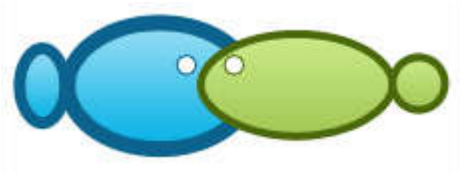

Spectral niches and vertical organization of marine phototrophs: from light attenuation to photophysiological acclimation

[1]Adela M. Dăescu, [2]Praveen Pandey, [3,4]Ioan G. Oroian, [3,5,6,7]I. Valentin Petrescu-Mag, [8]Ioan Bănățean-Dunea

[1] Department of Cell Biology, Histology and Embryology, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Cluj-Napoca, Romania; [2] Division of Plant Breeding and Genetic Resource Conservation, CSIR - Central Institute of Medicinal and Aromatic Plants, Lucknow, India; [3] Department of Environmental Engineering and Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, Romania; [4] Balkan Environmental Association (BENA), Thessaloniki, Greece; [5] Bioflux SRL, Cluj-Napoca, Romania; [6] Doctoral School of Engineering Science, University of Oradea, Oradea, Romania; [7] WABBA International Bodybuilding and Fitness LTD, London, United Kingdom; [8] Department of Biology and Plant Protection, Faculty of Agriculture, University of Life Sciences „King Mihai I" from Timișoara, Timișoara, Romania; Corresponding author: I. Bănățean Dunea, ioan_banatean@usvt.ro

Abstract. Marine phototrophs are vertically structured across the water column and benthic habitats in response to pronounced gradients in light intensity and spectral composition. As light propagates through seawater, selective attenuation progressively modifies the underwater light field, generally favoring blue to blue-green wavelengths in clear waters, while dissolved and particulate matter can shift the available spectrum toward greener conditions. These optical gradients generate distinct spectral niches that influence the distribution and performance of cyanobacteria, phytoplankton, macroalgae, and photosynthetic corals. However, vertical organization cannot be explained by wavelength alone. Pigment composition, chromatic acclimation, photoacclimation, morphology, internal optics, and nutrient availability interact to determine the realized depth distribution of marine phototrophs. This mini-review synthesizes evidence across pelagic, coastal, benthic, and sedimentary environments to examine how spectral quality and irradiance jointly shape vertical ecological organization. Particular attention is given to complementary pigment absorption in macroalgae and cyanobacteria, chromatic acclimation in *Synechococcus*, photoacclimation within deep chlorophyll maxima, and whole-organism optical adaptations in deep-water corals and seaweeds. Available evidence indicates that spectral specialization is most ecologically consequential under conditions of strong light limitation, whereas nutrient–light trade-offs and morphological adaptations can substantially modify or override simple wavelength-based predictions. Vertical organization should therefore be understood as a dynamic outcome of interactions among underwater optical properties, organismal light-harvesting strategies, and resource availability rather than as a fixed sequence of pigment-defined depth zones. This framework also highlights the potential sensitivity of spectral niches to future changes in ocean optical conditions and variability.

Keywords: chromatic acclimation, deep chlorophyll maximum, marine macroalgae, nutrient–light interactions, photoacclimation, photosynthetic corals, pigment composition, underwater light field, vertical zonation.

Introduction. Marine phototrophs are vertically organized throughout the water column and across benthic habitats, where the availability and spectral composition of light change markedly with depth. As sunlight propagates through seawater, its intensity decreases, and its spectral composition is progressively modified by the wavelength-dependent absorption and scattering properties of water and suspended or dissolved materials. In relatively clear oceanic waters, blue and blue-green wavelengths generally penetrate deeper than longer wavelengths, whereas coastal and particle-rich waters may exhibit stronger attenuation of blue light and relatively greener underwater light fields (Wood, 1985; Cornec et al., 2021; Thoral et al., 2023; Mattei et al., 2025). Consequently, organisms inhabiting different depths are exposed not simply to different amounts of light but also to distinct spectral environments (Petrescu-Mag et al., 2026).

These depth-dependent optical conditions can generate spectral niches because marine phototrophs differ in their pigment composition and in their capacity to absorb and use particular portions of the available spectrum. At the same time, irradiance itself is a major determinant of photosynthetic performance and microalgal growth, meaning that changes in the underwater light field involve both spectral quality and photon availability (Pejendino et al., 2025). Differences in photosynthetic pigments have long been associated with the vertical distribution of marine algae, while more recent studies demonstrate that spectral light quality can influence macroalgal community composition, particularly under conditions approaching the lower limits of light availability (Larkum et al., 1967; Thoral et al., 2023). At the same time, spectral specialization is not necessarily fixed. Marine cyanobacteria such as *Synechococcus* include lineages with distinct spectral preferences as well as chromatic acclimators capable of adjusting their pigment composition in response to the prevailing light color (Dufour et al., 2025; Mattei et al., 2025). Thus, the relationship between depth and phototroph distribution depends on both the underwater light field and the physiological capacity of organisms to exploit it.

Importantly, vertical organization cannot be interpreted as a simple sequence of pigment-defined depth zones. Irradiance, nutrient availability, water-column structure, photoacclimation, morphology, and internal optical properties can modify the ecological consequences of spectral differences. This is particularly evident in deep chlorophyll maxima, where chlorophyll accumulation may reflect photoacclimation rather than increased phytoplankton biomass, and in deep-water corals and macroalgae, where organismal optical properties contribute to efficient photon capture under strongly reduced irradiance (Kahng et al., 2012; Mignot et al., 2014; Gómez et al., 2019; Cornec et al., 2021). Therefore, understanding marine vertical organization requires an integrated view in which spectral quality, irradiance, resource availability, and organismal light-harvesting traits interact to determine realized depth distributions.

Optical Basis. In clear oceanic waters, wavelength-dependent absorption and scattering progressively reshape the underwater light spectrum with depth, generally leaving relatively greater availability of violet-blue and blue-green wavelengths than longer wavelengths (Wood, 1985; Holtrop et al., 2021; Mattei et al., 2025; Mattei et al., 2026). In more productive or particle-rich waters, the relative contribution of dissolved and particulate matter can further modify spectral attenuation, shifting the underwater light field toward greener conditions and reducing the depth of the euphotic zone (Cornec et al., 2021; Thoral et al., 2023; Mattei et al., 2025)

This spectral filtering creates distinct spectral niches, defined by the relative availability of different wavelength ranges in the underwater light field, which can favor organisms whose photosynthetic pigments and light-harvesting systems are better matched to those spectral conditions (Holtrop et al., 2021; Dufour et al., 2025; Mattei et al., 2025). The ecological consequences of spectral differences are expected to become particularly important under light-limited conditions, when differences in pigment absorption and whole-organism optical properties can affect photosynthetic performance and competitive outcomes (Wood, 1985; Kahng et al., 2012; Thoral et al., 2023).

Spectral quality must therefore be distinguished from total irradiance. Classic field work on attached algae showed that both wavelength and light intensity matter for sublittoral zonation, and later coastal modeling confirmed that pigmentation matters most

at the extremities of light limitation, not uniformly across all depths and water types (Larkum et al., 1967; Thoral et al., 2023).

Pigments and Functional Types. The mechanistic basis of spectral zonation is the diversity of chlorophylls, carotenoids, and phycobilins, which expand usable wavelengths beyond the chlorophyll core (Simkin et al., 2022; Petrescu-Mag, 2025). Pigment accumulation is also responsive to environmental conditions, indicating that pigment composition may reflect not only spectral adaptation but also physiological responses to factors such as salinity and nutrient conditions (Kissae et al., 2025; Sarri et al., 2025). Phycobilins are especially important in cyanobacteria and red algae because they capture broad spectral bands and help these groups use light that remains available in deeper water (Simkin et al., 2022; Larkum et al., 1967).

Synechococcus illustrates this principle at fine taxonomic scale. Marine lineages include blue-light specialists, green-light specialists, and chromatic acclimators that reversibly adjust antenna composition to ambient blue:green ratios (Dufour et al., 2025; Kehoe et al., 2025). Chromatic acclimation is widespread in marine *Synechococcus* and has been estimated to occur in more than 40% of sampled populations, with a tendency to be particularly important at depth and at higher latitudes where irradiance is often sub-saturating (Kehoe et al., 2025; Mattei et al., 2025).

Spectral specialization does not operate only through pigment identity. In corals and macroalgae, morphology and internal optics modify photon capture by changing absorptance, path length, tissue thickness, and stress tolerance (Kahng et al., 2012; Gómez et al., 2019; Kahng et al., 2019).

Typical Vertical Patterns. On rocky coasts, the traditional pattern is shallow dominance by many green algae, extensive brown algal canopies in the sublittoral, and increasing representation of red algae toward deeper, dimmer habitats, although the boundaries vary by water type and local ecology (Larkum et al., 1967; Thoral et al., 2023). Modern coastal modeling refines this pattern by showing that brown algae can perform efficiently across relatively broad spectra under lower light attenuation, whereas red algae become increasingly favored under stronger attenuation and more light-limited conditions (Thoral et al., 2023).

In polar benthos, vertical zonation also follows optical traits. Antarctic green sheet-like algae show lower absorption at rapidly attenuated wavelengths and higher Ek, whereas thick red and brown forms are better equipped for impoverished deep light and have much lower Ek values near 36 μmol m^{-2} s^{-1} (Gómez et al., 2019). On deep Hawaiian reefs, macroalgae dominate roughly 50–80 m, Leptoseris corals dominate around 80–90 m, and photosynthetic cover declines further below, indicating strong filtering by the downwelling light gradient (Kahng & Kelley, 2007).

Mesophotic corals show that benthic zonation can depend on whole-organism light harvesting as much as on pigments. Deep *Leptoseris* inhabits 68–113 m where PAR is only 3–11% of surface values, has lower reflectance than shallow *Porites*, and appears chromatically matched to the wavelengths available at depth. Yet this deep coral has lower areal pigment concentrations than *Porites*, suggesting that efficient internal light redistribution, including skeletal photon recycling, may contribute to deep-water photosynthetic performance rather than pigment abundance alone (Kahng et al., 2012).

Together, these examples illustrate that vertical organization emerges from the interaction between the underwater light field and organismal functional traits. Figure 1 provides a conceptual synthesis of the interacting optical, physiological, morphological, and resource-related mechanisms that contribute to vertical organization, whereas Table 1 summarizes representative patterns across major marine phototrophic groups.

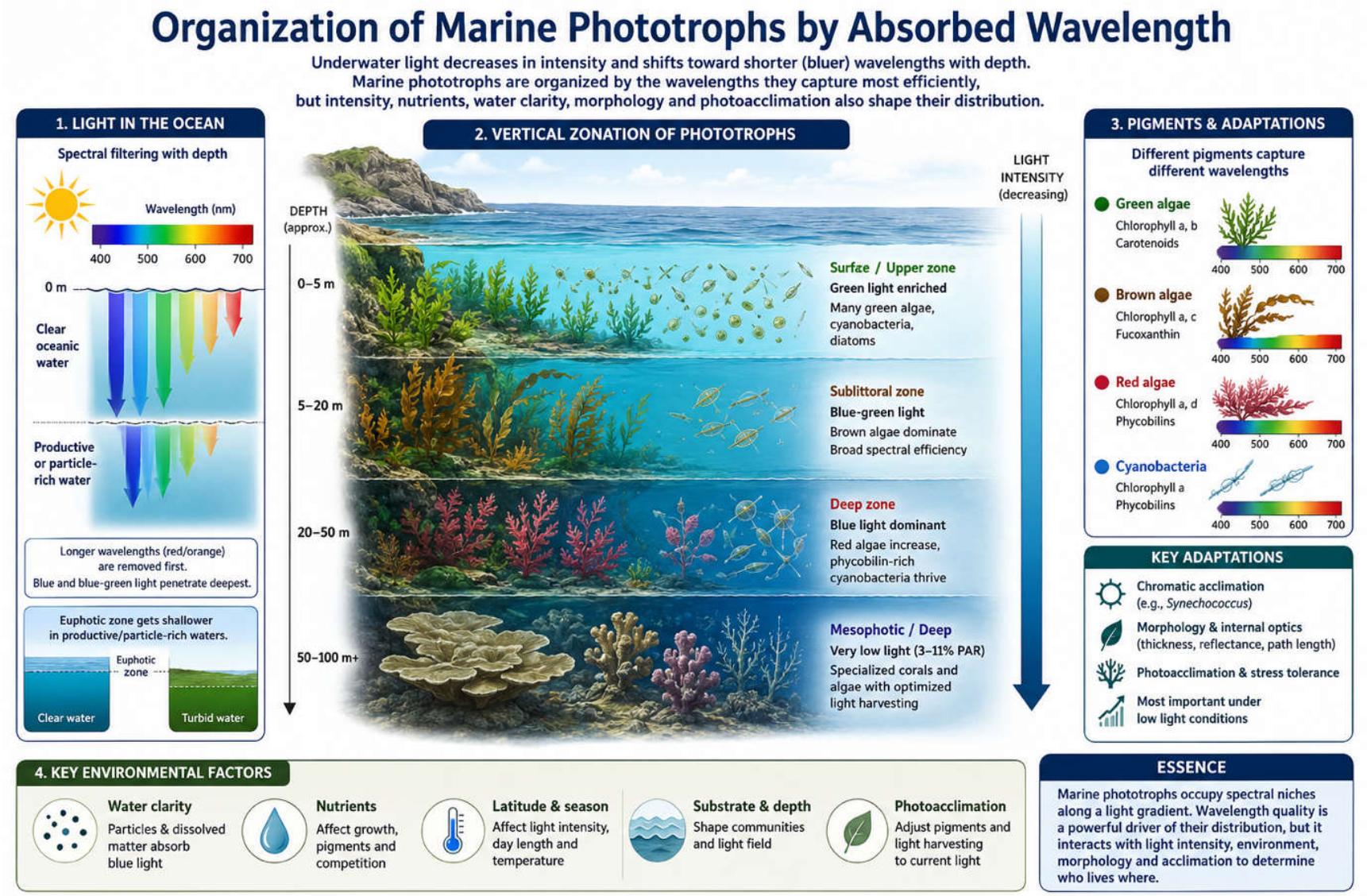

Figure 1. Conceptual framework linking underwater light attenuation, spectral niches, photophysiological acclimation, organismal optical traits, nutrient–light interactions, and vertical organization of marine phototrophs.

Table 1
Representative forms of vertical organization of marine phototrophs by spectral environment, pigment use, and depth-related functional traits

Environment or group	*Shallower spectral setting*	*Deeper spectral setting*	*Observed vertical organization*
Open-ocean picocyanobacteria	Higher blue:green variability near surface	Bluer field with depth	Blue-light specialists are better matched to blue-dominated environments, whereas chromatic acclimators can adjust their pigment composition across changing blue:green conditions (Mattei et al., 2025)
Shelf-sea thermocline phytoplankton	Upper DCM enriched in *Synechococcus* and nonphotosynthetic blue-absorbing pigments	Deeper thermocline enriched in photosynthetic carotenoids and eukaryotes	Taxonomic gradients track spectral gradients within the DCM (Hickman et al., 2009)
Coastal macroalgae	Green algae often favored in shallow water	Brown then red algae perform better in deeper or more attenuating settings	Pigment effects emerge strongly under low-light thresholds (Thoral et al., 2023)
Antarctic seaweeds	Sheet-like greens with high Ek in shallow habitats	Thick red and brown forms with low Ek in deeper habitats	Morpho-functional traits predict bathymetric position (Gómez et al., 2019)
Mesophotic corals	Shallow Porites under higher irradiance	Deep Leptoseris under 3–11% surface irradiance	Deep corals are chromatically adapted to depth-specific photons (Kahng et al., 2012).

Pelagic Stratification. In the plankton, the most conspicuous vertical expression of spectral and light-gradient organization is the deep chlorophyll maximum. Globally, DCM depth and occurrence are strongly related to upper-layer light attenuation, while their expression is further modulated by season, mixing, nutrient availability, and water-column structure (Mignot et al., 2014; Cornec et al., 2021; Xu et al., 2022) DCMs can be true biomass maxima or photoacclimation maxima, and chlorophyll peaks often lie 50–80 m below particle or biomass maxima in oligotrophic systems (Fennel & Boss, 2003; Cornec et al., 2021).

The DCM is therefore not a single ecological layer but a vertically structured habitat in which groups occupy different positions according to combined spectral, irradiance, and nutrient affinities (Hickman et al., 2009; Mignot et al., 2014; Latasa et al., 2016). In the Celtic Sea thermocline, *Synechococcus* peaks in the upper DCM, picoeukaryotes rise near or just above the chlorophyll peak, and deeper layers contain more eukaryotes and photosynthetic carotenoids whose absorption shifts toward longer wavelengths than the upper community (Hickman et al., 2009).

Open-ocean oligotrophic systems add a second pattern. Deep DCMs can remain productive because cells such as *Prochlorococcus* adjust pigment composition to use the remaining blue photons efficiently, allowing deeper populations to function at lower PAR than shallower communities (Mignot et al., 2014). In trait comparisons across groups, *Prochlorococcus* tends to occupy relatively shallower portions of the DCM, consistent with its ability to persist under low nutrient availability, whereas diatoms may occur deeper than their light optimum when nutrient acquisition provides a compensating advantage (Latasa et al., 2016).

A second table (Table 2) helps separate the main mechanisms from the visible zonation patterns.

Table 2
Processes that generate vertical organization of marine photosynthetic organisms by absorbed wavelength and by interacting light–nutrient constraints

Mechanism	*Taxa or setting*	*Vertical effect*	*Evidence*
Differential attenuation of wavelengths	Oceanic and coastal waters	Blue persists deeper in clear water; greener fields occur in turbid water	Dufour et al., 2025; Mattei et al., 2026
Complementary pigment absorption	Macroalgae, cyanobacteria, red algae	Distinct groups exploit different spectral bands	Larkum et al., 1967; Simkin et al., 2022
Chromatic acclimation	*Synechococcus*	Reversible adjustment to ambient blue:green ratio expands niche breadth	Kehoe et al., 2025; Mattei et al., 2025
Photoacclimation of chlorophyll:carbon ratio	Oligotrophic DCMs	Chlorophyll maxima can deepen below biomass maxima	Fennel & Boss, 2003
Morphology and internal optics	Corals and seaweeds	Thickness, absorptance, and skeletal scattering improve deep-light capture	Kahng et al., 2012; Gómez et al., 2019;
Nutrient–light coupling	Thermoclines and mesophotic reefs	Realized depth reflects tradeoffs, not color alone	Hickman et al., 2009; Kahng et al., 2019; Xu et al., 2022.

Evidence from marine sediments illustrates that spectral organization can operate at much smaller spatial scales. In relatively pigment-poor sediments, wavelength-dependent attenuation produces steep vertical spectral gradients, allowing photosynthetic microorganisms with distinct spectral absorption characteristics to occupy different sediment depths (Fenchel & Straarup, 1971).

Recent work also shows that spectral zonation is dynamic rather than fixed. Seasonal changes in mixed-layer depth and attenuation shift the blue:green ratio through the water column, generating multiple intermediate spectral niches and allowing coexistence through time and depth, especially for chromatically acclimating *Synechococcus* (Mattei et al., 2025). Model projections further suggest that projected changes in ocean optical conditions may reduce spectral variability over substantial areas, potentially weakening the competitive advantage of flexible pigment phenotypes relative to fixed specialists (Mattei et al., 2026).

Conclusions. As summarized conceptually in Figure 1, the vertical organization of marine phototrophs reflects a complex interaction between the physical structure of the underwater light field and the functional characteristics of photosynthetic organisms. Wavelength-dependent attenuation creates progressively different spectral environments with depth, providing the physical basis for spectral niche differentiation. However, the observed distribution of marine phototrophs cannot be attributed to spectral quality alone. Pigment composition, chromatic acclimation, photoacclimation, morphology, tissue and skeletal optics, and nutrient availability collectively determine how efficiently organisms exploit the light available at a given depth.

Across marine environments, different mechanisms can generate superficially similar patterns of vertical organization. Complementary pigment absorption may favor particular algal or cyanobacterial groups under specific spectral conditions, whereas flexible pigment regulation can broaden the realized niche of organisms such as *Synechococcus*. In deep-water corals and seaweeds, whole-organism optical properties and morphological traits may become as important as pigment concentration in maintaining photosynthesis under severely reduced irradiance. Similarly, the vertical structure of deep chlorophyll maxima demonstrates that light gradients interact continuously with nutrient distributions

and physiological acclimation, preventing the interpretation of depth patterns as simple spectral responses.

Overall, marine vertical zonation is best regarded as a dynamic balance among spectral quality, irradiance, nutrient availability, and organismal light-harvesting strategies. This perspective provides a more mechanistic framework for understanding coexistence and depth specialization among marine phototrophs. Moreover, because spectral variability itself is environmentally dynamic, alterations in ocean optical conditions may modify the competitive relationships between organisms with fixed and flexible pigmentation strategies. Future studies should therefore integrate underwater spectral measurements with organism-level optical, physiological, and nutrient-response traits to better predict how marine phototroph communities will reorganize under changing ocean conditions.

Acknowledgements. OpenAI ChatGPT-5.3 - https://openai.com - was used for plate editing. The authors assume full responsibility for the content and materials selected and processed for publication.

Authors Contributions. Conceptualization: AMD; Writing - original draft: AMD, IVPM, IGO; Writing - review & editing: IBD, PP.

Conflict of Interest. The authors declare that there is no conflict of interest.

Data Availability. Not applicable.

Funding. This research received no external funding.

References

Cornec, M., Claustre, H., Mignot, A., Guidi, L., Lacour, L., Poteau, A., D'Ortenzio, F., Gentili, B., & Schmechtig, C. (2021). Deep chlorophyll maxima in the global ocean: Occurrences, drivers and characteristics. *Global Biogeochemical Cycles*, *35*(4), e2020GB006759. https://doi.org/10.1029/2020GB006759

Dufour, L., Garczarek, L., Mattei, F., Gouriou, B., Clairet, J., Ratin, M., Kehoe, D. M., Huisman, J., Verspagen, J. M. H., & Partensky, F. (2025). Competition for light color between marine *Synechococcus* strains with fixed and variable pigmentation. *Applied and Environmental Microbiology*, *91*(8), e00087-25. https://doi.org/10.1128/aem.00087-25

Fenchel, T., & Straarup, B. J. (1971). Vertical distribution of photosynthetic pigments and the penetration of light in marine sediments. *Oikos*, *22*(2), 172–182. https://doi.org/10.2307/3543723

Fennel, K., & Boss, E. (2003). Subsurface maxima of phytoplankton and chlorophyll: steady-state solutions from a simple model. *Limnology and Oceanography*, *48*(4), 1521–1534. https://doi.org/10.4319/lo.2003.48.4.1521

Gómez, I., Navarro, N., & Huovinen, P. (2019). Bio-optical and physiological patterns in Antarctic seaweeds: a functional trait based approach to characterize vertical zonation. *Progress in Oceanography*, *174*, 17–27. https://doi.org/10.1016/j.pocean.2018.03.013

Hickman, A. E., Holligan, P. M., Moore, C. M., Sharples, J., Krivtsov, V., & Palmer, M. R. (2009). Distribution and chromatic adaptation of phytoplankton within a shelf sea thermocline. *Limnology and Oceanography*, *54*(2), 525–536. https://doi.org/10.4319/lo.2009.54.2.0525

Holtrop, T., Huisman, J., Stomp, M., Biersteker, L., Aerts, J., Grébert, T., Partensky, F., Garczarek, L., & van der Woerd, H. J. (2021). Vibrational modes of water predict spectral niches for photosynthesis in lakes and oceans. *Nature Ecology & Evolution*, *5*(1), 55–66. https://doi.org/10.1038/s41559-020-01330-x

Kahng, S. E., & Kelley, C. D. (2007). Vertical zonation of megabenthic taxa on a deep photosynthetic reef (50–140 m) in the Au'au Channel, Hawaii. *Coral Reefs*, *26*(3), 679–687. https://doi.org/10.1007/s00338-007-0253-7

Kahng, S. E., Akkaynak, D., Shlesinger, T., Hochberg, E. J., Wiedenmann, J., Tamir, R., & Tchernov, D. (2019). Light, temperature, photosynthesis, heterotrophy, and the lower depth limits of mesophotic coral ecosystems. In Y. Loya, K. A. Puglise, & T. C. L. Bridge (Eds.), *Mesophotic Coral Ecosystems* (pp. 801–828). Springer. https://doi.org/10.1007/978-3-319-92735-0_42

Kahng, S. E., Hochberg, E. J., Apprill, A., Wagner, D., Luck, D. G., Perez, D., & Bidigare, R. R. (2012). Efficient light harvesting in deep-water zooxanthellate corals. *Marine Ecology Progress Series*, *455*, 65–77. https://doi.org/10.3354/meps09657

Kehoe, D. M., Biswas, A., Chen, B., Dufour, L., Grébert, T., Haney, A. M., Joseph, K. L., Kumarapperuma, I., Nguyen, A. A., Ratin, M., Sanfilippo, J. E., Shukla, A., Garczarek, L., Yang, X., Schluchter, W. M., & Partensky, F. (2025). Light color regulation of photosynthetic antennae biogenesis in marine phytoplankton. *Plant and Cell Physiology*, *66*(2), 168–180. https://doi.org/10.1093/pcp/pcae115

Kissae, A.-N. H., Sarri, J. H., Amlani, M. Q., Jumsali, M. H., Jamil, W. M., Imbuk, E. S., Jalilul, J. M., Jeva, M. A., & Hairol, M. D. (2025). Incorporation of salinity and AMPEP concentration in nutrient medium on dry weight, cell density, growth response, and pigment accumulation of *Nannochloropsis* sp. culture. *AACL Bioflux*, *18*(3), 1593–1604.

Larkum, A. W. D., Drew, E. A., & Crossett, R. N. (1967). The vertical distribution of attached marine algae in Malta. *Journal of Ecology*, *55*(2), 361–371. https://doi.org/10.2307/2257881

Latasa, M., Gutiérrez-Rodríguez, A., Cabello, A. M. M., & Scharek, R. (2016). Influence of light and nutrients on the vertical distribution of marine phytoplankton groups in the deep chlorophyll maximum. *Scientia Marina*, *80*(S1), 57–62. https://doi.org/10.3989/scimar.04316.01A

Mattei, F., Hickman, A. E., Uitz, J., Dufour, L., Vellucci, V., Garczarek, L., Partensky, F., & Dutkiewicz, S. (2025). Chromatic acclimation shapes phytoplankton biogeography. *Science Advances*, *11*(8), eadr9609. https://doi.org/10.1126/sciadv.adr9609

Mattei, F., Hickman, A. E., Uitz, J., Vellucci, V., Garczarek, L., Partensky, F., & Dutkiewicz, S. (2026). Phytoplankton with flexible pigment content disadvantaged by projected future decrease in variability of the ocean light spectrum. *Global Change Biology*, *32*(1), e70671. https://doi.org/10.1111/gcb.70671

Mignot, A., Claustre, H., Uitz, J., Poteau, A., D'Ortenzio, F., & Xing, X. (2014). Understanding the seasonal dynamics of phytoplankton biomass and the deep chlorophyll maximum in oligotrophic environments: a Bio-Argo float investigation. *Global Biogeochemical Cycles*, *28*(8), 856–876. https://doi.org/10.1002/2013GB004781

Pejendino, A. M., Puerres, A. E., & Torres, G. A. (2025). Effect of photosynthetically active radiation on *Rhodomonas salina* (Wislouch) D. R. A. Hill & R. Wetherbee 1989, growth using a mathematical model under laboratory conditions. *AACL Bioflux*, *18*(6), 2458–2466.

Petrescu-Mag, I. V. (2025). Sexual selection in animals: pigment-based signaling and eco-evolutionary trade-offs. *Studia Universitatis "Vasile Goldiș," Seria Științele Vieții*, *35*(3), 106–116.

Petrescu-Mag, I. V., Oroian, I. G., Păsărin, B., Safirescu, O. C., Burduhos, P., Brașovean, I., Bordea, D., Moldovan, B., Pojar, T. N., Bănățean-Dunea, I., Oroian, F. C., & Pandey, P. (2026). Functional saturation of Earth's habitable domains: constraints on land systems and potential in marine environments. *Frontiers in Systems Biology*, *6*, 1941138. https://doi.org/10.3389/fsysb.2026.1941138

Sarri, J. H., Kissae, A. N. H., Hairol, M. H., Imlan, K. H., Ensano, F. N. T., Kissae, S. H., Robles, R. J. F., Imbuk, E. S., Kissae, S. W. H., Adjid, N. M., & Albar, F. R. (2025). Cell density, growth response, and pigment accumulation of *Nannochloropsis* sp. culture under salinity concentration. *AACL Bioflux*, *18*(6), 2547–2560.

Simkin, A. J., Kapoor, L., Doss, C. G. P., Hofmann, T. A., Lawson, T., & Ramamoorthy, S. (2022). The role of photosynthesis related pigments in light harvesting, photoprotection and enhancement of photosynthetic yield *in planta*. *Photosynthesis Research*, *152*(1), 23–42. https://doi.org/10.1007/s11120-021-00892-6

Thoral, F., Pinkerton, M. H., Tait, L. W., & Schiel, D. R. (2023). Spectral light quality on the seabed matters for macroalgal community composition at the extremities of light limitation. *Limnology and Oceanography*, *68*(4), 902–916. https://doi.org/10.1002/lno.12318

Wood, A. M. (1985). Adaptation of photosynthetic apparatus of marine ultraphytoplankton to natural light fields. *Nature*, *316*, 253–255. https://doi.org/10.1038/316253a0

Xu, W., Wang, G., Cheng, X., Jiang, L., Zhou, W., & Cao, W. (2022). Characteristics of subsurface chlorophyll maxima during the boreal summer in the South China Sea with respect to environmental properties. *Science of the Total Environment*, *820*, 153243. https://doi.org/10.1016/j.scitotenv.2022.153243

Received: 30 July 2026. Accepted: 01 September 2026. Published online: 07 September 2026.
Authors:
Adela Maria Dăescu (AMD), Department of Cell Biology, Histology and Embryology, Faculty of Veterinary Medicine, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Mănăștur Street, 400372 Cluj-Napoca, Romania, e-mail: adela.daescu@usamvcluj.ro
Praveen Pandey (PP), Division of Plant Breeding and Genetic Resource Conservation, CSIR - Central Institute of Medicinal and Aromatic Plants, Lucknow-226015, India, e-mail: pandeypraveen1986@yahoo.com
Ioan Gheorghe Oroian (IGO), Department of Environmental Engineering and Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Mănăştur Street, 400372 Cluj-Napoca, Romania, e-mail: ioan.g.oroian@gmail.com
Ioan Valentin Petrescu-Mag (IVPM), Department of Environmental Engineering and Protection, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Calea Mănăștur Street, 400372 Cluj-Napoca, Romania, ioan.mag@usamvcluj.ro
Ioan Bănățean-Dunea (IBD), Department of Biology and Plant Protection, Faculty of Agriculture, University of Life Sciences „King Mihai I" from Timișoara, 119 Calea Aradului, 300645 Timișoara, Romania, e-mail: ioan_banatean@usvt.ro

How to cite this article:
Dăescu, A. M., Pandey, P., Oroian, I. G., Petrescu-Mag, I. V., & Bănățean-Dunea, I. (2026). Spectral niches and vertical organization of marine phototrophs: from light attenuation to photophysiological acclimation. *AACL Bioflux*, *19*(5), 2047-2055.