

Assessing Eutrophication in the Coastal Bay by ASSETS Index Model

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Abstract—Xuan Dai is a coastal bay in Phu Yen Province, Vietnam. The bay has an area of 80 km² and a considerable depth from 8 to 18 m. This is an ecologically diverse area with great potential for aquaculture and fishing, which brings significant benefits to the people in the region. For years, the excessive development of aquaculture has enriched the water in the bay, resulting in mass deaths of lobsters. In this study, the ASSETS index model has been applied to Xuan Dai Bay to determine the trophic status and the natural and man-made processes related to eutrophication. The study results showed that the core zone of Xuan Dai Bay (CZ) was classified with a high influencing factor, with a high eutrophic condition, with a “no change” future outlook, and with a bad final overall ASSETS grade. Ky Lo Estuary (KLE) presents a low pressure, a low eutrophic condition, a “no change” future outlook, and a good final ASSETS index. These mean that CZ had a poor trophic status or the eutrophication happened in this system; whereas, KLZ presented a good trophic condition or no eutrophication. A basic management plan and early warning monitoring should take into consideration the condition of the water body to preserve the good trophic condition in KLZ, especially during dry seasons. For CZ, three groups of solutions have been proposed, including nutrient management, ecosystem restoration, and further researches. The results of the study also reveal the significance and benefit of applying integrated methods in water quality assessment and management in coastal zones. Deep understanding of water retention time, typology, nutrient loading, and the land/water uses of a system is the key factor for trophic status management strategy.

Keywords — trophic state; eutrophication; ASSETS model; Xuan Dai Bay.

I. INTRODUCTION

The sea environment has high levels of complexes, diverse habitats, and high production capacity [1]. They provide services and goods assisting a variety of uses that should be carried out sustainably. Nevertheless, sea environments are suffered from great impacts due to changes in natural characteristics, ecology destruction, and biodiversity degradation [2]. Eutrophication is one of the threats, which has left bad consequences for the health and integrity of water bodies in general, and coastal and transitional waters in special [3]–[5]. Eutrophication is a gradual process governed by the excessive abundance of inorganic nutrients, usually nitrogen and phosphorus, causing overgrowth and primary production, the biomass of algae, and degradation of water quality [6]. According to the European Marine Strategy Framework Directive (MSFD, 2008/56/EC) [6], unexpected consequences of eutrophication consist of losses in the ecosystem, biodiversity degradation,

lack of oxygen in the water column, and blooms of harmful algal. There are three kinds of harmful algae blooms: (1); potentially toxic algae; (2) harmful algae to shellfish even at low occurrence; and (3) high-biomass blooms those cause problems mainly because of the high-biomass itself [7]. Sometimes, high-biomass blooms are called “red tide”; nevertheless, in fact, they could be green, white, or brown discolorations of the sea. Phosphorous is adopted as the limiting factor in freshwaters, while nitrogen in transition and sea waters. However, eutrophication in estuarine and coastal bay systems in tropical areas is generally driven by a constant growth period and seasonal variability, which depends on changes in temperature, precipitation, and tidal exchange. On the other hand, seasonal light limitation of growth is the main characteristic of temperate systems [8].

In the passing years, eutrophication classification tools have been developed to assess the trophic state of human-impacted coastal water, enclosed seas, and bay waters [9]–[11]. These tools normally use the direct and indirect performances of eutrophication in sea environments. The

widely used tools are Trophic Index (TRIX), Eutrophication Index (E.I.), Transitional Water Quality Index (TWQI/LWQI), HELCOM Eutrophication Assessment Tool (HEAT), US Environmental Protection Agency National Coastal Assessment [3], [7], [10], [13]. Staniszewski et al. state that evaluating the trophic state of freshwaters is inefficient when only chemical data are used without any biological information of the system [14]. This statement is also true in the case of seawater. Ferreira et al. [7] have overviewed evaluating methods on eutrophication within the MSFD. They conclude that most eutrophication assessment methods take the first biological response is the increase in primary production, which is shown in increased chlorophyll a (Chl-a) and/or macroalgae occurrence. These are “direct effects” (primary symptoms), and reveal the primary stages of eutrophication. “Indirect effects” (secondary symptoms), which indicate additional well- developed issues, are low dissolved oxygen, occurrences of nuisance and toxic blooms, and losses of submerged aquatic vegetables (SAV) [7]. Most eutrophication assessment methods combine biological with physicochemical data that give information at an acceptable level of understanding as a basis for management strategy. Although some methods (TRIX, EPA NCA Water Quality Index) apply only selected physicochemical variables like dissolved oxygen, Chl-a, and nutrients, while others integrate additional water column parameters and biological data, such as the abundance of harmful algal bloom, macroalgae abundance, and changes in the distribution of SAV (e.g., ASSETS model). Many tools consider both “direct” and “indirect” performances of the eutrophication to give the best assessment of the nutrient status of the water systems (see [1]).

In this study, the Assessment of Estuarine Trophic Status (ASSETS) has been applied to Xuan Dai Bay to determine the trophic status and the natural and man-made processes related to eutrophication. ASSETS is a multi-index model which was developed by specialists taking part in the NOAA’s Estuarine Eutrophication Survey to evaluate the trophic and eutrophication state of coastal areas and estuaries of USA [15]. This method was also used to determine trophic status for 141 individual systems in a study by Bricker et al. [16], for one estuarine delta and four coastal lagoons at eastern Brazil by Luiz et al. [8], for the Marano and Grado Lagoon at Mediterranean coast by Acquavita [13], for Daya Bay of China by Wu et al. [17], for the Gulf of California by Ruiz-Ruiz et al. [18]. Studies show that the ASSETS index model seems to be strong enough to be applied to a range of different coastal systems [7].

II. MATERIAL AND METHODS

A. Study Area

Xuan Dai (latitude 13°20’30”–13°29’30”, and longitude 109°13’00”–109°20’30”) is a coastal bay in Phu Yen Province, Vietnam. The bay has an area of 80 km² and a considerable depth from 8 to 18 m. [19]. There are two rivers (Ky Lo River and Cau River) flowing into the bay. There is different resource exploitation in the bay because this is an ecologically diverse area, with a great potential for aquaculture and fishing, and brings significant benefits to the people in the region. Natural fishing in the bay consists of

the collection of spiny lobsters for culture and inshore capture fish. Aquaculture comprises lobster farming in ponds along the bay edge, and in submerged cages in the bay. The development of lobster culture has left bad effects on the water quality in the bay for years. Around Xuan Dai Bay, there are more than 2,300 households farming lobsters with nearly 66,800 cages. The intensive lobster farming and the prompt increase in the number of farming cages have been deteriorating the water quality of the bay. In May and June 2017, more than 1.6 million lobsters of 693 households in the bay died. In April 2019, this issue happened again, but it was in smaller quantities. One of the causes of this phenomenon is due to eutrophication in the bay [20].

Due to the natural beauty and unique landscape, Xuan Dai Bay has been approved by the Vietnamese Prime Minister to become a National tourism area by 2030. However, the aquaculture development in the bay currently conflicts with the plan to develop Xuan Dai Bay being the National tourism area. The restoration and protection of water quality, as well as the ecological values of Xuan Dai Bay, are the key tasks of the local authority.



Fig. 1 Study area

In this study, according to its typology, hydrodynamic regime, and land and water use, we divided Xuan Dai Bay into two components (Figure 1): the core zone of Xuan Dai Bay (CZ), and Ky Lo estuary (KLE). The main characteristics of the two components are summarized in Table 1.

TABLE I
CHARACTERISTICS OF THE TWO STUDY COMPONENTS IN XUAN DAI BAY

Features	KLE	CZ
Estuarine area (< 0.5 psu) (km ²)	5	0
Mixing zone area (0.5 - 25 psu) (km ²)	15	5
Seawater zone area (> 25 psu) (km ²)	20	30
Discharge (m ³ /s)	101	2
Rainy	30	6
Dry	65.5	10
Annual		
Average depth (m)	15	8
Estuarine volume (x10 ⁶ m ³)	300	245
The fraction of ebb water which is not replaced	0.4	0.16
Tidal prism (x10 ⁶ m ³)	120	40
Tidal range (m)	1.14	1.14
Number of tides per day	1	1
Catchment area (km ²)	1.920	213
Pressures	Rural Aquaculture Agriculture	Rural Aquaculture Agriculture

Note: KLE = Ky Lo Estuary; CZ = The core zone of Xuan Dai Bay [19]

B. Assessment of Estuarine Trophic Status (ASSETS) index model

1) *Pressure - Overall Human Influence (OHI)*: This indicator refers to nutrient inputs as they are modified by natural hydrology of the systems. Hydrologic and physical data of the water body are used separately to determine the flushing and dilution ability. Then, the flushing and dilution potential are combined to produce a susceptibility rating. Lower flushing and dilution ability lead to higher retention times for nutrients or higher susceptibility. The opposite situation can result in reducing eutrophication or low susceptibility. Nutrient input (as DIN) is determined as the followings [8]:

$$M_b = (\varepsilon T_p M_{sea}) (\varepsilon T_p + Q T)^{-1} \quad (1)$$

$$M_h = (T[Q M_{in} + M_{ef}]) (\varepsilon T_p + Q T)^{-1} \quad (2)$$

$$\text{Nutrient input} = M_h / (M_h + M_b) \quad (3)$$

where M_b is the mass of nutrient exchange with the ocean (in kilograms per cubic meter), ε is the fraction of water leaving the bay at ebb tides and does not return in the flood, T_p is the tidal prism (in cubic meters), M_{sea} is the DIN concentration offshore (in kilograms per cubic meter), Q is the freshwater input (in cubic meters per second), T is the tidal period (seconds), M_h is the anthropogenic influence (in kilograms per cubic meter), M_{in} is the DIN load from the rivers (in kilograms per cubic meter), and M_{ef} is the effluent discharge (in kilograms per second).

The nutrient input index is classified into three grades as high (0.8–1), moderate (0.4–0.8), and low (0–0.4).

The susceptibility and nutrient input index are combined to get the final overall human influence, which is ranked into five categories, as shown in Table 2.

2) *State - Overall Eutrophic Conditions (OEC)*: Overall eutrophic condition is the nutrient-related water quality conditions. OEC is calculated by combining primary symptoms with secondary symptoms, applying an aggregation matrix [16]. The primary symptoms are Chl-a

(90th percentile of average annual data values), and macroalgae. The secondary symptoms are DO (10th percentile of average annual data values), changes in the coverage of SAV, and the abundance of nuisance and/or harmful algal blooms (HABs). Primary and secondary symptom index is created by generating the abundance, frequency, and spatial coverage of occurrence of concentrations that are considered a problem and comparing it to reference conditions and limitations. The OEC is classified as presented in Table 2.

3) *Response - Future Outlook (FO)*: This is an indicator of management response, which provides a future condition of the system status based on predicted changes in nutrient loads and susceptibility. The assessment of expected changes in nutrient pressure is based on expected population changes, future treatment and remediation plans, and changes in watershed use. In this study, the main watershed use is lobster farming. The susceptibility component is combined with expected changes in nutrient pressure to determine the future outlook. The future outlook is framed into five classes, from worse to better [15].

TABLE II
CATEGORIES FOR OVERALL HUMAN INFLUENCE; OVERALL EUTROPHIC CONDITIONS; FUTURE OUTLOOK

Grade	OHI	OEC	FO
1	High	High	Worsen high
2	Moderate high	Moderate high	Worsen low
3	Moderate	Moderate	No change
4	Moderate low	Moderate low	Improve high
5	Low	Low	Improve high

Note: OHI = Overall Human Influence; OEC = Overall Eutrophic Conditions; FO = Future Outlook

4) *Integration - the overall ASSETS grade*: The pressure, state, and response indicators are grouped by combining the different index scores to get an overall index. The individual categories for OHI, OEC, and FO showed in Table 2 are integrated to give an overall ASSETS grade. The overall ASSETS grade may fall into one of five classifications: bad, poor, moderate, good, or high [8].

C. Sampling strategy and data analysis

Four water sampling campaigns were performed covering the wet and dry seasons in March, June, July, and December 2018 with 30 stations. Dissolved nutrient (ammonia, nitrite, and nitrate) samples were in-situ filtered by Whatman GF/F filter paper. Chl-a samples were in-situ filtered by Whatman GF/C filter paper. Dissolved oxygen and salinity were measured in situ by a water quality checker, WQC- 22A (TOA, Japan). Chl-a was determined by the TriLux Multi-parameter algae sensor (Chelsea - UK). Dissolved inorganic nitrogen is determined by the spectroscopic method on a UV-VIS Jasco V-630 (Japan) [21]. All water samples were preserved on the ice and in the dark during the transport to the respective laboratory. In the laboratory, the samples were preserved at -18°C prior to analyses.

The DO and Chl-a data were processed to determine values at the 10th percentile and 90th percentile, respectively. These results are shown in Table 4, 5.

During the field visit, we observed the occurrence and distribution of SAV, macroalgae, and toxic algae in the bay. We also did a quick interview with local people to get this

information in the past. Further information and data on occurrences, frequency, species composition SAV blooms, and HABs were referenced from [19], [20], [22].

III. RESULTS AND DISCUSSION

A. Pressure - Overall human influence (OHI)

The results of the evaluation and classification by the ASSETS model showed that the core zone of Xuan Dai Bay was highly sensitive to eutrophication, while Ky Lo Estuary had low susceptibility. The core zone of Xuan Dai is a closed bay and fed by the Cau River. Due to a small basin area of 113 km², this river has a low discharge rate with an annual average flow of 10 m³/s [19]. This means that the water volume of the bay does not change much by seasons, and depends on the tide. However, the tidal magnitude at this area is low (1.14 m), the depth of the bay is considerable (average 8 m), and the bay surface is large (40 km²). These natural properties make the dilution and flushing potential of this area is weak. According to [19], the retention time of water of the core zone of Xuan Dai Bay is from 5 to 28 days. Therefore, the retention time of nutrients in the water body is high, or the water body has a high susceptibility.

In contrast to the core zone of Xuan Dai Bay, the low susceptibility to eutrophication of Ky Lo Estuary is due to its open access to the sea, high tidal range, and much higher river discharge, resulting in high dilution and flushing ability. This leads to the rapid release of nutrients into the sea and keeps primary production low.

Table 3 presents average DIN concentrations in fresh and marine waters, calculated loading from man-made effluents to the systems, the respective scores, and classifications of nutrient input for the two systems. The monitoring results in this study showed that the average concentration of DIN in the river (M_{in}) in KLE was higher, with 5×10^{-4} kg/m³ than in CZ with 3.6×10^{-4} kg/m³. Offshore surface concentration was 9×10^{-5} kg/m³. Due to the intensive aquaculture activities with high density in CZ, the human load into the systems derived from waste sources (M_{ef}) was three times higher in this area than that in KLE. It is reported that every day, farmers feed

cultured lobsters in CZ with over 2,000 tons of food [19]. Meanwhile, nitrogen loading at KLE is only from the extensive agriculture and rural areas. Consequently, nutrient input is rank as “low” at KLE and “medium” at CZ.

The combination of the nutrient input and susceptibility scores results in the OHI. The medium nutrient loading combined with high susceptibility at CZ results in a moderate-high classification of OIH. For KLE, the low nutrient loading and susceptibility release a low classification of OHI.

TABLE III
NUTRIENT LOADING SCORES AND GRADES FOR BOTH SYSTEMS

Parameter	KLE	CZ
M_{in} (kg/m ³)	5×10^{-4}	3.6×10^{-4}
M_{sea} (kg/m ³)	9×10^{-5}	9×10^{-5}
M_{ef} (kg/s)	1.63	4.63
M_b (kg/m ³)	7.9×10^{-5}	7.9×10^{-5}
M_h (kg/m ³)	1×10^{-4}	5.5×10^{-5}
$M_h/(M_h + M_b)$	0.55	0.4
Nutrient input	Low	Medium

B. State - Overall Eutrophic Conditions (OEC)

According to the monitoring results, Chl-a concentration in CZ ranged from 2 to 20 µg/L. There is no seasonal difference. More than half of CZ had the 90th percentile value for Chl-a of 15 µg/L. At KLE, the 90th percentile concentrations for Chl-a in three zones (estuarine, mixing, seawater) were from 6.5 to 10 µg/L with high spatial coverage (> 50%), and a periodic frequency of abundance (Table 4). Microalgae occur in both systems. The major problem throughout the year in CZ is the massive spatial coverage of macroalgae, which accounts for more than 50% of the surface area, whereas KLE was dominated by phytoplankton. The results of the ASSETS model showed that the primary symptoms of eutrophication in CZ were classified as high, with a score of 1 (Table 4). The final ASSET rating for primary symptoms at KLE is low, with a score of 0.25.

TABLE IV
PRIMARY SYMPTOM PARAMETERS AND CLASSIFICATION RESULTS ACCORDING TO THE ASSETS MODEL

The core zone of Xuan Dai Bay (CZ)						
Zone	Area (km ²)	Chl-a (90 th percentile)			Macroalgae	
		Value (µg/L)	Spatial coverage	Frequency	Abundance	Frequency
Estuarine	0	-	-	-	-	-
Mixing	5	6	High (>50%)	Periodic	Observed	Periodic
Seawater	30	15	High (>50%)	Periodic	Observed	Periodic
Parameter ratings		High (1)			High (1)	
Indicator rating		High (1)				
Ky Lo Estuary (KLE)						
Zone	Area (km ²)	Chl-a (90 th percentile)			Macroalgae	
		Value (µg/L)	Spatial coverage	Frequency	Abundance	Frequency
Estuarine	5	6.5	High (>50%)	Periodic	-	-
Mixing	15	10	High (>50%)	Periodic	Observed	Episodic
Seawater	20	7	High (>50%)	Periodic	Observed	Episodic
Parameter ratings		Low (0.25)			Moderate (0.5)	
Indicator rating		Low (0.25)				

Note: - means not applicable. The values in parentheses are evaluation scores according to the ASSETS model.

For the secondary symptoms, there is not any information or data for SAV in previous studies. However, low contents of DO and HABs in CZ was recorded [20], [22]. KLE has not exhibited values revealing biological stresses related to the DO concentration. The 10th percentile DO values in different zones of KLE ranged from 6.4 to 7.0 mg/L (Table 5), and were good enough for aquatic species. KLE has a

low final grade for secondary symptoms. For CZ, the secondary symptoms are more serious. The 10th percentile DO values in this area were 3.5 and 4 mg/L (biological stress) with a high periodic frequency of occurrence. CZ presented moderate conditions related to the secondary symptoms because the occurrence of HABs happens frequently.

TABLE V
SECONDARY SYMPTOM PARAMETERS AND CLASSIFICATION RESULTS ACCORDING TO THE ASSETS MODEL

The core zone of Xuan Dai Bay (CZ)								
Zone	Area (km ²)	DO (10 th percentile)			Nuisance and toxic blooms			SAV
		Value (µg/L)	Spatial coverage	Frequency	Problems	Duration	Frequency	
Estuarine	0	-	-	-	-	-	-	-
Mixing	5	4.0	High (>50%)	Periodic	Observed	Monthly	Periodic	-
Seawater	30	3.5	High (>50%)	Periodic	Observed	Weekly	Periodic	-
Parameter ratings		Moderate (0,5)			High (1)			-
Indicator rating		High (1)						
Ky Lo Estuary (KLE)								
Zone	Area (km ²)	DO (10 th percentile)			Nuisance and toxic blooms			SAV
		Value (µg/L)	Spatial coverage	Frequency	Problems	Duration	Frequency	
Estuarine	5	6.7	High (>50%)	Periodic	No problem	No problem	No problem	-
Mixing	15	7.0	High (>50%)	Periodic	No problem	No problem	No problem	-
Seawater	20	6.4	High (>50%)	Periodic	No problem	No problem	No problem	-
Parameter ratings		Low (0,25)			No problem (0.25)			-
Indicator rating		Low (0.25)						

Note: “-” means not applicable. The values in parentheses are evaluation scores according to the ASSETS model

The results of the combination between primary with secondary symptoms to determine eutrophic conditions for the two systems are presented in Tables 6 and 7. High primary and secondary symptom levels result in a high OEC at CZ and indicate serious eutrophication problems in this system. KLE was graded as low OEC. It means that the level of performance of eutrophic status at KLE is minimal.

C. Response - Future outlook (FO)

The FO is an assessment of future nutrient pressures and the susceptibility of the systems. The susceptibilities of the systems have been assessed in part “Pressure - Overall human influence (OHI).” At present, Phu Yen province has a plan to re-arrange aquaculture activities at Xuan Dai Bay, and to reduce the number of farming cages; consequently, the amount of nutrient pressure from the aquaculture activities to the bay is expected to decrease. However, Xuan Dai Bay is planned to become a National Tourist Area, so that the amount of nutrient releasing from tourism and domestic activities will increase. So far, Phu Yen province has not had any plan to implement pollution treatment at the

sources before discharging into the bay. From the above analysis, the future nutrient pressures are assumed to be unchanged in comparison with the current nutrient input. The integration of the “no change” future nutrient pressure and high susceptibility results in the “no change” FO at CZ. Similarly, the low susceptibility and the “no change” future nutrient pressure led to the “no change” FO at KLE. Nutrient – related symptoms will most likely remain unchanged in both systems.

D. The final overall ASSETS grade

The combined pressure - state - response indices are presented in Table 6. CZ presented high eutrophic condition and pressure, and a “no change” future outlook; consequently, the final ASSETS grade in this system was poor. KLE was classified with low pressure, a low eutrophic condition, a “no change” future outlook, and a good final ASSETS index. These mean that CZ had a poor trophic status or the eutrophication happened in this system. KLE presented a good trophic condition or no eutrophication.

TABLE VI
CATEGORIES FOR OVERALL HUMAN INFLUENCE; OVERALL EUTROPHIC CONDITIONS; FUTURE OUTLOOK, AND THE FINAL ASSETS INDEX FOR CZ

Indices	Indicators	Parameters	Parameter ratings	Indicator ratings	Index ratings	Final ASSETS
Overall Human Influence (OHI)	Susceptibility	Dilution potential Flushing potential	Low Low	High	High	Poor
	Nutrient inputs			Moderate		
Overall Eutrophic Condition (OEC)	Primary symptoms	Chl-a Macroalgae	High High	High	High	
	Secondary symptoms	DO SAV Nuisance and toxic blooms	Moderate - High	High		
Future Outlook (FO)	Susceptibility	Dilution potential Flushing potential	Low Low	High	No change	
	Future nutrient pressure			No change		

TABLE VII
CATEGORIES FOR OVERALL HUMAN INFLUENCE; OVERALL EUTROPHIC CONDITIONS; FUTURE OUTLOOK, AND THE FINAL ASSETS INDEX FOR KLE

Indices	Indicators	Parameters	Parameter ratings	Indicator ratings	Index ratings	Final ASSETS
Overall Human Influence (OHI)	Susceptibility	Dilution potential Flushing potential	High High	Low	Low	Good
	Nutrient inputs			Moderate		
Overall Eutrophic Condition (OEC)	Primary symptoms	Chl-a Macroalgae	Low Moderate	High	Low	
	Secondary symptoms	DO SAV Nuisance and toxic blooms	Low - No problem	High		
Future Outlook (FO)	Susceptibility	Dilution potential Flushing potential	High High	Low	No change	
	Future nutrient pressure			No change		

E. Recommendations for management

The results of the ASSETS assessment are consistent with the average annual condition of the systems. It should be noted that the natural susceptibility (related to the ability to dilute and exchange nutrients) of water bodies is greatly dependent on the retention times of water, which vary with seasons. It is also dependent on the river discharges governed by precipitation [8]. In the ASSETS model, the natural susceptibility directly affects the influencing factors. The eutrophic condition gets better if the freshwater flow is larger. In this situation, nutrients pass through the system; consequently, primary producers potentially absorb lower nutrients. These conditions especially express in systems that have flow variations with seasons, like in KLE. Therefore, the conclusion of the good trophic condition by the ASSETS model in KLE does not probably reflect the reality. It means that in the ASSETS model, the hydrologic and physical components relating to the dilution and flushing potential have an important role in assessing the level of the trophic status rather than only the nutrient loading itself [8]. Seasonal change in the eutrophication level can happen in this system. A basic management plan and early warning monitoring should take into consideration the condition of the water body, the sources of nutrients, and expected changes in source amounts, especially during dry seasons.

CZ is a closed bay with a moderate tidal range. These conditions are favorable for aquaculture. However, the freshwater flow into this system has no different conditions between the seasons, revealing that the eutrophication lasts throughout the year, mainly due to its longer water retention periods. The sensitivity of CZ to eutrophication is fixed because it depends on the natural conditions of the system. To improve the trophic status of CZ, it must reduce the current and future nutrient loads. Measures need to be done to strictly manage lobster farming activities in the bay, re-plan the location of farming cages to improve the current circulation from the bay to the sea, and tidal current from the sea in the bay, and gradually reduce the number of farming cages. Researches on livelihood conversion for fishermen should be concentrated when reducing the number of farming cages and households in the bay. Automatic monitoring of water quality in the farming areas should be set up to promptly detect water pollution problems, and catch critical or extreme events. Aquaculture community management teams should be established to support the implementation of the Sustainable Aquaculture Development Plan in Xuan Dai Bay approved by the People's Committee of Phu Yen Province. Finally, restoration programs and measures of seagrasses, oyster beds, and wetlands are needed to contribute to enhancing the water quality of the bay.

IV. CONCLUSION

The approach of the ASSETS index model has demonstrated that natural characteristics have a great influence on the trophic status of the water body. To understand the environmental state, and to manage a coastal water system, it must be considered the dilution and flushing potential, nutrient loads, eutrophic conditions, and knowledge of the land or water uses. Currently, the ASSETS model only considers the nitrogen nutrient. More researches on phosphorus nutrient should be considered in the ASSETS model beside nitrogen to make a comprehensive evaluation of the trophic state of coastal waters.

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