

Using planktonic foraminifera assemblages to assess biases in museum historical collections

Marina C. Rillo, Michal Kučera, Thomas H. G. Ezard,
Andy Purvis & C. Giles Miller

March 7, 2018

1 Introduction

(General intro: importance of museum collections and specially historical collections) Although historical samples are an important resource of recent past data (Lister and Group, 2011), they often hold imprecise information about the sampling method or the method itself was inaccurate at the time. Here, we assessed potential sampling biased in two historical collections held by the Natural History Museum in London (NHMUK). We used planktonic foraminifera assemblages to study these biases.

The first historical collection studied is the Ocean-Bottom Deposits (OBD) Collection held by the NHMUK. This collection consists of about 40,000 samples from all the world's oceans and is the most comprehensive British collection of seabed samples and cores. The OBD samples collected during many of the famous marine expeditions on the 19th and 20th centuries, including the important HMS Challenger expedition which took place 150 years ago (1872-76) and sailed around the globe. The OBD collection is thus invaluable for studies of the ocean and ocean floor, including research looking at global change, including ocean acidification and marine pollution over the last century. The sampling of the sea floor before the 1970s (?) was inaccurate, usually the exact depth below the sea floor sampled was not measured and techniques such as dredging, sounding and collecting sediments from the anchor were applied. Sediment age estimation is thus imprecise and could include mixed sediments of the Holocene (last 11,700 years, Walker et al. 2008) and the Last Glacial Maximum (LGM, 21,000 years ago, MARGO Project Members et al. 2009). This potential bias leads to a under-use of historical oceanographic collections such as the OBD Collection.

Another historical collection held by the NHMUK is the Henry Buckley Planktonic Foraminifera Collection. Henry Buckley sampled sediments from the NHMUK OBD Collection to mount a specimens slides collection of modern planktonic foraminifera species (Rillo et al 2016). Good geographical scope and intraspecific resolution for diversity and ecological studies. There is little information of how Buckley chose the specimens he picked, thus the Buckley Collection could have a collector effort bias towards larger (or smaller) specimens, resulting in distorted shell size distributions. The presence of such bias could significantly affect the use of the collection to assess and understand species' morphological diversity.

Table 1: Sediments re-sampled for the bias analysis. Year: sediment collection year. N(forams) is the number of planktonic foraminifera picked

IRN	Year	Vessel	Ocean	Lat	Lon	Depth(m)	Mass(g)	N(forams)
32657			Indian	-50.017	123.067	-3976	grams	318
38482			Indian	-40.450	49.817	-3780	grams	177
36053			Indian	-26.937	111.182	-3350	grams	279
34991			Atlantic	-21.250	-14.033	-3740	grams	265
34671			Indian	-19.567	64.633	-2708	grams	376
34993			Pacific	-15.650	-179.062	-2519	grams	300
37148			Indian	-7.592	61.483	-3507	grams	305
33668			Pacific	-0.70	147.000	-2213	grams	331
33286			Atlantic	24.333	-24.467	-5153	grams	260
14609			Arctic	85.250	-167.900	-1774	grams	226
								2837

2 Methods

2.1 Sample processing

To assess these two sources of biases in the historical collections, we sampled ten historical samples from the NHMUK Ocean-Bottom Deposits (OBD) Collection (Table 1) that were also used to amass the Henry Buckley Collection of Planktonic Foraminifera. We focussed on core-top samples which encompass different oceans, latitudes and marine expeditions. However, the final choice of the ten OBD samples could not be completely randomized since it depended on the availability of the bulk sediment sample in the OBD Collection and its overlap with the samples used in the Buckley Collection. Once we defined the ten samples, we took roughly half of the amount available in the OBD jars and tubes (see Table 1 for sampled masses). Each of these samples was further split into two equal parts, leaving an archive sample and a sample to be processed. The processing of these re-sampled samples consisted of weighing each of them, then wet washing over a $63\mu\text{m}$ sieve and drying in a 60°C oven. The samples were further dry sieved over a $150\mu\text{m}$ sieve and the fraction bigger than $150\mu\text{m}$ was further split with a microsplitter to produce a sample containing around 300 adult specimens (Al-Sabouni et al., 2007). After the processing, each of the ten samples was dry sieved over a $150\mu\text{m}$ sieve and the fraction bigger than $150\mu\text{m}$ was further split with a microsplitter to produce a sample containing around 300 adult specimens (Al-Sabouni et al., 2007). All the planktonic foraminifera (PF) specimens in these splits were identified, resulting in a total of 2837 identified specimens from 33 different species (Table 1, plus add species list table - number individuals and samples per species). These ten PF assemblages were then used to (1) test whether the OBD Collection samples represent Holocene assemblages and (2) find the least biased shell size distribution metric of the Buckley Collection of PF.

2.2 Assemblage age

We tested whether the ten historical samples contained planktonic foraminifera assemblages more similar to Holocene assemblages than to the Last Glacial Maximum (LGM) assemblages. We calculated compositional similarity between our re-sampled assemblages and their nearest neighbouring assemblages within

a Holocene database (ForCenS, Siccha and Kucera 2017) and LGM data sets (Kucera et al., 2005). This comparison was based on the Horn index (Horn, 1966), which is an abundance-based overlap measure that preserves essential properties of similarity measurements (explain more - use of relative abundance) (Jost et al., 2011). We used the R package SpadeR (version 0.1.1, Chao et al. 2016) to calculate the Horn indexes and their confidence intervals.

2.3 Shell size distributions

We compared the populational shell size distributions obtained from the re-sampled assemblages with those obtained from the Buckley Collection assemblages. Only species present in both assemblages were considered. The specimens were imaged using the Zeiss Axio Zoom V16 microscope and the ZEN software at a resolution of $2.58 \mu\text{m} \times 2.58 \mu\text{m}$ per Pixel. Individual shell size was estimated based on the two-dimensional image of the specimen using the software Image-Pro Premier (version 9.1), which automatically recognizes each specimen and measures its shell area. This automated individual recognition is based on the contrast between the white shell and the black background of the slide. Brombacher et al. (2017) quantified the reproducibility of shell area measurements and concluded that shell area is highly consistent with remounting specimens on slides.

The comparison of the shell size distributions between the re-sampled and Buckley Collection’s assemblages included 65 populations of 20 species collected from the ten samples. We log-transformed the population shell size distributions and calculated the mean, median, 75th percentile, 95th percentile and maximum value of each distribution. We then regressed each of these five metrics of the Buckley Collection against the re-sampled data and calculated the mean squared error with respect to the identity function (1:1 relationship).

3 Results

3.1 Assemblage age

Our assemblages were consistently more similar to Holocene assemblages than to LGM assemblages (Fig. 1, [and Supp Info for further discussion](#)). This indicates that historical surface samples, such as those collected during the *HMS Challenger* expedition, represent well Holocene assemblages and can, therefore, be used in macroecological studies.

3.2 Shell size distributions

The residuals of the regressions were predominantly positive (Fig. 2a), and residuals increased with increasing species size ([Plot residuals as function of species size - Supp Info](#)). This indicates that the Buckley Collection has a consistent collector bias towards large specimens. Henry Buckley personally carried out all the sample processing, isolation of foraminiferal specimens and their identification, thus the collector biases in his collection are likely to be systematic, especially for within-species comparisons. The mean squared error was lowest for the 95th percentile (Fig. 2a), meaning that this metric is the least biased measurement of the Buckley Collection when considering log-transformed shell

Figure 1: Compositional similarity (Horn index) between assemblages from the re-sampled historical samples and assemblages from the Holocene (ForCenS, Siccha and Kucera 2017) and the Last Glacial Maximum (LGM, Kucera et al. 2005). Historical samples assemblages are more similar to assemblages from the Holocene than from the LGM.

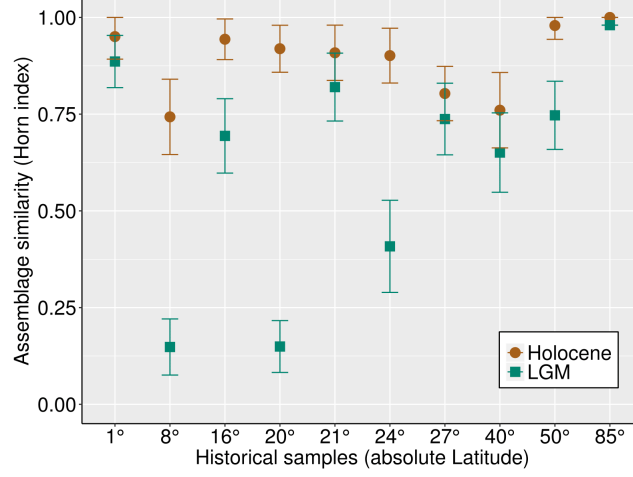
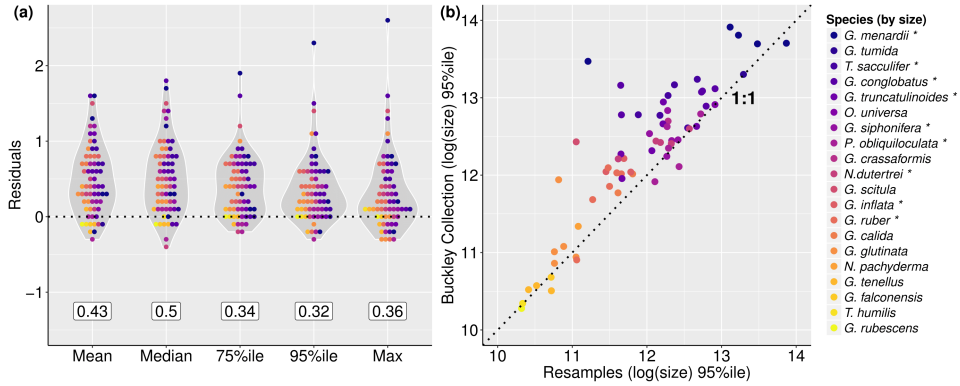


Figure 2: Difference in shell size distributions between populations of the re-sampled assemblages and the Buckley Collection assemblages (in total, 65 populations of 20 species from ten samples). Species are coloured and ordered by shell size (larger sizes in purple-blue, smaller sizes in orange-yellow); species marked with (*) were present in the morphometric dataset. **(a)** Residuals were calculated between the Buckley Collection and the re-sampled samples with respect to the identity function (1:1 relationship). Numbers indicate mean squared error (MSE), the 95th percentile metric shows the smallest MSE. **(b)** Plot of the 95th percentile of the population shell size distributions from the Buckley Collection against the re-sampled samples, line 1:1 represents the identity function.



area. Schmidt et al. (2004) also used the 95th percentile of the size distributions in PF assemblages because it is more robust to random sampling than the maximum size (which is easily distorted by a single outlier) and less sensitive to the sampling effort of picking smaller specimens than the distributions' mean and median values.

4 Discussion

5 Conclusion

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