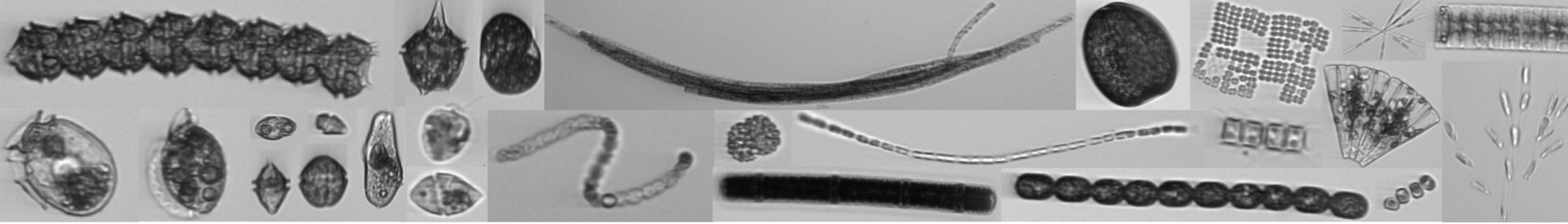

Multiplatform detection of filamentous cyanobacteria blooms in the Baltic Sea

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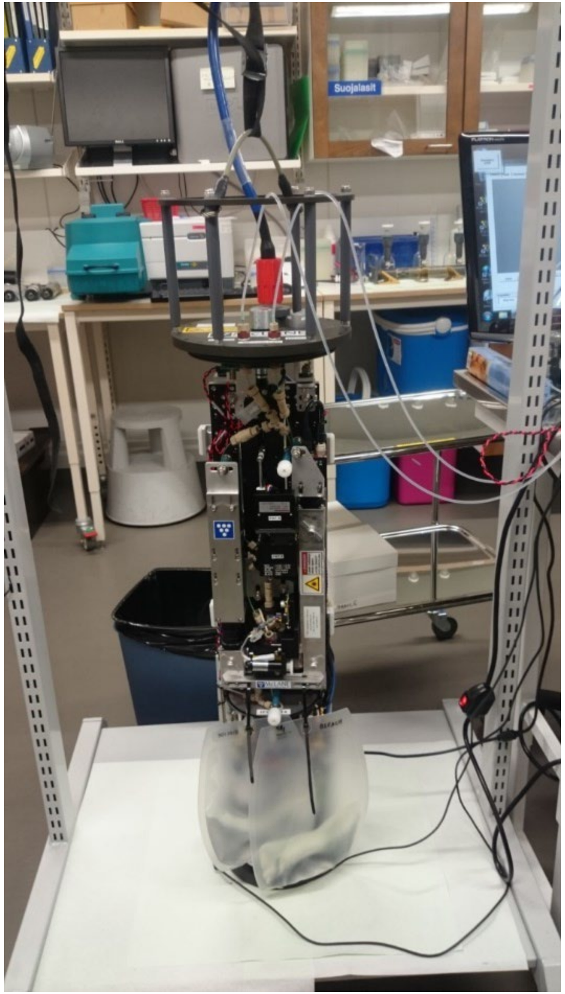
Finnish Environment Institute SYKE, Marine Research Centre
28.9.2022

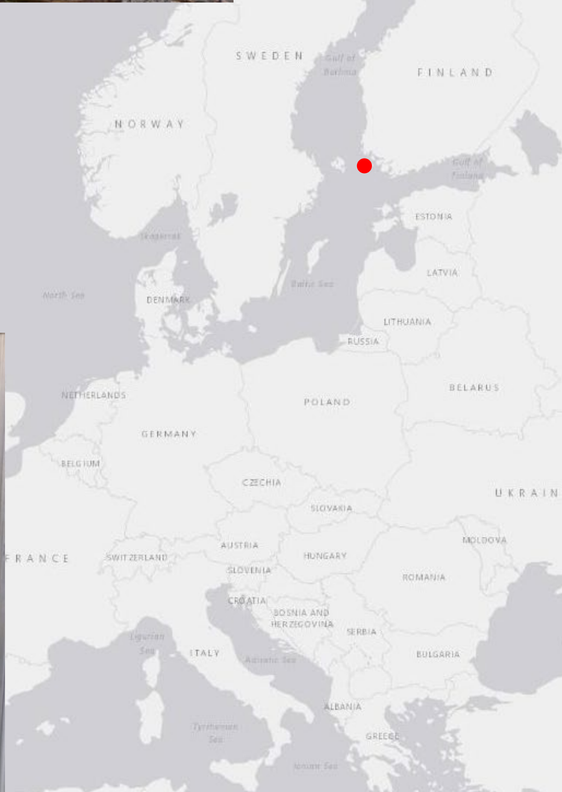
FinMARI Finnish Marine Research Infrastructure
SYKE
JERICO-S3
Temporary logo for KICK-OFF MEETING purposes only - Feb.2020
plus AQUA COSM
TAH TIINA JA ANTTI HERLININ SÄÄTIÖ
Academy of Finland project
FASTVISION
LUT University
FMI

Imaging FlowCytobot - IFCB

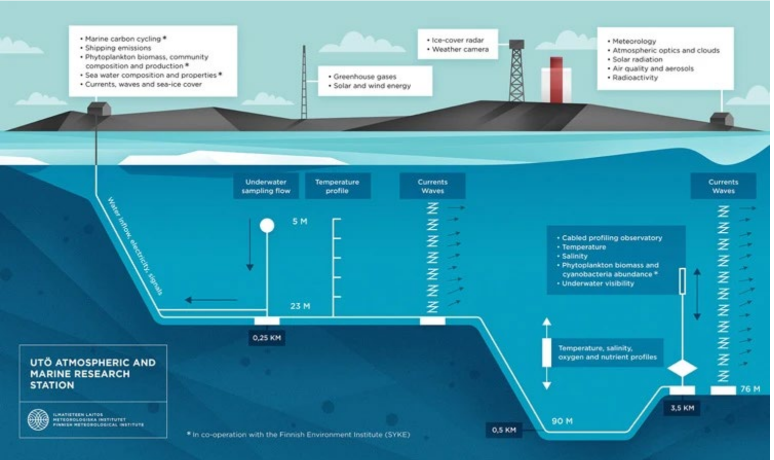
- Imaging flow cytometer
- Takes images of phytoplankton cells and colonies inside the size range of 10-150µm
- Can be operated remotely mounted on a flow through system at a research station (like in Utö), ship of opportunity, put to measure directly to the sea or used in a laboratory environment etc..
- Takes a sample of 5ml with approx. 20 min interval
- The camera is triggered by <u>chlorophyll-*a*</u> or scatter
- Even as many as ~30 000 high resolution images / hour
- 150 µm mesh in IFCB inlet to prevent it from clocking
- Data analyzed with image recognition algorithm

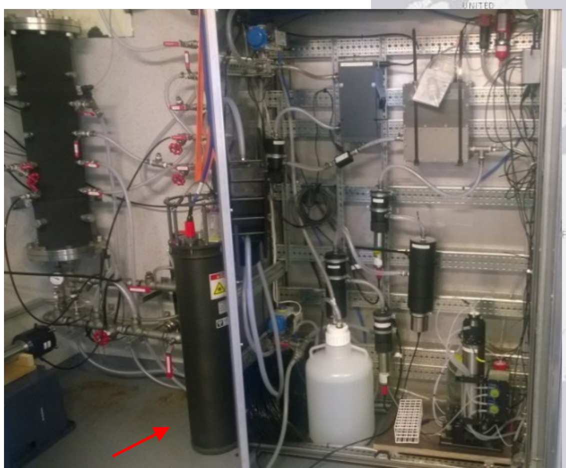


UTÖ Marine Research Station joint with **Finnish Meteorological Institute**

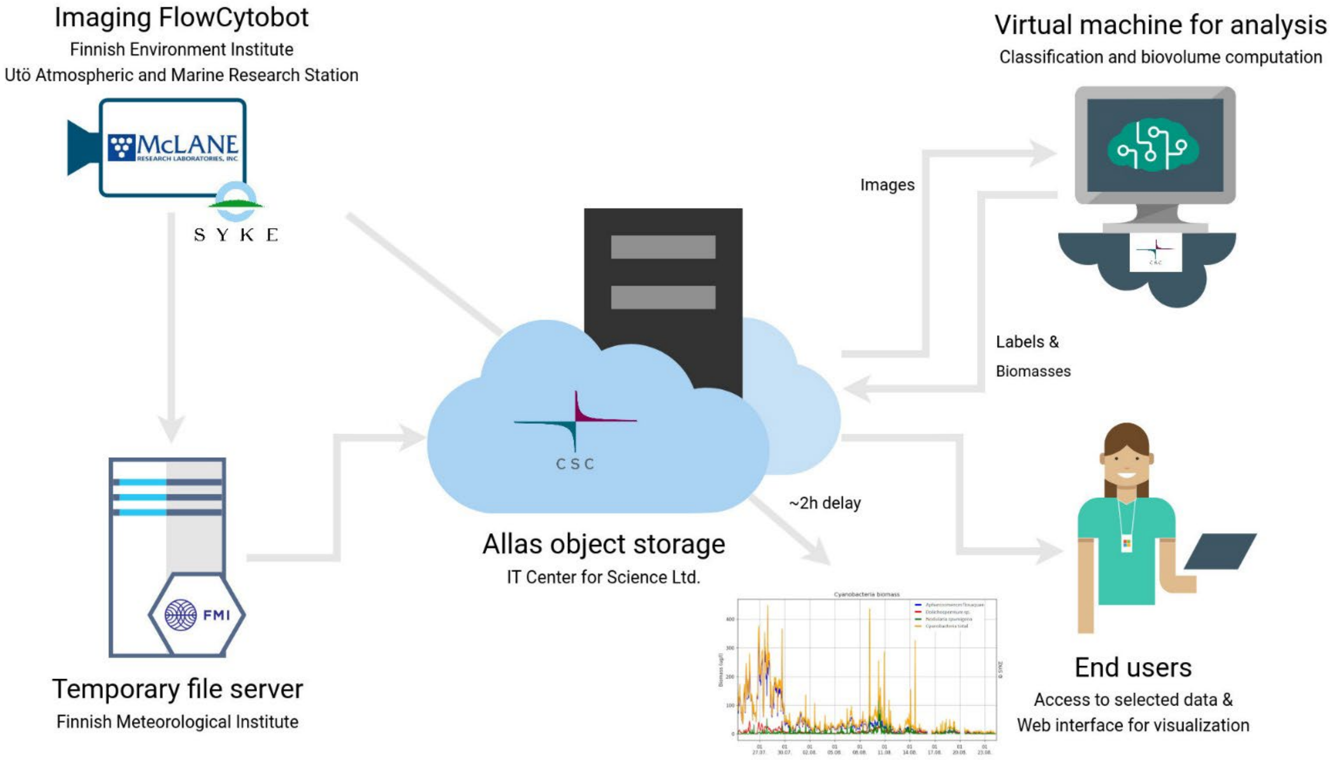


- Underwater pump with inlet at 5 m depth, 250 m offshore
- Water distributed to different sensors inside the station cabin
- Represents pelagial community of a mixed surface layer in brackish environment (salinity ~ 6 psu)
- Multiple parallel measurements from sea to atmosphere
- Continuous imaging flow cytometer observations from multiple years
- Light microscopy samples of cyanobacteria bloom in 2018





Near-real time classification via Convolutional Neural Networks



- Training data set publicly available
- http://doi.org/10.23728/b2share.abf913e5a6ad47e6baa273ae0ed6617a
- Evaluation data set publicly available
- http://doi.org/10.23728/b2share.7c273b6f409c47e98a868d6517be3ae3
- Visualization still under development
- https://plankton.live/
- https://ifcb.plankton.live/timeline?dataset=uto
- https://swell.fmi.fi/hab-info/

https://github.com/veot/syke-pic, Kraft et al. 2022 Front Mar Ski

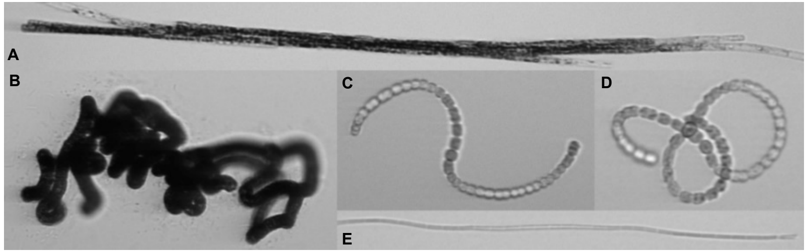
Classifier performance

- Kraft et al. 2022 Front Mar Sci
- Weighted F1-score of test data of our labeled image data set 0.95
- Weighted F1-score of our evaluation data (59 natural samples annotated entirely) 0.83
- Class-specific thresholds are used for filtering out the unidentifiable images, determined with our test set complemented with unidentifiable images (initial situation -> to be finetuned as data accumulates)

Table contains results of evaluation data for F1 > 0.7

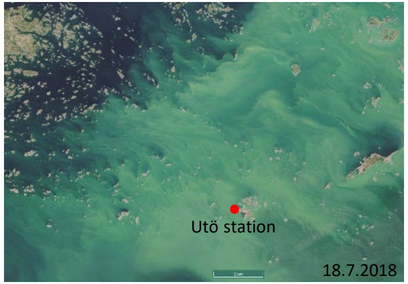
	Training	Validation	Test				2021 data			
Class / taxonomic group	**N**	**Thre**	**N**	**Pr**	**Re**	**F1**	**N**	**Pr**	**Re**	**F1**
Oscillatoriales	2664	0.31	888	0,99	1,00	0,99	3893	0,98	0,98	0,98
Monoraphidium contortum	196	0.69	66	0,98	0,98	0,98	439	0,99	0,96	0,97
Skeletonema marinoi	2477	0.46	825	1,00	0,99	0,99	7402	0,99	0,94	0,97
Heterocapsa triquetra	1966	0.39	655	0,98	0,97	0,97	2267	0,92	0,95	0,94
Cryptophyceae / Teleaulax sp.	4098	0.53	1366	0,96	0,97	0,96	16952	0,97	0,90	0,93
Aphanizomenon flosaquae	4193	0.24	1398	0,97	1,00	0,98	1849	0,87	0,98	0,92
Peridiniella catenata chain	116	0.7	38	0,97	1,00	0,99	89	0,99	0,87	0,92
Dolichospermum sp. / Anabaenopsis sp.	7368	0.38	2456	0,98	0,99	0,98	790	0,88	0,96	0,92
Pauliella taeniata	71	0.62	24	1,00	0,96	0,98	56	0,96	0,86	0,91
Oocystis sp.	505	0.5	169	0,88	0,93	0,90	161	0,91	0,89	0,90
Mesodinium rubrum	679	0.44	227	0,96	0,95	0,96	560	0,92	0,86	0,89
Melosira arctica	26	0.3	8	0,73	1,00	0,84	58	0,85	0,91	0,88
Dolichospermum sp. / Anabaenopsis sp. coiled	1502	0.41	501	0,93	0,96	0,95	70	0,74	0,99	0,85
Eutreptiella sp.	1348	0.43	450	0,95	0,94	0,94	1678	0,90	0,76	0,83
Licmophora sp.	44	0.43	15	1,00	0,80	0,89	78	0,90	0,77	0,83
Nodularia spumigena	101	0.32	34	0,80	0,94	0,86	62	0,80	0,85	0,83
Heterocapsa rotundata	368	0.56	123	0,84	0,90	0,87	2609	0,89	0,70	0,78
Ceratoneis closterium	27	0.41	9	1,00	1,00	1,00	75	0,68	0,91	0,78
Peridiniella catenata single	539	0.52	180	0,89	0,97	0,93	222	0,75	0,81	0,78
Pennales thick	126	0.37	42	0,93	0,88	0,90	1088	0,72	0,85	0,78
Thalassiosira levanderi	1522	0.63	508	0,95	0,95	0,95	2008	0,87	0,68	0,77
Chaetoceros sp. chain	829	0.51	277	0,93	0,95	0,94	693	0,76	0,77	0,76
Centrales	288	0.51	96	0,98	0,89	0,93	92	0,77	0,68	0,72
Dinophysis acuminata	130	0.68	44	0,98	0,91	0,94	17	0,79	0,65	0,71
Pennales thin	469	0.29	156	0,96	0,99	0,97	334	0,61	0,84	0,71
Cyclotella choctawhatcheeana	61	0.47	21	0,89	0,81	0,85	199	0,92	0,57	0,71
Gymnodiniales	41	0.29	14	0,92	0,86	0,89	38	0,78	0,64	0,70

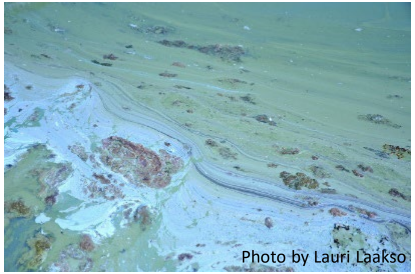
Cyanobacteria blooms in the Baltic Sea

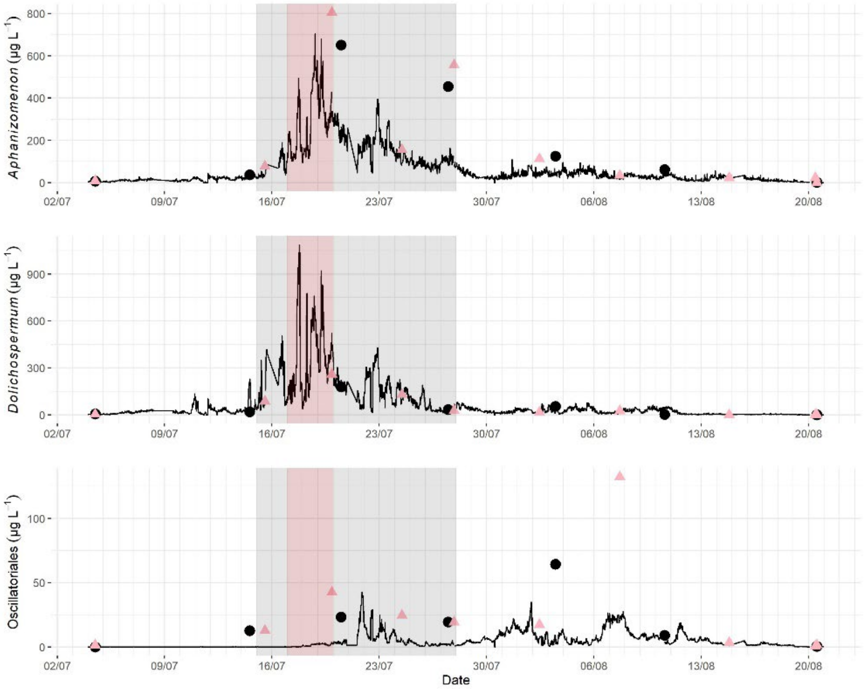


Common filamentous species

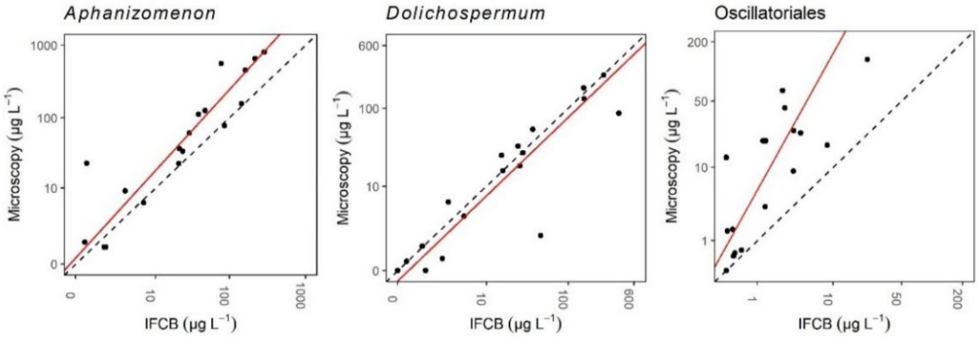
- *Aphanizomenon flosaquae* (A)
- *Dolichospermum* spp. (C,D)
- *Nodularia spumigena* (B)
- Oscillatoriales (E)





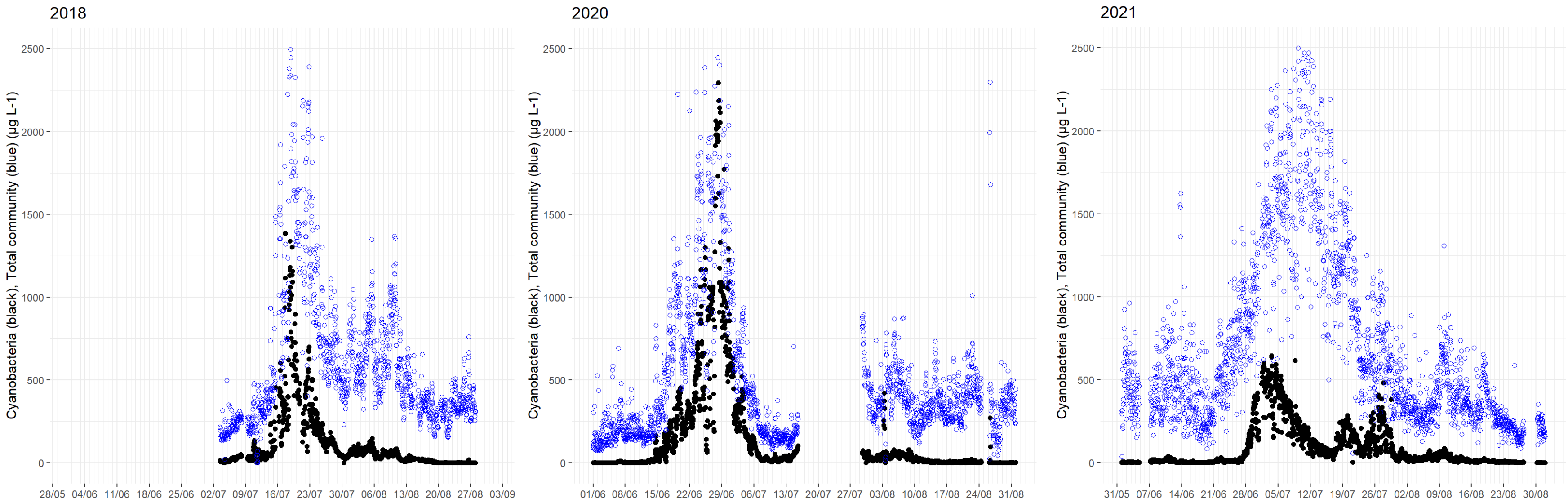


bloom period highlighted in grey (biomass > approximately 100 µg L-1), *bloom peak period* highlighted in red (the days with the highest peaks),light microscopy counts ● flow-through ▲ pump inlet

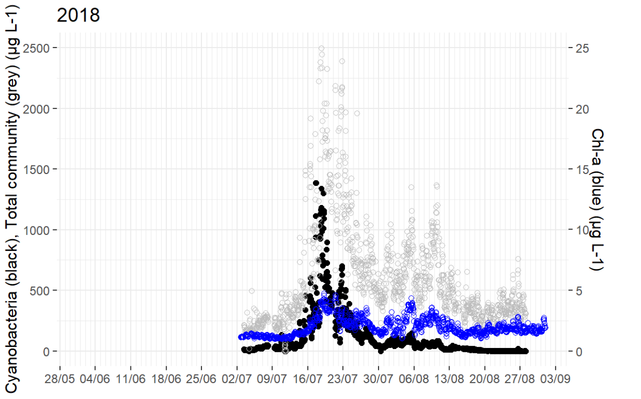


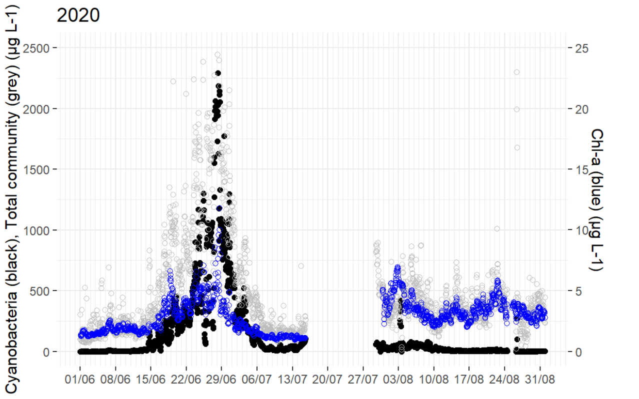
(Kraft et al. 2021 Front Mar Sci)

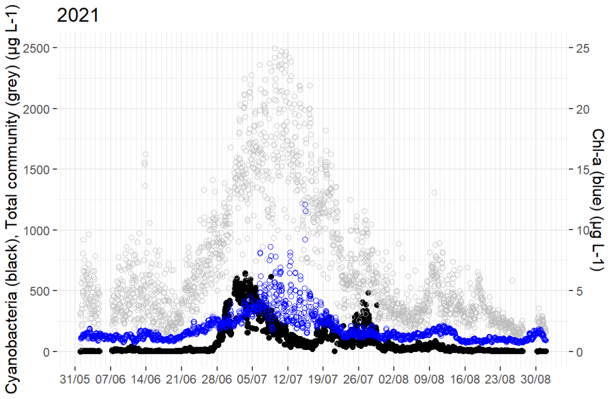
Cyanobacteria blooms in 2018, 2020, 2021

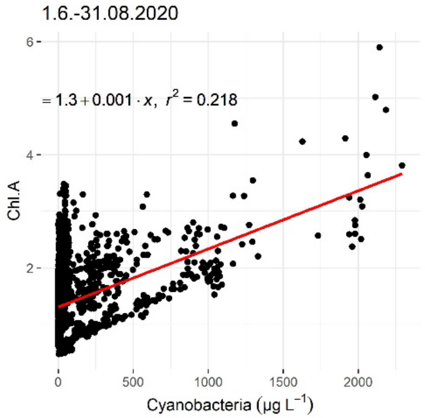


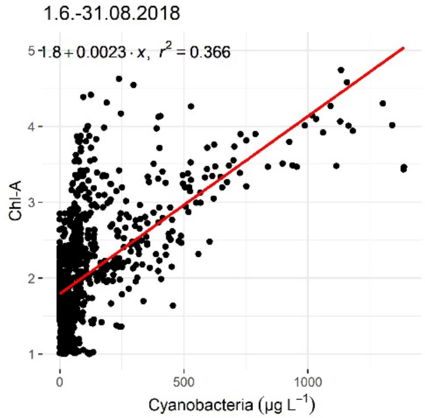
IFCB biomass – Chl a fluorescence correlation

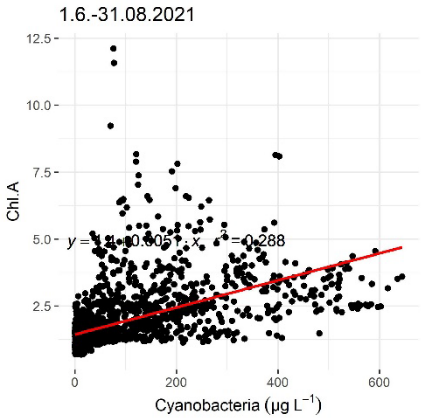




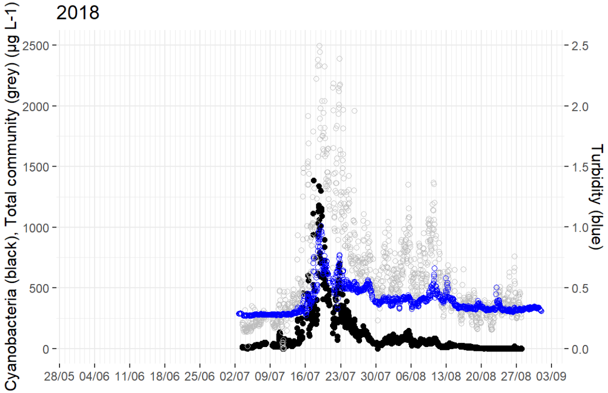


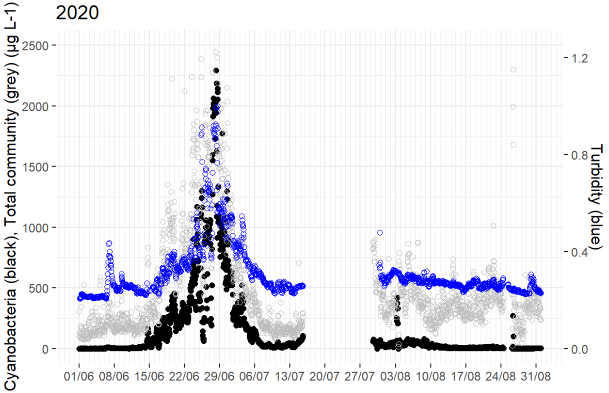


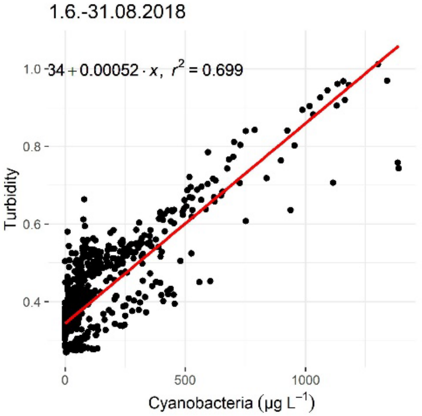


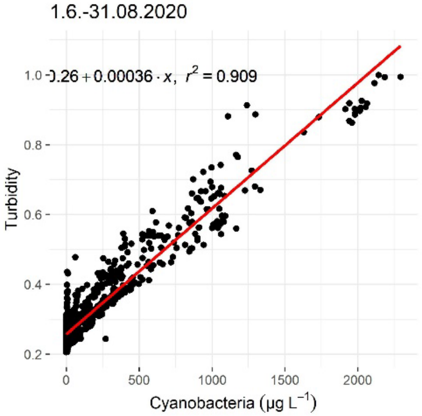


IFCB biomass – turbidity correlation

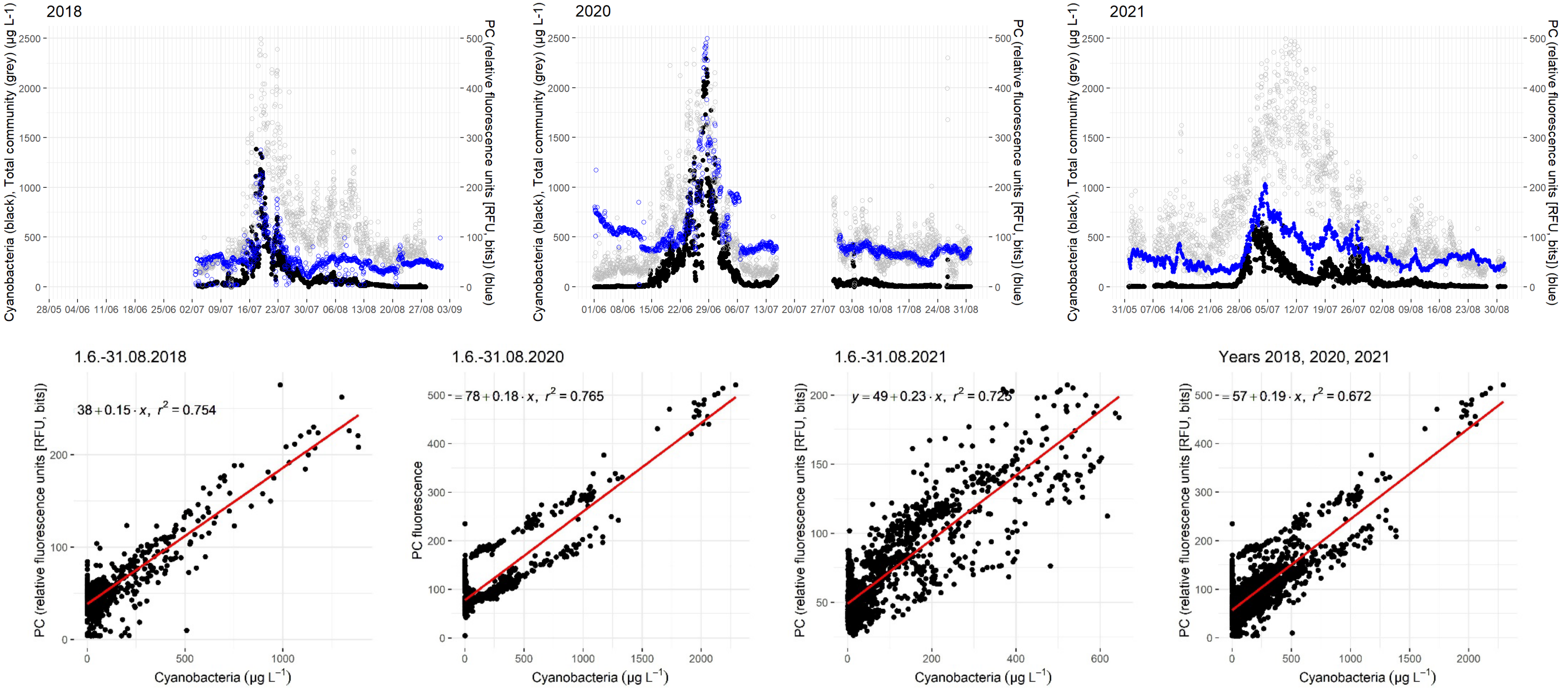




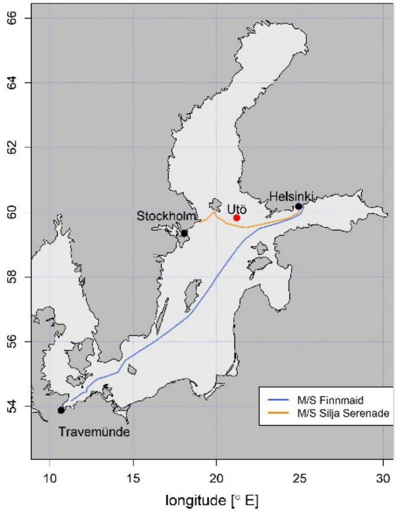




IFCB biomass – phycocyanin fluorescence correlation

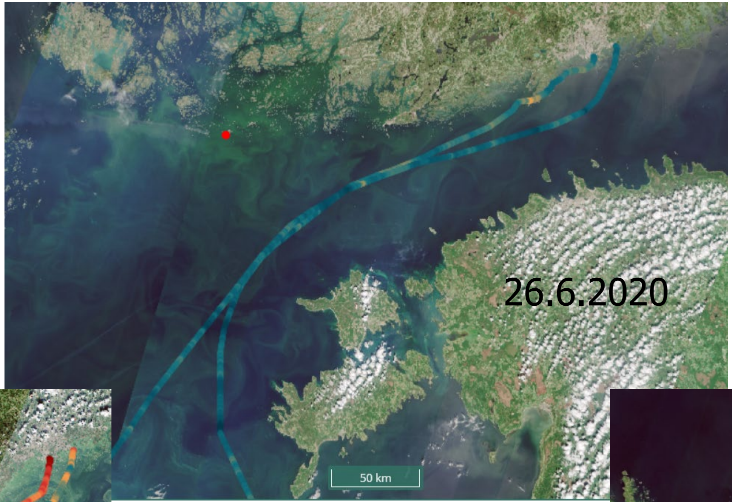


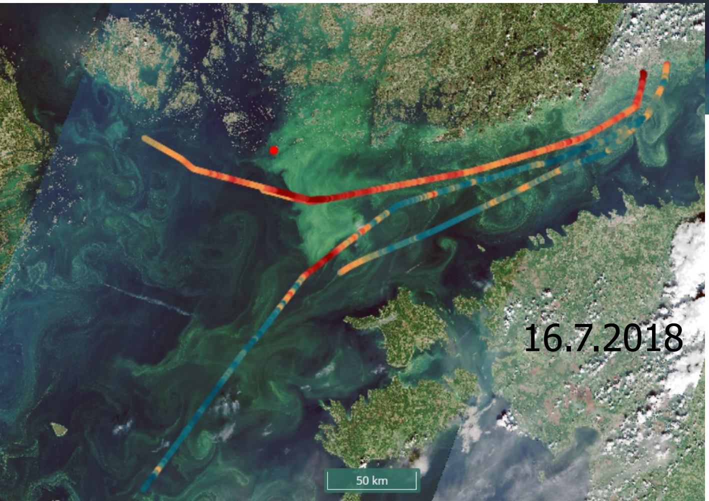
Could PC fluorescence be converted to biomass?



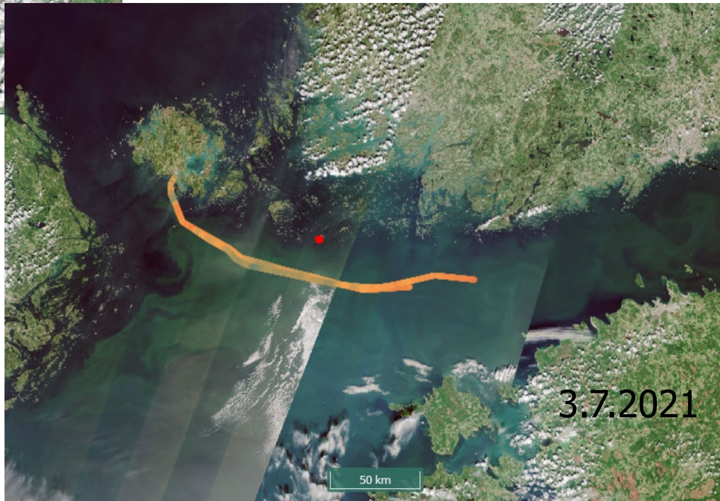
Ferrybox systems on Alg@line routes

- *Helsinki-Travemunde*
- *Helsinki-Stockholm*
- *Estimate of biomass magnitude using the formula from biomass PC fluorescence correlation*





Satellite images and PC fluorescence (units in volts) from TARKKA



References and sources

- Kraft et al. 2021. First application of IFCB high-frequency imaging-in-flow cytometry to investigate bloom-forming filamentous cyanobacteria in the Baltic Sea. Frontiers in Marine Science, 282.
- Kraft et al. 2022. Towards operational phytoplankton recognition with automated high-throughput imaging, near real-time data processing, and convolutional neural networks. Frontiers in Marine Science, 9.
- Seppälä et al. 2007. Ship-of-opportunity based phycocyanin fluorescence monitoring of the filamentous cyanobacteria bloom dynamics in the Baltic Sea. Estuarine, Coastal and Shelf Science, 73(3-4), 489-500
- Laakso et al. 2018. 100 years of atmospheric and marine observations at the Finnish Utö Island in the Baltic Sea. Ocean science, 14(4), 617-632.
- https://en.ilmatieteenlaitos.fi/uto
- https://www.finmari-infrastructure.fi/field-stations/uto-fmi/
- https://swell.fmi.fi/Algaline/
- https://www.finmari-infrastructure.fi/ferrybox/