113°54.570'
Northwestern	WT3	6.2 - 27.3	22°14.517' - 22°17.062'	113°50.099' - 113°52.152'
	WT4	13 - 32	22°20.502' - 22°25.125'	113°53.197' - 114°00.297'

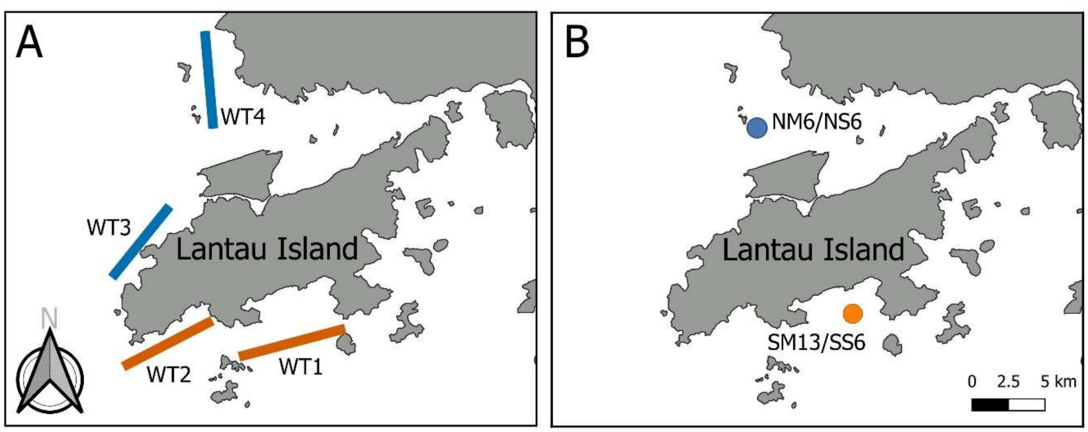

Figure 1. Maps of Lantau showing A) transects location and B) water and sediment quality sampling sites. Circles are the locations where water and sediment quality sampling occurred, and lines are approximate transects tracks based on GPS data. Orange corresponds to southeastern and blue northwestern Lantau waters.

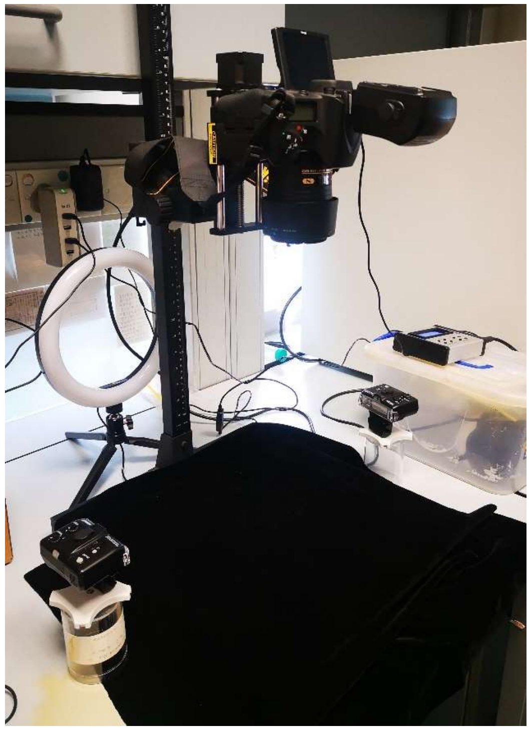

Figure 2. Camera setup used to obtain photos of the shells.

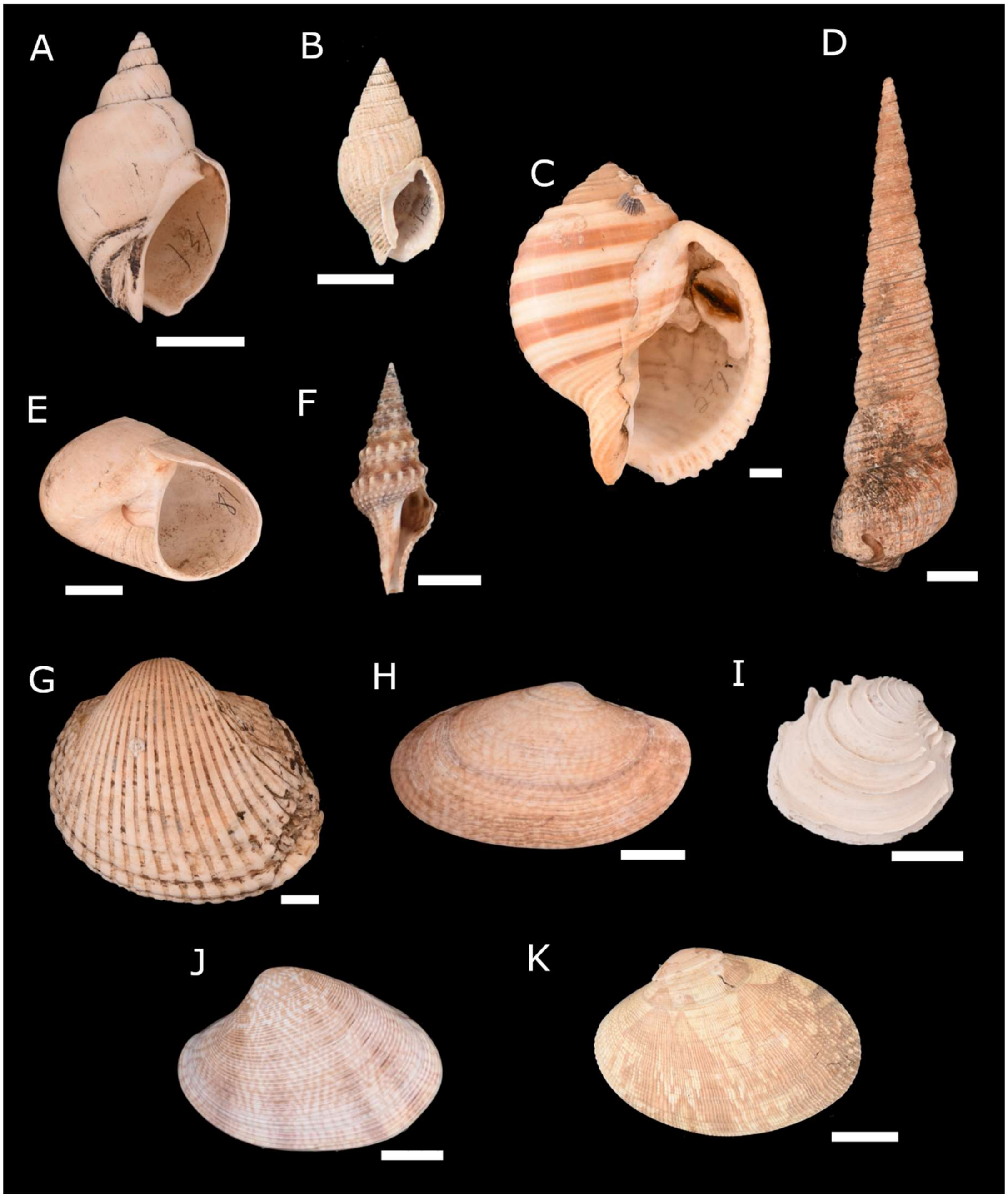

Figure 3. Representative mollusc shells morphospecies found around Lantau: the gastropods A) Babylonidae, B) *Nassarius siquijorensis*, C) Tonnidae, D) *Turritella bacillum*, E) Neritidae and F) *Turricula nelliae*; and the bivalves G) *Anadara globosa*, H) *Paratapes undulatus*, I) *Placamen lamellatum*, J) *Protapes gallus* and K) *Ruditapes philippinarum*. Scale bar = 10 mm.

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Statistical analyses were performed using the software R version 4.1.2 (R core team 2021). Shannon-Wiener diversity index were calculated for northwestern and southeastern Lantau shell morphospecies composition. We also compared dead shell size between southeastern and northwestern Lantau waters of the representative bivalve species *A. globosa*, *P. undulatus*, *P. lamellatum*, *P. gallus* and *P. gubernaculum*, and the gastropods *Bufonaria rana*, *Murex trapa* and *T. bacillum*. Fragmented shells which length could not be measured were excluded from the analyses. The shell size data were check for homogeneity and normality of the residual distribution by Levene and Shapiro-Wilks tests, respectively. The data did not meet the assumptions for parametric statistical tests even after transformation. Thus, we used a Permutational analyses of variance (PERMANOVA) routine to analyse the data (Anderson 2017). A Euclidian distances matrix was built for the shell sizes. We check the data for homogeneity of the data dispersion in the Euclidian matrix using the Betadisper function from package "vegan" (Oksanen et al. 2020). Homogeneity was archived for the bivalve data through log transformation, but not for gastropods data. Nonetheless, PERMANOVA was still used because it is considered a robust test even in cases of lack of data dispersion homogeneity (Anderson and Walsh 2013). The data for age distribution of the shells also did not met assumptions for parametric tests. A Euclidian matrix was built for the shells age distribution, and the distance matrix achieved homogeneity of dispersion. Thus, PERMANOVA routines were also applied to investigate differences in the shells age distribution among morphospecies and areas (southeastern and northwestern Lantau). PERMANOVA routines were performed using the function adonis2 from package “vegan” (Oksanen et al. 2020). The relationship between age and shell sizes was also investigated. The data was checked for homogeneity of residuals dispersion by Breusch-Pagan test (Breusch and Pagan 1979) using the R package “lmtest” (Zeileis and Hothorn 2002). No heteroscedasticity was observed, thus linear models were employed.

The environmental data showed that northwestern Lantau bottom waters historically have higher organic and inorganic nitrogen, NO_2^-, NO_3^-, orthophosphate, Faecal coliforms and *E. coli* content compared to southeastern waters (Figure 4). Northwestern sediments had higher concentration of metals such as chromium, copper, lead, mercury, nickel, zinc, and the metalloid arsenic during most of the time series, but in the late 90s and early 2000s the concentration of metals was similar in the two regions (Figure 5). LPAH, HPAH and TPCB are similar between the two areas (Figure 6).

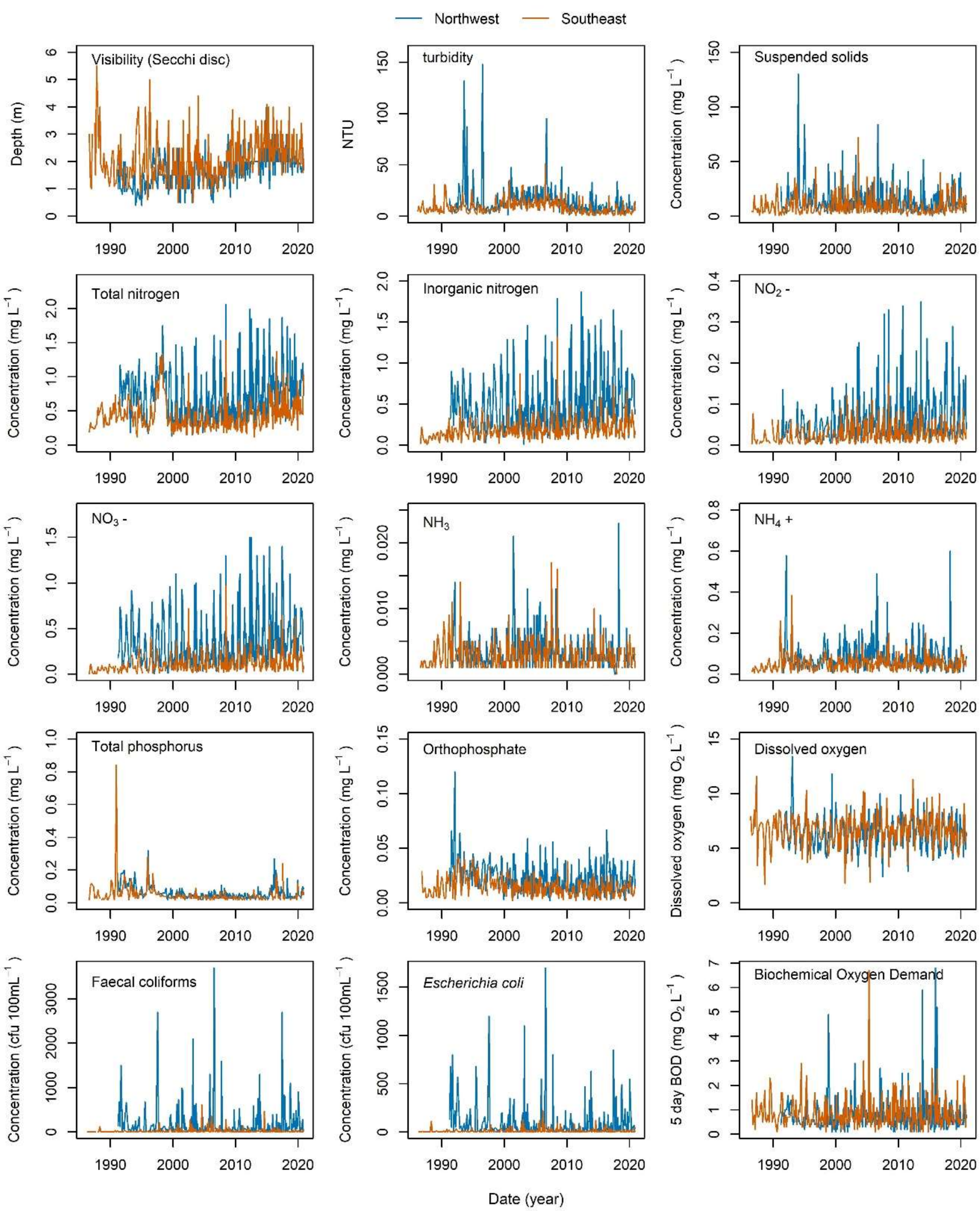

Figure 4. water quality parameters from bottom water at sampling sites near the trawling areas.

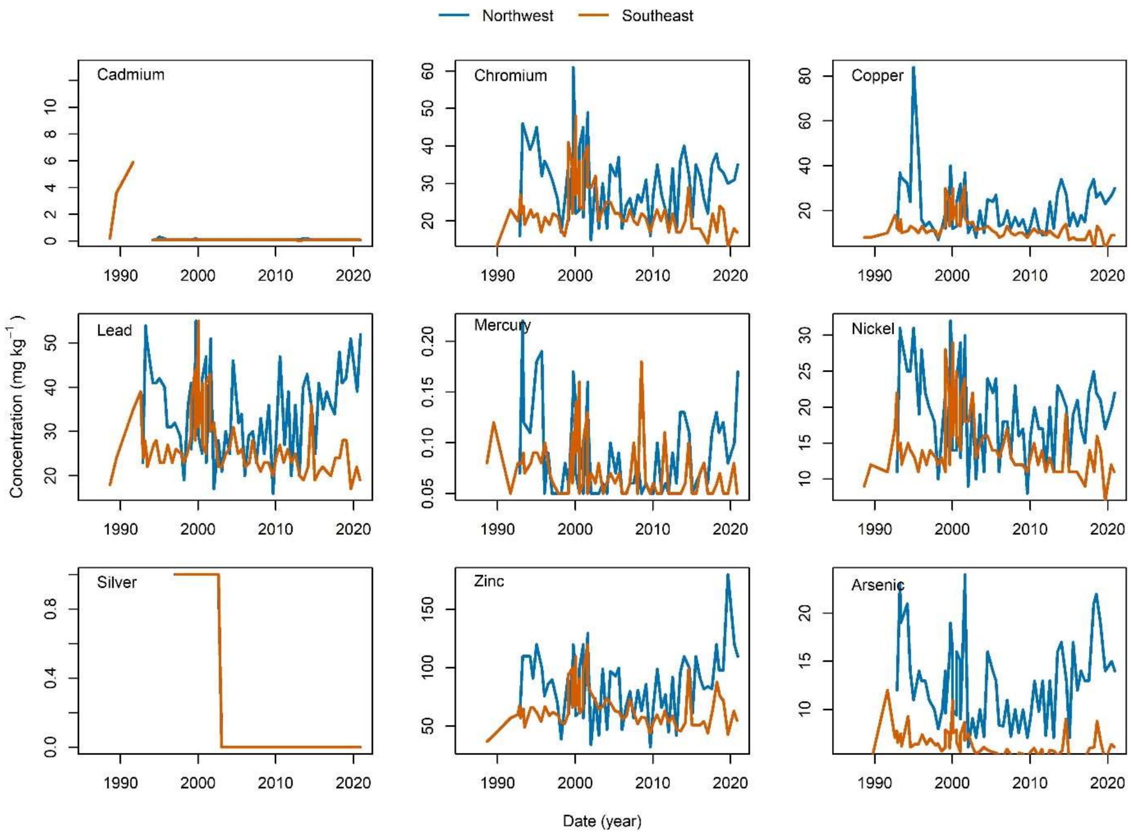

Figure 5. Concentration of metals and metalloids in marine sediments near the trawling areas, in the northwestern and southeastern Lantau waters.

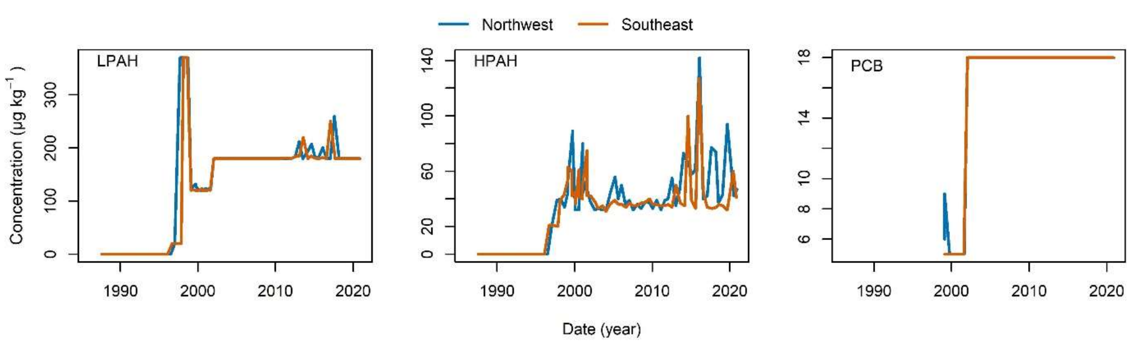

Figure 6. Concentration of low and high molecular weight polycyclic aromatic hydrocarbon (LPAH and HPAH, respectively) and total Polychlorinated biphenyls (PCB) in marine sediments near the trawling areas, in the northwestern and southeastern Lantau waters.

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The Shannon-Wiener index for southeastern Lantau shell diversity was 3.45 compared to 2.87 for northwest Lantau. It indicates higher diversity of shells in southeastern waters compared to the more impacted northwestern waters of Lantau (Table 2). The size comparison between southeastern and northwestern Lantau shells revealed that most morphospecies had similar sizes between the two sites, except for the gastropod *T. bacillum*, which had slightly larger shells in northwestern Lantau (PERMANOVA, pseudo-$F_{(4,374)} = 3.555$, SS = 0.212, $p = 0.030$, Figure 7). It is an indication that impacted waters, such as in northwest Lantau, may be more suitable for *T. bacillum* compared to southeastern Lantau, where the species reach slightly smaller sizes.

Table 2. Mollusc shells morphospecies diversity and abundance at the sampling transects around Lantau Island. Specimens collected in July and August are pooled together for their respective transects. WT, Western transects (Lantau). WT1 and WT2 represent southeast Lantau and WT3 and WT4 represent northwest Lantau.

Morphospecies	**Southeast**		**Northeast**	
	WT1	**WT2**	**WT3**	**WT4**
Adelphotectonica reevei		1	1	
Babylonia areolata		2	1	
Babylonia formosae	2	1		1
Babylonia lutosa	3	6	1	2
Brunneifusus ternatus		1		
Bufonaria rana	10	10	5	7
Calyptraea chinensis		1		
Calyptraea extinctorium	1			
Calyptraea morbida	2	4	1	1
Conus betulinus		1		1
Crepidula onix		1	4	1
Distortia reticularis	1	1		
Epitonium scalare		2		
Ergaea walshii	5	6	1	
Ficus variegata		1		
Funa jeffreysii	1			2
Hemifusus kawamurai		1		

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Hemifusus tuba	1	2		
Indothais lacera		1		2
Lataxiena fimbriata		1		
Linatella caudata		1		
Lophiotoma leucotropis	2	1		
Mammilla kurodai	1			
Mammilla mammata				1
Melo melo		1		
Monodonta labio				1
Murex trapa	17	12	3	10
Nassaria acuminata				1
Nassarius conoidalis		1		
Nassarius hepaticus		2		
Nassarius siquijorensis	4	6		8
Natica tigrina				2
Natica vitellus		1		
Neverita didyma	1	4	1	
Rapana bezoar	4	2	1	
Reticutriton pfeifferianus				1
Semicassis bisulcata	3	4		3
Tanea lineata	2	1		
Tonna chinensis	1			
Tonna dolium		1		
Tonna lischkeana	2			
Tonna sulcosa	3	5	2	
Tonna zonata				
Turricula javana		1		5
Turricula nelliae	6	10		8
Turritella bacillum	90	38	20	135
Bivalves				
Amusium pleuronectes	2	1		
Anadara broughtonii	6	5		
Anadara consociata	6	12	3	9
Anadara cornea	2			
Anadara craticulata		2		

Anadara crebricostata				1
Anadara globosa	12	31	15	4
Anadara inequivalvis				2
Anadara kafanovi	7	13		1
Anadara rhomboidalis	1			
Annomia spp.	1	9	4	3
Atrina pectinata	9	12		
Atrina penna		3		
Atrina vexillum	2	2		
Azorinus coarctatus	3			1
Barnea australasiae		1		
Chama dunkeri				1
Circe scripta		1		
Dosinia corrugara	3	9	1	1
Dosinia exasperata		2		1
Dosinia japonica	1			
Glycymeris aspersa		1		
Hanleyanus vestalis	4	2		2
Hiatula diphos				1
Joanisiella oblonga	1	1		
Lutraria complanata	18	6	3	
Lutraria maxima				1
Macomopsis chinensis				9
Mactotroma antecedens	1			
Mactra antiquata	1			
Mactrinula dolabrata	6	3		
Mactrinula reevesi	4			
Magallana sp.		5		
Maoricardium setosum		1		
Marcia hiantina		1		
Meretrix lamarckii		1		
Meropesta sinojaponica	1			
Mimachlamys crassicostata		8		
Minnivola pyxidata	2	3		
Modiolus modulaides	2			

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Mytilus galloprovincialis				1
Ostrea denselamellosa	1	4	7	1
Ostreidae spp.		1	1	1
Paphia euglypta	1	5		
Paratapes undulatus	38	58	9	17
Pelecyora nana		2		
Perna viridis		8	22	11
Pinna bicolor				1
Pinctada fucata		3		2
Pitar striatus		1		
Placamen lamellatum	10	14	1	10
Placuna ephippium	2			
Placuna placenta		2	2	1
Planostrea pestigris	8	22	3	
Protapes gallus	37	40	8	11
Psammacoma candida	10	19	5	
Psammacoma gubernaculum	59	61	31	25
Ruditapes philippinarum	1	8	2	70
Saccostrea cucculata		2		
Saccostrea glomerata			3	
Solecurtus exaratus	6	1		
Solen brevissimus	1			
Spondylus squamosus			1	
Talonostrea sp.	46	153		25
Tegillarca nodifera	1			1
Timoclea micra	1	1		
Trisidos semitorta		1		
Trisidos tortuosa	1	2		1
Vepricardium coronatum	24	22		1
Vepricardium sinense	7	8		1
Volachlamys singaporina	4		8	9
non identified shells	6	3		

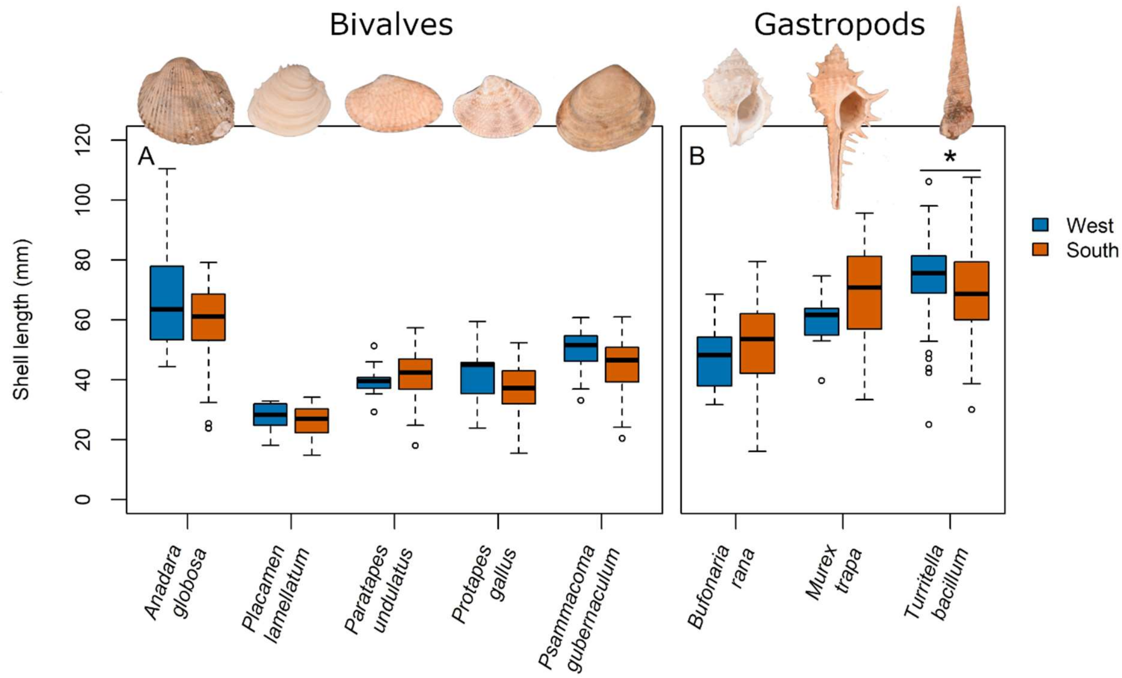

Figure 7. Comparison of the shell sizes of representative morphospecies of bivalves (A) and gastropods (B) between northwestern and southeastern Lantau waters. Boxplots show the median, 25th and 75th percentiles, and whiskers are 1.5 times the spread beyond the hinge. Asterisk represents significant differences between west and south Lantau shells (Pairwise PERMANOVA, $p < 0.05$).

From the dated shells, most of them were modern, post-industrial age (Table 3). Because only three shells of *T. bacillum* were dated, this species was excluded from statistical analyses. No significant differences were found for the age distribution of shell morphospecies between northwestern and southeastern Lantau (PERMANOVA, pseudo-$F_{(4,117)} = 1.131$, SS = 3.386, $p = 0.176$). There was, however, a difference in age between shells of the bivalves *A. globosa* and *P. undulatus* (PERMANOVA, pseudo-$F_{(4,117)} = 2.440$, SS = 6.906, $p = 0.016$; Pairwise PERMANOVA, $p = 0.010$), with the former being mostly present around the year 2000AC and afterwards, while the later has larger presence in the past (Figure *8* and Figure *9*).
Past macrobenthic surveys found *R. philippinarum* mostly in the Victoria Harbour area. But our results suggest they have wider distribution now. Shells of this morphospecies were particularly abundant on impacted northwestern Lantau waters, but not as much in the

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southeastern waters of the island. Also, *R. philippinarum*, a resistant bivalve species (Braga et al. 2021), show almost all modern, post-industrial dates. This suggests *R. philippinarum* may be more successful in the present-day polluted environments. *Paratapes undulatus*, on the other hand, has an abundant number of shells both in the northwestern and southeastern Lantau, but with larger number of shells being found in the southeast of the island. This species shows older shells compared to the other morphospecies, with mixed age distribution. This suggests that *P. undulatus* was historically present around Lantau and continue to exist around the island waters. However, the comparatively older shells and lower abundance in the northwest indicate that it may be less successful presently in the area compared to other species. These results corroborate the idea that *P. undulatus* is a more sensitive species, as suggested in previous studies (Horikoshi and Thompson, 1980; Shin, 1985; Shin et al., 2004). *Anadara globosa*, on the other hand, has abundant number of modern and lack of older shells. This may be an indication that this species is adapted to live in more impacted environments.

The gastropod shells belonging to *T. nelliae* were also modern, contradicting previous subtidal macrofauna surveys carried in 2001, 2012 and 2015, which did not find this species and indicated its populational decline (Shin, Huang, and Wu 2004; Wang et al. 2017; Jian-Wen Qiu, unpublished). The absence of *T. nelliae* in their survey could be attributed to the use of grab samplers, which may not be very effective in capturing highly motile predators. The scavenger gastropod *N. siquijorensis*, on the other hand, had slightly older shells in southeastern waters, while shells in the northwest were younger. This species is expected to be abundant in disturbed areas. The reason why *N. siquijorensis* shells were younger in the northwest compared to southeast may be due to the resilience of this species to impacted waters. *Nassarius siquijorensis* was present in baseline conditions and may have increased in abundance in the highly impacted waters of modern northwest Lantau.

Relative to changes in size with shell age, the regression analyses did not find any size changes through time in *A. globosa*, *R. philippinarum*, *N. siquijorensis*, *T. nelliae* and *T. bacillum*. However, for *P. undulatus,* there was a weak positive relationship between age and size (Figure 10). This relationship could indicate that modern more eutrophic waters affect the phenotype of this bivalve species. It could, however, also be an artifact of the fragmentation of larger older shells of this species.

Table 3. Calibrated 14C dates. WT, Western (Lantau) transects: WT1 and WT2 represent southern Lantau and WT3 and WT4 represent western Lantau.

		Age (AD)			
Morphospecies	Transect	from	to	median	Sample code
Anadara globosa	WT1	2005.05	2010.15	2007.9	WT1-07/18-AG37
Anadara globosa	WT1	1997.45	2003.05	2000.4	WT1-07/18-AG38
Anadara globosa	WT1	1989.4	1992.65	1990.8	WT1-07/18-AG39
Anadara globosa	WT1	1994.35	1999.35	1996.9	WT1-07/18-AG40
Anadara globosa	WT1	1995.9	2000.3	1998.2	WT1-08/18-AG267
Anadara globosa	WT1	1955.7	2017.05	2014.3	WT1-08/18-AG268
Anadara globosa	WT1	1730	1950	1880.3	WT1-08/18-AG269
Anadara globosa	WT1	1996.75	2001.85	1999.5	WT1-08/18-AG271
Anadara globosa	WT2	1955.5	2017.05	2014	WT2-07/18-AG101
Anadara globosa	WT2	1955.35	2018.8	2015.7	WT2-07/18-AG104
Anadara globosa	WT2	1957.85	1998.2	1995.4	WT2-07/18-AG105
Anadara globosa	WT2	1955.55	2019	2016.3	WT2-08/18-AG12
Anadara globosa	WT2	1957.9	1997	1995.1	WT2-08/18-AG13
Anadara globosa	WT2	2003.25	2007.3	2005.5	WT2-08/18-AG8
Anadara globosa	WT2	2003.5	2007.35	2005.6	WT2-08/18-AG9
Anadara globosa	WT3	1956.65	2013.45	2012	WT3-08/18-AG1
Anadara globosa	WT3	2005.4	2011.7	2008.6	WT3-08/18-AG10
Anadara globosa	WT3	2003.3	2007.45	2005.7	WT3-08/18-AG11
Anadara globosa	WT3	1955.35	2018.8	2015.8	WT3-08/18-AG13
Anadara globosa	WT3	1956.8	2013.3	2011.5	WT3-08/18-AG3
Anadara globosa	WT3	1990.05	1993.45	1992	WT3-08/18-AG4
Anadara globosa	WT3	1958.45	1999.75	1996.8	WT3-08/18-AG5
Anadara globosa	WT3	1955.35	2018.75	2015.8	WT3-08/18-AG6
Anadara globosa	WT3	1957.65	1995.45	1993.3	WT3-08/18-AG7
Anadara globosa	WT3	2002.7	2006.4	2004.4	WT3-08/18-AG8
Anadara globosa	WT3	1956.8	2013.3	2011	WT3-08/18-AG9
Anadara globosa	WT4	1999.3	2002.2	2000.7	WT4-08/18-AG39
Anadara globosa	WT4	1955.55	2017.95	2015.8	WT4-08/18-AG40
Anadara globosa	WT4	1994.7	1999.5	1996.6	WT4-08/18-AG41
Anadara globosa	WT4	1957.9	1996.55	1995.1	WT4-08/18-AG42
Nassarius siquijorensis	WT1	1958	2003	2002	WT1-08/18-108 Ns

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Continuation of Table 3. Calibrated 14C dates. WT, Western (Lantau) transects: WT1 and WT2 represent southern Lantau and WT3 and WT4 represent western Lantau.

		Age (AD)			
Morphospecies	Transect	from	to	median	Sample code
Nassarius siquijorensis	WT1	1958	2000	1997	WT1-08/18-106 Ns
Nassarius siquijorensis	WT1	1958	1998	1997	WT1-08/18-107 Ns
Nassarius siquijorensis	WT1	1760	1950	1893.6	WT1-07/18-NS187
Nassarius siquijorensis	WT2	1958	1995	1991	WT2-07/18-62 Ns
Nassarius siquijorensis	WT2	1957	2005	2004	WT2-07/18-63 Ns
Nassarius siquijorensis	WT2	406	706	563	WT2-07/18-64 Ns
Nassarius siquijorensis	WT2	1958	1998	1996	WT2-07/18-65 Ns
Nassarius siquijorensis	WT2	1756	…	1896	WT2-07/18-511 Ns
Nassarius siquijorensis	WT2	1840	1950	1916	WT2-08/18-NS184
Nassarius siquijorensis	WT4	1958	1998	1996	WT4-07/18-1 Ns
Nassarius siquijorensis	WT4	1957	2010	2007	WT4-07/18-2 Ns
Nassarius siquijorensis	WT4	1956.8	2013.35	2011.6	WT4-07/18-NS147
Nassarius siquijorensis	WT4	1957.1	2012.4	2010.7	WT4-07/18-NS148
Nassarius siquijorensis	WT4	1954.7	2019.5	2018.7	WT4-08/18-NS25
Nassarius siquijorensis	WT4	1954.75	2019.5	2018.9	WT4-08/18-NS26
Nassarius siquijorensis	WT4	2004.35	2007.35	2005.9	WT4-08/18-NS27
Turricula nelliae	WT1	1840	1950	1917.9	WT1-08/18-TN112
Turricula nelliae	WT1	1956.7	2015.95	2013.9	WT1-08/18-TN114
Turricula nelliae	WT1	1956.65	2015.65	2013.8	WT1-08/18-TN115
Turricula nelliae	WT2	1958	1995	1992	WT2-07/18-68 Tn
Turricula nelliae	WT2	1957	2008	2007	WT2-07/18-69 Tn
Turricula nelliae	WT2	1955	2016	2014	WT2-07/18-70 Tn
Turricula nelliae	WT2	1955	2018	2014	WT2-07/18-71 Tn
Turricula nelliae	WT2	1955	2017	2014	WT2-07/18-72 Tn
Turricula nelliae	WT2	1955	2014	2012	WT2-07/18-73 Tn
Turricula nelliae	WT2	1955	2015	2015	WT2-07/18-74 Tn
Turricula nelliae	WT2	1955	2014	2012	WT2-07/18-75 Tn
Turricula nelliae	WT2	1955	2015	2013	WT2-07/18-76 Tn
Turricula nelliae	WT2	1957.7	1995.5	1993.6	WT2-08/18-TN167
Turricula nelliae	WT4	1957	2011	2010	WT4-07/18-3 Tn
Turricula nelliae	WT4	1955.5	2015.35	2013.4	WT4-07/18-TN125

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Continuation of Table 3. Calibrated 14C dates. WT, Western (Lantau) transects: WT1 and WT2 represent southern Lantau and WT3 and WT4 represent western Lantau.

		Age (AD)			
Morphospecies	Transect	from	to	Morphospecies	Transect
Turricula nelliae	WT4	1850	1950	1919.1	WT4-07/18-TN135
Turricula nelliae	WT4	2007.55	2011.7	2009.6	WT4-07/18-TN136
Turricula nelliae	WT4	1957.2	2012.35	2010.6	WT4-07/18-TN126
Turricula nelliae	WT4	1956.75	1958.2	2012.1	WT4-07/18-TN137
Turricula nelliae	WT4	1956.75	2013.4	2011.8	WT4-07/18-TN138
Turricula nelliae	WT4	1956.75	2013.4	2011.8	WT4-07/18-TN139
Turricula nelliae	WT4	1956.75	2013.35	2011.8	WT4-07/18-TN140
Turritella bacillum	WT4	-5640	-5360	-5500.1	WT4-08/18-TB10
Turritella bacillum	WT4	1955.55	2019.5	2017.1	WT4-08/18-TB4
Turritella bacillum	WT4	1957.95	1994.4	1992.5	WT4-08/18-TB8
Ruditapes philippinarum	WT1	1864	...	1915	WT1-08/18-312 Rp
Ruditapes philippinarum	WT2	1990	1992	1991	WT2-07/18-450 Rp
Ruditapes philippinarum	WT2	1989	1992.15	1990.6	WT2-07/18-RP449
Ruditapes philippinarum	WT2	1955	…	2017	WT2-08/18-1 Rp
Ruditapes philippinarum	WT2	1955	…	2017	WT2-08/18-2 Rp
Ruditapes philippinarum	WT2	1955	2016	2014	WT2-08/18-3 Rp
Ruditapes philippinarum	WT2	1955	2014	2012	WT2-08/18-4 Rp
Ruditapes philippinarum	WT2	1955	2018	2015	WT2-08/18-5 Rp
Ruditapes philippinarum	WT2	1955	…	2017	WT2-07/18-451 Rp
Ruditapes philippinarum	WT3	1958	1993	1992	WT3-08/18-1 Rp
Ruditapes philippinarum	WT3	1545	1921	1735	WT3-08/18-2 Rp
Ruditapes philippinarum	WT4	1957.2	2012.35	2010.5	WT4-07/18-RP168
Ruditapes philippinarum	WT4	1955.4	2015.95	2013.7	WT4-08/18-RP104
Ruditapes philippinarum	WT4	1955.6	2016.75	2014.6	WT4-08/18-RP115
Ruditapes philippinarum	WT4	1955.5	2015.3	2013.3	WT4-08/18-RP79
Ruditapes philippinarum	WT4	1955.55	2018.7	2016.5	WT4-08/18-RP80
Ruditapes philippinarum	WT4	1955.75	2016.4	2014.4	WT4-08/18-RP83
Ruditapes philippinarum	WT4	1956.65	2015.9	2013.9	WT4-08/18-RP92
Paratapes undulatus	WT1	2003.3	2007.05	2005.1	WT1-07/18-PU86
Paratapes undulatus	WT1	2003.05	2006.8	2004.8	WT1-07/18-PU93
Paratapes undulatus	WT1	1956.9	2012.55	2010.9	WT1-08/18-PU171

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Continuation of Table 3. Calibrated 14C dates. WT, Western (Lantau) transects: WT1 and WT2 represent southern Lantau and WT3 and WT4 represent western Lantau.

		Age (AD)			
Morphospecies	Transect	from	to	Morphospecies	Transect
Paratapes undulatus	WT1	1958.15	1994.3	1992.5	WT1-08/18-PU186
Paratapes undulatus	WT1	1957	2012.45	2010.8	WT1-08/18-PU187
Paratapes undulatus	WT2	1958	1994	1993	WT2-07/18-166 Pu
Paratapes undulatus	WT2	1957	2010	2006	WT2-07/18-167 Ru
Paratapes undulatus	WT2	680	964	817	WT2-07/18-168 Ru
Paratapes undulatus	WT2	1957	2008	2007	WT2-07/18-170 Pu
Paratapes undulatus	WT2	1826	…	1910	WT2-07/18-179 Ru
Paratapes undulatus	WT2	2004.15	2007.35	2005.9	WT2-08/18-PU52
Paratapes undulatus	WT2	2004.65	2008.25	2006.4	WT2-08/18-PU54
Paratapes undulatus	WT2	2007.6	2011.8	2009.7	WT2-08/18-PU56
Paratapes undulatus	WT2	2006.65	2010.1	2008.2	WT2-08/18-PU63
Paratapes undulatus	WT3	1957	2001	2003	WT3-08/18-1 Pu
Paratapes undulatus	WT3	1613	1928	1752	WT3-08/18-2 Pu
Paratapes undulatus	WT3	1957	2013	2011	WT3-08/18-3 Ru
Paratapes undulatus	WT3	-3234	-2866	-3018	WT3-08/18-4 Pu
Paratapes undulatus	WT3	1955	2014	2012	WT3-08/18-5 Ru
Paratapes undulatus	WT3	1760	1950	1893	WT3-08/18-PU21
Paratapes undulatus	WT3	1955.4	2014.8	2012.5	WT3-08/18-PU22
Paratapes undulatus	WT3	1955.6	2016.45	2014.5	WT3-08/18-PU23
Paratapes undulatus	WT4	-800	-530	-680.9	WT4-07/18-PU152
Paratapes undulatus	WT4	-4540	-4260	-4394.7	WT4-07/18-PU153
Paratapes undulatus	WT4	-2440	-2110	-2259.6	WT4-07/18-PU154
Paratapes undulatus	WT4	2004.7	2008.2	2006.4	WT4-08/18-PU185
Paratapes undulatus	WT4	-3510	-3180	-3359.3	WT4-08/18-PU188
Paratapes undulatus	WT4	1550	1850	1715.6	WT4-08/18-PU192
Paratapes undulatus	WT4	-3650	-3370	-3532.8	WT4-08/18-PU194

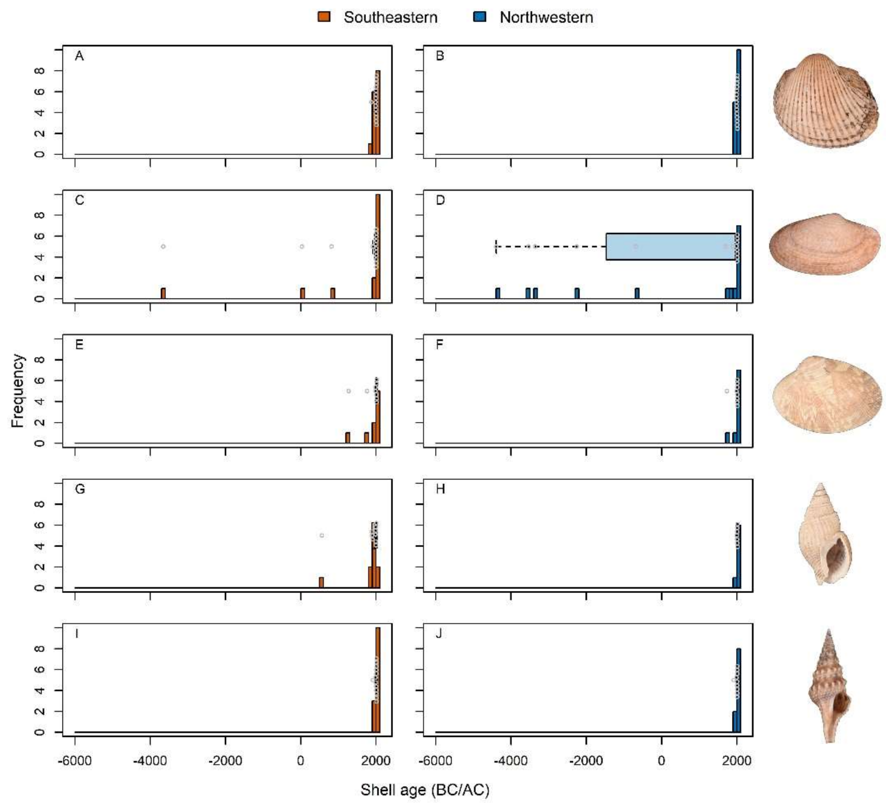

Figure 8. Histograms showing the shell age distribution of the species *Anadara globosa* (A and B) *Ruditapes philippinarum* (C and D), *Paratapes undulatus* (E and F), *Nassarius siquijorensis* (G and H) and *Turricula nelliae* (I and J) in Southeastern (A, C, E, G and I) and northwestern (B, D, F, H and J) Lantau, for the period from -6000 BC to 2020 AC. Boxplots show the median, 25th and 75th percentiles, and whiskers are 1.5 times the spread beyond the hinge. Grey circles represent the data points.

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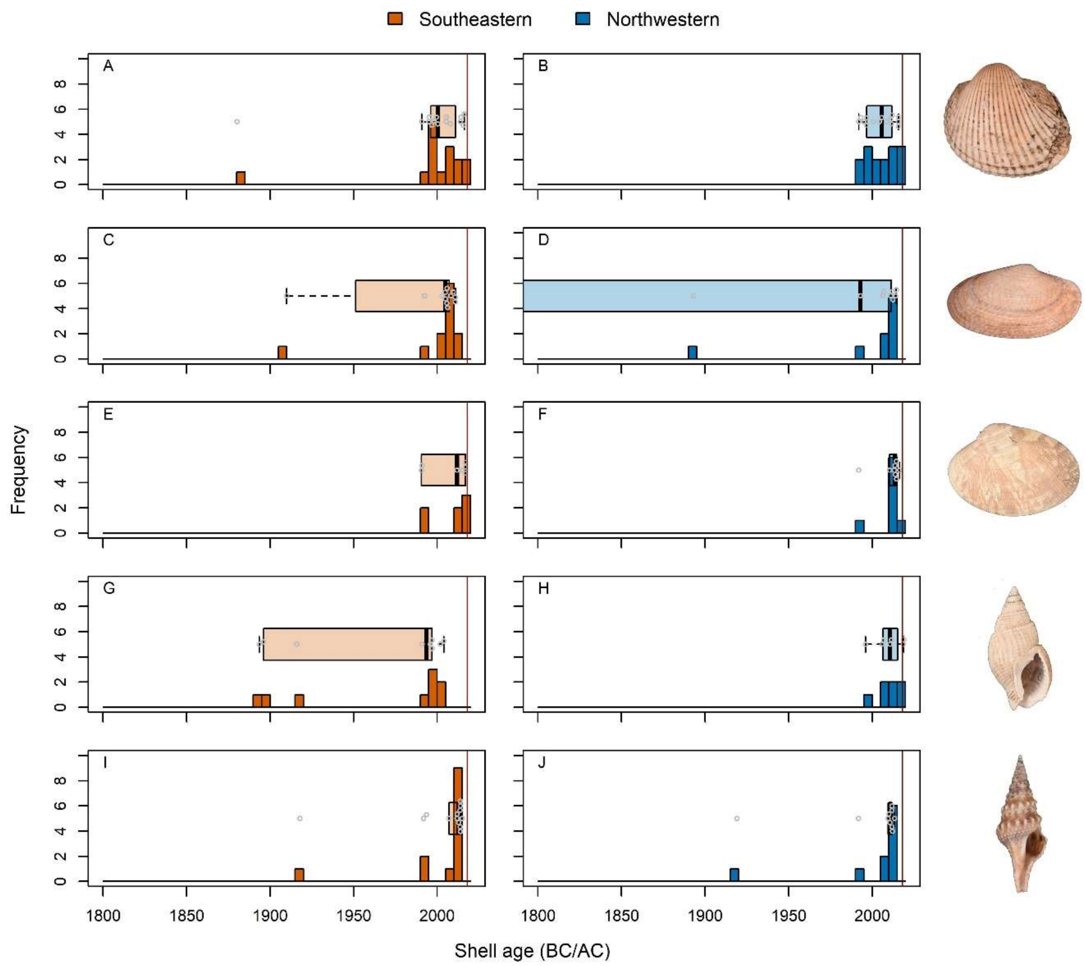

Figure 9. Histograms showing the shell age distribution of the species *Anadara globosa* (A and B) *Ruditapes philippinarum* (–C and D), *Paratapes undulatus* (E and F), *Nassarius siquijorensis* (G and H) and *Turricula nelliae* (I and J) in Southeastern (A, C, E, G and I) and northwestern (B, D, F, H and J) Lantau, for the period from 1800 to 2020 AC. Boxplots show the median, 25th and 75th percentiles, and whiskers are 1.5 times the spread beyond the hinge. Grey circles represent the data points. The purple line crosses the year of 2018, when sampling was conducted.

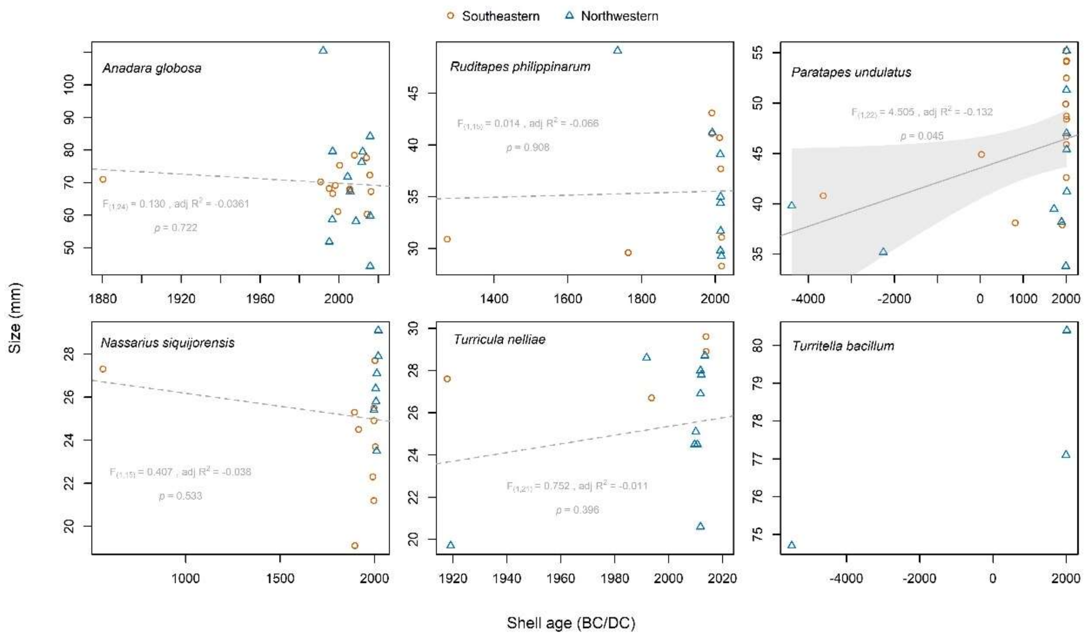

Figure 10. Relationship between shell ages and sizes. Orange circles and blue triangles represent Southeastern and Northwestern Lantau shells, respectively. The grey line represents significative regression, and dashed grey lines are non-significant linear regressions. Shaded grey area represent confident intervals (95%). F statistics, adjusted R^2 and significance values for the regressions are presented in the figure.

In conclusion, our environmental and shell community analyses, together with 14C dates, suggests (1) A highly impacted northwestern in comparison to southeastern Lantau waters, (2) different shell diversity, and therefore, mollusc communities between northwestern and southeastern Lantau waters, (3) different response between tolerant and sensitive mollusc species to environmental degradation in Lantau, and (4) Substantial changes in faunal composition in the Pearl River Estuary by anthropic environmental degradation.

As outreach activity, the project scope and preliminary results were presented at the 2nd International Conference on biodiversity, ecology and conservation of marine ecosystems (BECoME-2022) at the City University of Hong Kong.

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(v) Evaluation of the project effectiveness in achieving the proposed objectives as well as the impact (benefits) of the Project;

Our shell size and 14C age data, together with EPD environmental quality data, shows the differences in benthonic habitats quality and faunal composition between northwest and southwest Lantau. The shell dating also shows evidence of baseline mollusc species and of faunal changes through time in benthonic communities around Lantau.

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Specifically to the objectives in the section 3:

1. To plot the age distributions of key subtidal benthic molluscan species;
With the receive radiocarbon dates we were able to plot the age distribution of representative mollusc species present in Lantau benthonic ecosystems. The age distribution analyses showed prevalence of opportunistic and decline of sensitive key mollusc species.

2. To map the distributional changes of key subtidal benthic molluscan species; and from these
Based on the 14C dates we received and on shell distribution data, we could draw conclusions on differences of shell composition between northwestern and southeastern Lantau, and about the presence or absence of certain species through time.

3. To understand the abundance and distributional changes of Lantau subtidal molluscs in relation to human-induced environmental changes and pollution;
Our results show clear difference in shell diversity between the more polluted northwestern Lantau and the more pristine and more diverse southeastern side of the island. Additionally, our 14C dates show interesting aspects of the mollusc species distribution through time in Lantau coastal waters.

4. To know the baseline information of marine benthic ecosystem as a important habitat of Chinese White Dolphin and other iconic and keystone organisms in the past Hong Kong before becoming a mega city.
Our 14C dates show, for example, that species such as P. undulatus have been present in Lantau waters through time, with shells dating back to the Holocene, proving this species was present in baseline conditions. Meanwhile, species more resistant to environmental degradation, such as R. philippinarum and N. siquijorensis, have abundant modern shells in modern disturbed waters. These species may be opportunistic, with less abundant numbers in baseline conditions. Our results show the response of benthonic fauna to environmental degradation and changes from baseline conditions, and illustrates how Hong Kong subtidal habitats and consequently its fauna have changed from pre-industrial times.

(vi) Summary and way forward

Hong Kong has a long history of coastal degradation, however, there is little information about the subtidal fauna on times pre-human driven environmental degradation. There is also a lack of details in the response of subtidal fauna to anthropogenic impact through time. Lantau island in Hong Kong is an important biogeographical region and had been through intense coastal development, with greater degradation on the western side of the island compared to its southern side. Here, using 14C dating of dead shells belonging to representative mollusc species, we show evidence for baseline species and for subtidal mollusc fauna changes in Lantau waters through time. The results presented in this report also evidence differences between impacted northwestern and more pristine southeastern Lantau subtidal mollusc fauna.

The results of this project show the importance of mitigating anthropogenic impacts on subtidal mollusc communities in Lantau, especially in more pristine waters in the south/southeastern side of the island, to maintain the mollusc fauna diversity closer to its original composition. This study highlighting the need to preserve Lantau subtidal areas to avoid losses in species diversity and turnover of local species, what can lead to loss of ecological functions, as well as affect fisheries stocks.

(vii) Financial statement of the project (enclose as an appendix to the completion report) in the suggested format as set out in Appendix 2;

Financial statement are not disclosed due to confidentiality reasons.

(viii) Copies of supporting receipts for expenses incurred, and copies of respective quotation/tendering documents of the major expenses enclosed in an appendix to the completion report in accordance with Section 5.9.3 of this Guidance Note

Receipts/ quotation/tendering documents are not disclosed due to confidentiality reasons.

(ix) Staff attendance record in accordance with the attendance monitoring plan (enclosed as an appendix) (see Section 5.17);

Staff attendance record are not disclosed due to confidentiality reasons.

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(x) If applicable, recruitment record for all project staff employed in accordance with the recruitment plan under the project (enclosed in an appendix) (see Section 5.17).

Recruitment record are not disclosed due to confidentiality reasons.

(xi) A list of all project assets with photos enclosed as an appendix to the completion report.

NA. There are no project asset.

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I hereby irrevocably declare to the MEEF Management Committee and the Steering Committee of the relevant Funds including the Top-up Fund, that all the dataset and information included in the completion report has been properly referenced, and necessary authorisation has been obtained in respect of information owned by third parties.

Any opinions, findings, conclusions or recommendations expressed in this report do not necessarily reflect the views of the Marine Ecology Enhancement Fund or the Trustee.

I hereby irrevocably declare, warrant and undertake to the MEEF Management Committee and the Steering Committee of the relevant Funds including the Top-up Fund, that I myself, and the Organisation:-

1. do not deal with, and are not in any way associated with, any country or organisation or activity which is or may potentially be relevant to, or targeted by, sanctions administered by the United Nations Security Council, the European Union, Her Majesty's Treasury-United Kingdom, the United States Department of the Treasury's Office of Foreign Assets Control, or the Hong Kong Monetary Authority, or any sanctions law applicable;

2. have not used any money obtained from the Marine Ecology Enhancement Fund or the related Top-up Fund (and any derived surplus), in any unlawful manner, whether involving bribery, money-laundering, terrorism or infringement of any international or local law; and

3. have used the funds received (and any derived surplus) solely for the studies or projects which further the MEEF Objectives and have not distributed any portion of such funds (including any derived surplus) to members of the Recipient Organisation or the public.

Sincerely yours,
Moriaki Yasuhara (PI)

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Dr. Moriaki Yasuhara

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