

Policy for integrating ocean accounting into marine spatial planning of marine protected areas

¹Budi M. Ruslan, ²Luky Adrianto, ³R. Nunung Nuryartono, ²Gatot Yulianto, ⁴M. Firdaus Agung, ⁵Irfan Yulianto, ⁶Ari Kurniawan, ⁷Imam Fauzi, ⁴Ahmad Sofiullah

¹ Department of Resource and Environmental Economics, Faculty of Economics and Management, IPB University, Bogor, West Java, Indonesia; ² Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Bogor, West Java, Indonesia; ³ Department of Economics, Faculty of Economics and Management, IPB University, Bogor, West Java, Indonesia; ⁴ Ministry of Marine Affairs and Fisheries, Central Jakarta, Jakarta, Indonesia; ⁵ Rekam Nusantara Foundation, Bogor, West Java, Indonesia; ⁶ Khairun University, Tidore Islands, North Maluku, Indonesia; ⁷ Kupang Marine Management Office, Kupang, East Nusa Tenggara, Indonesia.
Corresponding author: B. M. Ruslan, budiruslanbudi@apps.ipb.ac.id

Abstract. Indonesia's marine governance faces growing complexity in balancing ecological protection and economic utilization, particularly within marine protected areas (MPAs) that serve both conservation and livelihood functions. In this context, ocean accounting (OA) offers a systematic approach to link environmental and economic data for evidence-based decision-making, yet its integration into marine spatial planning (MSP) remains limited. This study aims to construct a structured policy framework for embedding OA into MSP through an interpretive structural modeling (ISM) approach supported by expert evaluation. The ISM analysis identifies and organizes key *Need* and *Program Elements* that determine the success of OA-MSP integration. Results show that the most influential *Need Elements* include the availability of updated ecological-economic data, standardized procedures, inter-agency coordination, and institutional capacity building, while the pivotal *Program Elements* encompass sustainable financing mechanisms, technical training, regulatory alignment, and participatory monitoring systems. These elements form a hierarchical sequence in which foundational data and institutional readiness enable higher-level policy and management outcomes. The findings emphasize that effective OA integration requires a phased implementation strategy, beginning with strengthening data infrastructure and institutional collaboration before expanding into adaptive management and incentive-based programs. Overall, the study contributes a validated, expert-based policy framework that advances transparent, data-driven, and sustainable marine governance in Indonesia.

Key Words: blue economy, Indonesia, interpretive structural modeling, marine protected areas, marine spatial planning, ocean accounting, policy framework.

Introduction. The governance of coastal and marine spaces in the twenty-first century has grown increasingly complex, driven by the competing demands of economic utilization, environmental protection, and social well-being. Marine protected areas (MPAs), while established as core instruments for biodiversity conservation, are often situated within multifunctional seascapes that host fisheries, tourism, maritime transport, aquaculture, and extractive industries. This multiplicity of uses presents overlapping jurisdictions and ecological interdependencies that challenge effective spatial management (Saunders et al 2020; Zürcher et al 2022). In Indonesia, these challenges are magnified by the country's vast archipelagic configuration and the socio-economic reliance of coastal communities on marine resources. Effective management therefore demands an integrated policy framework that balances ecological sustainability with economic growth and social inclusion. Within this context, the *Need Elements* such as standardized procedures, inter-agency coordination, and capacity building and the *Program Elements* including training, financing mechanisms, and stakeholder

collaboration serve as essential scaffolding for developing coherent marine spatial governance within conservation areas.

Despite growing attention to the ocean economy, the current profile of ocean accounting (OA) in Indonesia reveals significant fragmentation. The ocean accounts of Indonesia, developed under the collaboration between SI, MMAF, and international partners, have demonstrated early progress in mapping marine economic and ecological data. However, these accounts remain largely descriptive and have yet to be systematically integrated into marine spatial planning (MSP) processes (SI 2024). Spatial planning instruments have not yet operationalized OA data to guide decision-making, resulting in policy gaps between economic valuation and spatial governance. This disconnect highlights the need for updated, integrated data systems, metadata synchronization among agencies, and geospatial infrastructures identified in the Need Element framework. At the same time, the lack of technical readiness and institutional mechanisms underscores the importance of Program Elements such as the development of OA training modules, regulatory drafting, and monitoring dashboards to ensure that OA becomes an actionable component of marine policy implementation.

To conceptualize and prioritize these policy and programmatic needs, this study employs the Interpretive Structural Modeling (ISM) approach supported by expert justification. ISM is an analytical method designed to identify hierarchical relationships among complex interrelated elements through expert consensus, forming a structural map of influence and dependence. In the context of OA integration, ISM enables the categorization of both Need and Program Elements into hierarchical levels that reflect their systemic influence in marine governance. The use of ISM also ensures that policy design is informed by the collective judgment of domain experts from marine planning, conservation, and economic sectors. The resulting framework not only provides a scientific basis for the policy hierarchy showing how foundational elements such as financing and data availability support advanced stages like business incentives but also establishes causal linkages among institutional, technical, and regulatory components critical for sustainable OA implementation.

The urgency and novelty of this research lie in its attempt to bridge conceptual and operational gaps between OA and MSP within MPA. While global discussions have increasingly emphasized the integration of natural capital accounting with spatial governance (Gacutan et al 2022; GOAP 2022), empirical models demonstrating this integration in developing maritime nations remain limited. Indonesia, as one of the world's largest archipelagic states, faces a strategic turning point in embedding OA within its marine governance framework to advance the Sustainable Development Goals (SDGs), particularly SDG 14 on Life Below Water. By constructing a structured, expert-based model of Need and Program Elements, this study introduces an innovative governance tool that synthesizes ecological, economic, and institutional dimensions into a unified policy pathway for OA-MSP integration. The research also offers policy implications for advancing the blue economy agenda through transparent, evidence-based marine management (Sugiharto 2023).

Based on these considerations, the objectives of this research are formulated into three: (1) first, to identify and structure the critical Need Elements required for the policy integration of OA into MSP of MPAs; (2) second, to delineate the Program Elements necessary to operationalize the identified needs into actionable planning tools; (3) third, to propose a strategic policy framework that aligns OA with MPS in MPAs, enhancing transparency, sustainability, and adaptive decision-making in Indonesia's marine management system.

Material and Method

Research framework. The analytical framework of this research integrates the Need and Program Elements into a sequential process from identification to structural modeling, ensuring both empirical rigor and policy relevance, as shown as in Table 1.

Table 1

Research framework for ISM analysis of OA-MSP integration

<i>Analytical stage</i>	<i>Objective</i>	<i>Output</i>
Element identification	Review literature and policies to determine relevant Need and Program Elements	Preliminary element list
Expert elicitation	Define relationships among elements using expert-based contextual assessment	Structural Self-Interaction Matrix (SSIM)
ISM analysis	Construct hierarchical and quadrant models of influence and dependence	Level structure and quadrant matrix of elements

This framework provides a logical path for deriving a policy model that connects technical data readiness (Need Elements) with actionable governance mechanisms (Program Elements).

Expert involvement and data collection

Expert selection. Experts were selected purposively to ensure balanced representation of knowledge domains relevant to OA, marine policy, and spatial planning. A total of nine experts participated, representing academia, government agencies, and practitioners. The criteria follow Singh & Kant (2008) and Sushil (2012). Criteria of each expert describe more in Table 2.

Table 2

Expert selection criteria

<i>Criterion</i>	<i>Description</i>
Institutional Academic and practionioner	Policy experts from MMAF and local Governace Scholars in marine governance, ecological economics, and environmental accounting
Conservation manager	Professionals involved in MPA management and spatial planning implementation

This expert configuration ensures multi-perspective input combining technical accuracy, institutional feasibility, and policy relevance.

Data collection. Primary data were collected via expert questionnaires and interviews, focusing on pairwise relationships between identified elements. Secondary data were obtained from official publications such as Integrated Ocean Accounts of Indonesia (OECD 2020; UNSC 2020; SI 2024), to ensure analytical triangulation.

Interpretive structural modeling (ISM) procedure. ISM was used to analyze the complex relationships among the identified policy elements. The technique systematically transforms expert perceptions into a structured model showing how elements influence one another hierarchically. The methodology, developed by Warfield (1974), is widely used in strategic management and policy system analysis, some steps of the methodology being described in Table 3.

The ISM analysis enables both structural visualization and systemic interpretation, identifying which elements are foundational drivers and which are outcomes or dependent variables.

Steps of the ISM method

<i>Step</i>	<i>Process description</i>	<i>Application in this study</i>
1	Identification of elements	Compilation of Need and Program Elements from literature and policy synthesis
2	Contextual relationship definition	Experts determine whether and how elements influence each other
3	Structural self-interaction matrix (SSIM)	Pairwise comparison using symbols (V, A, X, O) to express direction of influence
4	Reachability matrix and level partitioning	Conversion of SSIM to binary matrix (1-0) and identification of hierarchical levels
5	ISM model construction	Visual representation of hierarchical relationships among elements
6	ISM quadrant analysis	Classification of elements into four quadrants (Autonomous, Dependent, Linkage, Independent) based on driving power and dependence

Note: V means if element "a" influences element "b"; A means if "b" influences element "a"; X means each element influences each other; and O) means there is no direct relationship between the elements.

Validation and ethical considerations. Validation was carried out through:

1. Expert feedback sessions, where preliminary ISM results were reviewed for conceptual consistency;
2. Document triangulation, comparing model outcomes with official reports such as UNSC (2020) and SI (2024).

Ethical approval was ensured through voluntary participation, informed consent, and data anonymization in accordance with the guidelines of the Indonesian National Research and Innovation Agency (NRIA 2023).

Expected analytical output. The ISM process is expected to generate:

1. A hierarchical model of Need and Program Elements, showing their order of priority and influence;
2. A quadrant dependence-driving matrix identifying key leverage points for OA-MSP policy integration;
3. A conceptual policy roadmap for strengthening governance of marine protected areas through OA.

Results

Structure the critical Need Elements required for the policy integration of Ocean Accounting into Marine Spatial Planning of Marine Protected Areas. The integration of OA into MSP for MPAs demands a comprehensive policy framework supported by both institutional and technical enablers. The first essential element is the availability of updated and integrated ecological, economic, and social data, which ensures that ocean-based decisions are evidence-driven and contextually relevant (Hein et al 2020; SI 2024). To operationalize this integration consistently across governance levels, standard operational procedures (SOPs) for embedding OA into Regional Spatial Planning and Zoning Plan for Coastal Areas and Small Islands processes are required (UNSC 2020; MMAF 2021). Complementing these is the geospatial information system (GIS) infrastructure, which enables data visualization and facilitates communication among diverse stakeholders (Leenhardt et al 2015; GIA 2022). Building the capacity of conservation area managers to interpret OA data is equally critical to support adaptive and evidence-based policy-making (Cisneros-Montemayor et al 2021). Moreover, participatory mechanisms are essential to foster community legitimacy and social inclusion in OA compilation and marine management (Berkes 1999; Adhuri et al 2019).

The integration of OA with satellite, GIA data, and AI technologies enhances predictive ecosystem analysis for science-based planning (Gesami & Nunoo 2024), while open access to OA data ensures transparency and cross-sectoral collaboration (OECD

2020). To avoid redundancy, metadata synchronization among key agencies such as MMAF, SI, GIA, and MNDP is necessary (MNDP 2023). Furthermore, independent evaluation and audit systems are vital to guarantee the credibility and reliability of OA data (World Bank 2021). Economic incentives should also be designed to motivate private sector participation in integrating OA into conservation and business planning (Costanza et al 2014). Simultaneously, data protection and information security mechanisms must be enforced to prevent data misuse and manipulation (Jharkharia & Shankar 2004; OECD 2019). Finally, international collaboration is crucial to harmonize OA standards and align national practices with global agendas such as the SDGs and the blue economy framework (Foley et al 2010; UNSC 2020). Collectively, these twelve policy elements form a synergistic foundation for institutionalizing OA within MSP, promoting transparent, inclusive, and science-based management of marine protected areas (Table 4).

Table 4

Need Element of policy for integrating ocean accounting into marine spatial planning of marine protected areas

<i>No.</i>	<i>Element</i>	<i>Short explanation</i>	<i>Relevant citations</i>
N1	Availability of updated and integrated ecological, economic, and social data	Needed so that decisions based on OA are accurate and relevant to current conditions	Hein et al (2020); SI (2024)
N2	Standard operational procedures for integrating OA into RTR and RZWP3K	Provides technical guidance so that integration runs consistently across regions	UNSC (2020); MMAF (2021)
N3	Geospatial information system infrastructure to visualize ocean accounts	Provides a visual platform to facilitate analysis and communication of data	Leenhardt et al (2015); GIA (2022)
N4	Capacity building for conservation area managers to interpret OA	Ensures managers can use the data for adaptive policy-making	Cisneros-Montemayor et al (2021)
N5	Participatory mechanisms for local communities in compiling ocean accounts	Ensures social legitimacy and community involvement in marine spatial management	Berkes (1999); Adhuri et al (2019)
N6	Integration of OA with satellite, GIA data, and AI for ecosystem prediction	Supports predictive analysis and science-based planning	Gesami & Nunoo (2024)
N7	Open and transparent access to OA data for all stakeholders	Improves accountability and cross-sector collaboration	OECD (2020)
N8	Metadata synchronization among agencies (MMAF, SI, GIA, MNDP)	Prevents duplication and inconsistencies in the national database	MNDP (2023)
N9	Independent evaluation and audit system of OA data quality	Ensures validity and public trust in the data	World Bank (2021)
N10	Incentives for businesses that use ocean accounts in their planning	Motivates the private sector to integrate conservation aspects	Costanza et al (2014)
N11	Data protection and information security mechanisms for OA	Reduces risks of leaks, misuse, and manipulation of data	OECD (2019); Jharkharia & Shankar (2004)
N12	International collaboration to harmonize OA standards	Supports connectivity with global agendas such as SDGs and blue economy	Foley et al (2010); UNSC (2020)

The structural and quadrant analyses provide a systemic understanding of how different policy elements interact and influence one another in integrating OA into MSP of MPAs. The hierarchical structure (Figure 1) reflects a logical sequence from foundational technical components to policy enablers and strategic instruments, while the quadrant dependence analysis (Figure 2) reveals the dynamic relationships between these elements in terms of driving and dependent powers.

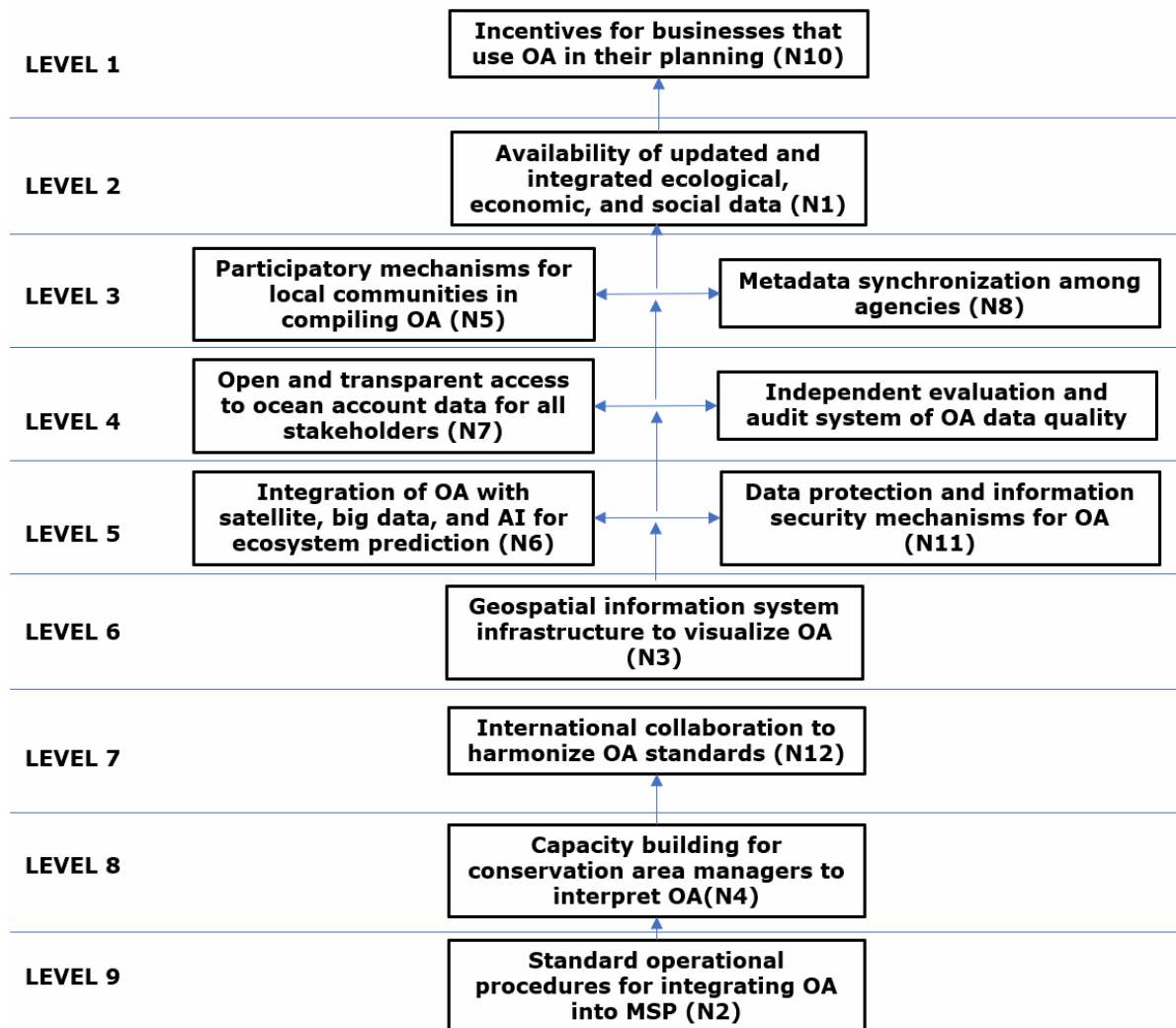


Figure 1. Level structuring of Need Element policy for integrating ocean accounting into marine spatial planning of marine protected areas.

At the base of the structure (Level 9) lies the establishment of Standard Operational Procedures (N2), which serve as the procedural backbone for consistent OA integration across regional planning instruments such as RTR and RZWP3K (UNSC 2020; MMAF 2021). The Capacity Building for Conservation Managers (N4) at Level 8 strengthens institutional competence to interpret OA data for adaptive management (Cisneros-Montemayor et al 2021). These foundational elements are reinforced by International Collaboration (N12) at Level 7, which harmonizes national OA practices with global frameworks like SDGs and blue economy standards (Foley et al 2010; UNSC 2020). The GIS infrastructure (N3) at Level 6 plays a pivotal role in linking technical datasets with spatial visualization, enabling cross-sector analysis and communication (Leenhardt et al 2015; GIA 2022).

At Levels 5 through 3, the structure becomes more interactive. Integration of OA with satellite, GIA data, and AI (N6) and Data Protection and Information Security (N11) are positioned at Level 5, enabling predictive, data-driven ecosystem planning while ensuring ethical data governance (OECD 2019; Gesami & Nunoo 2024). These elements

feed into Open Access (N7) and Independent Data Audit Systems (N9) at Level 4, which enhance transparency, accountability, and public trust (OECD 2020; World Bank 2021). The Participatory Mechanisms (N5) and Metadata Synchronization (N8) at Level 3 integrate social legitimacy and inter-agency coordination, ensuring that OA data reflects both scientific accuracy and stakeholder inclusivity (Berkes 1999; Adhuri et al 2019; MNDP 2023). Moving upward, Availability of Updated and Integrated Data (N1) at Level 2 provides the evidential base for sound policy decisions (Hein et al 2020; SI 2024), while the Incentives for Businesses (N10) at Level 1 drive long-term adoption and private sector alignment with OA-based management (Costanza et al 2014).

The quadrant dependence matrix complements this hierarchy by distinguishing elements according to their influence and reliance (Figure 2). Elements such as N2 (SOPs), located in Quadrant IV (Independent), have strong driving power but low dependence, serving as primary catalysts for system integration. Similarly, N3 (GIS infrastructure) and N4 (capacity building) exhibit high driving influence within Quadrant III (Linkage), where mutual interactions between policy, data infrastructure, and human capacity form a feedback loop crucial for operational sustainability (Leenhardt et al 2015; Cisneros-Montemayor et al 2021). Elements such as N1 (data availability), N5 (participation), N6 (AI integration), N7 (open access), N8 (metadata synchronization), N9 (audit), N11 (data security), and N12 (international collaboration) cluster in Quadrant III (Linkage), indicating that they are both influential and highly dependent on cross-sector coordination a hallmark of adaptive governance systems (OECD 2020; MNDP 2023). In contrast, N10 (incentives) occupies Quadrant II (Dependent), meaning it has low driving power and is primarily an outcome of other successfully implemented elements.

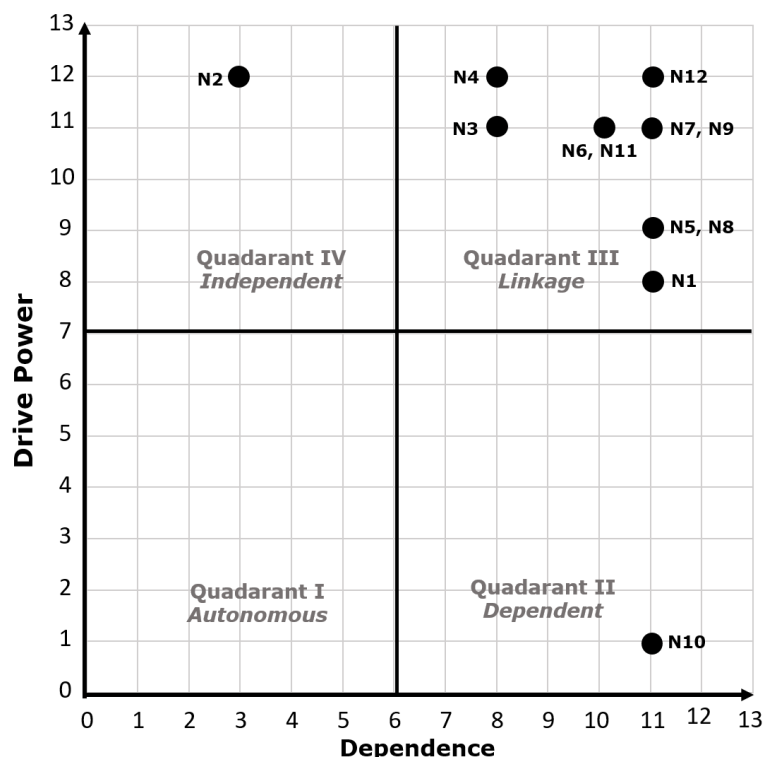


Figure 2. Quadrant interaction of Need Element policy for integrating ocean accounting into marine spatial planning of marine protected areas.

Taken together, these analyses suggest that integrating OA into MSP of MPAs requires a progressive, multi-level governance model that begins with technical standardization (N2, N3), advances through institutional and data coordination (N4-N8), and culminates in policy uptake and private sector incentives (N1, N10, N12). The interaction among “linkage” elements (Quadrant III) represents the adaptive engine of the system balancing scientific rigor, institutional legitimacy, and economic motivation to achieve transparent, data-informed marine governance. This systemic configuration demonstrates that the

success of OA integration hinges on harmonized standards, technological readiness, and participatory legitimacy, ultimately leading toward resilient and science-based marine spatial management (Foley et al 2010; Hein et al 2020; UNSC 2020).

Program Elements necessary to operationalize the identified needs into actionable planning tools. The internalization of OA into MSP within MPAs requires not only policy formulation but also a structured programmatic approach that translates policy objectives into operational actions. As shown in Table 5, the technical training and development of OA modules for managers (P1) serves as a fundamental step in strengthening human capital and institutional capability, enabling conservation area managers to interpret and utilize OA data effectively in decision-making (UNSC 2020; MFHRDT 2022). Building upon this foundation, the application of OA as an evaluation instrument (P2) ensures that conservation effectiveness is quantitatively measurable, providing a performance-based framework for adaptive policy-making (Hein et al 2020). To support transparency and monitoring, the development of a monitoring dashboard (P3) integrates OA data into user-friendly platforms that facilitate real-time tracking of ecosystem and economic indicators (Gesami & Nunoo 2024).

Table 5

Program Element for integrating ocean accounting into marine spatial planning of marine protected areas

<i>No.</i>	<i>Element</i>	<i>Short explanation</i>	<i>Relevant citations</i>
P1	Technical training and development of OA modules for managers	Strengthens technical capacity of conservation managers	UNSC (2020); MFHRDT (2022)
P2	Application of OA as an instrument to evaluate conservation effectiveness	Makes OA a performance measure for conservation policy	Hein et al (2020)
P3	Development of a monitoring dashboard based on OA	Facilitates reporting, transparency, and monitoring	Gesami & Nunoo (2024)
P4	Integration of OA results into regional planning and zoning documents	Ensures OA is part of official planning documents	MNDP (2023)
P5	Strengthening stakeholder collaboration based on OA data	Encourages cross-actor cooperation in MSP	Guerry et al (2015)
P6	Drafting technical regulations requiring OA in RZWP3K	Makes integration legally mandatory	MMAF (2021)
P7	Sustainable financing schemes for OA updating (national, regional budgets, CSR, donors)	Ensures long-term financial sustainability	World Bank (2021)
P8	Development of scenario simulation models (trade-off analysis) using OA	Helps government and businesses explore best options	Halpern et al (2015)
P9	Integration of OA into SDG, blue economy, and national OA evaluation	Links marine management to global agendas	OECD (2020); SI (2024)
P10	Strengthening networks of environmentally friendly businesses using OA data	Encourages sustainable business practices	FAO (2015)
P11	Application of fiscal and non-fiscal incentives for businesses using OA	Provides tangible encouragement for private sector	OECD (2021)
P12	International cooperation for technology transfer in OA	Accelerates adoption of advanced technology	Hodge & Greve (2016); MMAF (2022)

Institutionally, the integration of OA results into regional planning and zoning documents (P4) ensures that accounting outputs inform legal and administrative frameworks, embedding sustainability principles directly within spatial governance instruments such as Marine Spatial Planning (MSP) and Spatial Planning Document (MNDP 2023). Furthermore, stakeholder collaboration (P5) is critical for fostering multi-actor engagement and shared responsibility, aligning with the concept of ecosystem-based management that emphasizes co-production of knowledge among scientists, policymakers, and communities (Guerry et al 2015). The drafting of technical regulations (P6) formalizes OA implementation, transforming it from a voluntary initiative into a mandatory policy instrument at the regional level (MMAF 2021).

To ensure continuity, the establishment of sustainable financing schemes (P7) through national budgets, corporate social responsibility (CSR), and donor contributions provides the financial backbone for maintaining OA data systems and continuous updates (World Bank 2021). On the analytical front, the development of scenario simulation models (P8) using OA data supports trade-off analysis and future projections, thereby enhancing the predictive capacity of marine planning processes (Halpern et al 2015). Similarly, integration of OA with SDGs and blue economy frameworks (P9) aligns national marine management with global sustainability agendas, ensuring coherence between conservation outcomes and international commitments (OECD 2020; SI 2024).

From the perspective of economic instruments, strengthening networks of environmentally friendly businesses (P10) and application of fiscal and non-fiscal incentives (P11) demonstrate the role of OA in catalyzing sustainable market behavior and encouraging private sector participation (FAO 2015; OECD 2021). Finally, international cooperation for technology transfer (P12) accelerates innovation diffusion and enables the adoption of advanced OA technologies, reinforcing interoperability and global data standards (Hodge & Greve 2016; MMAF 2022). Collectively, these twelve program elements illustrate a systemic progression from capacity development and institutional embedding to financial, regulatory, and technological integration necessary to transform OA into an operational backbone of MSP for MPAs (Figure 3). This integrated approach bridges ecological, economic, and governance dimensions, ensuring that marine conservation planning is both evidence-based and globally aligned.

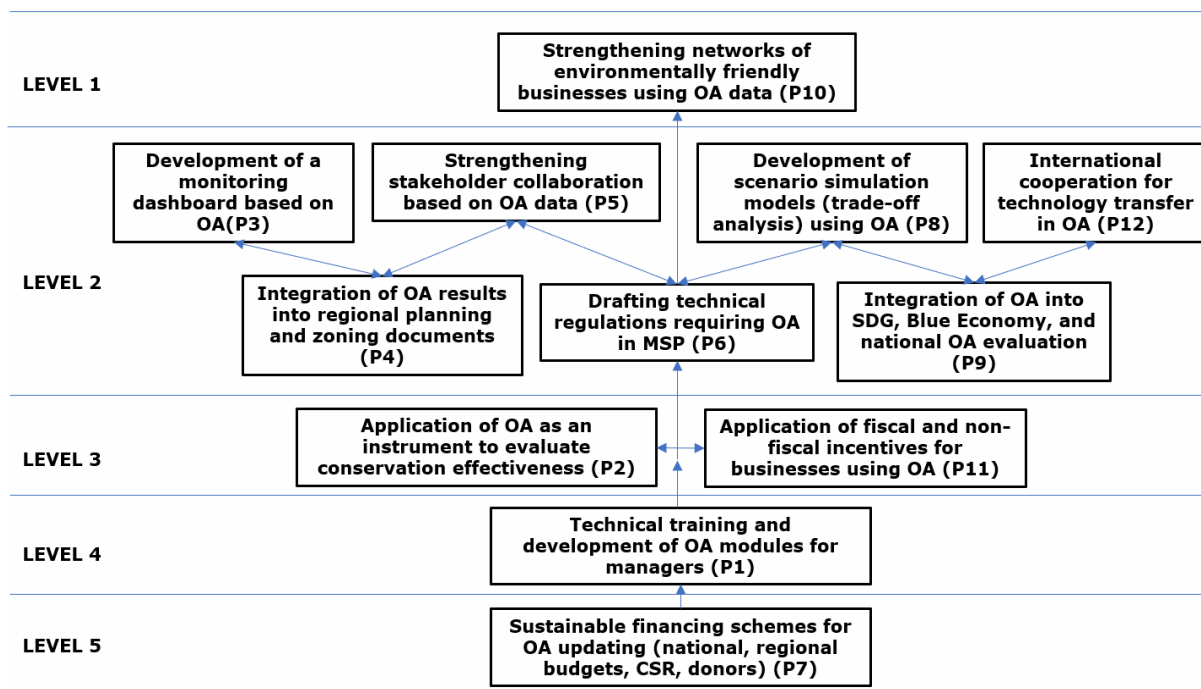


Figure 3. Level structuring of Program Element policy for integrating ocean accounting into marine spatial planning of marine protected areas.

The hierarchical and quadrant analyses of the Program Elements for integrating OA into MSP of MPAs reflect a well-structured policy operationalization pathway. This structure demonstrates how sequential and interactive elements ranging from capacity building and financing mechanisms to stakeholder collaboration and global alignment synergize to institutionalize OA as a practical management instrument in marine governance. At the foundational level (Level 5), the sustainable financing schemes for OA updating (P7) are positioned as the primary enabler. This element serves as the financial backbone ensuring that OA processes data collection, monitoring, and evaluation remain continuous and resilient against short-term budget fluctuations (World Bank 2021). Closely aligned at Level 4, the technical training and development of OA modules for managers (P1) strengthens institutional capacity by building the analytical and operational competencies of conservation area managers (UNSC 2020; MFHRDT 2022). Together, these foundational programs secure both the economic and human resource pillars necessary for the institutionalization of OA.

Progressing to Level 3, two critical operational elements emerge: the application of OA as an instrument to evaluate conservation effectiveness (P2) and the application of fiscal and non-fiscal incentives for businesses using OA (P11). These elements bridge technical capacity with policy implementation by translating OA data into actionable performance indicators for conservation and economic instruments that encourage private sector participation (Hein et al 2020; OECD 2021). The Level 2 elements integration of OA results into regional planning and zoning documents (P4), drafting of technical regulations (P6), and integration of OA into SDG, blue economy, and national OA evaluations (P9) represent the institutional consolidation stage. They ensure that OA data are formally embedded into planning and legal frameworks, thereby transitioning OA from a scientific tool to a regulatory standard (OECD 2020; MMAF 2021; MNDP 2023). Supporting these regulatory actions are interactive mechanisms such as stakeholder collaboration (P5), monitoring dashboard development (P3), scenario simulation models (P8), and international cooperation for technology transfer (P12), which collectively facilitate transparency, adaptive management, and global knowledge exchange (Guerry et al 2015; Hodge & Greve 2016; MMAF 2022; Gesami & Nunoo 2024).

Finally, Level 1 is characterized by the strengthening of networks of environmentally friendly businesses using OA data (P10), which serves as the apex of OA internalization. This element signifies the realization of OA-based sustainability practices across the private sector, encouraging green investments and responsible resource management (FAO 2015). This top-level integration demonstrates how OA data influence real-world economic behavior, ensuring that conservation and development objectives are balanced within the marine economy. The quadrant dependence analysis further reinforces this hierarchical logic (Figure 4). The Independent Quadrant (Quadrant IV) is occupied by P7 (sustainable financing schemes), which exhibits the highest driving power and lowest dependence, signifying its foundational role in sustaining the entire OA system. In contrast, most elements including P1, P2, P4, P5, P6, P8, P9, P11, and P12 are clustered in the Linkage Quadrant (Quadrant III), indicating that they are both highly influential and mutually interdependent. This interdependence suggests that success in OA integration requires coordination across technical, financial, legal, and participatory domains a hallmark of adaptive and network-based governance (Guerry et al 2015; Halpern et al 2015). The dependent position of P10 within this cluster suggests that sustainable business networks are the emergent outcome of effective OA operationalization, relying on preceding advancements in training, regulation, and data systems.

Overall, the program structure and quadrant interactions highlight a cascading policy logic where financial and technical capacity (P7, P1) drive the development of evaluative and incentive-based instruments (P2, P11), which in turn enable institutional mainstreaming (P4, P6, P9) and cross-sector collaboration (P3, P5, P8, P12). The culmination of these synergistic processes is the establishment of environmentally responsible marine industries (P10). This dynamic reflects the adaptive institutionalization of OA, aligning with the principles of integrated ocean governance and the UN's Blue Economy framework (Hein et al 2020; OECD 2020; MMAF 2021). By

positioning OA as both a scientific and governance tool, this model advances the capacity of MSP in MPAs to balance ecological protection, economic productivity, and social inclusion within an evidence-based decision-making system.

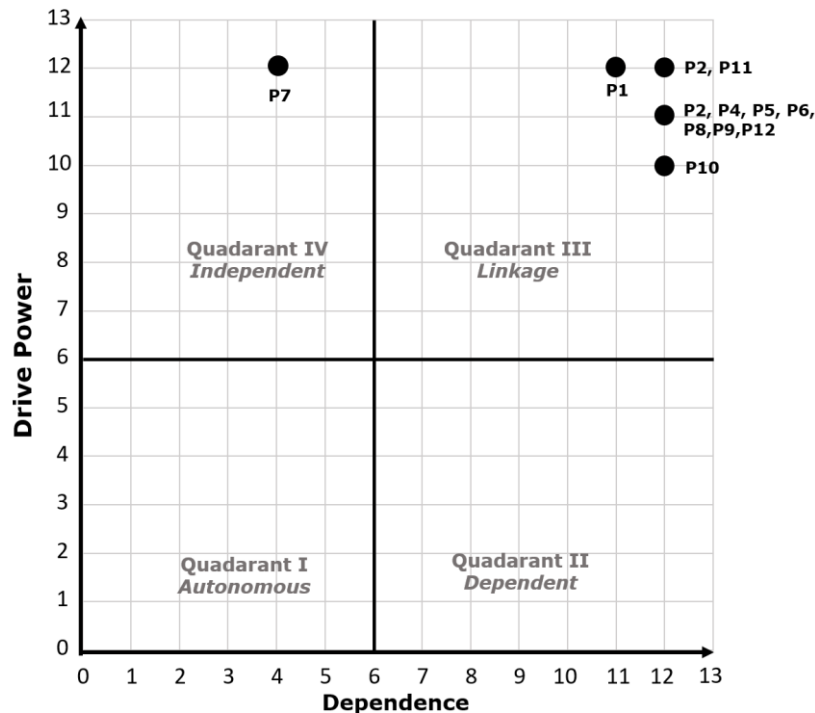


Figure 4. Quadrant interaction of Program Element policy for integrating ocean accounting into marine spatial planning of marine protected areas.

Discussion

Synthesizing the ISM findings for Need Elements. The ISM analysis of Need Elements reveals a clear, policy-relevant hierarchy in which data and institutional enablers form the foundational drivers that make downstream policy and management outcomes feasible. At the lowest levels of the ISM hierarchy are technical prerequisites availability of updated and integrated ecological, social and economic data (N1), robust geospatial information systems (N3), and metadata synchronization across agencies (N8) which together establish the empirical substrate for any accounting-informed planning (Leenhardt et al 2015; Hein et al 2020). These elements were positioned as high-driving, low-dependent factors in the ISM quadrant analysis, indicating that improving data quality and interoperability yields outsized leverage across the system. The next level emphasizes institutional capacities and procedures notably standard operational procedures (N2) for embedding OA outputs into planning instruments and capacity building for conservation managers (N4) which translate raw data into interpretable, policy-relevant information (Cisneros-Montemayor et al 2021; UNSC 2020). Finally, elements such as business incentives (N10) and public uptake/open access (N7) sit higher in the ISM as dependent outcomes that require the prior maturation of data systems, governance protocols, and trust infrastructure (OECD 2020). This structured pattern confirms that OA cannot be 'bolted on' to MSP; rather, it requires staged investments across data, institutionalization, and governance legitimacy in order to realize tangible conservation and economic outcomes.

Interpreting the ISM outcomes for Program Elements. The programmatic ISM produced a complementary, operationally oriented hierarchy. Sustainable financing mechanisms for maintaining OA (P7) and technical training and module development for managers (P1) emerged as principal drivers foundational investments that sustain monitoring cycles and build human capacity to use OA outputs in planning decisions

(UNSC 2020; World Bank 2021). Mid-level program elements such as OA application as an evaluation instrument (P2), monitoring dashboards (P3) and integration into regional zoning and legal instruments (P4 and P6) operate as linkage elements: they are both influential (they change practice) and dependent (they require funding, data, and trained staff to function). At the higher (more dependent) levels lie market-facing programs networking of green businesses (P10) and fiscal/non-fiscal incentives (P11) which depend on credible OA outputs, clear regulations, and demonstrated conservation benefits to be effective (FAO 2015; OECD 2021).

Policy implications from the hierarchical and quadrant patterns. Together, the Need and Program ISM topologies point to three practical implications for policymakers who seek to integrate OA into MSP of MPAs:

1. Prioritize foundational investments metadata standards, interoperable GIS, sustained budgets for OA maintenance, and manager training must be frontloaded because they structurally enable all downstream functionality (Hein et al 2020; World Bank 2021);

2. Design linkage processes intentionally tools such as dashboards, scenario models, and formal procedures for embedding accounts into planning instruments are both powerful and fragile: they will fail without strong technical and institutional backing (UNSC 2020; Gacutan et al 2022);

3. Sequence incentives after technical credibility fiscal or market incentives to stimulate private participation should follow demonstrable OA outputs and transparent auditing mechanisms, otherwise incentives risk perverse outcomes or low uptake (OECD 2020).

This sequencing is consistent with broader evidence that accounting frameworks require institutional embedding before they can change economic behavior at scale (Gacutan et al 2022; GOAP 2022).

Comparative table of program approaches and observed success in OA-MSP integration in conservation areas. Table 6 summarizes selected international experiences where OA or OA-like economic/environmental accounting techniques have been piloted or considered for integration into MSP particularly within or near conservation areas and provides an evidence-based judgement on relative implementation success. The "Success" column reflects observed or reported progress toward embedding accounting outputs into spatial planning decisions (qualitative: High/Medium/Low) and is accompanied by succinct justification and citation.

Lessons learned from international comparisons. Cross-case comparison highlights consistent enablers and constraints:

1. Enablers: dedicated funding and donor support (sustains data production), local capacity building (enables interpretation), and participatory processes that create legitimacy for account-based recommendations (UNSC 2020; World Bank 2021);

2. Constraints: persistent data gaps across social and ecological domains, fragmented institutional mandates across ministries and agencies, and absence of legal/regulatory requirements to use OA outputs in planning decisions (Gacutan et al 2022; McManus et al 2022; Reimer et al 2023). These constraints explain why several pilots improved knowledge without achieving formal MSP integration;

3. Design implication: successful cases tend to follow the ISM-predicted sequence secure data and finance, build capacity, develop operational tools (dashboards, models), then pursue regulatory embedding and market incentives rather than attempting immediate top-down policy prescriptions.

Table 6

International comparison of programs and observed success integrating ocean accounting into MSP (conservation areas)

<i>Country / case</i>	<i>Key program elements implemented</i>	<i>Observed success (High/Medium/Low)</i>	<i>Justification / evidence</i>
Indonesia (Gili Matra pilot)	Pilot OA compilation, stakeholder workshops, capacity building modules, draft dashboards	Medium	Pilot produced usable accounts and stakeholder interest but limited formal integration into RZWP3K/MSP; still largely descriptive and requires scaling, financing, and regulatory uptake (SI 2024; Indonesia pilot report).
Belize	OA workshops, national accounts pilots tied to MSP and Blue Economy planning; stakeholder training	Medium-High	Workshop outcomes showed clear utility of OA for MSP and decision support; momentum for integrating accounts into planning processes reported. (GOAP 2022/Belize case summary).
Canada (pilot projects)	Subnational ocean accounts, ecosystem valuation studies, engagement with planners	Medium	Pilots demonstrated technical feasibility and influenced economic framing of MSP but broader mainstreaming across jurisdictions has been gradual. (OceanAccounts.org; GOAP (2022) reviews)
Australia (selected regions)	Economic valuation and regional MSP, integration of ecosystem service indicators into planning tools	Medium-High	Regional programs have effectively used economic/environmental indicators to inform MSP; OA framing is recognized and being operationalized in select jurisdictions (Gacutan et al 2022; national MSP literature)
Portugal (Azores / EU contexts)	Integration of environmental accounting concepts within MSP planning under EU MSP guidance	Medium	EU MSP Directive and national practices support data integration; direct OA integration is emerging but not yet uniformly implemented. (Global review; EU MSP studies)
South Africa / Thailand (case studies in review)	National interest, pilot studies, but constrained by data/gov capacity	Low-Medium	Reviews identify high potential but practical barriers (data, coordination, finance) limit operational integration into MSP in conservation zones. (Gacutan et al 2022; global review)

*Notes: success ratings are qualitative and relative; they reflect published assessments of pilot outcomes, workshop reports, and peer-reviewed analyses rather than uniform metrics. The categorization captures whether OA outputs have demonstrably changed MSP documents, zoning decisions, or resource allocation in conservation areas; **Sources: Indonesia pilot reports (SI 2024); Global Ocean Accounts Partnership case summaries and Belize workshop documentation; Gacutan et al (2022) and related reviews; OceanAccounts.org syntheses; World Bank and OECD analyses on economic inputs to MSP.

Conclusions. The results of this study conclude that the successful integration of Ocean Accounting (OA) into Marine Spatial Planning (MSP) within Marine Protected Areas (MPAs) relies on the coherent alignment between institutional needs and programmatic implementation, as revealed through the Interpretive Structural Modelling (ISM) analysis. The Need Elements highlight that data integration, standardized operational procedures, inter-agency coordination, and capacity building form the fundamental drivers that enable OA to be effectively utilized in spatial planning. Meanwhile, the Program Elements emphasize that sustainable financing, technical training, regulatory instruments, and participatory monitoring tools serve as the operational mechanisms translating these needs into practice. Collectively, these findings demonstrate that OA integration must follow a sequential and adaptive process beginning with strengthening data systems and institutional frameworks, progressing toward the development of operational programs and monitoring systems, and culminating in the institutionalization of evidence-based and transparent marine governance. Through this structured approach, the study successfully meets its objectives by producing a validated policy model that links technical, institutional, and programmatic dimensions, providing a strategic framework for embedding Ocean Accounting into Marine Spatial Planning of Marine Protected Areas in Indonesia.

Acknowledgements. Thanks are expressed to all the people involved in writing, experts, conservation area managers who helped with data collection, as well as all parties who helped until this paper was written.

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

References

- Adhuri D. S., Imron M., Nurhidayah L., Solihin A., 2019 [Dynamics of fisheries resource management in Indonesia]. Graha Ilmu, 168 pp. [in Indonesian]
- Berkes F., 1999 Sacred ecology: traditional ecological knowledge and resource management. 1st edition. Taylor & Francis, 209 pp.
- Cisneros-Montemayor A. M., Moreno-Báez M., Reygondeau G., Cheung W. W. L., Crosman K. M., González-Espinosa P. C., Lam V. W. Y., Oyinlola M. A., Singh G. G., Swartz W., Zheng C. W., Ota Y., 2021 Enabling conditions for an equitable and sustainable blue economy. *Nature* 591(7850):396-401.
- Costanza R., de Groot R., Sutton P., van der Ploeg S., Anderson S. J., Kubiszewski I., Farber S., Turner R. K., 2014 Changes in the global value of ecosystem services. *Global Environmental Change* 26:152-158.
- FAO, 2015 Voluntary guidelines for securing sustainable small-scale fisheries in the context of food security and poverty eradication. FAO, Rome, 18 pp.
- Foley M. M., Halpern B. S., Micheli F., Armsby M. H., Caldwell M. R., Crain C. M., Prahler E., Rohr N., Sivas D., Beck M. W., Carr M. H., Crowder L. B., Duffy J. E., Hacker S. D., McLeod K. L., Palumbi S. R., Peterson C. H., Regan H. M., Ruckelshaus M. H., Sandifer P. A., Steneck R. S., 2010 Guiding ecological principles for marine spatial planning. *Marine Policy* 34(5):955-966.
- Gacutan J., Galparsoro I., Pınarbaşı K., Murillas A., Adewumi I. J., Praphotjanaporn T., Johnston E. L., Findlay K. P., Milligan B. M., 2022 Marine spatial planning and ocean accounting: synergistic tools enhancing integration in ocean governance. *Marine Policy* 136:104936.
- Gesami B. K., Nunoo J., 2024 Artificial intelligence in marine ecosystem management: addressing climate threats to Kenya's blue economy. *Frontiers in Marine Science* 11:1404104.
- GIA [Geospatial Information Agency], 2022 [Annual report]. Bogor, 136 pp. [in Indonesian]
- GOAP (Global Ocean Accounts Partnership), 2022 Linking ocean accounting to marine spatial planning [consultation draft report]. The Global Ocean Accounts Partnership, Sydney, Australia, 12 pp.

- Guerry A. D., Polasky S., Lubchenco J., Chaplin-Kramer R., Daily G. C., Griffin R., Ruckelshaus M., Bateman I. J., Duraiappah A., Elmqvist T., Feldman M. W., Folke C., Hoekstra J., Kareiva P. M., Keeler B. L., Li S., McKenzie E., Ouyang Z., Reyers B., Ricketts T. H., Rockström J., Tallis H., Vira B., 2015 Natural capital and ecosystem services informing decisions: from promise to practice. *Proceedings of the National Academy of Sciences of the USA* 112(24):7348-7355.
- Halpern B. S., Frazier M., Potapenko J., Casey K. S., Koenig K., Longo C., Lowndes J. S., Rockwood R. C., Selig E. R., Selkoe K. A., Walbridge S., 2015 Spatial and temporal changes in cumulative human impacts on the world's ocean. *Nature Communications* 6:7615.
- Hein L., Bagstad K. J., Obst C., Edens B., Schenau S., Castillo G., Soulard F., Brown C., Driver A., Bordt M., Steurer A., Harris R., Caparrós A., 2020 Progress in natural capital accounting for ecosystems. *Science* 367(6477):514-515.
- Hodge G. A., Greve C., 2016 On public-private partnership performance: a contemporary review. *Public Works Management and Policy* 22(1):55-78.
- Jharkharia S., Shankar R., 2004 IT enablement of supply chains: modeling the enablers. *International Journal of Productivity and Performance Management* 53(8):700-712.
- Leenhardt P., Teneva L., Kininmonth S., Darling E., Cooley S., Claudet J., 2015 Challenges, insights and perspectives associated with using social-ecological science for marine conservation. *Ocean and Coastal Management* 115:49-60.
- McManus C., McIlgorm A., Nichols R., Cooper A., 2022 An initial consideration of data availability issues in downscaling ocean accounting to inform sustainable aquaculture development: the example of Clew Bay, Ireland. *Marine Policy* 145: 105286.
- MFHRDT [Marine and Fisheries Human Resources Development and Training Agency], 2022 [Capacity building and marine training for marine data management]. [Marine and Fisheries Human Resources Development and Training Agency]. Jakarta, 47 pp. [in Indonesian]
- MMAF [Ministry of Marine Affairs and Fisheries], 2021 [Ocean Account Guidelines]. Jakarta: [Ministry of Marine Affairs and Fisheries]. 82 pp [in Indonesian] (limited publication)
- MMAF [Ministry of Marine Affairs and Fisheries], 2022 [Technical Cooperation Framework for Marine Data and Technology Transfer]. [Ministry of Marine Affairs and Fisheries]. Jakarta, 98 pp. [in Indonesian]
- MNDP [Ministry of National Development Planning], 2023 [Indonesia Blue Economy Road Map. 2nd edition]. [Ministry of National Development Planning]. Jakarta, 227 pp. [in Indonesian]
- NRIA [National Research and Innovation Agency], 2023 [Research Ethics Guidelines for Policy Studies in Indonesia]. [National Research and Innovation Agency]. Jakarta, 47 pp. [in Indonesian]
- OECD (Organization for Economic Co-operation and Development), 2019 Data Governance. Paris: Organization for Economic Co-operation and Development. Available at: https://www.oecd.org/en/topics/sub-issues/data-governance.html?utm_source=chatgpt.com. Accessed: July, 2025.
- OECD (Organization for Economic Co-operation and Development), 2020 Sustainable Ocean for All Harnessing The Benefits of Sustainable Ocean Economies For Developing Countries. Paris: Organization for Economic Co-operation and Development. Available at: https://www.oecd.org/content/dam/oecd/en/publications/reports/2020/09/sustainable-ocean-for-all_c0df60f6/bede6513-en.pdf. Accessed: July, 2025.
- OECD (Organization for Economic Co-operation and Development), 2021 A new era of digitalization for ocean sustainability? Prospects, benefits, challenges. OECD Science, Technology and Industry Policy Papers No. 111, OECD Publishing, Paris.

- Reimer J. M., Devillers R., Zuercher R., Groulx P., Ban N. C., Claudet J., 2023 The marine spatial planning index: a tool to guide and assess marine spatial planning. *npj Ocean Sustainability* 2(1):15.
- Saunders F., Gilek M., Ikaunieca A., Tafon R. V., Gee K., Zaucha J., 2020 Theorizing social sustainability and justice in marine spatial planning: democracy, diversity, and equity. *Sustainability* 12(6):2560.
- SI [Statistics Indonesia] 2024 [Marine and Coastal Resources Statistics]. [Statistics Indonesia]. Jakarta, 296 pp. [in Indonesian]
- Singh M. D., Kant R., 2008 Knowledge management barriers: an interpretive structural modeling approach. *International Journal of Management Science and Engineering Management* 3(2):141-150.
- Sugiharto A., 2023 The role of the blue economy for the future of Indonesian maritime defense. *Jurnal Maritim Indonesia* 3(4):294-302.
- Sushil, 2012 Interpreting the interpretive structural model. *Global Journal of Flexible Systems Management* 13(2):87-106.
- UNSC (United Nations Statistical Commission), 2020 Technical guidance on ocean accounting for sustainable development. United Nations Statistics Division/ESCAP. 160 pp.
- Warfield J. N., 1974 Developing interconnection matrices in structural modeling. *IEEE Transactions on Systems, Man, and Cybernetics* 4(1):81-87.
- World Bank, 2022 Applying economic analysis to marine spatial planning. The World Bank, Washington, DC, 67 pp.
- Zuercher R., Ban N. C., Flannery W., Guerry A. D., Halpern B. S., Magris R. A., Mahajan S. L., Motzer N., Spalding A. K., Stelzenmüller V., Kramer J. G., 2022 Enabling conditions for effective marine spatial planning. *Marine Policy* 143:105141.

Received: 28 October 2025. Accepted: 24 November 2025. Published online: 13 April 2026.

Authors:

Budi M. Ruslan, Department of Resource and Environmental Economics, Faculty of Economics and Management, IPB University, Dramaga Street, 16680 Bogor, West Java, Indonesia, e-mail: budiruslanbudi@apps.ipb.ac.id
 Luky Adrianto, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Dramaga Street, 16680 Bogor, West Java, Indonesia, e-mail: adrianto@ipb.ac.id
 R. Nunung Nuryartono, Department of Economics, Faculty of Economics and Management, IPB University, Dramaga Street, 16680 Bogor, West Java, Indonesia, e-mail: nuryartono@ipb.ac.id
 Gatot Yulianto, Department of Aquatic Resources Management, Faculty of Fisheries and Marine Sciences, IPB University, Dramaga Street, 16680 Bogor, West Java, Indonesia, e-mail: gyo@apps.ipb.ac.id
 M. Firdaus Agung, Ministry of Marine Affairs and Fisheries, Batu Street, 10110 Gambir, Central Jakarta, Jakarta, Indonesia, e-mail: firda_ku@yahoo.com
 Irfan Yulianto, Rekam Nusantara Foundation, Sempur Street, 16129 Bogor, West Java, Indonesia, e-mail: irfan@rekam.org
 Ari Kurniawan, Khairun University, Sofifi street, 97852 North Oba, Tidore Islands, North Maluku, Indonesia, e-mail: arikurniawan.dkpmalut@gmail.com
 Imam Fauzi, Kupang Marine Management Office, Yos Sudarso Street 85239, Alak, Kupang, East Nusa Tenggara, Indonesia, e-mail: imam.fauzi@MMAF.go.id
 Ahmad Sofiullah, Ministry of Marine Affairs and Fisheries, Batu Street, 10110 Gambir, Central Jakarta, Jakarta, Indonesia, e-mail: ahmad.sofiullah@MMAF.go.id

This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

How to cite this article:

Ruslan B. M., Adrianto L., Nuryartono R. N., Yulianto G., Agung M. F., Yulianto I., Kurniawan A., Fauzi I., Soufillah A., 2026 Policy for integrating ocean accounting into marine spatial planning of marine protected areas. *AAFL Bioflux* 19(2):685-700.