Assessment of FlowCam VisualSpreadsheet as a potential tool for
rapid semi-automatic analysis of lacustrine Arcellinida (testate
lobose amoeba)

by

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Abstract

Arcellinida are an established group of bioindicators in lake studies, but conventional labor-intensive microscopic analysis techniques often limit the number of samples analysed. In this study, the FlowCam with VisualSpreadsheet® (FCVS), a flow cytometer and microscope with machine learning software, was assessed as an instrument for rapid Arcellinida analysis. In a 2016 study, manual identification and quantification of Arcellinida was performed through conventional microscopy on 46 samples collected from Wightman Cove, Oromocto Lake, New Brunswick, Canada. The samples were reanalyzed by FCVS where Arcellinida were categorized into morphological classes. The datasets obtained through conventional microscopy and through FCVS were compared at the morphotype level using cluster and Bray-Curtis dissimilarity analyses. The methods produced highly similar arcellinidan assemblages that corresponded to specific lake habitats. FCVS was found to reduce analytical time by approximately 45%. FCVS shows potential as a reliable method for more rapid analysis of lacustrine Arcellinida; however, assemblage results can only be obtained at the morphotype level. Microscopic methods should still be used if species-level results are desired.

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Preface

The following thesis consists of a peer-reviewed manuscript, which will be submitted for publication to the peer-reviewed Elsevier journal Environmental Technology and Innovation. This document has been reformatted to fit within the Carleton University Thesis Template.

Tim Patterson originally came up with the study concept and carried out the sample collection with Helen Roe during field work in August 2016. I was responsible for implementation of the study. I performed all laboratory and statistical analyses. I drafted the manuscript along with the supporting figures and tables. All co-authors provided assistance and/or feedback throughout the project.

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1 Introduction

Arcellinida (testate lobose amoebae) are benthic protozoans that are abundant in most freshwater to brackish water sediments (Charman et al., 2000; Patterson and Kumar, 2002). The tests (shells) are preserved in Quaternary lake deposits and can be found throughout the fossil record into the Neoproterozoic (Medioli and Scott, 1983; Medioli et al., 1990ab; Porter and Knoll, 2000). The beret- or sac-like-shaped tests range in size from 30 to 300 μm and can either comprise agglutinated grains from the substrate (xenogenous) or secreted by the organism (autogenous; Patterson and Kumar, 2002).

During the past few decades, Arcellinida have become valuable bioindicators of ecosystem health, water quality, and seasonal and land-use change (e.g., urbanization, agriculture, forestry, and mining; e.g., Asioli et al., 1996; Dalby et al., 2000; Farooqui et al., 2011; Nasser et al., 2016; Neville et al., 2010; Patterson et al., 1996; Patterson et al., 2013; Patterson and Kumar, 2000ab; Reinhardt et al., 1998; Roe and Patterson, 2006; Roe et al., 2010; Medioli and Scott, 1983). The growing interest in Arcellinida has mainly been linked to their high abundance in organic-rich lake sediments, their rapid reproduction time (days to weeks), the durability of their tests, and their sensitivity to environmental change (Patterson and Kumar, 2002). Compared to other groups of microfossils (e.g., diatoms), Arcellinida within lake samples are taxonomically easy to identify since there are relatively few species in a given sample set (typically only ~ 30 species; Appendix A). However, micropaleontological analysis of each arcellinidan sample still often requires several hours (average estimation of nine hours per sample). The most commonly used methods of Arcellinida analysis require labor intensive sample preparation (isolating tests through wet sieving, and splitting samples into smaller

aliquots) followed by manual identification and quantification of Arcellinida in a petri dish under a microscope (Patterson and Kumar, 2002). For each sample, a statistically significant number of specimens must then be counted. The number of specimens counted per sample depends on the diversity of species observed but is typically ~ 150-200 specimens (Patterson and Fishbein, 1989). The process can take several weeks to months depending on the total number of samples to be analyzed, so the time required for quantification of specimens in each sample is often the limiting factor with regards to the scale of lacustrine studies undertaken. In order to maximize the potential of Arcellinida as useful and cost effective bioindicators of environmental change in lakes, the development of methods that allow for more rapid identification and enumeration of Arcellinida is desirable.

Recently, instruments that combine flow cytometry, imaging, and particle recognition software have been deployed to rapidly analyze many groups of bioindicators (e.g., diatoms, foraminifera, various algae; Black et al., 2019; Jyothibabu et al., 2018; Patil and Anil, 2019), but these methods have not yet been applied to quantitative Arcellinida research. One such instrument, the Flow Cytometer and Microscope (FlowCam®; FC), is equipped with VisualSpreadsheet® (VS) software that is designed to detect, image, enumerate, and characterize microscopic (30 – 300 µm) particles in a fluid stream (Fluid Imaging Technologies, Inc.; Sieracki et al., 1998). Here, FCVS technology is assessed as a potential tool for more rapidly detecting, imaging, characterizing, and classifying Arcellinida assemblages within lake sediment-water interface samples. The specific objective of this study is to evaluate the utility of the FCVS in Arcellinida analysis by determining; (1) whether the FCVS-derived arcellinidan assemblages distinguish the

same environmental variability as derived using conventional microscopy-obtained assemblages; and (2) whether or not the instrument can be used to reduce Arcellinida analysis time. If both of these objectives can be met there is considerable potential for use of the FCVS as a valuable tool to permit significantly larger arcellinidan sample datasets be analyzed, permitting for higher quality, cost effective and higher resolution projects to be carried out.

The FC instrument works by pumping fluid from a sample reservoir through thin plastic tubing into a flow cell composed of a glass chamber where particles are detected and imaged by the camera (Seiracki et al., 1998; Appendix B). The VS software stores the images and characterizes each particle by morphological, gray-scale, colour, and spectral measurements. The software allows FCVS operators to create libraries of images that are most representative of target particles, and these libraries can then be used to create filters that select for target particles in subsequent sample runs. During post-processing, the filters sort particles that are characteristically similar to those in the libraries into separate classes. As more images are collected the more refined the libraries can become. The FCVS can characterize, sort, and count thousands of particles in a short amount of time (Seiracki et al., 1998).

Using the FCVS to analyze Arcellinida presents some challenges. The FCVS was originally designed for aqueous applications (Seiracki et al., 1998) although it was subsequently adapted to study particles within sediment samples (D'Anjou et al., 2014; Kitahashi et al., 2018; Magonono et al., 2018; Mani et al., 2019). Sediment-water interface samples, such as those examined for Arcellinida, often contain high amounts of organic and minerogenic matter. The presence of this detritus means that arcellinidan

samples generally require additional preparation to prevent blockage of the instrument's narrow tubing by these particles. Sample dilution alone is not an efficient option, since this would significantly increase the length of time required for the instrument's sample processing. Conventional organic digestion methods are also not generally suitable as Arcellinida tests are easily damaged (Patterson and Kumar, 2002). Recent research has demonstrated that preparation methods involving chemical deflocculation have been determined to be most effective for preparing arcellinidan samples for FCVS analysis (Nasser et al., 2019).

Another major challenge arises from the limited ability of the FCVS to distinguish between specimens at lower taxonomic levels (genus and species; Álvarez et al., 2014; Buskey and Hyatt, 2006; Camoying and Yñiguez, 2016; Kitahashi et al., 2018).

Arcellinidan generally have a simple morphology and are typically globular, elongate, or compressed in shape. Past studies and recent molecular phylogenetic analysis indicate that Arcellinida test morphology is closely associated with environmental habitat (Bobrov et al., 1999; Lansac-Tôha et al., 2014; Mazei and Warren, 2012; Macumber et al., in review) and it has been suggested that variations in morphology alone can be sufficient for characterizing environmentally distinct arcellinidan assemblages. This morpho-group concept of classifying Arcellinida tests was investigated in this study. To this end the FCVS was used to reanalyze samples studied in Steele et al. (2018), recently published research carried out using conventional microscopy.

2 Methods

2.1 Microscope Analysis of Arcellinida

2.1.1 *Sample Collection*

Forty-six sediment-water interface samples (upper 3 mm of sediment) were collected from Wightman Cove, Oromocto Lake, Harvey Station (Tweedside), York County, New Brunswick, Canada on August 3, 2016 (Figure 1). A detailed description of the study area and field work methods are presented in Steele et al. (2018). Samples were collected from three quadrats within Wightman Cove that varied in substrate composition. Quadrat 1 (Q1; 45.641127° N, – 66.999987° W) was the shallowest sampling location (3 m) and was characterized by the highest abundance of lake bottom vegetation (~92% of substrate covered). Quadrat 2 (Q2; 45.641914° N, – 66.997589° W) was located in the central part of the basin at a water depth of 5 m, with ~ 66% vegetation cover. Quadrat 3 (Q3; 45.642866° N, – 66.994968° W) was located in the eastern part of the basin, 300 m south of Dead Brook (a slow-moving inlet stream). Q3 was the deepest sampling location (6 m) and was characterized by an unvegetated muddy substrate (<5% vegetation cover; Figure 2).

Figure 1. Map of the study area **a.** within New Brunswick, Canada, **b.** the location of Wightman Cove, Lake Oromocto, New Brunswick, Canada; and **c.** the sample locations of Quadrats 1, 2, and 3 (modified from Steele et al., 2018).

Figure 2. Photographs of underwater operations during sample collection from the three quadrats in Wightman Cove, Oromocto Lake, New Brunswick, Canada; **a.** sampling of Quadrat 1 using SCUBA gear within high vegetation cover; **b.** more sparsely distributed vegetation in Quadrat 2; and **c.** the muddy, non-vegetated substrate at Quadrat 3. Sixteen samples from each Quadrat were collected, with one sample lost from each of Quadrat 2 and 3 (46 samples total) (modified from Steele et al., 2018).

2.1.2 Species-level Arcellinida Analysis

Sample preparation, conventional microscopy methods and analytical results obtained from aliquots of samples re-analyzed in this study for comparison to the FCVS results are reported in Steele et al. (2018). Arcellinida species and informal strains were identified and quantified using reference to well-illustrated papers and keys that follow the same species/strain identification (Kumar and Dalby, 1998; Nasser et al., 2016; Patterson et al., 2012; Patterson et al., 2013; Patterson et al., 2015; Patterson and Kumar, 2000ab; Patterson and Kumar, 2002; Reinhardt et al., 1998; Roe et al., 2010; Roe and Patterson, 2014).

2.2 FlowCam VisualSpreadsheet® Analysis of Arcellinida

2.2.1 Modified Sample Preparation

Arcellinida-bearing samples typically contain high amounts of sediment and organic matter that can block the flow cell and/or prevent clear images of tests from being captured (Kitahashi et al., 2018). To resolve this issue without damaging tests through harsh digestion methods and without having to increase analysis time through sample dilution, a modified sample preparation protocol was developed (Nasser et al., 2019) and implemented in this study. This protocol uses low concentration (5%) potassium hydroxide (KOH), a chemical deflocculant, to disaggregate and remove a portion of organic and minerogenic colloidal matter without severely damaging Arcellinida (Nasser et al., 2019).

Prior to FCVS analysis, the six aliquots of each subsample were treated with 5% KOH for one hour. Aliquots were then wet sieved through a 297- μ m mesh (for thirty

seconds) and a 37- μ m mesh (for two minutes) to remove the KOH and any remaining coarse or fine debris. Each aliquot was diluted to 15 ml with distilled water prior to analysis. Even after treatment there was still a relatively high proportion of debris in most samples. Therefore, samples had to be kept in suspension within the sample reservoir, and the high number of debris particles imaged by the instrument increased the overall number of particles to be classified. A combination of chemical treatment and sample dilution limited the number of particles within the flow cell, causing fewer particles to overlap; thus, tests were relatively clearly imaged and identified to the morphological level.

2.2.2 A Morpho-group Approach

Using extra sediment-water interface samples from the Oromocto Lake sample dataset, several trial runs were completed to determine the FlowCam's image quality and the taxonomic level of Arcellinida that the instrument was able to detect. As a result of the preliminary trials, a classification concept modified from Mazei and Warren's morphological groups of difflugiids (2012, 2014, and 2015) was implemented in this study, which included six morpho-groups easily identifiable from the FCVS images (Figure 3): (1) compressed with irregular shape; (2) spherical or ovoid; (3) pyriform; (4) elongate; (5) horned (aborally spined) and (6) collared (urceolate, lobed, or toothed). The species-level microscope data previously obtained from the 46 sediment-water interface samples was reclassified into these six morpho-groups, and relative abundances of each morpho-group were tallied (Appendix C).

Figure 3. FlowCam VisualSpreadsheet® derived images of Arcellinida showing the six morpho-groups used for classification: **a.** compressed irregular, **b.** spherical, **c.** pyriform, **d.** linear, **e.** horned, and **f.** collared.

2.2.3 FlowCam Sample Processing

Arcellinida analysis was carried out on each of the six aliquots of all 46 sediment-water interface samples by the FCVS on Auto Image Mode at 4X magnification with a FC300 (300 μm deep) flow cell. At the beginning of each day of operation, the microscope was manually focused using extra sediment-water interface samples from the dataset. Prior to each sample run, the instrument was flushed and primed with distilled water. Each 15-ml aliquot was processed at a flow rate of 1.7 ml/min and imaged at a constant rate of 20 frames per second (the suggested settings for the particle and sample size used). To minimize blockage to the flow cell, samples were kept in suspension within the sample holder using a stir rod. For most samples, adequately clear images of tests were captured by the FCVS, including at least five target images that could be selected for each library. When running the automated classification, however, the software was not able to reliably distinguish Arcellinida from debris particles, even at the morphological level. Any identified tests had to be manually moved to the correct class.

2.2.4 Post Processing with VisualSpreadsheet®

Within the Library window of VS, 49 operator-created libraries were chosen by selecting images that captured most types, sizes, and orientations of particles (including organic and minerogenic debris, pollen, diatoms, and Arcellinida). Statistical filters were then generated by the software from the library images, and several operator-defined value filters were created to help ensure accurate sorting of particles. A classification template called 'Arcellinida' was created within the VS Classification Window. The template included 15 classes containing the previously generated statistical and value

filters. Six classes containing no filters were added to the template, corresponding to the six morphological groups used in this study.

Six aliquots of each of the 46 sediment-water interface samples were processed using the 'Arcellinida' template. For each aliquot, particles were automatically sorted into the first 15 classes by the software, and any identified tests were manually moved by the operator into one of the six classes corresponding to morphology (Figure 3). In this manner, Arcellinida were identified to a morphological level and quantified until a statistically significant number of tests (>150 per sample) was reached (Patterson and Fishbein, 1989). The FlowCam data was exported into an Excel Spreadsheet, and relative abundances were recorded (Appendix D).

2.3 Statistical Methods

Statistical analyses were carried out on the two microscope datasets and the FlowCam dataset using RStudio (version 1.1.463). Q-mode cluster analysis was performed on the three datasets separately, using Ward's Minimum Variance method (Ward, 1963) to group samples containing similar arcellinidan assemblage compositions (after Fishbein and Patterson, 1993). The PVClust package was used to determine the statistical significance of the identified assemblages (Figure 4). A Bray-Curtis dissimilarity index matrix (BCDM; Bray and Curtis, 1957) was generated using the two morphology-level datasets to assess the level of similarity between and within the relative abundances obtained through microscopy and through FlowCam (Table 1, Appendix E).

2.4 Analysis Time Comparison: Microscope vs FlowCam

To determine whether FCVS analysis was able to reduce Arcellinida analysis time, each step of preparation and analysis using conventional microscopy and FCVS was

recorded to generate an estimated average duration time per sample (Table 2). The average times were estimated based on the amount of time it would take an experienced individual to complete each step of Arcellinida analysis on samples containing average sizes and concentrations of tests and debris. The average times excluded consideration for the creation of FCVS libraries, filters, and the classification template, since they can all be saved, quickly modified, and reused on future sample sets.

3 Results

3.1 Cluster Analysis

3.1.1 Identified Arcellinida Assemblages

The Q-mode PVClust cluster analysis of the 28 Arcellinida species recognized within the 46 sediment-water interface samples (Steele et al., 2018) identified two distinct assemblages: Assemblage 1 (A1; Approximately Unbiased (AU) p -value = 0.97) and Assemblage 2 (A2; AU p -value = 0.98) (Figure 4a). Within A2, sub-assemblages A2a and A2b were identified at a lower level of significance (AU p -values = 0.00 and 0.61). The identified assemblage and sub-assemblages corresponded well with the three sampling locations including Q1 (A1), Q2 (A2a), and Q3 (A2b), with the exception of four outliers: Q1A2, Q1A3 and Q3A4 clustered with Q2 samples in A2a, and Q2A4 with Q3 samples in A2b (Figure 4a).

The PVClust cluster analysis results from the morphology-level microscope dataset showed two statistically significant assemblages (Figure 4b): Microscope Assemblage 1 (MA1; AU p -value = 0.99) and Microscope Assemblage 2 (MA2; AU p -value = 0.98). MA2 was further divided into two statistically less significant groups that were

recognized as sub-assemblages: MA2a and MA2b (AU p -values = 0.88 and 0.57, respectively). MA1, MA2a, and MA2b roughly correspond to the three sampling locations Q1 (MA2b), Q2 (MA2a), and Q3 (MA1) (Figure 4b). Eight outliers (samples Q1A3, Q2A4, Q2C1, Q2D3, Q2D4, Q2A3, Q2C2, and Q2C3) clustered with Q3 samples in MA1, while three outliers (samples Q1B3, Q1B4, and Q1A2) grouped with Q2 samples in MA2a (Figure 4b).

The FlowCam dataset was clustered into two distinct assemblages at a high statistical significance (AU p -value = 0.99): FlowCam Assemblage 1 (FA1) and FlowCam Assemblage 2 (FA2) (Figure 4c). At a slightly lower significance level, FA2 could be further divided into three sub-clusters: FA2a, FA2b, and FA2c (AU p -values = 0.92, 1.00, and 0.93, respectively). In this case, samples within FA1 corresponded to the sampling location Q3, with those within FA2b corresponding with Q2, and samples grouped in FA2a and FA2c corresponding with Q1. There were 8 outliers observed: Q2B1, Q2C4, Q2D3, Q1A2, Q2D1 clustered with Q3 samples in FA1; Q1D1 and Q3C4 grouped with Q2 samples in FA2b; and Q2A1 clustered with Q1 samples in FA2c (Figure 4c).

Figure 4. PVClust cluster analysis dendrogram for the 42 sediment-water interface samples analyzed through **a.** microscopy at the species level in Steele et al. (2018), **b.** microscopy at the morphological level, and **c.** FlowCam at the morphological level. For each analysis, major arcellinidan assemblages/sub-assemblages are indicated as well as assemblage compositions within each Quadrat.

3.1.2 Faunal Structure of Assemblages

Within the conventional microscope-derived dataset, the relative abundances of morphologies showed highly similar faunal structure between assemblages associated with Q3 and Q2 samples: MA1 was co-dominated by pyriform (33%) and spherical morphologies (29%), followed by compressed irregular (14%), horned (11%), linear (9%), and collared tests (4%); MA2a had similarly higher proportions of pyriform tests (29%) followed by spherical (24%), compressed irregular (21%), and horned (14%), linear (9%), and collared tests (3%) (Figure 5a). These relative abundances of morphologies are consistent with the fauna observed in Steele et al. (2018). A2b and A2a, the assemblages associated with Q3 and Q2 samples, were dominated by a pyriform species (*Diffflugia oblonga* Ehrenberg 1832 strain “oblonga” at 26% in A2b and 11% in A2a), and spherical species (12% *Diffflugia glans* Penard 1902 strain “glans”, 8% *Lesqeureusia spiralis* (Ehrenberg 1840), and 5% *Cucurbitella tricuspis* (Carter 1856) in A2b; 11% *D. glans* “glans”, and 7% *L. spiralis* in A2a). In both assemblages, a horned species, *Diffflugia elegans* Penard 1890, was observed at relatively high frequency (7%) (Steele et al, 2018).

The microscope-derived morphological assemblage that corresponded to Q1 samples was composed of more evenly distributed morphologies: MA2b was co-dominated by compressed irregular (23%), pyriform (22%), and spherical tests (22%), followed by horned (17%), linear (10%), and collared (6%) (Figure 5a). This relative increase in compressed irregular species and decrease in pyriform species compared to MA1 and MA2a was consistent with the fauna observed in Steele et al. (2018). A1, the assemblage associated with Q1 samples, was dominated by *D. oblonga* “oblonga” (19%), *Diffflugia*

elegans (11%), two compressed irregular strains (9% *Centropyxis aculeata* (Ehrenberg 1832) strain “aculeata” and 6% *Centropyxis constricta* (Ehrenberg 1843) strain “aerophila”), and 7% *D. glans* “glans” (Steele et al, 2018).

All four FCVS-obtained assemblages were similar in their faunal structure. FA1, corresponding with Q3 samples, was dominated by spherical tests (58%), followed by linear (23%), pyriform (13%), horned (4%), compressed irregular (2%), and collared (<1%); FA2b (associated with Q2 samples) had similarly higher proportions of spherical (47%) and linear tests (30%), with lower abundances of pyriform (14%), horned (5%), compressed irregular (4%), and collared tests (<1%) (Figure 5b). The two assemblages found within Q1 samples were highly comparable, with the main difference being the abundance of compressed irregular tests: FA2a was dominated by spherical morphologies (39%), followed by linear (26%), compressed irregular (16%), pyriform (11%), horned (8%), and collared tests (<1%); and FA2c had higher abundances of spherical (39%), linear (33%), and pyriform tests (12%), with lower proportions of horned (9%), compressed irregular (6%), and collared tests (<1%) (Figure 5b).

The faunal assemblage structure identified using conventional microscopy and FCVS were notably different. A higher proportion of pyriform tests were identified through conventional microscopy, while spherical and linear tests were more frequently identified using FCVS. The identification of collared tests (urceolate, lobed, or toothed) using FCVS images was significantly reduced compared to the proportions identified using conventional microscopy (Figure 5).

Figure 5. Relative abundances of morpho-groups in **a.** the microscope-derived assemblages, and **b.** the FlowCam-derived assemblages. Species included in each morphological class are shown in **a**. CCA *Centropyxis aculeata* “aculeata”, CAD *C.a.* “discoides”, CCA *C. constricta* “aerophila”, CCC *C.c.* “connstricta”, CCS *C.c.* “spinosa”, CK *Cyclopyxis khali*, CT *Cucurbitella tricuspis*, DB *Diffflugia bidens*, DGG *D. glans* “glans”, DG *D. globulosa*, LS *Lesqueureusia spiralis*, DOB *D. oblonga* “bryophila”, DOO *D.o.* “oblonga”, DOS *D.o.* “spinosa”, DOT *D.o.* “tenuis”, LV *Lagenodifflugia vas*, PC *Pontigulasia compressa*, DGM *D. glans* “magna”, DGD *D. glans* “distenda”, DOLin *D.o.* “linearis”, DOLan *D.o.* “lanceolata”, DF *D. fragosa*, DPA *D. protaeiformis* “acuminata”, DE *D. elegans*, DA *D. amphora*, MC *Mediolis corona*, DUU *D. urceolata* “urceolata”, DU *D. urens*.

3.2 Bray Curtis Dissimilarity Matrix

The results of the BCDM showed the statistically measurable differences in morphological assemblages within and between the three sampling locations for both the conventional microscopy and FCVS datasets (Appendix E, see Table 1 for median BCDM values compared). Within the conventional microscopy dataset (Table 1a), the samples from Q1 were quite similar to each other (median dissimilarity coefficient = 0.0950), as were the samples within Q2 (median dissimilarity coefficient = 0.0796) and Q3 (median dissimilarity coefficient = 0.0830). The samples from Q1 were more similar to those from Q2 (median dissimilarity coefficient = 0.1313) than samples from Q3 (median dissimilarity coefficient = 0.1887), and samples from Q2 were relatively similar to those from Q3 (median dissimilarity coefficient = 0.1177) (Table 1a). These results support the findings observed using cluster analysis, with a slight overlap of similarity between Q1 and Q2, and between Q2 and Q3 (Figure 4b).

Within the FCVS dataset (Table 1b), the samples within each quadrat were highly similar (Q1 median dissimilarity coefficient = 0.1009, Q2 median dissimilarity coefficient = 0.0859, and Q3 median dissimilarity coefficient = 0.0652). The BCDM results showed that differences in relative abundances in Q1 and Q3 samples were more notable (median dissimilarity coefficient = 0.2108) than when comparing Q1 and Q2 samples (0.1557) or Q2 and Q3 (0.1114) (Table 1b). These results are consistent with the results of conventional microscopy cluster analysis, which showed the greatest difference between Q1 and Q3 samples (Figure 4c). Although Q1 clustered into two sub-assemblages (FA2a and FA2c; Figure 4c), the BCDM showed that relative abundances in

Q1 samples were highly similar, indicating that FA2a and FA2c could be considered a single sub-assemblage.

When comparing the relative abundances obtained from the conventional microscopy and the FCVS (Table 1c), the differences between Q1 samples were notable (median dissimilarity coefficient = 0.386), and the differences in relative abundances between Q2 and Q3 were both quite significant (median dissimilarity coefficients = 0.440 and 0.406, respectively). These results support the difference in abundances of morpho-groups observed between conventional microscopy and FCVS methods when comparing the faunal assemblage makeup.

Table 1. Median Quadrat Bray-Curtis Dissimilarity Matrix values for morpho-group relative abundances from the:

a. Microscope-obtained dataset			
	Q1 – M	Q2 – M	Q3 – M
Q1 – M	0.0950	0.1313	0.1887
Q2 – M	-	0.0796	0.1177
Q3 – M	-	-	0.0830
b. FlowCam-obtained dataset			
	Q1 – FC	Q2 – FC	Q3 – FC
Q1 – FC	0.1009	0.1557	0.2108
Q2 – FC	-	0.0859	0.1114
Q3 – FC	-	-	0.0652
c. Microscope- and FlowCam- obtained datasets			
	Q1 – FC	Q2 – FC	Q3 – FC
Q1 – M	0.3719	-	-
Q2 – M	-	0.4410	-
Q3 – M	-	-	0.4024

3.3 Analysis Time Comparison: Microscope vs FlowCam

The Arcellinida analysis times required using conventional microscopy and the FCVS were compared (Table 2). It was estimated that sample preparation for microscopy (including subsampling, wet splitting, and sieving methods) took 1 hour and 3 minutes per sample, while sample preparation for the FCVS took an additional hour for chemical deflocculation (2 hours 3 minutes total). The FCVS protocol required 48 minutes to process each sample, including all 6 aliquots at an average run time of 8 minutes per aliquot. In order to identify and quantify >150 tests per sample, an average of 4 aliquots was required to be analyzed for microscopy and 2 aliquots using FCVS. This process was estimated to take 8 hours per sample (120 minutes per aliquot) for microscopy and 2 hours per sample (60 minutes per aliquot) for post-processing FCVS data. In total, it would take 9 hours and 3 minutes for conventional microscopic Arcellinida analysis of a single sample, and 4 hours and 51 minutes for FCVS analysis (Table 2).

Table 2. Comparison of microscope and FlowCam VisualSpreadsheet® Arcellinida analysis time per sample.

	Microscope	FlowCam
Subsampling (3 cc)	1 min	1 min
Splitting (into 6 aliquots)	1 hr	1 hr
Chemical deflocculation	-	1 hr
Sieving	2 min	2 min
FlowCam processing 6 aliquots x ~8 min/aliquot	-	48 min
Test ID/Quantification Microscope: ~4 aliquots, 120 min/aliquot FlowCam: ~2 aliquots, 60 min/aliquot	8 hr	2 hr
Total analysis time per sample	9 hr 3 min	4 hr 51 min

4 Discussion

4.1 Method Modifications

One of the major challenges to FCVS analysis of lacustrine Arcellinida relates to the organic-rich nature of the sediment-water interface samples. Running samples that have been processed using standard preparation methods (sieving and splitting only) is not possible because the sediment built up within the narrow FC tubing. Kitahashi et al. (2018) also acknowledged this difficulty with the instrument when running marine sediment samples. To solve this problem, they used a high-density solution instead of water. Here, this issue was mitigated by treating samples with a chemical deflocculant, 5% KOH. Removing a portion of organic and minerogenic colloidal matter considerably reduced the frequency of sediment build-up and reduced the amount of debris particles imaged. The treatment did not seem to cause severe damage to Arcellinida tests, as there were no observable differences in the number of broken tests compared to the previous microscopic analysis. The additional sample preparation protocols employed in this study using the recommended approach of Nasser et al. (2019) greatly improved the utility of the FCVS for processing organic-rich sediment samples.

The FCVS low image resolution and limited ability to resolve taxonomic units to no lower than genus level has been acknowledged in several recent studies (Álvarez et al., 2014; Buskey and Hyatt, 2006; Camoying and Yñiguez, 2016; Kitahashi et al., 2018). Some FlowCam users have attempted to optimize the FCVS hardware and software settings to obtain higher resolution images (Camoying and Yñiguez, 2016), while other researchers suggest re-examining samples under a microscope when encountering specimens that are difficult to identify from FCVS images (Buskey and Hyatt, 2006,

Kitahashi et al., 2018). It has been observed that in most cases though, classifying FCVS imaged taxa into “functional classes” of higher taxonomic groupings or “shape classes” based on morphology is often sufficient for most ecological studies (Álvarez et al., 2014). Following this approach, Arcellinida were identified at the morphological level in this study. This method of Arcellinida classification was determined to be reliable when reclassifying conventional microscope-obtained species-level results (Steele et al., 2018) into a morphology-level dataset.

The species-level microscopy results from Steele et al. (2018) clustered into three assemblages (A1, A2a, and A2b), which reflected the three different ecological environments within Wightman Cove, Oromocto Lake. In that previous study, the high diversity of A1 corresponded with the shallow, densely vegetated location of Q1; the lower diversity of A2b was related to the deeper, non-vegetated site of Q3 and its close proximity to runoff from Dead Brook; and A2a was characteristically similar to A1 and A2b, reflecting the mid-basin environment of Q2 between Q1 and Q3 (Figures 2 and 4a; Steele et al., 2018). When reclassifying the microscope-obtained data into six major morpho-groups, statistical analyses recognized the same distinct variation in assemblages between samples from Q1 and Q3, and a significant similarity of Q2 samples with the assemblages from Q1 and Q3 (Figure 4b, Table 1). These results suggest that the species level arcellinidan assemblages resulting from slight substrate differences between the three sampling locations were also observed at the morphological level. This indicates that the morphology-level conventional microscope dataset was reliable and could be used as an alternative taxonomic database for evaluation of the FCVS-obtained results.

4.2 FlowCam Arcellinidan Assemblage Variability

The PVClust cluster analysis results of the FCVS-obtained dataset showed that Q1 was characterized by two distinct sub-assemblages (FA2a and FA2c; Figure 4c). This slight division between Q1 samples can be observed in the faunal structures where FA2a contains a higher abundance of compressed irregular tests than FA2c (16% and 6%, respectively). The low mean dissimilarity coefficient (0.1009) derived from the BCDM, however, indicated that the two sub-clusters could be considered one sub-assemblage (Table 1).

Other than the division within Q1 samples, the cluster results from the FCVS dataset were nearly identical to those obtained through microscopy. Although the assemblages from both methods corresponded well to sample location, the faunal structures between the two methods differed considerably (Figure 5). This difference in relative abundances between sample methods was supported by the BCDM results. The FCVS method more frequently identified spherical and linear morphologies compared to conventional microscopy; and although collared tests were rarely counted during microscopy (3-6%), their identification was extremely rare during FCVS analysis (<1%). This considerable difference in relative abundances of morpho-groups between the two methods could be attributed to image resolution and specimen orientation with the FCVS. Certain morphologies (e.g. spherical) may be more distinguishable from debris particles and therefore more easily recorded from FCVS images. Many Arcellinida, especially within the collared morpho-group, have distinguishing characteristics that can be hidden by certain orientations. Since FCVS does not allow for manual manipulation of tests orientation (as in conventional microscopy), this could explain why certain groups were

recorded less frequently during FCVS analysis. The assemblage results from both methods should still be valid, since in both cases a statistically significant number of tests were counted.

The overall comparison of Arcellinida analysis results suggest that both conventional microscopy and the FCVS methods distinguish the same variation in morphological assemblages. It is likely that these assemblage patterns are both a result of the slight differences in sampling environment; therefore, the results support the use of FCVS as an effective tool for analyzing Arcellinida at the morphological level.

4.3 FlowCam VisualSpreadsheet® Arcellinida Analysis Time

In addition to testing whether or not variations in arcellinidan assemblages could be accurately detected from FCVS-obtained data, it was important to know whether the instrument was able to reduce analytical time. After comparing the time it would take an experienced operator to perform each step of Arcellinida analysis (including sample preparation and the identification and quantification of specimens) using either conventional microscopy or the FCVS, it was determined that, despite having to carry out sample deflocculation, the FCVS was able to reduce analysis time by roughly 45% (Table 2). This represents a significant time saving, particularly for projects where there are a large number of samples.

There can be a significant difference between sediment samples with regard to the organic and minerogenic content, as well as the total concentration and size of contained Arcellinida specimens. These factors can affect overall analysis time, though both conventional microscopic and FCVS methods would be equally affected. It is also possible that identification and quantification times required for Arcellinida analysis

using conventional microscopic approaches might be reduced if disaggregation methods were applied during standard sample preparation (Nasser et al., 2019). However, it is likely that the FCVS approach would still significantly reduce required overall analytical time.

4.4 Limitations and Evaluation of FlowCam VisualSpreadsheet®

The initial objective of this study was to assess the possibility of replacing conventional microscopic methods of species-level identification and quantification of Arcellinida with a more rapid FCVS-based method. These results show that, due to the relatively low image resolution, the inability to manipulate test orientation during analysis, and the morphological similarity of many Arcellinida species tests to debris particles, species-level identification of Arcellinida was not possible using FCVS. On the other hand, the six morphological groups used in this study, based on Mazei and Warren's morphological groups of difflugiids (2012, 2014, and 2015), were relatively easily identified from the imaged particles (Figure 3). Since the assemblages obtained through FCVS were comparable to morpho-groups distinguished through microscopy, the results reported here support the use of a morphological classification scheme for paleoecological research. Although the software could not automatically distinguish between tests and debris particles, the software's classification resulted in categories of characteristically similar particle images for more efficient manual identification and enumeration of tests.

In addition to poor image (and therefore taxonomic) resolution and the software's inability to 'identify' specific Arcellinida taxa, another limitation of the instrument and software was the significant learning curve associated with becoming proficient with the

instrument (e.g., determining optimal instrument settings and input parameters for the creation of libraries, filters, and classification templates, etc.). Another drawback was specimen loss during analysis, as the nearly destructive nature of the method meant it was difficult to ensure full recovery of samples. Furthermore, any remarkable specimens observed during FCVS analysis cannot be easily retrieved by the user for more detailed examination.

Arcellinida analysis using the FCVS was only possible when carried out semi-manually at the morphological level, but the FCVS-obtained assemblages did reflect substrate variation in the same manner as the conventional microscopy-obtained results (Figure 4). It was determined that the FlowCam can reduce Arcellinida analysis time by a significant amount (Table 2), once the learning curve associated with the instrument and software is overcome. This study indicates that the FCVS has potential as a method for more rapid analysis of Arcellinida but cannot fully replace conventional microscopic methods where identification of specific taxa is required. The FCVS is potentially a more useful method for analyzing large numbers of samples and will provide coarser taxonomic resolution assemblage results. The more labour- and time-intensive microscopic methods may be a better option for analyzing smaller data sets and will provide species-level assemblage results.

5 Conclusions

This study was designed to determine if the results obtained when evaluating samples for their arcellinidan assemblage makeup using a FCVS would be comparable to those obtained using conventional microscopy. The dataset employed was comprised of 46 samples from three quadrats (stations) in Wightman Cove, Oromocto Lake, New

Brunswick, Canada, and had previously been analyzed using conventional microscopy (Steele et al., 2018). It was determined that FCVS could provide a 45% saving in analytical time despite having to employ an additional preparation technique whereby samples had to be left for three hours in a 5% KOH solution to deflocculate organic debris, which tends to clog the flow cell in the FCVS. The FCVS was inferior to conventional microscopy in that the lower resolution microscope in the instrument made it difficult for it to resolve specimens to the species or strain level. However, when a morpho-group approach to taxonomic division was employed, for both FCVS and conventional microscopy, very similar results were obtained. As a morpho-group approach to taxonomy has been demonstrated to be nearly as useful in identifying ecologically significant lacustrine environments as assemblages derived using a species/strain approach, the FCVS shows considerable promise as a tool for quantifying Arcellinida, particularly for studies comprised of large numbers of samples.

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Appendices

Appendix A

Supplementary Table 1. Summary of Arcellinida taxa reported in twelve recent studies (species/strains, lake(s) location indicated).

	Nasser et al, 2019 Lac du Castor Blanc/Oromocto Lake, Canada	Steele et al, 2018 Oromocto Lake, Canada	Sigala et al, 2016 29 tropical lakes, central Mexico	Qin et al, 2016 37 lakes, Yangtze, China	Nasser et al, 2016 59 lakes, NT, Canada	Patterson et al, 2015 Lake Quistococha, Peru	Camacho et al, 2015 Guardiana Estuary, Portugal	Caffau et al, 2015 Lago Fagnano, Argentina	Drijepan et al, 2014 Sluice Pond, MA, USA	Sonneburg et al, 2013 Rice Lake, ON, Canada	Qin et al, 2013 Lake Donghu, Wuhan, China	Patterson et al, 2013 James and Granite Lake, ON, Canada
Arcella arenaria							•					
Arcella conica			•									•
Arcella dentata			•									
Arcella discoides			•	•								
Arcella gibbosa			•									
Arcella hemisphaerica												•
Arcella megastoma			•									
Arcella vulgaris	•		•		•	•			•	•		•
Arcella sp.							•					
Argygnnia triangulata			•									
Bullinularia indica							•			•		
Centropyxis aculeata 'aculeata'	•	•	•	•	•	•	•		•	•	•	•
Centropyxis aculeata 'discoides'	•	•	•		•	•						•
Centropyxis arcuata							•					
Centropyxis cassis				•							•	
Centropyxis constricta 'aerophila'	•	•	•		•				•	•		•
Centropyxis constricta 'constricta'	•	•	•		•		•	•	•	•		•
Centropyxis constricta 'spinosa'	•	•	•		•	•						•
Centropyxis deflandrei			•									
Centropyxis ecomis			•	•		•					•	
Centropyxis elongata								•				

Appendix A (cont.)

Supplementary Table 1. (cont.)

	Nasser et al, 2019 Lac du Castor Blanc/Oromocto Lake, Canada	Steele et al, 2018 Oromocto Lake, Canada	Sigala et al, 2016 29 tropical lakes, central Mexico	Qin et al, 2016 37 lakes, Yangtze, China	Nasser et al, 2016 59 lakes, NT, Canada	Patterson et al, 2015 Lake Quistococha, Peru	Camacho et al, 2015 Guardiana Estuary, Portugal	Caffau et al, 2015 Lago Fagnano, Argentina	Drijiepan et al, 2014 Sluice Pond, MA, USA	Sonneburg et al, 2013 Rice Lake, ON, Canada	Qin et al, 2013 Lake Donghu, Wuhan, China	Patterson et al, 2013 James and Granite Lake, ON, Canada
<i>Centropxyxis orbicularis</i>							•					
<i>Centropxyxis platystoma</i>				•								
<i>Codonella cratera</i>									•			
<i>Conicocassis pontigulasiformis</i>					•							
<i>Cucurbitella tricuspis</i>	•	•	•	•	•				•	•		•
<i>Cyclopyxis aplanata</i>											•	
<i>Cyclopyxis kahli</i>	•	•	•					•				•
<i>Cylcopyxis</i> sp.							•					
<i>Cyphoderia ampulla</i>			•									
<i>Diffflugia acuminata</i> 'immanata'	•											
<i>Diffflugia acutissima</i>				•							•	
<i>Diffflugia amphora/amphoralis</i>		•		•								
<i>Diffflugia bicornis</i>	•			•								
<i>Diffflugia bidens</i>	•	•	•				•					
<i>Diffflugia biwae</i>				•								
<i>Diffflugia curvicaulis</i>	•				•							
<i>Diffflugia difficilis</i>						•						
<i>Diffflugia distenda</i>			•									
<i>Diffflugia elegans</i>	•	•		•	•						•	
<i>Diffflugia fragosa</i>		•	•							•		
<i>Diffflugia glans</i> 'distenda'	•	•										•
<i>Diffflugia glans</i> 'glans'	•	•	•		•			•			•	•
<i>Diffflugia glans</i> 'magna'	•	•										•
<i>Diffflugia globulosa/globulus</i>		•						•		•	•	
<i>Diffflugia gramen</i>			•									

Appendix A (cont.)

Supplementary Table 1. (cont.)

	Nasser et al, 2019 Lac du Castor Blanc/Oromocto Lake, Canada	Steele et al, 2018 Oromocto Lake, Canada	Sigala et al, 2016 29 tropical lakes, central Mexico	Qin et al, 2016 37 lakes, Yangtze, China	Nasser et al, 2016 59 lakes, NT, Canada	Patterson et al, 2015 Lake Quistococha, Peru	Camacho et al, 2015 Guardiana Estuary, Portugal	Caffau et al, 2015 Lago Fagnano, Argentina	Drijiepan et al, 2014 Sluice Pond, MA, USA	Sonneburg et al, 2013 Rice Lake, ON, Canada	Qin et al, 2013 Lake Donghu, Wuhan, China	Patterson et al, 2013 James and Granite Lake, ON, Canada
<i>Diffugia labiosa</i>			•								•	
<i>Diffugia lacustris</i>											•	
<i>Diffugia lithophila</i>											•	
<i>Diffugia lobostoma</i>											•	
<i>Diffugia longum</i>											•	
<i>Diffugia mammillaris</i>				•								
<i>Diffugia oblonga</i> 'bryophila'	•	•	•									
<i>Diffugia oblonga</i> 'lanceolata'	•	•	•	•	•						•	•
<i>Diffugia oblonga</i> 'linearis'	•	•	•					•				
<i>Diffugia oblonga</i> 'oblonga'	•	•	•	•	•		•	•	•	•	•	•
<i>Diffugia oblonga</i> 'spinosa'	•	•	•		•							•
<i>Diffugia oblonga</i> 'tenuis'	•	•	•		•			•				
<i>Diffugia oblonga</i> 'triangularis'												•
<i>Diffugia protaeiformis</i> 'acuminata'	•	•	•	•	•						•	•
<i>Diffugia protaeiformis</i> 'amphoralis'			•					•		•		•
<i>Diffugia protaeiformis</i> 'basiconella'												•
<i>Diffugia protaeiformis</i> 'claviformis'	•		•		•	•						
<i>Diffugia protaeiformis</i> 'metaturboina'												•
<i>Diffugia protaeiformis</i> 'protaeiformis'	•				•		•		•	•		•
<i>Diffugia protaeiformis</i> 'scalpellum'	•				•	•						
<i>Diffugia pulex</i>				•								
<i>Diffugia smilion</i>				•							•	
<i>Diffugia urceolata</i> 'elongata'	•		•									•
<i>Diffugia urceolata</i> 'lageniformis'								•				
<i>Diffugia urceolata</i> 'urceolata'	•	•	•	•	•		•		•	•	•	•

Appendix A (cont.)

Supplementary Table 1. (cont.)

	Nasser et al, 2019 Lac du Castor Blanc/Oromocto Lake, Canada	Steele et al, 2018 Oromocto Lake, Canada	Sigala et al, 2016 29 tropical lakes, central Mexico	Qin et al, 2016 37 lakes, Yangtze, China	Nasser et al, 2016 59 lakes, NT, Canada	Patterson et al, 2015 Lake Quistococha, Peru	Camacho et al, 2015 Guardiana Estuary, Portugal	Caffau et al, 2015 Lago Fagnano, Argentina	Drijiepan et al, 2014 Sluice Pond, MA, USA	Sonneburg et al, 2013 Rice Lake, ON, Canada	Qin et al, 2013 Lake Donghu, Wuhan, China	Patterson et al, 2013 James and Granite Lake, ON, Canada
<i>Diffugia urens</i>	•	•							•	•		
<i>Diffugia viscidula</i>								•				
<i>Diffugia</i> sp.				•								
<i>Euglypha acanthophora</i>			•									
<i>Euglypha</i> sp.										•		
<i>Heliopera sphagni</i>										•		
<i>Lagenodiffugia vas</i>	•	•			•			•		•		•
<i>Lesquereusia modesta</i>			•	•							•	
<i>Lesquereusia spiralis</i>	•	•	•		•	•			•			•
<i>Lesquereusia</i> sp.							•					
<i>Mediolis corona</i>	•	•	•	•	•	•	•		•		•	•
<i>Nebela collaris</i>										•		•
<i>Nebela penardianna</i>							•					
<i>Pentagonia maroccana</i>			•									
<i>Phryganella nidulus</i>											•	
<i>Phryganella</i> sp.										•		
<i>Pontigulasia compressa</i>	•	•		•	•		•		•		•	•
<i>Pontigulasia elisa</i>											•	
<i>Pontigulasia incisa</i>				•								
<i>Pseudodiffugia fulva</i>			•									
<i>Pyxidicula</i> sp.							•					
<i>Scutiglypha cabrolae</i>			•									
Total Taxon Identified	33	28	41	23	24	10	17	12	13	18	23	29

Appendix B

B1. FlowCam (Benchtop, Series 4) instrument.

B2. FlowCam block diagram (modified from Fluid Imaging Technologies, Inc., 2014).

Appendix C

Supplementary Table 2. Microscope-obtained dataset: relative abundances of six arcellinidan morpho-groups within the 46 sediment-water interface samples.

	Compressed	Spherical	Pyriform	Linear	Horned	Collared
Q1A1-M	28.21	18.23	18.23	9.40	22.22	3.70
Q1A2-M	17.49	23.76	29.37	9.24	15.51	4.62
Q1A3-M	20.87	22.02	34.86	9.40	9.86	2.98
Q1A4-M	28.83	20.72	23.42	8.41	13.81	4.80
Q1B1-M	19.58	21.39	21.39	12.05	20.78	4.82
Q1B2-M	25.65	23.05	22.73	8.12	12.99	7.47
Q1B3-M	24.30	20.56	27.73	8.72	16.20	2.49
Q1B4-M	21.77	24.83	26.87	10.20	11.22	5.10
Q1C1-M	18.46	23.83	25.50	10.40	17.11	4.70
Q1C2-M	26.07	20.79	22.44	6.93	16.50	7.26
Q1C3-M	18.31	27.32	21.13	11.27	13.52	8.45
Q1C4-M	26.89	23.28	21.97	6.89	17.38	3.61
Q1D1-M	18.51	21.79	23.88	12.54	14.63	8.66
Q1D2-M	25.33	21.33	24.33	10.67	13.33	5.00
Q1D3-M	25.80	20.87	21.45	8.12	17.97	5.80
Q1D4-M	17.18	18.87	21.69	10.14	25.35	6.76
Q2A1-M	21.05	23.03	29.28	8.22	15.79	2.63
Q2A2-M	19.40	26.09	29.10	11.37	11.71	2.34
Q2A3-M	14.47	26.69	30.87	8.68	17.04	2.25
Q2A4-M	17.02	22.80	38.91	8.21	10.94	2.13
Q2B1-M	18.27	24.77	30.34	10.53	13.00	3.10
Q2B2-M	20.51	23.40	32.37	5.45	16.35	1.92
Q2B4-M	20.62	25.43	29.21	5.84	14.78	4.12
Q2C1-M	17.21	23.70	33.44	11.04	10.06	4.55
Q2C2-M	20.00	28.84	33.02	6.51	10.70	0.93
Q2C3-M	16.87	27.71	32.53	9.64	11.45	1.81
Q2C4-M	22.92	24.90	27.67	7.11	13.83	3.56
Q2D1-M	17.92	23.11	30.66	9.91	15.57	2.83
Q2D2-M	22.22	21.72	28.79	13.13	10.10	4.04
Q2D3-M	14.42	27.40	39.42	8.65	4.81	5.29
Q2D4-M	12.86	31.43	25.71	9.05	17.62	3.33
Q3A1-M	13.30	29.06	30.05	11.82	11.82	3.94
Q3A2-M	16.82	27.73	28.64	13.18	9.55	4.09
Q3A3-M	13.43	25.87	33.83	15.42	9.45	1.99
Q3A4-M	13.12	28.05	27.60	14.48	11.76	4.98
Q3B1-M	13.37	31.98	29.65	9.30	12.21	3.49
Q3B2-M	9.55	29.15	38.19	10.05	11.06	2.01
Q3B4-M	13.97	30.17	31.28	8.94	11.73	3.91
Q3C1-M	14.58	34.90	29.69	9.38	5.21	6.25
Q3C2-M	10.67	27.53	37.64	10.67	7.87	5.62
Q3C3-M	13.49	29.77	33.49	8.84	9.30	5.12
Q3C4-M	14.97	29.95	36.90	5.88	6.42	5.88
Q3D1-M	11.96	27.17	33.15	8.70	16.85	2.17
Q3D2-M	11.06	34.13	34.13	6.25	10.10	4.33
Q3D3-M	10.64	34.57	35.64	4.79	7.98	6.38
Q3D4-M	17.50	34.38	30.00	5.63	7.50	5.00

Appendix D

Supplementary Table 3. FlowCam dataset: relative abundances of six arcellinidan morpho-groups within the 46 sediment-water interface samples.

	Compressed	Spherical	Pyriform	Linear	Horned	Collared
Q1A1-FC	14.94	43.15	12.03	21.58	8.30	0.00
Q1A2-FC	5.68	60.70	6.99	21.83	4.80	0.00
Q1A3-FC	6.98	39.68	9.52	31.75	12.06	0.00
Q1A4-FC	15.46	35.75	11.11	30.92	6.76	0.00
Q1B1-FC	5.06	42.62	7.17	36.29	8.86	0.00
Q1B2-FC	6.60	40.28	12.15	34.38	6.60	0.00
Q1B3-FC	8.70	40.00	11.30	30.43	9.57	0.00
Q1B4-FC	8.54	36.18	14.57	29.65	11.06	0.00
Q1C1-FC	4.04	37.13	16.91	32.35	9.56	0.00
Q1C2-FC	13.57	42.14	10.00	25.00	8.57	0.71
Q1C3-FC	15.28	38.43	14.41	25.76	5.68	0.44
Q1C4-FC	17.15	37.96	8.76	26.28	9.85	0.00
Q1D1-FC	5.04	49.16	10.92	30.25	4.62	0.00
Q1D2-FC	9.78	45.33	8.89	31.11	4.89	0.00
Q1D3-FC	15.68	39.72	10.45	25.09	8.71	0.35
Q1D4-FC	17.15	36.86	8.76	24.82	12.41	0.00
Q2A1-FC	1.90	33.41	16.82	40.28	7.35	0.24
Q2A2-FC	4.29	41.92	14.39	35.10	4.29	0.00
Q2A3-FC	2.73	48.39	15.88	24.57	8.19	0.25
Q2A4-FC	3.15	48.90	13.56	29.34	5.05	0.00
Q2B1-FC	2.04	55.10	15.99	21.43	5.44	0.00
Q2B2-FC	3.54	48.03	14.57	29.13	4.72	0.00
Q2B4-FC	5.58	44.65	16.28	27.91	5.58	0.00
Q2C1-FC	4.86	51.35	10.27	29.73	3.78	0.00
Q2C2-FC	4.52	43.88	19.02	27.12	5.46	0.00
Q2C3-FC	2.85	43.47	16.39	33.97	3.33	0.00
Q2C4-FC	2.80	56.58	11.48	24.93	4.20	0.00
Q2D1-FC	1.84	60.29	9.56	24.63	3.68	0.00
Q2D2-FC	1.76	49.12	11.84	36.02	1.26	0.00
Q2D3-FC	3.33	57.44	10.77	24.62	3.85	0.00
Q2D4-FC	3.36	52.20	9.30	30.49	4.65	0.00
Q3A1-FC	1.06	59.01	10.60	24.73	4.24	0.35
Q3A2-FC	1.65	64.78	11.82	19.39	2.36	0.00
Q3A3-FC	1.44	60.05	15.55	19.86	3.11	0.00
Q3A4-FC	0.79	54.86	19.42	21.26	3.41	0.26
Q3B1-FC	0.00	51.49	18.15	26.07	4.29	0.00
Q3B2-FC	1.91	62.91	13.52	18.54	3.12	0.00
Q3B4-FC	1.58	59.94	16.72	18.30	3.15	0.32
Q3C1-FC	1.50	56.02	15.41	22.93	3.76	0.38
Q3C2-FC	0.75	60.85	13.97	22.69	1.75	0.00
Q3C3-FC	2.22	53.33	14.44	26.11	3.89	0.00
Q3C4-FC	0.88	47.65	16.76	31.18	3.24	0.29
Q3D1-FC	0.40	59.92	12.96	21.46	5.26	0.00
Q3D2-FC	4.31	55.02	13.40	23.44	3.83	0.00
Q3D3-FC	1.22	60.37	8.23	25.91	3.35	0.91
Q3D4-FC	1.31	52.13	14.75	27.21	4.59	0.00

Appendix E

Supplementary Table 4. Bray-Curtis Dissimilarity Matrix (BCDM). Upper diagonal is shown in sections A through Q, corresponding to location within the matrix.

A	B	C	D	E	F	G	H	I	J	K
					L	M	N	O	P	Q

Section A of BCDM.

	Q1A1-M	Q1A2-M	Q1A3-M	Q1A4-M	Q1B1-M	Q1B2-M	Q1B3-M	Q1B4-M	Q1C1-M
Q1A1-M	0	0.176	0.204	0.094	0.101	0.131	0.118	0.174	0.149
Q1A2-M		0	0.09	0.115	0.104	0.11	0.075	0.068	0.039
Q1A3-M			0	0.137	0.154	0.134	0.098	0.08	0.118
Q1A4-M				0	0.113	0.05	0.07	0.097	0.105
Q1B1-M					0	0.117	0.111	0.114	0.066
Q1B2-M						0	0.088	0.08	0.1
Q1B3-M							0	0.084	0.081
Q1B4-M								0	0.061
Q1C1-M									0

Section B of BCDM.

	Q1C2-M	Q1C3-M	Q1C4-M	Q1D1-M	Q1D2-M	Q1D3-M	Q1D4-M	Q2A1-M	Q2A2-M
Q1A1-M	0.103	0.186	0.088	0.173	0.118	0.08	0.11	0.158	0.207
Q1A2-M	0.122	0.102	0.113	0.084	0.097	0.119	0.129	0.038	0.064
Q1A3-M	0.161	0.163	0.154	0.136	0.112	0.159	0.2	0.071	0.079
Q1A4-M	0.052	0.131	0.061	0.103	0.04	0.053	0.152	0.101	0.14
Q1B1-M	0.1	0.096	0.098	0.072	0.089	0.073	0.068	0.11	0.124
Q1B2-M	0.039	0.089	0.059	0.084	0.045	0.051	0.144	0.095	0.127
Q1B3-M	0.071	0.153	0.076	0.112	0.063	0.069	0.148	0.042	0.095
Q1B4-M	0.117	0.092	0.113	0.093	0.061	0.115	0.158	0.07	0.051
Q1C1-M	0.102	0.081	0.087	0.061	0.074	0.093	0.103	0.064	0.078
Q1C2-M	0	0.121	0.042	0.094	0.062	0.027	0.121	0.104	0.164
Q1C3-M		0	0.133	0.055	0.102	0.123	0.124	0.132	0.092
Q1C4-M			0	0.126	0.075	0.04	0.144	0.086	0.144
Q1D1-M				0	0.073	0.106	0.107	0.103	0.104
Q1D2-M					0	0.059	0.138	0.091	0.102
Q1D3-M						0	0.106	0.101	0.161
Q1D4-M							0	0.156	0.181
Q2A1-M								0	0.062
Q2A2-M									0

Appendix E (cont.)

Section C of Λ CDM.

	Q2A3-M	Q2A4-M	Q2B1-M	Q2B2-M	Q2B4-M	Q2C1-M	Q2C2-M	Q2C3-M	Q2C4-M
Q1A1-M	0.211	0.252	0.198	0.193	0.186	0.232	0.254	0.24	0.161
Q1A2-M	0.06	0.095	0.04	0.069	0.048	0.059	0.112	0.075	0.066
Q1A3-M	0.118	0.059	0.071	0.079	0.095	0.051	0.077	0.075	0.095
Q1A4-M	0.169	0.176	0.131	0.142	0.115	0.156	0.177	0.173	0.085
Q1B1-M	0.148	0.189	0.123	0.139	0.129	0.144	0.195	0.175	0.131
Q1B2-M	0.164	0.163	0.117	0.134	0.107	0.143	0.161	0.16	0.076
Q1B3-M	0.101	0.134	0.092	0.076	0.08	0.132	0.136	0.129	0.054
Q1B4-M	0.117	0.12	0.056	0.106	0.065	0.074	0.102	0.088	0.046
Q1C1-M	0.082	0.134	0.059	0.089	0.075	0.086	0.141	0.109	0.077
Q1C2-M	0.166	0.198	0.155	0.125	0.114	0.18	0.186	0.197	0.095
Q1C3-M	0.133	0.178	0.092	0.163	0.117	0.123	0.151	0.118	0.115
Q1C4-M	0.141	0.183	0.135	0.105	0.099	0.17	0.166	0.177	0.076
Q1D1-M	0.143	0.16	0.094	0.138	0.112	0.115	0.177	0.146	0.113
Q1D2-M	0.156	0.16	0.094	0.131	0.104	0.118	0.162	0.146	0.074
Q1D3-M	0.158	0.195	0.152	0.135	0.123	0.177	0.195	0.194	0.103
Q1D4-M	0.17	0.211	0.16	0.185	0.175	0.175	0.241	0.197	0.178
Q2A1-M	0.07	0.096	0.056	0.04	0.039	0.096	0.096	0.093	0.047
Q2A2-M	0.077	0.098	0.033	0.09	0.062	0.066	0.073	0.05	0.069
Q2A3-M	0	0.106	0.065	0.075	0.08	0.1	0.098	0.06	0.098
Q2A4-M		0	0.086	0.095	0.121	0.063	0.09	0.068	0.123
Q2B1-M			0	0.076	0.058	0.051	0.085	0.051	0.061
Q2B2-M				0	0.047	0.096	0.072	0.087	0.072
Q2B4-M					0	0.099	0.079	0.094	0.036
Q2C1-M						0	0.086	0.054	0.107
Q2C2-M							0	0.048	0.093
Q2C3-M								0	0.102
Q2C4-M									0

Appendix E. (cont.)

Section D of Λ CDM.

	Q2D1-M	Q2D2-M	Q2D3-M	Q2D4-M	Q3A1-M	Q3A2-M	Q3A3-M	Q3A4-M	Q3B1-M
Q1A1-M	0.178	0.181	0.32	0.207	0.253	0.241	0.293	0.256	0.252
Q1A2-M	0.024	0.086	0.144	0.098	0.086	0.079	0.128	0.099	0.086
Q1A3-M	0.073	0.064	0.123	0.175	0.124	0.106	0.099	0.15	0.128
Q1A4-M	0.129	0.111	0.234	0.174	0.184	0.17	0.226	0.178	0.184
Q1B1-M	0.11	0.115	0.245	0.144	0.163	0.147	0.203	0.155	0.189
Q1B2-M	0.124	0.111	0.216	0.169	0.17	0.156	0.212	0.162	0.17
Q1B3-M	0.07	0.082	0.213	0.135	0.154	0.141	0.181	0.157	0.149
Q1B4-M	0.081	0.053	0.153	0.13	0.096	0.076	0.132	0.088	0.109
Q1C1-M	0.052	0.098	0.181	0.083	0.112	0.098	0.154	0.107	0.123
Q1C2-M	0.135	0.135	0.253	0.171	0.208	0.194	0.25	0.2	0.208
Q1C3-M	0.116	0.134	0.184	0.128	0.112	0.098	0.169	0.104	0.132
Q1C4-M	0.117	0.135	0.25	0.143	0.191	0.179	0.23	0.194	0.188
Q1D1-M	0.09	0.092	0.212	0.145	0.135	0.113	0.169	0.119	0.16
Q1D2-M	0.103	0.073	0.215	0.158	0.146	0.132	0.188	0.138	0.16
Q1D3-M	0.132	0.132	0.25	0.158	0.205	0.191	0.247	0.197	0.205
Q1D4-M	0.139	0.18	0.263	0.166	0.202	0.188	0.244	0.194	0.211
Q2A1-M	0.034	0.075	0.176	0.118	0.117	0.111	0.146	0.136	0.113
Q2A2-M	0.059	0.063	0.146	0.122	0.061	0.052	0.088	0.078	0.081
Q2A3-M	0.053	0.14	0.123	0.068	0.072	0.097	0.097	0.099	0.072
Q2A4-M	0.082	0.12	0.087	0.174	0.126	0.119	0.103	0.152	0.129
Q2B1-M	0.029	0.075	0.139	0.115	0.064	0.066	0.095	0.091	0.076
Q2B2-M	0.054	0.115	0.176	0.143	0.141	0.142	0.14	0.167	0.14
Q2B4-M	0.063	0.089	0.162	0.121	0.105	0.096	0.146	0.121	0.105
Q2C1-M	0.062	0.071	0.104	0.153	0.079	0.062	0.069	0.099	0.104
Q2C2-M	0.102	0.12	0.129	0.145	0.097	0.098	0.108	0.131	0.1
Q2C3-M	0.065	0.111	0.104	0.114	0.06	0.058	0.073	0.087	0.067
Q2C4-M	0.075	0.076	0.175	0.123	0.116	0.104	0.154	0.119	0.112
Q2D1-M	0	0.087	0.155	0.109	0.09	0.091	0.114	0.117	0.095
Q2D2-M		0	0.176	0.172	0.103	0.061	0.115	0.103	0.132
Q2D3-M			0	0.172	0.118	0.12	0.114	0.134	0.126
Q2D4-M				0	0.082	0.118	0.151	0.092	0.054
Q3A1-M					0	0.05	0.075	0.037	0.034
Q3A2-M						0	0.074	0.047	0.079
Q3A3-M							0	0.075	0.104
Q3A4-M								0	0.067
Q3B1-M									0

Appendix E. (cont.)

Section E of Λ CDM.

	Q3B2-M	Q3B4-M	Q3C1-M	Q3C2-M	Q3C3-M	Q3C4-M	Q3D1-M	Q3D2-M	Q3D3-M
Q1A1-M	0.315	0.252	0.307	0.319	0.282	0.326	0.239	0.324	0.364
Q1A2-M	0.15	0.083	0.132	0.145	0.106	0.15	0.085	0.151	0.188
Q1A3-M	0.123	0.109	0.161	0.122	0.099	0.129	0.121	0.137	0.167
Q1A4-M	0.248	0.178	0.229	0.241	0.199	0.238	0.195	0.241	0.276
Q1B1-M	0.246	0.187	0.232	0.232	0.208	0.251	0.175	0.255	0.29
Q1B2-M	0.235	0.165	0.201	0.219	0.182	0.211	0.19	0.225	0.244
Q1B3-M	0.204	0.148	0.207	0.22	0.177	0.22	0.127	0.218	0.258
Q1B4-M	0.156	0.103	0.14	0.145	0.116	0.159	0.142	0.166	0.198
Q1C1-M	0.18	0.121	0.168	0.17	0.143	0.187	0.11	0.189	0.226
Q1C2-M	0.272	0.202	0.238	0.257	0.219	0.236	0.192	0.25	0.27
Q1C3-M	0.189	0.13	0.161	0.167	0.148	0.184	0.154	0.198	0.218
Q1C4-M	0.253	0.186	0.245	0.257	0.215	0.239	0.169	0.237	0.277
Q1D1-M	0.217	0.158	0.189	0.195	0.176	0.212	0.169	0.226	0.245
Q1D2-M	0.217	0.158	0.202	0.201	0.177	0.221	0.182	0.226	0.259
Q1D3-M	0.269	0.2	0.24	0.254	0.217	0.246	0.186	0.259	0.285
Q1D4-M	0.268	0.209	0.24	0.251	0.227	0.263	0.198	0.277	0.296
Q2A1-M	0.169	0.111	0.171	0.183	0.141	0.178	0.096	0.177	0.217
Q2A2-M	0.121	0.079	0.133	0.133	0.108	0.152	0.103	0.151	0.191
Q2A3-M	0.111	0.058	0.13	0.13	0.087	0.134	0.028	0.128	0.168
Q2A4-M	0.083	0.107	0.174	0.107	0.106	0.109	0.108	0.135	0.16
Q2B1-M	0.122	0.072	0.133	0.127	0.102	0.145	0.091	0.144	0.184
Q2B2-M	0.163	0.123	0.198	0.183	0.141	0.155	0.086	0.157	0.189
Q2B4-M	0.169	0.099	0.156	0.169	0.126	0.14	0.106	0.142	0.178
Q2C1-M	0.112	0.081	0.129	0.091	0.067	0.11	0.103	0.112	0.149
Q2C2-M	0.105	0.078	0.142	0.135	0.079	0.099	0.097	0.098	0.138
Q2C3-M	0.077	0.048	0.116	0.1	0.063	0.107	0.064	0.105	0.145
Q2C4-M	0.177	0.111	0.17	0.182	0.14	0.166	0.124	0.165	0.205
Q2D1-M	0.137	0.088	0.152	0.15	0.118	0.161	0.078	0.16	0.2
Q2D2-M	0.178	0.126	0.163	0.162	0.138	0.182	0.166	0.18	0.22
Q2D3-M	0.094	0.1	0.097	0.055	0.07	0.053	0.121	0.12	0.114
Q2D4-M	0.135	0.073	0.124	0.158	0.102	0.159	0.074	0.121	0.161
Q3A1-M	0.082	0.03	0.094	0.093	0.055	0.113	0.081	0.095	0.135
Q3A2-M	0.125	0.073	0.104	0.105	0.079	0.123	0.118	0.127	0.161
Q3A3-M	0.093	0.09	0.144	0.091	0.071	0.126	0.089	0.115	0.149
Q3A4-M	0.117	0.066	0.117	0.107	0.081	0.139	0.106	0.126	0.16
Q3B1-M	0.093	0.027	0.07	0.115	0.056	0.112	0.081	0.075	0.115
Q3B2-M	0	0.08	0.15	0.054	0.077	0.101	0.084	0.088	0.109
Q3B4-M		0	0.081	0.098	0.034	0.086	0.07	0.072	0.112
Q3C1-M			0	0.119	0.079	0.088	0.151	0.093	0.089
Q3C2-M				0	0.065	0.07	0.103	0.092	0.079
Q3C3-M					0	0.058	0.076	0.058	0.082
Q3C4-M						0	0.133	0.082	0.067
Q3D1-M							0	0.101	0.141
Q3D2-M								0	0.04
Q3D3-M									0

Appendix E. (cont.)

Section F of Λ CDM.

	Q3D4-M	Q1A1-FC	Q1A2-FC	Q1A3-FC	Q1A4-FC	Q1B1-FC	Q1B2-FC	Q1B3-FC	Q1B4-FC
Q1A1-M	0.292	0.371	0.549	0.438	0.39	0.513	0.47	0.428	0.382
Q1A2-M	0.116	0.317	0.495	0.384	0.337	0.459	0.417	0.374	0.328
Q1A3-M	0.144	0.333	0.511	0.422	0.352	0.475	0.432	0.39	0.356
Q1A4-M	0.204	0.356	0.534	0.423	0.375	0.498	0.455	0.413	0.367
Q1B1-M	0.218	0.313	0.491	0.38	0.332	0.455	0.412	0.37	0.324
Q1B2-M	0.186	0.336	0.514	0.403	0.355	0.477	0.435	0.393	0.347
Q1B3-M	0.186	0.355	0.533	0.422	0.374	0.496	0.454	0.412	0.366
Q1B4-M	0.127	0.297	0.475	0.372	0.316	0.439	0.396	0.354	0.308
Q1C1-M	0.153	0.305	0.483	0.372	0.324	0.447	0.404	0.362	0.316
Q1C2-M	0.211	0.37	0.548	0.437	0.389	0.512	0.469	0.427	0.381
Q1C3-M	0.159	0.261	0.439	0.328	0.281	0.403	0.361	0.318	0.272
Q1C4-M	0.205	0.346	0.524	0.413	0.365	0.487	0.445	0.403	0.357
Q1D1-M	0.187	0.304	0.482	0.371	0.323	0.446	0.403	0.361	0.315
Q1D2-M	0.187	0.327	0.505	0.394	0.347	0.469	0.427	0.384	0.338
Q1D3-M	0.221	0.357	0.535	0.425	0.377	0.499	0.457	0.414	0.368
Q1D4-M	0.241	0.357	0.535	0.424	0.377	0.499	0.456	0.414	0.368
Q2A1-M	0.144	0.335	0.513	0.402	0.354	0.477	0.434	0.392	0.346
Q2A2-M	0.118	0.273	0.451	0.343	0.292	0.415	0.372	0.33	0.284
Q2A3-M	0.135	0.298	0.472	0.361	0.323	0.435	0.393	0.351	0.305
Q2A4-M	0.149	0.337	0.515	0.416	0.357	0.479	0.436	0.394	0.349
Q2B1-M	0.115	0.294	0.472	0.361	0.314	0.436	0.394	0.351	0.305
Q2B2-M	0.142	0.359	0.537	0.426	0.378	0.501	0.458	0.416	0.37
Q2B4-M	0.106	0.335	0.513	0.402	0.354	0.476	0.434	0.392	0.346
Q2C1-M	0.114	0.3	0.478	0.387	0.319	0.442	0.399	0.357	0.321
Q2C2-M	0.096	0.294	0.472	0.374	0.313	0.436	0.393	0.351	0.308
Q2C3-M	0.105	0.274	0.452	0.347	0.293	0.416	0.373	0.331	0.285
Q2C4-M	0.132	0.327	0.505	0.394	0.347	0.469	0.426	0.384	0.338
Q2D1-M	0.134	0.317	0.495	0.384	0.337	0.459	0.416	0.374	0.328
Q2D2-M	0.148	0.299	0.477	0.385	0.318	0.441	0.398	0.356	0.319
Q2D3-M	0.127	0.327	0.465	0.426	0.336	0.469	0.404	0.391	0.36
Q2D4-M	0.135	0.263	0.421	0.31	0.288	0.384	0.342	0.3	0.254
Q3A1-M	0.106	0.255	0.416	0.308	0.279	0.38	0.338	0.295	0.249
Q3A2-M	0.096	0.238	0.416	0.33	0.258	0.38	0.337	0.295	0.264
Q3A3-M	0.156	0.249	0.412	0.328	0.274	0.376	0.334	0.293	0.261
Q3A4-M	0.131	0.24	0.4	0.292	0.265	0.364	0.321	0.279	0.233
Q3B1-M	0.084	0.25	0.413	0.302	0.275	0.376	0.334	0.292	0.246
Q3B2-M	0.162	0.309	0.433	0.332	0.334	0.397	0.355	0.312	0.266
Q3B4-M	0.088	0.266	0.434	0.327	0.291	0.398	0.355	0.313	0.267
Q3C1-M	0.055	0.239	0.383	0.34	0.248	0.383	0.318	0.305	0.274
Q3C2-M	0.137	0.312	0.443	0.374	0.333	0.417	0.365	0.339	0.308
Q3C3-M	0.086	0.276	0.439	0.356	0.3	0.403	0.36	0.321	0.29
Q3C4-M	0.08	0.308	0.467	0.412	0.317	0.455	0.39	0.378	0.346
Q3D1-M	0.156	0.318	0.467	0.356	0.343	0.43	0.388	0.346	0.3
Q3D2-M	0.074	0.282	0.422	0.33	0.307	0.385	0.343	0.301	0.264
Q3D3-M	0.077	0.3	0.432	0.362	0.321	0.404	0.353	0.327	0.296
Q3D4-M	0	0.255	0.425	0.36	0.267	0.403	0.346	0.325	0.294

Appendix E. (cont.)

Section G of Λ CDM.

	Q1C1-FC	Q1C2-FC	Q1C3-FC	Q1C4-FC	Q1D1-FC	Q1D2-FC	Q1D3-FC	Q1D4-FC	Q2A1-FC
Q1A1-M	0.419	0.395	0.366	0.366	0.518	0.488	0.372	0.34	0.461
Q1A2-M	0.365	0.341	0.312	0.312	0.464	0.434	0.318	0.287	0.407
Q1A3-M	0.381	0.357	0.328	0.328	0.48	0.45	0.334	0.328	0.423
Q1A4-M	0.404	0.38	0.351	0.351	0.503	0.473	0.357	0.325	0.446
Q1B1-M	0.361	0.337	0.308	0.308	0.46	0.43	0.314	0.282	0.403
Q1B2-M	0.383	0.36	0.33	0.331	0.483	0.453	0.336	0.305	0.425
Q1B3-M	0.402	0.379	0.349	0.35	0.501	0.472	0.355	0.324	0.444
Q1B4-M	0.345	0.321	0.292	0.292	0.444	0.414	0.298	0.278	0.387
Q1C1-M	0.353	0.329	0.3	0.3	0.452	0.422	0.306	0.275	0.395
Q1C2-M	0.418	0.394	0.365	0.365	0.517	0.487	0.371	0.34	0.46
Q1C3-M	0.309	0.286	0.256	0.257	0.408	0.379	0.262	0.231	0.351
Q1C4-M	0.393	0.37	0.34	0.341	0.493	0.463	0.346	0.315	0.435
Q1D1-M	0.352	0.328	0.299	0.299	0.451	0.421	0.305	0.274	0.394
Q1D2-M	0.375	0.351	0.322	0.322	0.474	0.444	0.328	0.297	0.417
Q1D3-M	0.405	0.382	0.352	0.353	0.504	0.475	0.358	0.327	0.447
Q1D4-M	0.405	0.381	0.352	0.352	0.504	0.474	0.358	0.327	0.447
Q2A1-M	0.382	0.359	0.329	0.33	0.482	0.452	0.336	0.304	0.424
Q2A2-M	0.32	0.297	0.267	0.268	0.42	0.39	0.274	0.249	0.362
Q2A3-M	0.341	0.318	0.296	0.316	0.44	0.411	0.307	0.29	0.383
Q2A4-M	0.385	0.361	0.332	0.334	0.484	0.454	0.338	0.323	0.427
Q2B1-M	0.342	0.319	0.289	0.289	0.441	0.411	0.295	0.264	0.384
Q2B2-M	0.406	0.383	0.353	0.354	0.506	0.476	0.36	0.328	0.448
Q2B4-M	0.382	0.359	0.329	0.33	0.481	0.452	0.335	0.304	0.424
Q2C1-M	0.347	0.324	0.295	0.295	0.447	0.417	0.301	0.293	0.39
Q2C2-M	0.341	0.318	0.288	0.289	0.441	0.411	0.295	0.28	0.383
Q2C3-M	0.321	0.298	0.268	0.272	0.421	0.391	0.275	0.256	0.363
Q2C4-M	0.375	0.351	0.322	0.322	0.474	0.444	0.328	0.297	0.417
Q2D1-M	0.365	0.341	0.312	0.312	0.464	0.434	0.318	0.287	0.407
Q2D2-M	0.346	0.323	0.293	0.294	0.446	0.416	0.3	0.291	0.388
Q2D3-M	0.382	0.349	0.299	0.36	0.434	0.405	0.339	0.36	0.402
Q2D4-M	0.29	0.274	0.261	0.281	0.389	0.36	0.272	0.255	0.332
Q3A1-M	0.286	0.265	0.253	0.272	0.385	0.356	0.263	0.252	0.328
Q3A2-M	0.286	0.262	0.233	0.24	0.385	0.355	0.239	0.24	0.328
Q3A3-M	0.283	0.26	0.247	0.271	0.381	0.351	0.258	0.271	0.324
Q3A4-M	0.27	0.251	0.238	0.257	0.369	0.339	0.248	0.238	0.312
Q3B1-M	0.282	0.261	0.248	0.267	0.381	0.352	0.258	0.244	0.324
Q3B2-M	0.303	0.32	0.307	0.326	0.402	0.375	0.317	0.314	0.345
Q3B4-M	0.304	0.28	0.264	0.283	0.403	0.373	0.274	0.264	0.346
Q3C1-M	0.296	0.262	0.211	0.272	0.351	0.322	0.251	0.272	0.33
Q3C2-M	0.33	0.325	0.306	0.345	0.412	0.382	0.325	0.345	0.355
Q3C3-M	0.311	0.286	0.274	0.298	0.408	0.378	0.284	0.298	0.351
Q3C4-M	0.368	0.335	0.287	0.34	0.436	0.406	0.32	0.34	0.388
Q3D1-M	0.336	0.329	0.316	0.336	0.435	0.406	0.327	0.31	0.378
Q3D2-M	0.291	0.293	0.28	0.3	0.39	0.361	0.291	0.297	0.34
Q3D3-M	0.317	0.313	0.295	0.333	0.401	0.371	0.312	0.333	0.355
Q3D4-M	0.315	0.282	0.242	0.266	0.394	0.364	0.26	0.266	0.347

Appendix E. (cont.)

Section H of Λ CDM.

	Q2A2-FC	Q2A3-FC	Q2A4-FC	Q2B1-FC	Q2B2-FC	Q2B4-FC	Q2C1-FC	Q2C2-FC	Q2C3-FC
Q1A1-M	0.494	0.453	0.506	0.489	0.495	0.449	0.535	0.442	0.498
Q1A2-M	0.44	0.4	0.452	0.435	0.442	0.396	0.481	0.38	0.444
Q1A3-M	0.456	0.415	0.468	0.451	0.457	0.411	0.497	0.396	0.46
Q1A4-M	0.479	0.438	0.491	0.474	0.48	0.434	0.52	0.419	0.483
Q1B1-M	0.436	0.395	0.448	0.431	0.437	0.391	0.477	0.376	0.44
Q1B2-M	0.459	0.418	0.471	0.454	0.46	0.414	0.499	0.398	0.463
Q1B3-M	0.477	0.437	0.49	0.473	0.479	0.433	0.518	0.417	0.482
Q1B4-M	0.42	0.379	0.432	0.415	0.421	0.375	0.461	0.36	0.424
Q1C1-M	0.428	0.387	0.44	0.423	0.429	0.383	0.469	0.368	0.432
Q1C2-M	0.493	0.452	0.505	0.488	0.494	0.448	0.534	0.433	0.497
Q1C3-M	0.384	0.344	0.397	0.379	0.386	0.34	0.425	0.324	0.388
Q1C4-M	0.469	0.428	0.481	0.464	0.47	0.424	0.509	0.408	0.473
Q1D1-M	0.427	0.386	0.439	0.422	0.428	0.382	0.468	0.367	0.431
Q1D2-M	0.45	0.41	0.462	0.445	0.452	0.406	0.491	0.39	0.454
Q1D3-M	0.48	0.44	0.493	0.475	0.482	0.436	0.521	0.42	0.484
Q1D4-M	0.48	0.439	0.492	0.475	0.482	0.435	0.521	0.42	0.484
Q2A1-M	0.458	0.417	0.47	0.453	0.459	0.413	0.498	0.398	0.462
Q2A2-M	0.396	0.355	0.408	0.391	0.397	0.351	0.436	0.335	0.4
Q2A3-M	0.417	0.376	0.429	0.412	0.418	0.372	0.457	0.356	0.421
Q2A4-M	0.46	0.419	0.472	0.455	0.462	0.416	0.501	0.4	0.464
Q2B1-M	0.417	0.377	0.429	0.412	0.419	0.373	0.458	0.357	0.421
Q2B2-M	0.482	0.441	0.494	0.477	0.483	0.437	0.522	0.422	0.486
Q2B4-M	0.458	0.417	0.47	0.453	0.459	0.413	0.498	0.397	0.462
Q2C1-M	0.423	0.382	0.435	0.418	0.424	0.378	0.463	0.363	0.427
Q2C2-M	0.417	0.376	0.429	0.412	0.418	0.372	0.457	0.357	0.421
Q2C3-M	0.397	0.356	0.409	0.392	0.398	0.352	0.437	0.337	0.401
Q2C4-M	0.45	0.409	0.462	0.445	0.452	0.405	0.491	0.39	0.454
Q2D1-M	0.44	0.399	0.452	0.435	0.441	0.395	0.481	0.38	0.444
Q2D2-M	0.422	0.381	0.434	0.417	0.423	0.377	0.462	0.362	0.426
Q2D3-M	0.41	0.403	0.424	0.411	0.411	0.373	0.45	0.356	0.414
Q2D4-M	0.365	0.325	0.378	0.361	0.367	0.321	0.406	0.305	0.37
Q3A1-M	0.361	0.321	0.374	0.356	0.363	0.317	0.402	0.301	0.366
Q3A2-M	0.361	0.32	0.373	0.356	0.363	0.317	0.402	0.301	0.365
Q3A3-M	0.357	0.317	0.369	0.352	0.359	0.313	0.398	0.297	0.361
Q3A4-M	0.345	0.304	0.357	0.34	0.346	0.3	0.386	0.285	0.349
Q3B1-M	0.357	0.317	0.37	0.353	0.359	0.313	0.398	0.297	0.362
Q3B2-M	0.378	0.338	0.39	0.373	0.38	0.334	0.419	0.318	0.382
Q3B4-M	0.379	0.338	0.391	0.374	0.381	0.335	0.42	0.319	0.383
Q3C1-M	0.328	0.317	0.34	0.325	0.329	0.287	0.368	0.27	0.332
Q3C2-M	0.388	0.351	0.4	0.383	0.39	0.344	0.429	0.328	0.392
Q3C3-M	0.384	0.343	0.396	0.379	0.386	0.34	0.425	0.324	0.388
Q3C4-M	0.412	0.389	0.424	0.407	0.413	0.367	0.453	0.352	0.416
Q3D1-M	0.412	0.371	0.424	0.407	0.413	0.367	0.452	0.351	0.416
Q3D2-M	0.366	0.326	0.379	0.362	0.368	0.322	0.407	0.306	0.371
Q3D3-M	0.377	0.338	0.389	0.372	0.378	0.332	0.417	0.316	0.381
Q3D4-M	0.37	0.336	0.382	0.365	0.372	0.326	0.411	0.31	0.374

Appendix E. (cont.)

Section I of Λ CDM.

	Q2C4-FC	Q2D1-FC	Q2D2-FC	Q2D3-FC	Q2D4-FC	Q3A1-FC	Q3A2-FC	Q3A3-FC	Q3A4-FC
Q1A1-M	0.539	0.573	0.575	0.544	0.551	0.561	0.565	0.523	0.497
Q1A2-M	0.485	0.519	0.521	0.491	0.497	0.507	0.512	0.469	0.431
Q1A3-M	0.501	0.535	0.537	0.506	0.513	0.523	0.527	0.485	0.447
Q1A4-M	0.524	0.558	0.56	0.529	0.536	0.546	0.55	0.508	0.47
Q1B1-M	0.481	0.515	0.517	0.486	0.493	0.503	0.507	0.465	0.427
Q1B2-M	0.504	0.538	0.54	0.509	0.515	0.526	0.53	0.487	0.45
Q1B3-M	0.522	0.556	0.559	0.528	0.534	0.545	0.549	0.506	0.468
Q1B4-M	0.465	0.499	0.501	0.47	0.477	0.487	0.491	0.449	0.411
Q1C1-M	0.473	0.507	0.509	0.478	0.485	0.495	0.499	0.457	0.419
Q1C2-M	0.538	0.572	0.574	0.543	0.55	0.56	0.564	0.522	0.484
Q1C3-M	0.429	0.463	0.466	0.435	0.441	0.452	0.456	0.413	0.375
Q1C4-M	0.514	0.548	0.55	0.519	0.525	0.536	0.54	0.497	0.46
Q1D1-M	0.472	0.506	0.508	0.477	0.484	0.494	0.498	0.456	0.418
Q1D2-M	0.495	0.529	0.531	0.501	0.507	0.517	0.522	0.479	0.441
Q1D3-M	0.525	0.559	0.562	0.531	0.537	0.548	0.552	0.509	0.471
Q1D4-M	0.525	0.559	0.561	0.53	0.537	0.547	0.552	0.509	0.471
Q2A1-M	0.503	0.537	0.539	0.508	0.514	0.525	0.529	0.487	0.449
Q2A2-M	0.441	0.475	0.477	0.446	0.452	0.463	0.467	0.424	0.387
Q2A3-M	0.461	0.496	0.498	0.467	0.473	0.484	0.488	0.445	0.408
Q2A4-M	0.505	0.539	0.541	0.51	0.517	0.527	0.532	0.489	0.451
Q2B1-M	0.462	0.496	0.498	0.468	0.474	0.485	0.489	0.446	0.408
Q2B2-M	0.527	0.561	0.563	0.532	0.538	0.549	0.553	0.511	0.473
Q2B4-M	0.502	0.537	0.539	0.508	0.514	0.525	0.529	0.486	0.449
Q2C1-M	0.468	0.502	0.504	0.473	0.48	0.49	0.494	0.452	0.414
Q2C2-M	0.462	0.496	0.498	0.467	0.473	0.484	0.488	0.446	0.408
Q2C3-M	0.442	0.476	0.478	0.447	0.453	0.464	0.468	0.426	0.388
Q2C4-M	0.495	0.529	0.531	0.5	0.507	0.517	0.522	0.479	0.441
Q2D1-M	0.485	0.519	0.521	0.49	0.497	0.507	0.512	0.469	0.431
Q2D2-M	0.467	0.501	0.503	0.472	0.478	0.489	0.493	0.451	0.413
Q2D3-M	0.455	0.489	0.491	0.46	0.466	0.477	0.481	0.439	0.401
Q2D4-M	0.41	0.444	0.447	0.416	0.422	0.433	0.437	0.394	0.356
Q3A1-M	0.406	0.44	0.443	0.412	0.418	0.429	0.433	0.39	0.352
Q3A2-M	0.406	0.44	0.442	0.411	0.418	0.428	0.433	0.39	0.352
Q3A3-M	0.402	0.436	0.438	0.408	0.414	0.425	0.429	0.386	0.348
Q3A4-M	0.39	0.424	0.426	0.395	0.402	0.412	0.416	0.374	0.336
Q3B1-M	0.402	0.436	0.439	0.408	0.414	0.425	0.429	0.386	0.348
Q3B2-M	0.423	0.457	0.459	0.429	0.435	0.446	0.45	0.407	0.369
Q3B4-M	0.424	0.458	0.46	0.429	0.436	0.446	0.451	0.408	0.37
Q3C1-M	0.372	0.406	0.409	0.378	0.384	0.395	0.399	0.356	0.318
Q3C2-M	0.433	0.467	0.469	0.439	0.445	0.455	0.46	0.417	0.379
Q3C3-M	0.429	0.463	0.465	0.434	0.441	0.451	0.456	0.413	0.375
Q3C4-M	0.457	0.491	0.493	0.462	0.469	0.479	0.483	0.441	0.403
Q3D1-M	0.456	0.491	0.493	0.462	0.468	0.479	0.483	0.44	0.403
Q3D2-M	0.411	0.445	0.448	0.417	0.423	0.434	0.438	0.395	0.357
Q3D3-M	0.422	0.456	0.458	0.427	0.433	0.444	0.448	0.405	0.368
Q3D4-M	0.415	0.449	0.451	0.42	0.427	0.437	0.442	0.399	0.361

Appendix E. (cont.)

Section J of Λ CDM.

	Q3B1-FC	Q3B2-FC	Q3B4-FC	Q3C1-FC	Q3C2-FC	Q3C3-FC	Q3C4-FC	Q3D1-FC	Q3D2-FC
Q1A1-M	0.499	0.538	0.506	0.513	0.559	0.518	0.512	0.537	0.508
Q1A2-M	0.446	0.484	0.452	0.459	0.505	0.464	0.458	0.484	0.455
Q1A3-M	0.461	0.5	0.468	0.475	0.521	0.48	0.474	0.5	0.47
Q1A4-M	0.484	0.523	0.491	0.498	0.544	0.503	0.497	0.522	0.493
Q1B1-M	0.441	0.48	0.448	0.455	0.501	0.46	0.454	0.479	0.45
Q1B2-M	0.464	0.503	0.471	0.478	0.524	0.483	0.477	0.502	0.473
Q1B3-M	0.483	0.522	0.49	0.497	0.543	0.502	0.496	0.521	0.492
Q1B4-M	0.425	0.464	0.432	0.439	0.485	0.444	0.438	0.463	0.434
Q1C1-M	0.433	0.472	0.44	0.447	0.493	0.452	0.446	0.472	0.442
Q1C2-M	0.498	0.537	0.505	0.512	0.558	0.517	0.511	0.537	0.507
Q1C3-M	0.39	0.429	0.396	0.404	0.449	0.409	0.402	0.428	0.399
Q1C4-M	0.474	0.513	0.481	0.488	0.534	0.493	0.487	0.512	0.483
Q1D1-M	0.432	0.471	0.439	0.446	0.492	0.451	0.445	0.471	0.441
Q1D2-M	0.456	0.494	0.462	0.469	0.515	0.474	0.468	0.494	0.465
Q1D3-M	0.486	0.525	0.492	0.5	0.545	0.505	0.498	0.524	0.495
Q1D4-M	0.485	0.524	0.492	0.499	0.545	0.504	0.498	0.524	0.494
Q2A1-M	0.463	0.502	0.47	0.477	0.523	0.482	0.476	0.501	0.472
Q2A2-M	0.401	0.44	0.408	0.415	0.461	0.42	0.414	0.439	0.41
Q2A3-M	0.422	0.461	0.429	0.436	0.482	0.441	0.435	0.46	0.431
Q2A4-M	0.466	0.504	0.472	0.479	0.525	0.484	0.478	0.504	0.475
Q2B1-M	0.423	0.462	0.429	0.437	0.482	0.442	0.435	0.461	0.432
Q2B2-M	0.487	0.526	0.494	0.501	0.547	0.506	0.5	0.525	0.496
Q2B4-M	0.463	0.502	0.47	0.477	0.523	0.482	0.476	0.501	0.472
Q2C1-M	0.428	0.467	0.435	0.442	0.488	0.447	0.441	0.466	0.437
Q2C2-M	0.422	0.461	0.429	0.436	0.482	0.441	0.435	0.46	0.431
Q2C3-M	0.402	0.441	0.409	0.416	0.462	0.421	0.415	0.44	0.411
Q2C4-M	0.455	0.494	0.462	0.469	0.515	0.474	0.468	0.494	0.464
Q2D1-M	0.445	0.484	0.452	0.459	0.505	0.464	0.458	0.484	0.454
Q2D2-M	0.427	0.466	0.434	0.441	0.487	0.446	0.44	0.465	0.436
Q2D3-M	0.415	0.454	0.422	0.429	0.475	0.434	0.428	0.458	0.424
Q2D4-M	0.371	0.41	0.378	0.385	0.431	0.39	0.384	0.409	0.38
Q3A1-M	0.367	0.406	0.374	0.381	0.427	0.386	0.379	0.405	0.376
Q3A2-M	0.367	0.405	0.373	0.38	0.426	0.385	0.379	0.405	0.376
Q3A3-M	0.363	0.402	0.369	0.377	0.422	0.382	0.375	0.401	0.372
Q3A4-M	0.35	0.389	0.357	0.364	0.41	0.369	0.363	0.388	0.359
Q3B1-M	0.363	0.402	0.37	0.377	0.423	0.382	0.376	0.401	0.372
Q3B2-M	0.384	0.423	0.39	0.398	0.443	0.403	0.396	0.422	0.393
Q3B4-M	0.385	0.423	0.391	0.398	0.444	0.403	0.397	0.423	0.394
Q3C1-M	0.333	0.372	0.34	0.347	0.393	0.352	0.346	0.372	0.342
Q3C2-M	0.394	0.433	0.4	0.408	0.453	0.412	0.406	0.432	0.403
Q3C3-M	0.39	0.428	0.396	0.403	0.449	0.408	0.402	0.428	0.399
Q3C4-M	0.417	0.456	0.424	0.431	0.477	0.436	0.43	0.456	0.426
Q3D1-M	0.417	0.456	0.424	0.431	0.477	0.436	0.43	0.455	0.426
Q3D2-M	0.372	0.411	0.379	0.386	0.432	0.391	0.385	0.41	0.381
Q3D3-M	0.382	0.421	0.389	0.396	0.442	0.401	0.395	0.42	0.391
Q3D4-M	0.376	0.414	0.382	0.389	0.435	0.394	0.388	0.414	0.385

Appendix E. (cont.)

Section K of Λ CDM.

	Q3D3-FC	Q3D4-FC
Q1A1-M	0.587	0.517
Q1A2-M	0.533	0.463
Q1A3-M	0.549	0.479
Q1A4-M	0.572	0.502
Q1B1-M	0.529	0.459
Q1B2-M	0.551	0.482
Q1B3-M	0.57	0.501
Q1B4-M	0.513	0.443
Q1C1-M	0.521	0.451
Q1C2-M	0.586	0.516
Q1C3-M	0.477	0.408
Q1C4-M	0.561	0.492
Q1D1-M	0.52	0.45
Q1D2-M	0.543	0.473
Q1D3-M	0.573	0.504
Q1D4-M	0.573	0.503
Q2A1-M	0.55	0.481
Q2A2-M	0.488	0.419
Q2A3-M	0.509	0.44
Q2A4-M	0.553	0.483
Q2B1-M	0.51	0.441
Q2B2-M	0.574	0.505
Q2B4-M	0.55	0.481
Q2C1-M	0.515	0.446
Q2C2-M	0.509	0.44
Q2C3-M	0.489	0.42
Q2C4-M	0.543	0.473
Q2D1-M	0.533	0.463
Q2D2-M	0.514	0.445
Q2D3-M	0.502	0.433
Q2D4-M	0.458	0.389
Q3A1-M	0.454	0.385
Q3A2-M	0.454	0.384
Q3A3-M	0.45	0.381
Q3A4-M	0.438	0.368
Q3B1-M	0.45	0.381
Q3B2-M	0.471	0.402
Q3B4-M	0.472	0.402
Q3C1-M	0.42	0.351
Q3C2-M	0.481	0.411
Q3C3-M	0.477	0.407
Q3C4-M	0.505	0.435
Q3D1-M	0.504	0.435
Q3D2-M	0.459	0.39
Q3D3-M	0.469	0.4
Q3D4-M	0.463	0.393

Appendix E. (cont.)

Section L of Λ CDM.

	Q3D4-M	Q1A1-FC	Q1A2-FC	Q1A3-FC	Q1A4-FC	Q1B1-FC	Q1B2-FC	Q1B3-FC	Q1B4-FC
Q1A1-FC		0	0.178	0.139	0.099	0.153	0.129	0.101	0.134
Q1A2-FC			0	0.21	0.25	0.187	0.204	0.207	0.245
Q1A3-FC				0	0.101	0.075	0.059	0.038	0.066
Q1A4-FC					0	0.143	0.09	0.073	0.082
Q1B1-FC						0	0.065	0.085	0.131
Q1B2-FC							0	0.051	0.088
Q1B3-FC								0	0.048
Q1B4-FC									0

Section M of Λ CDM.

	Q1C1-FC	Q1C2-FC	Q1C3-FC	Q1C4-FC	Q1D1-FC	Q1D2-FC	Q1D3-FC	Q1D4-FC	Q2A1-FC
Q1A1-FC	0.169	0.044	0.073	0.085	0.147	0.117	0.05	0.096	0.237
Q1A2-FC	0.252	0.186	0.223	0.227	0.124	0.154	0.21	0.238	0.311
Q1A3-FC	0.08	0.102	0.136	0.102	0.109	0.084	0.1	0.105	0.161
Q1A4-FC	0.114	0.089	0.064	0.07	0.134	0.098	0.065	0.085	0.159
Q1B1-FC	0.104	0.121	0.179	0.147	0.103	0.092	0.143	0.172	0.139
Q1B2-FC	0.077	0.115	0.114	0.138	0.089	0.082	0.115	0.164	0.116
Q1B3-FC	0.075	0.077	0.101	0.087	0.092	0.071	0.073	0.113	0.156
Q1B4-FC	0.06	0.117	0.094	0.104	0.136	0.119	0.11	0.106	0.131
Q1C1-FC	0	0.153	0.13	0.142	0.13	0.139	0.146	0.16	0.082
Q1C2-FC		0	0.069	0.061	0.132	0.093	0.028	0.074	0.221
Q1C3-FC			0	0.066	0.152	0.123	0.047	0.086	0.186
Q1C4-FC				0	0.173	0.123	0.038	0.026	0.223
Q1D1-FC					0	0.059	0.151	0.199	0.189
Q1D2-FC						0	0.116	0.149	0.198
Q1D3-FC							0	0.052	0.216
Q1D4-FC								0	0.238
Q2A1-FC									0

Appendix E. (cont.)

Section N of Λ CDM.

	Q2A2-FC	Q2A3-FC	Q2A4-FC	Q2B1-FC	Q2B2-FC	Q2B4-FC	Q2C1-FC	Q2C2-FC	Q2C3-FC
Q1A1-FC	0.159	0.123	0.15	0.159	0.15	0.121	0.164	0.133	0.171
Q1A2-FC	0.207	0.153	0.143	0.096	0.149	0.162	0.112	0.18	0.215
Q1A3-FC	0.105	0.153	0.133	0.219	0.134	0.117	0.124	0.137	0.129
Q1A4-FC	0.136	0.191	0.156	0.242	0.157	0.141	0.156	0.16	0.16
Q1B1-FC	0.072	0.147	0.127	0.213	0.128	0.117	0.118	0.131	0.101
Q1B2-FC	0.046	0.137	0.1	0.187	0.102	0.085	0.111	0.105	0.074
Q1B3-FC	0.097	0.132	0.112	0.198	0.113	0.096	0.114	0.116	0.121
Q1B4-FC	0.112	0.138	0.127	0.203	0.119	0.102	0.153	0.122	0.134
Q1C1-FC	0.078	0.115	0.118	0.18	0.109	0.091	0.15	0.093	0.08
Q1C2-FC	0.145	0.121	0.147	0.189	0.146	0.117	0.142	0.129	0.167
Q1C3-FC	0.128	0.139	0.141	0.183	0.131	0.102	0.169	0.114	0.152
Q1C4-FC	0.184	0.178	0.188	0.244	0.187	0.158	0.184	0.17	0.208
Q1D1-FC	0.083	0.088	0.031	0.118	0.038	0.069	0.022	0.089	0.092
Q1D2-FC	0.095	0.136	0.084	0.174	0.084	0.081	0.074	0.107	0.104
Q1D3-FC	0.162	0.141	0.165	0.209	0.165	0.136	0.163	0.148	0.186
Q1D4-FC	0.21	0.189	0.214	0.255	0.213	0.184	0.209	0.196	0.234
Q2A1-FC	0.109	0.167	0.167	0.218	0.163	0.149	0.209	0.153	0.11
Q2A2-FC	0	0.121	0.077	0.159	0.067	0.072	0.1	0.08	0.035
Q2A3-FC		0	0.057	0.068	0.054	0.066	0.103	0.075	0.1
Q2A4-FC			0	0.09	0.014	0.057	0.046	0.072	0.075
Q2B1-FC				0	0.092	0.105	0.111	0.112	0.137
Q2B2-FC					0	0.046	0.052	0.062	0.067
Q2B4-FC						0	0.085	0.027	0.062
Q2C1-FC							0	0.104	0.104
Q2C2-FC								0	0.068
Q2C3-FC									0

Appendix E. (cont.)

Section O of Λ CDM.

	Q2C4-FC	Q2D1-FC	Q2D2-FC	Q2D3-FC	Q2D4-FC	Q3A1-FC	Q3A2-FC	Q3A3-FC	Q3A4-FC
Q1A1-FC	0.168	0.202	0.204	0.173	0.18	0.194	0.216	0.204	0.194
Q1A2-FC	0.076	0.054	0.19	0.066	0.11	0.069	0.089	0.086	0.127
Q1A3-FC	0.189	0.206	0.16	0.19	0.125	0.208	0.274	0.264	0.253
Q1A4-FC	0.212	0.245	0.192	0.217	0.165	0.236	0.297	0.287	0.277
Q1B1-FC	0.183	0.201	0.112	0.184	0.117	0.202	0.268	0.258	0.248
Q1B2-FC	0.163	0.2	0.105	0.172	0.119	0.191	0.245	0.232	0.221
Q1B3-FC	0.168	0.203	0.153	0.174	0.123	0.194	0.253	0.243	0.232
Q1B4-FC	0.204	0.241	0.193	0.213	0.169	0.232	0.286	0.248	0.238
Q1C1-FC	0.195	0.232	0.157	0.203	0.151	0.222	0.276	0.229	0.205
Q1C2-FC	0.159	0.181	0.198	0.161	0.155	0.175	0.245	0.235	0.221
Q1C3-FC	0.182	0.219	0.21	0.19	0.185	0.206	0.264	0.228	0.214
Q1C4-FC	0.213	0.231	0.24	0.215	0.19	0.232	0.299	0.289	0.278
Q1D1-FC	0.08	0.111	0.067	0.083	0.033	0.102	0.165	0.155	0.145
Q1D2-FC	0.138	0.156	0.117	0.14	0.073	0.157	0.224	0.214	0.203
Q1D3-FC	0.179	0.206	0.217	0.18	0.179	0.194	0.264	0.254	0.241
Q1D4-FC	0.226	0.242	0.265	0.226	0.216	0.243	0.31	0.3	0.289
Q2A1-FC	0.241	0.269	0.157	0.255	0.203	0.257	0.314	0.266	0.241
Q2A2-FC	0.147	0.184	0.081	0.155	0.106	0.174	0.229	0.193	0.182
Q2A3-FC	0.086	0.12	0.122	0.097	0.104	0.109	0.164	0.117	0.1
Q2A4-FC	0.077	0.114	0.069	0.087	0.047	0.105	0.159	0.131	0.121
Q2B1-FC	0.057	0.084	0.146	0.068	0.104	0.076	0.097	0.049	0.037
Q2B2-FC	0.086	0.123	0.08	0.094	0.055	0.113	0.167	0.13	0.119
Q2B4-FC	0.119	0.156	0.126	0.128	0.101	0.147	0.201	0.154	0.136
Q2C1-FC	0.069	0.089	0.079	0.067	0.025	0.088	0.15	0.14	0.129
Q2C2-FC	0.127	0.164	0.141	0.136	0.117	0.155	0.209	0.162	0.116
Q2C3-FC	0.14	0.172	0.077	0.15	0.106	0.168	0.213	0.166	0.148
Q2C4-FC	0	0.037	0.114	0.014	0.066	0.028	0.085	0.075	0.082
Q2D1-FC		0	0.137	0.029	0.084	0.021	0.068	0.06	0.101
Q2D2-FC			0	0.125	0.081	0.132	0.168	0.165	0.157
Q2D3-FC				0	0.067	0.024	0.084	0.074	0.089
Q2D4-FC					0	0.085	0.151	0.141	0.13
Q3A1-FC						0	0.076	0.064	0.088
Q3A2-FC							0	0.049	0.108
Q3A3-FC								0	0.058
Q3A4-FC									0

Appendix E. (cont.)

Section P of Λ CDM.

	Q3B1-FC	Q3B2-FC	Q3B4-FC	Q3C1-FC	Q3C2-FC	Q3C3-FC	Q3C4-FC	Q3D1-FC	Q3D2-FC
Q1A1-FC	0.19	0.213	0.218	0.18	0.207	0.171	0.191	0.177	0.151
Q1A2-FC	0.154	0.087	0.1	0.099	0.08	0.117	0.194	0.064	0.08
Q1A3-FC	0.204	0.272	0.278	0.226	0.256	0.186	0.155	0.237	0.192
Q1A4-FC	0.228	0.296	0.301	0.25	0.28	0.209	0.181	0.26	0.216
Q1B1-FC	0.199	0.266	0.272	0.22	0.25	0.18	0.149	0.231	0.186
Q1B2-FC	0.172	0.24	0.245	0.194	0.224	0.154	0.123	0.205	0.16
Q1B3-FC	0.183	0.251	0.257	0.205	0.235	0.165	0.142	0.216	0.171
Q1B4-FC	0.189	0.267	0.262	0.211	0.247	0.172	0.155	0.237	0.188
Q1C1-FC	0.156	0.258	0.231	0.193	0.237	0.162	0.108	0.228	0.182
Q1C2-FC	0.186	0.243	0.245	0.193	0.227	0.167	0.184	0.207	0.163
Q1C3-FC	0.171	0.245	0.238	0.186	0.224	0.153	0.17	0.215	0.166
Q1C4-FC	0.229	0.297	0.303	0.251	0.281	0.211	0.229	0.262	0.217
Q1D1-FC	0.096	0.163	0.169	0.117	0.147	0.077	0.071	0.134	0.083
Q1D2-FC	0.154	0.222	0.228	0.176	0.206	0.136	0.106	0.19	0.142
Q1D3-FC	0.205	0.263	0.265	0.213	0.246	0.186	0.203	0.227	0.183
Q1D4-FC	0.253	0.308	0.314	0.262	0.292	0.234	0.254	0.273	0.228
Q2A1-FC	0.194	0.295	0.266	0.228	0.274	0.202	0.143	0.265	0.24
Q2A2-FC	0.133	0.21	0.207	0.155	0.189	0.115	0.084	0.19	0.131
Q2A3-FC	0.069	0.145	0.125	0.078	0.125	0.065	0.075	0.115	0.082
Q2A4-FC	0.072	0.14	0.145	0.094	0.124	0.053	0.053	0.112	0.073
Q2B1-FC	0.068	0.078	0.059	0.028	0.07	0.049	0.108	0.049	0.043
Q2B2-FC	0.07	0.149	0.144	0.092	0.128	0.053	0.045	0.124	0.078
Q2B4-FC	0.087	0.183	0.16	0.118	0.162	0.087	0.07	0.153	0.104
Q2C1-FC	0.085	0.148	0.154	0.102	0.132	0.063	0.082	0.127	0.068
Q2C2-FC	0.076	0.19	0.164	0.125	0.17	0.095	0.081	0.16	0.111
Q2C3-FC	0.107	0.194	0.171	0.134	0.174	0.104	0.048	0.184	0.135
Q2C4-FC	0.079	0.084	0.089	0.043	0.068	0.041	0.118	0.059	0.034
Q2D1-FC	0.106	0.067	0.075	0.063	0.05	0.07	0.14	0.05	0.065
Q2D2-FC	0.117	0.175	0.179	0.134	0.143	0.099	0.072	0.159	0.126
Q2D3-FC	0.093	0.082	0.088	0.05	0.066	0.052	0.128	0.061	0.036
Q2D4-FC	0.089	0.149	0.155	0.103	0.133	0.063	0.084	0.12	0.079
Q3A1-FC	0.089	0.077	0.076	0.053	0.052	0.064	0.126	0.043	0.06
Q3A2-FC	0.149	0.027	0.06	0.089	0.054	0.114	0.179	0.061	0.098
Q3A3-FC	0.1	0.033	0.017	0.042	0.036	0.078	0.13	0.038	0.072
Q3A4-FC	0.057	0.092	0.059	0.04	0.074	0.068	0.1	0.071	0.063
Q3B1-FC	0	0.133	0.103	0.064	0.101	0.041	0.063	0.098	0.078
Q3B2-FC		0	0.035	0.073	0.046	0.096	0.163	0.051	0.08
Q3B4-FC			0	0.053	0.053	0.092	0.13	0.053	0.086
Q3C1-FC				0	0.048	0.04	0.096	0.054	0.034
Q3C2-FC					0	0.075	0.132	0.035	0.064
Q3C3-FC						0	0.077	0.08	0.038
Q3C4-FC							0	0.143	0.114
Q3D1-FC								0	0.063
Q3D2-FC									0

Appendix E. (cont.)

Section Q of Λ CDM.

	Q3D3-FC	Q3D4-FC
Q1A1-FC	0.225	0.173
Q1A2-FC	0.062	0.131
Q1A3-FC	0.216	0.177
Q1A4-FC	0.255	0.2
Q1B1-FC	0.197	0.171
Q1B2-FC	0.21	0.145
Q1B3-FC	0.213	0.156
Q1B4-FC	0.251	0.161
Q1C1-FC	0.242	0.15
Q1C2-FC	0.193	0.17
Q1C3-FC	0.226	0.155
Q1C4-FC	0.233	0.211
Q1D1-FC	0.121	0.068
Q1D2-FC	0.16	0.127
Q1D3-FC	0.22	0.188
Q1D4-FC	0.255	0.237
Q2A1-FC	0.276	0.187
Q2A2-FC	0.194	0.109
Q2A3-FC	0.14	0.064
Q2A4-FC	0.124	0.044
Q2B1-FC	0.107	0.058
Q2B2-FC	0.133	0.043
Q2B4-FC	0.166	0.075
Q2C1-FC	0.099	0.061
Q2C2-FC	0.174	0.083
Q2C3-FC	0.178	0.099
Q2C4-FC	0.057	0.059
Q2D1-FC	0.023	0.087
Q2D2-FC	0.143	0.093
Q2D3-FC	0.051	0.073
Q2D4-FC	0.091	0.055
Q3A1-FC	0.033	0.072
Q3A2-FC	0.084	0.13
Q3A3-FC	0.075	0.088
Q3A4-FC	0.112	0.077
Q3B1-FC	0.11	0.034
Q3B2-FC	0.085	0.114
Q3B4-FC	0.088	0.104
Q3C1-FC	0.079	0.051
Q3C2-FC	0.062	0.087
Q3C3-FC	0.08	0.021
Q3C4-FC	0.138	0.063
Q3D1-FC	0.066	0.085
Q3D2-FC	0.087	0.059
Q3D3-FC	0	0.092
Q3D4-FC		0