

Microbial Distribution and Activity in a Coastal Acid Sulfate Soil System

Yu-Chen Ling and John W. Moreau

School of Earth Sciences, University of Melbourne, Melbourne, VIC 3010, Australia

Introduction: Bioremediation in coastal acid sulfate soil systems

Coastal acid sulfate soil (CASS) systems were formed when people drained the coastal area exposing the soil to the air. Drainage makes iron sulfides oxidize and release acidity to the environment, low pH pore water further dissolved the heavy metals. The acidity and toxic metals then contaminate coastal and nearby ecosystems and cause environmental problems, such as fish kills, decreased rice yields, release of greenhouse gases, and construction damage. In Australia, there is about a \$10 billion “legacy” from acid sulfate soils, even though Australia is only occupied by around 18% of the global acid sulfate soils.

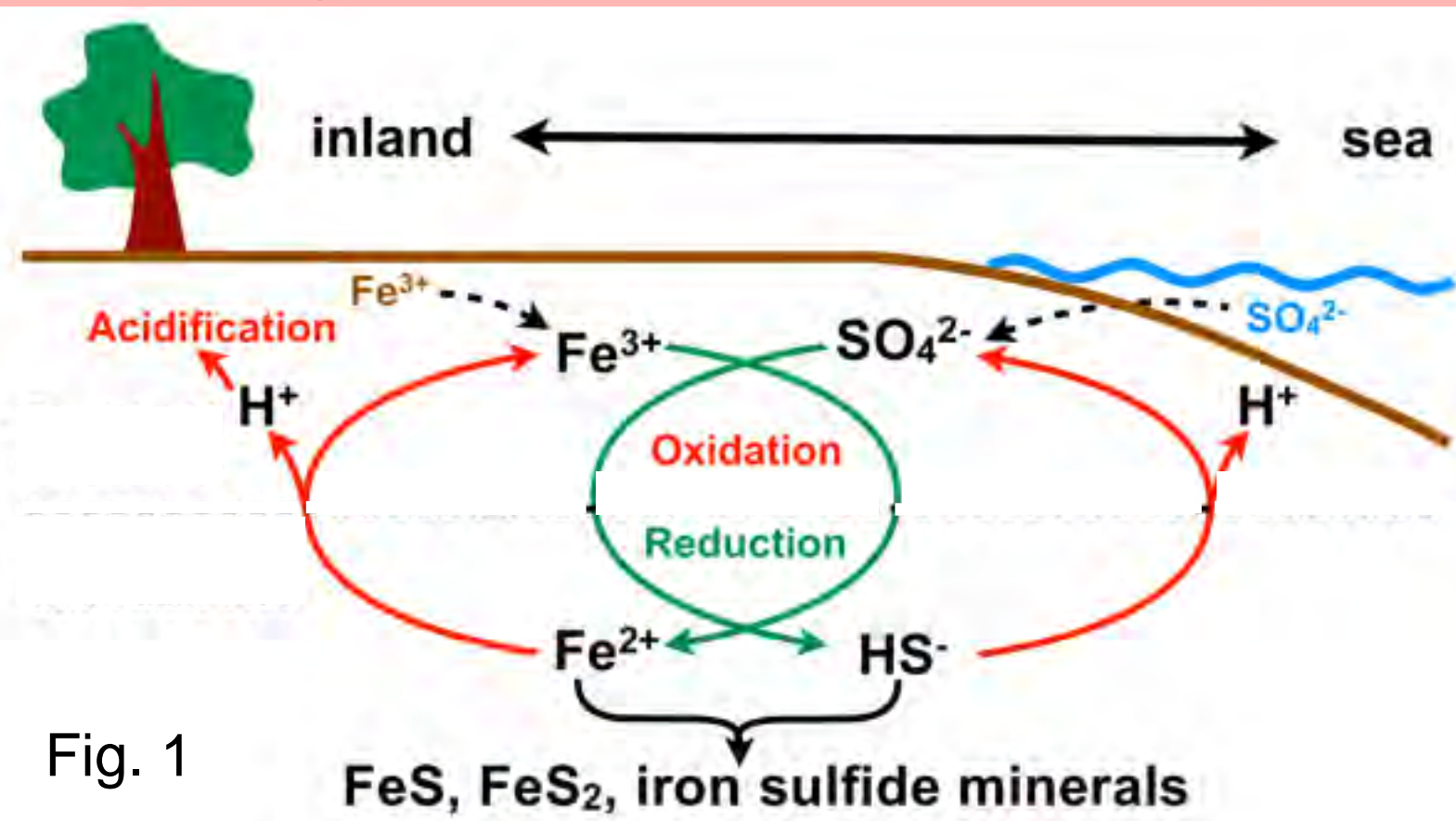


Fig. 1

Tidal inundation provides a potential economic treatment for the CASS issue. Microbial reduction contributes to more than 50% of the alkalinity by generating iron(II) and sulfide, which will combine and deposit iron sulfide minerals back to the soils. However, there is limited knowledge about microbial dynamics in long-term efficiency in the CASS system.

Motivation: Providing detailed information about microbial distribution and activity patterns for people who want to build up a complete biogeochemical model, which can be used to predict and evaluate bioremediation long-term efficiency or potential land management.

Study site and methods

Study site: East Trinity wetland, Cairns
1970s-2001: Drainage;
After 2001: Tidal inundation treatment

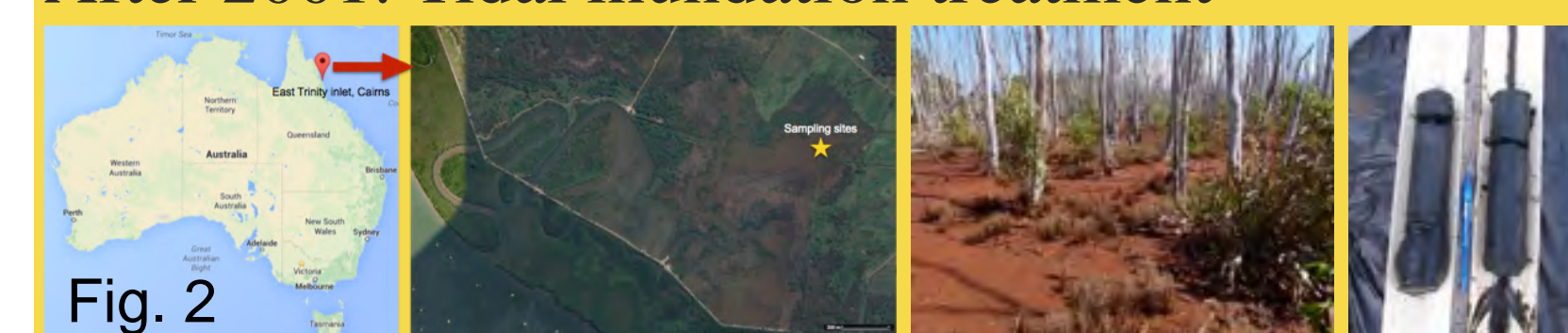


Fig. 2

Sampling:

3 sites x 20 cm depth x 4 tidal times

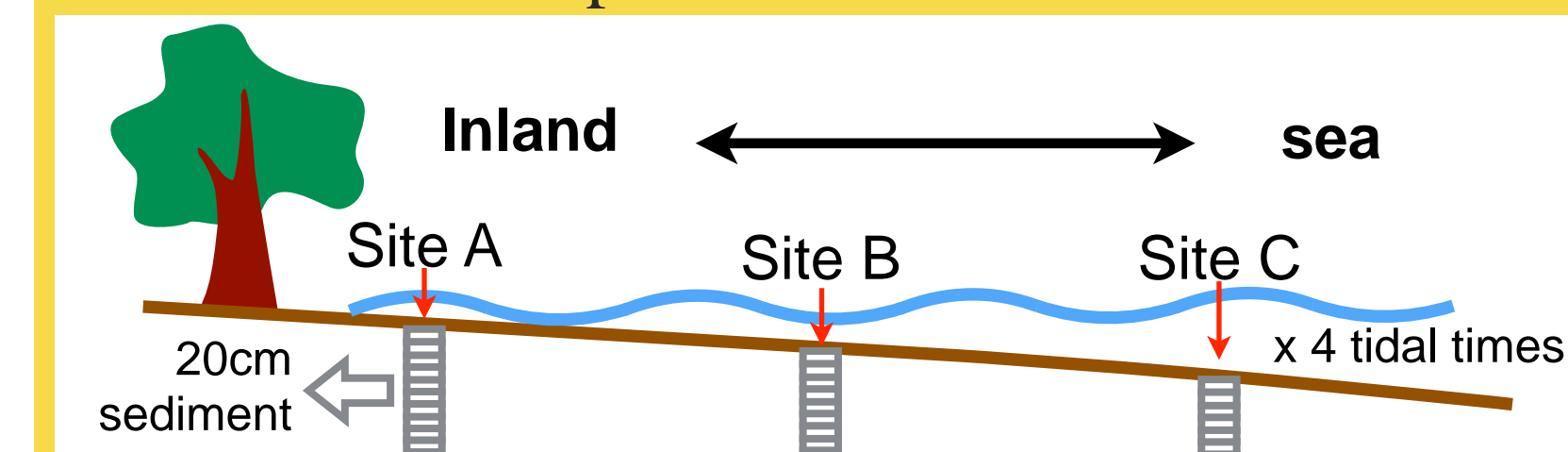


Fig. 3 Sampling strategy

Experiments:

- 1) DNA extraction
- 2) RNA isolation ▶ cDNA synthesis
- 3) 16S rRNA, 16S rRNA gene amplicons

Sequencing (454 and Miseq sequencing)
Bioinformatic analyses (Mothur software)

Microbial distribution (DNA abundances)
Microbial activity (cDNA:DNA ratios)

Microbial distribution controlled by environmental parameters

Microbial structures can be grouped into three zones based on the highest similarity between samples (Fig. 4). These three zones were consistent with their geological background (Fig. 5). Zone 1: Organic horizon, had the lowest pH value. Zone 2: surface tidal zone, was influenced the most by tidal activity. Zone 3: Sulfuric zone, this area got neutralized the most.

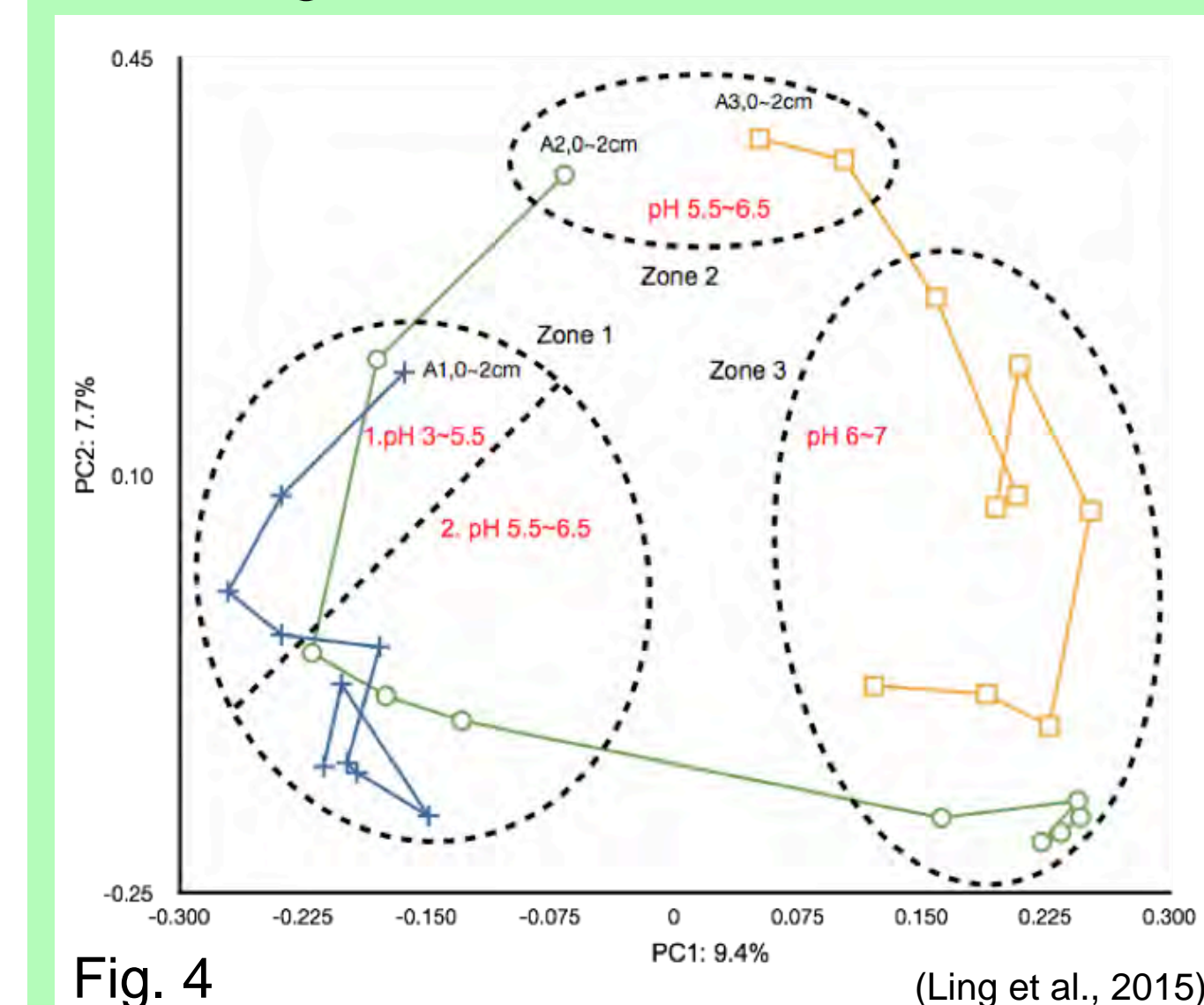


Fig. 4

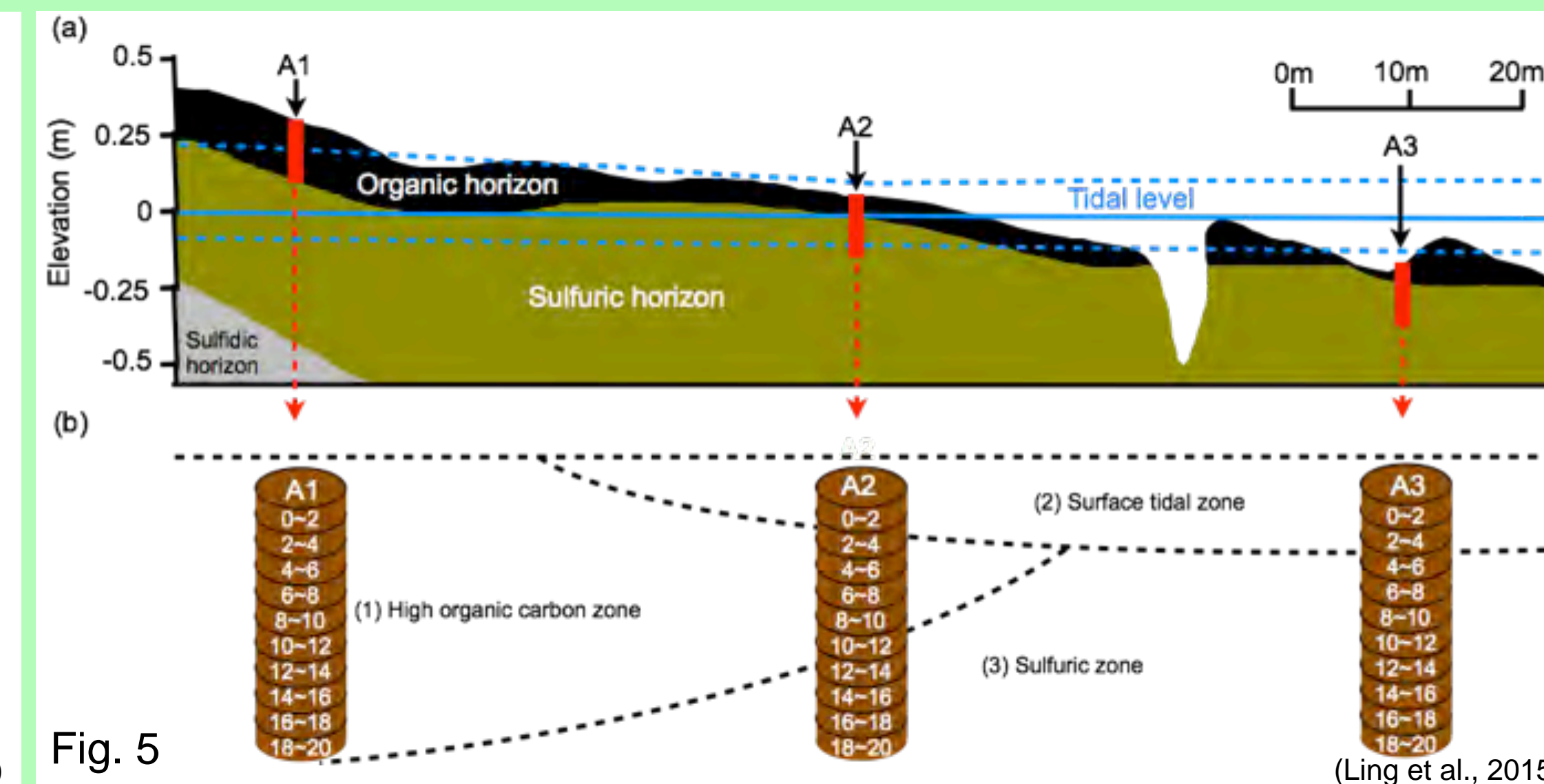


Fig. 5

These three zones showed similar microbial members but in different abundances, which were controlled by environmental parameters.

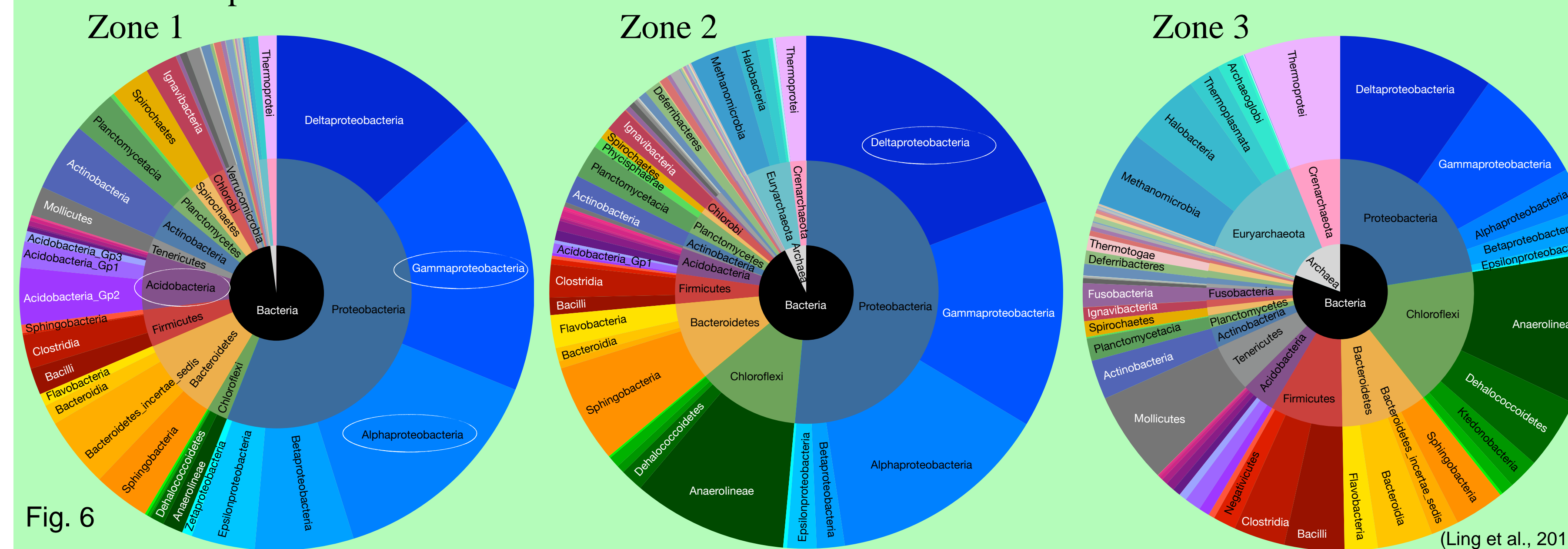


Fig. 6

For example, Zone 1 contained microorganisms that favor a lower pH condition, Zone 2 contained the most sulfate-reducing bacteria.

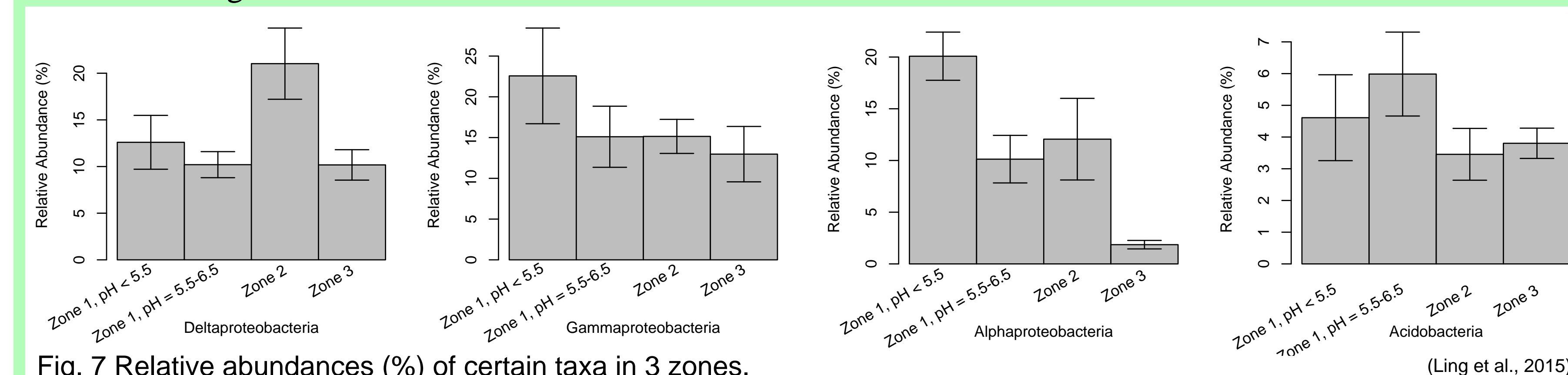


Fig. 7 Relative abundances (%) of certain taxa in 3 zones.

The abundance of iron-reducing bacteria was proportional to sulfate reducing bacteria in Zone 3, this suggests that iron sulfides deposition favors both iron and sulfate reduction.

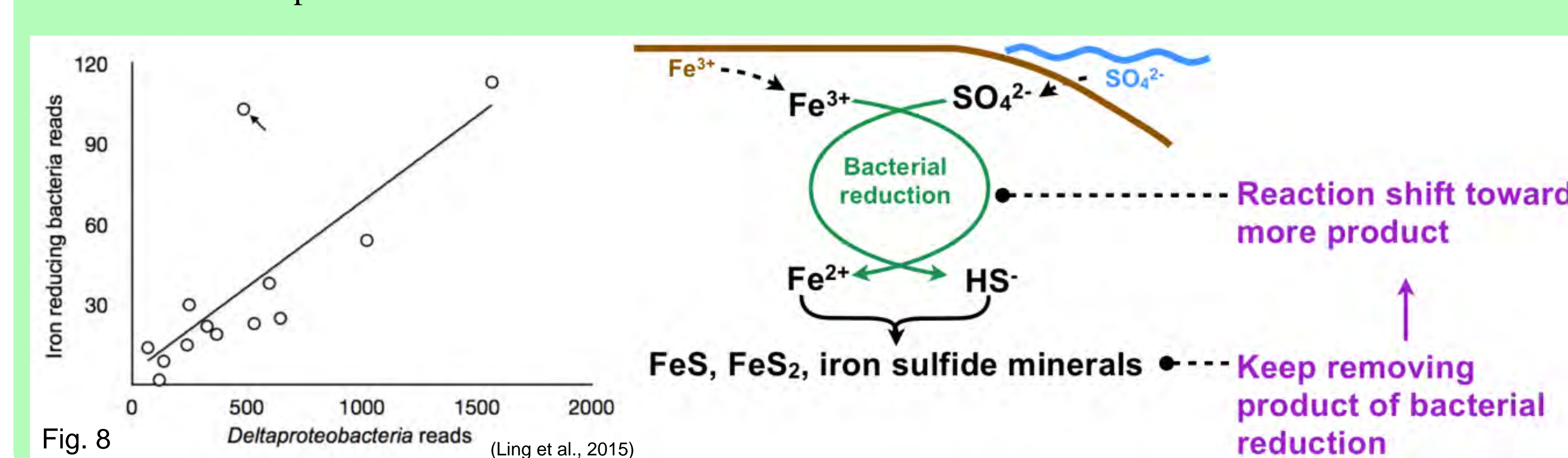
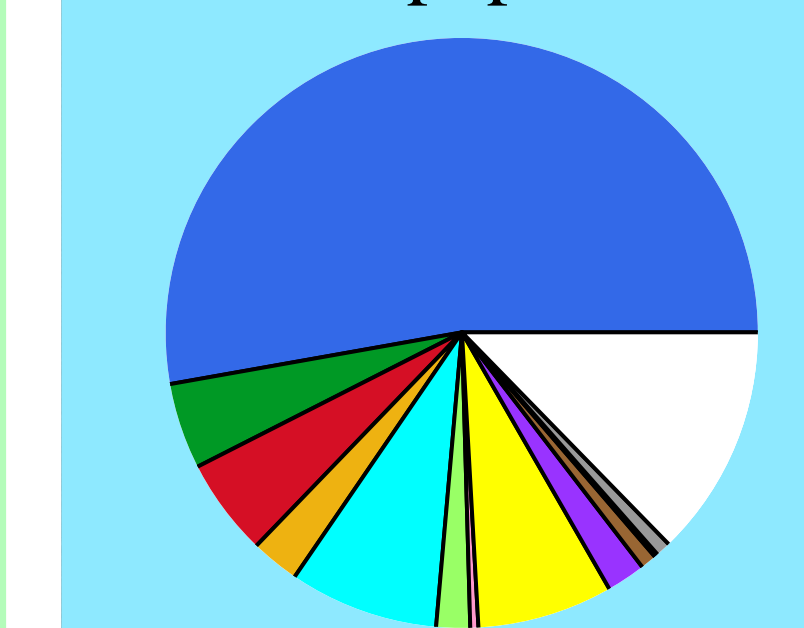


Fig. 8

Microbial activity showed two patterns

Abundant populations, such as Deltaproteobacteria, kept constant activity across tidal cycling, whereas rare populations changed activity response to environmental variations. Activity = cDNA/DNA

Abundant populations:



Rare populations:

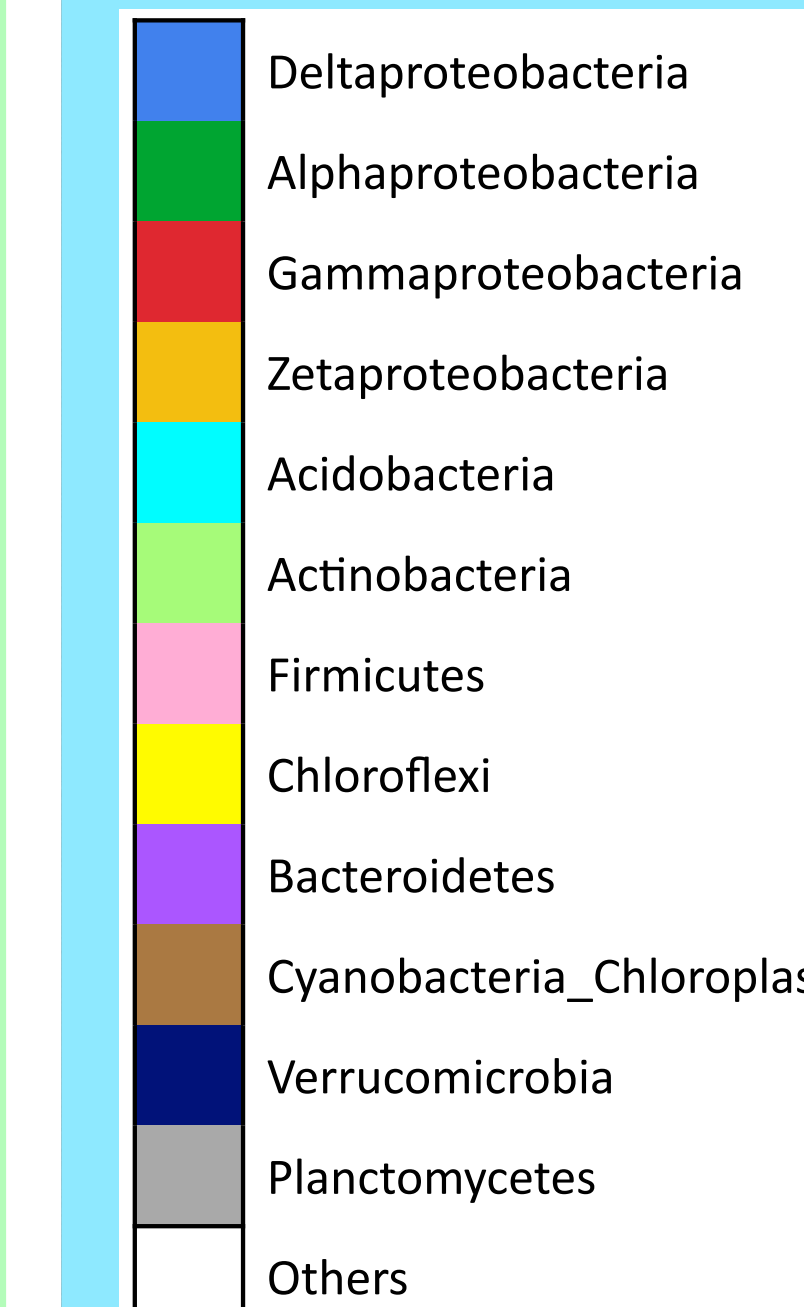
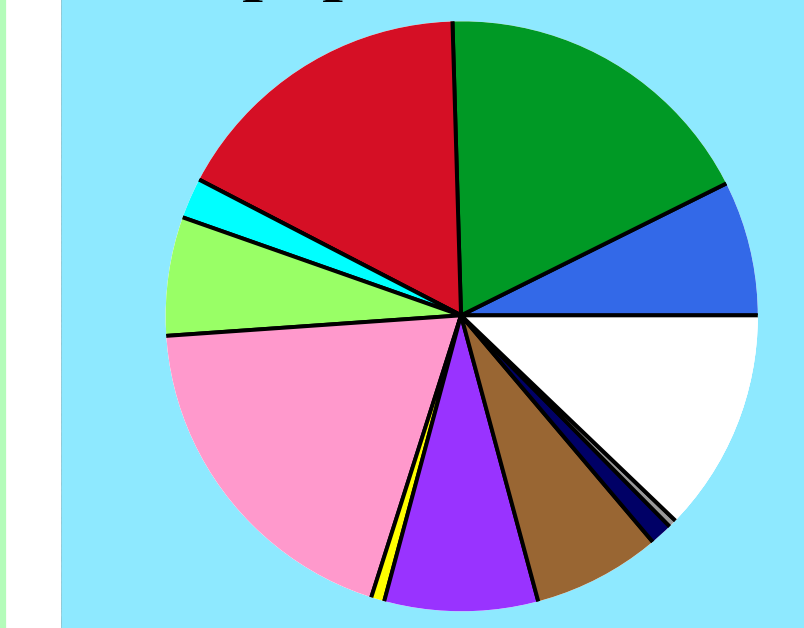


Fig. 9 Microbial compositions

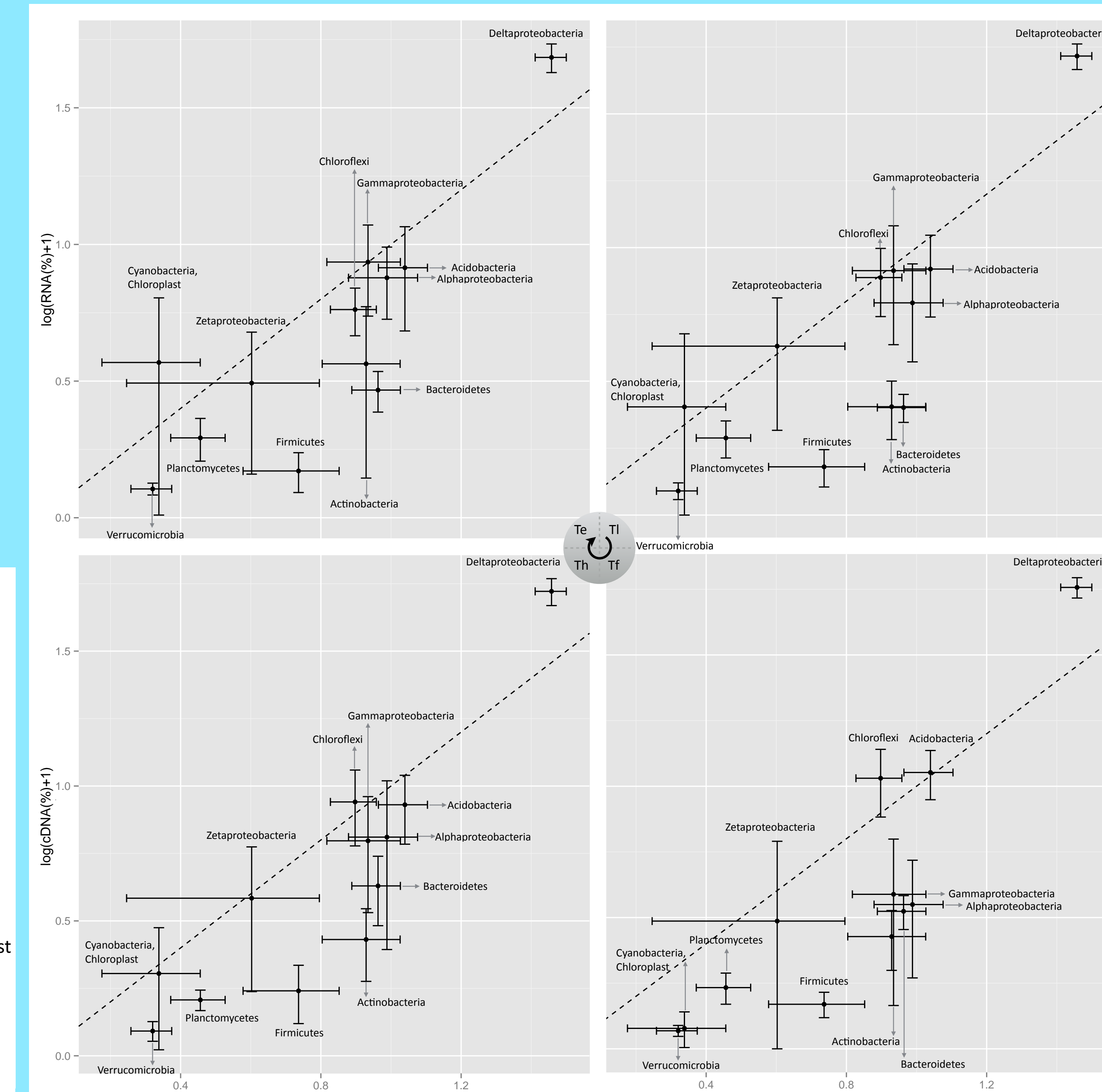


Fig. 10 Microbial activity (cDNA:DNA) across a tidal cycle

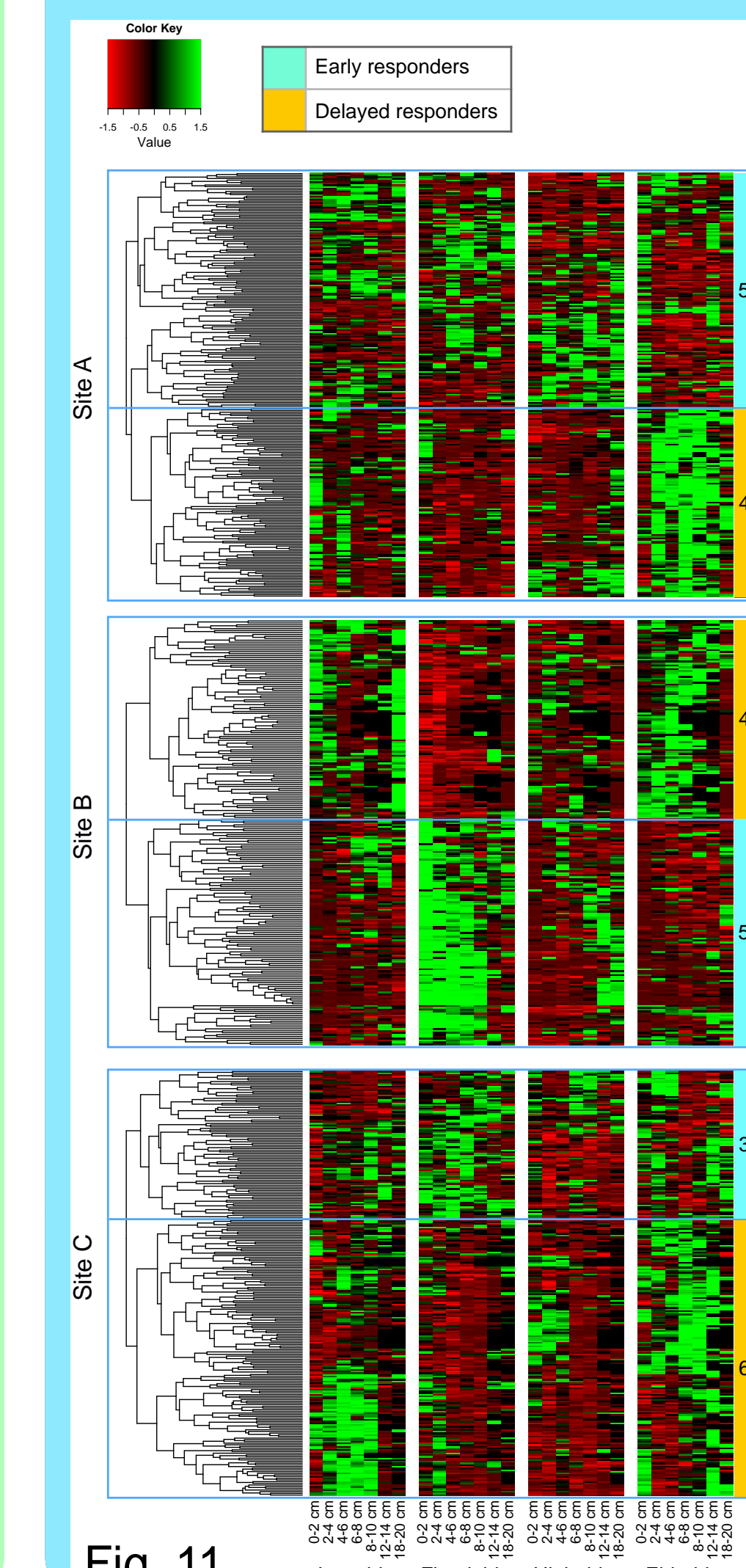


Fig. 11

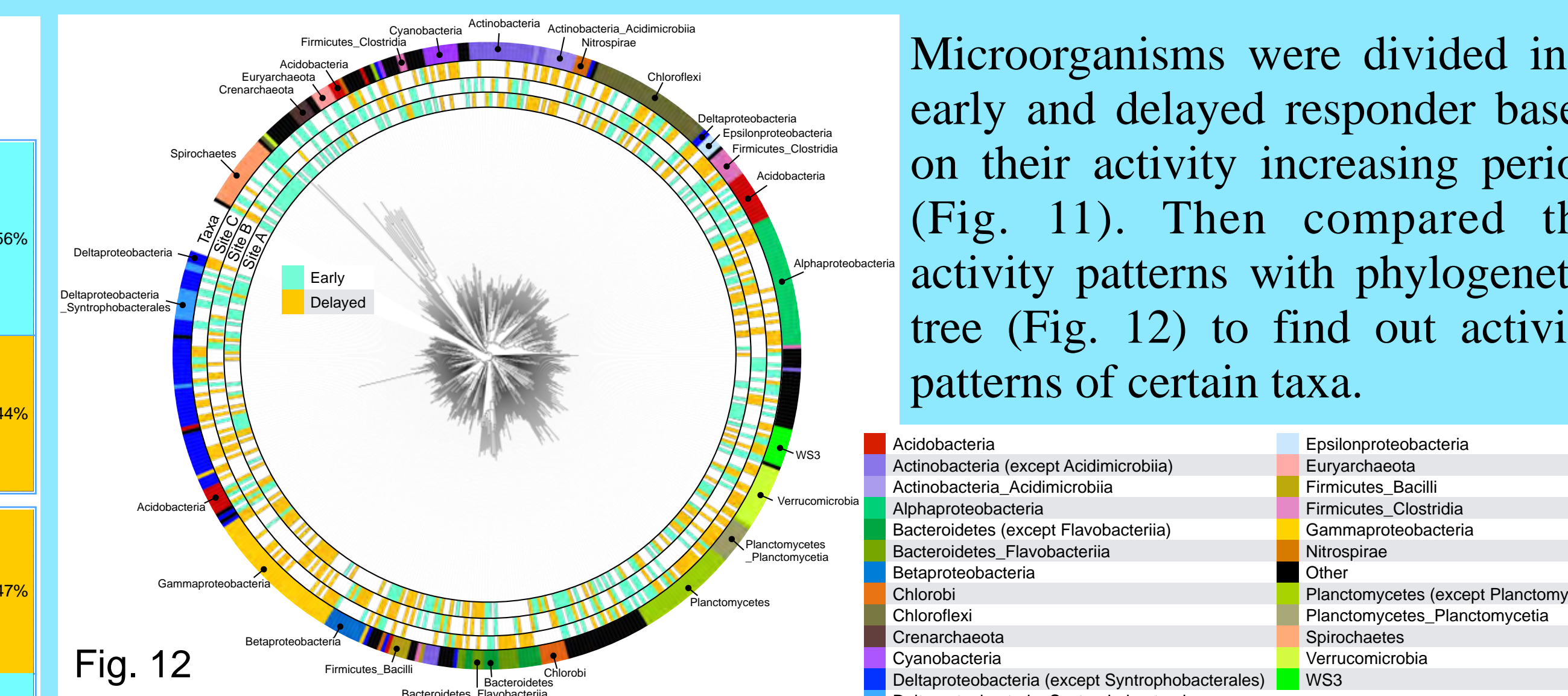


Fig. 12

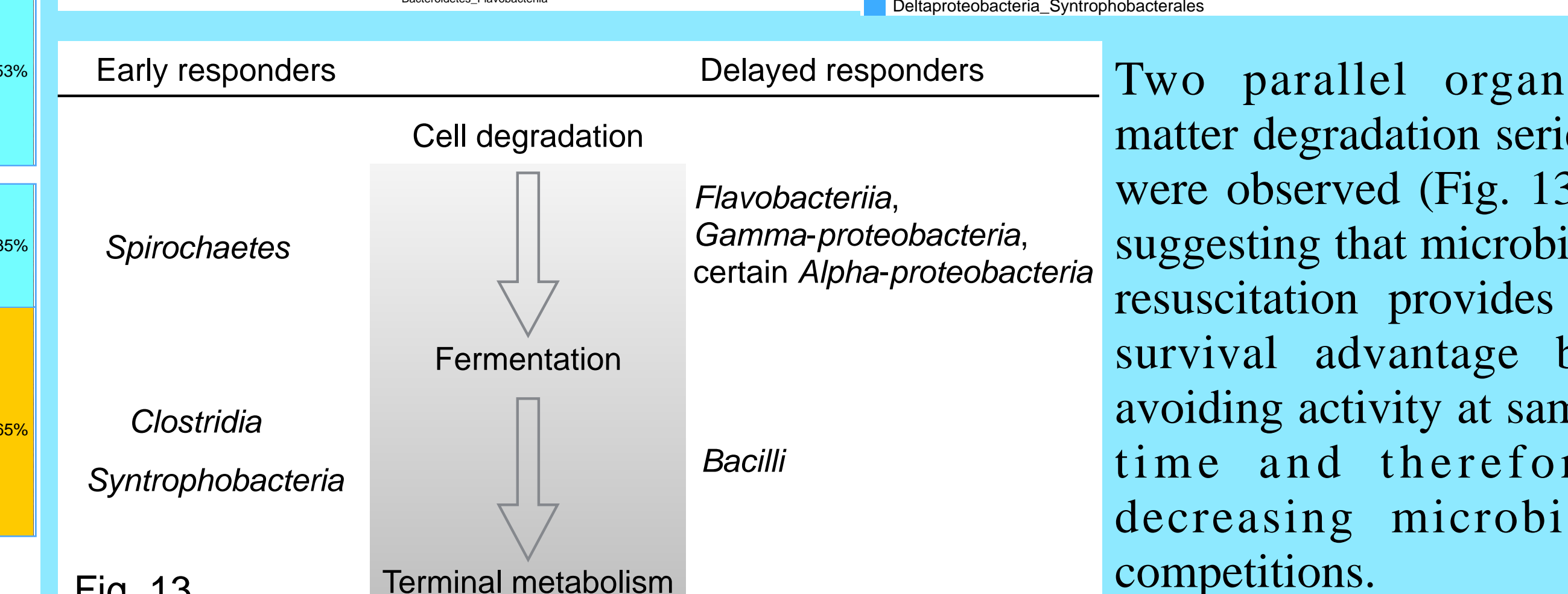


Fig. 13

Microorganisms were divided into early and delayed responder based on their activity increasing period (Fig. 11). Then compared the activity patterns with phylogenetic tree (Fig. 12) to find out activity patterns of certain taxa.

Two parallel organic matter degradation series were observed (Fig. 13), suggesting that microbial resuscitation provides a survival advantage by avoiding activity at same time and therefore decreasing microbial competitions.

Conclusions

Microbial distribution differed from typical redox zonations and is controlled by environmental parameters such as pH, soil layering, water saturation, and iron sulfide mineralization.

Microbial activity showed that abundant population kept constant activity across tidal cycling, whereas rare populations change activity in response to environmental changes, and overall had a higher activity.

Microbial resuscitation provides a survival advantage for microorganisms in a dynamic environment. This study suggests both abundant and rare populations may play important roles in the ecology.

Acknowledgments

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