

Environmental Changes of Lagoon Ecosystem in South East Asia Region: Ecological Perspectives and Future Directions

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Abstract:

Lagoons are valuable ecosystems which play an important role in providing ecological services to coastal populations, sources of freshwater and refuge of fauna species. They are fragile ecosystems which are susceptible to degradation in the face of environmental changes due to natural or anthropogenic impacts. South East Asia has the highest diversity of lagoon species and habitat types, but basic information on lagoon habitats is still lacking. The assessment of lagoon ecosystem indicates the general valuation of natural resources that affected by direct and indirect anthropogenic activities. A thorough review of literature showed that very little work has been carried out on lagoon ecosystem functions and future management directions in South East Asia region. The most notable research in this aspect has been the recent findings by secondary sources, which provided an insight into the lagoon ecology of particular functions and future management directions in ecosystems of selective countries. This study unveils the embryonic potential and role of lagoon in tropical ecosystem management which could be a source of thought for future research in land use planning in coastal areas, nature conservation for tourism, aquaculture and sustainable management of these lagoon ecosystems.

Keywords: Lagoons, Ecosystems, Environmental Changes, South East Asia

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I. Introduction

South East Asia is composed of eleven countries of impressive diversity in religion, culture and history: Brunei, Myanmar, Cambodia, Timor-Leste, Indonesia, Laos, Malaysia, the Philippines, Singapore, Thailand and Vietnam. Now lagoons are most threatens areas which largely accounts for its growing international significance. Lagoons are located at the land-sea interface and are generally characterized by high biological productivity and shallowness that are linked by open sea. Lagoons occupied by the most biodiversity habitat and provided essential goods and services such as fisheries, coastal protection, recreation and tourism. Lagoon ecosystem has been damaged by anthropic development, such as changes in land use patterns for agricultural activities, loss of mangroves due to logging and modifications, carried out by local stakeholders, to the natural environment of the lagoon that alter the water quality and affect the aquatic species (Chacón et al., 2021). However, in spite of these services, lagoons are threatened by human activities, coastal erosion, disaster and climate change, and better information on their ecological and socio-economic importance is needed to achieve their conservation and sustainable use. They are used by many fish and bird species, either as feeding, nursery or spawning grounds in lagoon areas by their partial or entire life cycles (Constanza et al., 1997; Oertli et al., 2005), and are classified as confined areas (Agardy et al., 2003). Coastal lagoons are among the world's most productive ecosystems and it is most part affected by many anthropogenic activities and disturbed by human development pressure. Coastal lagoon resources production potential is extremely high that eventually of 113 kg/ha per year, these environments are on average twice as productive as the sea areas of 59 kg/ha per year (Chauvet, 1988). The performance of a lagoon ecosystem is governed to a great extent by nature of its hydrological relationship with the neighboring environment: the marine domain and the continental domain (Frisoni, 1987). The strength and nature of the inputs from the catchment area alter the organization of lagoon colonies, sometimes to the point of disrupting the trophic association within these ecosystems, particularly if these inputs are generally the result of human activities such as agriculture production, urban development and tourism industries. An understanding of the structure and the functioning of ichthyological communities in lagoons in relation to their fish habitat is important for the management and preservation of these "complexes"

(Vasconcelos et al., 2007), which are often exceedingly strong anthropogenic pressures (Stein et al., 2021). The broadly resources assessment and decision-making tool is part of a future approach of scientific management, which increasingly positive discriminations the restorative management of lagoon ecosystem, rather than simulated action to re-stock which are themselves a source of new risk (genetic pollution, introduction of parasites, pathogens or microbes etc). In addition, the fishery resources available in lagoon are directly linked to the livelihood of the fisherman living nearby areas of open sea. Some studies have been conducted more focused on biodiversity (Audouit et al., 2019) and species composition (Singh & Chong 2010; Nyanti et al. 2012), water characteristics (Saifullah et al. 2014) and length–weight relationships of fishery resources in various mangroves dominated estuaries and require for need future lagoon management. Therefore, this study has been carried out to determine the status and seasonal changes of fishery resources available in the tropical lagoon ecosystem in relation to hydro-biological factors.

II. Material and Methods

The review gathered information from a range of different scientific publications on lagoon ecosystems. Articles were collected without any time restrictions. Terms such as “lagoon ecosystem”, “South East Asia lagoon”, and “tropical lagoon functions” were used for searching research articles in freely available online journals subscribed to by the Google scholarly articles. Collected research articles were sorted out and finally synthesis of literature focused on some specific countries in the South East Asia tropical lagoon areas (Table-1). In addition, conference proceedings and books chapters on relevant issues were also analyzed for common understanding of the addressed issue.

III. Results and Discussions

In South East Asia region, policy makers have begun to advocate sustainable destination planning for lagoon ecosystem management which comes with a set of management approaches that can help to ensure that lagoon is not environmentally damaging, contributes to conservation and local community development, and provides opportunities for enhanced conservation and sustainable development for future. There are significant number of lagoon situated in South East Asia region as like Tam Giang Lagoon, Vietnam; Semerak Lagoon, Malaysia; Likas Lagoon, Malaysia; Songkhla Lagoon, Thailand; Khung Krabaen Lagoon, Thailand; Segara Anakan, Indonesia; Puerto Galera Bay lagoon, Philippines; Songculan Lagoon, Philippines.

Table no 1: Lagoon Ecosystems in South East Asia general features

Lagoon Name	Country	General features	Sources
Songculan Lagoon	Philippines	This lagoon exhibit high sensitivity to anthropogenic inputs, making them excellent sentinels of pollution	Kotwicki et al, 2009
Tam Giang Lagoon	Vietnam	Species community changes, increased local conflict and placed a significant loss on aquatic resources	Funge-Smith et al, 1998
Semerak Lagoon	Malaysia	Some species tends to accumulate heavy metals contamination	Shaari et al., 2015
Likas Lagoon	Malaysia	Most of the areas are prone to external pollution and the produce (fish, prawns) can be a health risk impact on aquaculture	R. Sharif et al., 2008
Setiu Lagoon	Malaysia	The lagoon appeared to exploit by aquaculture activities and water pollution	Tahir et al., 2006
Songkhla Lagoon	Thailand	Effects of the fluctuation in salinity and the local dynamics of water current	Kotwicki et al, 2009
Khung Krabaen Lagoon	Thailand	Possible effect of deterioration of water quality due to anthropogenic pressure	Pokavanich et al, 2018
Segara Anakan Lagoon	Indonesia	Mangrove-fringed shallow coastal lagoon which is of high ecological and economic value because of its richness and diversity in living natural resources	Yuwono et al, 2007
Puerto Galera Bay Lagoon	Philippines	The growing influence of human activities is affecting the quality of its marine biological resources	M.L. San Diego et al, 1995
Sre Ambel Lagoon	Cambodia	Continuously degraded the lagoon ecosystems including sand exploitation, industrial crops, and a ceramic industry, a decline of fish catch	Dok Doma, 2011

3.1 Lagoon Functions and Ecological Services Analysis

Function analysis were carried out in lagoon characteristics (processes and components) into a comprehensive list of goods and services which can then be quantified in appropriate units (biophysical or otherwise) to determine their value (importance) to human society. The main functions (goods and services) provided by the lagoon can be classified in five primary categories:

- 1) Habitat functions: These functions refer to the refugia to wild plants and animals in order to maintain biological and genetic diversity in the given ecosystem.
- 2) Regulation functions: This group of functions relates to the capacity of natural (or semi-natural ecosystems) to regulate essential ecological processes and life support systems which, in turn, contributes to the maintenance of a healthy environment by providing protected areas from the storms, clean air and water.
- 3) Production functions: Nature provides many resources, ranging from food and raw materials to genetic material and ornamental resources.
- 4) Carrier functions: Ecosystems supply breathing hole for species interaction and a suitable substrate or medium for many anthropogenic activities such as habitat and recreation.
- 5) Information functions: Natural ecosystems contribute to the maintenance of mental health by providing opportunities for reflection, spiritual enrichment, cognitive development and aesthetic experience.

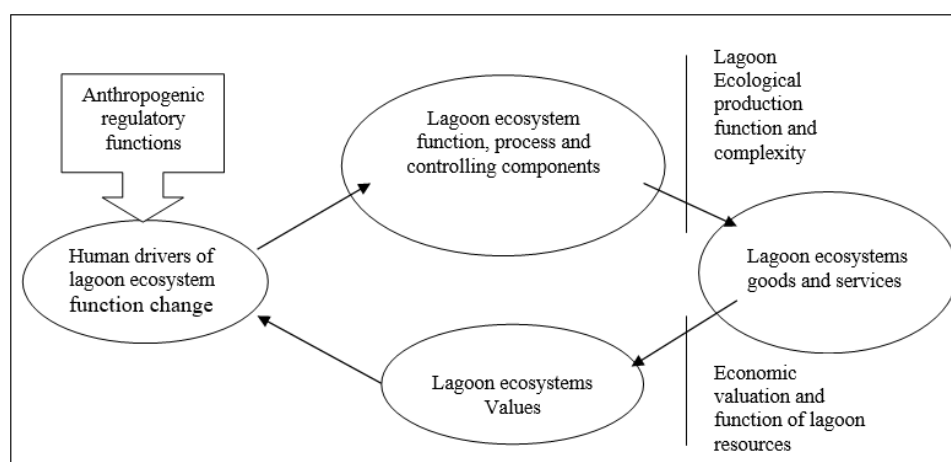


Fig-1: Interrelations of lagoon ecosystem functions valuation steps

Fig-1, Make a point of the lagoon economic valuation component number of different ways in which humans benefit from or value, ecosystem goods and services. The first distinction is between the “Economic values” as opposed to “non-use values” arising from these goods and services. In addition, entail human “interaction” with the environment, whereas non-use values do not, as they represent an individual valuing the pure “existence” of a natural habitat or ecosystem or wanting to future generations. First head use values refer to both consumptive and non-consumptive uses that involve with environmental goods and services, such as recreational activities, resource harvesting, drinking clean water, breathing unpolluted air, and so forth. Second head use values refer to those ecosystem services whose values can only be measured indirectly, derived from supporting and protecting activities that have directly measurable values by lagoon.

The capacity of lagoon ecosystems to provide services in a sustainable manner depends on the biotic and abiotic characteristics which should be quantified with ecological, bio-physical or other appropriate indicators. For example, the capacity of the lagoon ecosystem to provide fish can be measured by maximum sustainable harvest levels (in terms of biomass) and the capacity for recreational use by aesthetic quality indicators and carrying capacity for visitor numbers. As a synthesis of the function analysis (Table-2) provides information about the availability of the functions, goods and services of lagoon ecosystem.

Table no 2: Functions and services analysis of lagoon ecosystem

Sl. No	Typology of lagoon ecosystem	Lagoon ecological functions and services
1	Supporting services	Maintenance of essential ecological processes and life support systems
(a)	Refugium	For resident species and migratory species, maintenance of biodiversity and evolutionary processes
(b)	Migration habitat	Marine species dependency on the lagoon ecosystem
(c)	Nursery functions	Many fishes spend larval stage outside the lagoon and return
2	Regulatory services	Maintenance of environmental quality
(a)	Carbon fixation (calcification)	Climate control, CO ₂ / Ca budget control

(b)	Coastal protection	Coastal lagoon protection from storms and swell
(c)	Sediment-catchment	Recycling the sediments drained by rivers in the bays
(d)	Organic waste treatment	Waste assimilation, natural storage and recycling of organic waste (certain amount)
3	Provisioning services	Provision of resources and substrate
(a)	Food from the lagoon	Sea food products, species fish in the coastal areas, lagoon fishing
(b)	Genetic resources & Medicinal resources	Bio-prospecting sources of unique biological materials for medicines
(c)	Ornamental resources	Aquarium trade (live fishes and coral), shells and jewellery
(d)	Tourism facilities and housing	Hotels on the shore and bungalows (permanent infrastructure and spatial activities), diving centers and houses along the lagoon
4	Cultural and amenity services	Providing opportunities for cognitive development
(a)	Aesthetic and cultural heritage	Lagoons provide information of local culture and heritage
(b)	Natural recorder	Natural recorders of past climate and environmental variation

3.2 Stakeholders Dependencies of Lagoon Ecosystem

Lagoons deliver ecosystem goods and services that provide not only livelihoods of human but also numerous benefits to human health and welfare, which makes them complex social-ecological systems (Newton et al., 2014). The main services provided by lagoon ecosystems include food provisioning (mainly fish and shellfish), freshwater storage, hydrological balance, climate regulation, flood protection, water purification, oxygen production, fertility, recreation and ecotourism (C. Solidoro et al., 2010; R. Lopes et al., 2013). Lagoon ecosystems also support a wide range of human activities, including economic sectors such as fisheries and aquaculture, as well as leisure and tourism industry (Newton et al., 2014).

Table no 3: Diverse interests of stakeholders and dependencies on the South East Asia Lagoon

Stakeholder/ Dependencies	Common Characteristics	Resource Use	Dependency on Lagoon	Economic Interest
Fishing Community	Primary but passive	Different fish harvesting, depletion of fish stock	Direct	Economic benefits (access to, and harvesting of fish)
Sand Miners	Primary but passive	Erosion of soil	Direct	Economic benefits from continued sandmining
Environmental Protection Agency	Secondary and active	Climate change effect	Indirect	Ecological/environmental health of the lagoon
Traditional Authorities & Believers	Secondary and active	Cultural use of the lagoon	Direct	Sustenance of the cultural values of the lagoon
Environmental Groups	Secondary and active	Conflict mitigation between stakeholder	Indirect	The ecological/environmental integrity of the lagoon.
Tourism/ Leisure Businesses	Key but primary	Leisure facilities around lagoon, extensive human impact	Direct	Business/economic benefits, maintenance of the environmental/ landscape aesthetics of the lagoon
Central Regional Development Commission	Secondary and active	Management based planning and control	Indirect	Ecological/environmental/economic health and benefits of the lagoon
Residents around the Lagoon	Primary but passive	Disposal of waste into lagoon, water withdrawal	Direct	Waste disposal and access to water
Academics and Researchers	Primary and key; but can also be active or passive	Use of flora and fauna, water or the wetland for teaching and research	Indirect	Teaching and research
International Organizations	Secondary and active	Lagoon comparative analysis and research	Indirect	Preservation of the ecological/environmental and socio-economic integrity of the lagoon
Government Agencies and Departments	Secondary and active	Impact analysis to local stakeholder and beneficiaries	Indirect	Ecological/environmental/economic health of the lagoon
Tourist Board	Secondary and active	Attraction of tourist	Direct	Development of the lagoon for tourism
Small Scale Vegetable Farmers	Primary but passive	Irrigation, changes in volume of water and farming	Direct	Economic /social/ environmental benefits

3.3 Potential Regional Cooperation for Lagoon Management

Environmental changes due to human impacts take place at unprecedented rates, leading to situations where it is imperative to act and safeguard ecosystems from future damages of lagoon ecosystem in tropical regions (Hofmann et al. 2015). South East Asia region lagoons have been continuously affected by humans. It is no doubt that presently coastal lagoon is one of the world's most threatened tropical ecosystems in the world. Many reports have been identified major causes of lagoon degradation in South East Asia countries that pose

potentially threats to the diversity of many important species. In addition, proper scientific guidelines from government could help to recover the present conditions of tropical lagoon ecosystems in South East Asia countries as future directions of lagoon ecosystem management. In broad research on lagoon ecosystem in South East Asia countries and their diversity of lagoon resources, and their importance in our economy and livelihood, is to some extent inadequate. A lot of works has been done on fish diversity, marine or coastal ecosystem functions and linkages between fisheries and Seagrass-mangroves ecosystem but there is very limited work on coastal lagoon ecosystem. However, it is highly expected that the South East Asia countries coastal lagoon areas have explored through this research for future resource extraction process from lagoon ecosystem and future sustainable management of fisherman livelihood. Thus, this study aims to investigate the society and livelihoods and community or nature, conservation for future sustainable resource extraction process from lagoon ecosystem and elucidating how a connection to the sea impacts on lagoons and the coastal communities, their supports are important to managing tropical lagoons ecosystem. This research could provide valuable information to improve the South East Asia countries lagoon ecosystems for future management directions.

Table no 4: Suggestions for future direction and potential regional cooperation in the different thematic areas

Thematic research area	Future direction/expansion of lagoon
Conservation and management on lagoon environment	Research into more effective lagoon management policy and integrated future lagoon management, review of current lagoon protected areas and reserves to include more habitats, and science-based zoning plans. Improvement of decision support tools for natural resource administrator.
Connectivity on lagoon ecosystems	Studies on various aspects of connectivity of lagoon meadows within the thematic gaps in knowledge and information need to be conducted for future lagoon management. These studies should be used to inform management and policy decisions.
Climate change that effect on lagoon	Economic and finance of lagoon management options and challenges in the South East Asia region context, exploratory climate change scenarios for lagoon habitats and increasing resilience to effects of climate change.
Genetics	Increase population genetics studies to better understand connectivity and gene flow in lagoon biodiversity and inter species, expand number of species.
Mapping	Intensive mapping needs to be carried out across the South East Asia region, connect rapid development in mapping tools.

3.4 Ecosystem-Based Management (EBM) For Future Lagoon Management Directions

Comprehensive management of lagoon ecosystem will involve an ecosystem-based management (EBM) approach which links coastal hydrologic upstream adjoining environment. In preference to managing lagoon ecosystem as single-use resource, they should be managed as multiple-use resources for fisheries, coastal protection, carbon sequestration and the traditional provision of wood products. This study will be assessed baseline information of fishery resources of this pristine lagoon ecosystem, which will eventually help to conserve and manage its fishery resources in lagoon in near future. Furthermore, ongoing livelihood pressure and an uncertain and shifting access rights situation raise numerous obstacles to sustainable resource use and ecosystem protection in the lagoon. A number of future actions can be identified for lagoon ecosystems. These insights are specific to on-going initiatives in the lagoon, but also have broader relevance to the management of multipart of lagoon systems. The modification of all visions and strategies for lagoon management will be shifted from the short-term and an integrated, participatory, long-term and ecosystem-based approaches which are effective for future management. However, noteworthy effort will be required to address socio-economic and ecosystem challenges confronting the lagoon, conditions for successful innovation, experimentation and shared knowledge are now a reality that focus of on-going research. Mangrove's forest and coastal lagoon are unique ecosystems which offer tremendous value and benefits. Lagoons are very much diverse but facing tremendous threats. Future directions will be ensured to engage for implementation of reforestation and conservation program for save the valuable natural resources. These followings future program to take consideration:

- (a) Strengthening the information, education and communications program protection and conservation of mangroves and lagoons areas.
- (b) There is a need for a more effective awareness campaign on the ecological and socio-economic importance of mangroves, lagoon and other ecosystems. The government should implement new mangrove planting guidelines to enhance the survival rate of lagoon species. The scientific community needs to provide the decision makers with relevant and update information and continue research activity.
- (c) Institution should also continue to closely engage the local community in the management resources as it is a more sustainable approach. They must be given technical assistant, training, education and diverse livelihood program to enhance their capability. There is a greater need for conservation that integrates research, advocacy and action including all sectors of the society at all levels.
- (d) Ecotourism is to be developed in a mangrove area, sustainable development and holistic approach must be strengthened in the management, conservation, protection and utilization of the services provider by lagoon

ecosystems. The lagoon area must have management zonation with a strict protection zone and multiple use zones which include ecotourism designated areas.

(e) Lagoon ecosystem must be preserved future breeding zone and ensure for not excess extraction of natural resources.

(f) Empowerment and improved engagement of poor stakeholders in the management of lagoon ecosystems in a community level.

(g) Improved livelihood opportunities, enhanced food security and improved health for these vulnerable communities those are affected.

(h) Sustained production from lagoon fisheries, and increased production from aquaculture.

(i) This study will provide information and comprehensive data about fish composition, diet, feeding habit, fish diversity and their interaction in lagoon ecosystems between mangrove and seagrass.

(j) The findings from this study can be used to help researchers and government authorities in finding better ideas and actions in improving lagoon ecosystem management.

Lagoon future resource management preferences will be investigated and compare which of the four management options they would prefer for management in the future: (1) Management by the government, (2) Management by fishers and government, (3) Local community-based management excluding women and (4) Local community-based management including women.

IV. Conclusion

Lagoon ecological functions could be a tool for environmental conservation, local natural resource equality, poverty alleviation and so on. In brief, though local communities are major stakeholders, all the coastal based lagoon areas in South East Asia region development efforts by the all government agencies followed a top-down approach without appropriate consultation with the local people and communities who would likely be benefited or affected. This is the reason behind the conflict among the stakeholders, and such conflict is ultimately hindering development of the lagoon future management in this region. For future sustainable development and lagoon, the voice and feelings of local community members should be taken under consideration. They should be given access and rights to operate and deliver lagoon management activities as priority based in others development sectors in coastal areas. So far, there is a deficiency in research concerning the extent of the impact of socioeconomics activities on future lagoon management of South East Asia region. The future of the lagoon as a surface water body is uncertain, however; actions can be done to mitigate the impacts of anthropogenic activities and climate change. An adequate management of the South East Asia region lagoon may lead to the restoration of water inflow to the lagoon; the implementation of programs for ecological protection and restoration may contribute to improving the health of the lagoon ecosystem.

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References

- [1]. Agardy T, Bridgewater P, Crosby MP, Day J, Dayton PK, Kenchington R, Laffoley D, Mc Conney P, Murray PA, Parks JE, Peau L. (2003). Unresolved issues and ideological clashes around marine protected areas. *Aquatic Conservation: Marine and Freshwater Ecosystems* 13: 353-367.
- [2]. Audouit, Ch, Pasqualini, V., De Wit, R., Flanquart, H., Deboudt, Ph, and Rufin-Soler, C. (2019). Comparing social representation of water quality in coastal lagoons with normative use of ecological indicators. *Mar. Polic.* 101, 137–146. doi: 10.1016/j.marpol.2017.08.023.
- [3]. Chacón Abarca, Samantha, Valeria Chávez, Rodolfo Silva, M. L. Martínez, and Giorgio Anfuso (2021). "Understanding the Dynamics of a Coastal Lagoon: Drivers, Exchanges, State of the Environment, Consequences and Responses" *Geosciences* 11, no. 8: 301. <https://doi.org/10.3390/geosciences11080301>.
- [4]. Chauvet C., (1988). "Manuel sur l'aménagement des peches dans les lagunes cotieres: la bordigue mediterraneenne", Doc. Tech. Peches, p. 290, FAO, Rome.
- [5]. Costanza R, D'Arge R, De Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, et al., 1997. The value of the world's ecosystem services and natural capital. *Nature* 387: 253-260.
- [6]. C. Solidoro, G. Cossarini, S. Libralalto, S. Salon (2010). Remarks on the redefinition of system boundaries and model parametrization for downscaling experiments, *Progress in Oceanography*, 84 (2010), pp. 134-137.
- [7]. De Groot, R.S., (1992). Functions of Nature: evaluation of nature in environmental planning, management and decision-making. Wolters Noordhoff BV, Groningen, the Netherlands 345 p.
- [8]. Dok Doma (2011), Final Report by Rufford Small Grant Foundation Department of Rural Water Supply, Ministry of Rural Development, Phnom Penh, Cambodia, August 2011.
- [9]. Frisoni G.F., "L' influences du bassin versant sur le fonctionnement des lagunes mediterraneens. Concept d'eutropisation et de confinement. Exemple d'application: l'étang de Sanga (Corse)", *Bulletin d'Ecologie*, vol. 18, no 2, pp. 169-175, 1987a.

- [10]. Funge-Smith, S. J., and Briggs, M. R. P. 1998. "Nutrient Budgets in Intensive Shrimp Ponds: Implications for Sustainability." *Aquaculture* 164: 117-33.
- [11]. Hofmann E, Bundy A, Drinkwater K et al (2015). IMBER—research for marine sustainability: synthesis and the way forward. *Anthropocene* 12:42–53.
- [12]. Kotwicki L., *Meiofauna of Sandy Beaches*, (2009). http://www.marbef.org/wiki/Meiofauna_of_Sandy_Beaches. 2009.
- [13]. M.L. San Diego-McGlone, C.L. Villanoy, P.M. Aliño (1995), *Marine Pollution Bulletin*, Volume 31, Issues 4–12, April–December 1995, Pages 355-366.
- [14]. Newton, A., Icelly, J. D., Cristina, S., Brito, A., Cardoso, A. C., Colijn, F. Zaldívar, J. M. (2014). An overview of ecological status, vulnerability and future perspectives of European large shallow, semi-enclosed coastal systems, lagoons and transitional waters. *Estuarine, Coastal and Shelf Science*, 140,95–122.<http://dx.doi.org/10.1016/j.ecss.2013.05.023>.
- [15]. Nyanti L, Nur Asikin R, Ling TY, Jongkar G. (2012). Fish diversity and water quality during flood mitigation works at Semariang mangrove area, Kuching, Sarawak, Malaysia. *Sains Malaysiana* 41:1517–25.
- [16]. Oertli B, Biggs J, Céréghino R, Grillas P, Joly P, Lachavanne JB. (2005). Conservation and monitoring of pond biodiversity: introduction. *Aquatic Conservation: Marine and Freshwater Ecosystem* 15: 535-540.
- [17]. Pokavanich, Tanuspong & Buranapratheprat, Anukul & Chittima, Aryuthaka. (2018). Hydrodynamics Modeling of Khung Krabaen Lagoon, Chanthaburi Province, Thailand. *MATEC Web of Conferences*. 147. 05009. [10.1051/mateconf/201814705009](https://doi.org/10.1051/mateconf/201814705009).
- [18]. R. Lopes, N. Videira, (2013). Valuing marine and coastal ecosystem services: An integrated participatory framework, *Ocean & Coastal Management*, 84 (2013), pp. 153 162, [10.1016/j.ocecoaman.2013.08.001](https://doi.org/10.1016/j.ocecoaman.2013.08.001)
- [19]. R. Sharif, A. R. Ghazali, N. F. Rajab, H. Haron, and F. Osman (2008) "Toxicological evaluation of some Malaysia locally processed raw food products," *Food and Chemical Toxicology*, vol. 46, pp. 368-374. Jan 2008.
- [20]. Saifullah ASM, Abu Hena MK, Idris MH, Halima AR, Johan I. (2014). Seasonal variation of water characteristics in Sibuti river estuary in Sarawak, Malaysia. *Malaysian Journal of Science* 33:9–22.
- [21]. Shaari, Hasrizal & Mohd, Maidatul & Abdullah, Nor & Bidai, Joseph. (2015). Heavy Metals monitoring in *Psammotaea elongata* from Semarak Lagoon, Kelantan, Malaysia. *Oriental Journal of Chemistry*. 31. [10.13005/ojc/310246](https://doi.org/10.13005/ojc/310246).
- [22]. Singh HR, Chong VC. (2010). Shallow coastal waters of Pahang, Peninsular Malaysia as fish nursery grounds. *Journal of Science and Technology in the Tropics* 6:126–32.
- [23]. Stein, E.D.; Gee, E.M.; Adams, J.B.; Irving, K.; Van Niekerk, L. (2021). Advancing the Science of Environmental Flow Management for Protection of Temporarily Closed Estuaries and Coastal lagoons. <https://doi.org/10.3390/w13050595>.
- [24]. Tahir, N.M., H.M. Abd Rahim and M.K.A., Rashid, (2006). "Distribution and characterization of hydrocarbons in sediments of Setiu Wetland, Terengganu: A preliminary study," *Malaysia Journal of Analytical Sciences*, vol. 10, no. 1, pp. 177-184.
- [25]. Vasconcelos R.P., Reis-Santos P., Fonseca V. et al., (2007). "Assessing anthropogenic pressures on estuaries fish nurseries along the Portuguese coast: a multi metric index and conceptual approach", *Science of Total Environment*, vol. 374, pp. 199-215.
- [26]. Yuwono, Edy & Jennerjahn, Tim & Nordhaus, Inga & Ardli, Erwin & Sastranegara, Moh & Pribadi, Rudhi. (2007). Ecological status of Segara Anakan, Indonesia: A mangrove-fringed lagoon affected by human activities. *Asia J Water Environ Pollut*. 4. 61-70.