ORIGINAL PAPER

Applying Ocean Account in Thailand: Lessons learned and challenges from the Phang Nga Bay Pilot Project

Orapa Suwattano[1], Ukrit Sattaphumin[1], Thamasak Yeemin[2], Walaiporn Phonphan[3], Teerapong Praphotjanaporn[4], Prapasri Pongwattana[5], Makamas Suthacheep[2], Wichin Suebpala[2]*

[1] Department of Marine and Coastal Resources, Bangkok, Thailand
[2] Marine Biodiversity Research Group, Department of Biology, Faculty of Science, Ramkhamhaeng University, Thailand
[3] Faculty of Science and Technology, Suan Sunandha Rajabhat University.
[4] Global Ocean Accounts Partnership, University of New South Wales, Australia
[5] Bangkaew, Bang Phli, Samut Prakan, Thailand

*Corresponding author: *wichin.s@gmail.com*

Received: 06 October 2024 / Revised: 30 December 2024 / Accepted: 31 December 2024

Abstract: Oceans are composed of various marine and coastal ecosystems, contributing to global biodiversity and providing essential services to humanity. However, anthropogenic pressures such as overexploitation, pollution, and climate change threaten the health of marine ecosystems, degrading the quality of ecosystem services and thus affecting socio-economic development and livelihoods. The concept of an ocean account emerges as a tool to quantify and value the services provided by the ocean, facilitating informed decision-making for sustainable management. In this paper, we introduce the core concept of ocean account and its application through the case illustration of the Phang Nga Bay Ocean Account Project. Relevant secondary data and primary data were compiled and systematically analyzed under the ocean account framework. Remote sensing technology and current models were employed to determine spatially analytical units: drainage basins and marine regions. For each analytical unit, ecosystem assets and conditions, as well as governance accounts were established for key ecosystems such as mangroves, seagrass beds, coral reefs, rare marine animals, etc.; human activities were also spatially analyzed. An example analysis of solid waste flow revealed the land-sea interaction in terms of pollution. From an economic perspective, the value added from the ocean in 2017 was 417,339 million baht consisting of directed marine economic activities (214,415 million baht) and activities related to marine tourism (202,923 million baht), employed 178,911 people. The main challenge is the data availability of the ecosystem and economy, making the interaction between ecosystem-economic sectors more difficult. This highlights that the ocean account framework is valuable as basic scientific information that supports other management tools, particularly marine spatial planning. Lessons learned and challenges from the Phang Nga Bay Pilot Project serve as an initial step and model for using this concept in other areas in Thailand, contributing to the effective management of marine and coastal ecosystems in Thailand.

Keywords: ecosystem accounting, marine environmental management, Phang Nga Bay, ocean account

1. Introduction

More than 70% of the Earth's surface is composed of diverse marine and coastal ecosystems such as coral reefs, seagrass beds, mangroves, open seas, etc. These ecosystems are crucial for maintaining global biodiversity, playing a crucial role in supporting ecosystem functions (Duffy 2009, Lotze 2021) and providing essential services that support human livelihoods and economic activities (Palumbi et al. 2009). Marine ecosystem components, functions, and services are generally linked, highlighting that the quality of ecosystem services depends on the integrity of ecosystem components and functions (Pinto et al. 2014, Armoškaitė et al. 2020). The linkage between marine biodiversity and the blue economy is a critical area of study, as it underscores the importance of sustainable practices in utilizing ocean resources while preserving the health of marine ecosystems. Marine biodiversity serves as a basis for the blue economy, as it provides essential ecosystem services that support various economic activities such as tourism, fisheries, resource extraction (Tisdell & Hazra 2022). Subsequently, the global community calls for a balance between the conservation and use of marine biodiversity as a core consideration of the blue economy, ensuring the sustainability and resilience of ecological and socio-economic resilience (Ehlers 2016). Moreover, greenhouse gas emissions and climate change pose difficulties in achieving a sustainable blue economy and fulfilling the Sustainable Development Goals (SDGs) (Hossain et al. 2024).

Oceans and marine biodiversity have been increasingly experiencing multiple threats and pressures, particularly from a wide range of human activities such as habitat loss, overexploitation, pollution, changes in land use and sea use as well as climate change (Wernberg et al. 2011, Ding et al. 2017, Rist et al. 2024, Thiagarajan & Devarajan 2024, Wang et al. 2024). They threaten the health of marine ecosystems and biodiversity, leading to biodiversity loss, degrading the quality of ecosystem services and thus affecting socio-economic development and livelihoods. Based on the IPBES report, a continuously increased global rate of species extinction was reported, and it tends to increase in the future (IPBES 2019). The ongoing biodiversity crisis poses significant challenges to economic development. Overfishing and degradation of marine ecosystems and habitats have been linked to declines in fish populations and overall marine productivity and biodiversity, driving some marine fishes to near extinction, thus further affecting the fisheries sector (Coleman & Williams 2002, Yan et al. 2021). The degradation of coral reefs and the disappearance of iconic species also impact marine tourism development and sustainability, which is one of the most significant economic sectors of coastal states and islands (Leposa 2020, González Hernández et al. 2023). Conversely, inappropriately managed tourism may also cause the degradation of coral reefs and their services, which further generate negative impacts on their attractiveness and the development of a sustainable blue-tourism economy (Gallegati et al. 2025).

As global concerns over the anthropogenic impacts on marine and coastal ecosystems, particularly from economic activities have been growing, the United Nations, in collaboration with policymakers, managers, and the scientific communities around the world, has developed a framework for intergrade analysis of both physical and monetary information, called the UN System of Environmental-Economic Accounting (SEEA). The SEEA was developed in alignment with the structure and classifications of the System of National Accounts (SNA), providing an additional standard set of indicators used to measure and value the benefits as well as the flows of products and values between environmental and human systems (UN 2014). At an early stage, the SEEA is composed of two major frameworks: Central Framework (UN 2014) and methodological frameworks for various thematic areas such as SEEA-Energy (UN 2019), SEEA-Water (UN 2012), SEEA-Agriculture, Forestry, and Fisheries (UN 2020), SEEA-Ecosystem Accounts (SEEA-EA) (UN 2024), etc. The SEEA-EA has been applied in at least 21 countries such as Australia, Netherlands, Norway, UK, Mauritius, USA, EU countries (Cummins et al. 2023), for assessing the ecosystem extent, condition, ecosystem services and monetary values of different ecosystem types and objectives, for example, coral reefs (Yuan et al. 2024), coastal and marine areas (Dvarskas 2019), water quality (Younesi et al. 2024), environmental income of publicly-owned, protected, pine-forest-farm (Campos et al. 2022), etc.

Later, the Ocean Accounting Framework with Technical Guidance on Ocean Accounting for Sustainable Development was then developed by the Global Ocean Accounting Partnership (GOAP) to fulfill the need for an ocean-focused approach based on the SNA and SEEA. Ocean accounts (OA) are defined as a systematic compilation of relevant information regarding marine and coastal environments with various aspects, including natural resources, economic activities, environmental health, pollution, and social circumstances and governance. Ocean Accounts serve as a powerful tool for the sustainable development and management of oceans and are essential for addressing the complexities of human interactions with marine and coastal environments (GOAP 2021). Basically, Ocean Accounting within the coastal domain has been used primarily to assess changes in ecosystem extent, condition, and ecosystem services in response to human activities such as coastal populations, coastal and marine activities. Climate change and adaptation are also embraced in the framework (GOAP 2021). This framework has been extensively applied in various countries. For example, Gacutan et al. (2022a) used ocean accounting to assess ecosystem services and benefits in a coastal lake in Australia, SEEA Ecosystem Accounts were constructed for the OSPAR regional sea (Alarcon Blazquez et al. 2023). Based on the global review conducted by Gacutan et al. (2022c), twenty-six countries have co-developed Ocean Accounts (OA) and Marine Spatial Planning (MSP). However, most case studies showed no clear alignment between the two concepts. The authors argue that both OA and MSP could support each other, for instance, overlapping activities and operations, data, and institutional sharing. Engaging OA and MPS could be beneficial to effective ocean governance in the future as OA can provide inputs for the MPS process (Gacutan et al. 2022b).

The concept of SEEA was introduced in Thailand with the establishment of a National Committee on SEEA to foster and support SEEA implementation in Thailand. The concept has been applied to several studies such as environmental impact assessment (Kaenchan et al., 2017), water resources management (Chuenchum et al., 2018), Green GDP (Kunanuntakij et al., 2017), management decision support system (Wajeetongratana, 2018), etc. Yet, Ocean Account (OA) is still new in Thailand with only a few studies; for example, Meerod et al. (2018) applied the SEEA concept to support Thailand's blue economy. Tourism Satellite Account (TSA) and SEEA were also used in a pilot study on the construction of SEEA accounts, including water, energy, greenhouse gas emissions, and solid waste (UN ESCAP, n.d.). As a large gap in knowledge on Ocean Accounting in Thailand is still found, the Pilot Project was initiated in Phang Nga Bay.

Phang Nga Bay, located on the Andaman Sea coast of Thailand, is a region of significant ecological, geological, and cultural importance. This bay is characterized by both terrestrial and marine environments, making it significant for various human activities, particularly tourism activities. Phang Nga Bay covers three provinces, including Phang Nga, Phuket, and Krabi, characterized by a tropical monsoon climate, which significantly influences its ecosystems and natural resources. The bay experiences wet and dry seasons, with the wet season typically occurring from May to October, driven by the southwest monsoon. During this period, heavy rainfall can lead to increased freshwater input into the bay, affecting coastal water quality, particularly salinity and nutrient dynamics in the marine and coastal ecosystems (Moses et al. 2015). The tidal range in Phang Nga Bay is substantial, averaging between 2.5 to 3.0 meters, which influences sediment transport and coastal erosion processes (Moses et al. 2015). Phang Nga Bay is a region of rich marine biodiversity and significant ecological resources, which are vital for both local communities. The bay has unique geographical features and diverse marine and coastal ecosystems, including limestone karsts, mangrove forests, seagrass beds, coral reefs, and underwater pinnacles. These ecosystems provide a diverse habitat that supports a variety of marine species, including fisheries resources e.g., commercially important fish, crustaceans, bivalves, gastropods, as well as rare and endangered marine species, including sea turtles, whales and dolphins, and dugongs (DMCR 2024). The marine and coastal ecosystems also provide a wide range of ecosystem services supporting a wide range of marine-related human activities, found in the bay, including marine tourism, captured fisheries, coastal aquaculture, mariculture, and marine transport. In terms of fisheries, the bay's ecosystems are essential breeding and nursery grounds for many commercially important fish species, contributing to both small- and large-scale fisheries, which are critical for the livelihoods of the local economy. Marine tourism in Phang Nga Bay plays an important role in driving local and national economies, generating large amounts of revenue. Yet, the impact of tourism on marine resources in Phang Nga Bay can potentially generate adverse environmental impacts, leading to habitat degradation, generation of pollution, and disturbances to marine wildlife. Because of its ecological importance and the risk that could occur due to economic development, this area was selected as a pilot area for applying the concept of Ocean Account (OA) to support and mainstream conservation and economic development.

This article aims to provide overall outputs and lessons learned from the OA pilot project in Phang Nga Bay, Andaman Sea, Thailand. Perspectives on the use of this concept to support sustainable management of marine and coastal resources linked to sustainable ocean economy development are also provided.

2. Materials and Methods

2.1 Study area

Phang Nga Bay was selected as a study area, covering three provincial boundaries: Phang Nga, Phuket, and Krabi (Figure 1).

2.2 Theoretical Framework

This study applies the Ocean Accounts Framework, recommended by the Global Ocean Accounts Partnership (GOAP), which consists of one or more tables of the following elements: a) environmental assets include the extent and condition of biotic and abiotic natural resources, b) flows of goods and services related to oceans to the economy, c) flows of pollutants or residuals from the economy to the oceanic environment, d) ocean economy, which is referred to “Ocean Economy Satellite

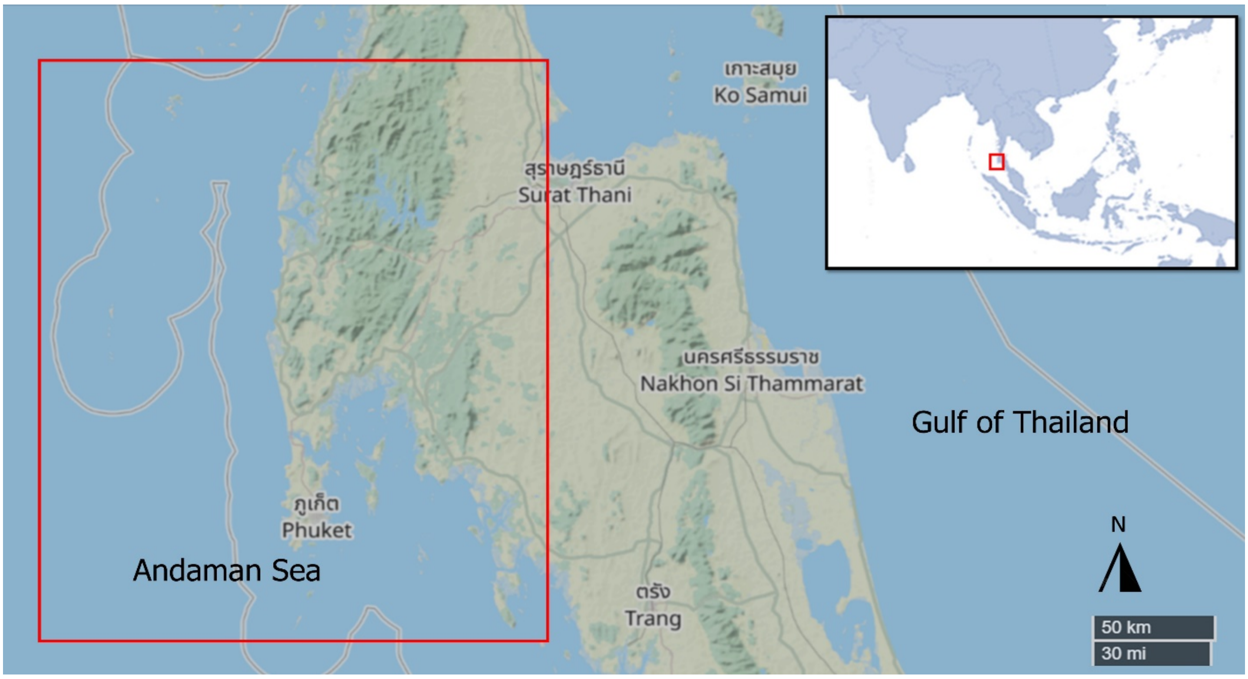

Figure 1. Map of the Study Area
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Accounts" generated by ocean-related industry sectors, and f) ocean governance which regulates and manages the dynamics of environmental and socio-economic system. The Ocean Accounts Framework recommends engaging both spatially explicit and spatially independent information (GOAP 2021). Given the spatial principles of the SEEA-EEA, Basic Spatial Units (BSUs) are recommended to be established as an analytical unit. Ecosystem types (ETs) should also be identified, and they should be consistently analyzed under the framework over time. Classification of ocean ecosystems can be made to match the national context, objectives, data availability, and future needs (GOAP 2021).

2.3 Analytical procedures

The Pilot Project on "The Study and Data Analysis for the Establishment of Ocean Accounts of Phang Nga Bay, in Phang Nga, Phuket, and Krabi Province" was conducted from 2021 – 2022, consisting of four main objectives: 1) establishment of ocean asset accounts and service accounts, 2) valuation of ocean economy by constructing an ocean economy satellite account, 3) establishment of ocean governance account, and 4 analyses of risk and vulnerability due to land-based solid waste. To support the construction of the Ocean Accounts and analyses, the compilation of existing data is important. Relevant information, particularly spatial data, from different sources was compiled, while other types of data were also gathered to support other analyses and the design of accounts and basic spatial units.

To designate basic spatial units, relevant information from spatial data, digital elevation models, and oceanic current models are important for establishing drainage basins and marine regions. Spatial data included the governance boundaries (provincial, district, and sub-district levels), land-use maps, and basin maps. The raster format of ASTER Global DEM, with its resolution of 30 m, was used to analyze flow direction and accumulation on land. Oceanic current patterns were determined using COAWST

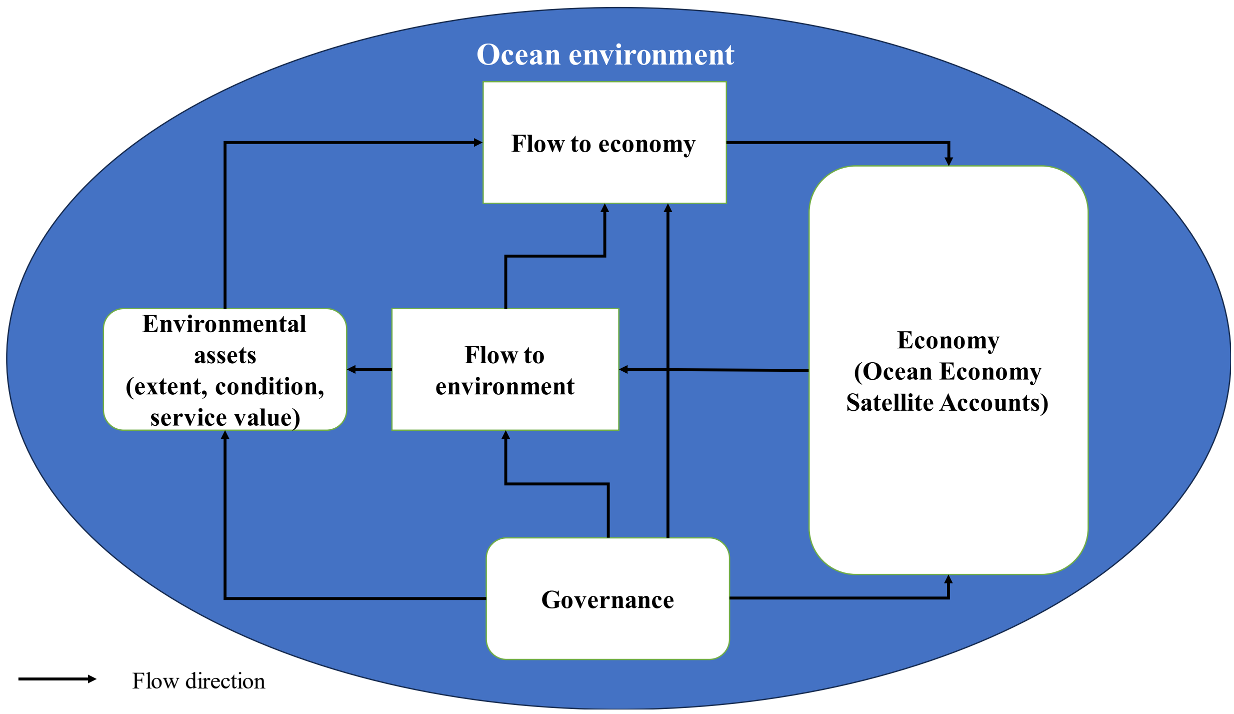

Figure 2. Conceptual Basis for Ocean Accounts
Adapted from GOAP (2021)

(Coupled Ocean – Atmosphere –Wave – Sediment Transport) in which four relevant models are incorporated including Weather Research and Forecasting Model (WRF), Regional Ocean Model System (ROMS), SWAN: Simulating Waves Nearshore Model (SWAN), and Community Sediment Transport Modeling System (CSTMS) (Warner et al. 2010). A Geographic Information System (GIS) was used to analyze all spatial data and generate maps.

Development of ocean asset accounts used analytical results from spatial data analysis. Major inputs cover spatial information on marine and coastal resources in terms of their extent and condition/status. For this pilot project, five types of environmental assets were identified, including mangroves, seagrass beds, coral reefs, artificial reefs, and rare marine animals, while asset condition accounts are composed of indicators categorized into the following groups: abundance/density, biodiversity, ecosystem status, and water quality status. Ocean service accounts were extended from the ocean asset accounts by estimating the economic values of certain ecosystem services. The estimation of economic values was based on the ecosystem extent and service factors compiled from research and reports of DMCR and GOAP (Januar et al., 2022).

The valuation of the ocean economy started by compiling and studying economic information and the economic conditions of Phang Nga, Phuket, and Krabi. Marine-related sectors were identified based on the 2009 Thailand Standard Industrial Classification (TSIC). Input-Output Table was then established, using ocean ratio and GPP, to create an ocean economy satellite account consisting of the direct and indirect gross-value-added, and employment for the three provinces. Indirect impacts were estimated using the Leontief inverse matrix (Miller et al., 2009). The development of ocean governance

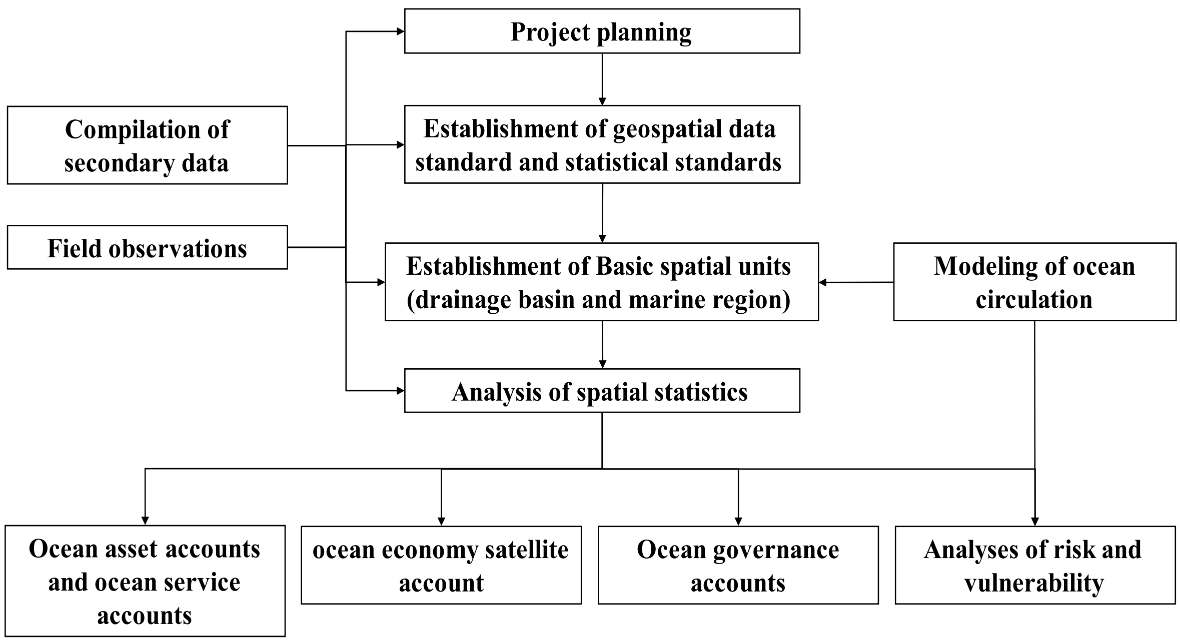

Figure 3. Analytical procedure of the Phang Nga Bay Pilot Project

accounts used secondary information to identify area-based management boundaries, marine and coastal activities, natural resources, relevant stakeholders, and institutions, for each marine region.

Risk and Vulnerability Analysis was also conducted on a specific topic to illustrate the connection between land-based activities and risk on marine and coastal ecosystems. For this analysis, the risk of land-based solid waste on marine ecosystems was analyzed.

3. Results

3.1 Establishment of Basic Spatial Units

Based on the analyses of relevant information from spatial data, digital elevation models, and oceanic current models, basic spatial units can be established, consisting of thirteen drainage basins of land areas and twelve marine regions of marine areas (Table 1 and Figure 4). The basic spatial units are based on locations of marine and coastal resources, topography, land, and marine provincial boundaries, the flow direction of rivers and canals, and ocean circulation patterns.

3.2 Ocean Asset Accounts

Physical asset extent account

Physical asset extent accounts were created for all marine regions. Each of them consists of five main ecosystem assets: mangroves, seagrass beds, coral reefs, artificial reefs, and rare marine animals. These accounts provide quantitative information on changes in ecosystem assets. The changes can be caused by natural phenomena, human management/intervention, harvesting/ extraction, reclassification, rediscoveries, or reappraisals. For this project, the assessment and reference periods for each ecosystem asset were not similar because the survey cycles and the data availability for each asset were different. Additionally, the information on managed/ natural expansion and regression, as well as extraction/harvesting, was not available, making it difficult to complete the accounts. For coral reefs, the change in coral reef extent was unable to estimate as no annual survey data for coral extent was available. An example of the physical asset extent account for marine region 1 (drainage basins 9 and 10) is shown in Table 2. The tables for other marine regions can be found as online supplementary data.

Table 1. Areas and connections between drainage basin and marine regions

Drainage Basin	Areas	Marine Regions
1	Phang Nga (north): Kuraburi, Taguapa, Kapong	12
2	Phang Nga (West): Taguapa, Tai Mueang, Taguathung	11
3	Phang Nga (inner gulf): Taguathung	5
4	Phang Nga: Yao Noi- Yoa Yai islands	6
5	Phang Nga-Krabi (inner gulf)	4
6	Krabi: Plai praya, Muang Krabi, Ao Luek	3
7	Krabi: Ao Luek, Khao Phanom, Klong Thom	2
8	Krabi: Phi Phi island	7
9	Krabi: Klong Thom, Lanta island (East)	1
10	Krabi: Lanta island (West)	1
11	Phuket (North)	10
12	Phuket (West)	9
13	Phuket (East)	8

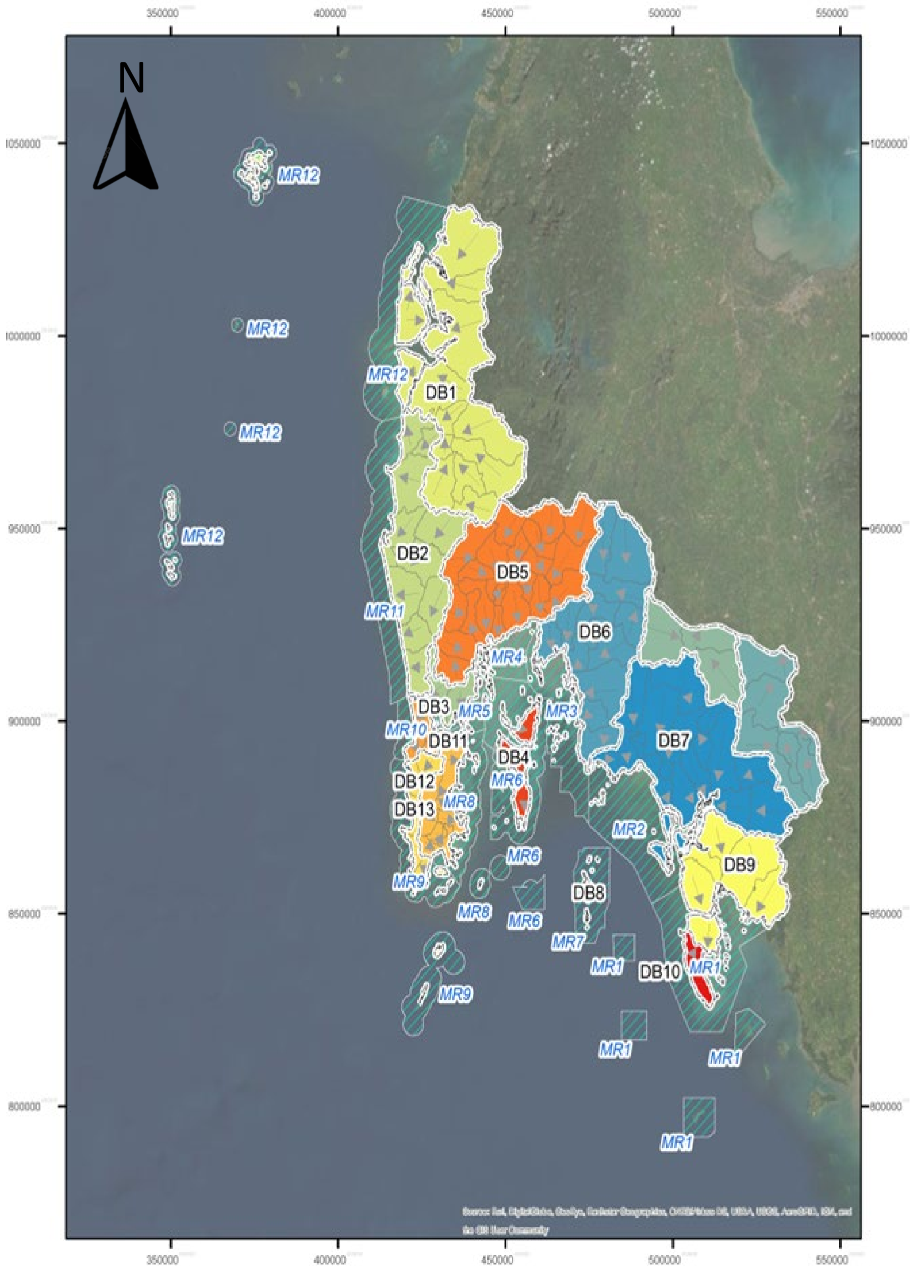

Figure 4. Boundaries of drainage basins and marine regions
Remark: Different colors represent different sub-basins

Physical asset condition account

Condition account provides quantitative information on ocean assets' conditions for each ecosystem assets. For each condition, a set of indicators is provided with reference levels. The reference level is based on the results of scientific evidence or existing indicators being used for environmental/ ecosystem monitoring. For example, live and dead coral coverage has been used to assess the status of coral reefs; thus, knowing such information can determine either their abundance or status. Likewise, the percentage of seagrass coverage can reflect their abundance and status. In this study, several indicators of water quality assessment are included in the condition account as water quality directly influences the condition of ecosystems. An example of the physical asset condition account for marine region 1 (drainage basins 9 and 10) is shown in Table 2. The tables for other marine regions can be found as online supplementary data.

Table 2. Example of the physical asset extent account for marine region 1 (drainage basins 9 and 10)

Physical asset extent account	Ecosystem assets				
	Mangroves[1]	Seagrass beds[2]	Coral reefs[3]	Artificial reefs[4]	Marine rare animals[5]
Opening stock	135.25	2.11	2.49	1,330	3
+ Additions to stock					
Managed expansion	0.00	0.00	0.00	169	0
Natural expansion	0.00	7.60	0.00	0	0
Reclassifications	0.00	0.00	0.00	0	0
Discoveries	0.00	0.00	0.00	0	229
Reappraisals, (+)	36.74	0.00	0.00	0	0
Total additions to stock	36.74	7.60	0.00	0	0
–Reductions in stock					
Managed regression	0.00	0.00	0.00	0	0
Natural regression	0.00	0.00	0.00	0	0
Reclassifications	0.00	0.00	0.00	0	0
Extractions/harvesting	0.00	0.00	0.00	0	0
Reappraisals, (-)	0.00	0.00	0.00	0	0
Total reduction in stock	0.00	0.00	0.00	0	0
= Closing stock	171.99	9.71	2.49	1,499	232
Unit	km^2	km^2	km^2	Units	individuals

[1]Compared between 2009 and 2017
[2]Compared between 2008 - 2012 and 2015 - 2019
[3]No annual monitoring information on coral reef extent was available
[4]Compared between 2010 and 2017
[5]Compared between 2009 - 2010 and 2016 - 2017

3.3 Ocean Service Accounts

The estimation of economic values was based on the ecosystem extent and service factors. Due to data limitations, particularly spatial data, ocean services accounts cover only regulating services in terms of carbon stock and coastal protection. The value of carbon stock was estimated for mangroves and seagrass beds, while the value of coastal protection was assessed for mangroves and coral reefs.

DMCR reported that the average carbon storage of mangroves was 15 TonC per Rai, consisting of aboveground (10.21 TonC per rai) and below-ground (4.79 tonC per rai) (DMCR 2022). Thus, the total area of 519,889.06 rai of mangroves in Phang Nga Bay can store carbon as much as 7,798,335.94 TonC; the total carbon storage could be converted to a monetary value of 24,954.68 million baht based on the carbon price of EU ETS (85 Euro/TonC or 3200 THB/TonC, January 2023) (Table 4). The average carbon storage of seagrass beds was 21.44 TonC per Rai, 97% of the total carbon is found in sediment (Stankovic et al., 2021). Thus, the estimated carbon storage was 740,923.52 TonC for the total area of 34,558.00 rai of seagrass beds; the total carbon storage could be converted to a monetary value of 2,370.96 million baht based on the carbon price of EU ETS (Table 5).

Mangroves and coral reefs are recognized as they are natural barriers for coastal protection. Economists estimated monetary values of mangroves and coral reefs with 1610 USD/ha or 8,800 Baht/rai (Samonte-Tan, 2007) and 12,250 USD/Ha or 67,620 Baht/rai (Pascal et al., 2016), respectively. Given the total area of mangroves in 2017 in Phang Nga Bay, the total costal protection value reached 4,575.02 Baht. The coastal protection value of coral reefs in the bay was 2,147.07 million Baht.

Table 3. Example of the physical asset condition account for marine region 1 (drainage basins 9 and 10)

Condition	Indicator	Reference level	Ecosystem assets					
			Mangroves	**Seagrass beds**	**Coral reefs**	**Artificial reefs**	**Rare marine animals**	**Coastal waters**
Abundance	% live coral cover	>66.66%	-	-	36.40	NA	-	-
	% dead coral cover	<33.34	-	-	59.30	NA	-	-
	% cover of seagrass	>50	NA	16.67	.	NA	-	-
	Vegetation Index	>0.5	NA	-	-	-	-	-
	Fish abundance (ind./100 m^2)	NA	NA	NA	NA	NA	-	NA
	Benthos abundance (ind./m^2)	NA	NA	NA	NA	NA	-	NA
	Rare marine animal abundance (ind./100 m^2)	-	-	-	-	-	NA	-
Biodiversity	Species richness	NA	NA	3	NA	NA	NA	NA
	number of genera	NA	NA	NA	NA	NA	NA	NA
	Shannon's index of fishes	NA	NA	NA	NA	NA	-	NA
	Shannon's index of benthos	NA	NA	NA	NA	NA	-	NA
Status	Status level	>2.50/4 for seagrass >3.40/5 for corals WQI>80	NA	1.33	2.25	NA	-	87
Water quality	Temperature (C)	20-30	NA	NA	NA	NA	-	29.52
	pH	7 - 8.5	NA	NA	NA	NA	-	8.12
	Salinity (ppt)	30-36	NA	NA	NA	NA	-	31.26
	Dissolved oxygen (mg/L)	>4	NA	NA	NA	NA	-	5.99
	BOD (mg/L)	1.5 - 2	NA	NA	NA	NA	-	NA
	Suspended solid(mg/L)	<30	NA	NA	NA	NA	-	36.41
	Phosphate (mcg/L)	15	NA	NA	NA	NA	-	0.37
	Ammonia nitrogen (mcg/L)	70	NA	NA	NA	NA	-	21.12
	Nitrate nitrogen (mcg/L)	20	NA	NA	NA	NA	-	26.40
	Fecal coliform (CFU/100 ml)	70	NA	NA	NA	NA	-	NA
	Total coliform (MPN/100L)	1,000	NA	NA	NA	NA	-	34.81

Table 4. Carbon storage of mangroves and their monetary values of carbon storage service

Drainage basins	Mangroves in 2017 (Rai)	Above-ground biomass (Tons C)	Below-ground biomass (Tons C)	Total C (Tons C)	Value (Million Baht)
1. Phang Nga (north): Kuraburi, Taguapa, Kapong	142,599.38	1,455,939.62	683,051.01	2,138,990.63	6,844.77
2. Phang Nga (West): Taguapa, Tai Mueang, Taguathung	21,070.81	215,133.00	100,929.19	316,062.19	1,011.40
3. Phang Nga (inner gulf): Taguathung	13,381.56	136,625.75	64,097.68	200,723.44	642.32
4. Phang Nga: Yao Noi-Yoa Yai islands	6,263.06	63,945.87	30,000.07	93,945.94	300.63
5. Phang Nga-Krabi (inner gulf)	103,873.75	1,060,550.99	497,555.26	1,558,106.25	4,985.94
6. Krabi: Plai praya, Muang Krabi, Ao luek	40,455.38	413,049.38	193,781.25	606,830.63	1,941.86
7. Krabi: Ao luek, Khao Phanom, Klong Thom	71,410.00	729,096.10	342,053.90	1,071,150.00	3,427.68
8. Krabi: Phi Phi island	0.00	0.00	0.00	0.00	0.00
9. Krabi: Klong Thom, Lanta island (East)	101,356.88	1,034,853.69	485,499.43	1,520,353.13	4,865.13
10. Krabi: Lanta island (West)	6,140.17	62,691.12	29,411.41	92,102.53	294.73
11. Phuket (North)	2,967.39	30,297.09	14,213.82	44,510.91	142.43
12. Phuket (West)	0.00	0.00	0.00	0.00	0.00
13. Phuket (East)	10,370.69	105,884.72	49,675.59	155,560.31	497.79
Total	519,889.06	5,308,067.33	2,490,268.61	7,798,335.94	24,954.68

Table 5. Carbon storage of seagrass beds and their monetary values of carbon storage service

Marine regions	Seagrass beds in 2515 – 2019 (rai)	Biomass[1] (Tons C)	Sediment[1] (Tons C)	Total C[1] (Tons C)	Value [2] (Million Baht)
1. Krabi: Klong Thom, Lanta island	6,067.00	3,902.29	126,174.19	130,076.48	416.24
2. Krabi: Ao Luek, Khao Phanom, Klong Thom	10,221.00	6,574.15	212,564.09	219,138.24	701.24
3. Krabi: Plai praya, Muang Krabi, Ao Luek	2,872.00	1,847.27	59,728.41	61,575.68	197.04
4. Phang Nga-Krabi (inner gulf)	0.00	0.00	0.00	0.00	0.00
5. Phang Nga (inner gulf): Taguathung	1,969.00	1,266.46	40,948.90	42,215.36	135.09
6. Phang Nga: Yao Noi-Yoa Yai islands	3,199.00	2,057.60	66,528.96	68,586.56	219.48
7. Krabi: Phi Phi island	0.00	0.00	0.00	0.00	0.00
8. Phuket (East)	3,362.00	2,162.44	69,918.84	72,081.28	230.66
9. Phuket (West)	0.00	0.00	0.00	0.00	0.00
10. Phuket (North)	0.00	0.00	0.00	0.00	0.00

Table 5. Carbon storage of seagrass beds and their monetary values of carbon storage service (continue)

Marine regions	Seagrass beds in 2515 – 2019 (rai)	Biomass[1] (Tons C)	Sediment[1] (Tons C)	Total C[1] (Tons C)	Value [2] (Million Baht)
11. Phang Nga (West): Taguapa, Tai Mueang, Taguathung	203.00	130.57	4,221.75	4,352.32	13.93
12. Phang Nga (north): Kuraburi, Taguapa, Kapong	6,665.00	4,286.93	138,610.67	142,897.60	457.27
Total	34,558.00	22,227.71	718,695.81	740,923.52	2,370.96

3.4 Valuation of Ocean Economy

Based on the Input-Output Tables and Ocean ratio, the ocean economy satellite account shows the importance of high values and employment of ocean sectors in Phang Nga Bay. Various activities, particularly fisheries, aquaculture, and marine tourism-related activities, showed a high ocean ratio, reflecting a high contribution of such activities to the gross provincial product (Table 6).

Direct marine economy's value-added shows that in 2017 was 214,415.64 million baht, accounting for 57.34% of the gross provincial product of Phang Nga, Phuket, and Krabi. The remaining 42.66% was added value from other sectors unrelated to the sea. Furthermore, this direct marine economy value added generated economic value in other production sectors that used marine economy sectors as production factors for goods and services, leading to an indirect marine economic value represented by a total added value of 209,922.09 million baht, or 56.14% of the gross provincial product of Phang Nga, Phuket, and Krabi in 2017. This also resulted in employment in marine-related sectors, both direct and partial, in Phang Nga, Phuket, and Krabi, with 178,911 people employed, accounting for 26.60% of the population aged 15 and over who were employed in these provinces (Table 7).

In 2018, the direct marine economy's value added was 231,929.36 million baht, or 58.58% of the gross provincial product of Phang Nga, Phuket, and Krabi. The number of people employed in marine-related sectors, both direct and partial, in Phang Nga, Phuket, and Krabi was 189,539, accounting for 27.81% of the population aged 15 and over who were employed in these provinces.

In 2019, the direct marine economy's value added was 244,761.60 million baht, or 59.39% of the gross provincial product of Phang Nga, Phuket, and Krabi. Employment in marine-related sectors, both direct and partial, in these provinces was 196,525 people, accounting for 28.78% of the population aged 15 and over who were employed in these provinces.

In 2020, the COVID-19 pandemic caused the direct marine economy's value added to drop to 111,618.77 million baht, or 43.15% of the gross provincial product of Phang Nga, Phuket, and Krabi. This was due to the province's reliance on tourism, which was severely impacted by the pandemic. Employment in marine-related sectors, both direct and partial, in Phang Nga, Phuket, and Krabi was 104,266, accounting for 15.61% of the population aged 15 and over who were employed in these provinces.

3.5 Ocean Governance Accounts

Ocean governance account was developed to understand various aspects related to governance. This account is beneficial and serves as a basis and input for Marine Spatial Planning (MSP). It includes the collection of secondary data related to management, laws,

Table 6. Ocean ratio based on TSIC of gross regional and provincial product chain volume measures

TSIC code	Items	Ocean ratio (%)
	All GPPs	
A	**Agriculture, forestry and fisheries**	
2	Forestry and logging	**34.72**
3	Fisheries and aquaculture	**98.94**
	Non-agricultural sector	
C	production	
10	production of food products	**10.03**
30	Manufacture of other transport equipment	**100**
31	furniture production	
32	Production of other types of products	**0.95**
33	Repair and installation of machinery and equipment	**66.06**
D	Electricity, gas, steam and air conditioning systems	
3510	Production, transmission and distribution of electricity	**0.64**
F	Construction	
42	Civil engineering work	**0.46**
G	Wholesale and retail: Repair of automobiles and motorcycles	
46-47	Wholesale and retail: Trade, excluding motor vehicles and motorcycles	**24.17**
H	Transportation and storage locations	
50	Marine transport	**99.57**
51	Air transport	
52	Warehouse-related activities and transportation support activities	**82.02**
53	Postal activities and sending and receiving documents/items	
I	Accommodation and food services	
55	Accommodation	**98.31**
56	Food and beverage services	**99.38**
K	Financial and insurance activities	
65	Insurance, reinsurance and pension funds, excluding compulsory social security.	**45.59**
66	Activities supporting financial services and insurance activities	**45.59**
N	Administrative activities and other support services	
79	Travel business agent Travel organizing business and reserve services and related activities	**86.05**
O	Public administration national defense and compulsory social security	**1.08**
P	Education	**1.79**
R	Arts, Entertainment and Recreation	**1.57**

Table 7. Summary of value added and employment related to the ocean sector of the three provinces

Ocean Economy satellite account	2017		2018		2019		2020P	
	VA ocean	% VA ocean of GPP	VA ocean	% VA ocean of GPP	VA ocean	% VA ocean of GPP	VA ocean	% VA ocean of GPP
Direct (Million Baht)	214,415.60	57.34	231,929.40	58.58	244,761.60	59.39	111,618.80	43.15
Indirect (Million Baht)	202,922.9	56.14	NA	NA	NA	NA	NA	NA
Employment (people)	178,911		189,539		196,525		104,266	
Employment in ocean sector/total employment (%)	26.6		27.81		28.78		15.61	

Remark: VA denotes value-added; indirect values cannot be estimated for 2018 – 2020.

and regulations regarding the management and use of the oceans. At least 50 agencies or organizations are involved in the governing system of Phang Nga Bay, including central and regional government agencies and local administration, private sectors, local communities, academic and research institutions, public organizations, and NGOs. For each marine region, the areas of marine regions, coastal zones for small-scale fisheries, national parks, environmental protection areas, areas for aquatic conservation, non-hunting areas, tourism activities, fishing activities, etc. were provided.

In Phang Nga Bay, there are many laws and regulations that can be categorized into three groups:

1) the protection and conservation of marine and coastal resources, for instance, National Parks Act, B.E. 2562 (2019), Act on the Promotion of Marine and Coastal Resources Management, B.E. 2558 (2015), Royal Ordinance on Fisheries B.E. 2558 (2015), Wild Animal Reservation and Protection Act (No.3), B.E. 2557 (2014), etc.

2) pollution prevention, control, and management, such as Thailand's environmental promotion act is the Enhancement and Conservation of National Environmental Quality Act, B.E. 2535 (1992), Navigation in the Thai Waters Act, B.E. 2456 (1913), Factory Act, B.E.2535 (1992), Public Health Act, BE 2535 (1992), Industrial Estate Authority of Thailand Act of B.E. 2522 (1979), the Act on the Maintenance of the Cleanliness and Orderliness of the Country, B.E. 2535 (1992) etc.;

3) other regulations used to regulate or control environmental impacts from human activities such as The Maritime Interest Protection Act, B.E. 2562 (2019), National Tourism Policy Act (No. 2), B.E. 2562 (2019), The Determining Plan and Process of Decentralization to Local Government Organization Act, B.E. 2542 (1999), etc.

3.6 Risk and Vulnerability Analysis

In this study, an account of physical supply and use for solid waste was constructed since there was complete data for risk and vulnerability analysis. Solid waste is one of the major problems in Phang Nga Bay. The Pollution Control Department (PCD) reported that 629,987.9 tons of solid waste was generated in Phang Nga Bay in 2017.

Based on our calculation, the waste generated in the Phang Nga Bay area came from households and industries, accounting for 398,552.9 tons or 63% of the total waste, while waste from the tourism industry accounts for 231,435.0 tons or 37%. However, when considering each drainage basin, it was found that in areas with popular tourist attractions, such as Drainage basin 4 (Koh Yao Noi) or Drainage Basin 12 (Patong Beach), most of the waste came from the tourism industry, making up 95% and 76% of the total waste in each drainage basin, respectively.

In general, most waste in the Phang Nga Bay area was managed, with 594,976.7 tons or 94% of the total waste. The majority of this waste was managed properly, accounting for 85% of the total managed waste, through methods such as Waste to Energy (WTE) and recycling. However, 35,011.2 tons or 6% of the total waste was not managed, mainly consisting of waste outside the service areas of local government organizations, with households handling it themselves in improper ways, such as dumping or burning. In drainage basins 11, 12, and 13, all waste was properly managed through methods like Waste to Energy and recycling.

To analyze the risk and vulnerability for each area, several factors were considered including 1) methods of waste treatment (open dumping gives the high possibility of contamination), 2) location of open dump site (less than 300 meters from natural canal or rivers or shoreline), 3) flow direction of rivers/canals, and 4) marine circulation pattern of two monsoons (Northeast and Southwest monsoons). In several drainage basins in the Phang Nga Bay area, improper waste management methods, such as open dumping, were found, posing a risk of waste being blown away or leaking into the environment. Five waste treatment facilities in the drainage basins 3, 4, 5, 7, and 9, where open dumping sites are located near (less than 300 meters) canals/rivers/shorelines, possible to flow into the sea, increasing the likelihood of waste flowing into rivers and the sea. Risky and vulnerable areas can be identified as the following:

- If waste contamination occurs in canals or rivers in Drainage basin 3, the waste is likely to be swept down to Marine Region 5. This area contains 68,092.77 rai of mangrove forests, 106 rai of coral reefs, and 1,969 rai of seagrass beds, which could be immediately affected by the waste. Additionally, currents will carry the waste to Marine Region 6 during both the Northeast Monsoon (December to May) and the Southwest Monsoon (June to November).

Table 8. Supply and use for solid waste in Phang Nga Bay

Supply Table (Unit: Tons)										
	Generation of solid waste								Flow from the environment	Total supply
	Management and treatment					Sectors				
	landfill	incineration	Recycling and reuse	Open dumping	Other treatment	Tourism	Industries and households	import	Recovered residuals	
Generation of solid waste						**231,435.0**	**398,552.9**			**629,987.9**
						37%	**63%**			
Use Table (Unit: Tons)										
	Waste management								Flow to environment	Total use
	Management and treatment					Final consumption				
	landfill	incineration	Recycling and reuse	Open dumping	Other treatment	Tourism	Industries and households	Export	Of which to ocean	
Management and treatment	**86,405.6**	**310,767.7**	**113,367.2**	**83,985.8**	**450.5**				**35,011.2**	**629,987.9**

- If waste contamination occurs in canals or rivers in Drainage basin 4, the waste is likely to be carried to Marine Region 6. This area contains 41,678.72 rai of mangrove forests, 4,012 rai of coral reefs, and 2,787 rai of seagrass beds, which could also be immediately affected. Furthermore, currents will transport the waste to other marine areas. During the Northeast Monsoon (December to May), the waste will reach Marine Region 2 and 7 in order, while during the Southwest Monsoon (June to November), it will reach Marine Region 8.
- If waste contamination occurs in canals or rivers in Drainage basin 5, the waste is likely to be carried to Marine Region 4. This area has only 5,556.86 rai of mangrove forests, which could be immediately affected. Additionally, currents will carry the waste to other marine areas. During the Northeast Monsoon (December to May), the waste will reach Marine Region 3, and during the Southwest Monsoon (June to November), it will reach Marine Region 5.
- If waste contamination occurs in canals or rivers in Drainage basin 7, the waste is likely to be carried to Marine Region 2. This area contains 9,367.87 rai of mangrove forests, 3,610 rai of coral reefs, and 11,121 rai of seagrass beds, all of which could be immediately affected. Furthermore, currents will transport the waste to other marine areas. During the Northeast Monsoon (December to May), the waste will be carried to Marine Region 1, while during the Southwest Monsoon (June to November), it will be carried to Marine Region 3 and 6, respectively.
- If waste contamination occurs in canals or rivers in Drainage basin 9, the waste is likely to be carried to Marine Region 1. This area contains 89,293.48 rai of mangrove forests, 1,554 rai of coral reefs, and 6,067 rai of seagrass beds, which could be immediately affected. Additionally, currents will carry the waste to other marine areas. During the Northeast Monsoon (December to May), the waste will float within Marine Region 1, while during the Southwest Monsoon (June to November), it will be carried to Marine Region 7 and 2 in order.

Figures 5(a) and 5(b) show the overall potential areas of waste contamination in the drainage basins and marine regions (MR) during the Northeast and Southwest Monsoons. They indicate the amount of waste that may occur in each marine area, which is affected by the risks of contamination from open dumping stations. It was found that areas MR1, MR2, MR3, MR4, MR6, and MR7, located in Krabi Province and parts of Phang Nga Province, have a higher risk of accumulating waste compared to other areas, especially during the Northeast Monsoon. Although Phuket Province generated the highest amount of waste due to being a major tourist destination with a large number of visitors, its waste management system is effective, and open dumping is not practiced. This significantly reduces the risk of waste accumulation and contamination in the Marine Region of Phuket. Furthermore, when considering the water circulation during each season, the waste will likely be swept to MR5 (Loh Yuang and Khlong Kien Sub-districts, Takua Thung District, Phang Nga Province), MR8 (Eastern side of Phuket Island), MR9 (Racha Yai Island and Racha Noi Island), and MR10 (Southern and Western parts of Phuket Island), including MR7 (Phi Phi Islands) in Krabi Province. These areas were thus highly vulnerable to the accumulation of waste in the future

4. Discussion and conclusions

This pilot study of Ocean Account in Phang Nga Bay is the first comprehensive study of applying the concept of Ocean Account in creating effective management and balance of the conservation and the use of coastal and marine resources based on existing information, ensuring the sustainability of marine ecosystems and economic development. Ocean account is an integrated approach, supporting multidisciplinary research and showing various benefits; for example, OA helps identify knowledge gaps and important issues for future research, supports science-based policy

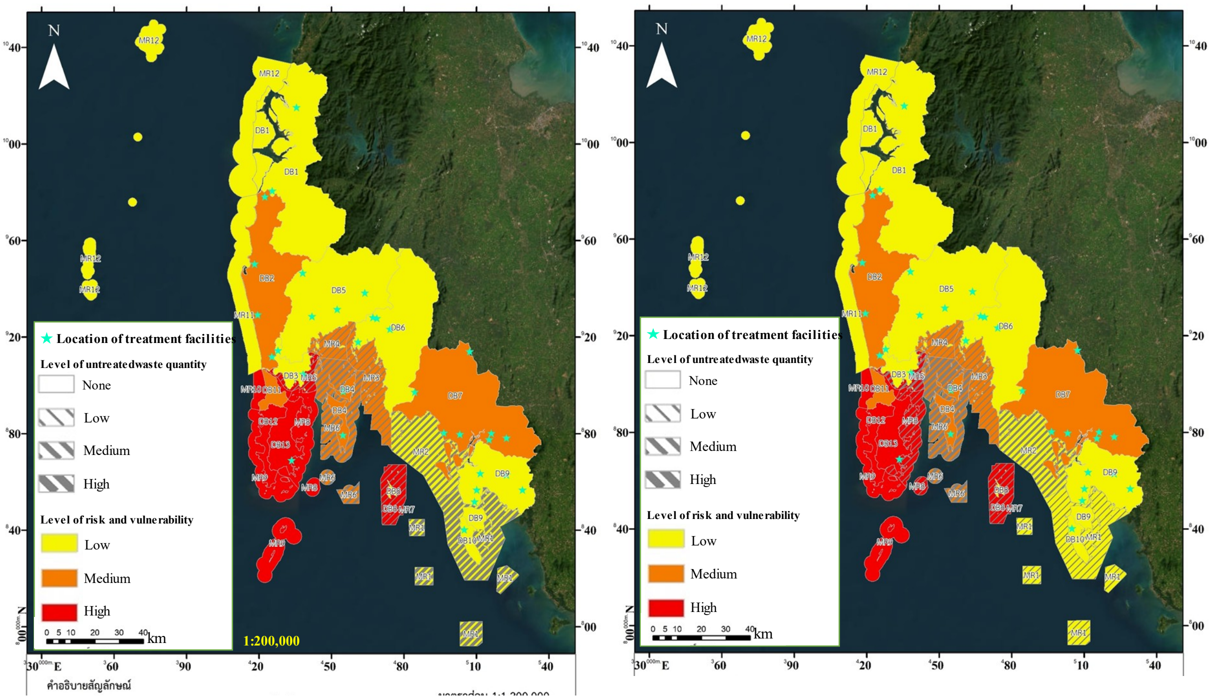

Figure 5. Level of untreated solid waste quantity and level of risk and vulnerability of each drainage basin and marine region during (a) Northeast monsoon and Southwest monsoon (b)

formulation and decision-making, also serves as foundational inputs for other management approaches such as marine spatial planning (MSP), Ocean Health Index (OHI), etc. Yet, there were various challenges learned during the project implementation, including 1) data gap, 2) scale issues, collaboration, and communication among stakeholders.

The findings of this study offer the following policy recommendations:

Ocean Accounts process spatial data and analyze the interconnections of human activities and their impacts on marine and coastal resources. These accounts can support the management of marine and coastal resources, particularly in zoning for the use of these resources, as well as in the concept of Marine Spatial Planning (MSP) and the promotion of sustainable use according to the principles of the Blue Economy. Therefore, the development of ocean accounts should be promoted in other areas as well.

A key issue is the insufficient and incomplete data available, which affects the accuracy of the Ocean Accounts. Therefore, there should be support for developing systems to study, survey, collect, and manage the necessary data, particularly on the extent and condition of marine and coastal resources, fishery resources, pollution data, and economic data. This data will help improve and update the ocean accounts in the future, and the economic value of marine resources should be continuously calculated each year. Additionally, mechanisms for integrating, sharing, and linking relevant data among agencies should be established.

The DB12 and DB13 in Phuket, where human economic activities are dense, are highly vulnerable to threats impacting marine and coastal resources. These areas, including parts of Phang Nga Province (such as La Yong and Klong Kien Subdistricts in Takua Thung District) and various areas in Phuket (such as the eastern side of the island, Racha Islands, and Phi Phi Islands in Krabi), are considered highly fragile. Therefore, controlling land-based activities, particularly pollution control, is crucial, especially the management of waste and wastewater entering natural water sources.

Waste is a significant problem in Phang Nga Bay due to its importance as a tourist destination. The study found that 231,395.2 tons of waste, or 40% of total waste generated, comes from the tourism industry. Around 83,985.8 tons of waste are collected by seven waste management sites in the area. However, 35,011.2 tons, or 6% of the total waste, are not managed properly and end up polluting natural water bodies and being carried into the sea. It is essential to strengthen cooperation in waste management based on scientific principles to reduce the risk of marine pollution, which can affect areas such as MR5, MR8, MR9, and MR10 in Phuket, as well as MR7 in Krabi.

The wastewater problem in these areas is linked to population density and community settlements, particularly in well-known tourist destinations with high numbers of residents or tourists. Untreated wastewater, discharged into natural water bodies, deteriorates water quality in marine areas. While many tourist areas still meet water quality standards, some, such as Patong Beach in Phuket, have poor water quality with elevated levels of ammonia, nitrate, and coliform bacteria. Other areas like Rawai Beach and Kamala Beach in Phuket, Ao Nang and Nopparat Thara Beach in Krabi, and Thap Lamu in Phang Nga have similarly exceeded standards. Therefore, the development of wastewater collection and treatment systems in these areas should be promoted to protect water quality and minimize the impacts on marine and coastal resources and tourism. It is also important to foster integration between agencies to ensure continuous water quality monitoring.

The governance approach in Phang Nga Bay shows a diverse range of stakeholders and mechanisms for co-governance, emphasizing community participation and promoting good governance. However, there are obstacles, such as poor communication, lack of trust among local stakeholders, and other issues that hinder the effectiveness of co-governance. It is essential to promote local-level activities in collaboration with stakeholders, providing opportunities for them to be involved in all processes. This will strengthen interactions and relationships between stakeholders and foster local understanding. These efforts will help reduce conflicts over the use of marine and coastal resources and mitigate the impacts of land-based human activities. Furthermore, cross-sectoral integration should be encouraged to ensure effective management of the environmental impacts or pollution resulting from land-based economic activities.

Acknowledgments

The authors express deep gratitude to various agencies, particularly the Department of Marine and Coastal Resources, for the provision of secondary data. This article is a part of the project “The pilot study and data analysis for the establishment of ocean accounts in Phang Nga Bay, Phang Nga, Phuket, and Krabi Province,” funded by the National Research Council of Thailand and coordinated by the Department of Marine and Coastal Resources. We also appreciate constructive comments and helpful recommendations from anonymous reviewers, making this manuscript comprehensive.

Appendix. Supporting information

Supplementary data to this article can be found online at https://drive.google.com/drive/folders/1dtJhYBvxKnrsv-S8KAOGqiHU_6ilDZUH?usp=sharing

References

Alarcon Blazquez MG, van der Veeren R, Gacutan J, James PAS (2023) Compiling preliminary SEEA

Ecosystem Accounts for the OSPAR regional sea: experimental findings and lessons learned. One Ecosystem 8:e108030

Armoškaitė A, Puriņa I, Aigars J, Strāķe S, Pakalniete K, Frederiksen P, Schrøder L, Hansen HS (2020) Establishing the links between marine ecosystem components, functions and services: An ecosystem service assessment tool. Ocean Coast Manage 193:105229

Campos P, Mesa B, Álvarez A, Oviedo JL, Caparrós A (2022) Towards measuring environmental income through a refined United Nations SEEA EA: Application to publicly-owned, protected, pine-forest-farm case studies in Andalusia, Spain. Ecol Econ 201:107570

Chuenchum, P, Pattanapong, N, Suttinon, P, Ruangrassamee P. 2018. Cross-sectoral analysis of water usage in Thailand Using Input–Output Model. Engineering Journal 22(6): 93- 115.

Coleman FC, Williams SL (2002) Overexploiting marine ecosystem engineers: potential consequences for biodiversity. Trends Ecol Evol 17:40-44

Cummins GH, Navarro ML, Griffin K, Partridge J, Langlois TJ (2023) A global review of ocean ecosystem accounts and their data: Lessons learned and implications for marine policy. Mar Policy 153:105636

Ding Q, Chen X, Chen Y, Tian S (2017) Estimation of catch losses resulting from overexploitation in the global marine fisheries. Acta Oceanol Sin 36:37-44

DMCR (2024) State of Marine and Coastal Resources and Coastal Erosion: Thailand National Report 2023. Department of Marine and Coastal Resources. 627 pp.

Duffy JE (2009) Why biodiversity is important to the functioning of real-world ecosystems. Front Ecol Environ 7:437-444

Dvarskas A (2019) Experimental ecosystem accounting for coastal and marine areas: A pilot application of the SEEA-EEA in Long Island coastal bays. Mar Policy 100:141-151

Ehlers P (2016) Blue growth and ocean governance—how to balance the use and the protection of the seas. Wmu J Marit Aff 15:187-203

Gacutan J, Galparsoro I, Pınarbaşı K, Murillas A, Adewumi IJ, Praphotjanaporn T, Johnston EL, Findlay KP, Milligan BM (2022b) Marine spatial planning and ocean accounting: Synergistic tools enhancing integration in ocean governance. Mar Policy 136:104936

Gacutan J, Lal KK, Herath S, Lantz C, Taylor MD, Milligan BM (2022a) Using Ocean Accounting towards an integrated assessment of ecosystem services and benefits within a coastal lake. One Ecosystem 7:e81855

Gacutan J, Pınarbaşı K, Agbaglah M, Bradley C, Galparsoro I, Murillas A, Adewumi I, Praphotjanaporn T, Bordt M, Findlay K, Lantz C, Milligan BM (2022c) The emerging intersection between marine spatial planning and ocean accounting: A global review and case studies. Mar Policy 140:105055

Gallegati S, Masiá P, Fanelli E, Danovaro R (2025) The impact of natural capital loss on blue-tourism economy: The Red Sea case study. Mar Policy 172:106507

GOAP (2021). Technical Guidance on Ocean Accounting for Sustainable Development v.1.0. Global Ocean Accounts Partnership. 285 pp.

González Hernández MM, León CJ, García C, Lam-González YE (2023) Assessing the climate-related risk of marine biodiversity degradation for coastal and marine tourism. Ocean Coast Manage 232:106436

Hossain MA, Islam MN, Fatima S, Kibria MG, Ullah E, Hossain ME (2024) Pathway toward sustainable blue economy: Consideration of greenhouse gas emissions, trade, and economic growth in 25 nations bordering the Indian ocean. J Clean Prod 437:140708

IPBES (2019), Global assessment report of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Brondízio, E. S., Settele, J., Díaz, S., Ngo, H. T. (eds). IPBES secretariat, Bonn, Germany.

Januar, R., Furqan, R., Wijaya, A. (2022). Ecosystem Services Factors. Global Ocean Accounts Partnership. 153 pp.

Kaenchan, P, Gheewala, SH 2017. Budget constraint and the valuation of environmental impacts in Thailand. The International Journal of Life Cycle Assessment, 22(11): 1678-1691.

Kunanuntakij, K., Varabuntoonvit, V., Vorayos, N., Panjapornpon, C., Mungcharoen, T. 2017. Thailand Green GDP assessment based on environmentally extended input-output model. Journal of Cleaner Production, 167: 970-977

Leposa N (2020) Problematic blue growth: a thematic synthesis of social sustainability problems related to growth in the marine and coastal tourism. Sustain Sci 15:1233-1244

Lotze HK (2021) Marine biodiversity conservation. Curr Biol 31:R1190-R1195

Meerod, W, Santithaweeruek, Y, Bumroongwong, K (2018). Developing the System of Environmental-Economic Accounting for Blue Economy (SEEA-Blue Economy) in Thailand Context. The report presented to the Thailand Research Fund. 234 pp.

Miller, Ronald E, Blair PD (2009) Input-output Analysis: Foundations and Extensions, 2nd ed. Cambridge: Cambridge University Press.

Moses C, Robinson D, Kazmer M, Williams R (2015) Towards an improved understanding of erosion rates and tidal notch development on limestone coasts in the Tropics: 10 years of micro-erosion meter measurements, Phang Nga Bay, Thailand. Earth Surf Proc Land 40:771-782

Palumbi SR, Sandifer PA, Allan JD, Beck MW, Fautin DG, Fogarty MJ, Halpern BS, Incze LS, Leong JA, Norse E, Stachowicz JJ, Wall DH (2009) Managing for ocean biodiversity to sustain marine ecosystem services. Front Ecol Environ 7:204-211

Pascal N, Allenbach M, Brathwaite A, Burke L, Le Port G, Clua E (2016) Economic valuation of coral reef ecosystem service of coastal protection: A pragmatic approach. Ecosyst Serv 21:72-80

Pinto R, de Jonge VN, Marques JC (2014) Linking biodiversity indicators, ecosystem functioning, provision of services and human well-being in estuarine systems: Application of a conceptual framework. Ecol Indic 36:644-655

Rist L, Norström A, Queiroz C (2024) Biodiversity, peace and conflict: understanding the connections. Curr Opin Env Sust 68:101431

Samonte-Tan GPB, White AT, Tercero MA, Diviva J, Tabara E, Caballes C (2007) Economic Valuation of Coastal and Marine Resources: Bohol Marine Triangle, Philippines. Coast Manage 35:319-338

Stankovic M, Ambo-Rappe R, Carly F, Dangan-Galon F, Fortes MD, Hossain MS, Kiswara W, Van Luong C, Minh-Thu P, Mishra AK, Noiraksar T, Nurdin N, Panyawai J, Rattanachot E, Rozaimi M, Soe Htun U, Prathep A (2021) Quantification of blue carbon in seagrass ecosystems of Southeast Asia and their potential for climate change mitigation. Sci Total Environ 783:146858

Thiagarajan C, Devarajan Y (2024) The Urgent Challenge of Ocean Pollution: Impacts on Marine Biodiversity and Human Health. Reg Stud Mar Sci:103995

Tisdell CA, Hazra S (2022) The Conservation of Marine Biodiversity in South Asia and the Blue Economy. In: Hazra S, Bhukta A (eds) The Blue Economy: An Asian Perspective. Springer International Publishing, Cham, pp181-199

UN (2012). The System of Environmental-Economic Accounting for Water (SEEA-Water). United Nations: New York. 197 pp.

UN (2014). System of Environmental-Economic Accounting 2012: Central Framework. United Nations: New York. 346 pp.

UN (2019). The System of Environmental-Economic Accounting for Energy (SEEA-Energy). United Nations: New York. 161 pp.

UN (2020). The System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries (SEEA-AFF). United Nations: New York. 134 pp.

UN (2024). System of Environmental-Economic Accounting – Ecosystem Accounting (SEEA-EA). United Nations: New York. 409 pp.

UN ESCAP. n.d. Thailand ocean accounts pilot: case study on sustainable tourism, the environment and the ocean tourism satellite account and SEEA (TSA-SEEA) in the tourism development cluster Andaman (Phuket, Krabi, Phang Nga, Trang, Satun Province) Retrieved from http://communities.unescap.org/system/files/04.1.3_pilot_tha_-_ocean_accounts_final_report_5_pages_summary.pdf

Wajeetongratana, P. 2018. Environmental Accounting for Thailand Business Competitiveness Stimulation: Modern Interpretation and Implementation Algorithms. Advanced Science Letters 24(9): 6317-6319.

Wang Z, Wang T, Zhang X, Wang J, Yang Y, Sun Y, Guo X, Wu Q, Nepovimova E, Watson AE, Kuca K (2024) Biodiversity conservation in the context of climate change: Facing challenges and management strategies. Sci Total Environ 937:173377

Warner JC, Armstrong B, He R, Zambon JB (2010) Development of a Coupled Ocean–Atmosphere–Wave–Sediment Transport (COAWST) Modeling System. Ocean Model 35:230-244

Wernberg T, Russell BD, Moore PJ, Ling SD, Smale DA, Campbell A, Coleman MA, Steinberg PD, Kendrick GA, Connell SD (2011) Impacts of climate change in a global hotspot for temperate marine biodiversity and ocean warming. J Exp Mar Biol Ecol 400:7-16

Yan HF, Kyne PM, Jabado RW, Leeney RH, Davidson LNK, Derrick DH, Finucci B, Freckleton RP, Fordham SV, Dulvy NK (2021) Overfishing and habitat loss drive range contraction of iconic marine fishes to near extinction. Sci Adv 7:eabb6026

Younesi M, Saadatpour M, Afshar A (2024) Integration of the system of environmental economic accounting-ecosystem accounting (SEEA-EA) framework with a semi-distributed hydrological and water quality simulation model. Ecosyst Serv 70:101672

Yuan M-H, Lin K-T, Pan S-Y, Yang C-K (2024) Exploring coral reef benefits: A systematic SEEA-driven review. Sci Total Environ 950:1752