protection and fisheries resources enhancement, it is vital that a plan of action highlighting the key activities in a strategic plan and the sequencing of these activities in the proper time frame be put in place. The national or regional plan should also indicate the responsible agencies for initiating action or assigning tasks to be accomplished to meet the objectives within the stipulated duration of time.

To restore fishery resources, several management tools including the installation of ARs have been applied. However, the disadvantages of the ARs are the lack of collaboration between the government and fishers, in which the fishers are only involved in the identification of fishing ground and following the regulations. Therefore, the absence of fisher co-management could not effectively promote resources management because the fishers have always the tendency to disobey due to lack of ownership. Hence, seeking modern tools to enhance the fishery resources by incorporating the resource users to be resource managers is required. For example, fish enhancing devices (FED) or known as floating ARs, are currently being explored in the Philippines and other countries in the western Pacific including Thailand (Cabral *et al.*, 2014; Manajit *et al.*, 2019).

Sharing indigenous and scientific knowledge (particularly impact assessment of degraded natural habitats and fisheries resources due to human activities) among the stakeholders targeting on raising awareness on the importance of habitats and fisheries resources to humans should be conducted regularly. Research on habitat and fisheries resources enhancement should be continuously carried out, and the results could significantly support the policy formulation as well as increase fishers' acceptance when the management plans are implemented. The future activities of the ongoing project "Sustainable Utilization of Marine Fisheries Resources and Resource Enhancement in Southeast Asia" implemented by SEAFDEC/TD from 2020 to 2024 include fish larvae identification and determining of spawning-nursing grounds and season using larvae survey results, artificial reef design and construction, and evaluating methods of enhancing fisheries program in terms of environment and fisher economy.

### 6.1.4 Application of Fishery Information Systems for Fisheries Management

Geo-information technology refers to an integration of knowledge and technologies involving Geographic Information System (GIS), Remote Sensing (RS), and Global Navigation Satellite System (GNSS), which could be applied in a wide range of work (GISTDA, 2015). GIS is commonly used for visual display, quantification, and analyses of spatial data. Ecological data, including fisheries data, generally contain a spatial component and are well suited for analysis through GIS. Moreover, RS is the process

of detecting and monitoring the physical characteristics of an area by measuring its reflected and emitted radiation at a distance. RS could therefore be used to classify objects on earth, including those on the surface as well as in the atmosphere and oceans, based on propagated signals. (Eder & Neely, 2013).

These technologies, such as the GIS and RS applications, could be used in various stages of monitoring, conservation, management, sustainable development, and environmental protection, and so on. Results of analysis using the GIS technology could be applied to any decision-making plans quickly and accurately (GISTDA, 2015). GIS and RS technologies are potential tools for fisheries management especially when it comes to decision-making processes, as they could give clear visualization of the data and information in place and time. Over the past decades, there were a lot of instances where GIS and RS had been used in fisheries science and found to have the capability to support the management of fisheries and aquaculture in various aspects.

### Application of GIS and RS

The recent activities of SEAFDEC that aim to support and encourage the Southeast Asian countries to utilize the GIS and RS technologies for the sustainable utilization of the fishery resources in the region, SEAFDEC/TD initiated in 2020 the five-year project "Sustainable Utilization of Fisheries Resources and Resources Enhancement in Southeast Asia" which includes the activity to use Fisheries GIS or FGIS and RS to improve fisheries management. At the onset, the "Regional Consultation Workshop on the Utilization of FGIS and RS to Improve Fisheries Management in Southeast Asia" was organized in 2020 to update the SEAFDEC Member Countries on the use of GIS and RS in research and studies on fisheries and environmental science. Information on the status of utilization of these technologies in the studies or research activities in the SEAFDEC Member Countries, compiled during the Regional Consultation Workshop, are summarized in **Box 29** (SEAFDEC/TD, 2020).

### Issues and Challenges

Although raised in the 1990s, the major challenges for GIS and RS applications (**Box 30**) have not yet been fully addressed (Nishida, 1994) because of the fragmented nature of the fisheries, especially in the Southeast Asian region.

### Available resources

The current available resources that could be used to support the application of GIS and RS in fisheries and aquaculture management are shown in **Box 31**. Accessibility to such resources is also indicated for easy reference.

**Box 29.** Application of GIS and RS technologies in fisheries of the ASEAN Member States

**Brunei Darussalam**
- The study "Analysis of Species Assemblages and Fishing Gear Clusters in the Coastal Waters Brunei Darussalam," conducted in 2006 is already completed. This study, which had 3-phase assessment, was principally intended to elaborate a new fisheries strategy --- defining the optimal fishing effort configuration (number of licenses by type of fishing gear) and related policy/management options (*e.g.* trawl ban, managed fisheries) for improved management of the country's fisheries.
- The study "Fish Aggregating Devices (FADs) Site Identification," which was completed in 2017, was meant to (i) improve the production of high value fish species, particularly neritic tuna, and enable fishers to target the export markets, and (ii) increase the fishing time and reduce searching time, which generally leads to reduction in fuel consumption. Using the data compiled through the use of GIS and RS technologies, fishers were able to deploy FADs in the purse seiners' common fishing areas of the country, which are mostly within zone 2, 3 and 4.
- The study on "Site Identification and Design for Artificial Reefs (AR)," which is still ongoing, aims to: 1) Produce connectivity and dispersal model output; 2) Assess the viability of sites of choice as potential AR deployment stations; and 3) Consolidate findings to highlight potential AR sites for baseline investigations. The scope of the study covers: 1) Primary Data Collection and Surveys (water sampling and ADCP); and 2) Model Setup to simulate the recruitment of coral larvae at each potential site based on its dispersal pattern and prevailing currents and makes use of GIS and RS technologies. The study intends to come up with model simulation of the potential AR deployment sites.

**Indonesia**
- The research "Identification Potential Fishing Ground (PFG) in Indonesian Waters based on RS Data and Geostatistical Model," is still ongoing, requires analyzing the information on sea surface temperature (SST) and primary productivity, to come up with the geostatistical model that would indicate the areas which could be potential fishing grounds

**Malaysia**
- The research study "Fish Site Identification (FSI)," as a collaborative work between DOFM, Malaysia Space Agency (MySA), Fisheries Development Authority of Malaysia (LKIM), and National Fishermen's Association of Malaysia (NEKMAT). The first phase on "FSI on pelagic fish" was conducted from 2007 until 2010, while the application of the findings by fishers started in 2011 with 40,000 fishers involved. After using the FSI results, the concerned fishers were able to increase their catch by 30 % and prove that the accuracy of the FSI was 80 %, as a result the fishers could reduce their total operation cost by about 30 %. The subsequent study on FSI for tuna is ongoing and is in the various stages of verification at sea.
- The research study "Carrying capacity studies for fisheries cage culture system in Johor, Kelantan, Terengganu, Selangor, Penang," which was carried out by FRI in Kg. Acheh, Perak, and in Batu Maung, Penang (DOFM). While the case studies had been completed, the results established the value of the current carrying capacity of the areas of concern. Risk assessment was done, and the forward actions formulated had been considered and are in the various stages of implementation, specifically in some cases where relocation of fish cage systems to other areas had to be undertaken.
- The research study "Blood cockle stock assessment and spatial distribution for natural/induced spawning programme in Penang, Johor, Melaka and Kedah," which was carried out by FRI Kg. Acheh, Perak and FRI Batu Maung, Penang (DOFM). The research attempted to locate the natural spawning grounds of blood cockle. On the completion of the study, the current stock and spatial distribution were established, while further actions were formulated and their implementation is currently ongoing.
- The research study aimed at identifying "The Location of Gold Fish Farms in Johor and Koh Fish Farms in Perak," which is under the responsibility of the Fisheries Biosecurity Division of DOFM, which is still ongoing. Ornamental fish is an important export-oriented commodity and ornamental fish culture has been considered as one of the fastest-growing sub-sectors of Malaysia's agriculture sector. The country has been using GIS and RS for mapping the locations of the ornamental fish farms and in determining the corresponding management systems adopted by the farms.

**Singapore**
- The research study "Coastal and marine habitat mapping for the Straits of Malacca using SPOT and LANDSAT data" which was undertaken by CRISP/ NUS and was completed in 2013.
- The research study on "Monitoring water quality in Singapore reservoirs with hyperspectral remote sensing technologies" which was carried out by CRISP/ NUS. And was completed in 2019.
- Research study "Spatiotemporal variations of extreme sea levels around the South China Sea: assessing the influence of tropical cyclones monsoons and major climate modes" which was conducted by EOS/NTU and was also completed in 2019.

**Thailand**
- The two ongoing research projects of the DOF of Thailand: 1) Fisheries Monitoring System: Vessel Monitoring System (VMS), and 2) Fisheries Map, are meant to help the fisheries officers in monitoring and managing the fishing activities in the waters of Thailand
- Flooding compensation assessment for affected aquaculture farmers using Geo-Informatic Technology: Case study of Supanburi Province
- Geographic information system application for artificial reef potential site assessment: Case study of Chumphon Province
- Surface model and Geographic Information System (GIS) application to site selection for sea ranching of black tiger shrimp (*Penaeus monodon*) in Songkhla Lake
- Application of Geographic Information System to Aquaculture Database in Phuket Province
- Approach for assessing the sustainability of marine shrimp area using spatial analysis technique
- Application of Geo-Informatics to study shrimp farm area change in Nakhon Si Thammarat Province
- Integrated coastal management of the northern part of the inner Gulf of Thailand
- Site suitability assessment for artificial marine habitat deployment in the coastal seas of Chon Buri Province with spatial analysis

| **Box 29.** Application of GIS and RS technologies in fisheries of the ASEAN Member States *(Cont'd)* |
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**Viet Nam**
- The study on "Researching the application of remote sensing and GIS supporting the management, surveillance and warning of diseases in aquaculture" which was carried out by Vietnam Institute of Fisheries Economics and Planning (VIFEP), started in 2017 and finished at the end of 2020. The study was meant to research and apply RS and GIS technology in monitoring, management, and warning of any environmental and diseases problems in aquaculture in coastal areas of Viet Nam and to develop WebGIS for management, monitoring, and warning of diseases in aquaculture areas. Pilot case studies were undertaken in Khanh Hoa Province and Ben Tre Province for the lobster, shrimp, and clam culture areas.
- The ongoing research project "Satellite monitoring of Vietnamese Marine Domain and Resources Project (Movimar)" which is a responsibility of the Fisheries Information Center, Directorate of Fisheries. This project availed of imported techniques and equipment from Collecte Localisation Satellites (CLS) in France that are now being used to undertake the activities related to monitoring and tracking fishing vessels. The tracking device is now installed in about 3,000 fishing vessels.
- The research project "Building geographic information system (WebGIS) to support the management of aquaculture in coastal zones in Nghe An Province" which was conducted by VIFEP. Although the research was already completed, the system is still operating online. The project supported the management of shrimp and clam culture areas of five (5) coastal districts in Nghe An Province.
- The research study "Planning tidal flats for aquaculture in Quynh Luu District using remote sensing (satellite data and flycam data)" by VIFEP which was already completed, and the results of the study are being used to support the detailed planning of tidal flats of Quynh Luu Districts-Nghe An Province. The plan is mainly aimed for sustainable aquaculture management.

| **Box 30.** Major challenges for GIS and RS applications in fisheries of the Southeast Asian region |
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**Data**
- Standardization of data collection structures with adjustment for discrepancies in space or time
- Conversion of analog data to digital data
- Consolidation of data gathered and databases
- Automation of data collection systems
- Establishment of simple database linked to GIS platform
- Consideration of 3D or 4D database for GIS
- Development of easy methods to access oceanographic and satellite information
- Development of easy methods to process matrix (raster) information

**Presentation**
- Application of enhanced visualization to fisheries GIS
- Effective and easy ways to present 3D and 4D parameters of fisheries and oceanographic information such as catch, CPUE, temperature, and salinity

**Stock assessment, prediction, and spatial numeral analyses**
- Development of linkages between GIS and stock assessment
- Applying GIS methods, models, simulation, and geo-statistics in a fluid, dynamic 3D environments
- Development of space-oriented prediction methods for fishing and oceanographic conditions

**Fisheries management using GIS**
- Space-oriented fisheries management
- Ecosystem-based fisheries management
- Essential fish habitats and marine reserves
- Fishing effort monitoring systems using global positioning system (GPS) and vessel monitoring system (VMS)
- Fisheries impact assessment (development of space-based stock assessment)
- Spatial allocation of the results of stock assessments such as MSY and TAC
- Monitoring and modeling of quota arrangements

**Software**
- Development of user-friendly and high-performance fisheries GIS software that can handle simple parameters and also satellite information, and perform simple mapping as well as complex integrated spatial numerical analyses

**Human interaction**
- Establishment of the international fisheries GIS association for networking to exchange ideas and information
- Collaborative and interactive GIS activities in fisheries resource research by fisheries scientists, oceanographers, fishers, and fisheries managers for effective, meaningful, and realistic achievements
- Fostering a trustful relationship between researchers, fishers, and politicians

### *Way Forward*

Under the project "Establishment and Operation of a Regional System of Fisheries *Refugia* in the South China Sea and Gulf of Thailand" implemented by SEAFDEC from 2016 to 2022 with support from the UNEP/GEF, also known as the Fisheries *Refugia* Project, a combined national and regional Google Earth-based Geographical Information Systems (GIS) on fisheries and marine biodiversity would be developed featuring information on locations and management status of coastal habitats, fisheries *refugia*, MPAs, and critical habitats for threatened and endangered species. These national GIS databases will be used in the preparation of annual syntheses of new and additional data relating to the science and management of fish life-cycle and critical habitat linkages. Details of this Google Earth-based GIS information in the Fisheries *Refugia* Project appear on the project website https://fisheries-refugia.org/.

| Box 31. Available resources that support the application of GIS and RS in fisheries and aquaculture management |
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**GIS Resources**
- Esri Open Data Hub (https://hub.arcgis.com/search)
- FAO Global Gateway to Geographic Information Systems (GIS (http://www.fao.org/fishery/collection/gisfish/en)
- Natural Earth Data (http://www.naturalearthdata.com/downloads/)
- NASA Earth Observations (https://neo.sci.gsfc.nasa.gov/)
- NOAA OneStop: A NOAA Data Search Platform (https://data.noaa.gov/onestop/)
- OpenStreetMap (https://gisgeography.com/openstreetmap-download-osm-data/)
- Socioeconomic Data and Applications Center (SEDAC) (https://sedac.ciesin.columbia.edu/)
- UNEP Environmental Data Explorer (http://geodata.grid.unep.ch/index.php)
- FAO Map Catalog (https://data.apps.fao.org/map/catalog/srv/eng/catalog.search#/home)

**RS Resources**
- FAO Global Gateway to Geographic Information Systems (GIS), Remote Sensing and Mapping for Aquaculture and Inland Fisheries (http://www.fao.org/fishery/gisfish/index.jsp)
- JAXA's Global ALOS 3D World (https://www.eorc.jaxa.jp/ALOS/en/aw3d30/)
- LP DAAC MODIS land products (https://lpdaac.usgs.gov/data/)
- NASA Earthdata Search (https://search.earthdata.nasa.gov/)
- NASA Earth Observations (https://neo.sci.gsfc.nasa.gov/)
- NASA MODIS Land (https://modis-land.gsfc.nasa.gov/)
- NASA OceanColor (https://oceancolor.gsfc.nasa.gov/)
- NOAA Comprehensive Large Array-data Stewardship System (https://www.avl.class.noaa.gov/saa/products/welcome)
- NOAA OneStop (https://data.noaa.gov/onestop)
- Sentinel Open Access Hub (https://scihub.copernicus.eu/dhus/#/home -
- USGS Earth Explorer (https://earthexplorer.usgs.gov/)
- VITO Vision (https://www.vito-eodata.be/PDF/portal/Application.html#Home)

Another Project "Strengthening the Effective Management of Inland Fisheries and Aquaculture in AMSs with GIS and RS Technology" implemented by SEAFDEC also applies GIS and RS technologies in fisheries and aquaculture. This Project makes use of the catch data collected from selected fishing grounds of the participating countries as target sites, which are then analyzed together with the environmental information obtained from satellite data images of such target sites. The final output from the data analysis could include levels of impacts of the environmental factors and changes in the inland fishery resources that could be used for the effective improvement of inland capture fisheries management.

From the aforementioned projects and studies, it could be deduced that several Southeast Asian countries have applied the GIS and RS technologies in their endeavors in fisheries and aquaculture management, *e.g.* in fishing vessels and fleet management; conservation and management of fishery resources and habitats in inland, coastal, and marine waters; improved collection system for catch and landing data from small-scale and commercial fisheries; fishery resources and habitat enhancement, among others (Wanchana & Sayan, 2018). These geo-informatics technologies have the potentials to be used in data and information compilation and analyses, the results of which could help in decision making, especially in formulating management strategies for sustainable utilization of the respective countries' national fishery resources.

## 6.2    Challenges and Future Direction

Fisheries management is an important factor in ensuring the sustainable utilization of fishery resources. Overcapacity and illegal, unreported and unregulated (IUU) fishing have

been identified as among the major causes for overfishing that lead to the collapse of the fishery resources. With the relevant International Plans of Action (IPOAs), such as the IPOA for Management of Fishing Capacity (IPOA-Capacity) and the IPOA to Prevent, Deter and Eliminate the Illegal, Unreported and Unregulated Fishing (IPOA-IUU) adopted by the Council of FAO under the framework of the Code of Conduct for Responsible Fisheries, such IPOAs have guided the countries in the Southeast Asian region to develop their respective plans for the management of fishing capacity and combating IUU fishing, and for the application of the "tools" that cover various measures for combating IUU fishing activities in different situations and contexts.

More specifically, the need to combat IUU fishing is specified in SDG Target 14.4 viz: "*By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics*." Meanwhile, Target 14.6 indicated that "*By 2020, prohibit certain forms of fisheries subsidies which contribute to overcapacity and overfishing, eliminate subsidies that contribute to illegal, unreported and unregulated fishing and refrain from introducing new such subsidies, recognizing that appropriate and effective special and differential treatment for developing and least developed countries should be an integral part of the World Trade Organization fisheries subsidies negotiation*."

With reference to the "ASEAN Guidelines for Preventing the Entry of Fish and Fisheries Products from IUU Fishing Activities into the Supply Chain" and the "Regional Plan