

## Article

# From Marine Natural Capital Valuation to Fiscal Integrity: A Governance Design for Blue Natural Capital Value at Risk in Indonesia

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## Abstract

Marine ecosystem degradation may reduce state revenues, increase recovery spending, and weaken fiscal sustainability, yet Indonesia does not yet have a routine governance mechanism that links marine natural capital valuation to fiscal-risk assessment in the State Budget Financial Note. This article develops a governance design, Blue Natural Capital Value at Risk (BNC-VaR), to translate changes in marine ecosystem conditions into fiscal-exposure signals for Indonesian public finance. Ecological condition indicators, such as fish-stock status, coral-reef condition, and mangrove extent, are converted into traceable valuation parameters and then into structured outputs, including fiscal-exposure scenarios, budget-relevance notes, and medium-term fiscal-sustainability readings across revenue, expenditure, deficit, and financing channels. The design treats ecological change as affecting the fiscal position through mediated and disclosable pathways rather than automatic causal effects. It adapts Value at Risk as a risk logic for public fiscal governance rather than as a conventional market-based probabilistic measure. Using theory synthesis and a model-paper approach across six analytical stages, the study produces five design principles, four formal propositions, and a five-component institutional architecture, with the Directorate General of State Assets Management positioned as a valuation custodian. As a conceptual contribution, BNC-VaR offers an operational architecture and implementation roadmap for future empirical testing in Indonesia and other archipelagic or marine-resource-dependent fiscal systems.

**Keywords:** blue natural capital; fiscal risk; ecosystem valuation; public financial management; marine governance; fiscal sustainability; Indonesia



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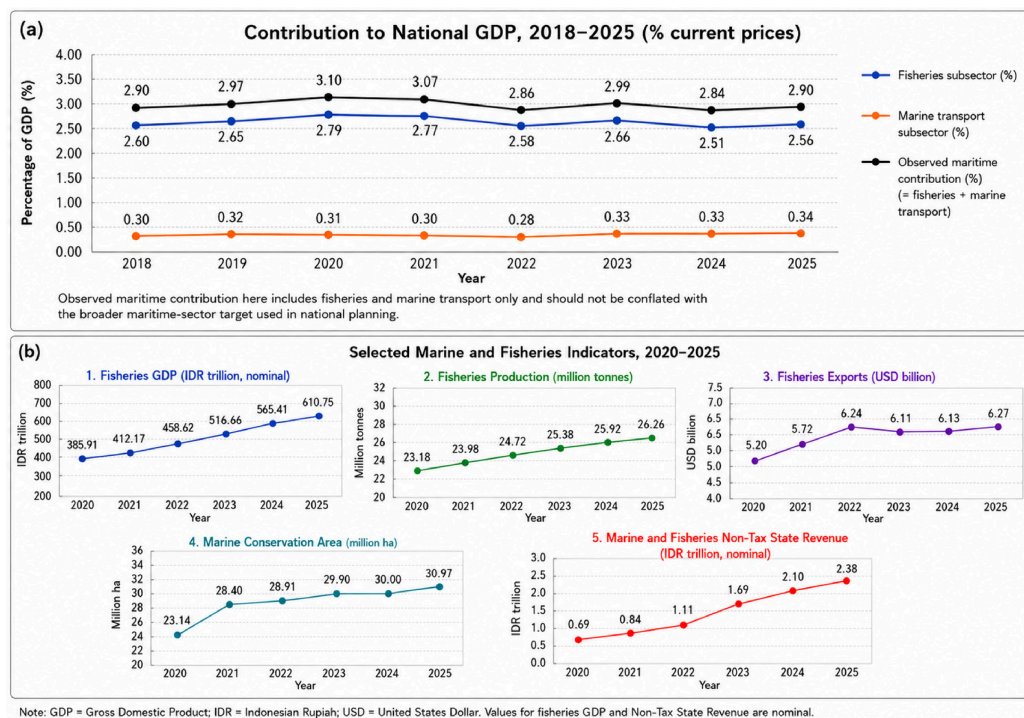
## 1. Introduction

The United Nations Sustainable Development Agenda places the protection of marine ecosystems as a core objective through Sustainable Development Goal 14 [1]. For archipelagic states, this objective is not only environmental. Marine ecosystems support revenue bases, coastal livelihoods, food systems, tourism activity, and public spending needs. The fiscal question is therefore whether changes in marine ecosystem conditions can be recognised early enough within planning, fiscal risk, and budget routines. To the best of the authors' knowledge, the existing literature does not yet offer a governance design that operationally links marine natural capital valuation to fiscal-risk assessment in the state budget cycle, particularly in Indonesia [2]. Without such a mechanism, marine ecological changes that may reduce revenues or increase recovery and adaptation spending remain difficult to trace in fiscal planning documents such as the State Budget Financial Note.

Indonesia is a relevant case due to the scale of its marine territory and the administrative importance of marine resources. The country has 17,504 islands, approximately 108,000 km of coastline, and around 6.4 million km<sup>2</sup> of waters [3–5]. Yet the economic signal is not straightforward. The fisheries sector is a narrow national-accounts category, contributing around 2.5–2.8% of Gross Domestic Product during 2018–2025, while marine transport contributed around 0.28–0.34% over the same period. Taken together, these two consistently observable subsectors averaged about 2.95% of Gross Domestic Product, reaching 2.90% in 2025. This observed series should not be conflated with the broader maritime-sector target in the 2025–2029 National Medium-Term Development Plan (RPJMN), which refers to a broader aggregate that includes fisheries, marine and coastal tourism, sea transport and ports, offshore energy, and the coastal industry [3,6]. The blue economy, in contrast, is not a national-accounts sector but a sustainable development and governance paradigm for managing marine resources.

Figure 1 shows why the fiscal relevance of marine resources cannot be inferred from a single headline indicator. As depicted, Indonesia's marine and fisheries sector shows broad economic and administrative expansion between 2020 and 2025. Nominal fisheries Gross Domestic Product, fisheries production, marine conservation areas, and Non-Tax State Revenue all increased over the period, while fisheries exports remained broadly positive despite some year-to-year variation. Non-Tax State Revenue refers to government revenue other than taxes and grants, including natural resource levies, service charges, and administrative receipts. These trends indicate sectoral growth and expanding administrative reach, but they also reveal a critical blind spot: headline performance indicators by themselves do not show whether the ecological pressures underlying marine assets have been translated into accountable fiscal-risk information.

This distinction matters because the ecological foundations of marine economic value remain vulnerable. Official and secondary sources report that about 38% of assessed fish stocks are overfished, that mangrove loss may reach up to 52,000 hectares per year, that around one-third of coral reefs are in poor condition, and that plastic pollution causes estimated economic losses of about USD 450 million per year [3,4]. Coral-reef degradation can affect fisheries productivity and marine tourism by reducing habitat quality, fish-stock support, and tourism attractiveness [7–9]. Mangrove loss can increase coastal vulnerability and future restoration or disaster-response spending. These ecological changes do not automatically become fiscal events. They become fiscally relevant only when they affect administratively recognised revenue objects, taxable activities, expenditure obligations, fiscal-risk categories, or financing needs. This is the governance gap addressed in this article.



**Figure 1.** Selected trends in Indonesia's maritime and fisheries economy. Panel (a) presents the contribution of fisheries and marine transport to the national Gross Domestic Product (GDP) for 2018–2025 [10]. Panel (b) presents selected Ministry of Marine Affairs and Fisheries performance indicators for 2020–2025 [11]. Fisheries Gross Domestic Product and Non-Tax State Revenue values are presented in nominal terms. Figure 1 was prepared with the assistance of ChatGPT (OpenAI, GPT 5.5) for data visualisation and layout refinement, using numerical data supplied by the authors from official sources. The authors verified the underlying data, reviewed the visual output, and approved the final figure.

Indonesia already has policy and accounting entry points, but these remain incomplete for use in fiscal risk. The 2025–2029 National Medium-Term Development Plan, stipulated through Presidential Regulation No. 12 of 2025, prioritises the blue economy as part of economic transformation and targets an increase in the broader maritime sector's contribution to Gross Domestic Product from 8.1% to 9.1% by 2029 [6]. The Wealth Accounting and the Valuation of Ecosystem Services programme also supported the development of natural capital accounting in Indonesia, including land and peat accounts, and strengthened the policy relevance of environmental-economic accounting [12]. However, ecosystem-accounting outputs do not inherently translate into fiscal-risk inputs. A separate translation mechanism is required to determine which ecological indicators matter for fiscal exposure, how valuation parameters should be controlled, and how uncertainty should be disclosed before the information is included in budget documents.

International experience confirms that the gap is not the absence of nature-related finance but the absence of a routine fiscal-risk transmission mechanism. The System of Environmental-Economic Accounting provides standardised ecosystem accounts [13], Ocean Accounts extend accounting logic to the marine domain [14], the Marine Natural Capital Risk Register maps asset-level risks and benefits [15], and green public financial management offers an environmental entry point into public finance [16]. Other archipelagic and island contexts also show partial solutions. Seychelles used a sovereign blue bond to support marine protection and fisheries governance [17]. Belize's 2021 debt-for-nature arrangement linked debt treatment to marine conservation commitments [18]. The Philippines adopted blue-bond guidance to define eligible blue projects [19]. Pacific

small island states generally address climate and disaster exposure through aggregate macro-fiscal risk, contingency, and resilience-financing instruments [20]. These mechanisms matter, but they operate mainly at the accounting, risk-mapping, market-finance, or aggregate macro-fiscal level. They do not provide a recurring process for translating ecosystem-condition change into fiscal-exposure signals within the annual budget cycle.

The data used in this article should therefore be read with two limitations in mind. First, the Indonesian economic series used in the Introduction draws on official sectoral and national accounts indicators, but these indicators do not directly measure ecological fiscal exposure. The nominal growth in fisheries Gross Domestic Product and Non-Tax State Revenue should therefore be interpreted as an administrative and economic trend, not as a direct measure of ecological resilience. Second, no standardised cross-country dataset currently quantifies marine ecological fiscal exposure on a comparable basis across archipelagic and island states. The cross-country comparison in this paper is therefore limited to governance mechanisms rather than harmonised fiscal-impact estimates.

This article proposes a governance design for Blue Natural Capital Value at Risk (BNC-VaR), linking changes in marine ecosystem conditions to fiscal-risk readings in the Indonesian state budget cycle. The proposed design is structured as a five-component institutional architecture covering ecosystem data, valuation and parameterisation, fiscal-risk analysis, budgetary implications, and fiscal sustainability. Within this architecture, the Directorate General of State Assets Management serves as a valuation custodian, responsible for maintaining methodological consistency, parameter traceability, and quality assurance across fiscal functions. The term “Value at Risk” is used as an adaptation of public fiscal-risk logic rather than as a conventional market-risk measure. Its conceptual adaptation is clarified in Section 2.5.

The research question guiding this paper is as follows: how can a governance design enable changes in marine ecosystem conditions to be traced into fiscal-exposure signals relevant to the Indonesian State Budget Financial Note process?

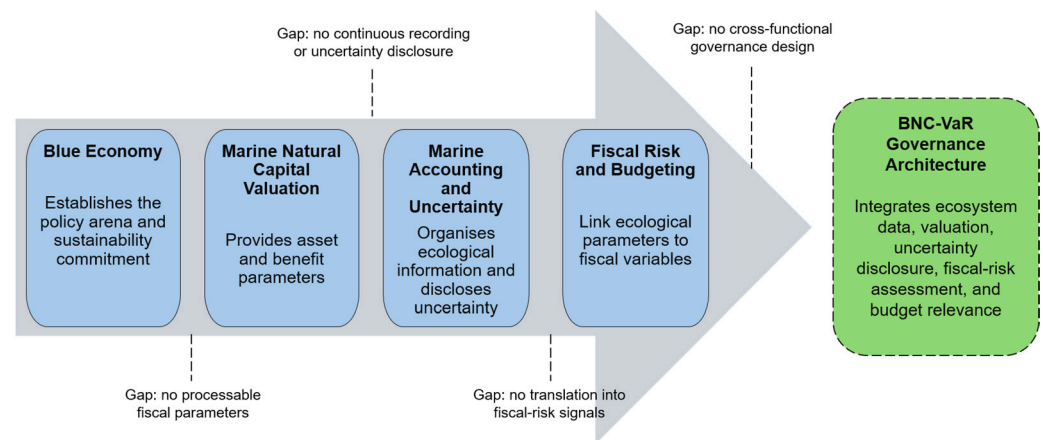
To answer this question, the study uses theory-driven corpus construction, theory synthesis, and a model-paper approach. The analysis follows six linked stages: problem identification, corpus assembly, thematic synthesis, gap-to-requirement mapping, architecture specification, and proposition formulation with internal validation. This design is appropriate because the study does not test a ready-made empirical model. It constructs an institutional architecture from the existing theoretical, accounting, valuation, and fiscal-risk literature, then specifies how the architecture can be evaluated in future empirical work.

The article contributes three elements. First, it provides a gap-mapping matrix that connects the blue economy, marine natural capital valuation, marine accounting, and fiscal-risk literature. Second, it develops five design principles and four evaluable propositions for ecological-to-fiscal translation. Third, it specifies an institutional architecture that can integrate marine ecosystem information into existing fiscal-risk and budgetary routines without creating a parallel administrative infrastructure. The central argument is that fiscal integrity under ecological uncertainty depends not on perfect ecological valuation but on traceable parameters, transparent disclosure of uncertainty, and consistent institutional handoffs from ecosystem data to fiscal risk and budget use.

## 2. Theoretical Study

This theoretical study positions marine issues as development administration challenges that require interdisciplinary synthesis. As illustrated in Figure 2, the conceptual foundation of the BNC-VaR model spans four functionally distinct literature clusters: the blue economy, marine natural capital valuation, marine accounting and uncertainty, and fiscal risk and budgeting. Rather than reviewing these fields in isolation, this section exam-

ines them along a sequential path from ecology to fiscal policy. The progression moves from establishing the policy arena to defining asset and benefit parameters, organising ecological information and uncertainty disclosure, and identifying entry points into public finance.



**Figure 2.** Logical progression of the four literature clusters towards the Blue Natural Capital-Value at Risk (BNC-VaR) governance architecture. The figure shows how each literature cluster performs a necessary function while leaving an unresolved gap that requires the next analytical step.

Each transition in Figure 2 reveals a specific functional disconnect. Broad blue-economy commitments do not, by themselves, yield usable valuation parameters. Stand-alone valuations require an accounting and reporting framework to remain traceable across decision processes. Marine-accounting outputs, in turn, require a fiscal-risk interface before they can inform budgetary and fiscal-sustainability decisions. The critical analysis in the following subsections identifies these unresolved gaps and explains why a cross-functional governance design is required.

The critical reading of these four clusters is framed by institutional theory and anticipatory governance. Institutional theory, as developed by North [21], explains how formal rules shape actors' behaviour and reduce transaction costs in public decision chains. It helps explain why ecology-to-fiscal translation requires separated institutional functions, coordination rules, and stable governance mechanisms. However, institutional stability alone does not explain how public institutions should respond to risks that are not yet recognised by existing rules, particularly gradual and cumulative ecological pressures that fall outside conventional fiscal-risk readings [21]. Anticipatory governance addresses this limitation by emphasising foresight, policy integration, actor engagement, and explicit disclosure of knowledge limits and scenario plausibility [22–24]. Together, these perspectives provide the analytical lens for reading the four clusters and deriving the design requirements in the synthesis subsection.

### 2.1. The Blue Economy as an Arena for Development Governance

A bibliometric review of the blue economy shows that this field has grown rapidly since 2017, with a primary focus on marine sustainability, coastal governance, and blue finance [25]. This growth has led to frameworks such as the sustainable ocean economy [26,27] and blue bonds [28], which aim to link marine activities with financing mechanisms. Recent international market guidance has further extended the use of these instruments. The International Capital Market Association (ICMA) Green Bond Principles provide voluntary process guidelines [29], while ICMA's Sustainable Bonds for Nature: A Practitioner's Guide and the International Finance Corporation (IFC) Guidelines for Blue Finance extend this guidance to nature-related objectives [30]. The IFC Guidelines for Blue Finance, including the updated Version 2.0, provide guidance for financing blue-economy

activities and marine-related objectives [31,32]. However, these frameworks remain largely finance-oriented. They do not explain how fiscal institutions incorporate marine ecological pressures into the state budget cycle. This blind spot matters because governments that plan, finance, or underwrite blue-economy development without monitoring ecological risks may overlook emerging fiscal burdens during budget preparation.

Because the blue economy lacks a single, universally agreed upon operational definition, effective governance requires a pragmatic approach that links the concept to existing policy frameworks and strengthens institutional coherence [33]. Sustainable blue finance also depends on legal and institutional mechanisms that connect stakeholders and align incentives [28]. More broadly, integrating interconnected sustainability issues requires horizontal and vertical coordination, political leadership, and the involvement of social actors so that blue-economy policies do not remain merely normative statements [34].

The blue-economy literature establishes the policy arena for governing marine sustainability and finance. However, it does not provide a mechanism for translating marine ecological pressures into fiscal parameters that the budget system can process. This limitation creates a need for marine natural capital valuation, which explains how ecological conditions can be translated into valuation parameters for fiscal-governance purposes.

## 2.2. *Marine Natural Capital and Valuation as a Basis for Decisions*

Consistent decision-making requires a shared understanding of what constitutes a natural resource asset and how it supports the ecosystem services it provides [35]. Building on this premise, this study conceptualises assets not as neutral biophysical entities but as the material basis of the social, economic, and ecological benefits that public policy seeks to safeguard. Integrated approaches caution against reducing valuation solely to economic efficiency, because public decisions must also consider equity and sustainability within interconnected human and natural systems [36]. Valuation in development administration is therefore not simply a calculation technique but a decision-making infrastructure that helps governments assess what is at stake when asset conditions change.

Within coastal and marine environments, public decisions cannot rely on a single economic value, because values and decision contexts vary [37]. The capacity of natural assets to sustain long-term public benefits is also shaped by governance quality [38]. Marine natural capital asset and risk registers provide a way to map relationships among asset status, associated benefits, and risks to ecosystem service provision [15]. Valuations relevant to public finance must therefore explain not only what is valuable, but also what is fiscally exposed when an asset is stressed.

The valuation literature provides the asset and benefit basis for decision-making, but it remains weak as a recurring system for fiscal parameterisation. Valuations are often point-in-time, location-specific, assumption-dependent, and disconnected from downstream fiscal users. This limitation necessitates a recording framework and explicit disclosure of uncertainty, which are addressed in the marine-accounting cluster.

## 2.3. *Marine Accounting, Uncertainty, and the Risk Register*

Ecosystem accounting supports coastal and marine governance by increasing transparency, clarifying material dependencies, and linking natural resource stocks and flows to ecosystem services and broader values [39]. The System of Environmental-Economic Accounting Ecosystem Accounting (SEEA EA) framework provides an integrated statistical basis for organising habitat data, measuring ecosystem services, and linking this information to economic activity [13]. Ocean accounting extends this logic to the marine environment by connecting data on ecosystems, the economy, and human well-being [14,40]. In practice, coupling marine spatial planning with marine accounting can strengthen

evidence-based policy decisions [14]. From a development administration perspective, this body of literature provides the state with the information capacity to transform scattered ecological data into policy-relevant information. The National Research and Innovation Agency (BRIN) plays a critical role in providing the scientific evidence base for marine ecosystem-condition indicators, ensuring that the ecological parameters used in BNC-VaR are rooted in the latest scientific standards.

Within the nature-finance domain, measurement, reporting, and verification remain central constraints in connecting natural capital to financial and fiscal decision-making [41]. General sustainability disclosure requirements have been strengthened through standards such as International Financial Reporting Standards Sustainability Disclosure Standard 1 (IFRS S1) [42], while emerging nature-related disclosure frameworks seek to improve the reporting of nature-related risks and dependencies [43]. These developments improve the discipline of disclosure, but they do not, by themselves, provide a layer-by-layer mechanism for translating marine ecosystem conditions, valuation assumptions, and uncertainty into a public fiscal-risk assessment. This limitation reinforces the need for explicit uncertainty disclosure within the BNC-VaR architecture.

A critical reading of marine-accounting practice identifies three structural limitations for fiscal governance. First, uncertainty reporting remains difficult because ocean data are spatially variable, temporally uneven, and often produced across different institutional systems [40,44]. Second, ecosystem accounts do not automatically translate their outputs into parameters that fiscal-risk units can process. Third, accounting and disclosure frameworks do not by themselves provide a fiscal-governance protocol for anticipatory risk disclosure [22,23]. Marine accounting can therefore organise ecological information and improve uncertainty disclosure, but it does not provide a complete transmission path to the fiscal-risk and budget system. This gap leads to the fiscal-risk and budgeting cluster.

#### *2.4. Fiscal Risk, Resilience, and Budget Integration*

Environmental shocks, including disasters and climate-related events, can depress growth, reduce revenues, and increase government spending on recovery and adaptation [20,45]. In developing countries, fiscal stress can arise through both physical and transition risks [46]. Adaptive risk management emphasises gradual assessment and sensitivity to high-impact, low-probability events [47,48]. However, these general frameworks have limited explanatory power for the Indonesian marine context. Most fiscal-risk assessments rely on top-down macroeconomic scenarios rather than ecosystem-specific transmission pathways. As a result, fiscal-stress-testing instruments rarely incorporate ecological parameters that are traceable to biophysical data.

Integrating environmental issues into budgeting is also ineffective if they remain treated as a stand-alone function [34,49]. Effective cross-sectoral governance depends on reliable information exchange [50], while successful risk coordination is shaped by formal rules, institutional quality, networks, and bureaucratic hierarchies [51]. Yet this literature does not yet specify a cross-functional architecture capable of connecting ecosystem data providers, valuation nodes, fiscal-risk units, and budget units into a single accountable decision chain.

The fiscal-risk literature shows that ecological stress can affect fiscal variables through exposure pathways, but it does not provide an ecosystem-specific governance design. Without a blue-economy policy arena, ecological fiscal risk lacks a development context. Without valuation, it lacks traceable parameters. Without accounting for and disclosing uncertainty, it relies on opaque assumptions. These four research clusters, therefore, define the architectural requirements synthesised in the next subsection.

### 2.5. Synthesis of Conceptual Gaps and Design Needs

The four study clusters collectively identify four interdependent gaps. These are the absence of an operational mechanism for translating ecological pressures into fiscal signals, the absence of an institutional parameterisation node linking valuation outputs to fiscal decisions, the absence of adequate uncertainty disclosure for fiscal analysis, and the absence of a cross-functional design connecting ecological data, valuation parameters, fiscal-risk units, and budget documents. Table 1 summarises how these conceptual gaps translate directly into architectural requirements and specific BNC-VaR components.

**Table 1.** From literature gaps to Blue Natural Capital Value at Risk (BNC-VaR) architectural requirement.

| Study Cluster                     | Conceptual Gap                                                                                                | Architectural Requirement                                                                         | BNC-VaR Component                                                        |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------|
| Blue Economy                      | No operational mechanism translates marine ecological pressures into fiscal signals                           | Validated ecosystem-condition data as the entry point for fiscal translation                      | Layer 1: Ecosystem Data                                                  |
| Marine Natural Capital Valuation  | No institutional parameterisation node links valuation outputs with the fiscal decision chain                 | Traceable valuation parameters and documented asset assumptions                                   | Layer 2: Valuation and Parameterisation                                  |
| Marine Accounting and Uncertainty | No adequate uncertainty disclosure framework supports fiscal analysis                                         | Explicit disclosure of data quality, valuation assumptions, sensitivity ranges, and limits of use | Cross-layer uncertainty disclosure across the ecological-to-fiscal chain |
| Fiscal Risk and Budgeting         | No mechanism translates ecological parameters into fiscal-exposure signals                                    | Fiscal exposure scenarios based on ecological parameters and valuation inputs                     | Layer 3: Fiscal-Risk Analysis                                            |
| Fiscal Risk and Budgeting         | No cross-functional design connects ecological-fiscal signals with budget units and official fiscal documents | Integration of fiscal-exposure signals into budget channels and fiscal-sustainability readings    | Layers 4A: Budget Implications, Layer 4B: Fiscal Sustainability          |

These requirements provide the foundation for the five design principles and four formal propositions developed in this article. They also clarify that BNC-VaR is not a stand-alone environmental-accounting tool but a governance architecture that links the full ecological-to-fiscal chain from ecosystem data and valuation to fiscal-risk analysis, budgetary implications, and medium-term sustainability.

This synthesis also clarifies the adaptation of the term “Value at Risk”. In the financial literature, Value at Risk is a probabilistic loss threshold or quantile-based estimate of potential loss, within a specified time horizon at a given confidence level [52]. In this article, the term is deliberately adapted for public fiscal governance while retaining its core logic: identifying exposure to potential loss. Within the BNC-VaR framework, “value” refers to the parameterised value of marine natural assets, while “at risk” refers to mediated and conditional fiscal exposure arising from changes in marine natural capital. The framework, therefore, operates as an institutional governance instrument rather than a market-based risk measure.

## 3. Methods

This research is a conceptual article that uses theory-driven corpus construction, theory synthesis, and a model-paper approach within the social sciences tradition. It does not conduct a systematic literature review, a meta-analysis, a bibliometric review, or a PRISMA-based evidence synthesis. The purpose is not to aggregate empirical findings, but

to construct a governance architecture by synthesising concepts, mechanisms, and institutional functions from previously separate domains [53–55]. This approach is appropriate because the study develops a conceptual model rather than testing causal relationships or generating primary data [56]. In public administration, theory synthesis is well-suited to problems that cut across institutional domains [57], particularly when the object of analysis spans ecology, valuation, public finance, and governance. The development of conceptual models with internal validation through logical consistency checks is also consistent with the public administration modelling tradition [58].

The analytical corpus was constructed purposively and functionally. A source was included when it defined a core construct, explained an ecological-to-fiscal mechanism, provided valuation, accounting, or uncertainty-disclosure logic, identified a fiscal-risk or budget-governance linkage, supplied an operational benchmark, or established a relevant Indonesian institutional mandate. A source was excluded if it was purely descriptive, sector-specific, lacked transferable governance or fiscal relevance, was unrelated to valuation, accounting, uncertainty disclosure, fiscal risk, or public governance, or could not support any design requirement of the proposed architecture. The final corpus comprised 42 documents: 26 peer-reviewed journal articles, 9 technical reports, normative references and international benchmarks, and 7 official Indonesian policy documents. This analytical corpus is distinct from the full reference list, which also contains foundational works and additional sources. Peer-reviewed sources were retrieved primarily from Scopus, Web of Science, and ScienceDirect, covering publications from 2016 to 2026. Older sources were retained only when they provided foundational concepts or official normative references.

Independent of the purposive corpus assembly, a structured scoping search was conducted strictly to confirm the absence of prior integrated studies and ensure architectural novelty rather than to serve as a systematic retrieval protocol. The search was run using Publish or Perish in April 2026 across the aforementioned databases and timeframe, with three Boolean combinations: “blue natural capital” AND “fiscal risk”, “marine ecosystem” AND “budget governance”, and “VaR” AND “public finance” AND “ecosystem”. This search did not mechanically determine the corpus. Its purpose was to assess whether prior studies had combined marine natural capital valuation, uncertainty disclosure, ecological-to-fiscal translation, fiscal-risk assessment, and budget-cycle relevance within a single institutional governance architecture. The search did not identify a prior study that included this specific combination, although substantial literature exists in each domain.

The BNC-VaR model follows an explicit input–process–output logic. Its inputs are marine ecosystem-condition indicators together with the relevant valuation mandate and fiscal-governance documents. Its process parameterises these inputs into traceable valuation parameters, discloses uncertainty at each step, and translates the parameters into fiscal-exposure scenarios. Its outputs are fiscal-exposure signals, budgetary-implication readings, and fiscal-sustainability readings. The operational details of this logic, including actors, outputs, recipients, and uncertainty disclosure at each layer, are presented in Section 4.1.

The model was constructed through six sequential analytical stages, as summarised in Table 2. Each stage converted a defined input into a documented output under a specific quality-control rule that preserved traceability, internal consistency, and conceptual testability.

Three synthesis instruments supported the six-stage process. The document synthesis matrix mapped each source to its analytical domain, extracted construct, and contribution to model construction. The ecological-to-fiscal chain map specified the logical pathway from changes in ecosystem conditions to valuation parameters and fiscal-exposure signals. The institutional function matrix identified the actors, outputs, and coordination mecha-

nisms associated with each architectural component. The component-level traceability to conceptual, operational, and normative bases is reported in Appendix A Table A1, and the source-level analytical corpus is reported in Appendix B Table A2.

**Table 2.** Six-stage analytical process for BNC-VaR construction.

| Stage                                                   | Input                                        | Analytical Task                                                                                           | Main Output                       | Quality-Control Rule                                                                                         |
|---------------------------------------------------------|----------------------------------------------|-----------------------------------------------------------------------------------------------------------|-----------------------------------|--------------------------------------------------------------------------------------------------------------|
| 1. Problem identification                               | Seed literature and policy context           | Identify the functional disconnect between marine natural capital valuation and fiscal-risk governance.   | Gap statement                     | The gap must be framed as a functional disconnect, not as a general topic area.                              |
| 2. Corpus assembly                                      | Domain literature and policy documents       | Select sources using functional inclusion and exclusion criteria.                                         | Purposive analytical corpus       | Each source must support at least one construct, mechanism, mandate, benchmark, or design requirement.       |
| 3. Thematic synthesis                                   | Purposive analytical corpus                  | Extract constructs, limitations, and unresolved issues across the four study clusters.                    | Per-cluster construct and gap map | Each source's contribution and limitation must be recorded in the analytical corpus matrix.                  |
| 4. Gap-to-requirement mapping                           | Per-cluster gap map                          | Convert conceptual gaps into architectural requirements.                                                  | Requirement map                   | A gap is retained only when it constrains ecological-to-fiscal translation.                                  |
| 5. Architecture specification                           | Requirement map                              | Specify components, functions, actors, outputs, and relationships in the proposed architecture.           | BNC-VaR operating architecture    | Each component must be traceable to at least two analytical bases: conceptual, operational, or normative.    |
| 6. Proposition formulation and internal validation [59] | Operating architecture and design principles | Formulate propositions and test their logical consistency against the architecture and design principles. | Formal propositions               | A proposition is retained only when it is conceptually testable or falsifiable in future empirical research. |

Reliability in this conceptual design rests on transparent inference rather than statistical replication. Beyond the explicit selection criteria and the search boundary set out above, two further safeguards governed inference. Each model component had to draw support from at least two analytical bases. Internal validation also checked the consistency between the identified gaps, architectural requirements, design principles, and formal propositions. Internal falsification was applied by examining whether existing literature or alternative institutional arrangements could challenge the proposed architecture. Where such challenges existed, they were carried into the model as explicit constraints rather than set aside.

This study has three methodological limitations. First, as a purely conceptual architecture, the model requires future empirical testing. Second, the corpus is limited to English-language and Indonesian-language sources available through the selected databases and official repositories, so relevant insights in other languages may be absent. Third, purposive source selection necessarily involves interpretive judgement, which was mitigated by documenting the corpus boundary, the exclusion logic, the synthesis instruments, the quality-control rules, and evidence of traceability. Because one author is affiliated with the Directorate General of State Assets Management, the proposed custodian role should be read as a functionally justified institutional design rather than as an assertion of institutional interest. Alternative institutional placements are considered in Section 4.2.

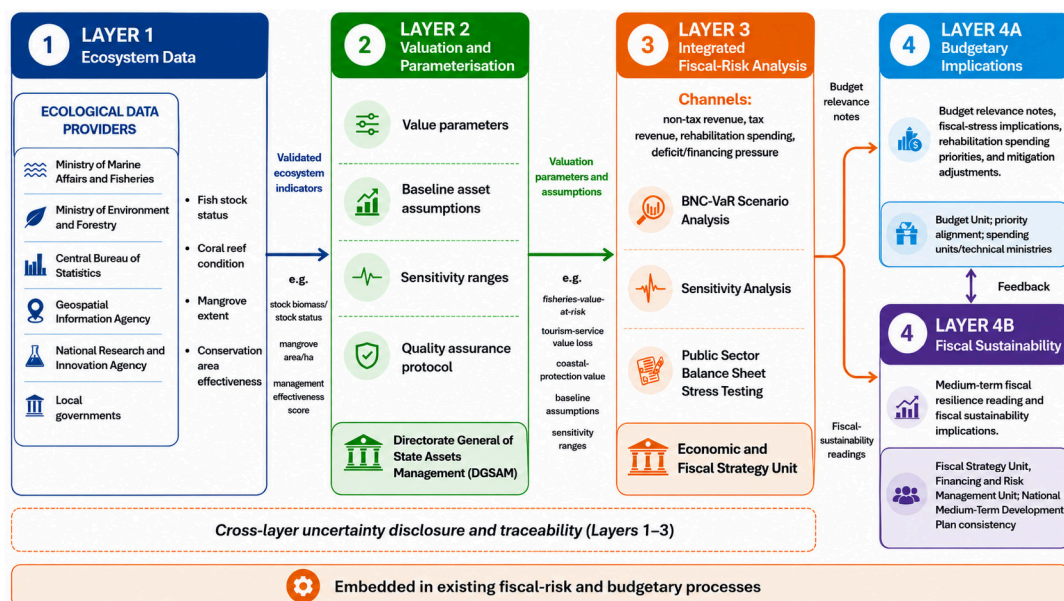
Another aspect to note is the use of AI-assisted tools in figure preparation. Figures 1 and 4 were prepared or visually refined with the assistance of ChatGPT (OpenAI, GPT-5.5). For Figure 1, the tool was used solely to assist with data visualisation and layout refinement, based on numerical data supplied by the authors from official sources. The authors verified the

underlying data, checked the plotted values, reviewed the visual output, and approved the final figure. For Figure 4, the tool was used only to assist the visual preparation of the schematic, including layout refinement, pathway arrangement, and label presentation, based on author-provided conceptual instructions derived from the manuscript's explanation of ecological-to-fiscal transmission pathways. The tool was not used to generate research data, conduct formal analysis, select references, formulate findings, or determine the model's interpretation. The authors reviewed, edited, verified, and approved the final figures, including the data labels in Figure 1 and the labels, causal logic, transmission pathways, and analytical meaning in Figure 4. To the best of the authors' knowledge, the figures do not reproduce any previously published figure, photograph, artwork, logo, third-party dataset visualisation, or copyrighted third-party material.

## 4. Results and Discussion

### 4.1. BNC-VaR Operating Architecture and Formal Propositions

The main result of this study is a BNC-VaR governance architecture that embeds marine natural capital valuation into an existing fiscal-risk and budgetary process rather than creating a parallel administrative system. As shown in Figure 3, the model operates through five functional components, namely ecosystem data, valuation and parameterisation, integrated fiscal-risk analysis, budgetary implications, and fiscal sustainability. These components are connected through institutional handovers that convert ecological information into valuation parameters, fiscal-exposure scenarios, budgetary-implication readings, and medium-term fiscal-sustainability readings.



**Figure 3.** BNC-VaR operating architecture and institutional handovers within existing fiscal-risk and budgetary processes.

Figure 3 is limited to the operating logic of the model. The operational details of each component, including actors, outputs, recipients, timing, uncertainty disclosure, and responsibility boundaries, are specified in Table 3. This separation keeps the figure uncluttered while still presenting a clear operating scheme.

**Table 3.** Core specifications of the BNC-VaR operating architecture.

| Component                                | Main Actors                                        | Output                                                                              | Recipient or Use Point                                                                             | Timing                                                                                                     | Uncertainty Disclosure                                                                     | Responsibility Boundary                                                                                                                                     |
|------------------------------------------|----------------------------------------------------|-------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Layer 1. Ecosystem Data                  | MoMAF; MoEF; BPS; BIG; BRIN; local governments     | Validated ecosystem indicators and spatial metadata                                 | DGSAM                                                                                              | Annual pre-budget consolidation; update after major ecological shocks                                      | Data quality, spatial coverage, time-series consistency, and measurement limits            | Validates ecological conditions only; does not produce valuation parameters or fiscal-risk interpretation.                                                  |
| Layer 2. Valuation and Parameterisation  | DGSAM, supported by university-based expert panels | Value parameters, asset assumptions, sensitivity ranges, and QA note                | DG-EFS; DG-Budget                                                                                  | Before the formulation of the fiscal-risk scenario in the budget preparation cycle, retained across cycles | Valuation scope, baseline assumptions, sensitivity ranges, limits of use                   | Acts as State Asset Manager and valuation custodian to set and assure valuation parameters; does not decide budget allocation.                              |
| Layer 3. Integrated Fiscal-Risk Analysis | DG-EFS, using DGSAM parameters                     | Ecological fiscal-exposure scenarios                                                | DG-Budget; DG-FRM; MoF leadership; Financial Note risk process                                     | Financial Note and medium-term fiscal outlook cycle: 3 to 5 years                                          | Causality limits, exposure channels, scenario assumptions, parameter traceability          | Interprets exposure across revenue, expenditure, deficit, financing, and sustainability channels; does not produce ecological data or valuation parameters. |
| Layer 4A. Budgetary Implications         | DG-Budget                                          | Budget-relevance notes, fiscal-stress implications, and mitigation priority options | State Budget formulation; budget units; spending units; technical ministries                       | Annual budget formulation and allocation discussion                                                        | Cost range, expenditure sensitivity, priority assumptions, scenario limits                 | Converts fiscal-risk signals into budgetary options; does not alter ecological data, valuation assumptions, or medium-term fiscal-sustainability readings.  |
| Layer 4B. Fiscal Sustainability          | DG-EFS; DG-FRM                                     | Fiscal-resilience and sustainability reading                                        | MoF leadership; medium-term fiscal framework; financing-risk process; development-plan consistency | Medium-term fiscal framework and fiscal-risk reporting cycle                                               | Structural uncertainty, macro-fiscal assumptions, financing sensitivity, medium-term risks | Assesses medium-term fiscal and financing implications; does not control data production, valuation, or annual budget allocation.                           |

Note: MoMAF = Ministry of Marine Affairs and Fisheries; MoEF = Ministry of Environment and Forestry; MoF = Ministry of Finance; BPS = Central Bureau of Statistics; BIG = Geospatial Information Agency; BRIN = National Research and Innovation Agency; DGSAM = Directorate General of State Assets Management; DG-EFS = Directorate General of Economic and Fiscal Strategy; DG-Budget = Directorate General of Budget; DG-FRM = Directorate General of Financing and Risk Management; QA = Quality Assurance.

The five components are derived from the gap-to-requirement logic developed in Table 1. Ecosystem data are required because fiscal analysis cannot begin without a validated ecological entry point. Valuation and parameterisation are required because ecological indicators do not automatically become fiscal parameters. An integrated fiscal-risk analysis is required because valuation parameters must be interpreted through the revenue, expenditure, deficit, financing, and sustainability channels. Budgetary implications and fiscal sustainability are placed at the same level, Layers 4A and 4B, because they are two downstream uses of integrated fiscal-risk analysis rather than a strict hierarchy. The two-way link between them reflects feedback between annual budget relevance and medium-term fiscal resilience. The components draw on established literature on natural capital asset classification and decision-making [35], marine accounting and risk register approaches [15,40], and the blue economy as a cross-sectoral governance paradigm [25]. The synthesis offered here combines these strands into a single ecological-to-fiscal chain designed for fiscal risk and budgetary use.

The architecture is governed by five design principles. Traceability requires each component to map to a distinct analytical function rather than to intuitive relevance. Conditional causality requires the model to treat ecological-to-fiscal links as mediated and context-dependent rather than automatic and to avoid causal claims beyond what the data support. Uncertainty disclosure requires knowledge limits and assumption sensitivity to be stated at each stage. Cross-functional coherence requires risk, budget, and sustainability readings to draw on a common set of parameters. Administrative realism requires the model to operate within existing institutional structures without major restructuring. These principles serve as evaluative standards against which each component and the model as a whole can be assessed.

Building on this architecture, the study formulates four formal propositions. They are framed as claims that future empirical research can evaluate, not as restatements of the model.

P1. In island economies experiencing material marine ecological pressures, ecological fiscal exposure remains hidden when ecological parameters, valuation nodes, and fiscal-risk transmission mechanisms are disconnected.

P2. Effective ecological-to-fiscal translation requires an institutional custodian function that is distinct from ecosystem managers and fiscal-risk users.

P3. Valid ecological-to-fiscal translation depends on explicit uncertainty disclosure across data, parameterisation, fiscal-risk analysis, and budget-use stages.

P4. Traceability, transparency, and consistency can strengthen fiscal integrity even when precise ecological-to-fiscal causal estimates remain unavailable.

Each proposition is bounded. P1 does not hold where a country already has a formal mechanism linking marine ecosystem conditions to fiscal-risk analysis in official budget documents. P2 becomes less institutionally salient where data production, valuation, and fiscal use are performed by a single entity. P3 may require adaptation where ecological data are already highly standardised. P4 is most relevant where precise ecological-to-fiscal causal quantification is not yet feasible.

Table 4 specifies observable indicators, Indonesian data sources, and verification methods for these propositions, distinguishing qualitative from quantitative approaches. The table makes the model evaluable using existing fiscal and administrative records, without requiring a new data bureaucracy.

**Table 4.** Methodological roadmap for empirical verification of BNC-VaR propositions.

| Proposition                           | Observable Indicators                                                                                                                                              | Indonesian Data Sources                                                                                                                                                                                                              | Approach                                                      | Verification Method                                                                                                                             |
|---------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| P1. Hidden ecological fiscal exposure | Marine ecological risk categories; ecosystem-condition references; linkage to revenue, expenditure, deficit, financing, or fiscal sustainability.                  | Financial Note and State Budget Bill materials, especially the fiscal-risk section; APBN documents; LKPP; sectoral reports from MoMAF, MoEF, BPS, BRIN, and BIG; BPK audit findings on marine revenue or ecosystem-related spending. | Qualitative, supported by descriptive document coding         | Code fiscal-risk documents for marine ecological references; compare fiscal disclosure with sectoral ecosystem evidence and audit findings.     |
| P2. Need for a valuation custodian    | Valuation protocol; parameter ownership; QA procedure; traceability of assumptions; role separation between data providers, valuation custodian, and fiscal users. | Government valuation regulations; DGSAM valuation assignment files and valuation reports; internal valuation technical guidelines; data handover records; inter-agency coordination minutes or technical notes.                      | Qualitative, using process tracing and institutional analysis | Trace parameter flow from ecosystem data to valuation outputs and fiscal users; assess whether the custodian function is formally identifiable. |

Table 4. *Cont.*

| Proposition                                                              | Observable Indicators                                                                                                                                                                                | Indonesian Data Sources                                                                                                                                                                                    | Approach                                    | Verification Method                                                                                                                                                 |
|--------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| P3. Cross-stage uncertainty disclosure                                   | Data-quality notes; sensitivity ranges; causality limits; scenario assumptions; limits of use; continuity of uncertainty notes across handovers.                                                     | One Data Indonesia metadata; ecosystem-data metadata from MoMAF, MoEF, BPS, BRIN and BIG; valuation workpapers; fiscal-risk scenario files; budget-preparation notes; Financial Note supporting materials. | Mixed qualitative and quantitative          | Code uncertainty disclosure; compare sensitivity ranges; test whether uncertainty information is retained from data, valuation, fiscal-risk, and budget-use stages. |
| P4. Fiscal integrity through traceability, transparency, and consistency | Audit trail; cross-cycle parameter consistency; documented methodological changes; clear decision-use boundaries; feedback between annual budget implications and medium-term fiscal sustainability. | DGSAM valuation reports and QA records; DG-EFS fiscal-risk files; DG-Budget budget-formulation notes; DG-FRM financing-risk materials; KEM-PPKF; Financial Note; LKPP; BPK audit reports.                  | Qualitative, with a possible scoring rubric | Assess traceability and fiscal-integrity criteria; compare parameter consistency across budget cycles; validate findings through expert review.                     |

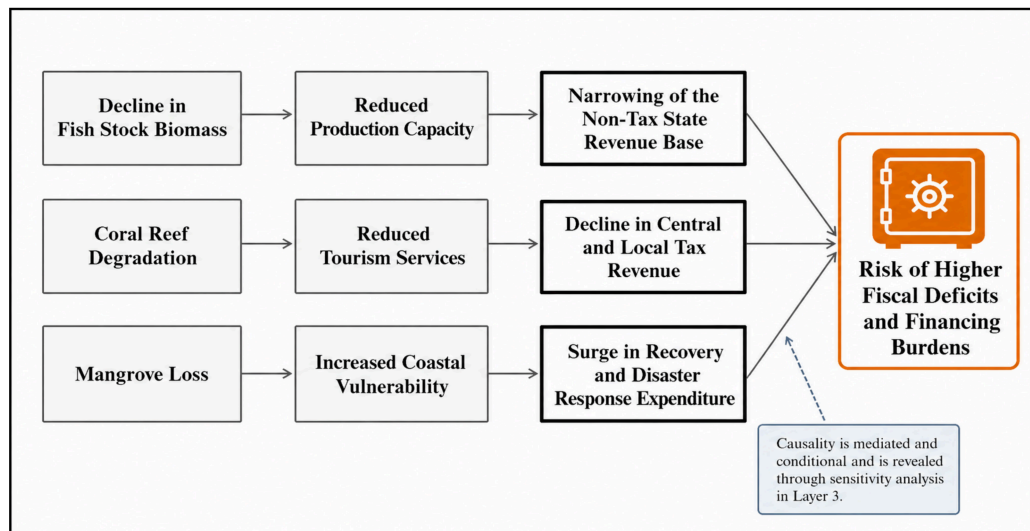
Note: APBN = State Revenue and Expenditure Budget; LKPP = Central Government Financial Report; BPK = Audit Board of Indonesia; KEM-PPKF = Macroeconomic Framework and Fiscal Policy Principles.

Future empirical research can collect the data required for Table 4 from existing fiscal documents, valuation records, ecosystem-data metadata, audit reports, and budget-preparation materials. The proposed verification strategy, therefore, evaluates whether ecological information can be traced from ecosystem indicators to valuation parameters, fiscal-exposure scenarios, budgetary implications, and fiscal-sustainability readings within Indonesia's existing fiscal and administrative records.

#### 4.2. Ecological-to-Fiscal Transmission and Institutional Interpretation

The ecological-to-fiscal transmission logic rests on a simple but consequential distinction. Marine ecosystem degradation is not, in itself, a fiscal event. It becomes fiscally relevant only when ecological change affects an administratively recognised revenue base, an expenditure obligation, a fiscal-risk category, or a financing need. The analytical problem is therefore not whether ecosystems decline but whether the effects of that decline can be recognised, valued, transmitted, and used within the fiscal decision chain. This places ecological information inside existing fiscal-risk, budgetary, and medium-term fiscal planning routines rather than outside them.

Figure 4 illustrates the transmission logic through three stylised maritime-economy pathways. Its purpose is not to assert automatic fiscal effects but to identify where ecological change must be parameterised before it can be read as fiscal exposure. In the fisheries pathway, declining fish-stock biomass becomes fiscally relevant only when measurable changes in stock status, capture volume, production value, or licensing objects narrow the Non-Tax State Revenue base. In the coral-reef pathway, degradation may affect fiscal exposure through tourism-service channels, where live coral cover, habitat quality, tourism attractiveness, and associated service-flow value mediate potential central and local tax receipts. In the mangrove pathway, ecosystem loss operates mainly through the expenditure channel, as increased coastal vulnerability may raise spending on prevention, recovery, restoration, and disaster response [3,5]. The same structure can be adapted to other maritime or environmental contexts by replacing the ecosystem indicator, valuation parameter, fiscal channel, and responsible institution while preserving the sequence of measurement, parameterisation, fiscal interpretation, and budgetary use.



**Figure 4.** Illustrative ecological-to-fiscal transmission pathways. This figure was generated with the assistance of ChatGPT (OpenAI, GPT-5.5) based on author-provided conceptual instructions and was reviewed and approved by the authors.

These pathways show that ecological fiscal exposure is mediated rather than automatic. Fiscal relevance depends not only on ecological severity but also on administrative recognition. A severe stock decline can remain fiscally invisible if it is not reflected in reported catch, licensing objects, or fiscal-risk documentation, while a moderate reef deterioration can become fiscally visible once it affects taxable tourism activity or rehabilitation needs. Figure 4 does not claim that ecological decline automatically produces a specific deficit or financing burden. It identifies where causal claims must be tested, because each pathway requires evidence linking the ecological parameter to a production or service effect, that effect to a revenue or expenditure object, and that object to a fiscal outcome, through links that may be delayed, indirect, or conditional on administrative capacity. Crucially, this mediated transmission must also account for confounding macroeconomic variables. A decline in marine non-tax revenue or tourism taxes may stem from exogenous economic shocks, such as demand contraction or price volatility, rather than purely from ecosystem degradation. The framework acknowledges this attribution problem without claiming perfect econometric causality.

To avoid a false sense of precision, BNC-VaR treats valuation outputs as decision-support boundary information rather than deterministic estimates of fiscal loss. Within Layer 3, numerical values are interpreted through sensitivity ranges, documented assumptions, and conditional causality notes to reduce the risk of conflating ecological signals with broader economic noise. The resulting “Value at Risk” therefore functions as a heuristic signal of anticipatory fiscal exposure, not as an exact accounting deficit. This design is reinforced by separating the valuation-custody function from the fiscal-interpretation function. The valuation custodian maintains parameter consistency and quality assurance, while fiscal-risk units translate these parameters into aggregate macro-fiscal exposures. This separation requires budget decision-makers to account for ecological uncertainty in fiscal-risk assessment, rather than treating valuation figures as unquestionable facts.

Institutional uncertainty is part of the transmission problem. Even where ecological and valuation evidence exist, transmission may be weakened by unclear mandates, fragmented data standards, limited data sharing, or differing evidentiary thresholds between technical and fiscal institutions. This administrative-recognition layer is not always robust in practice. Audit findings on licensing-related marine non-tax revenue administration in Indonesia indicate weaknesses in internal controls, compliance, data collection, reference-

price setting, and information-system support across fisheries resources, marine-space use, and small-island utilisation. In particular, the Audit Board noted that the Ministry's information system had not yet supported the identification of all non-tax revenue objects related to capture-fisheries resources, and that the fisheries-vessel database had not been fully synchronised with the vessel database of the Ministry of Transportation. These findings show that administrative-recognition capacity is a present constraint on translating marine resource use into accountable fiscal information [60]. Therefore, actual fiscal exposure strictly depends on whether the fiscal system has a traceable pathway for receiving, validating, interpreting, and using ecological information.

No single organisation controls the whole ecological-to-fiscal chain. Positioning Directorate General of State Assets Management (DGSAM) as the valuation custodian is consistent with its state asset management and government valuation functions. In the BNC-VaR architecture, this role does not require DGSAM to produce ecological data or determine fiscal policy. Its function is to maintain valuation-parameter consistency, document assumptions, apply quality-assurance procedures, and provide traceable parameter handovers to fiscal-risk users. For marine natural capital valuation, this custodian role should be supported by structured scientific and methodological assurance. Technical agencies and research institutions provide ecological evidence, while BRIN, universities, and independent experts support the peer review of parameter protocols, disclosure of uncertainties, and assessment of causality assumptions. This arrangement strengthens methodological credibility without turning academic actors into implementing agencies or replacing the authority of fiscal institutions. The handover points between these functions are analytically decisive because they determine whether ecological information remains isolated within sectoral boundaries or enters the state's fiscal architecture.

This reframes fiscal integrity as a property of the translation process. The relevant question is not whether ecological fiscal impacts can already be estimated with numerical precision but whether the fiscal system can demonstrate how an ecological signal was identified, translated, interpreted under uncertainty, and used. Fiscal integrity in this sense rests on three operational conditions: traceability of parameters back to ecological data, transparency about assumptions and uncertainty, and consistency of methods across budget cycles. Without these conditions, ecological information may enter policy discussion as a general concern, but it cannot function as accountable fiscal information.

#### *4.3. Comparative Position, Novelty, and Boundary Conditions*

The contribution of this study lies in the interface between existing approaches rather than in the invention of a new stand-alone concept. Blue economy, natural capital valuation, ecosystem accounting, green public financial management, fiscal stress testing, and nature-based financing instruments each address part of the problem. Their limitation is functional rather than conceptual. They do not, by themselves, connect the full chain from ecological measurement to budgetary use within a single traceable decision process. The novelty of BNC-VaR is therefore located at the governance-design level. It specifies how outputs from ecological and accounting systems can be translated into fiscal-exposure readings that are usable in existing budget and fiscal-risk processes.

This positioning is consistent with Indonesia's existing experience in natural capital accounting. The Wealth Accounting and the Valuation of Ecosystem Services (WAVES) supported strengthening of the Integrated System of Environmental-Economic Accounts (SISNERLING) shows that SEEA-based natural capital accounting can provide structured evidence on natural capital, support inter-ministerial data coordination, and inform planning and policy dialogue, including the RPJMN, Nationally Determined Contribution (NDC) strategic planning, and long-term development vision [12]. It also shows that the

Ministry of Finance had already been engaged in policy dialogue on the fiscal potential of natural resources, although that engagement had not yet produced a routine fiscal-risk transmission mechanism [12]. The remaining gap is therefore not the absence of natural capital accounting or fiscal-institutional awareness. The gap lies in the absence of a routine governance mechanism that converts ecosystem-condition change into parameterised fiscal-exposure information for budget-cycle fiscal-risk disclosure.

The comparison below uses a functional stopping point as the organising criterion. Rather than treating existing approaches as competitors, it asks what each approach produces, where its output enters public-finance decision-making, and where it stops before becoming a recurrent fiscal-risk reading within the budget cycle. Table 5 benchmarks BNC-VaR against relevant accounting, risk, public-finance, and blue-finance approaches by combining application scenarios, operational costs, departmental adaptability, fiscal-risk limitations, and the specific interface added by BNC-VaR.

**Table 5.** Comparative positioning of BNC-VaR against relevant accounting, fiscal, and blue-finance approaches.

| Approach                                                                | Application Scenario                                                                          | Relative Operational Cost                                                                                       | Departmental Adaptability                                                                                          | Limitation for Fiscal-Risk Disclosure                                                                              | BNC-VaR Positioning                                                                                         |
|-------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| System of Environmental-Economic Accounting (SEEA) Ecosystem Accounting | National accounts of ecosystem extent, condition, services, and asset value                   | High, due to statistical, spatial, biophysical, and monetary accounting requirements                            | Strong for statistical and environmental-accounting agencies, less direct for fiscal-risk units                    | Produces ecosystem accounts but does not translate ecosystem change into budget-cycle exposure                     | Uses ecosystem accounts as upstream evidence for valuation, custody, and fiscal-risk translation            |
| Ocean Accounts                                                          | Marine accounts linking ecosystems, ocean uses, economic activity, and social benefits        | High, due to ecological, spatial, socio-economic, and marine-use integration                                    | Strong for marine planning, statistics, and ocean-policy institutions, less embedded in fiscal-disclosure routines | Reports marine condition and use, but lacks a routine pathway to fiscal-risk statements                            | Converts marine-accounting outputs into parameterised fiscal-exposure readings                              |
| Marine Natural Capital Risk Register                                    | Asset-level mapping of marine risks, benefits, and dependencies                               | Moderate, requiring risk identification, validation, and periodic updating                                      | Strong for environmental and resource-management bodies, weaker for budget and fiscal-risk institutions            | Maps risks and dependencies but does not link them to revenue, expenditure, deficit, or financing analysis         | Links risk register logic to valuation parameters, uncertainty disclosure, and fiscal-use points            |
| Green public financial management                                       | Environmental integration into planning, budgeting, tagging, reporting, and oversight         | Moderate, because it builds on existing public-finance systems                                                  | Strong for finance ministries and budget institutions, adaptable across environmental issues                       | Provides budget entry points but lacks marine-specific parameters and valuation assurance                          | Adds marine-specific parameterisation and traceable ecological-to-fiscal translation within budget routines |
| Fiscal stress testing                                                   | Simulation of shocks to revenue, expenditure, deficit, debt, and financing needs              | High, due to macro-fiscal modelling, scenarios and data requirements                                            | Strong for fiscal strategy, macroeconomic, debt, and financing units; weaker for ecological data producers         | Captures aggregate shocks but lacks traceable ecosystem-condition inputs and valuation parameters                  | Provides ecologically grounded exposure parameters for fiscal-stress logic                                  |
| Value-at-Risk approaches in the blue economy                            | Financial-risk estimation from sustainability pressures for investors, portfolios, or markets | Moderate to high, depending on financial, market, and exposure data quality                                     | Strong for investors, regulators, and financial institutions; weaker for public-budget institutions                | Estimates financial exposure but lacks public-sector handover and budget-cycle mechanisms                          | Adapts risk logic to public fiscal governance rather than market portfolio management                       |
| Green and blue finance instruments                                      | Capital mobilisation or pricing linked to environmental and blue-economy commitments          | Moderate to high; depends on transaction design, verification, monitoring, reporting, and investor requirements | Strong for finance ministries, debt offices, regulators, development banks, and issuers                            | Links nature to finance or debt terms, but does not produce internal fiscal-risk readings from ecosystem condition | Provides fiscal-exposure readings that can inform but not replace financing instruments                     |

The comparison shows that BNC-VaR is not a substitute for these existing frameworks. It is a downstream governance processor. Its function is to receive ecological, accounting, risk, or valuation outputs and convert them into fiscal-exposure information that can be interpreted by fiscal-strategy, budget, and fiscal-sustainability units. This position falls between a comprehensive ecosystem accounting system and a single valuation exercise. It occupies the institutional interface between ecological evidence and fiscal decision-making.

This positioning also clarifies the relationship with nature and blue-finance instruments. As outlined above, these instruments already link environmental commitments to sovereign finance, investor confidence, market eligibility, and debt terms [17–19,29,30,32,41]. Their fiscal relevance is therefore recognised. However, they operate primarily at the financing, issuance, guidance, or transaction-design node. They do not themselves determine how a decline in fish-stock biomass, coral-reef condition, or mangrove protection should be converted into a recurrent fiscal-risk signal within a state budget process. BNC-VaR addresses a different node: the in-cycle interpretation of ecosystem condition as fiscal exposure before, or independent of, any financing transaction.

The applicable context is therefore specific. BNC-VaR is most relevant for archipelagic, coastal, or marine-resource-dependent economies that meet three conditions. First, marine degradation has material revenue or expenditure implications. Second, fiscal functions are institutionally separated across data, valuation, risk, budget, and financing units. Third, the government already has a disclosure vehicle, such as a Financial Note, a fiscal-risk statement, a medium-term fiscal framework, or a budget risk report. The ecological context is also bounded. The framework is most applicable where ecosystem change can be linked to an identifiable fiscal channel, such as fisheries revenue, tourism-related taxation, coastal-protection expenditure, rehabilitation spending, disaster-response costs, or financing pressure.

The framework has objective limitations. It depends on the quality, continuity, and spatial resolution of upstream ecosystem data. It requires a legally recognisable valuation-custodian function, because without such authority, parameter consistency across budget cycles cannot be maintained. It adds limited value in highly integrated fiscal systems where data production, valuation, risk analysis, and budget allocation are already performed within one institution. It also identifies fiscal exposure, but by itself, it does not prevent ecological degradation or finance restoration. Finally, the operational-cost comparison in Table 5 is qualitative because no published costing exists for implementing these frameworks in Indonesia on a comparable basis.

These limits do not weaken the contribution. They define its proper scope. The framework should be evaluated not as a universal replacement for existing approaches but as a boundary mechanism that connects their outputs to fiscal governance. Future empirical research can therefore examine which institutional conditions most affect the translation of ecological to fiscal outcomes: the strength of the custodian mandate, the quality of ecosystem metadata, the stability of interdepartmental handovers, the disclosure of uncertainty, and the consistency of valuation parameters across budget cycles.

#### *4.4. Implementation Roadmap and Future Empirical Agenda*

The implementation question is administrative rather than conceptual. The preceding sections have specified the operating architecture, the ecological-to-fiscal transmission logic, and the comparative position of BNC-VaR. From a practical perspective, its most immediate entry point is the preparation of the Financial Note, where it can complement existing fiscal-risk analysis by adding ecological exposure signals without replacing established fiscal mechanisms. The National Medium-Term Development Plan 2025 to 2029 prioritises the blue economy as part of economic transformation [6], while Minister of

Finance Regulation No. 99 of 2024 provides an initial regulatory basis by including marine natural resources among objects of valuation [61]. These entry points open a pathway for integrating ecological dimensions into fiscal planning, but they do not, by themselves, resolve data fragmentation, weak institutional handovers, or uncertainty disclosure.

Table 6 presents the roadmap in compact form, targeting four administrative failure points: fragmented ecosystem data, discontinuity of valuation parameters, methodological uncertainty, and the absence of a routine budget-cycle entry point. The detailed actor mapping, legal bases, governance instruments, and reference benchmarks are provided in Appendix C Table A3. This separation keeps the main text focused on implementation logic while preserving the operational detail needed for administrative feasibility assessment.

**Table 6.** Compact implementation roadmap for BNC-VaR in Indonesia.

| Phase                                                | Administrative Constraint                                                                                                                                                                    | Targeted Governance Action                                                                                                                                                                                                | Operational Output                                                                                                                              |
|------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| Phase 1. Data governance alignment                   | Marine ecosystem data remain fragmented across technical, statistical, geospatial, and local-government institutions, with inconsistent metadata, spatial resolution, and temporal frequency | Align existing ecosystem data flows within the One Data Indonesia framework [62] without creating a new repository; define minimum metadata requirements for spatial coverage, temporal consistency, and confidence level | Standardised marine ecosystem-condition indicators and metadata protocol for valuation use                                                      |
| Phase 2. Custodian and parameter protocol            | No institutional function maintains consistency in valuation parameters, version control, and quality assurance across budget cycles                                                         | Formalise a valuation-custodian function within the government-valuation framework; establish a version-controlled parameter register and a documented handover protocol for fiscal-risk users                            | Marine valuation parameter register, quality-assurance record, and parameter handover protocol                                                  |
| Phase 3. Controlled pilot and uncertainty disclosure | Ecological-to-fiscal translation remains methodologically uncertain and lacks a standard disclosure protocol                                                                                 | Conduct a controlled pilot in one marine sector or ecosystem; apply layer-specific uncertainty disclosure covering data quality, sensitivity ranges, causality limits, and scenario assumptions                           | Pilot BNC-VaR report, uncertainty-disclosure protocol, and reviewed fiscal-exposure scenario                                                    |
| Phase 4. Budget-cycle integration and scaling        | Marine ecological fiscal exposure is not yet routinely integrated into fiscal-risk disclosure, medium-term fiscal planning, or budget relevance review                                       | Embed pilot outputs into existing fiscal documents and routines, including the Fiscal-Risk Statement, medium-term fiscal framework, and budget-relevance review; expand gradually based on pilot evidence                 | Ecological fiscal-exposure note or annex, medium-term ecological-risk scenario, and periodic traceability, transparency, and consistency review |

Note: The detailed actor mapping, legal bases, governance instruments, and operational outputs underlying this compact roadmap are provided in Appendix C Table A3. The roadmap connects existing data, valuation, fiscal-risk, budget, financing, and accountability functions and does not establish a parallel administrative infrastructure.

The sequencing in Table 6 is deliberately incremental. Fiscal use should not precede minimum data compatibility, and budget-cycle integration should not precede parameter ownership, uncertainty disclosure, and pilot testing. Bypassing these stages risks creating a false sense of fiscal relevance, allowing ecological information to enter policy documents without the traceability, comparability, and uncertainty controls required for accountable fiscal-risk disclosure.

This staged pathway is necessary because the main implementation risk is not technical complexity alone. It is the possibility that ecological information will move through institutions without stable metadata, accountable parameter ownership, or clear decision-use boundaries. Siloed data between ministries can constrain the information exchange required for integrated fiscal analysis [51]. Early implementation should therefore prioritise three safeguards before any fiscal-risk disclosure is made: common metadata standards, a documented parameter register, and an assurance forum, supported by BRIN's scientific leadership and university-based independent peer review, that reviews traceability, uncertainty, and cross-cycle consistency.

Domestic experience reinforces this caution. The WAVES programme in Indonesia demonstrated the importance of inter-agency coordination, reliable data, and regulatory support for natural capital accounting [12]. Its lesson for this framework is not that ecosys-

tem accounting is insufficient but that accounting outputs do not automatically become fiscal-risk inputs. A translation mechanism is still required to determine which ecological indicators matter for fiscal exposure, how valuation parameters are controlled, and how uncertainty is disclosed before the information is incorporated into fiscal documents.

The future empirical agenda follows directly from the four implementation safeguards embedded in the roadmap. To reduce the risk of empirical overextension, future studies should begin with strict analytical bounding rather than attempting a nationwide assessment of all marine ecosystems and fiscal channels simultaneously. Initial testing should focus on one administratively identifiable ecosystem–fiscal linkage, such as capture-fisheries licensing and non-tax revenue in a selected fisheries management area, reef-based tourism and local tax exposure in a defined marine tourism destination, or mangrove loss and rehabilitation spending in a specific coastal district. Within such bounded settings, research can systematically test the four safeguards. First, it can examine whether stronger ecosystem metadata improves parameter reliability, thereby addressing the data-fragmentation problem in Phase 1. Second, it can assess whether a version-controlled custodian register improves cross-cycle comparability, which corresponds to the parameter-continuity safeguard in Phase 2. Third, it can evaluate whether uncertainty-disclosure protocols are retained during institutional handovers, directly testing the methodological safeguard introduced in Phase 3. Fourth, it can examine whether ecological fiscal-exposure notes improve the quality of fiscal-risk disclosure, which tests the budget-cycle integration objective in Phase 4. Because these questions are expressed in terms of institutional functions rather than country-specific agencies, they can later be examined comparatively across other archipelagic, coastal, or resource-dependent economies. Improvements in ecosystem-data quality, marine spatial planning, and marine accounting could then support a semi-quantitative version of the framework without altering its core role as an institutional governance design [14,63].

## 5. Conclusions

This article has addressed a persistent disconnect in public administration. Marine ecological degradation is increasingly recognised as an economic and fiscal concern, yet it rarely enters the state budget cycle as a recurring, parameterised fiscal-risk signal. To address this gap, the study developed the BNC-VaR architecture. Rather than adding a parallel environmental-accounting system, BNC-VaR is designed as an institutional boundary mechanism that translates validated ecosystem data into traceable valuation parameters, discloses uncertainty at each stage, and channels the result into existing fiscal-risk, budgetary, and fiscal-sustainability routines. Its central claim is conceptual. Fiscal integrity under ecological uncertainty depends less on perfect ecological valuation than on traceable parameters, transparent disclosure of uncertainty, and consistent institutional handovers.

The framework's value in archipelagic and coastal states rests on administrative realism as much as on technical precision. The Indonesian analysis indicates that credible ecological-to-fiscal translation requires clear institutional handovers, a formal valuation custodian, and disciplined disclosure of uncertainty. Without these safeguards, implementation could create a false sense of fiscal relevance, allowing ecological data to enter policy documents without the accountability controls that sound public financial management requires. The framework, therefore, identifies fiscal exposure and the institutional conditions for its recognition. It does not, by itself, produce precise ecosystem valuations, halt degradation, or predict specific fiscal outcomes.

These considerations are especially relevant for the Global South. Many developing coastal and archipelagic economies combine a high structural reliance on marine natural capital for revenue and livelihoods with limited fiscal space to absorb ecological and climate

shocks. In such economies, unmonitored marine degradation can represent not only an environmental loss but also a latent, largely unrecorded fiscal exposure. By making the translation of ecological stress into fiscal exposure explicit and traceable, BNC-VaR offers an institutional basis for bringing ecological risk into medium-term fiscal planning earlier than current routines allow. Because the architecture is defined by institutional functions rather than by country-specific bodies, other governments can map the same sequence onto their own data, valuation, fiscal risk, and budget institutions.

As a conceptual contribution, the framework is offered as a testable foundation rather than a finished instrument. Its four propositions and five design principles are intended for empirical evaluation in future work, drawing on existing fiscal documents, valuation records, and audit findings. Subject to that evaluation, integrating marine natural capital into fiscal governance is less an environmental accounting exercise than a means of strengthening valuation assurance, fiscal integrity, and public accountability amid accelerating ecological change.

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**Conflicts of Interest:** One of the authors (F.K.) is affiliated with the Directorate General of State Assets Management, Ministry of Finance of the Republic of Indonesia, which is functionally positioned as the institutional custodian in the proposed BNC-VaR governance framework. The authors declare that this positioning is based solely on functional and regulatory justification as elaborated in the paper and does not represent an assertion of institutional interest. The remaining authors declare no conflicts of interest.

## Abbreviations

The following abbreviations are used in this manuscript:

|            |                                                                                  |
|------------|----------------------------------------------------------------------------------|
| APBN       | State Revenue and Expenditure Budget                                             |
| Bappenas   | Ministry of National Development Planning                                        |
| BNC-VaR    | Blue Natural Capital Value at Risk                                               |
| BIG        | Geospatial Information Agency                                                    |
| BPK        | Audit Board of Indonesia                                                         |
| BPS        | Central Bureau of Statistics                                                     |
| BRIN       | National Research and Innovation Agency                                          |
| DG-Budget  | Directorate General of Budget                                                    |
| DG-EFS     | Directorate General of Economic and Fiscal Strategy                              |
| DG-FRM     | Directorate General of Financing and Risk Management                             |
| DGSAM      | Directorate General of State Assets Management                                   |
| ICMA       | International Capital Market Association                                         |
| IFRS S1    | International Financial Reporting Standards Sustainability Disclosure Standard 1 |
| IFC        | International Finance Corporation                                                |
| KEM-PPKF   | Macroeconomic Framework and Fiscal Policy Principles                             |
| LKPP       | Central Government Financial Report                                              |
| MoEF       | Ministry of Environment and Forestry                                             |
| MoF        | Ministry of Finance                                                              |
| MoMAF      | Ministry of Marine Affairs and Fisheries                                         |
| NDC        | Nationally Determined Contribution                                               |
| QA         | Quality Assurance                                                                |
| RPJMN      | National Medium-Term Development Plan                                            |
| SEEA       | System of Environmental-Economic Accounting                                      |
| SISNERLING | Integrated System of Environmental-Economic Accounts                             |
| WAVES      | Wealth Accounting and the Valuation of Ecosystem Services                        |

## Appendix A

**Table A1.** Detailed traceability matrix for developing the main components of the BNC-VaR architecture.

| Component                                                 | Analytical Question                                                                                                                                   | Synthesis Trace and Analytical Basis                                                                                           | Key References                                                                                                                                                                                                                                 | Role in the Model                                                                                                                                                                                                            |
|-----------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Ecosystem data as the entry point                         | What biophysical conditions of marine ecosystems are relevant as initial signals of fiscal exposure?                                                  | Derived from the blue-economy cluster, marine accounting, and the normative framework of sustainable development.              | United Nations [1]; Sambodo [3]; Ocktaviani et al. [4]; United Nations [13]; Gacutan et al. [14]; Rees et al. [15]; Martínez-Vázquez et al. [25]; Bennett et al. [26]; Bennett et al. [27]; Chen et al. [39]; Cummins et al. [40].             | Serves as the entry point for the ecological-to-fiscal translation chain. This component ensures that the model starts from ecosystem conditions that can be documented and are relevant to public decision-making.          |
| Valuation parameterisation by the institutional custodian | How can ecosystem conditions be translated into value parameters and baseline assumptions that fiscal functions can use across institutional domains? | Derived from the marine natural resource valuation cluster, ecosystem accounting, and the institutional mandate for valuation. | Castañeda et al. [12]; United Nations [13]; Rees et al. [15]; Leach et al. [35]; Costanza [36]; De Valck et al. [37]; Barbier & Burgess [38]; Ministry of Finance [61]; Trueb et al. [63]; Ministry of Finance [64]; Ministry of Finance [65]. | Provides the basis for value parameterisation, baseline assumptions, and valuation quality assurance. This component positions DGSAM as the institutional custodian of valuation parameter consistency across budget cycles. |

Table A1. *Cont.*

| Component                                              | Analytical Question                                                                                                                                    | Synthesis Trace and Analytical Basis                                                                                                                | Key References                                                                                                                                                                                                                                                                | Role in the Model                                                                                                                                                                                                    |
|--------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Explicit uncertainty disclosure                        | What are the knowledge limits, assumption sensitivities, and data limitations at each stage of ecological-to-fiscal translation?                       | Derived from the marine accounting and uncertainty cluster and reinforced by the anticipatory governance perspective.                               | United Nations [13]; Urueña [22]; Kallo & Välimaa [23]; Cummins et al. [40]; Navarro et al. [44]; International Monetary Fund [66].                                                                                                                                           | Functions as a cross-layer control mechanism, especially in Layers 1, 2, and 3. This component protects epistemological integrity by preventing BNC-VaR from being claimed as an overly certain predictive model.    |
| Fiscal exposure signals based on ecological parameters | How can changes in marine ecosystem conditions be translated into exposure signals relating to revenue, expenditure, financing, or fiscal liabilities? | Derived from the fiscal risk, climate risk, adaptive risk management, and Value at Risk adaptation clusters.                                        | Government of the Republic of Indonesia [2]; Aydin et al. [16]; Cabezon et al. [20]; Uribe & Chuliá [45]; D'Orazio [46]; Hochrainer-Stigler et al. [47]; Hochrainer-Stigler et al. [48]; International Monetary Fund [66]; Kennedy et al. [67].                               | Produces fiscal-exposure signals that fiscal-risk units can process. This component provides the main bridge from ecological parameters to fiscal variables within the State Budget framework.                       |
| Integration into budgeting and fiscal sustainability   | How can ecological fiscal-exposure signals be incorporated into the budget cycle, the Financial Note, and medium-term fiscal-sustainability readings?  | Derived from the fiscal risk and budgeting cluster, Green PFM, development administration, cross-actor governance, and national development policy. | Government of the Republic of Indonesia [2]; Sambodo [3]; Government of the Republic of Indonesia [6]; Aydin et al. [16]; Voyer et al. [33]; Breuer et al. [34]; Elliott et al. [49]; Reyes-Gonzalez et al. [50]; Hammerschmid et al. [51]; International Monetary Fund [66]. | Serves as the model's exit point towards official fiscal documents and budgetary decision-making. This component connects BNC-VaR with fiscal integrity, institutional coordination, and development sustainability. |

Note: This matrix explains the traceability basis of each main component of the BNC-VaR architecture in relation to its underlying analytical question, supporting synthesis trace, key references used in the manuscript, and specific role in model development. The use of this matrix follows the principles of conceptual article writing, which require each model element to be used validly and traceably in order to build new knowledge [42].

## Appendix B

Table A2. Analytical corpus matrix of the study.

| No. | Document Category             | Source              | Analytical Domain | Contribution to the Model                                                                                                                                                                                    | Supported BNC-VaR Layer |
|-----|-------------------------------|---------------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| 1   | Peer-reviewed journal article | Gacutan et al. [14] | A, C              | Connects marine spatial planning with ocean accounting. This document shows that marine spatial data and Ocean Accounts can support cross-sectoral decision-making.                                          | 1, 2                    |
| 2   | Peer-reviewed journal article | Rees et al. [15]    | B, C              | Offers the concept of a marine natural capital asset and risk register. This document connects marine assets, ecosystem services, asset conditions, and risks of benefit loss.                               | 1, 2, 3                 |
| 3   | Peer-reviewed journal article | Cabezón et al. [20] | D                 | Shows that natural disasters and climate change can depress growth and fiscal positions in island states. This document supports the need for an anticipatory fiscal-risk framework for archipelagic states. | 3, 4B                   |

Table A2. Cont.

| No. | Document Category             | Source                       | Analytical Domain | Contribution to the Model                                                                                                                                                                                                      | Supported BNC-VaR Layer |
|-----|-------------------------------|------------------------------|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| 4   | Peer-reviewed journal article | Urueña [22]                  | E                 | Provides a theoretical basis for anticipatory governance, plausibility, and the management of future uncertainty. BNC-VaR uses this document to avoid excessive predictive claims and to emphasise accountable risk readings.  | 3, 4B                   |
| 5   | Peer-reviewed journal article | Kallo & Välimaa [23]         | E                 | Explains anticipatory governance through visions, roadmaps, and anticipatory practices in government. This document strengthens the position of BNC-VaR as an anticipatory governance instrument.                              | 3, 4A, 4B               |
| 6   | Peer-reviewed journal article | Martínez-Vázquez et al. [25] | A                 | Maps the development of blue-economy research and its relationship with sustainability, governance, and the circular economy. This document provides academic legitimacy for selecting the blue economy as the BNC-VaR domain. | 1, 4B                   |
| 7   | Peer-reviewed journal article | Bennett et al. [26]          | A, E              | Affirms that the blue economy must protect ecological sustainability and social justice. This document provides the basis for arguing that marine economic growth without ecosystem protection can generate development risks. | 1, 4B                   |
| 8   | Peer-reviewed journal article | Bennett et al. [27]          | A, E              | Strengthens the social and justice dimensions of the blue economy. This document helps BNC-VaR interpret ecological impacts not only as fiscal issues but also as issues concerning the distribution of benefits and risks.    | 4A, 4B                  |
| 9   | Peer-reviewed journal article | Shiiba et al. [28]           | A, D              | Explains blue finance as a financing mechanism for marine conservation and development. This document strengthens the relationship between ecological pressures, financing needs, and responsive fiscal design.                | 4A, 4B                  |
| 10  | Peer-reviewed journal article | Voyer et al. [33]            | A, E              | Explains policy coherence and coordination in blue-economy development. This document supports the need for a connecting node in BNC-VaR implementation.                                                                       | 2, 4A                   |
| 11  | Peer-reviewed journal article | Breuer et al. [34]           | E                 | Explains the importance of integrated institutional design in implementing the sustainable development agenda. BNC-VaR adapts this logic to connect ecological data, valuation, fiscal risk, and budgeting.                    | 2, 3, 4A                |
| 12  | Peer-reviewed journal article | Leach et al. [35]            | B                 | Provides a classification framework for natural capital assets to support public and private decision-making. This document is important for identifying stocks, benefit flows, and risks in the valuation layer.              | 1, 2                    |
| 13  | Peer-reviewed journal article | Costanza [36]                | B                 | Provides the conceptual basis that natural capital valuation should be linked to efficiency, justice, and sustainability. This document supports the logic of value parameterisation in BNC-VaR.                               | 2, 4B                   |

Table A2. Cont.

| No. | Document Category             | Source                         | Analytical Domain | Contribution to the Model                                                                                                                                                                                                               | Supported BNC-VaR Layer |
|-----|-------------------------------|--------------------------------|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| 14  | Peer-reviewed journal article | De Valck et al. [37]           | B, C              | Offers a framework for extending ecosystem accounting to complex coastal contexts. This document helps incorporate market, non-market, and social values into marine natural capital parameterisation.                                  | 2                       |
| 15  | Peer-reviewed journal article | Barbier & Burgess [38]         | B, E              | Explains the relationship between natural capital, institutional quality, and SDG achievement. This document strengthens the argument that natural capital management requires strong institutional capacity.                           | 2, 4B                   |
| 16  | Peer-reviewed journal article | Chen et al. [39]               | C, E              | Explains the potential of ecosystem accounting to support coastal and marine governance. This document strengthens the link between ecosystem accounts, transparency, and decision-making.                                              | 1, 2                    |
| 17  | Peer-reviewed journal article | Cummins et al. [40]            | C                 | Provides global lessons on ocean ecosystem accounts, data quality, documentation, and reporting limitations. This document strengthens the need for methodological transparency in the data and valuation layers.                       | 1, 2                    |
| 18  | Peer-reviewed journal article | Navarro et al. [44]            | C                 | Affirms the importance of uncertainty disclosure in Ocean Accounts. This document supports the BNC-VaR principle of disclosing data quality, sensitivity ranges, and fiscal inference limits.                                           | 1, 2, 3                 |
| 19  | Peer-reviewed journal article | Uribe & Chuliá [45]            | D                 | Shows the relationship between fiscal crisis risk, climate vulnerability, climate readiness, and governance quality. This document supports the argument that institutional quality shapes fiscal resilience to ecological risks.       | 3, 4B                   |
| 20  | Peer-reviewed journal article | D'Orazio [46]                  | D                 | Explains the relationship between climate risk, fiscal policy, and the need to strengthen fiscal capacity in developing countries. This document supports the position of BNC-VaR as an instrument for reading ecological fiscal risk.  | 3, 4A, 4B               |
| 21  | Peer-reviewed journal article | Hochrainer-Stigler et al. [47] | D                 | Offers adaptive risk management, risk thresholds, and risk layering approaches for governments. BNC-VaR adapts these ideas to assess when ecological risks require mitigation or fiscal financing.                                      | 3, 4A                   |
| 22  | Peer-reviewed journal article | Hochrainer-Stigler et al. [48] | D                 | Explains fiscal resilience in a multi-risk context and changes in government financing capacity. This document strengthens the design of the fiscal risk and fiscal-sustainability layers.                                              | 3, 4B                   |
| 23  | Peer-reviewed journal article | Elliott et al. [49]            | E                 | Provides a development administration basis for understanding the role of the state in development transformation. This document positions BNC-VaR as a development governance design rather than merely a technical fiscal instrument. | 4B                      |

Table A2. Cont.

| No. | Document Category                                                              | Source                           | Analytical Domain | Contribution to the Model                                                                                                                                                                                                        | Supported BNC-VaR Layer |
|-----|--------------------------------------------------------------------------------|----------------------------------|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| 24  | Peer-reviewed journal article                                                  | Reyes-Gonzalez et al. [50]       | E                 | Explains the influence of information and actor motivation in governance networks. This document is relevant for designing information exchange mechanisms among actors in the ecological-to-fiscal chain.                       | 2, 3, 4A                |
| 25  | Peer-reviewed journal article                                                  | Hammerschmid et al. [51]         | E                 | Explains that public administration collaboration still requires the formal authority of the state. BNC-VaR uses this argument to design cross-functional coordination that remains based on institutional mandates.             | 2, 3, 4A                |
| 26  | Peer-reviewed journal article                                                  | Trueb et al. [63]                | C, E              | Explains institutional modalities for initiating ocean accounting, including government-led and externally led modes. This document is important for the design of the institutional custodian in BNC-VaR.                       | 1, 2                    |
| 27  | Technical report, normative reference, and international benchmarking document | United Nations [1]               | A, E              | Provides the normative basis for sustainable development, including SDG 14. This document gives normative legitimacy to the claim that marine governance must connect with development agendas and state governance.             | 1, 4B                   |
| 28  | Technical report, normative reference, and international benchmarking document | World Bank [5]                   | A, E              | Provides the context of Indonesia's blue-economy reform from an international institutional perspective. This document strengthens the need for governance reform in marine affairs, fisheries, tourism, and coastal ecosystems. | 1, 4A                   |
| 29  | Technical report, normative reference, and international benchmarking document | Castañeda et al. [12]            | B, C              | Explains the relationship between natural capital accounts and policy in Indonesia. This document shows that natural capital accounting can become an input for national policy, not merely a statistical exercise.              | 1, 2, 4A                |
| 30  | Technical report, normative reference, and international benchmarking document | United Nations [13]              | B, C              | Provides an ecosystem accounting framework for connecting ecosystem conditions with their values and benefits. BNC-VaR adapts it as the basis for organising data, accounts, and valuation parameters.                           | 1, 2                    |
| 31  | Technical report, normative reference, and international benchmarking document | Aydin et al. [16]                | D                 | Provides a Green PFM framework for making public financial management more climate-sensitive. BNC-VaR adopts this principle to incorporate marine ecological exposure into the fiscal cycle.                                     | 3, 4A                   |
| 32  | Technical report, normative reference, and international benchmarking document | International Monetary Fund [66] | D                 | Provides principles for identifying, analysing, disclosing, and managing fiscal risks. This document forms the basis for positioning BNC-VaR within the official fiscal-risk framework.                                          | 3, 4A, 4B               |
| 33  | Technical report, normative reference, and international benchmarking document | Kennedy et al. [67]              | A, D              | Provides a Value at Risk approach in the blue economy through system modelling and financial-risk analysis. BNC-VaR adapts this approach towards public fiscal exposure.                                                         | 3, 4A                   |

Table A2. Cont.

| No. | Document Category                                                              | Source                                      | Analytical Domain | Contribution to the Model                                                                                                                                                                                                                             | Supported BNC-VaR Layer |
|-----|--------------------------------------------------------------------------------|---------------------------------------------|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------|
| 34  | Technical report, normative reference, and international benchmarking document | Natural Capital Committee [68]              | B, E              | Provides a benchmark for natural capital reporting and the use of natural capital in public policy. This document strengthens the need for regular and traceable natural asset reporting.                                                             | 2, 4B                   |
| 35  | Technical report, normative reference, and international benchmarking document | The Treasury [69]                           | E                 | Provides a benchmark for a well-being framework that connects natural capital with state decision-making. BNC-VaR adapts this cross-capital logic to read the relationship between ecosystems, fiscal policy, and well-being.                         | 4A, 4B                  |
| 36  | Official Indonesian policy document                                            | Government of the Republic of Indonesia [2] | D                 | Provides the official entry point for fiscal-risk disclosure in the State Budget. BNC-VaR uses this document as the conceptual location for incorporating marine ecological risks into fiscal readings.                                               | 3, 4A, 4B               |
| 37  | Official Indonesian policy document                                            | Sambodo [3]                                 | A, E              | Provides the direction of Indonesia's blue-economy development, including priority sectors, ecological challenges, and cross-sectoral agendas. This document serves as the national contextual anchor for BNC-VaR design.                             | 1, 4A, 4B               |
| 38  | Official Indonesian policy document                                            | Ocktaviani et al. [4]                       | A, B              | Provides the sectoral context for marine management, conservation, marine spatial planning, marine services, and the blue economy. This document supports the identification of ecosystem and sectoral indicators relevant to BNC-VaR.                | 1, 4A                   |
| 39  | Official Indonesian policy document                                            | Government of the Republic of Indonesia [6] | A, D, E           | Provides the national development planning framework that directs development priorities, ecological resilience, and economic transformation. This document positions BNC-VaR as a supporting instrument for national development governance.         | 4A, 4B                  |
| 40  | Official Indonesian policy document                                            | Ministry of Finance [61]                    | B, E              | Provides the specific legal mandate for the valuation of marine natural resources by Government Valuers, directly justifying the positioning of DGSAM as the institutional valuation custodian in the framework.                                      | 2                       |
| 41  | Official Indonesian policy document                                            | Ministry of Finance [64]                    | B, E              | Provides the mandate basis for valuation by Government Valuers within DGSAM. This document strengthens the positioning of DGSAM as a valuation node and custodian of parameter consistency.                                                           | 2                       |
| 42  | Official Indonesian policy document                                            | Ministry of Finance [65]                    | D, E              | Provides the strategic direction of the Ministry of Finance for 2025 to 2029 and its links with economic transformation, governance, and the blue economy. This document strengthens the legitimacy of BNC-VaR within the Ministry of Finance agenda. | 3, 4A, 4B               |

Note: This matrix documents all 42 selected documents that form the analytical corpus of this study. The Analytical Domain column uses the following codes: A = blue economy, B = marine natural resource valuation, C = marine accounting and uncertainty, D = fiscal risk and budgeting, and E = cross-cluster or substantive methodological domain. Codes A to D represent the four substantive study clusters analysed in the third stage of the research. Code E is not positioned as a fifth substantive cluster but as an integrative lens that helps explain relationships among actors, functions, and institutional levels from a development administration perspective. The Supported BNC-VaR Layer column uses the following codes: 1 = ecosystem data, 2 = valuation and parameterisation, 3 = fiscal-risk analysis, 4A = budget implications, and 4B = fiscal sustainability.

## Appendix C

**Table A3.** Implementation assurance and transferability matrix for the BNC-VaR roadmap.

| Phase in Table 6                                     | Added Function of Appendix Table A3                                                | Indonesian Role Boundary and Instrument Anchor                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | Decision Gate Before Fiscal Use                                                                                                                                                                                                                                                                 | Transferability Rule                                                                                                                                                                                                                                                                                      |
|------------------------------------------------------|------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phase 1. Data governance alignment                   | Converts data alignment into metadata and validation gate                          | MoMAF, MoEF, BPS, BIG, BRIN, and local governments remain ecosystem-data producers or validators. DGSAM receives only a validated baseline parameter inventory for valuation use. One Data Indonesia provides the domestic data governance anchor [62], while SEEA Ecosystem Accounting and Ocean Accounts may serve as metadata references [13,14].                                                                                                                                                                                                                                                                                                             | No ecosystem indicator should enter valuation or fiscal interpretation unless its source institution, metadata, spatial coverage, temporal reference, and confidence level are documented.                                                                                                      | Other countries may substitute equivalent marine, statistical, geospatial, scientific, and subnational institutions. The transferable requirement is validated ecosystem indicators with minimum metadata standards.                                                                                      |
| Phase 2. Custodian and parameter protocol            | Converts the custodian role into a version-control and quality-assurance mechanism | DGSAM acts as a valuation custodian within the government valuation framework. Technical agencies remain data providers or validators, while DG-EFS receives valuation parameters for fiscal-risk scenario construction. The instrument anchors are Minister of Finance Regulation No. 99 of 2024 [61], internal valuation procedures, and relevant valuation standards.                                                                                                                                                                                                                                                                                         | No fiscal-risk scenario should be prepared unless the parameter version, baseline assumptions, sensitivity range, appraisal record, quality-assurance note, and handover log are documented.                                                                                                    | Other countries may assign the custodian role to a public valuation office, treasury valuation unit, natural capital accounting authority, or finance ministry unit. The transferable requirement is accountable parameter custody and cross-cycle version control.                                       |
| Phase 3. Controlled pilot and uncertainty disclosure | Converts piloting into an uncertainty-assurance mechanism                          | DGSAM undertakes parameterisation and valuation assurance. DG-EFS prepares fiscal-risk scenarios. DG-Budget reviews budget relevance. BRIN supports scientific validation, while universities and independent experts provide methodological peer review and external assurance of traceability, uncertainty disclosure, causality limits, and scenario assumptions. Disclosure references such as International Financial Reporting Standards Sustainability Disclosure Standard 1 (IFRS S1) and Taskforce on Nature-related Financial Disclosures (TNFD) may be used only by analogy because they were not designed as public fiscal-risk instruments [42,43]. | Pilot outputs should not enter fiscal-risk disclosure unless an assurance forum, involving BRIN, universities, and independent experts where relevant, has reviewed traceability, data uncertainty, valuation sensitivity, causality limits, scenario assumptions, and cross-cycle consistency. | Other countries may pilot the framework in the marine sector most relevant to their fiscal exposure, such as fisheries, coral reefs, mangroves, coastal tourism, or small-island infrastructure. The transferable requirement is controlled piloting with explicit uncertainty disclosure before scaling. |

Table A3. Cont.

| Phase in Table 6                              | Added Function of Appendix Table A3                                                          | Indonesian Role Boundary and Instrument Anchor                                                                                                                                                                                                                                                                                                                                                                                              | Decision Gate Before Fiscal Use                                                                                                                                                                                                                 | Transferability Rule                                                                                                                                                                                                                                                                                                     |
|-----------------------------------------------|----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Phase 4. Budget-cycle integration and scaling | Converts scaling into integration with existing fiscal documents and accountability routines | DG-EFS leads fiscal-risk integration. DG-Budget assesses budget relevance. DG-FRM assesses financing and medium-term fiscal-resilience implications. DGSAM maintains parameter continuity. BPK remains an external auditor and accountability institution, not an implementation unit. The instrument anchors are the Financial Note, the fiscal-risk disclosure process, the medium-term fiscal framework, and the financing-risk process. | Scaling should occur only after the pilot has produced an audit-ready documentation trail, a reviewed fiscal-exposure note or annex, a medium-term ecological-risk scenario, and a periodic traceability, transparency, and consistency review. | Other countries may embed the framework into their own fiscal-risk statement, budget-risk report, medium-term fiscal framework, sovereign-risk process, or public-sector balance-sheet review. The transferable requirement is integration into an existing fiscal document, not the creation of a new reporting system. |

Note: Table A3 complements Table 6 by specifying role boundaries, instrument anchors, decision gates, and transferability rules rather than repeating the roadmap. Its central logic is that ecological information should enter fiscal governance only through documented handovers, accountable parameter custody, uncertainty disclosure, and reviewable fiscal-use points. External standards may serve as methodological benchmarks, but do not substitute for domestic legal authority or administrative mandates. Because each phase is defined by institutional functions, countries applying BNC-VaR may substitute their own institutions while preserving the same functional sequence.

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