Black Sea Journal of Engineering and Science
doi: 10.34248/bsengineering.1862201

Open Access Journal
e-ISSN: 2619 – 8991

Research Article
Volume 9 - Issue 2: 734-741 / March 2026

SATELLITE-BASED ANALYSIS OF NIGHT-TIME RADIANCE DYNAMICS IN NEAR-SHORE AND OFFSHORE AQUACULTURE SYSTEMS IN ÇANDARLI BAY (NORTHERN AEGEAN SEA, TÜRKİYE)

Deniz Devrim TOSUN[1]*

[1]*Istanbul University, Faculty of Aquatic Sciences, Department of Aquaculture and Fish Diseases, 34134, Istanbul, Türkiye*

Abstract: Artificial Light at Night (ALAN) has emerged as a growing environmental concern in coastal regions, where marine aquaculture operations coexist with expanding urbanization and tourism infrastructure. This study presents a decadal satellite-based assessment of night-time radiance dynamics associated with marine aquaculture systems in Çandarlı Bay, a semi-enclosed coastal environment in the Northern Aegean Sea, Türkiye. Monthly composites from the Visible Infrared Imaging Radiometer Suite Day/Night Band (VIIRS DNB) were analyzed for the period 2014–2024 to examine long-term trends in relative radiance at offshore and near-shore aquaculture sites, alongside marine and terrestrial control zones. Aquaculture installations were classified into two spatial typologies: a near-shore island-associated cluster and an offshore solitary system. To evaluate aquaculture-related radiance independently from broader coastal illumination, an Aquaculture Light Index (ALI) was developed to quantify radiance contrast relative to a dark-water marine reference. Temporal trends were assessed using STL decomposition, the Mann–Kendall trend test, and Theil–Sen slope estimation. The offshore aquaculture system exhibited no significant long-term trend in relative radiance, indicating a stable nocturnal light signature over the study period. In contrast, near-shore aquaculture sites showed a statistically significant decline in relative radiance contrast, coinciding with increasing night-time brightness in the adjacent terrestrial control area. These findings indicate that observed changes in aquaculture-related radiance are primarily associated with intensifying coastal background illumination rather than progressive increases in farm-level lighting. The study demonstrates the importance of spatial context and background radiance when interpreting satellite-derived ALAN signals in coastal aquaculture environments.

Keywords: Artificial Light at Night (ALAN), Marine aquaculture, Night-time radiance, Satellite-based analysis, Coastal urbanization

***Corresponding author:** Istanbul University, Faculty of Aquatic Sciences, Department of Aquaculture and Fish Diseases, 34134, Istanbul, Türkiye
E mail: ddt@istanbul.edu.tr (D. D. TOSUN)
Deniz Devrim TOSUN https://orcid.org/0000-0001-6612-6624

Received: January 12, 2026
Accepted: February 13, 2026
Published: March 15, 2026

Cite as: Tosun, D. D. (2026). Satellite-based analysis of night-time radiance dynamics in near-shore and offshore aquaculture systems in Çandarlı Bay (Northern Aegean Sea, Türkiye). *Black Sea Journal of Engineering and Science*, *9*(2), 734-741.

1. Introduction

Global demand for aquatic food has increased steadily over recent decades, driven by population growth, changing dietary preferences, and the stagnation of capture fisheries. As a result, aquaculture has become a central component of global food systems, now providing more than half of the aquatic animal protein consumed by humans worldwide (FAO, 2024). Within the framework of the FAO's "Blue Transformation" agenda, aquaculture is increasingly positioned not only as a production sector but also as a strategic instrument for food security and sustainable coastal development.

Within this global context, Türkiye has emerged as one of the leading aquaculture producers, particularly in finfish farming. Over the past two decades, aquaculture production in Türkiye has expanded rapidly, exceeding half a million tonnes annually and placing the country among the top producers in Europe. This growth has been driven primarily by marine cage farming of species such as sea bass, sea bream, and rainbow trout, with production largely concentrated along the Aegean and Mediterranean coasts (Aydın et al., 2025). The spatial concentration of marine aquaculture in semi-enclosed bays has consequently made fish farms increasingly prominent elements of the coastal seascape.

At the same time, coastal regions of Türkiye have undergone substantial transformation over recent decades due to urban expansion, the proliferation of secondary housing developments, and the rapid growth of tourism-related infrastructure. These processes have resulted in pronounced changes in land-use patterns and settlement density along the coastline, particularly in tourism-oriented regions of the Aegean and Mediterranean (Sarıkaya et al., 2024). As a result, marine aquaculture activities are increasingly embedded within highly competitive multi-use coastal systems where economic development, environmental values, and social perceptions intersect. Within such settings, tourism–aquaculture conflicts arise primarily from competition for coastal and marine space, perceived environmental impacts, and differing stakeholder values. These tensions are especially pronounced in regions where aquaculture production coincides with strong tourism dependence, such as Mediterranean coastal systems. Conceptual and governance-oriented frameworks frequently emphasize spatial planning and stakeholder mediation as mechanisms to reduce conflict intensity and improve coexistence outcomes.

Theoretical interpretations of tourism–aquaculture conflicts draw on several established frameworks. Moore's Circle of Conflict model (Almeida et al., 2017) attributes disputes to multiple interacting sources, including institutional organization, public policy arrangements, power asymmetries, structural constraints, information gaps, and divergent stakeholder values or relationships. Spatial planning approaches, particularly Maritime Spatial Planning (MSP), propose zoning instruments such as Aquaculture Zones of Allocation (AZAs) to reduce competition with tourism activities, mitigate visual intrusion, and limit resource-use conflicts. Political ecology perspectives further frame these tensions as expressions of power relations within blue economy sectors, emphasizing how aquaculture–tourism interactions may reflect broader struggles over access, representation, and cultural meaning in coastal environments.

Recent empirical studies have reinforced the prominence of these conflicts across different geographic contexts. Hall (2021) documented how aquaculture contributes to spatial competition with recreational and tourism uses, often framed through concerns over seascape degradation. Wood and Filgueira (2022) identified drivers of social acceptability for bivalve aquaculture in Atlantic Canada, showing that tourism-related concerns can amplify opposition through perceived environmental risks. Markus (2024) reviewed legal siting frameworks and reported persistent conflicts between aquaculture development and tourism interests over marine space access. Similarly, Sumaila and Villasante (2025) highlighted aquaculture–tourism interactions as a recurrent source of regulatory and habitat-related disputes within broader blue economy risk assessments.

At the same time, contrarian perspectives challenge the assumption that tourism and aquaculture are inherently incompatible. Case-based narratives describe emerging aquaculture–tourism synergies (Le Gouvello et al., 2017), such as farm visitation initiatives in Greece that aim to educate tourists, stimulate local seafood consumption, and reframe aquaculture as a positive coastal activity. Halpern and Selkoe (2024) argue that proactive governance and adaptive policy design can foster synergies rather than trade-offs, particularly through multi-use platforms and integrated coastal planning. These perspectives complicate dominant conflict-based narratives by highlighting potential economic, cultural, and educational co-benefits. Despite this expanding body of conceptual and empirical work, significant research gaps remain. Direct quantitative assessments of aquaculture-derived radiance within dynamically evolving coastal light environments are particularly scarce. Socioeconomic dimensions of tourism–aquaculture interactions also remain insufficiently examined, particularly with respect to emerging offshore systems and climate-related pressures.

Among the most frequently cited points of contention in tourism–aquaculture debates is night-time illumination associated with offshore cage systems. Artificial lighting is commonly framed as a form of light pollution, with aquaculture installations portrayed as visually intrusive nocturnal features in otherwise natural coastal environments (Schultz et al., 2026). In parallel with these perception-based debates, coastal areas in Türkiye have experienced marked increases in terrestrial artificial light at night associated with urban growth, secondary housing, and tourism-related infrastructure. This broader brightening of the coastal nightscape alters the background against which offshore structures are observed, complicating attribution of perceived visual impacts solely to aquaculture activities.

Despite the prominence of light pollution claims in aquaculture-related conflicts, quantitative studies that isolate aquaculture-derived night-time light signals from terrestrial background illumination remain limited. Few investigations apply contrast-based approaches that distinguish localized aquaculture emissions from concurrent coastal radiance trends. Consequently, it remains unclear whether observed changes in aquaculture visibility reflect intensification of operational lighting or shifts in surrounding background illumination.

Against this background, the present study tests the hypothesis that the apparent visual prominence attributed to near-shore aquaculture installations is not necessarily driven by intensification of operational lighting but may instead result from changes in the surrounding coastal light environment. Using a decade-long time series of satellite-derived night-time radiance data, this study compares offshore and near-shore aquaculture systems within Çandarlı Bay, together with marine and terrestrial control zones, to disentangle aquaculture-related light signals from broader coastal artificial lighting dynamics. By operationalizing radiance as a relative contrast metric (ALI) rather than relying on absolute brightness values, the study advances existing ALAN assessments by explicitly accounting for evolving background illumination conditions. This reframing positions light pollution as a measurable radiometric contrast rather than solely a perception-based claim.

2. Materials and Methods

2.1. Study Area and Geographic Typologies

The study was conducted in Çandarlı Bay, a semi-enclosed coastal system located in the Northern Aegean

Sea, Türkiye. The area represents one of the major marine aquaculture zones in the region, characterized by intensive cage-based finfish farming and close proximity to coastal settlements. The Area of Interest (AOI) encompasses licensed aquaculture zones located off the coasts of Denizköy and Bademli (38.90°–38.93° N; 26.81°–26.84° E).

To evaluate the influence of coastal proximity on satellite-based night-time radiance signals, aquaculture sites were categorized into two spatial typologies based on their relative position to the coastline and surrounding terrestrial features. Typology A (Near-Shore Island Cluster) includes three farms (Farms 2, 3, and 4) grouped in the lee of a local island chain, maintaining a minimum Euclidean distance of approximately 1,580 m from the nearest residential settlement. Typology B (Offshore Solitary System) consists of a single deep-water farm (Farm 1) located more than 2,600 m offshore and spatially isolated from immediate terrestrial light sources. This typological classification was designed to capture differences in background illumination conditions, rather than differences in farm structure or production practices (Figure 1).

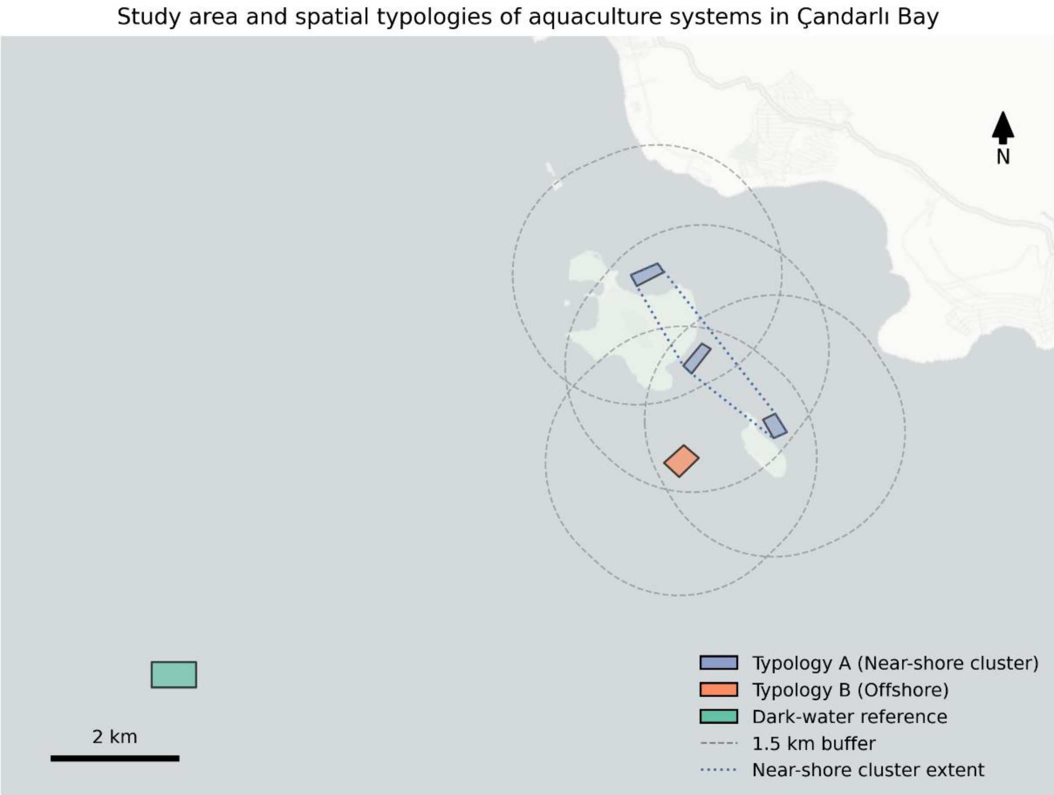

Figure 1. Study area and spatial configuration of aquaculture systems in Çandarlı Bay (Northern Aegean Sea, Türkiye).

Near-shore aquaculture sites forming the island-associated cluster (Typology A) and the offshore solitary aquaculture system (Typology B) are shown together with the dark-water marine reference area used to characterize background radiance conditions. Dashed circles represent the 1.5 km adjacency buffer applied around each aquaculture site to exclude direct terrestrial artificial light spillover from coastal settlements. The dotted polygon outlines the spatial extent of the near-shore cluster, highlighting the typological distinction between clustered near-shore and isolated offshore systems. The scale bar and north arrow are provided for spatial reference.

2.2. Terrestrial and Marine Reference Control Zones

To validate the origin of observed radiance trends and to distinguish aquaculture-derived signals from broader background illumination, two control zones were defined. A Marine Reference Zone (dark-water control) was established in open pelagic waters (38.87° N, 26.75° E), located more than 5 km from any artificial structure, shipping lane, or coastline. This zone represents the natural background radiance of the marine environment and provides a baseline against which aquaculture-related signals were normalized.

In addition, a Terrestrial Control Zone was delineated over the Denizköy settlement (38.91° N, 26.84° E), the nearest urbanized area to the aquaculture sites. This land-based control zone was monitored to quantify long-term changes in terrestrial Artificial Light at Night (ALAN) and to assess whether coastal urbanization is altering the background contrast against which offshore aquaculture installations are visually perceived.

2.3. Satellite Data Acquisition

Night-time radiance data were obtained from the Visible Infrared Imaging Radiometer Suite (VIIRS) onboard the Suomi National Polar-orbiting Partnership (Suomi-NPP) satellite. The analysis utilized the VIIRS Day/Night Band (DNB) monthly composite product (VNP46A3/vcmcfg), which provides cloud-free, moonlight-corrected average radiance values expressed in $nW·cm^{-2}·sr^{-1}$. The VIIRS DNB sensor is specifically designed for low-light detection and has been widely applied in Artificial Light at Night (ALAN) studies due to its high radiometric sensitivity and stable calibration characteristics (Li et al., 2025).

The temporal scope of the study spans a complete decade, from January 2014 to December 2024, yielding a total of 120 monthly observations for each zone. This time frame was selected to capture long-term operational and environmental dynamics while minimizing the influence of short-term meteorological variability or sensor-related noise.

2.4. Data Pre-processing and Geometric Validation

Given the native spatial resolution of approximately 742 m for the VIIRS DNB sensor, a 1.5 km adjacency radius (corresponding to approximately two VIIRS pixels) was projected around the centroid of each aquaculture site. This buffer distance was selected to ensure adequate spatial sampling while minimizing pixel contamination from adjacent light sources.

Geospatial analysis confirmed that the primary terrestrial light sources, including the Denizköy settlement and surrounding seasonal housing developments, fall outside the defined buffer zones of the aquaculture sites. This geometric validation ensures that the retrieved marine radiance signals are not affected by direct pixel adjacency, blooming effects, or land-based light spillover, thereby isolating offshore operational illumination.

2.5. Calculation of the Aquaculture Light Index (ALI)

To evaluate changes in the visual prominence of aquaculture installations relative to their marine background, an Aquaculture Light Index (ALI) was developed. This index quantifies radiance contrast rather than absolute brightness, allowing for the assessment of relative visibility under changing background conditions. A relative formulation was preferred over absolute radiance values in order to account for concurrent variations in coastal background illumination and to isolate aquaculture-related contrast from broader regional lighting dynamics.

The ALI was calculated for each month (*t*) as (equation 1):

$$ALI_{(t)} = (L_{(farm,t)} - L_{(ref,t)}) / L_{(ref,t)} \quad (1)$$

where $L_{farm,t}$ represents the mean radiance of aquaculture zone pixels at month *t*, and $L_{ref,t}$ represents the mean radiance of the marine reference (dark-water) zone at the same time. Positive ALI values indicate that aquaculture installations are brighter than the surrounding background, while negative or decreasing values indicate reduced contrast against the marine environment

2.6. Statistical Analysis

The 10-year time series for all zones (Typology A, Typology B, and the terrestrial control) were decomposed into seasonal and trend components using the STL (Seasonal and Trend decomposition using Loess) method, which is widely applied for isolating long-term trends in time series exhibiting pronounced seasonal variability (Trull et al., 2022). All subsequent trend analyses, including the Mann–Kendall test and Theil–Sen slope estimation, were performed on the STL-extracted trend component in order to isolate long-term monotonic behavior from seasonal variability.

To assess the statistical significance of monotonic trends in the extracted trend components, the non-parametric Mann–Kendall trend test was employed. The magnitude of detected trends was quantified using the Theil–Sen slope estimator. These non-parametric methods are commonly used in environmental time-series analysis due to their robustness against non-normal data distributions and sensitivity to outliers (Gumus et al., 2022). Statistical significance was evaluated at a threshold of $\alpha=0.05$.

All statistical analyses were performed using Python (version 3.9), employing the *pymannkendall* library for trend testing and the Google Earth Engine (GEE) API for data handling and spatial analysis.

3. Results

3.1. Spatial Validity of Offshore Radiance Signals

Geospatial buffering analysis confirmed that the selected aquaculture sites are optically isolated from direct terrestrial light contamination. As illustrated in Figure 1, a 1.5 km adjacency radius (approximately two VIIRS pixels) was projected around the centroid of each farm location. The primary sources of terrestrial artificial light, including the Denizköy settlement and associated seasonal residential developments, were consistently located outside these buffer zones. This spatial configuration verifies that the radiance signals extracted for subsequent analyses originate from offshore sources and are not influenced by direct pixel adjacency or land-based light spillover.

3.2. Decadal Spatiotemporal Trends (2014–2024)

The temporal evolution of the Aquaculture Light Index (ALI) for the two aquaculture typologies is illustrated in Figure 2. Visual inspection of the STL-derived trend components indicates relative stability in the offshore system and a progressive decline in contrast for the near-shore cluster over the study period. Mann–Kendall trend analysis revealed divergent temporal trajectories among the aquaculture typologies and the terrestrial control zone over the 10-year observation period (Table 1). Trends are reported based on STL-extracted trend components and quantified using Theil–Sen slope estimates.

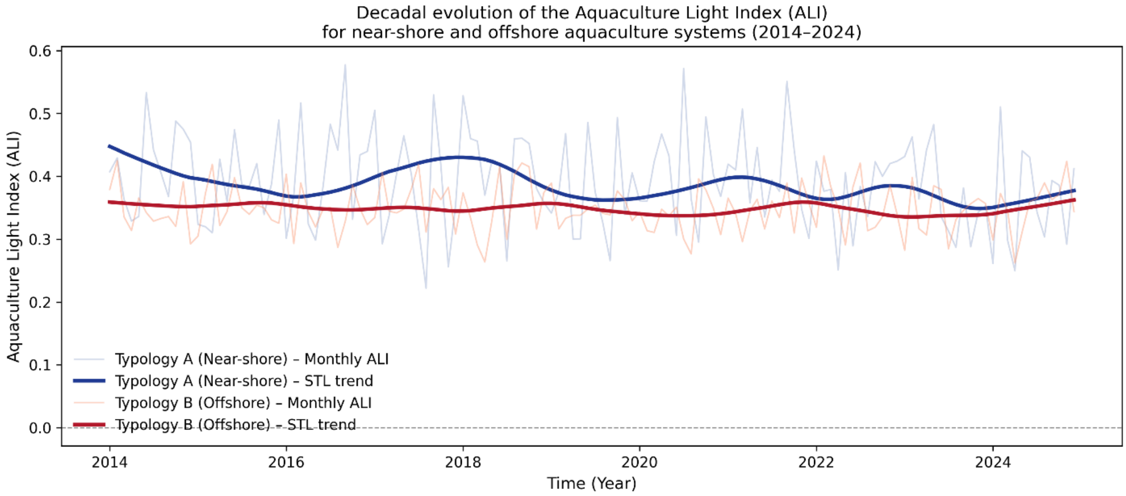

Figure 2. Decadal evolution of the Aquaculture Light Index (ALI) for the Near-Shore Island Cluster (Typology A) and the Offshore Solitary System (Typology B) in Çandarlı Bay between 2014 and 2024. Thin lines represent monthly ALI values, while thick lines indicate STL-derived long-term trends. Positive ALI values denote higher radiance at aquaculture sites relative to the marine background, whereas decreasing ALI values indicate reduced visual contrast against the surrounding night-time environment.

To examine the radiometric basis underlying the observed ALI patterns, the decadal evolution of raw VIIRS DNB night-time radiance was assessed for near-shore and offshore aquaculture systems alongside the terrestrial control site (Figure 3). Figure 3 highlights the increasing terrestrial radiance trend relative to the comparatively stable offshore emissions, providing context for the declining near-shore contrast observed in Figure 2.

Table 1. Mann–Kendall trend statistics (2014–2024)

Site Typology	Trend Direction	P-value	Theil–Sen Slope (yr^{-1})
Offshore Solitary System (Typology B)	No trend	0.0807	−0.0013
Near-Shore Island Cluster (Typology A)	Decreasing	< 0.001	−0.0067
Terrestrial Control (Denizköy)	Increasing	< 0.001	+0.0030

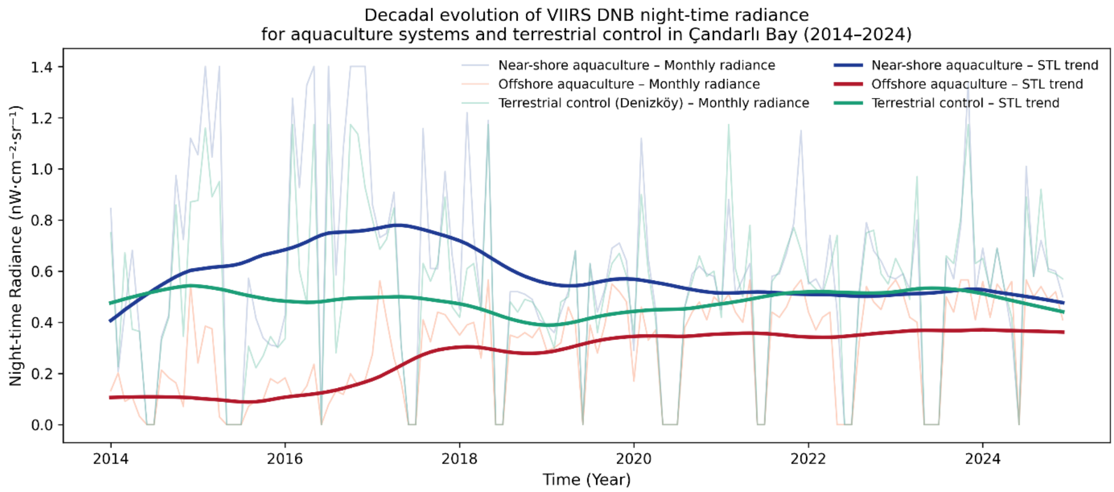

Figure 3. Decadal evolution of VIIRS DNB night-time radiance for near-shore aquaculture systems (Typology A), offshore aquaculture systems (Typology B), and the terrestrial control site (Denizköy) in Çandarlı Bay between 2014 and 2024.

Thin lines represent monthly radiance values, while thick lines indicate STL-derived long-term trends. For visualization purposes, extreme monthly radiance outliers were clipped at the 95th percentile, whereas all statistical analyses were conducted using the full, unmodified time series.

3.2.1. Near-Shore Island Cluster (Typology A)

In contrast, the near-shore island cluster demonstrated a pronounced and statistically significant decreasing trend in ALI values over time. The Mann–Kendall test identified a highly significant monotonic decline P<0.001, with a negative Theil–Sen slope of -0.0067 yr^{-1}. This trend reflects a consistent reduction in relative radiance contrast between the clustered near-shore aquaculture installations and the marine background across the study period.

3.2.2. Terrestrial Control Zone (Denizköy Settlement)

To contextualize the observed offshore contrast dynamics, the raw radiance time series of the nearest coastal settlement (Denizköy) was analyzed using the same statistical framework. The terrestrial control zone exhibited a highly significant increasing trend in radiance intensity (P<0.001), with a positive Theil–Sen slope of 0.0030 yr^{-1}. This indicates a sustained intensification of terrestrial artificial light emissions in the coastal environment over the same temporal window.

4. Discussion

This study provides a decadal, satellite-based assessment of nocturnal radiance dynamics associated with marine aquaculture installations in Çandarlı Bay, interpreted within the broader context of coastal Artificial Light at Night (ALAN). Satellite-observed night-time radiance has become a widely used proxy for characterizing anthropogenic lighting patterns following the introduction of the VIIRS Day/Night Band (DNB), which offers improved spatial resolution, radiometric sensitivity, and calibration stability compared to earlier low-light sensors (Elvidge et al., 2015; Elvidge et al., 2021). Evaluations of VIIRS monthly composite products further demonstrate their suitability for long-term trend analysis and for distinguishing built-up areas from background radiance, particularly in heterogeneous coastal and urban transition zones (Shi et al., 2014). By jointly analyzing offshore aquaculture sites, near-shore installations, a marine reference zone, and a terrestrial control area, the present results reveal spatially differentiated and temporally divergent radiance trajectories rather than a uniform intensification of coastal lighting.

4.1. Temporal Stability of Offshore Aquaculture Operations

The Offshore Solitary System (Typology B) exhibited no statistically significant monotonic trend in relative radiance contrast over the 10-year observation period. This temporal stability indicates that, once operational routines are established, offshore cage-based aquaculture installations can maintain a consistent satellite-detectable radiance profile relative to the surrounding pelagic environment.

Offshore aquaculture systems are spatially constrained by fixed cage-grid configurations and licensing boundaries, which inherently limit the progressive expansion of illuminated infrastructure. Consequently, changes in operational lighting are more likely to manifest as short-term, episodic events rather than sustained long-term intensification. Such transient radiance anomalies are a documented characteristic of night-time satellite observations of offshore environments, where illuminated features are typically detected as localized intensity spikes rather than spatially diffuse sources (Elvidge et al., 2015; Elvidge et al., 2021). The intermittent deviations observed in the offshore time series are therefore interpreted as short-lived operational signals rather than structural changes in baseline illumination.

The absence of a detectable long-term trend should not be interpreted as a limitation of the dataset or analytical approach. Long-term VIIRS-based studies demonstrate that many offshore and coastal-adjacent regions exhibit statistically stable radiance levels over multi-year periods when analyzed using monthly composite products, even in rapidly developing coastal systems (Liu et al., 2021; Liu et al., 2025). In this context, the observed stability of the offshore aquaculture system represents a genuine radiometric characteristic rather than a methodological artefact.

4.2. Divergent Near-Shore Trends and Background Radiance Dynamics

In contrast to the offshore system, the Near-Shore Island Cluster (Typology A) demonstrated a statistically significant decline in relative radiance contrast over the study period. This finding indicates that near-shore aquaculture installations have become progressively less distinct relative to their surrounding nocturnal background at the satellite-observation scale. This interpretation is further supported by the contrasting behavior of raw night-time radiance observed at the terrestrial control site and the aquaculture systems, which reveals stable offshore emissions alongside increasing coastal background luminance.

The concurrent increase in radiance intensity observed in the terrestrial control zone provides critical context for interpreting this contrast decline. Satellite-derived night-time radiance products explicitly account for background luminance and atmospheric glow effects, which can mask localized light sources as ambient brightness increases (Elvidge et al., 2021). Empirical evaluations of VIIRS DNB data further show that increases in surrounding background radiance—particularly in coastal and peri-urban environments—can reduce the detectability of fixed-intensity offshore light sources without requiring any change in their absolute emission levels (Shi et al., 2014; Elvidge et al., 2015).

Large-scale analyses of coastal ALAN further demonstrate that night-time radiance in coastal regions exhibits substantial spatial heterogeneity and temporally divergent trends, even within the same regional context (Xiao et al., 2023). Such findings reinforce the interpretation that changes in relative contrast at near-shore aquaculture sites may arise from evolving background radiance conditions rather than uniform increases in local light emissions.

4.3. Spatial Dominance over Temporal Variability in Coastal ALAN

Recent Mediterranean-scale assessments provide additional evidence that spatial configuration exerts a substantially stronger influence on ALAN distributions than interannual variability. In the Sicilian coastal zone, Maccarrone and Quinci (2024) demonstrated that year-to-year changes explain only a negligible fraction of total ALAN variance, whereas proximity to the coastline and land–sea domain boundaries dominate observed night-time radiance patterns. These results highlight a systematic offshore attenuation of ALAN intensity and support the interpretation that stable offshore radiance profiles and declining near-shore contrast can arise from spatial background structure rather than temporal changes in local light emissions.

4.4. Background Radiance Variability and Atmospheric Modulation

Recent studies further indicate that background night-time radiance in coastal regions is not static but dynamically modulated by atmospheric and environmental processes. Using long-term VIIRS monthly composites, Liu et al. (2025) showed that diffuse background radiance over coastal and marine-adjacent areas increases during humid periods due to enhanced atmospheric scattering, independent of changes in ground-based light emissions. This mechanism provides a physically grounded explanation for the amplification of background radiance and the masking of localized light sources observed in coastal systems.

4.5. Implications for Coastal Light Management

The results underscore the importance of interpreting aquaculture-related nocturnal radiance within the broader context of coastal lighting dynamics. While mitigation measures at the farm level—such as directional lighting, shielding, and operational optimization—remain relevant, the findings indicate that long-term changes in the coastal night-time radiance environment cannot be attributed to marine installations alone.

In semi-enclosed coastal systems such as Çandarlı Bay, increases in terrestrial ALAN associated with residential expansion, tourism infrastructure, and transportation networks may exert a stronger influence on background nocturnal conditions than the relatively stable radiance profiles of offshore aquaculture operations. Consequently, effective management of coastal night-time light environments requires an integrated land–sea perspective that considers cumulative radiance contributions across sectors rather than focusing exclusively on marine activities.

In addition to its site-specific application, the Aquaculture Light Index (ALI) framework may be transferable to other coastal or offshore systems where distinguishing localized anthropogenic light sources from evolving background radiance is methodologically important. By expressing radiance as a relative contrast against a stable marine reference, the index allows for consistent long-term comparisons in regions experiencing concurrent coastal urbanization or environmental variability. Such an approach may therefore support future ALAN assessments in heterogeneous coastal settings beyond the present study.

5. Conclusion

This study provides a decadal, satellite-based evaluation of night-time radiance dynamics associated with marine aquaculture systems in Çandarlı Bay, using VIIRS DNB observations to examine spatially differentiated patterns of Artificial Light at Night (ALAN) in a semi-enclosed coastal environment. By integrating offshore and near-shore aquaculture sites with marine and terrestrial control zones, the analysis moves beyond site-specific brightness assessments and emphasizes the role of spatial context and background radiance in shaping satellite-detectable light signals.

The results demonstrate that offshore aquaculture operations exhibit a temporally stable radiance profile over the 2014–2024 period, indicating that established cage-based systems do not necessarily contribute to progressive increases in nocturnal light emissions at the satellite-observation scale. In contrast, near-shore aquaculture installations show a declining relative radiance contrast over time, a pattern that coincides with increasing background luminance in adjacent coastal settlements. This divergence highlights that changes in perceived aquaculture-related light signatures can arise from evolving coastal background conditions rather than from intensification of farm-level lighting practices.

These findings underscore the importance of interpreting aquaculture-related ALAN within a broader coastal lighting framework. Focusing exclusively on marine installations risks misattributing changes in nocturnal radiance to aquaculture activities while overlooking the dominant influence of terrestrial urbanization and associated infrastructure on background illumination. The study therefore supports an integrated land–sea perspective for assessing and managing coastal night-time light environments, particularly in regions where aquaculture, tourism, and residential development coexist.

Methodologically, the study demonstrates the utility of relative radiance metrics and long-term satellite composites for disentangling localized light sources from diffuse background signals in complex coastal settings. While the analysis is geographically specific to Çandarlı Bay, the approach is transferable to other semi-enclosed coastal systems where concerns regarding aquaculture-related light pollution intersect with broader patterns of coastal development.

Overall, the results suggest that policy discussions and management strategies addressing coastal ALAN should be grounded in spatially explicit, evidence-based assessments that consider cumulative radiance contributions across sectors. In this context, marine aquaculture should be evaluated as one component of a dynamically changing coastal nightscape, rather than as an isolated or dominant driver of nocturnal light pollution.

Author Contributions

The percentages of the author' contributions are presented below. The author reviewed and approved the final version of the manuscript.

	D.D.T.
C	100
D	100
S	100
DCP	100
DAI	100
L	100
W	100
CR	100
SR	100

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The author declares no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because there was no study on animals or humans.

References

Almeida, J., Costa, C., & Da Silva, F. N. (2017). A framework for conflict analysis in spatial planning for tourism. *Tourism Management Perspectives*, *24*, 94–106. https://doi.org/10.1016/j.tmp.2017.07.021

Aydın, İ., Öztürk, R. Ç., Eroldoğan, O. T., Arslan, M., Terzi, Y., Yılmaz, S., Diken, G., Yıldırım, Ö., Bodur, T., Gültepe, N., Erdem, Ö. A., Evliyaoğlu, E., Dürrani, Ö., Gülen, S., Batır, E., Altınok, İ., & Sevgili, H. (2025). An in-depth analysis of the finfish aquaculture in Türkiye: Current status, challenges, and future prospects. *Reviews in Aquaculture*, *17*(2), Article e70010. https://doi.org/10.1111/raq.70010

Elvidge, C. D., Baugh, K., Zhizhin, M., Hsu, F. C., & Ghosh, T. (2021). VIIRS night-time lights. In *Remote sensing of night-time light* (pp. 6–25). Routledge.

Elvidge, C. D., Zhizhin, M., Baugh, K., & Hsu, F. C. (2015). Automatic boat identification system for VIIRS low light imaging data. *Remote Sensing*, *7*(3), 3020–3036. https://doi.org/10.3390/rs70303020

FAO. (2024). *The state of world fisheries and aquaculture 2024: Blue transformation in action*. Food and Agriculture Organization of the United Nations. https://www.fao.org/documents/card/en/c/cc0461en

Gumus, V., Avsaroglu, Y., & Simsek, O. (2022). Streamflow trends in the Tigris river basin using Mann–Kendall and innovative trend analysis methods. *Journal of Earth System Science*, *131*, Article 34. https://doi.org/10.1007/s12040-021-01770-4

Hall, C. M. (2021). Tourism and fishing. *Scandinavian Journal of Hospitality and Tourism*, *21*(3), 241–248. https://doi.org/10.1080/15022250.2021.1955739

Halpern, B. S., & Selkoe, K. A. (2024). Reaping the synergies between ocean aquaculture and fisheries. *One Earth*, *7*(10), 1670–1673. https://doi.org/10.1016/j.oneear.2024.09.007

Le Gouvello, R., Hochart, L. E., Laffoley, D., Simard, F., Andrade, C., Angel, D., & Marino, G. (2017). Aquaculture and marine protected areas: Potential opportunities and synergies. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *27*, 138–150. https://doi.org/10.1002/aqc.2821

Li, J., Lu, L., & Li, X. (2025). Estimating city emission function with VIIRS/DNB data and vegetation phenology. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, 24331–24341. https://doi.org/10.1109/JSTARS.2025.3610127

Liu, S., So, C. W., & Pun, C. S. J. (2021, July). *Analyzing long-term artificial light at night using VIIRS monthly product with land use data: Preliminary result of Hong Kong*. 2021 IEEE International Geoscience and Remote Sensing Symposium IGARSS (pp. 6821–6824). IEEE. https://doi.org/10.1109/IGARSS47720.2021.9553915

Liu, S., So, C. W., & Pun, C. S. J. (2025). Analyzing the sources and variations of nighttime lights in Hong Kong from VIIRS monthly data. *Remote Sensing*, *17*(8), Article 1447. https://doi.org/10.3390/rs17081447

Maccarrone, V., & Quinci, E. M. (2024). Assessment of artificial light at night across geographical features in the Sicilian coastal zone. *Land*, *13*(12), Article 2219. https://doi.org/10.3390/land13122219

Markus, T. (2024). Finding the right spot: Laws governing the siting of aquaculture activities. *Frontiers in Aquaculture*, *3*, Article 1428497. https://doi.org/10.3389/faquc.2024.1428497

Sarıkaya Levent, Y., Şahin, E., & Levent, T. (2024). The role of tourism planning in land-use/land-cover changes in the Kızkalesi tourism destination. *Land*, *13*(2), Article 151. https://doi.org/10.3390/land13020151

Schultz, K. M., Scyphers, S. B., Hughes, A. R., Kimbro, D. L., Kirk, S., & Grabowski, J. H. (2026). Coastal resident's perceptions and attitudes of the visual impacts of oyster aquaculture cultivation methods along the Atlantic coast of the US. *Ocean & Coastal Management*, *271*, Article 107951. https://doi.org/10.1016/j.ocecoaman.2025.107951

Shi, K., Huang, C., Yu, B., Yin, B., Huang, Y., & Wu, J. (2014). Evaluation of NPP-VIIRS night-time light composite data for extracting built-up urban areas. *Remote Sensing Letters*, *5*(4), 358–366. https://doi.org/10.1080/2150704X.2014.905728

Sumaila, U. R., & Villasante, S. (2025). Surging blue economy, increasing conflict risks and mitigation strategies. *Frontiers in Marine Science*, *12*, Article 1499386. https://doi.org/10.3389/fmars.2025.1499386

Trull, O., García-Díaz, J. C., & Peiró-Signes, A. (2022). Multiple seasonal STL decomposition with discrete-interval moving seasonalities. *Applied Mathematics and Computation*, *433*, Article 127398. https://doi.org/10.1016/j.amc.2022.127398

Wood, S. E., & Filgueira, R. (2022). Drivers of social acceptability for bivalve aquaculture in Atlantic Canadian communities. *Ecology and Society*, *27*(3), Article 34. https://doi.org/10.5751/ES-13358-270309

Xiao, Q., Zhou, M., Lyu, Y., Lu, J., Zhang, K., Figueiro, M., & Bauer, C. (2023). County-level artificial light at night (ALAN) in the contiguous US (2012–2019): Spatial variations, temporal trends, and environmental justice analyses. *Environmental Science and Pollution Research*, *30*(54), 115870–115881. https://doi.org/10.1007/s11356-023-30572-y