



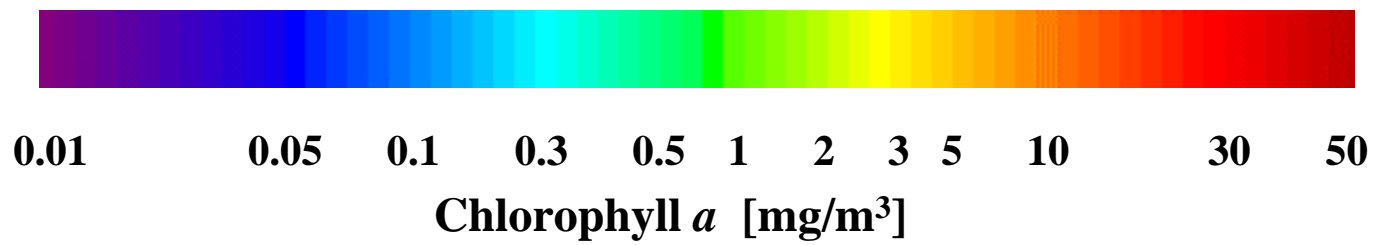
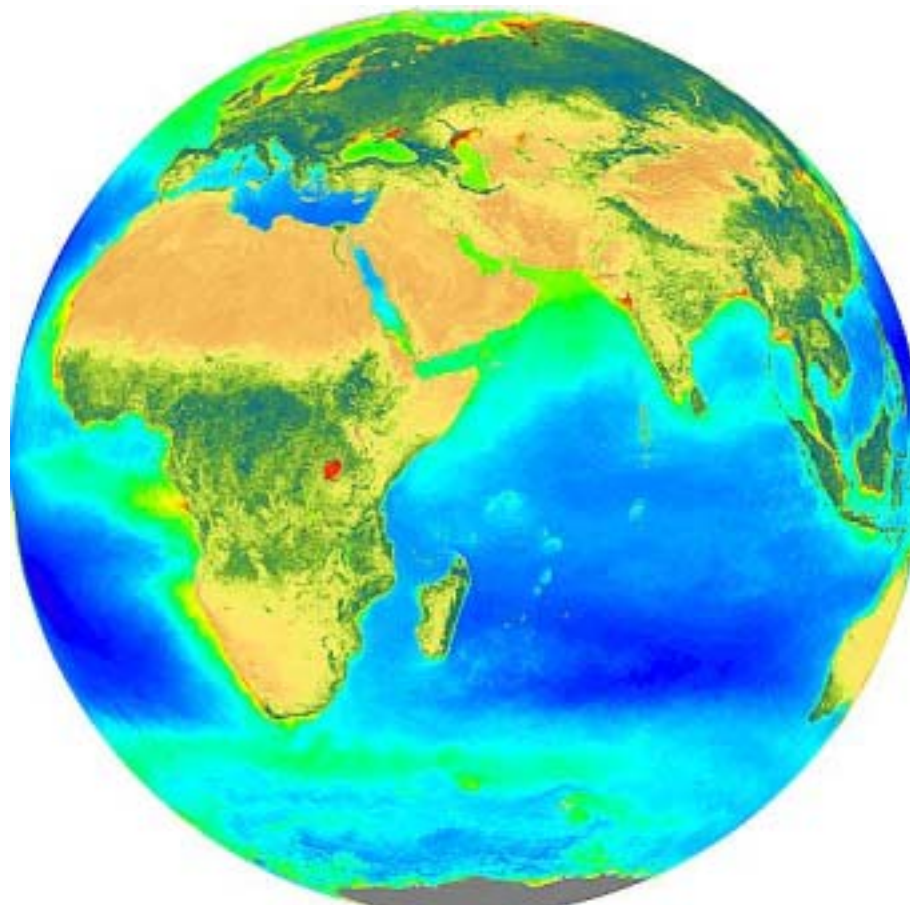
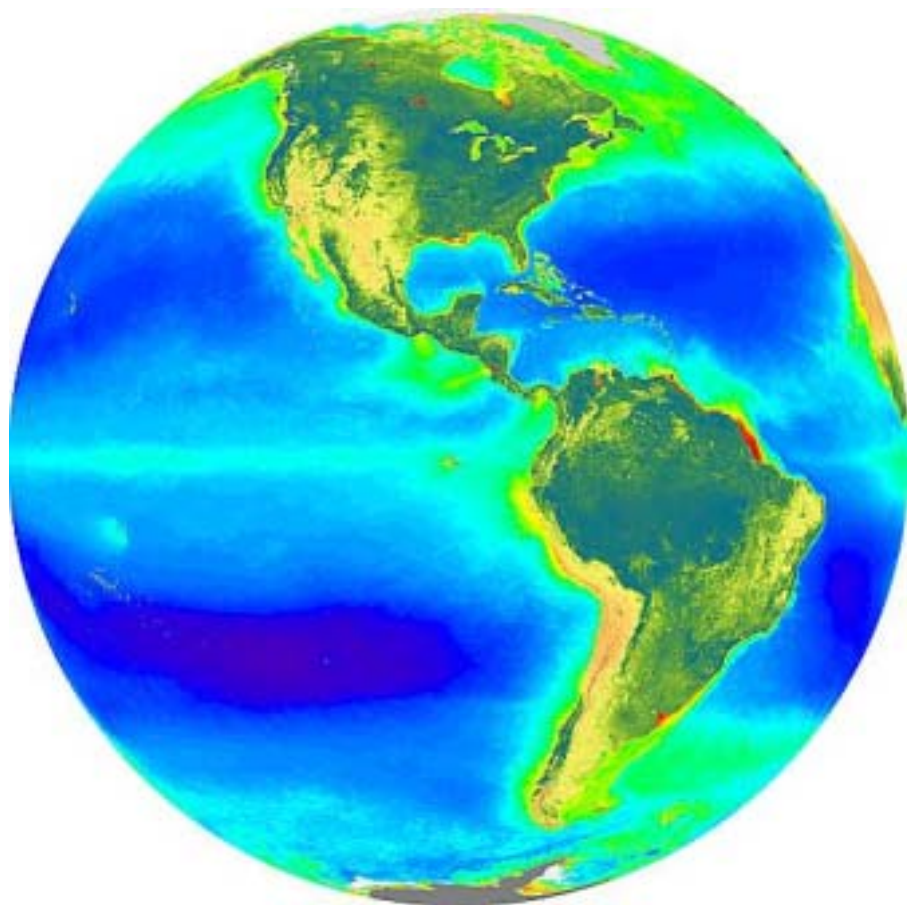
Marine Viruses and Cyanobacterial Community Structure

**1) Martin Mühling, 1) Fuller N.J., 1) Millard A., 1) Scanlan D.J.,
2) Post A.F., 3) Wilson W.H., and 1) Mann N.H.**

1) University of Warwick, Coventry, UK

2) The Interuniversity Institute for Marine Science Eilat, Israel

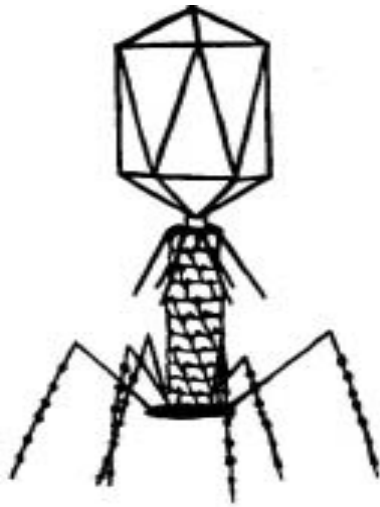
3) Marine Biological Association, Plymouth, UK



Marine cyanophage

- Phage infecting marine *Synechococcus* have been isolated and characterized
- The large majority of isolates are myoviruses, some siphoviruses and podoviruses

Myoviruses



Virus host interactions

- **Minimum density for productive infection is $\sim 10^4$ host cells per mL**
(Wiggins & Alexander, AEM 1985)
- **Seasonal pattern of lysogeny: induction of prophage during winter**
(McDaniel et al., Nature 2002)
- **Viruses are responsible for “reduced primary productivity . . . by as much as 78%”**
(Suttle et al., Nature 1990)
- **Cyanophage “have a negligible effect in regulating densities of marine *Synechococcus*”**
(Waterbury & Valois, AEM 1993)

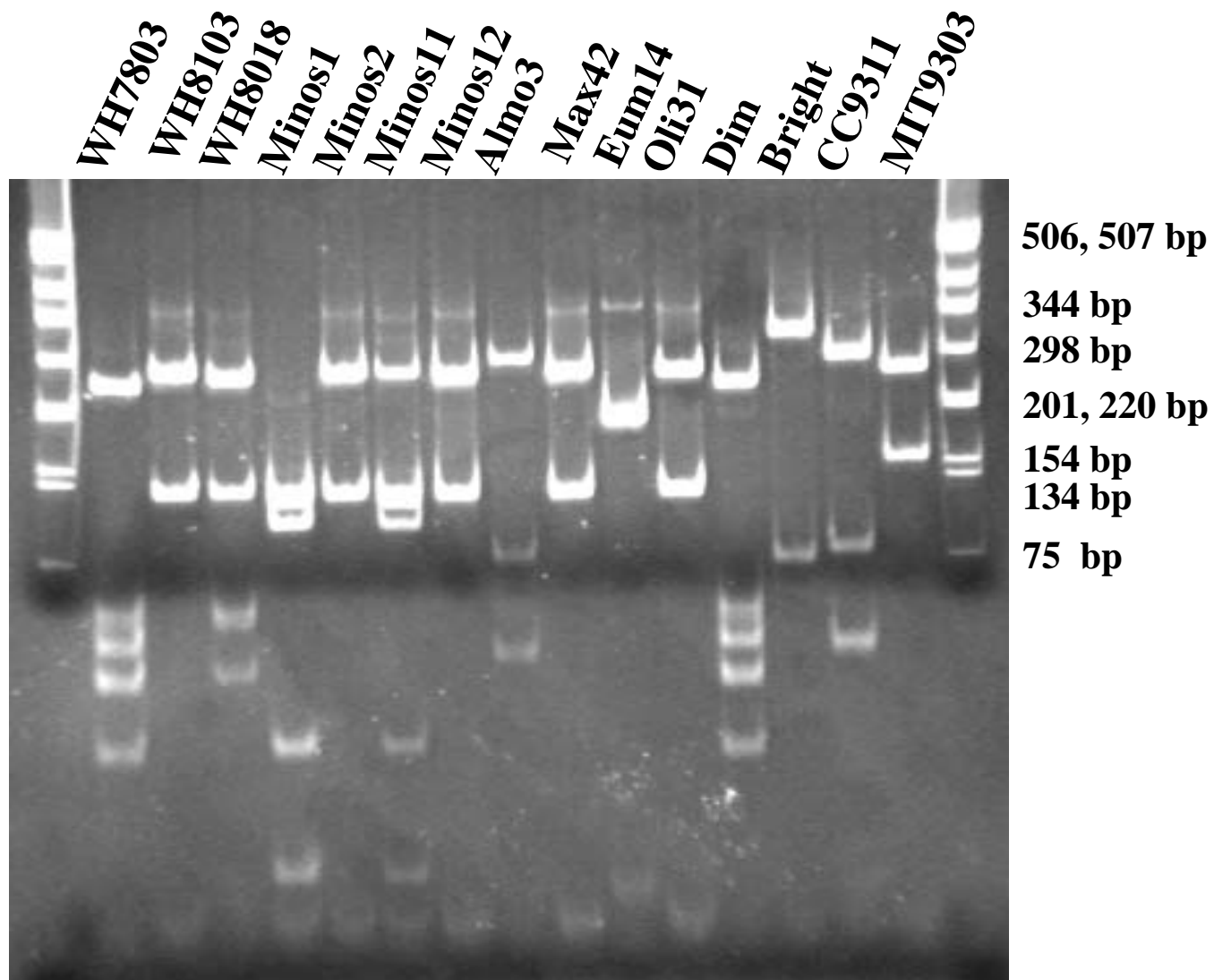
Do cyanophage have an impact on

a) the abundance and

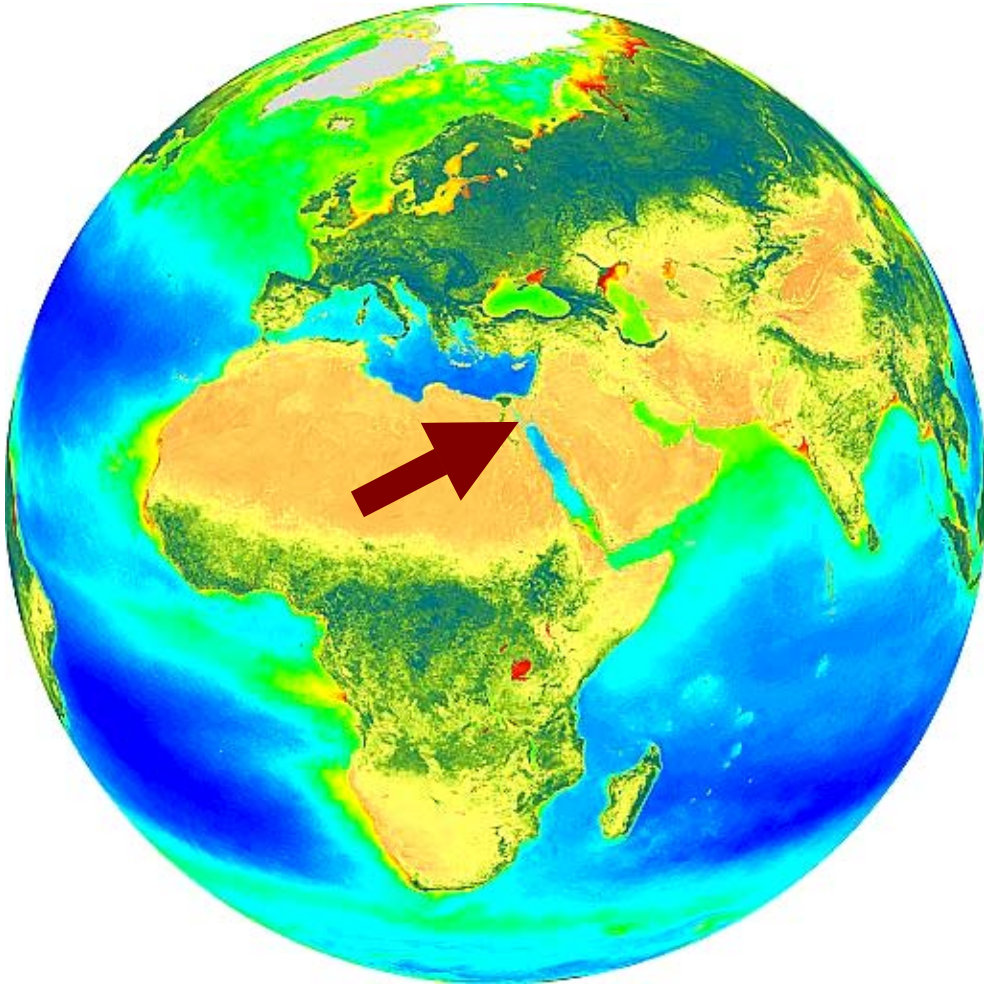
b) the community structure

of marine *Synechococcus* and *vice versa*?

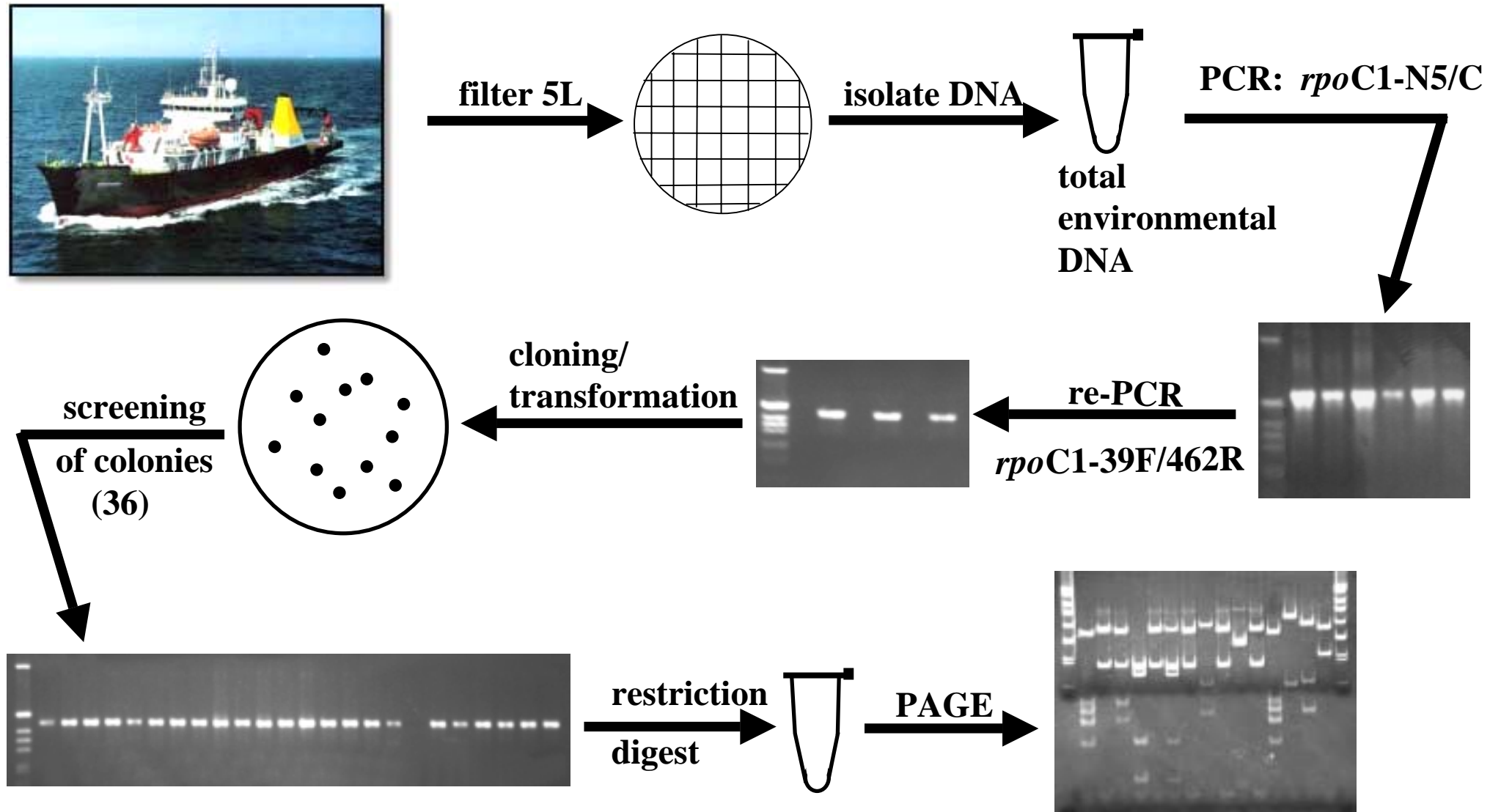
RFLP of *rpoC1* gene fragments - *Bst*UI, *Hae*III, *Bcl*II



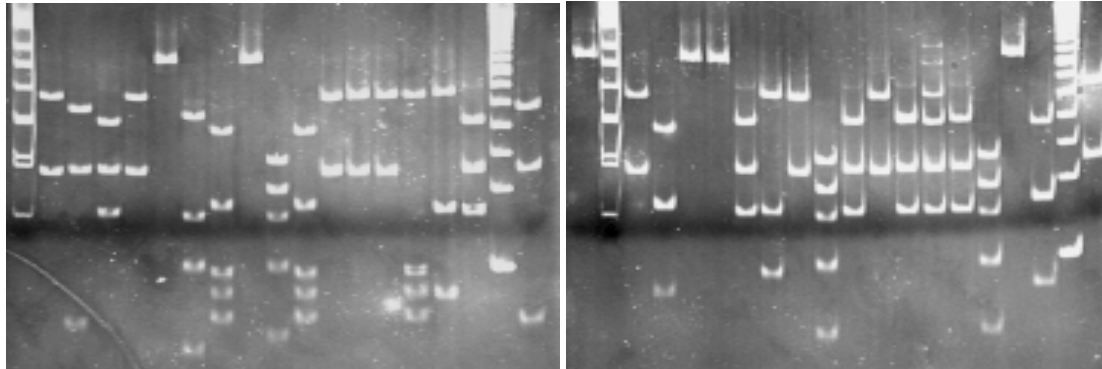
Sampling site in the Red Sea - Gulf of Aqaba



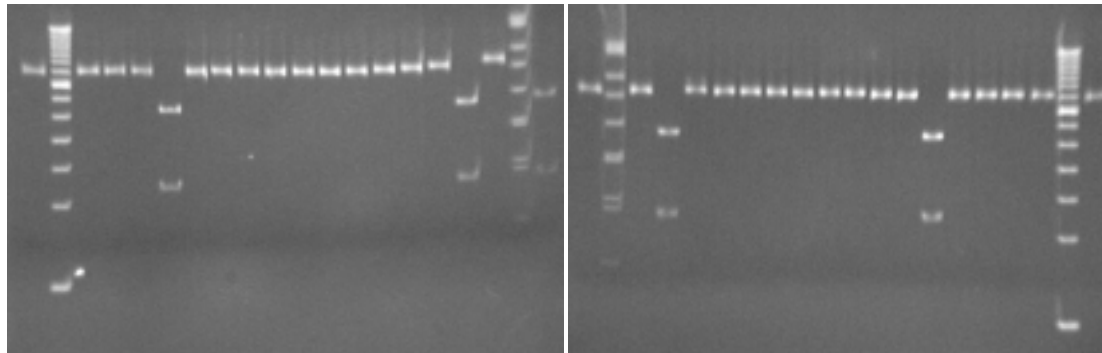
Analysis of *Synechococcus* population structure - Methodology



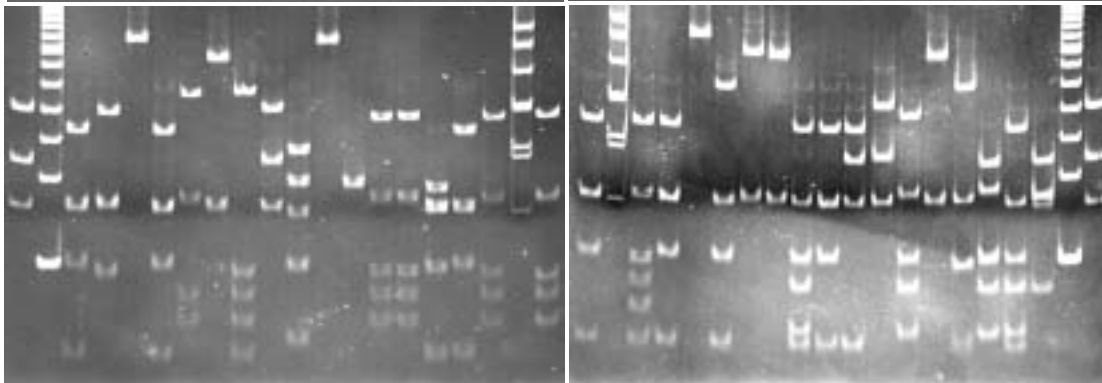
Examples of *Synechococcus* diversity versus annual cycle



19. April 1999 - 10m

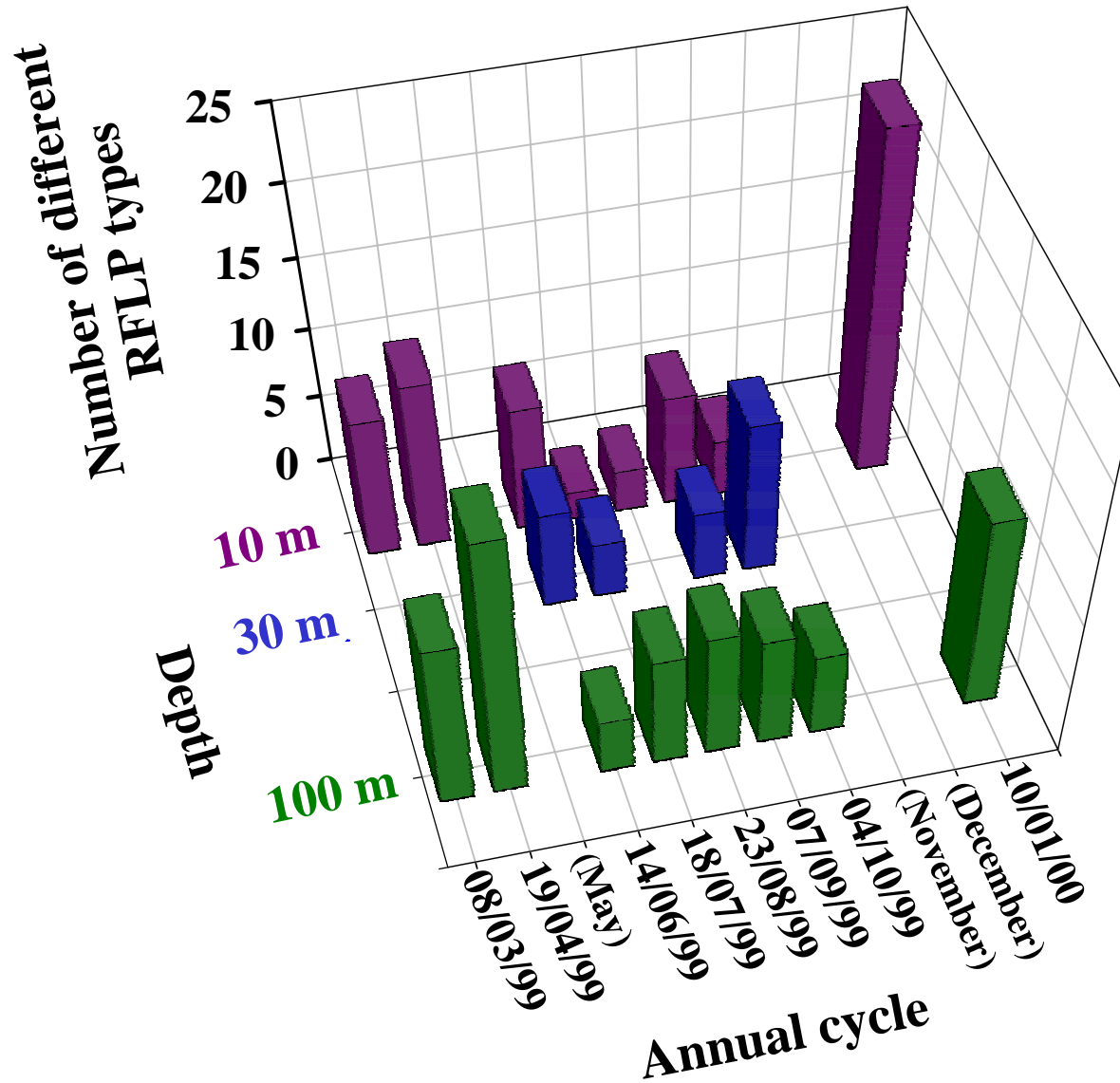


18. July 1999 - 10m

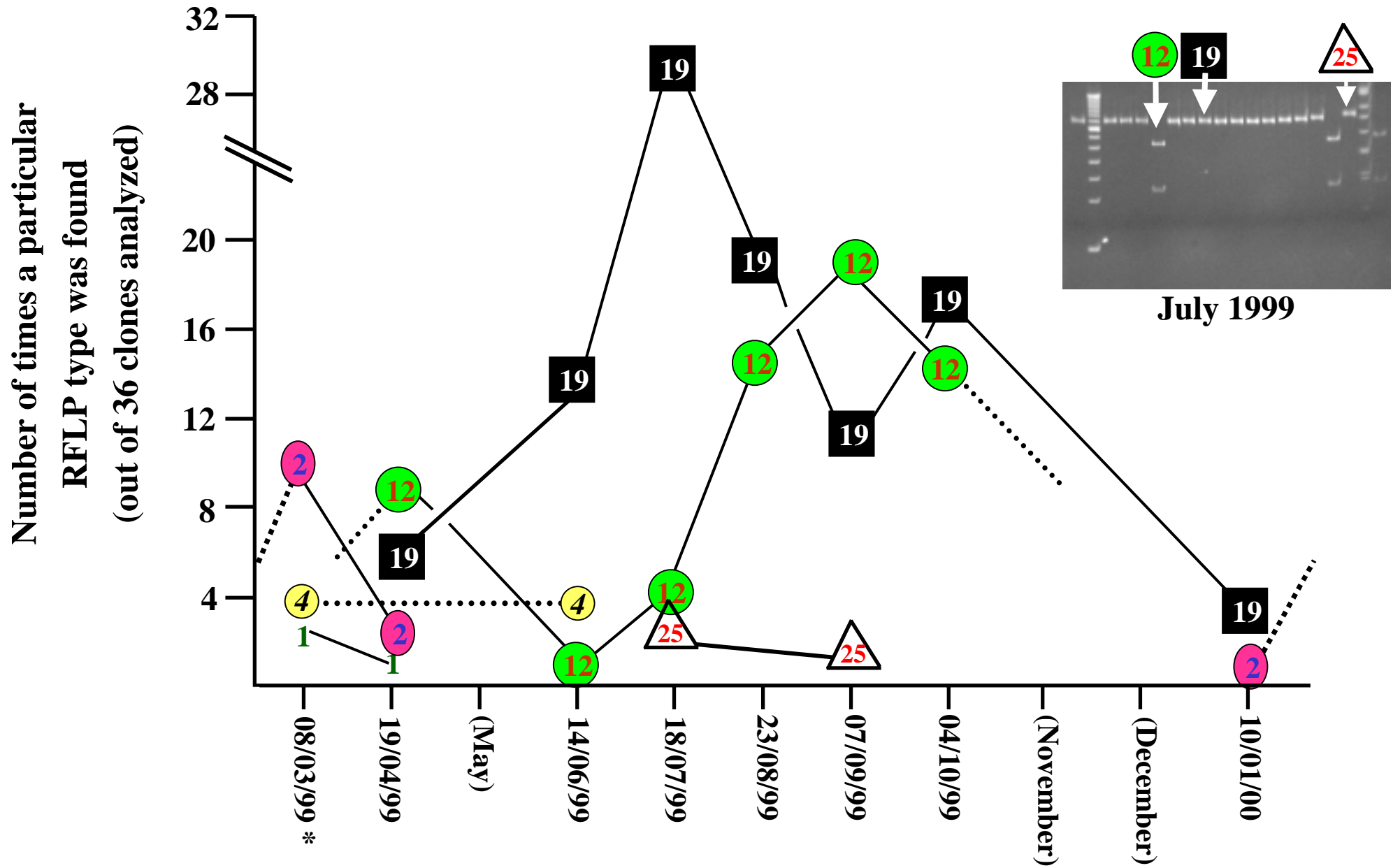


10. January 2000 - 10m

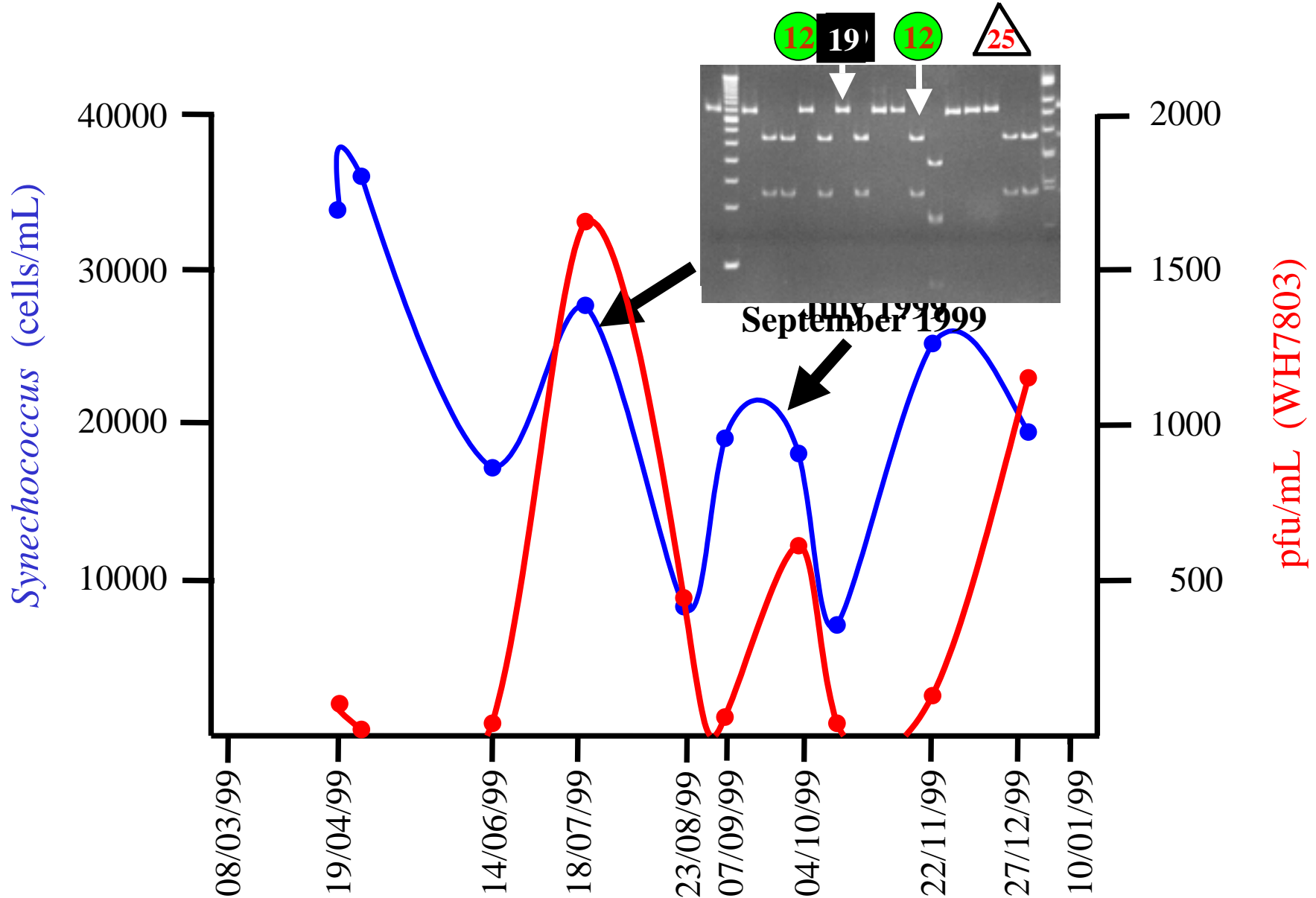
Synechococcus diversity in time and space



Occurrence of RFLP types over annual cycle (semiquantitatively) - 10 m



Abundance of cyanophages infecting *Synechococcus* spp. – 10m



Partial g20 alignment

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*      20      *      40      *      60      *      80      *      100
3-PM2   : -C-TTCTGGTTTGATG---GATCTAAAACAAAAGGTTG---ACATTAAGCTTTCTCCATRAAGGCATCAASTCTCTCAATCAACTTAGAATGATCGAGGAC : 92;
3-WHM1  : -CACTCAGGTAATCAA---GACCTGAATAAAAAGGTTG---ACTCTTAGTCACCTACATAAGGCAGTTAAGGCAGTCAACCRAACTTAGAATGATCGAAGAC : 93;
3-BnM1  : -CAGTCTGGTCTCTCTT---GACGCAAAACAAAGGTTG---GTTCTTTTCATACCTCCATRAAGGCATCAAGGCACCTCAATCAACTTCGGCATGATCGAGGAC : 93;
F4      : -CATTCCTGGATGATGTC---GATTGTGTGCGGTARARAT---ATCATCGGGTATTTGCATCGTGGCTGTAAACCTGCTAACCAATTAARATTAATGAGAGAT : 93;
NB020525 : -CACAGCGGATTAATGCGCGSTGTGTGCCSTGTGCCCFACATTAATCGGTATCTTGATCGTGCCTTCAAGCCGTGCAACCAGTTGAAATGCTAGAGAT : 99;
      Ca tc GG T t Ga ca a a g a T g ta cT cA GC aT AA C AA CAa T a aaTg T GA GA

*      120     *      140     *      160     *      180     *      200
3-PM2   : TCACTTGTATCTATCGTTTATCTCGTGCCTCCCGAGCGTAGAATTTTCTATATGATGTTGGTAACTCAACCAAGGTTARAGGCAGAACAAATACCTGCGGTG : 192;
3-WHM1  : TCCTTGGTATCTACCGTTTGGAGTAGAGCACCAGAGCGTGGTATTTTCTACATTTGACGTTGGTAACTCAACCAAGGTTAAAGCGGAACAATATCTCCGGTG : 193;
3-BnM1  : TCTCTGGTCACTATCGTTTATCACCGCGCACCGAAGCGTAGAATTTTCTACATTTGATGTTGGCAATCTCCCAAGGTTAAAGCGGAGCAATACCTCAGAG : 193;
F4      : GCTGTAGTCATTAATCGCAATTACTCGTGCCTCCGACCGTCCGGTTTGGTATGTAGACACAGGTAAATAGGCCCTGCTCGTAAAGCTGCTGAGCAGCTGCAAC : 193;
NB020525 : GCGTTCGGTATCTATCGTCTAGCACGTGCCCCGAGCGTCCCGTATCTATGTTGACGTTGGTAACTCAACCAAGGTTAAAGCGGAGCAATACGTAAGT : 199;
      C T GT ATcTAtcGt T c cG GC CC GA CGT G TttcTA TtGA gttGGtAAT T CC a AAGC ga cAatAc T g

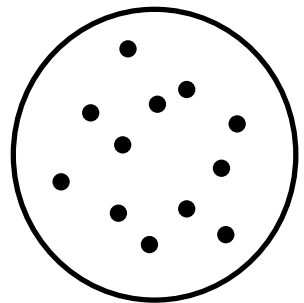
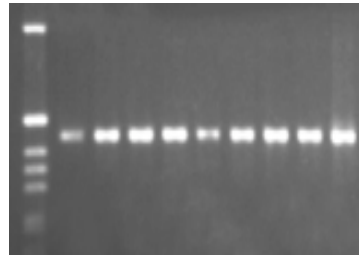
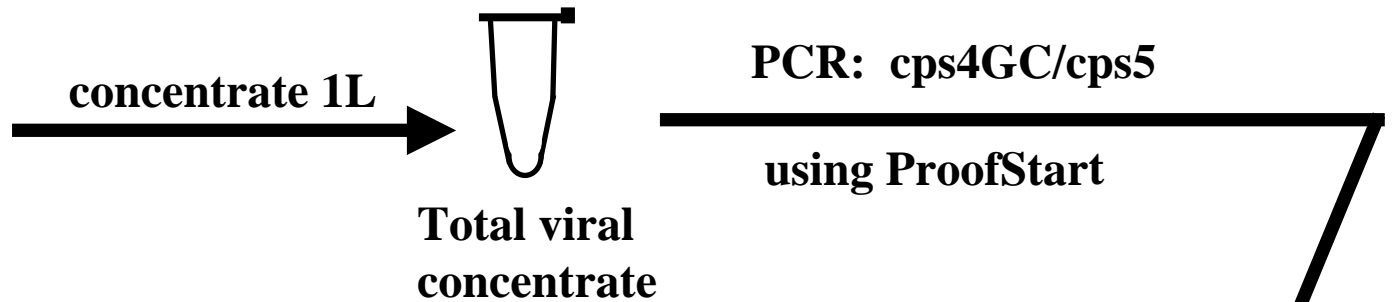
*      220     *      240     *      260     *      280     *      300
3-PM2   : ATGTTATATGT--CACGTTACAGAAACAAAGCTTGTATACGATGCTCAACACAGGAGAGATTTCGTGATGATAAAAGCATATATGCTATATGCTGGAAGATTTCTGG : 290;
3-WHM1  : AAGTTATATGA--GTTCGTTATAGAAACAAGATGGTCTATGATGCCAACACTGGCGAGATTAAAGACGACAAAGAAATTATATGTCMAATGCTTGAGCAATTTCTGG : 291;
3-BnM1  : AGGTTATATGG--GACGTTACCGCAACAAACTTGTATATGATGCAACACAGGTTGAAATCAAGGACGACAAAGAAATATATGTCGATGCTTGAGGATTTCTGG : 291;
F4      : ATGTTATATGA--CACGATG--AAAACCGTGTATGATATGATGCAACACAGGTTAAATTAARAAATCAACAGCATAATATATGCTATATGACCGAAGACTATTTGG : 291;
NB020525 : GTATCATGCAAAACGTTA--AAATCGCGTGTGTGTACGACACACAGACTGGTCAAGTTAAAAATACCACTAATGCAATATGTCGATGCTTGAGACTACTAC : 297;
      a gT ATG aCGtTa aAAc T GT TA GAtgca a AC GG A aT aa A a aa aA tATGTC ATGct GAaGA T cTgg

*      320     *      340     *      360     *      380     *      400
3-PM2   : TTACCTCCGCGTGAAGGTGGTAGAGGAACCTGAGATCACTACACTTCCAGGCGGTGAGAACCTTGGTGAACCTCAAGGATGTTGAGTATTTCAAAAAGAAAC : 390;
3-WHM1  : CTCCTCCGTCGTGAAGGCGGTAGAGGTACAGARATCTCCACACTTCCAGGTTGGACAAACCTTGGCGAACTGGAGACGTTAAGTATTTCCAGGAGAAAC : 391;
3-BnM1  : TTACCAAGTACAGAAAGGTGGTCCGTGGAACAGARATTTCTACACTGCGTGGTGGACAGAACCTTGGTGAACCTGACTGACGTTGAATACTTCAAGGAGAAAT : 391;
F4      : TTGCAGCGCCGTCATGGTAAAGCTGTGACAGARGTTGATACCTTCCAGGTTGCTGATATATGTCGCAATATGGAAGATATTCGTTGGTTTACAGACAGGCTC : 391;
NB020525 : CTACCAAGCGGAGAGGTTCGAAGGTTACTGAGGTARGCACACTACCTGGCGTTCAGTCCGTTGGAGACATCGAAGACGTTATTGTAATTCAAACCGTAAAT : 397;
      T Cc CG cG GAAGgt Gg AC GA T ACaT CCTGG Gg cA aa ctTGG gA T a GA gTt Ta TTcaa a aa

*      420
3-PM2   : TTTAGAACTCACTCAACCTACGACCTTCC : 419
3-WHM1  : TGTACAGGGCCTCAACGTACCTGGTTCA : 420
3-BnM1  : TATATCGTGCCTCAATGTTCCCATTTCA : 420
F4      : TTTATATGGCAATACGTGTTCCCTCTTTCA : 420
NB020525 : TGTATARAACRAATGCGAATTCGACATCA : 426
      T TA a gCa T T CC tTca

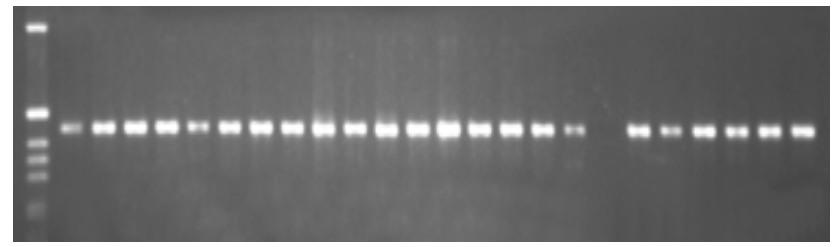
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Analysis of viral population structure - Methodology

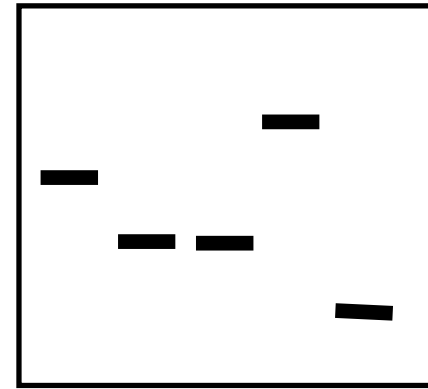


Cloning into ZeroBlunt vector/
transformation

screening of colonies (36)

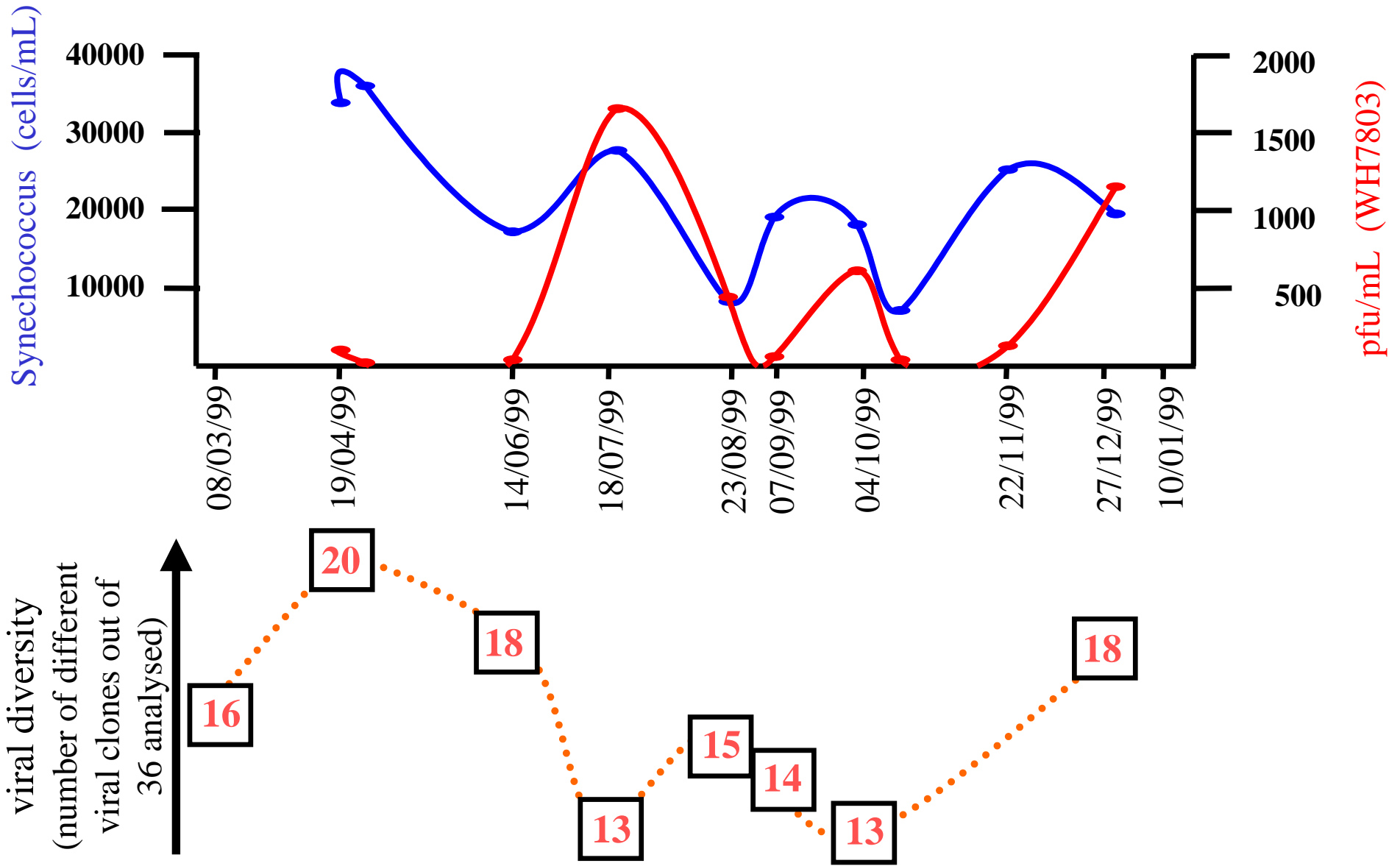


DGGE

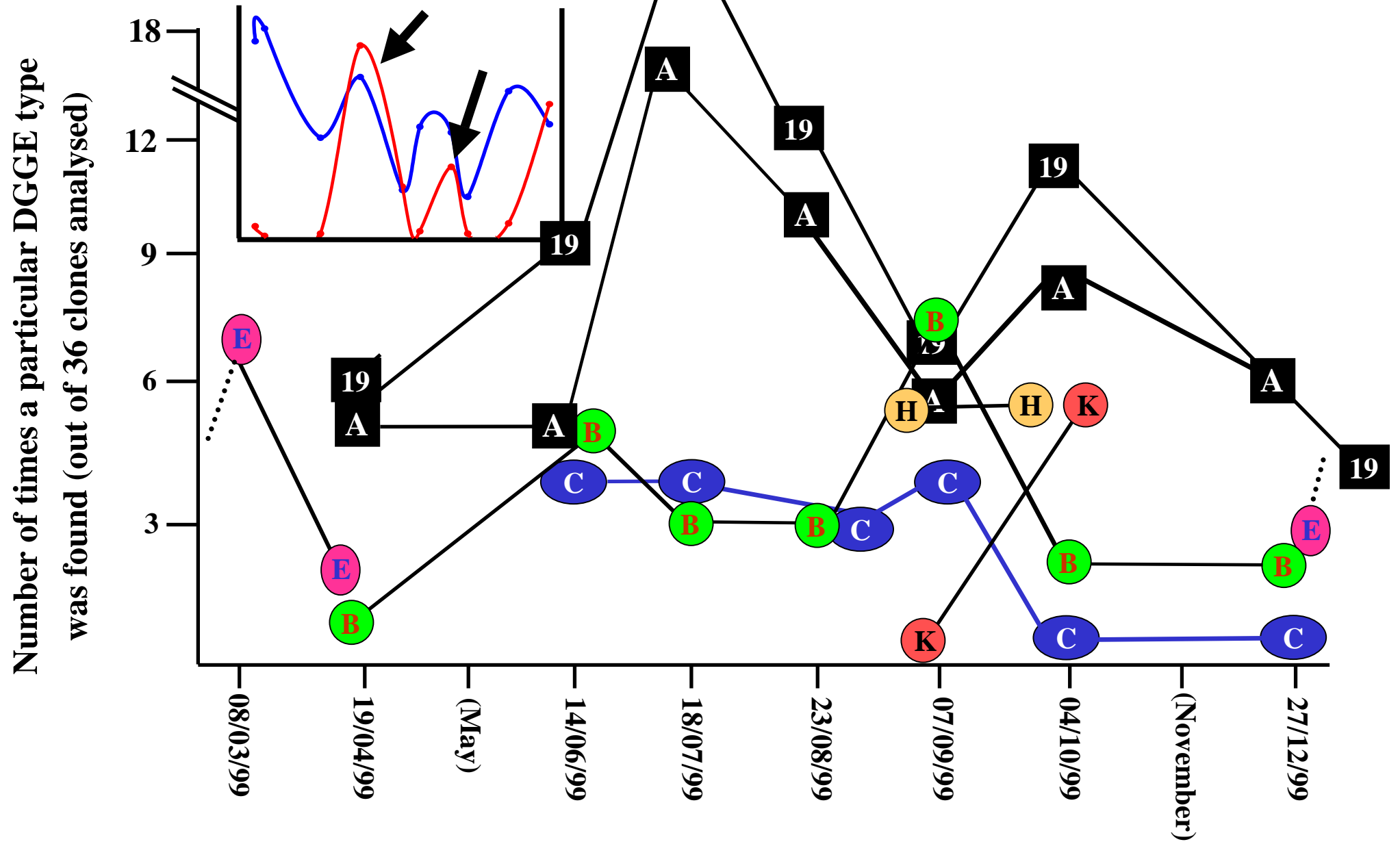


25%
↓
denaturing gradient
35%

Viral diversity versus cyanophage abundance



Occurrence of viral DGGE types over a 19-month cycle (semiquantitatively) - 10 m



Conclusion

Cyanophage have an impact on the abundance and population structure of marine *Synechococcus* spp. in the oligotrophic marine environment:

- I. Lytic cyanophage are responsible for the the decline of the summer blooms**
- II. Lysogenic cyanophage are responsible for the decline of the early winter bloom**
- III. Virus-host interactions influence the population structure of both marine *Synechococcus* and their co-occurring cyanophage**