Comparison and evaluation of the 2014 and 2025 Environmental Impact Assessments (EIAs) for the Amvrakikos Gulf aquaculture POAY

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MacAlister Elliott & Partners Limited
7 Lynwood Court, Priestland's Place, Lymington, Hampshire, SO41 9GA, England
www.macalister-elliott.com

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Author(s)	Patrick White, Sophie Fridman
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Name	Title	Signature	Date
Sophie Fridman	Senior Aquaculture Consultant	S. Fridman	4th November 2025
Sophie Fridman	Senior Aquaculture Consultant	S. Fridman	2nd June 2026
Alex Senechal	Principal Consultant	A Senechal	20th July 2026

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Abbreviations and Acronyms

EIA	Environmental Impact Assessment
POAY	Organized Aquaculture Development Areas

Assessment criteria

The following assessment categories have been used when considering various aspects of the EIA:

- **Critical weakness**: A critical weakness refers to a significant flaw or deficiency in the EIA report that has the potential to substantially undermine the accuracy, comprehensiveness, or credibility of the assessment. This could include fundamental errors or omissions in data collection or analysis, failure to consider key environmental impacts, or lack of compliance with regulatory requirements. Critical weaknesses typically require urgent attention and correction to ensure the integrity of the assessment process and the validity of its conclusions.
- **Major weakness:** A major weakness denotes a notable deficiency in the EIA report that, while not as severe as a critical weakness, still has a significant impact on the overall quality and reliability of the assessment. This may include inadequate documentation of methodologies, incomplete analysis of potential impacts, or insufficient consideration of alternative measures or mitigation strategies. Major weaknesses require substantial remediation to address deficiencies and improve the overall robustness of the assessment.
- **Weakness:** A weakness refers to a less significant flaw or limitation in the EIA report that may detract from its effectiveness or thoroughness but does not severely compromise its overall validity or utility. This could include minor inconsistencies in data presentation, gaps in information, or shortcomings in the assessment of certain environmental factors. While weaknesses may not necessarily invalidate the assessment, they still warrant attention and corrective action to enhance the credibility and reliability of the findings.
- **Minor weakness:** A minor weakness indicates a relatively minor or incidental flaw in the EIA report that has minimal impact on the overall quality or integrity of the assessment. This might include inconsistencies or minor omissions in documentation. While minor weaknesses may not significantly affect the substance of the assessment, they should still be addressed to ensure clarity, accuracy, and professionalism in the report

Executive summary

The original Strategic Environmental Impact study for the Organized Aquaculture Development Areas (POAY) in and around the Gulf of Amvrakikos was published by NAYS Ltd. in 2014 and was based on data collected and analyzed in 2009 and published data from 1982 to 2010. This analysis is a review of a new EIA published in 2025 by NAYS Ltd.

There are significant problems with the version of the report that was made available through the Department of the Environment in Greece. It is a poorly scanned copy where parts of the text were incomplete or inaccurately rendered. Hyperlinks in the original report were unclickable and unable to be checked. Despite multiple requests to the department to make an electronic version available that was not scanned, this was not available.

The NAYS EIA comparison and assessment for the Amvrakikos Gulf aquaculture POAY presents a structured attempt to evaluate alternative development options and environmental implications, but the analysis remains primarily descriptive and lacks depth in scientific and policy integration. NAYS compares the “zero solution” with the proposed POAY zoning scenario, summarizes spatial configurations, and provides qualitative statements on expected impacts.

This comparison report focuses on how the revised EIA addresses environmental, spatial, and management aspects relative to the earlier study. While the updated document reflects progress in aligning aquaculture planning with new Greek spatial-planning legislation (Laws 4447/2016 and 4759/2020) and introduces a more structured zoning approach through the POAY, its environmental assessment remains largely qualitative and administrative rather than analytical.

The updated EIA for the Amvrakikos POAY was prepared to ensure closer alignment with national and EU legislative frameworks, integrate the latest environmental monitoring results, and address climate and ecological vulnerabilities in one of Greece’s most environmentally sensitive marine systems. The revision enables aquaculture development to proceed under modernized environmental safeguards, coordinated spatial planning, and adaptive management principles consistent with EU sustainability objectives.

The 2025 EIA reduces the proposed total finfish production by roughly 27.87% compared with 2014, eliminates or reassigns several high-output zones, and introduces standardized capacity limits based on park size. Three central zones (5, 6, and 7) have been converted to shellfish cultivation, supporting the shift toward nutrient-extractive aquaculture (**Table 1**).

Table 1. Comparison between the two EIAs

Parameter	2014 EIA	2025 EIA	Difference
No. of active finfish zones	15	8	Reduced by 7 zones
Total finfish production (approx.)	7499.5 tonnes	5590 tonnes	Reduced by 2159.5 tonnes
Fish farm zone area (stremmata)	*	540	*
Zones converted to shellfish farming	*	Zones 5, 6, 7	Increased by 3 shellfish zones

*Information was not provided in either EIA.

The updated EIA demonstrates a clearer link between aquaculture zoning and the national spatial framework and provides more detailed site descriptions, technical criteria for siting (depth, spacing, and buffer zones), and better alignment with legal obligations under national and EU frameworks. These additions represent procedural improvements compared with the earlier report. **However, from a scientific and ecological perspective, progress is limited.** The revised EIA continues to rely heavily on dated studies (1998–2007) and general Mediterranean literature rather than incorporating new field data or site-specific surveys for key habitats.
The 2025 EIA continues to demonstrate the following weaknesses:

- **No quantitative modelling.** No nutrient-dispersion or carrying-capacity models used; flushing and sustainability assumptions unverified. *(Critical weakness)*
- **No cumulative impact assessment:** Combined effects of multiple farms on benthic health and eutrophication not analyzed. *(Critical weakness)*
- **Poor coverage of Natura 2000, SPA/SPC, and Ramsar commitments.** No compatibility analysis for protected habitats, birds, or dolphins. *(Major weakness)*
- **Weak monitoring framework.** Indicators vague and non-measurable; no sampling design or threshold values. *(Major weakness)*
- **No alternative production scenarios.** Intensity or location options not explored to reduce impacts. *(Major weakness)*
- **No link to carrying-capacity or eutrophication indices.** Production not related to ecological or nutrient-load thresholds. *(Major weakness)*
- **Weak baseline comparison.** The zero-alternative rejected on administrative, not environmental, grounds. *(Weakness)*
- **Descriptive, not analytical.** Many impact statements qualitative and unsupported by evidence. *(Minor weakness)*

Caveat
This analysis and summary were prepared using a poorly scanned and machine-translated copy of the Amvrakikos EIA. As a result, parts of the text were incomplete or inaccurately rendered. Additionally, any links in the original EIA report were unclickable and unable to be checked. Certain place names, figures, tables, and section titles may contain transcription or translation errors. All factual details, numerical data, and terminology should therefore be cross-checked against the original Greek-language version of the report to ensure full accuracy and correct interpretation.

Reasons for the updating of the EIA

The new Environmental Impact Assessment (EIA) for the Amvrakikos Gulf ΠΟΑΥ (Organized Aquaculture Development Area) was undertaken to revise and validate earlier planning studies in accordance with new Greek and EU legislation, updated environmental information, and revised spatial management requirements. The update ensures that aquaculture development in the Gulf aligns with current ecological, legal, and climate-adaptation frameworks, replacing outdated datasets and integrating results from the mandatory monitoring programs of existing farms.

Changes required by Greek Legislation:

- **Spatial planning and POAY frameworks.**

  Adjustments to the layout, zoning, and total area of the POAY parks were made to comply with the latest national spatial planning laws and the Ministry of Environment Circular No. 31760/23-06-2016, which defines how aquaculture units are to be organized within designated Areas for Aquaculture Development (ΠΑΥ).
  The circular establishes the hierarchy of ΠΟΑΥ (Organized Development Areas) and ΠΑΣΜ (Informal Clusters), setting limits of five farms and a maximum total leased area of 100 stremmata per PASM, with farm spacing between 500 m and 2 km.
  In Amvrakikos, where multiple farms already operate in clusters, these were recognized as ΠΑΣΜ pending formal integration into a ΠΟΑΥ, ensuring legal continuity and structured transition to an organized management scheme.

- **Institutional and administrative updates**

  The EIA incorporates recent ministerial decisions, regional planning adjustments, and administrative requirements for fish farm producer consensus (minimum 60%) in the establishment of a POAY. It also formalizes stakeholder input, reflecting the opinions of Decentralized Administration Services, Fisheries Authorities, and Environmental Directorates collected through a renewed consultation process.

- **Rest and recovery zones**

  The design now distinguishes between productive zones and resting (fallow) zones, in accordance with updated Greek fisheries and aquaculture management legislation, allowing recovery of benthic habitats and compliance with the national aquaculture zoning strategy.

Changes required by EU Legislation

- **Environmental and biodiversity protection**

  The updated EIA incorporates a “Due Assessment Document” evaluating impacts on Natura 2000 sites, as required by Article 6 of the EU Habitats Directive (92/43/EEC) and transposed into Greek law. Mapping and conservation status of protected habitats, such as Posidonia oceanica meadows and bird protection zones, were updated using the most recent EU Standard Data Forms and national Natura 2000 database revisions. The study also aligns with the EU Water Framework Directive (2000/60/EC) and the Marine Strategy Framework Directive (2008/56/EC), ensuring that proposed aquaculture activities maintain or improve ecological and chemical water quality status.

- **River Basin Management Plans (RBMPs)**

  References to water body status were updated according to the 2nd Revision of the River Basin Management Plans for Western Central Greece and Epirus, reflecting EU water policy requirements for catchment-based environmental planning.

- **Climate change adaptation**

  Following the EU Climate Adaptation Strategy (COM/2021/82), the EIA integrates new climate variables—temperature, wind, and current changes—derived from national and regional adaptation plans. These factors were assessed in relation to their potential to alter circulation, stratification, and ecological productivity in Amvrakikos, an enclosed and climate-sensitive basin.

Changes due to additional scientific and environmental information requirements

- **Updated monitoring and data integration**

  The EIA incorporates recent water quality, sediment, and ecological monitoring data from the mandatory programs of existing aquaculture units. This reflects the current condition of the marine environment, replacing outdated datasets used in earlier studies.
  Specific indicators such as dissolved oxygen, chlorophyll-a, nutrients, and redox potential were reassessed to evaluate the cumulative effects of aquaculture activity in the Gulf.

- **Revised spatial and environmental baselines**

  New hydrographic, meteorological, and topographic data were included to refine the environmental baseline for site-specific and cumulative impact analysis.
  Updated mapping distinguishes between productive, non-productive, and environmentally sensitive zones, improving spatial precision for licensing and management.

Any changes to the proposed POAY (farm numbers, sizes, production, location)

The comparison between the 2014 and 2025 Environmental Impact Assessments (EIAs) for the proposed marine fish production zones in the Amvrakikos Gulf shows a clear adjustment in both spatial distribution and production intensity of aquaculture activities. These changes reflect a shift toward a more conservative, spatially rationalized, and environmentally adaptive planning framework consistent with updated national and EU environmental legislation.

In the 2014 EIA, existing marine fish production was distributed across 11 separate zones, producing 4998 tons of marine fish. Total planned production under the 2014 expansion scheme exceeds 10,700 tonnes, with multiple high-output sites located close to one another, reflecting an expansion-oriented design typical of that period's aquaculture policy. See tables 2 and 3 for more information on the existing aquaculture and the 2014 proposed expansion plan.

Figure 1. Google earth image 10/2024. Red rectangles show extent of the cage mooring systems, green circle shows SPA designated area and yellow line shows 50 m distance

In contrast, the 2025 EIA introduces a revised spatial and production layout that reduces overall density and redistributes farming activity to minimize environmental pressures and align with updated spatial planning rules (Circular 31760/2016). Several zones (5, 6, and 7) are now reserved for shellfish farming only, effectively removing finfish production from those areas to reduce nutrient loading and benthic impacts. The remaining fish production zones (1–4, 8–11) demonstrate lower or redistributed production tonnages, compared to broader high-intensity use zones proposed in 2014. See tables 2 and 3 for additional insight into the differences between the 2014 and 2025 proposed expansion plans.

Zone	Existing Capacity (t)	Existing Units	2014 Proposed Capacity (t)	2014 Proposed Units	2025 Proposed Capacity (t)	2025 Proposed Units	Proposed Capacity Change (t)
1	380	2	300	2	300	1	0
2	460	2	300	1	1,380	4	+1,080
3	920	3	1,380	4	380	1	-1,000
4	230	1	380	1	760	1	+380
5	340	1	760	1	1,136	1	+376
6	0	0	1,136	1	852	1	-284
7	0	0	600	1	852	1	+252
8	230	1	852	1	590	2	-262
9	0	0	852	1	760	2	-92
10	560	3	590	2	500	2	-90
11	340	2	760	2	920	2	+160
12	300	2	500	2	**	**	-500
13	708	2	920	2	**	**	-920
14	530	1	590	1	**	**	-590
15	0	0	852	1	**	**	-852
Total (All)	**4998**	**20**	**10772**	**23**	**8430**	**18**	**-2342**
Total (Marine Fish)	4998	20	7080	*	5,590	15	-1,490
Total (Bivalves)	0	0	3692	*	2,840	3	-852

*Information was not provided in either EIA.
**Zone no longer exists.

Table 3. Comparison of Proposed Marine Fish farm area (2014 *vs.* 2025)

Zone	Existing Area (str)	Existing Units	2014 Proposed Area (str)	2014 Proposed Units	2025 Proposed Area (str)	2025 Proposed Units	Proposed Area Change (str)
1	30	2	20	2	20	1	0
2	40	2	20	1	100	4	+80
3	80	3	100	4	30	1	-70
4	20	1	30	1	80	1	+50
5	40	1	80	1	120	1	+40
6	0	0	120	1	90	1	-30
7	0	0	40	1	90	1	+50
8	20	1	90	1	75	2	-15
9	0	0	90	1	60	2	-30
10	55	3	75	2	60	2	-15
11	25	2	60	2	115	2	+55
12	20	2	60	2	**	**	-60
13	53.8	2	115	2	**	**	-115
14	40	1	75	1	**	**	-75
15	0	0	90	1	**	**	-90
Total (All)	**423.8**	**20**	**1065**	**23**	**840**	**18**	**-225**
Total (Marine Fish)	423.8	20	*	*	540	15	***
Total (Bivalves)	0	0	*	*	300	3	***

*Information was not provided in either EIA.
**Zone no longer exists.
***Can not be computed due to missing information in the EIA.

Suitability of the Greek simplified formula for fish carrying capacity

The NAYS EIA uses the Greek simplified formula to calculate fish carrying capacity. This is a model that was devised for open bays (which Amvrakikos is not) so the question is whether this is the appropriate model for this location.

The carrying-capacity model $D = [150 + 8(E–10)]\ f_A\ f_B\ f_K$ estimates the fish farm annual fish production carrying capacity for different sizes of farm based on site conditions, where f_A, f_B, and f_K are step factors for distance from shore, water depth, and current speed (in cm s^{-1}). Each factor increases production only when a site moves into a higher category.

When distance increases from less than 100 m to more than 1,000 m, f_A doubles (×2.0), giving a 100 % rise in D. Depth rising from less than 20 m to over 60 m raises f_B from 0.9 to 2.0 (×2.22, or +122 %). Current speed increasing from below 3 cm s^{-1} to above 10 cm s^{-1} raises f_K from 1 to 2.5 (×2.5, or +150 %). Because the model multiplies these terms, moving from the lowest to the highest classes for all three factors raises predicted production roughly 11 times for the same farm area.

Step changes show how sensitive the model is at boundaries. A small shift from 100 m to 150 m offshore increases D by 25 %. Increasing depth from 20 m to 25 m adds 11 %, and from 40 m to 45 m adds 50 %. A change in current speed from 2.5 to 4 cm s^{-1} raises D by 50 %, while increasing from 5 to 8 cm s^{-1} adds 33 %. The strongest effects occur around the 3–5 cm s^{-1} and 5–10 cm s^{-1} current-speed thresholds and the 40 m depth boundary, where small measurement differences can cause large jumps in calculated carrying capacity.

Overall, the sensitivity analysis shows that current speed has the greatest influence on predicted fish production, followed by water depth, while distance from shore has the smallest effect. In this model, hydrodynamic energy and flushing potential are the main drivers controlling the estimated carrying capacity.

Suitability for use in the Amvrakikos Gulf

The Greek carrying-capacity formula ;

$$D = [150 + 8(E–10)]\, f_A\, f_B\, f_K$$

is unsuitable for estimating sustainable production limits in the Amvrakikos Gulf. It is an empirical scoring tool, not a true biophysical model, and fails to capture the complex hydrodynamics, ecological sensitivity, and cumulative loading that define this semi-enclosed system.

- **Conceptual limitations.** The formula treats carrying capacity as a simple product of site geometry (distance, depth) and current speed, scaled linearly within the lease area. It assumes that production increases indefinitely with these parameters and that all physical factors act independently. In reality, waste dispersion, oxygen balance, and nutrient cycling in Amvrakikos are non-linear, seasonally variable, and strongly constrained by slow water exchange and stratification. The Gulf's flushing time—measured in months—means particulate and dissolved wastes accumulate, creating eutrophication and benthic anoxia. Such conditions cannot be represented by a static multiplier model.

- **Ignoring cumulative effects.** The gulf already supports many farms located in clusters (ΠΑΣΜ). The formula estimates each site's output independently, without considering overlapping deposition footprints, nutrient plumes or shared oxygen demand. This omission is critical in Amvrakikos Gulf, where cumulative nutrient loads from multiple farms and river inflows drive high TRIX values and periodic hypoxia. Sustainable management requires a system-level mass-balance of nitrogen and phosphorus inputs and flushing losses, not an additive site-by-site index.

- **Lack of ecological linkage.** The model has no connection to environmental quality standards, benthic thresholds, or habitat protection criteria. It cannot predict effects on seagrass (*Posidonia oceanica*) meadows, soft-sediment communities, or protected species that are prominent in the gulf. Consequently, it cannot support compliance with EU Water Framework Directive (WFD), Marine Strategy Framework Directive (MSFD), or Natura 2000 conservation objectives.

- **Unsuitable parameterization for enclosed basins.** The range of f_K (1–2.5 for currents up to >10 cm s^{-1}) implies open-coast energy conditions. In Amvrakikos Gulf, current speeds are often <2 cm s^{-1} and mixing is weak. The formula would therefore systematically overestimate carrying capacity if applied directly, suggesting high production even when flushing is minimal. Similarly, distance from shore and depth provide little mitigation in a low-exchange environment, as waste still accumulates in the same hydrodynamic cell.

Appropriate alternatives

A valid assessment should use predictive impact models such as MERAMOD, DEPOMOD, or FARM, calibrated with site-specific current measurements, bathymetry, and sediment data. These can simulate waste dispersion, organic deposition, oxygen demand, and nutrient concentrations under realistic residence times. System-scale modelling of total nutrient inputs and water renewal is also essential to define maximum allowable biomass consistent with good ecological status.

Conclusion

The simple Greek carrying-capacity formula may be useful for preliminary siting in exposed coastal waters but is unsuitable for determining sustainable production limits in the Amvrakikos Gulf. The Gulf's enclosed geometry, weak circulation, and ecological sensitivity require a process-based, cumulative-impact approach that links farm outputs to water-quality and habitat responses. Reliance on this empirical formula would risk substantial overestimation of the Gulf's true environmental capacity and conflict with EU environmental obligations.

Suitability of the Greek simplified formula for shellfish carrying capacity for enclosed seas

Theoretical model for determining shellfish farm capacity

The NAFS EIA states that the theoretical model for estimating shellfish farm capacity is designed to identify the minimum viable production level required for each farming unit to operate sustainably and remain economically viable.

Production capacity depends primarily on the number, size, and layout of farming structures within the allocated marine area. Based on the economic and technical assessment, each shellfish farming park has been designed with an annual production capacity of 284 tonnes. To achieve this output efficiently, a marine area of approximately 30 stremmata is required. Each park will therefore occupy a site measuring 250 m × 120 m, sufficient to accommodate the longline structures and ensure proper spacing for water circulation and harvesting operations.

Each 30-stremma farming park will operate on a longline system and comply with the requirements of Joint Ministerial Decision 121570/1866/12-6-2009, which mandates a minimum distance of 200 meters between aquaculture parks of different species. Site orientation considers prevailing winds, waves, and current direction, optimizing exposure for water exchange and food availability.

Production model – 284 Tonnes per unit

Based on national and international experience, the mortality rate for cultured shellfish is estimated at around 11%. At the start of the production cycle, each unit receives 9.1 million spat (juvenile oysters or mussels) with an average weight of 2 g, corresponding to an initial biomass of 18.2 tonnes. The production cycle lasts 12 months and consists of three rearing stages:

1. **Phase I (2 g → 8 g):** 3 months of early growth, the most critical stage, with 4% mortality.
2. **Phase II (8 g → 16 g):** 3 months, with approximately 3% mortality.
3. **Phase III (16 g → 35 g):** 6 months of final fattening, with 4% mortality before harvest.

Shells are initially suspended on 6.5 longlines (horizontal lines), each 91.2 m long, totaling 592.8 m of line. Each line supports 182 droppers (vertical lines, 4 m each), giving a total of 4,732 m of culture rope. The initial stocking density is 3.8 kg/m, rising to 15 kg/m by the end of the production cycle.

Following two thinning stages, the final structure comprises 26 longline systems, each 91.2 m long, holding 1,821 stockings (nets) of 4 m each, providing optimal space for growth and handling. At the end of the cycle, total output per unit reaches 284 tonnes of market-size shellfish.

Within the POAY, new parks may be used to: **(a)** relocate existing units inside the POAY zone, **(b)** transfer existing units from outside into the POAY, **(c)** rearrange units within the POAY per §4.3.2.2, and **(d)** install new units.

However, the 2025 EIA states;
In total, **existing units outside the POAY zones represent approximately 610 tonnes of capacity**, which will be redistributed within the organized POAY framework to ensure compliance with national aquaculture spatial planning policy and minimize environmental impacts on the Amvrakikos ecosystem.
According to the POAY design,

- 10-stremmata farming parks will have a capacity of 200 tonnes per year,
- 15-stremmata farming parks will have a capacity of 250 tonnes per year,
- 20-stremmata breeding parks will have a capacity of 300 tonnes, and
- 25-stremmata breeding parks will have a capacity of 340 tonnes.

However, the proposed shellfish production does not relate to this POAY design.

Environmental impact of Shellfish culture

Shellfish farming in an enclosed sea such as Amvrakikos Gulf can influence the marine ecosystem in several ways. Unlike finfish aquaculture, shellfish culture is nutrient extractive rather than additive, as bivalves feed on naturally available phytoplankton and suspended organic matter, thereby removing nutrients from the water column instead of releasing them (Dame, 2011; Petersen & Riisgård, 2012). However, when cultured biomass becomes too high in areas with slow water circulation, the animals may over-filter the water, depleting phytoplankton and altering plankton community structure (Grant & Bacher, 1998; Ferreira et al., 2007). This can reduce food availability for wild filter feeders and disrupt ecological balance.

Shellfish farms also generate biodeposits (faeces and pseudofaeces) that settle on the seabed. In open, well-flushed areas these are dispersed and recycled, but in semi-enclosed systems like Amvrakikos, biodeposits can accumulate, causing organic enrichment, oxygen depletion, and shifts in benthic community composition (Gibbs, 2007; Cranford et al., 2012). Sensitive habitats such as *Posidonia oceanica* seagrass meadows are particularly vulnerable to shading by farm structures and smothering from sedimentation.

At the same time, shellfish can deliver positive ecosystem services, improve water clarity and reduce nutrient concentrations in eutrophic systems (Alleway et al., 2019; van der Schatte Olivier et al., 2020). Yet, in Amvrakikos Gulf, the limited flushing, long water residence time, and existing eutrophication constrain the system’s ability to assimilate additional farming pressure (Stamou et al., 2012; Kountoura et al., 2011). Sustainable aquaculture development therefore requires careful estimation of food-based carrying capacity and continuous environmental monitoring to balance the extractive benefits of shellfish culture with the ecological limits of this sensitive marine environment (Ferreira et al., 2008; Bricker et al., 2018).

Shellfish carrying capacity modelling

The theory of shellfish carrying capacity is based on available food, often called the production or ecological carrying capacity, and is founded on the balance between the food demand of cultured shellfish and the rate at which food (mainly phytoplankton and particulate organic matter) is supplied and renewed in the farming area.
Shellfish such as mussels and oysters are filter feeders that obtain energy directly from suspended microalgae and detritus in the water column. Their growth depends on the flux of food particles passing through the farm, determined by water current speed, phytoplankton concentration, and the rate of water renewal. When the standing biomass of shellfish becomes too large, their collective filtration removes phytoplankton faster than it can be replenished by primary production or advection. This leads to food depletion, slower growth, and reduced yields, even before any measurable environmental degradation occurs.

Thus, food-based carrying capacity models calculate the maximum standing stock (biomass) that can be supported by the local seston (particulate matter) supply rate without significantly lowering phytoplankton concentrations below natural background levels. They are usually expressed as a mass balance between filtration (clearance rate × biomass) and food input (water flow × phytoplankton concentration). When these two rates are equal, the system is at its production limit.

Food-based carrying capacity defines the biological upper limit of sustainable shellfish biomass, controlled by the availability and renewal rate of food, rather than by farm area, infrastructure, or environmental thresholds such as oxygen depletion or benthic impact.

The theoretical model currently applied to estimate the carrying capacity for shellfish farming in the Amvrakikos Gulf is primarily a technical–economic model rather than an ecological and food availability one. It fixes the production capacity of each shellfish park at 284 tonnes within a 30-stremmata marine plot and defines this capacity through infrastructure parameters such as the number of longlines, stocking density, and survival rates of cultured shellfish. While this approach provides a standardized production benchmark and supports economic planning, it does not represent the environmental carrying capacity of the Amvrakikos ecosystem. The model assumes that production potential depends only on farm area and equipment layout, without accounting for the physical, chemical, and biological processes that regulate shellfish growth and environmental sustainability.

In the Amvrakikos Gulf, such simplification is inappropriate. The Gulf is a semi-enclosed lagoonal system with an extremely long water residence time, weak tidal exchange, and stratified water masses that often experience oxygen depletion near the seabed. These conditions severely limit the natural assimilative capacity of the system. The model neglects critical factors such as current velocity, water renewal rate, primary productivity, chlorophyll-a concentration, nutrient cycling, and temperature variations, all of which determine the food supply available for shellfish and the capacity of the environment to absorb bio deposits. By ignoring these processes, the model risks substantially overestimating sustainable biomass and promoting production levels that could intensify eutrophication and benthic degradation.

Another major weakness is the model's failure to consider cumulative and spatial effects. The Amvrakikos Gulf already contains multiple aquaculture zones (both fish and shellfish farms) operating within the same hydrodynamic basin. The existing model treats each park as an isolated production unit, whereas in reality, farms interact through shared water masses. Suspended particles, nutrients, and organic wastes from one site can influence adjacent farms, leading to phytoplankton depletion, increased sedimentation, and localized hypoxia. Sustainable planning in such a confined and ecologically sensitive system requires a bay-wide mass-balance approach that quantifies total nutrient inputs, food consumption by filter feeders, and the cumulative impact on oxygen dynamics and benthic habitats.

Furthermore, the model lacks any connection to environmental quality standards or legislative frameworks, such as the EU Water Framework Directive (WFD), Marine Strategy Framework Directive (MSFD), or the Natura 2000 conservation objectives applicable to the Gulf. It does not predict how production intensity might affect ecological indicators such as TRIX, dissolved oxygen, or redox potential, nor does it address the risk to Posidonia oceanica meadows and other sensitive benthic communities that are protected under EU law. The absence of such linkages prevents its use as a regulatory tool for sustainable management or environmental permitting.

The model does not account for seasonal and climatic variability. Temperature, wind patterns, and freshwater inflows from the Arachthos and Louros rivers significantly influence stratification, circulation, and nutrient availability in the Gulf. Climate change projections for the region show increasing temperatures and altered wind regimes, which are expected to further reduce water mixing and exacerbate low-oxygen events. The theoretical model provides no mechanism to integrate these variables or assess their impact on shellfish growth rates and mortality.

The shellfish carrying capacity and farm model provides a useful economic reference for farm design but is unsuitable for defining the ecological carrying capacity of shellfish production in the Amvrakikos Gulf. It oversimplifies a highly complex ecosystem, disregards hydrodynamic and ecological processes, and ignores cumulative and climate-driven pressures. For sustainable management, a process-based ecosystem model should be adopted—one that couples hydrodynamic circulation with shellfish filtration rates, phytoplankton productivity, nutrient loading, and benthic recovery. Such a model would allow regulators to determine total allowable biomass for the entire gulf, distribute production spatially among farms, and ensure compliance with environmental quality objectives and conservation standards.

Core deficiencies

- **No food budget.** Capacity is set by ropes and survival, not by available seston. Bivalve growth in Amvrakikos is food-limited for long periods. A model must link biomass to chlorophyll-a, POM, and advection.

- **No depletion accounting.** Long residence time means farms re-filter the same water mass. The model ignores downstream depletion along flow paths and farm-to-farm interactions.
- **No hydrodynamics.** Orientation is noted but filtration vs. throughput flux ($m^3 s^{-1}$ crossing the farm) is not quantified. Residence time, stratification, and episodic exchange with the outer Ionian are missing.
- **No benthic feedback.** Bio deposition, sulphide/redox thresholds, and recovery in “rest parks” are not modelled, so benthic limits can be exceeded silently.
- **No seasonal climate signal.** Temperature and calm-weather periods raise filtration demand and lower oxygen. The model assumes steady 12-month growth.
- **No cumulative cap.** Many farms operate in clusters. The method scales parks additively without a bay-wide nutrient or phytoplankton production cap.
- **No linkage to EQS/Natura 2000.** It cannot test WFD/MSFD indicators (chl-a, DO, TRIX), Posidonia risk, or bird and habitat objectives.

Any changes in supporting infrastructure

The 2025 EIA states that to support the floating aquaculture units operating within the Amvrakikos POAY, specific land-based areas along the seashore are proposed for the construction of essential support infrastructure. These areas will provide access to floating farms and accommodate facilities for the loading and unloading of raw materials, fish, feed, and equipment, as well as the transport of personnel. The development includes the construction of small piers and service docks.
Within the proposed concession zone of the foreshore (estimated at 2 to 6 stremmata), and taking into account the area’s geomorphology, ancillary facilities are planned. These include prefabricated storage buildings for day-to-day operational materials, temporary installations such as feed silos, pipelines, air-conditioning or cooling tanks, and seawater pumping and drainage systems. Boreholes may also be installed where needed.

Additional onshore support structures will include warehouses, net drying and repair areas, workshops, pumping stations, waste and by-product management facilities, and staff parking areas. These installations will provide the necessary logistical and maintenance functions for aquaculture operations.

Land-based production and service facilities, such as feed preparation plants, hatcheries, spawning and sorting stations, fish packaging and processing units, and shellfish depuration and dispatch centers, are also proposed. Administrative offices and worker service buildings will be co-located within these zones.

Fish hatchery capacity

According to the 2025 EIA, the hatchery capacity and fry supply in Zone 2, the existing hatchery can produce about 2 million fry per year, supporting Zone 2 only. This results in a deficit of about 2.14 million fry, so it is proposed that fry be sourced from the SKE–X–1 hatchery or external suppliers. In contrast, Zone 8 produces 4.53 million fry annually, sufficient to support Zones 8, 4, and 11, with a surplus of 2.76 million fry. The recommendation is to maintain current operations and continue supplying neighbouring zones. The Menidi hatchery, with a capacity of 7.2 million fry per year, serves all zones and has adequate capacity, functioning as the regional supply hub. Other zones do not have hatchery facilities, leading to deficits that must be met through national or imported fry supplies. Overall, Menidi and Skepastos Lofos are key to regional fry sufficiency, while Zone 2 and smaller zones remain dependent on external inputs.

Our assessment is that the Amvrakikos POAY has access to sufficient hatchery capacity overall, however, its distribution is uneven. Zone 8 and Menidi act as central suppliers, while Zone 2 and others will depend on shared or external hatchery resources. Upgrading and coordinating fry production will be essential to ensure consistent fish stocking and sustainable aquaculture growth within the Gulf.

Packaging and shipping capacity in the Amvrakikos POAY

According to the 2025 EIA, the total existing packaging and dispatch capacity in and around the Amvrakikos Gulf is 7,920 tonnes per year, which is not sufficient to support the projected POAY production capacity of approximately 8,430 tonnes/year across all zones. However, the capacity is unevenly distributed, with significant surpluses in some areas and shortfalls in others.

Zones 1, 3, 8, and Menidi currently exhibit substantial surplus capacity, while Zones 2, 4, 9, 10 and 11 show notable deficits. The newly established shellfish zones (5, 6, and 7) have no existing facilities and therefore require dedicated infrastructure for processing, purification, and dispatch.

The assessment of packaging and shipping infrastructure across the proposed Amvrakikos POAY zones demonstrates an uneven and strategically unmanageable distribution of capacity. While several areas already possess sufficient or surplus facilities, others—particularly new or expanded zones—require additional investment to ensure full alignment between production output and post-harvest handling capacity.

Finfish aquaculture zones

According to the 2025 EIA, most finfish farming areas already possess packaging facilities within reasonable proximity.

- **Zone 1 (Pogonitsa Bay)** has a robust surplus, bolstered by the Preveza Fish Market, enabling it to serve as a regional packaging hub for nearby areas, including Zone 2 (Skafidaki–Faros Laskaras).
- **Zone 3 (Cape Myrtavi)** also maintains spare capacity, which could support local expansion or emergency redistribution during seasonal peaks.

- **Zone 8 (Lofos)** holds one of the largest existing plants (1,510 t/year) with a 920-ton surplus, making it an ideal support facility for Zones 4 and 11, which currently lack sufficient packaging capacity.
- **Zone 9 (Kakovrachos)** and **Zone 10 (Akri Gelada)** represent the main capacity bottlenecks, where production will exceed available facilities after POAY expansion. A new or upgraded regional packaging plant (1,000–1,500 t/year) is proposed to service these two zones efficiently.
- **Zone 11 (Akri Haliki)** is adequately served if combined with the SKE–X–3 support facility and could also benefit from logistical collaboration with Zone 8.

The Menidi packaging plant (2,000 t/year) is another significant regional asset. Its scale and central location make it suitable for shared use among multiple zones, particularly those along the southern and eastern coastline of the Gulf. The plant's accessibility, via both road (≈40 minutes from Vonitsa) and marine transport, makes it an essential logistical node for the POAY.

Our assessment is that most finfish aquaculture zones around the Gulf have adequate fish processing and packaging capacity, though distribution is uneven. Surpluses in Zone 1 and Zone 3 enable them to support nearby areas, while Zone 8 with its large plant and surplus capacity, can assist Zones 4 and 11**,** which remain under-served. The Menidi plant functions as a central regional hub due to its size and strong transport links. In contrast, Zones 9 and 10 lack sufficient facilities and are projected to face shortfalls after POAY expansion, requiring a new or upgraded regional plant of about 1,000–1,500 t/year**.** Overall, the current processing capacity in the Gulf is inadequate but geographically concentrated, with targeted investment and additional infrastructure needed to support 2025 POAY production.

Shellfish aquaculture zones

Shellfish farming represents an environmentally compatible expansion within the POAY. However, these zones currently lack any packaging or purification facilities, which are essential for compliance with EU food safety and hygiene regulations.

To address this, the plan proposes a centralized Shellfish Shipping and Purification Centre (SSC) with a total capacity of 4,000 tonnes/year, located in the Ormos Sogono–Agia Triada corridor. This site was selected for its:

- Proximity to all three shellfish zones (5, 6, and 7)
- Existing coastal access and transportation routes
- Suitable land availability for depuration and storage infrastructure.

The SSC would perform depuration, packaging, cold storage, and dispatch functions, serving as a shared service facility for all shellfish producers in the region. It will also improve traceability, compliance with health regulations, and export readiness.

Environmental and planning considerations
All packaging and dispatch facilities must comply with national environmental licensing (Law 4685/2020) and EU environmental directives.
Priority must be given to:

- Reusing or upgrading existing permitted sites before constructing new ones;
- Locating new facilities within existing land-use zones or industrial areas to limit additional coastal modification; and
- Promoting renewable energy use and wastewater management systems in processing plants to minimize their ecological footprint.

Conclusions

- The Amvrakikos POAY demonstrates inadequate total packaging capacity, so strategic redistribution and modernization are required.
- Zones 1, 3, 8, and Menidi will act as regional processing hubs, while Zones 9 and 10 will need new or upgraded plants.
- The establishment of a Shellfish Shipping and Purification Centre (4,000 t/year) is a key infrastructural priority for Zones 5–7.
- It is recommended that there should be coordinated logistics, shared use of surplus capacity, and investment in modern facilities will ensure efficient, compliant, and sustainable post-harvest management across all aquaculture zones in the Amvrakikos Gulf.

Any changes in alternative possibilities

Zero Solution
The zero solution represents the *non-implementation* of the project, in this case, the decision *not to establish the POAY (Organized Aquaculture Development Area)*. Under this scenario, existing aquaculture units would continue to operate as they do now, maintaining their current locations, licensing conditions, and associated land-based facilities throughout the Amvrakikos Gulf. This scenario serves as the baseline for evaluating alternative development options.
However, maintaining the current fragmented system is inconsistent with Greece’s legal and spatial planning framework, which requires productive sectors such as aquaculture to operate within organized zones to ensure environmental protection, compatibility with other coastal uses, and long-term sustainability.

Environmental and spatial implications

Maintaining the current unorganized system could lead to continued spatial conflicts, inefficient use of marine resources, and limited environmental oversight. The absence of coordinated management under a POAY would hinder:

- Monitoring of environmental impacts and carrying capacity
- Infrastructure upgrades and waste management
- Compliance with EU environmental and Natura 2000 directives.

Design and technical parameters

The 2025 EIA states that in the alternative POAY design, proposed zones respect the minimum legal distances from the coastline (≥50 m) and are aligned with the geomorphology and depth of the Amvrakikos Gulf. Marine fish farming zones are positioned beyond the 18 m depth contour, while shellfish areas begin from the 10 m isobath. These parameters ensure adequate water renewal, environmental protection, and safe navigation.

Table 4. Comparison of proposed siting and operational criteria

Parameter	Mediterranean marine fish farms	Shellfish farms
Minimum distance from coast	**≥ 50 m**	**≥ 50 m**
Minimum water depth (isobath)	**≥18 m** – farms must be positioned beyond this depth	**≥10 m** – zone boundaries adjusted until 10 m depth is reached
Exceptions to depth rule	None – all units must comply with the 18 m isobath	**Zones 6 and 7** may start at slightly shallower depths due to seabed morphology
Distance from zone boundary (for anchoring)	**20–50 m buffer** to allow mooring outside the park area	Similar buffer applied where required for anchoring and service access
Spacing between parks (same operator)	**100–250 m**	**100–250 m**
Spacing between parks (different operators)	**≥500 m**	**≥500 m**

Parameter	Mediterranean marine fish farms	Shellfish farms
Distance between fish and shellfish farms	**≥200 m** separation to avoid operational and environmental interference	Same condition applies
Park configuration	Not aligned in rows; positioned to ensure **water circulation and current flow**	Similarly arranged to maintain **flushing and oxygenation**

The 2025 EIA proposes siting distances of more than 50 m from shore, fish farms located in areas deeper than 18 m, and a distance greater than 100 - 250 m between fish farm operators and between fish farms. These defaults are minimal and do not reflect Amvrakikos' enclosed hydrodynamics, Ramsar status, and seagrass sensitivity.

- Shore line buffers of 50 m are too close due to weak-flushing close to the coast, bird disturbance and visual conflict, and a buffer of 100 m aligns with stricter regional norms used in sensitive waters
- A depth of 18m for cages that have nets up to 8 m deep will cause high impact on the seabed. Greater depth at 25 m improves dispersion, reduces anoxia risk, and matches stricter sensitive-area rules.
- Intra-park cage spacing of 100m will mean that mooring anchors and sediment footprints may overlap between parks and will cause high biosecurity and dissolved nutrient risks. Minimum buffers of 250 meters will reduce these risks.

POAY zoning scenario

Under the POAY zoning scenario, aquaculture activities would be spatially reorganized into defined marine and land zones around the Amvrakikos Gulf.

Zoning in the Preveza–Pogonitsa–Faros Laskaras Area

A single zone (Zone 1) was initially proposed near Agios Thomas and Pogonitsa Bay, extending 700–800 m offshore. However, this configuration was found unsuitable, as it lies along a vessel navigation channel, restricting access to the Preveza Fish Market and nearby mooring areas.

Subsequent analysis showed that the combined Zones 1, 2, and 3, covering Agios Thomas to Cape Laskaras, did not fully comply with legal spacing requirements (minimum 500 m between units), offered poor protection from wave action, and limited water exchange. These weaknesses prompted the redesign of the zones to improve circulation, safety, and operational efficiency.

Zone 3 was later split into two parts, forming Zone 4, to create open water corridors that preserve traditional fishing activities.

Vonitsa and Southern Gulf Area (Zones 10–11)

In Vonitsa Bay and adjacent areas, existing units were found to violate the 500 m separation rule. To correct this, farms belonging to the same ownership groups (designated A, B, T) were reorganized or merged across Zones 10 and 11. Several sub-scenarios were tested:

- *Scenario 1–2:* Non-merger of companies, maintaining legal separation distances but requiring unit relocation further from land bases.
- *Scenario 3–4:* Merger of companies with shared interests, enabling closer grouping but occasionally restricting navigation.

The final design (Alternative F) proposed limited expansion of Zone 11 to maintain legal spacing and navigation safety, while ensuring continuity of operations.

Shellfish and eel farming zones

The updated design also incorporates new shellfish zones and two land-based aquaculture zones:

- **Zones 5–9:** Dedicated to mussel and shellfish farming, designed to align with current flow patterns to support nutrient exchange and growth.
- **Zones 10–14:** Finfish aquaculture zones (mixed marine species).
- **Zone X-1 (Preveza)** and **Zone X-2 (Logaros Lagoon):** Land-based eel and tilapia farming units using closed or semi-closed water systems.

Final adjustments and alternatives

Following public consultation (2020–2022) and review by the Amvrakikos–Lefkada Management Agency and Decentralised Administration of Epirus–Western Macedonia, further revisions were made:

- Zone 7 (Agia Triada) was abolished due to licensing and environmental conflicts.
- The final approved plan (Alternative Z) now includes 14 marine zones and 2 land zones.
- Minor amendments in 2023 (Alternative H) optimized spatial layout without significant environmental impacts.

Conclusions

The “zero” or “do-nothing” alternative is conceptually sound as a baseline scenario, as required by the EU SEA and EIA Directives. However, its treatment in the report is brief and lacks quantitative or ecological comparison. The analysis correctly notes that maintaining the current unorganized aquaculture framework contradicts Greece’s spatial planning law (Law 4447/2016 and 4759/2020), which mandates zoning for productive sectors such as aquaculture. It also identifies valid governance risks, continued environmental fragmentation, poor monitoring, and non-compliance with Natura 2000 obligations.

Despite these valid observations, the assessment remains administrative rather than environmental. It does not quantify the cumulative load or ecological consequences of retaining dispersed fish farms under current licenses, nor does it evaluate how existing units perform relative to carrying capacity thresholds or Ramsar conservation objectives. The argument that the zero option would result in “continued inefficiency” is unsupported by spatial or water-quality data.

The POAY zoning alternative represents the proposed action scenario and is presented in more detail, covering design parameters, site-selection criteria, and spacing rules. The inclusion of a comparative table defining distances, depths, and spacing between farms (≥18 m depth for finfish, ≥10 m for shellfish, ≥200 m separation between categories, etc.) reflects alignment with national and EU aquaculture guidelines. The plan aims to reorganize scattered units into coherent zones to improve management efficiency, navigation safety, and environmental monitoring.

However, the evaluation remains largely procedural and lacks an explicit environmental modelling basis. There is no hydrodynamic or nutrient-dispersion modelling to verify that the prescribed distances and depth thresholds will actually prevent benthic enrichment or eutrophication in the Gulf’s low-exchange environment. Similarly, the statement that the design “ensures adequate water renewal and environmental protection” is not supported by current measurements or simulations.

The analysis is restricted to spatial reorganization and does not examine alternative production levels (e.g., reduced biomass limits, seasonal fallowing regimes, or lower feed inputs) or alternative production locations (e.g., siting farms in higher-exchange areas or outside the inner gulf). These variables could substantially alter environmental outcomes, yet the EIA treats production intensity as fixed and does not explore how scaling or relocation might improve ecological compatibility. As a result, the alternatives analysis fails to address fundamental aspects of environmental optimization.

Any new studies on sensitive fauna in the gulf

The EIA explicitly states that *Posidonia oceanica* “is not found in the Amvrakikos Gulf,” with meadows occurring only outside the Preveza Strait in the Ionian Sea. This is based on the seabed and macroflora sampling conducted by the Technological Educational Institute (TEI) of Western Greece in 2014 which is the most recent direct field investigation referenced. It used visual transects and the Ecological Assessment Index (EAI) based on *Posidonia oceanica* and *Cymodocea nodosa* as indicator species, but no *Posidonia* stands were detected within the Gulf sampling grid.

However, the EIA does not consider possible secondary effects of aquaculture nutrient loading near the Preveza Strait, where *Posidonia* meadows exist outside the Gulf. There is no modelling or monitoring plan to track whether eutrophication or organic deposition could affect these external meadows.

The EIA reaffirms the Gulf's role as a major migratory corridor hosting up to 188 species of birds during migration and over 145,000 waterbirds in winter, but these figures are derived from older counts (Chanerinos, 1996; Zogaris, 2003) rather than new population estimates.

While the EIA recognizes that Amvrakikos is a Ramsar and Natura 2000 site, it does not evaluate bird disturbance or displacement risks from the proposed aquaculture zones. No bird-sensitive spatial analysis, buffer zoning, or mitigation design (e.g. netting restrictions, noise limits, lighting control) appears to have been carried out. The aquaculture compatibility discussion remains general, referencing EU guidance that aquaculture can coexist with protected areas if "good management practices" are applied, without providing local empirical support.

Given the Ramsar and SPA designations, updated bird monitoring (especially for *Pelecanus crispus*, *Aythya nyroca*, and migratory waders) would be essential to demonstrate compliance with the Birds Directive (2009/147/EC) and Ramsar criteria on disturbance avoidance.

The text identifies a resident population of bottlenose dolphins (*Tursiops truncatus*), describing Amvrakikos as one of the few semi-enclosed gulfs in the Mediterranean with an isolated population. It notes the ecological importance of this population and its inclusion under EU Habitats Directive Annex II and Natura 2000 Site GR2110001 protections. The report cites older studies (e.g. Bearzi et al., 2005; 2008) that estimated a resident group of around 150 dolphins**,** with feeding patterns concentrated near river mouths and shallow coastal waters. However, these data predate 2010 and have not been updated with recent monitoring results or reports.

Environmental impacts, monitoring and mitigation plan

Section 7 of the Amvrakikos EIA provides a review of the expected environmental impacts of establishing aquaculture development zones (POAY) and plans for environmental monitoring and mitigation.

Section 7 describes the potential impacts on the environment, but a closer analysis reveals that most of the discussion is generic, largely based on dated scientific references, and insufficiently supported by recent site-specific data or quantitative modelling.

Benthic organisms
The EIA concludes that the impacts of aquaculture on the seabed and benthic fauna will be limited to a radius of 10 – 25 m around the fish cages and that any changes will be temporary and reversible. This conclusion draws heavily on studies by Karakassis et al.

(1998 – 2007) and similar work undertaken more than two decades ago. While these studies were valuable for general understanding of Mediterranean fish-farm effects, they cannot substitute for current measurements in Amvrakikos, a semi-enclosed gulf with complex hydrodynamics and weak water exchange in its central basin. The assumption that all proposed POAY zones lie in areas deeper than 18 m with sufficient currents is unverified by local hydrological data.

The EIA provides no recent benthic sampling, redox potential profiles, organic-carbon data, or macrofaunal diversity indicators. It also omits analysis of cumulative deposition from multiple adjacent farms, which could lead to long-term anoxia or sulphide accumulation in sediments. The mitigation measures proposed, mainly “appropriate siting” and “good management practices”, are too general and not linked to measurable indicators. There is no monitoring protocol proposed using recognized metrics such as TRIX, MERAMOD, or benthic redox and faunal recovery thresholds. Consequently, the section is descriptive rather than analytical and fails to demonstrate that benthic impacts will remain within ecologically acceptable limits.

Water nutrient levels

The EIA argues that nutrient releases from fish farms will not cause significant eutrophication in the Gulf and cites results from older national research programs (EPET II 1998; AQUAENV 1999; MedVeg 2004) showing negligible effects on chlorophyll a and dissolved oxygen near farms. Yet, the same document also acknowledges more recent measurements by the University of Patras (2022 – 2024) indicating that the ecological status of Amvrakikos waters has deteriorated to mesotrophic levels with poor to moderate quality. This internal inconsistency weakens the credibility of the conclusions.

The EIA includes no nutrient-budget or carrying-capacity model to quantify nitrogen and phosphorus discharge against the Gulf’s water renewal time and oxygen balance. It assumes adequate dilution through current flow but does not provide measured or modelled flushing rates or seasonal stratification effects. The proposed mitigation, locating cages in deeper areas and combining fish farming with shellfish culture to promote filtration, is conceptually sound but lacks quantified evidence of efficiency or planned monitoring to verify nutrient reduction. Without thresholds, adaptive management triggers, or temporal monitoring design, the proposed measures cannot ensure that eutrophication risks remain within acceptable limits.

Birds

The EIA provides almost no current information on avifauna, despite the Amvrakikos Gulf being both a Ramsar wetland and a Natura 2000 site that supports significant populations of pelicans, herons, cormorants, and migratory waterbirds. It merely states that aquaculture zones will be located away from settlements and tourist beaches, implying limited human–wildlife conflict. There is no assessment of potential disturbance to foraging, roosting, or breeding areas, no seasonal sensitivity analysis, and no mention of possible attraction of birds to fish cages or feed residues.

The document also fails to address the regulatory restrictions on bird deterrent devices, such as nets or acoustic scare systems, within Ramsar areas. Consequently, the proposed framework does not demonstrate compliance with Ramsar guidelines or EU Birds Directive requirements. A robust avifaunal monitoring program, including baseline counts and spatial overlap analysis with aquaculture sites, is needed to evaluate and mitigate potential impacts.

Dolphins and other marine mammals
No dedicated analysis is provided for dolphins or other marine mammals known to inhabit the Amvrakikos Gulf, notably the common bottlenose dolphin (*Tursiops truncatus*), which forms a small, semi-resident population of regional importance. The EIA does not consider potential acoustic disturbance from boat traffic, cage operations, or construction activities, nor does it assess collision or entanglement risks.

This omission is serious because the Gulf's shallow and confined waters amplify sound propagation and make dolphins particularly vulnerable to chronic disturbance. The absence of any acoustic monitoring plan or reference to the conservation objectives of the Habitats Directive (92/43/EEC) indicates non-compliance with EU obligations for protected marine species. Targeted studies and mitigation measures such as vessel-speed limits, exclusion zones, and noise-management plans should have been incorporated.

Overall evaluation
Section 7 of the EIA demonstrates awareness of earlier Mediterranean research on aquaculture impacts but fails to incorporate the substantial scientific knowledge generated since 2010 or to apply site-specific evidence for Amvrakikos. Most of the mitigation measures are declarative statements that "no impact is expected," without analytical justification, quantitative limits, or monitoring design. Cumulative effects are not addressed, and there is no linkage between proposed activities and the ecological carrying capacity of the semi-enclosed gulf. Critical information gaps include recent Posidonia mapping, updated benthic and water-quality data, comprehensive bird and dolphin assessments, and an operational environmental monitoring system.

Conclusion and recommendations
The EIA section remains largely qualitative and optimistic, with insufficient verification and no adaptive-management mechanism. To comply with the requirements of the EU SEA Directive, the Habitats and Birds Directives, and the Amvrakikos Ramsar management framework, a supplementary or revised EIA should be prepared. This should include new benthic and water-quality surveys, modelling of nutrient dispersion and oxygen dynamics, cumulative-impact analysis, and specific fauna studies (birds and dolphins). Clear environmental performance indicators, threshold values, and monitoring responsibilities should be established to ensure that aquaculture development remains compatible with the ecological integrity of the Amvrakikos Gulf.

Environmental monitoring

The EIA states that a monitoring system will be developed "to optimize the environmental performance of the project," focused on the main biotic and abiotic factors: water quality, seabed condition, biodiversity, and social or landscape parameters. **Table 5** refers broadly to "environmental objectives" for each factor (e.g., protection of marine ecosystems, prevention of harmful discharges, maintenance of landscape aesthetics), but these are expressed as goals rather than measurable indicators.

The 2025 EIA recommends the following plan to monitor the environmental performance of the project; it is recommended to use and recording of the following indicators.

Table 5. Proposed monitoring indicators

POSSIBLE MONITORING INDICATORS	LEVEL
Quantity of cultivated species (tons/year)	Total number of POAY zones
	Per marine Zone
Average size per species (weight)	Total number of POAY zones
	Per marine Zone
Number, area, capacity of aquaculture units per year	Total number of POAY zones
	Per marine Zone
Number, capacity of organic aquaculture units per year	Total number of POAY zones
	Per marine Zone
Number of packaging plants and hatcheries per year	Total number of POAY zones
	Per marine Zone
Number of projects and activities for which an Environmental Terms Approval Decision (AEPO) was issued per year	Total number of POAY zones
	Per marine Zone
Road burden on regional and national roads per year	Total number of POAY zones
	Per marine Zone
Number of units subject to a program for monitoring ecological parameters per year.	Total number of POAY zones
	Per marine Zone
Number of environmental compliance checks	Total number of POAY zones
	Per marine Zone
Verified violations of environmental terms	Total number of POAY zones
	Per marine Zone
Water quality parameters that will be monitored on a continuous basis	Total number of POAY zones
	Per Zone
Sediment parameters that will be monitored annually	Total number of POAY zones
	Per Zone

Monitoring is said to include "qualitative and quantitative evaluation" of the project's effects over time and to comply with EU Directive 2001/42/EC and national aquaculture legislation. However, the EIA does not specify sampling frequency, methods, responsibilities, or thresholds for action. The proposed monitoring framework remains a conceptual outline, not an operational plan.

The absence of thresholds, for example, limits on organic carbon accumulation or nutrient concentrations, makes it impossible to evaluate compliance or trigger management responses. Without defined units of measurement, sampling locations, or frequency, the indicators cannot support adaptive management or regulatory enforcement.

Only through a quantified, adaptive monitoring system with explicit performance indicators can the POAY project demonstrate sustainable aquaculture development and maintain ecological integrity within the Amvrakikos Gulf.

Natura 2000 overlaps

The 2025 EIA study states that in the study area, there are a significant number of areas included in lists of sensitive or protected ecosystems, with their ecological and aesthetic value as the main criterion. The Amvrakikos area is one of the largest wetlands in Greece. The Amvrakikos National Park was established on March 21, 2008, by Joint Ministerial Decision 11989 (Government Gazette D' 123/21-03-2008). It is located on a central passageway for migratory birds in the Mediterranean Sea (Barellos, 2006) and guarantees the survival of a wide variety of species "at a high level of quality and quantity" (Papagiannis, 1986). This complex of semi-enclosed marine and wetland ecosystems is an important breeding area for fish and invertebrates of high value (UNEP, 2007). "The general environmental diversity of the biotic diversity (flora-fauna) is of great importance, not only for the local quality and balance of the environment, but also from a regional and international perspective (Papagiannis et al., 1986).
The 2025 EIA study concludes that in any case, both floating cage farm and terrestrial waste in the P.O.A.Y. do not negatively affect the habitats or any protected area. However, our assessment concludes otherwise.

Natura 2000 network expansion and protection measures
The Joint Ministerial Decision 50743/11-12-2017 (Gov. Gazette 4432/B/15-12-2017) updated Greece’s Natura 2000 Network, expanding it to 446 protected areas and revising conservation objectives for many existing sites. The list now includes new marine and coastal zones, with clear protection and management rules for each area. In addition, two key ministerial decisions (167378/14-5-2007 and 2886/142447/26-2-2019) specifically protect Posidonia oceanica seagrass meadows, banning trawling and other destructive fishing practices in designated zones. These habitats are important for biodiversity and serve as nursery grounds for many fish species.

The Amvrakikos Gulf contains extensive protected marine habitats included in the Natura 2000 Network. The 2017 and 2019 legal updates mean that any expansion of fish or shellfish farms must now consider proximity to these protected sites and demonstrate that operations will not disturb sensitive habitats. This limits where new farms can be established and may require buffer zones, modified anchoring systems, or the relocation of some existing units.

Integration with EU water and marine legislation

Under the EU Water Framework Directive (2000/60/EC), Member States must maintain or restore the good ecological and chemical status of all surface and coastal waters. When a Natura 2000 site overlaps with a water body, its environmental objectives must meet both biodiversity and water-quality standards. This ensures that activities such as aquaculture, fishing, or coastal development do not degrade water quality or aquatic habitats.

The Amvrakikos Gulf is classified as an enclosed coastal water body with limited exchange with the Ionian Sea and already shows signs of eutrophication and oxygen depletion (Ferentinos et al. 2010; Kountoura & Zacharias 2013). Any new aquaculture activity must therefore prove that nutrient emissions, waste deposition, and organic loading will not worsen water quality or prevent the achievement of "good ecological status." This creates a strong regulatory barrier to expanding fish farming unless nutrient-neutral or extractive systems such as shellfish culture are prioritized.

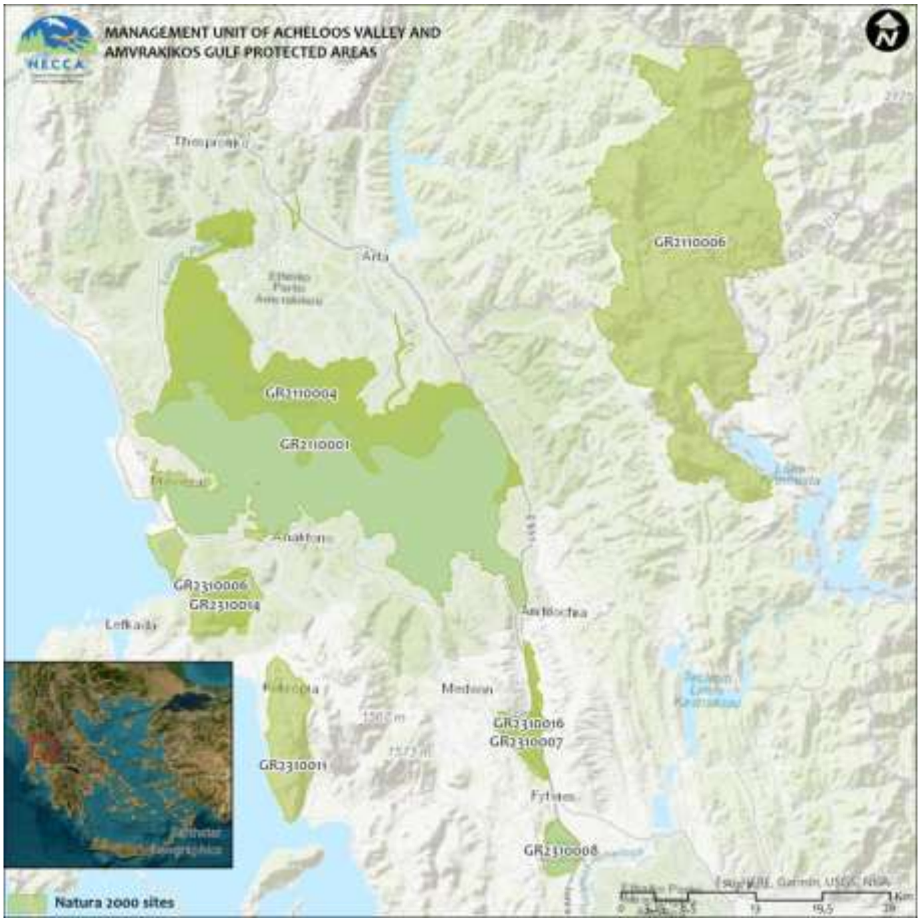
Strategic Environmental Assessment (SEA) — Directive 2001/42/EC

Directive 2001/42/EC requires that all national or regional plans and programs likely to have environmental impacts, including aquaculture zoning (ΠΟΑΥ), undergo a Strategic Environmental Assessment (SEA). In Greece, this requirement was implemented through Decision YPEXODE/EYPE/oik.107017/28-8-2006. The SEA process evaluates cumulative, long-term, and cross-sectoral impacts before a plan is approved. It helps identify suitable areas for development, environmental limits, and measures for impact reduction.

Because the Amvrakikos POAY covers multiple aquaculture sites within an enclosed ecosystem, the SEA process is essential. It requires that the total carrying capacity for fish and shellfish be assessed at the bay-wide level, not per farm. The updated SEA for 2025 should include updated data on water quality, sediment condition, and climate change impacts, ensuring that future aquaculture expansion is environmentally and socially acceptable.

6. Compatibility of Aquaculture with environmentally protected areas.

The Gulf has been designated as a National Park of Greece, as it includes two Natura 2000 sites (GR2110001 – an SCI site, GR2110004 - an SPA site).



A Natura 2000 Special Protection Area (SPA) and a Site of Community Importance (SCI) differ mainly in their legal purpose and conservation focus under EU nature legislation.

- **SPA (Special Protection Area):**

  Established under the EU Birds Directive (2009/147/EC), SPAs are designated to protect wild birds and their habitats, especially migratory and threatened species. They ensure the preservation of suitable breeding, feeding, and resting areas and restrict activities that could disturb birds or degrade their habitats.

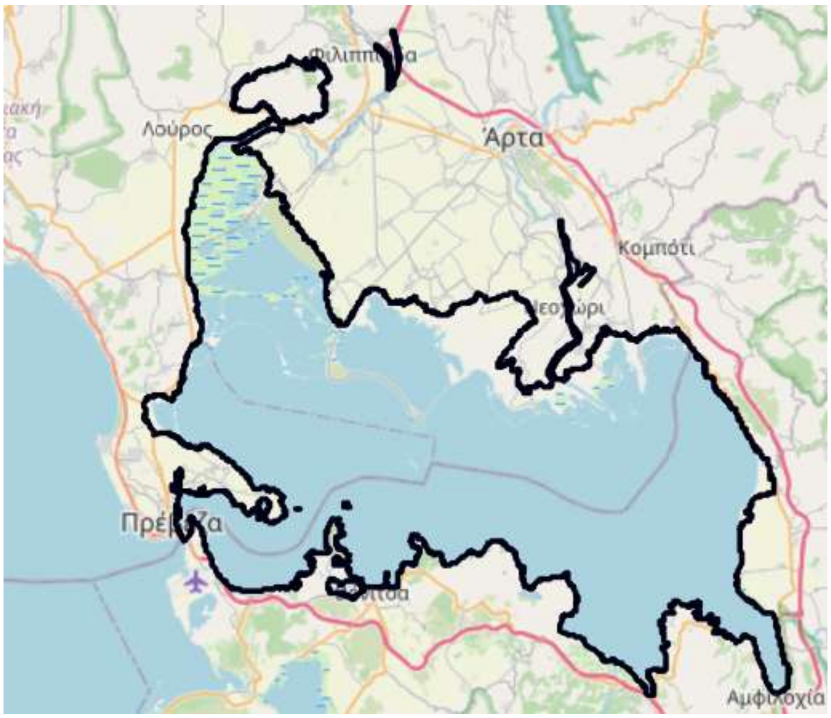
- **SCI (Site of Community Importance):**

  Designated under the EU Habitats Directive (92/43/EEC), SCIs protect a wider range of habitats and species of plants and animals considered of European importance. Once formally adopted by Member States, SCIs become Special Areas of Conservation (SACs) and are subject to management measures that maintain or restore favorable conservation status for listed species and habitats.

For aquaculture, both SPA and SCI/SAC designations impose strict environmental safeguards but differ in focus:

- In SPAs, fish farming projects must ensure that bird populations and feeding habitats are not disturbed, particularly in areas used by cormorants, herons, and migratory seabirds that may interact with farms.
- In SCIs/SACs, the emphasis is on preventing damage to benthic habitats, such as *Posidonia oceanica* meadows, reefs, or lagoons, and avoiding pollution or physical alteration that could affect protected species.

Any new or expanded aquaculture activity within or near these sites must undergo an "Appropriate Assessment" (AA) under Article 6 of the Habitats Directive to demonstrate no adverse effect on the integrity of the site. In enclosed and sensitive areas such as Amvrakikos Gulf, where both SPAs and SCIs overlap, this means that finfish farm expansion is tightly constrained, while low-impact or nutrient-extractive systems (e.g. shellfish culture) are more likely to be compatible with Natura 2000 conservation objectives.



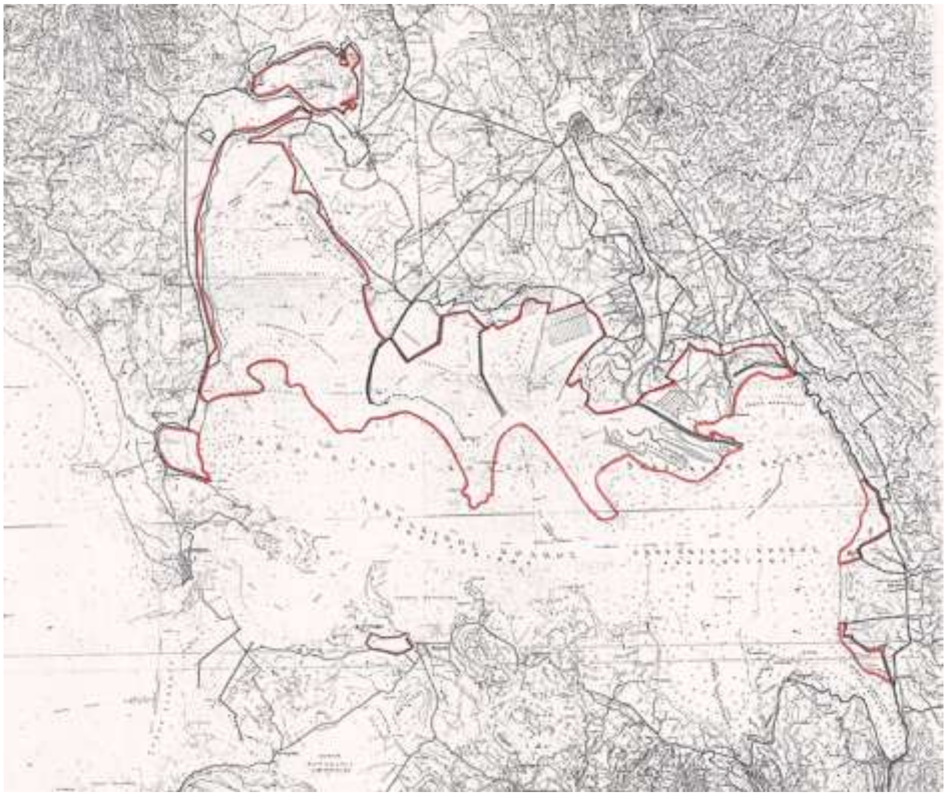
GR2110001 SCI boundaries
Source:https://natura2000.eea.europa.eu/Natura2000/sdf/#/sdf?site=GR2110001&release=55&nav=7

GR2110004 SPA boundaries
*Source:*https://natura2000.eea.europa.eu/Natura2000/sdf/#/sdf?site=GR2110004&release=55&nav=7

Natura 2000
In 2012, the European Commission published guidelines titled *“Aquaculture and Natura 2000”* to clarify how aquaculture can operate within or near protected areas. These guidelines emphasize that aquaculture and biodiversity protection can be compatible, provided that activities are properly sited, scaled, and managed. They recommend early strategic planning, appropriate environmental assessment (AA) under the Habitats Directive, and ongoing monitoring to avoid negative impacts on habitats and species.

These EU guidelines are directly applicable to Amvrakikos, where many aquaculture farms lie inside or adjacent to Natura 2000 zones. Expansion of fish or shellfish farming is only possible if it complies with appropriate assessment requirements and demonstrates no adverse effect on site integrity. The guidelines also encourage using low-impact and restorative aquaculture practices, such as mussel and oyster farming, which can help improve water quality. Therefore, while finfish expansion is likely to remain limited, shellfish farming may be favored as a more compatible and environmentally sustainable option for future development in the Gulf.

Ramsar designated sites.
The northern part is designated as a Ramsar site which mirrors the boundaries of the Natura 2000 SPA boundaries.



Source: https://rsis.ramsar.org/RISapp/files/36403923/pictures/GR61_map1602.pdf

In Ramsar-designated wetlands, aquaculture development is subject to strict environmental limitations because these sites are recognized under the Ramsar Convention (1971) as wetlands of international importance, particularly for their biodiversity, hydrological functions, and value as habitats for waterbirds. The convention requires all contracting parties, including Greece, to maintain the ecological character of listed wetlands and promote their wise use, meaning that development can only occur if it is compatible with conservation objectives.

Key limitations for aquaculture development in Ramsar sites

- **No alteration of the wetland's ecological character.** Any aquaculture project must not change the hydrology, salinity, sedimentation patterns, or nutrient balance of the wetland. Activities that affect tidal flows, freshwater inputs, or water quality are restricted.

- **Prohibition of habitat loss or degradation.** Conversion of natural lagoons, marshes, mudflats, or seagrass beds into aquaculture ponds or cages is not allowed. Infrastructure such as bunds, pens, or canals can only be approved if they do not reduce wetland area or functionality.

- **Strict control of pollution and waste discharge.** Farms must demonstrate that feed residues, faeces, or chemicals (antibiotics, antifoulants) will not cause nutrient enrichment, oxygen depletion, or contamination of the wetland. In most Ramsar areas, zero-discharge or recirculating systems are preferred.

- **Compatibility with wildlife and migratory bird protection.** Ramsar sites are often designated for their importance to migratory waterbirds. Aquaculture activities must not disturb feeding, roosting, or breeding areas, and the use of deterrents (e.g. bird nets, sound devices) is heavily restricted.

- **Cumulative impact assessment and prior approval.** Any proposal must undergo an Environmental Impact Assessment (EIA) and, where relevant, an Appropriate Assessment if the site also overlaps with a Natura 2000 SPA or SCI. The EIA must assess cumulative pressures from existing aquaculture, agriculture, and fisheries.

- **Preference for extensive and low-impact systems.** The Ramsar framework supports extensive, traditional, or polyculture systems that work with natural productivity (e.g. lagoon-based shellfish or mullet farming), rather than intensive cage or pond culture.

The Amvrakikos Gulf Wetlands are a Ramsar-listed site and also part of the Natura 2000 Network. This dual protection means that aquaculture development is highly restricted.

- **New finfish cage farms** face strong limitations due to their nutrient and waste discharge potential.

Expansion of existing farms requires proof that operations will not alter the wetland's ecological character or water quality.

- **Shellfish farming**, being nutrient-extractive and non-polluting, is generally considered more compatible with Ramsar conservation objectives.

In summary, within Ramsar areas like Amvrakikos, aquaculture is only permissible if it is low-impact, small-scale, and ecologically compatible, maintaining the natural functions and biodiversity that justify the site's international protection.

Important Marine Mammal Area (IMMA) and an Important Bird Area (IBA)

The Gulf has been recognized as an Important Marine Mammal Area (IMMA) and an Important Bird Area (IBA). The Gulf of Amvrakikos hosts a small population of bottlenose dolphins that live in the Gulf year-round. The current population estimate of common bottlenose dolphins is approximately 150 individuals in the Amvrakikos Gulf, in distinct groups of 20-30 dolphins.

https://www.marinemammalhabitat.org/factsheets/gulf-of-ambracia/

https://ornithologiki.gr/en/our-work/conservation-scientific-research/important-bird-areas

In both IBA and IMMA zones, aquaculture is permissible only if it does not disturb key species or degrade critical habitats. In the Amvrakikos Gulf, which hosts both IBA and IMMA designations, these constraints make further finfish expansion environmentally and politically sensitive, while extensive, low-impact shellfish aquaculture represents the most realistic and sustainable development pathway.

Regional Spatial Planning Framework (PCH)
Article 5 of the Regional Spatial Planning Framework (PCH) identifies several key interregional and intraregional development areas, including Aitoloakarnania, which is noted for its comparative advantages in livestock production, horticulture, fisheries, its extensive lake and lagoon systems, and tourism potential.

Regarding the strategic priorities for the protection and sustainable use of the natural environment and landscape in the Region of Western Greece, the Regional Development Plan (RDP) emphasizes the following principle:

“The coastal zone must be planned under an Integrated Coastal Zone Management (ICZM) approach that balances environmental protection with sustainable economic development. This includes safeguarding coastal protected areas, conserving marine ecosystems, and promoting compatible activities such as sustainable tourism, fisheries, and aquaculture. Civil protection policies and climate adaptation measures must also be incorporated.”

The RDP further highlights the urgent need for a coastal protection policy to address the impacts of climate change and sea level rise. It calls for the application of mild environmental interventions and adaptive management measures, and where such approaches are not sufficient, the use of targeted technical solutions to protect vulnerable coastal and lagoon ecosystems.

Analysis of environmental impacts described in the EIA

The new information added to the 2025 Environmental Impact Assessment (EIA) adds detail to the environmental baseline and analytical depth of Section 6. The 2014 EIA relied on data from 2009.

1. **Field measurements and surveys (2014)**

   The 2014 field campaigns provide an improvement over the 2009 dataset, which relied largely on secondary literature and older monitoring data. The inclusion of benthic macrofauna and chlorophyll-a measurements adds direct evidence of ecological conditions, enabling the recalibration of eutrophication and benthic indices to Mediterranean-specific thresholds. This strengthens the EIA’s capacity to link aquaculture impacts with biological response variables. However, the limited temporal coverage (a single summer campaign) constrains representativeness. Seasonal replication and integration with national monitoring networks would be necessary to confirm long-term trends.

The specific updates include;

- Benthic macrofauna sampling (July 2014): Conducted at 23 stations by the Technological Educational Institute (TEI) of Western Greece. Samples were collected with a Van Veen grab, sieved, fixed with formaldehyde, and analyzed for taxa composition and abundance.

- Chlorophyll-a and physicochemical data (July 2014): Measured at five stations to assess eutrophication and ecological quality using Mediterranean chlorophyll classification scales (Simboura et al., 2005).

- Data from these campaigns became the foundation for the updated eutrophication models and ecological status classification used in the 2020–2025 revisions.

2. **Integration of new analytical methodologies:** The study explicitly refers to the update of the *Study for the Establishment of a P.O.A.Y. in Amvrakikos Gulf* carried out in 2020, which applied new analytical methodologies developed in the 1st Revision of the River Basin Management Plans (2017). These include methods for assessing ecological and chemical status, hydro morphological alterations, and eutrophication in coastal and transitional waters. The indicators for ecological, chemical, and hydro morphological status are now harmonized with EU Water Framework Directive (WFD 2000/60/EC) standards, replacing earlier qualitative descriptions.

3. **Recent research references since 2009.** Newly cited studies include:

    - *Ferentinos et al. (2010)* — Fjord-like circulation and oxygen depletion patterns.
    - *Bank of Greece (2011)* — Climate and socioeconomic impacts.
    - *Kountoura & Zacharias (2011)* — Spatial distribution of hypoxia/anoxia zones.
    - *Dimitriou et al. (2012)* — Benthic Quality Index calibration for WFD compliance.
    - *Kountoura & Zacharias (2013)* — Temporal eutrophication changes, showing a shift toward lower nutrient enrichment.
    - *Kehayias & Aposporis (2014) — Zooplankton variation linked to hydrology and hypoxia in the Amvrakikos Gulf.Georgiou et al., 2021* on hypoxia/anoxia dynamics and sill circulation patterns in Amvrakikos Gulf.
    - *Marcos et al. (2016)* — Mediterranean sea level rise and its implications.
    - *Cascarano et al., 2021* on temperature effects on pathogens and diseases in Mediterranean aquaculture.
    - *Katselis et al., 2022* mapping Greek marine finfish farms and their potential environmental impact.

- *Prandekou et al., 2022* on benthic foraminifera as indicators of bottom-water quality in semi-enclosed gulfs.

These studies add detail to the hypoxia-anoxia mechanisms linked to fjord-like stratification and introduce updated perspectives on water exchange, disease ecology, and benthic bioindicators which is a shift from descriptive oceanography to ecosystem-based impact understanding. Yet, the studies remain fragmented and were not always integrated quantitatively into the EIA's modelling framework. Their findings are cited qualitatively rather than statistically validated within the site-specific context.

4. **Updated environmental and Natura 2000 data** Inclusion of the latest EUNIS habitat and Natura 2000 data is an advance over the previous EIA, when only the original SAC listing was referenced. Current habitat extents, conservation objectives, and sensitivity ratings are now up to date, closer in line with the EU Habitats and Birds Directives. This reinforces legal defensibility and risk screening for aquaculture siting. The weakness is that no explicit cross-analysis was provided between aquaculture footprints and the revised habitat areas for the Special Area of Conservation GR2110001 (Amvrakikos Gulf, Delta Louros and Arachthos), reducing the value of these datasets for impact quantification.

5. **Use of revised hydrological and ecological assessment framework** The text references work aligned with the 2nd Review of River Basin Management Plans (by 2024), covering deadline extensions for achieving water quality objectives, exception justifications, and methodological refinement in line with EU Directive 2000/60/EC. This is an improvement over the 2009 baseline, embedding the project in a catchment-scale framework. It also introduces more transparent justifications for WFD exemptions. However, the study still uses a simplified formula for the estimation of carrying capacity and lacks an integrated mass-balance nutrient model to link aquaculture loading scenarios to catchment nutrient budgets which limits precision in predicting environmental impacts.

6. **Policy and planning documents**

The Multi-Annual National Strategic Plan for Aquaculture 2014–2020 is referenced as the main national policy framework linking aquaculture expansion with Natura 2000 protection guidelines (2018). The linkage between aquaculture development zones and Natura 2000 obligations is now clearer. The link between aquaculture zones and Natura 2000 protection rules is now clearer, which makes the plan more relevant for management. However, the EIA still describes policies rather than judging how well they are followed. For example, it does not analyze total nutrient loads or the farming capacity limits set by national standards.

Comments on whether the 14 issues identified in the 2014 EIA are still valid.

The evaluation of the 2014 EIA identified a number of weaknesses that the 2025 EIA has not yet addressed.

1. The carrying capacity calculation uses the Greek formula that was developed for bays and open locations. The formula needs to be validated in the enclosed gulf conditions. This continues to be a major weakness.

2. There is still an absence of alternative, less impactful aquaculture methods in the 2025 EIA report, which focuses on the base case and the proposed production increase without exploring sustainable options. This approach neglects the potential for less environmentally damaging practices, undermining the assessment's comprehensiveness. This continues to be a major weakness.

3. The 2025 EIA report still does not adequately quantify the nutrient output of the individual farms (or collectively) to assess if the environment can assimilate these additional inputs or predict what impacts they would have locally around the farms and cumulatively in the Gulf. This continues to be a major weakness.

4. The 2025 report still does not adequately address the cumulative impacts of multiple fish farms in the same area in the sensitive ecosystem that is found in the Gulf. This is a major weakness, as the cumulative impact of multiple farms will be far greater than the impact of a single farm on such an enclose gulf as Amvrakikos.

5. The Amvrakikos Gulf is designated as Special Areas of Conservation (SACs) and Special Protection Areas (SPAs) which underscores its ecological value and need for protective measures. The 2025 report still does not provide a detailed analysis of the potential impact on sensitive species such dolphins and birds or provide detailed mitigation measures that farms should follow to protect interaction with them. This continues to be another major weakness, as these species are particularly vulnerable to the impacts of fish farming.

6. The 2025 EIA improves the environmental monitoring measures that should be undertaken to identify some mitigation measures that could be taken to minimize the impact of fish farming. However, the report does not provide a detailed assessment of the effectiveness of these mitigation measures. To ensure that these measures are effective, the EIA report should provide a more thorough analysis of potential mitigation measures that can be undertaken by farm operators. This is a major weakness.

In addition, there is a need for the following additional studies and surveys to be conducted (these are major weaknesses):

7. A study to map the distribution of *P. oceanica* in the Amvrakikos Gulf and assess the potential impact of fish farming.

8. A study to identify the location and range of sea turtles in the area and assess the potential impact of fish farming.
9. A study to develop mitigation measures to reduce the interaction with birds.

While the planned aquaculture expansion in the Gulf of Amvrakikos aims to enhance production, it introduces significant environmental risks to a vulnerable ecosystem. This necessitates the quantification of outputs, prediction of impacts, consideration of cumulative impact effective farm management and mitigation measures to ensure the gulf's ecological integrity and the protection of valuable habitats and species for the future, highlighting a critical weakness in the current approach to safeguarding one of Greece's most important wetlands.

Conclusions

The comparison and assessment section of the Amvrakikos EIA represents an attempt to evaluate the relative environmental, spatial, and technical implications of different aquaculture development scenarios, yet it falls short of a comprehensive, evidence-based environmental appraisal. While the document demonstrates formal compliance with EIA procedural requirements, such as including a “zero solution” baseline and a proposed “POAY zoning” alternative, the comparative assessment is largely descriptive and administrative in tone rather than analytical or scientific in substance.

The EIA’s preference for the POAY scenario is justified primarily by reference to Greek spatial planning legislation (Laws 4447/2016 and 4759/2020), which mandates that aquaculture activities operate within organized development areas to ensure coherence with other coastal uses and long-term environmental management. This argument is institutionally valid but does not constitute environmental proof of reduced impact or improved ecological sustainability. The analysis does not provide quantitative evidence to support the assumption that the reorganization of farms into designated zones will lead to lower nutrient loading, improved water quality, or better benthic recovery. The report’s conclusion that the POAY will “ensure environmental protection through proper siting and management” is a declarative statement, unsupported by numerical modelling, empirical monitoring data, or measurable thresholds.

The comparative framework also lacks integration of biophysical processes. There is no hydrodynamic or nutrient dispersion modelling to test whether the selected zones offer sufficient water renewal or dilution capacity. Given that the Amvrakikos Gulf is a semi-enclosed and weakly flushed ecosystem, such modelling would be essential to verify that the proposed layout prevents organic matter accumulation or eutrophication. Similarly, the EIA does not evaluate how the redistribution of farms may alter sedimentation patterns, redox potential, or benthic biodiversity at the scale of the Gulf. These omissions weaken the scientific credibility of the comparison and its ability to inform adaptive management.

The assessment of ecological receptors is uneven and outdated. While the document references studies from the late 1990s and early 2000s (e.g., Karakassis et al.) to justify limited benthic impacts, it fails to incorporate more recent research or site-specific data. There is no discussion of updated monitoring results for *Posidonia oceanica*, no recent mapping of seagrass beds or soft-bottom habitats, and no evaluation of dolphin or bird populations that are critical to the conservation value of the Amvrakikos Ramsar and Natura 2000 site. The omission of these elements undermines compliance with the EU Habitats and Birds Directives, which require demonstration that proposed developments will not adversely affect site integrity or conservation objectives.

The comparison also lacks a cumulative impact perspective. Each POAY zone is assessed in isolation, with no attempt to model combined organic and nutrient loads from multiple farms operating simultaneously within the semi-enclosed gulf. Without this integrated analysis, the cumulative pressure on water quality, benthic fauna, and higher trophic levels remains unknown. The result is a fragmented assessment that fails to address the very coordination and sustainability issues the POAY system is meant to resolve.

The proposed monitoring framework reinforces these weaknesses. The section lists broad objectives (“protect biodiversity,” “maintain water quality”) but provides no operational detail such as no sampling design, frequency, indicator species, or threshold values for corrective action. Without measurable parameters, the monitoring plan cannot function as an adaptive management tool or as evidence of compliance with environmental obligations.

Weakness classification

Category	**Description**	**Severity**
Absence of quantitative modelling	No nutrient dispersion, or carrying-capacity models were used to compare the zero and POAY scenarios. The assumption of adequate flushing and depth-based sustainability is unverified.	**Critical weakness**
Lack of cumulative impact assessment	No evaluation of the combined load from multiple farms across zones or their aggregated influence on benthic health and eutrophication.	**Critical weakness**
Insufficient coverage of Natura 2000, SPA/SPC and Ramsar obligations	The EIA mentions protected designations but provides no compatibility analysis with conservation objectives for birds, dolphins, or seagrass habitats.	**Major weakness**
Monitoring plan lacks indicators and thresholds	Indicators are general (“protect biodiversity,” “avoid eutrophication”) with no measurable parameters, sampling design, or trigger values.	**Major weakness**
Failure to consider alternative production levels or locations	The assessment does not explore reduced-intensity or alternative-site scenarios that could alter impact magnitude.	**Major weakness**

Category	Description	Severity
No integration with carrying-capacity or eutrophication index frameworks	The EIA does not relate expected production volumes to nutrient assimilation limits or ecological thresholds.	**Major Weakness**
Weak justification for rejecting the zero alternative	The zero option is dismissed on administrative grounds without quantified environmental comparison or potential adaptive improvements.	**Weakness**
Descriptive rather than evaluative narrative	Impact statements are qualitative ("expected to be minor") and lack supporting evidence or uncertainty ranges.	**Minor weakness**

References

Key Legislative and Policy references

- **Greek Ministry of Environment Circular No. 31760/23-06-2016** — Spatial planning conditions for aquaculture development (ΠΟΑΥ and ΠΑΣΜ).
- **Joint Ministerial Decision 121570/1866/12-6-2009** — Environmental and spatial separation of aquaculture parks.
- **Law 4447/2016** — Spatial Planning and Sustainable Development Framework.
- **Law 4759/2020** — Urban and regional planning reform.
- **EU Habitats Directive (92/43/EEC)** and **Birds Directive (2009/147/EC)** — Natura 2000 protection requirements.
- **Water Framework Directive (2000/60/EC)** and **Marine Strategy Framework Directive (2008/56/EC)** — Environmental quality and ecosystem protection.
- **EU Climate Adaptation Strategy (COM/2021/82)** — Integration of climate resilience into planning.
- **2nd Revision of Greek River Basin Management Plans (2021–2027)** — Updated hydrological and water quality data for Western Central Greece and Epirus.

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