Supplementary Materials

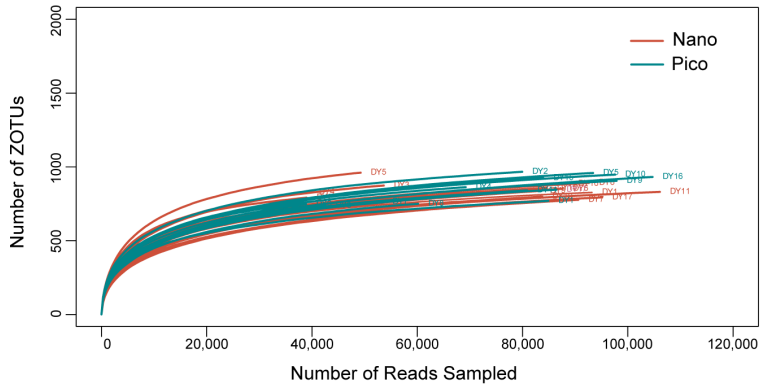


Figure S1. Rarefaction curves of haptophyte SSU rRNA in each sample.

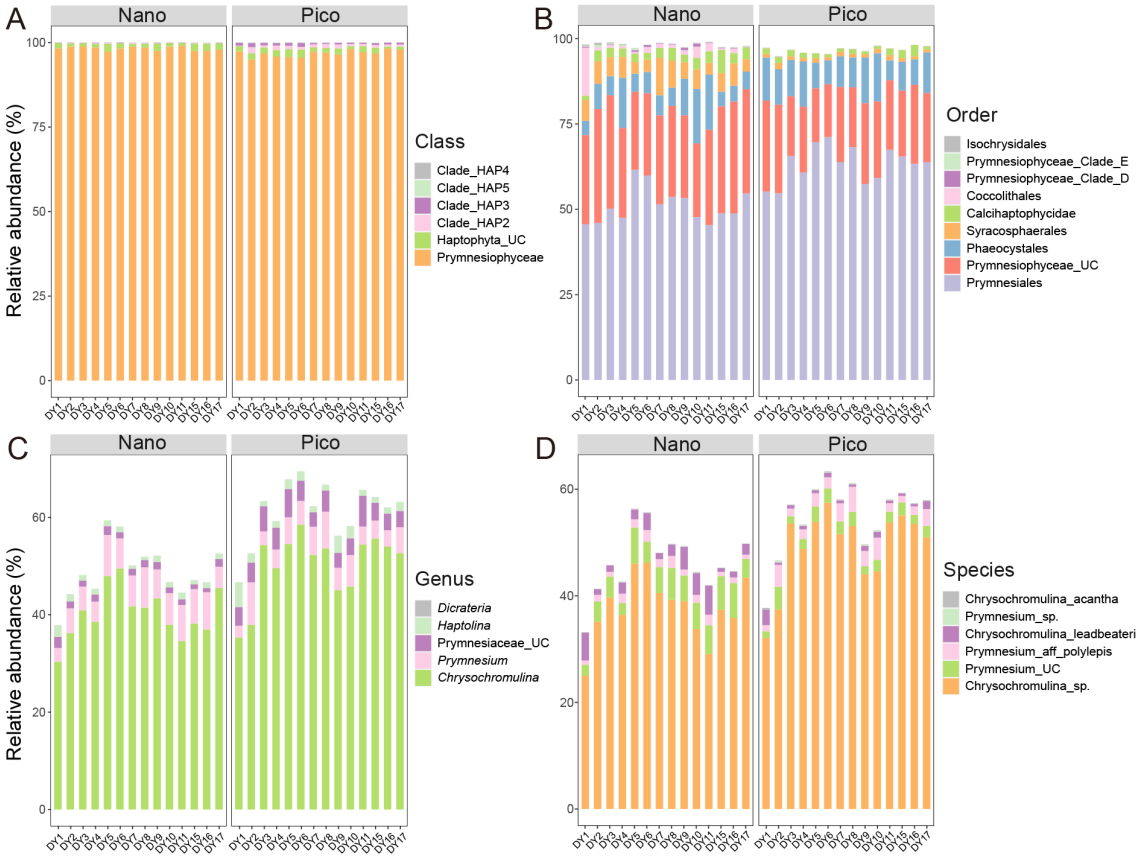


Figure S2. Taxonomic composition of pico- and nano-haptophytes in each sample. Proportions of sequence abundance of haptophytes on the class level (**A**), within Prymnesiophyceae (**B**), within Prymnesiales (**C**), and within *Chrysochromulina* and *Prymnesium* (**D**).

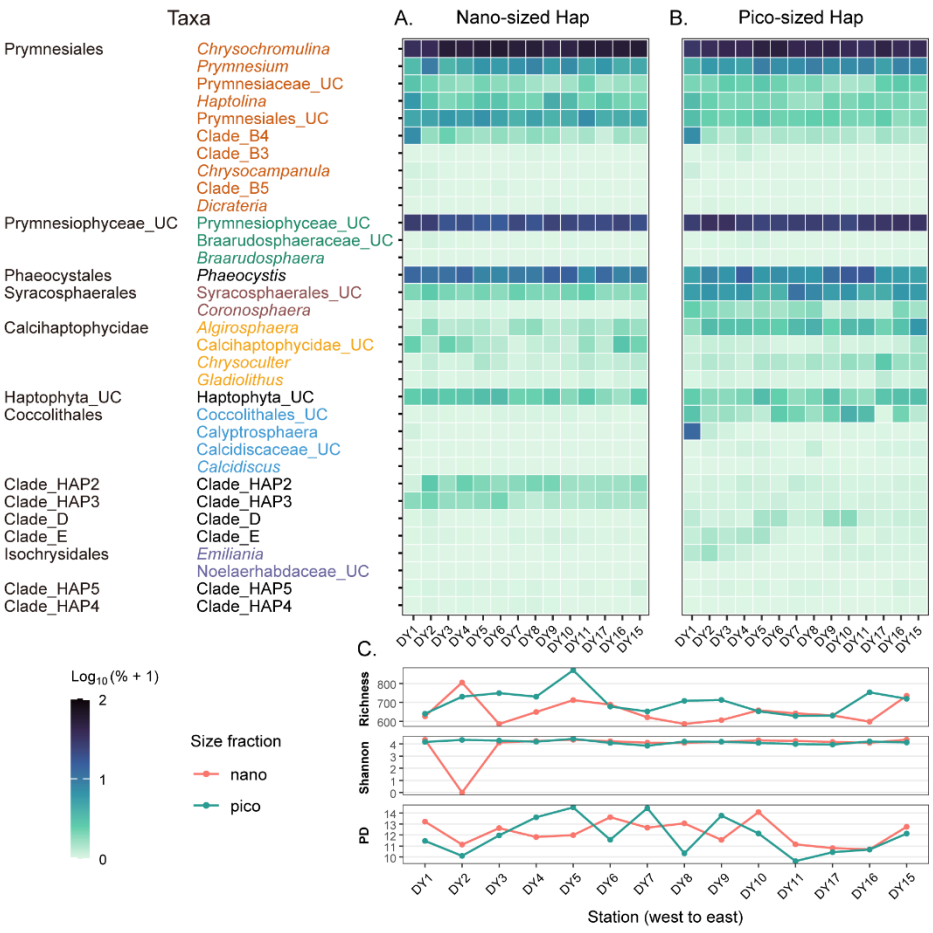


Figure S3. Spatial distribution of the relative abundance of haptophyte communities across the longitudinal transect. Heatmaps display the taxonomic composition of (**A**) nano- and (**B**) pico- haptophyte assemblages at the genus or clade level. (**C**) Distribution of the alpha diversity indices for both size fractions along the sampling transect. Sampling stations are ordered geographically from West to East. Color gradients represent the Log10-transformed relative abundances (Log10 (% + 1)).

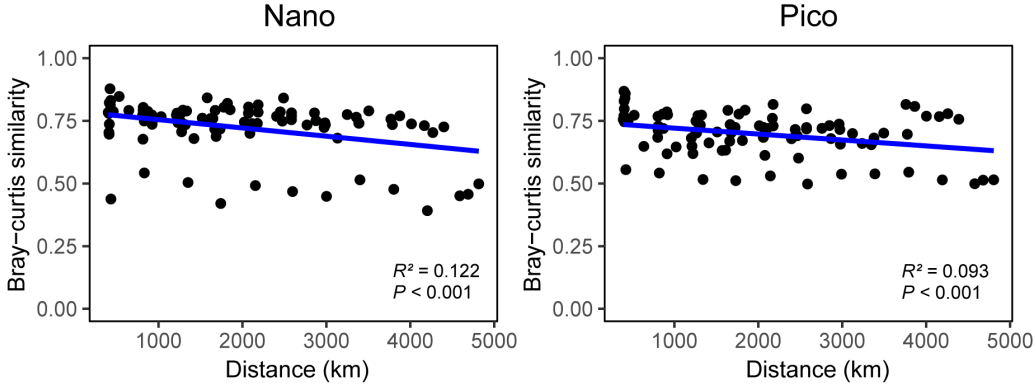


Figure S4. The distance-decay pattern between the community similarity of nano- (**left**) and pico-sized (**right**) haptophytes and geographic distance. Black dots represent pairwise comparisons between samples. The solid blue lines indicate the linear regression fits.

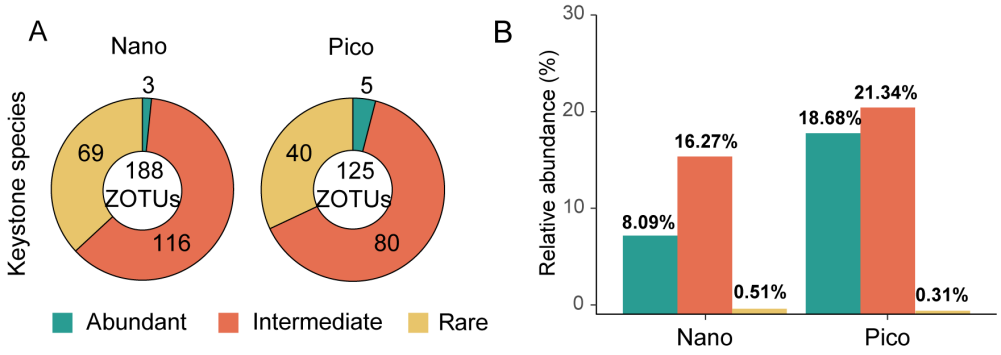


Figure S5. Keystone species analysis of nano- and pico-sized networks. (**A**) Total number of connectors in the nano- and pico- sized networks, along with their distribution across three ZOTUs categories. (**B**) Relative abundance of connectors in the nano- and pico-sized networks.

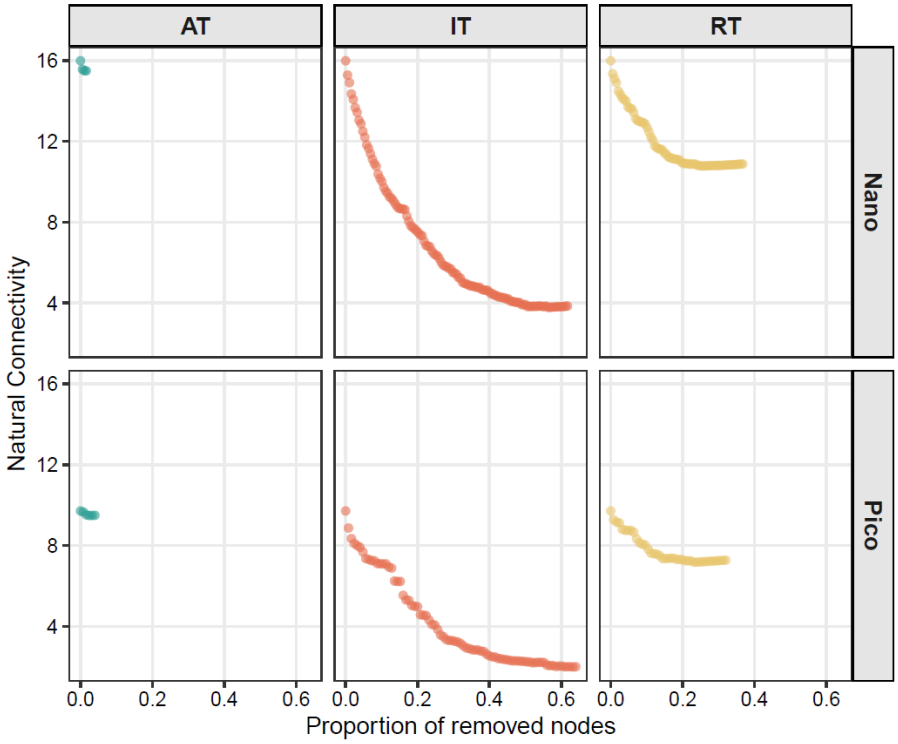


Figure S6. Network stability in response to the targeted removal of keystone species across different abundance categories (AT, IT, and RT) in nano- and pico-haptophyte subcommunities.

Table S1. The abundant taxa of nano and pico-sized unique ZOTUs, and shared ZOTUs of both fractions.

Size Fraction	ZOTU ID	Relative Abundance	BLAST	Identity	Accession
Nano	ZOTU 3	7.61%	*Syracosphaera pulchra*	100%	KF422621
Nano	ZOTU 5	4.78%	*Syracosphaera pulchra*	100%	KF422621
Nano	ZOTU 10	2.29%	Haptophyta sp.	100%	KR338487
Nano	ZOTU 14	1.71%	Prymnesiophyceae sp.	100%	MZ687705
Nano	ZOTU 19	1.95%	uncultured eukaryote	100%	KU743849
Nano	ZOTU 81	2.29%	*Azadinium trinitatum*	100%	LS974170
Pico	ZOTU 7	5.63%	*Chrysochromulina* sp.	100%	MZ611704
Pico	ZOTU 9	3.79%	*Phaeocystis* sp. JD-2012	97.49%	JX660995
Pico	ZOTU 11	2.89%	Haptophyta_UC	100%	MG983557

Pico	ZOTU 18	3.37%	*Chrysochromulina* sp.	99.72%	MZ611704
Pico	ZOTU 36	2.25%	*Prymnesium* sp.	100%	MZ687721
Both	ZOTU 1	10.97%	Haptophyta_UC	100%	MZ687671
Both	ZOTU 2	3.92%	*Phaeocystis*_sp.	98.88%	JX660995
Both	ZOTU 4	3.26%	*Chrysochromulina cymbium*	100%	AM491018
Both	ZOTU 6	6.26%	*Chrysochromulina strobilus*	100%	KY980316
Both	ZOTU 8	6.55%	*Chrysochromulina andersonii*	99.72%	AB180202
Both	ZOTU 82	2.15%	*Chrysochromulina andersonii*	98.4%	AB180202

BLAST: the nearest BLAST hit in NCBI-nr to each unique abundant ZOTU. The relative abundance of shared ZOTUs is the mean of the relative abundance of the corresponding ZOTU in both the nano- and pico-sized samples.

Table S2. Mantel test showing the correlations between the environmental factors and the haptophyte community.

Environmental Factors	**Nano**		**Pico**	
	r	***p***	***r***	***p***
Geographical distance	0.083	0.023	0.049	0.168
Temperature	0.010	0.496	0.080	0.677
Salinity	0.789	0.007	0.930	0.047
N	0.336	0.009	0.195	0.048
P	0.731	0.005	0.336	0.046
Si	0.382	0.002	0.377	0.030
Bacteria, abundance	0.476	0.006	0.300	0.009
Prochlorococcus, abundance	0.366	0.005	0.370	0.047
Synechococcus, abundance	0.241	0.036	0.456	0.128
PPEs, abundance	0.683	0.003	0.258	0.030
Ciliate, abundance	-0.356	0.005	-0.206	0.035
Ciliate, biomass	-0.308	0.005	-0.255	0.043
PNFA	0.005	0.379	0.138	0.753
PNFB	0.753	0.004	0.310	0.043
HNFA	0.118	0.224	0.206	0.143
HNFB	0.130	0.006	0.131	0.008
NFA	0.027	0.328	0.215	0.953
NFB	0.778	0.001	0.205	0.029
Phytoplankton pigments				
Chl *a*	-0.119	0.969	-0.063	0.768
Chl *b*	-0.099	0.885	-0.047	0.663
Chl *c3*	0.101	0.874	0.066	0.756
Chl *c2*	0.104	0.922	0.051	0.693
Peridinin	-0.057	0.677	-0.021	0.507
19 but fucoxanthin	0.084	0.806	0.036	0.567
19 hex fucoxanthin	0.047	0.245	-0.004	0.464
Fucoxanthin	0.070	0.212	0.028	0.284
Neoxanthin	-0.099	0.893	-0.047	0.640
Violaxathin	0.030	0.328	0.008	0.384
Diadinoxanthin	-0.109	0.933	-0.109	0.979
Alloxathin	-0.052	0.607	-0.089	0.894
Zeaxanthin	-0.002	0.407	-0.031	0.661
DV.chlorophyll *a*	-0.064	0.691	-0.058	0.751

Table S3. Topological properties of the nano- and pico-sized co-occurrence networks of haptophyte communities.

Index	**Nano**	**Pico**
Nodes	285	161
Edges	345	140
Average degree	2.421	1.739
Network diameter	17	6
Network density	0.009	0.011
Modularity	0.934	0.893
Average clustering coefficient	0.515	0.386
Average path length	5.024	1.864
Positive	75.65%	85%
Negative	24.35%	15%