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Aquatic Research for Prosperity of the Nation

Abstract Book



Ocean University of Sri Lanka
Ministry of Skills Development, Vocational Education, Research & Innovations



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This is the booklet of the abstracts with
all authors, and emails of corresponding authors

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About

This is the second research symposium of the Ocean University of Sri Lanka. The symposium theme is the "**Aquatic Research for Prosperity of the Nation**". All information about the symposium can be found at www.ocu.ac.lk

Vice Chancellor's Message



It is my great pleasure to convey this message to the Second Annual Proceedings of the Ocean University Research Symposium–2020 planning to be conducted online.

The annual symposium is a landmark event where undergraduate students, alumni, and related professionals come together and actively participate in presenting their new findings for constructive discussion that paves the way for ocean, marine and, maritime related technology applications. It is such a precious moment for us because, in addition to the fact that this function underlines University's success in its field of providing education and research, this will also witness the performance of our undergraduates displayed before you. It provides a great opportunity for the student to establish relationships with all stakeholders, industry leaders, academics from various disciplines and exchange views, share knowledge to achieve synergies in progress. Your online presence is an inspiration to young researchers who are opening their talents before you to reach greater heights. I hope the topic is timely and inspires you to innovate new products, develop new technologies and processes in the broad field of marine, maritime and fisheries sector.

I wish to offer my gratitude to all those who helped in organizing and steering this event to a successful completion.

Prof. Nalin Ratnayake Vice Chancellor / Ocean University of Sri Lanka

Keynote Speakers

Keynote Speaker: Prof. Peter Burkill



Peter is an Emeritus Professor of Ocean Science at the University of Plymouth, UK. He is also an Associate Fellow of the Marine Biological Laboratory in Plymouth. His background is as a research active biological oceanographer with a h-index >50.

However, about 20 years ago he switched to 'opening doors for others', first when he was Head of the George Deacon Division of Ocean Science Department at the University of Southampton's National Oceanography Centre, then as Director of Sir Alister Hardy Foundation for Ocean Science (SAHFOS) in Plymouth and latterly at the University of Plymouth. He was elected President of the Scientific Committee on Oceanic Research (SCOR) in 2012 and initiated the Second International Indian Ocean Expedition (IIOE-2) in 2015. He was a Guest Scientist at India's National Oceanography Centre in Goa for several years. He describes the Indian Ocean as his 'favorite ocean as it is warm, dynamic and poorly understood'.

Keynote Speaker: Prof. Dongxiao Wang



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CT: Contributed Talk, IS: Invited Speaker, KS: Keynote Speech, IT: Invited Talk.

KEYNOTE

The International Indian Ocean Expedition (IIOE-2) and Its Relevance to Sri Lanka

Prof. Peter Burkill

KS

University of Plymouth, UK and MBA, UK

Sri Lanka is an island nation surrounded by the ocean. In 2015 the Second International Indian Ocean Expedition began with major international body sponsorship. My talk will explain what the IIOE-2 is, outline some key recent findings and why these are relevant to Sri Lanka.

I will describe how IIOE-2 is likely to develop in the future including how the program is likely to evolve from purely 'curiosity driven research' to one which focusses more in addressing societal needs perhaps as part of the UN Decade program. As a stepping in this process, I suggest that 'Transformational Research' should play a key role in this evolution.

Ocean Island for Time Series Observatory in the South China Sea

Prof. Dongxiao Wang

KS

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The first survey of oceanographic scientific cruise for Xisha Island was the year 1928, which was supported by Sun Yat-sen University. From then on, increasing surveys pay attentions on the water mass property, ocean circulation, atmospheric structure, and chemical and biological elements around Xisha Island, especially for the Northern South China Sea open cruise (NSCS open cruise) in past decade. The NSCS open cruise began in 2004, it allowed researchers on board to carry out their observational instruments for experiments. In this way, the cruises could investigate ocean dynamic processes and air-sea interaction around Xisha Island by equipped instruments on board included CTD, underway-CT, MVP, ADCP, Turbo-MAP, global positioning system sounding, shipboard automatic weather station (AWS) and air-sea flux observation system and so on. From 2007 onward, the open cruise started to arrange moored buoys in waters near the Xisha Island at each year. These yearly cruise observations promote the studying of the SCS Western Boundary Currents, mesoscale eddy and environmental ecology around Xisha Island. Besides those scientific cruises, a number of South China Sea observation stations appeared within the last decade. Xisha station was the first deep-sea observation station to be established in Chinese waters. It is located off the coast of Yongxing Island, one of the main islands of the Xisha group, and is situated in the deep-water (>1000 m) basin of the north-central SCS. Xisha station is equipped with an AWS, moorings, shore-based wave and tide gauges, bottom-moored sediment traps, and moored buoys. In addition, a 20-m air-sea boundary flux tower equipped with gradient and eddy covariance observations for the measurement of air-sea boundary fluxes has been in operation since 2013. These fixed multifunction observation platforms in the ocean and at the air-sea interface provides long-term and continuous real-time data, which complement the open-cruise observations in the SCS. Then, Dongsha Islands stations were established at the year of 2014, equipped with moorings and CTDs. Those stations are located in the middle of the continental slope in the northern south China sea, and have been last for more than five years. Based on these observations, the multi-scales variability of slope flow and cross flow have been studied. Such as the contributions of mesoscale eddy and the Kuroshio intrusion on the cross slope flow variability have been investigated. In addition, many ocean dynamic processes can be investigated.

OCEANOGRAPHY AND HYDROGRAPHY

Turbulence and Mixing in High Energetic Ocean Environment Around Sri Lanka

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Surface salinity of the Bay of Bengal (BOB) is greatly affected by precipitation during the south-west monsoon, river discharges as well as evaporation. The net effect is a low surface salinity in the BOB, creating a hydrologic imbalance and hydrophysical property gradient with Arabian Sea that has elevated surface salinity due to higher evaporation rates leading to circulation in the northern Indian Ocean. Large freshwater influx to BoB produces a barrier layer at low-saline shallow mixed layer overlying a highly stratified sharp thermohalocline. As a barrier layer is a distinct feature of the BOB stratification, understanding of small-scale mixing across this layer is crucial for fluxes in the Bay. Measurements survey for physical oceanographic studies was carried out in April and September of 2014 using research vessel R/V Samuddrika belongs to National Aquatic Resources Research and Development Agency to obtain insights on turbulence and mixing in ocean environment around Sri Lanka. The data collection was carried out at longitudinal and latitudinal transects along the east and west coasts of Sri Lanka respectively. Apart from the main transects, a short distance drifting station was taken at the shelf break to the south of Sri Lanka. It was found that the probability distributions of the logarithm of the kinetic energy dissipation rate follow a generalized extreme value model in strongly stratified pycnocline, which was dynamically detached from the low-saline surface mixed layer. The prevalence of intermittent highly-energetic turbulent patches in the pycnocline over both sections is most probably associated with non-stationary, intermittent internal wave breaking and sporadic shear-induced instabilities. The eddy diffusivity in the pycnocline near the shelf break was found to be a function of the gradient Richardson number.

Keywords: Bay of Bengal, turbulence, mixing, barrier layer

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Phytoplankton Community Structure in Relation to Physico-Chemical Parameters, Off West and South-West Coasts of Sri Lanka

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Marine phytoplankton account for more than 45% of the photosynthetic net primary production on Earth and they stand on the base of the marine food chain thus affects higher trophic levels such as shellfish and finfish population. Further, phytoplankton is a key component of marine ecosystems and act as a potential bio-indicator of water quality alterations in response to local and global impacts. Some species of phytoplankton can have harmful effects on organisms at different trophic. The objective of this study is to evaluate the phytoplankton community structure in relation to physico-chemical properties of seawater. The study was conducted in off west and southwest coasts of Sri Lanka during March 2017. Phytoplankton and water samples were collected along three transects of 20 km towards offshore in Colombo, Beruwala and Mirissa each containing 10 sampling sites. Phytoplankton samples were collected towing a net (10 μm mesh) vertically from known depth with a speed of 0.5 m s^{-1} and preserved in Lugol's solution. The collected phytoplankton samples were identified to the lowest possible taxonomic level and counted under the Sedgwick rafter cell using Light Microscope. Water samples were collected at 1 m depth using the Ruttner Sampler and analysed for chlorophyll_a, nutrients and TSS using standard methods of seawater analysis. This study identified 58 phytoplankton species comprised of diatoms (35 species), dinoflagellates (23 species) and cyanobacteria (1 species). In general, phytoplankton abundance and species diversity decreased towards offshore in three transects. Total phytoplankton and diatom abundances were significantly varied among the three transect lines and significantly higher abundance ($901 \pm 327 \text{ no./l}$) was reported at Mirissa than that of Colombo and Beruwala (One-way ANOVA; $p < 0.05$). Total phytoplankton abundance significantly correlated with dinoflagellates, toxic species of dinoflagellates., chlorophyll_a and nitrate-N ($p < 0.01$). Ten toxic species of dinoflagellates were reported in the study. Diatoms were dominated in all the three sites with 86%, 97% and 94% in Colombo, Beruwala and Mirissa respectively. Diatom species of *Chaetoceros sp.* (30%) and *Nitzschia sp.* (50%) are dominated in Colombo and Mirissa respectively while *Trichodesmium sp.* (85%) is in Beruwala and indicate the possibility of blooms of these species at particular sites when environmental conditions are favorable.

Keywords: Colombo, diatoms, dinoflagellates, physico-chemical properties, phytoplankton

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Evaluating the Trend of the Sea Level Anomalies South of Sri Lanka

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The global sea level rise is one of the severe emerging environment issues and it is being accelerated by massive fossil burning, melting of glaciers and many human induced activities. Moreover, scientists have revealed that, global warming has contributed for increasing sea level about 8 inches since 1880 and the rate of rise is accelerating. However, global predictions for the sea level rise is ubiquitous and regional scale predictions are scanty. More studies have to be conducted for predicting sea level changes in regional scale to design proper mitigation and adaptation plans for coastal developments. Thus, this study is designed to find the trend of the sea level change in the southern part of Sri Lanka in a grid of latitude 5-6°N and longitude 79-82°E, from 1993 to 2018 using the satellite data collected from Marine Copernicus European Space Agency. Data was processed by R mathematical software to find the area averaged monthly anomalies, and overall sea level height at each grid point for the past 25 years. The observed area-averaged monthly anomaly data plotted shows an increasing trend in the regression line, which is significant at 5% significance level ($p = 2.2 \times 10^{-16}$). Minimum and maximum values of overall sea level height recorded at each grid points for study period are 0.82 m and 0.86 m respectively. The grid point that showed the highest sea level over the past 25 years in the considered grid is 5.875°N and 81.875°E. In conclusion, over the past 25 years the sea level has shown a statistically significant increase. Since this study is focused only for the southern part of Sri Lanka, detailed studies to analyze sea level changes around Sri Lanka and models for future predictions are recommended. Such developed studies could be used, to ensure suitable mitigation and adaptation measures to implement sustainable developments in the coastal areas.

Keywords: R-software, grid area, sea level anomalies

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Yellowfin Tuna (*Thunnus Albacares*) Abundance in Relation to Temperature Distribution in the Indian Ocean

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Yellowfin tuna (*Thunnus albacares*) is an epipelagic fish which inhabits offshore waters distributed in the water column. Purpose of the study was to identify the abundance and distribution of yellowfin tuna (YFT) based on the temperature in the study area that covers Northeast part of the Indian Ocean. Modeled temperature data were obtained from Copernicus Marine Environment Monitoring Service (CMEMS) in 16 depth levels (0–200 m). YFT catch records of 2018 were obtained from the Department of Fisheries and Aquatic Resources. According to the logbook data, YFT fishing activities is operated in several areas within the Sri Lankan EEZ as well as in the international water of Bay of Bengal and Arabian Sea. YFT catch locations is changing throughout the year. The observed results shows that there is a seasonal variation of surface temperature that influence the catch rates of YFT in the Indian Ocean. The catch rates has slight variability in the study period, with high catch rates recorded during the northeast monsoon while the lowest found in inter-monsoons from March–April and October–November periods. The average catch per unit of effort was 01.74 ± 0.75 calculated as number of fishes per 100 hooks per day. The results shows that the YFT were found in temperature ranges between 18–26°C in the water column. According to the temperature in different depth levels and the YFT catch rates of longliners falls 60–100 m depth ranges. There is a significant relationship between temperature and YFT catch rates. However, seasonal variation of temperature in the water column influence the abundance of YFT reveals that the knowledge of temperature distribution is essential to locate YFT fishing grounds. Temperature is one of a strong predictor for YFT, although there are some other ocean environmental parameters may influence the catch rates.

Keywords: Tuna Abundance, Temperature, Indian Ocean

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Observational Insight Into the Equatorial Intermediate Currents (EICs) in the Indian Ocean and Dynamics

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Observing and monitoring the Equatorial Indian Ocean (EIO) currents and associated variability are essential for understanding the evolution of the regional weather and Earth's climate. Such circulation system in EIO redistributed the mass, salt and heat is home to intense and highly variable biogeochemical constituents and plankton. The Equatorial Intermediate Currents (EICs, 200–1200 m) in the Indian Ocean have unique dynamic characteristics and complex vertical structures, which induce strong heat and volume transports, influencing the oceanic energy and biochemical balances. Due to the lack of direct observations, the EICs are only partly understood and difficult to predict. A deep-ocean mooring array is sustained since 2015 in the EIO by the Chinese Academy of Sciences to improve the understanding of the Indian Ocean EICs. The moored results indicate that the EICs are trapped near the equator and characterized by prominent semiannual oscillations with westward phase propagation and identifiable vertical structure. The underlying causes were elucidated with an oceanic reanalysis and continuously stratified linear ocean model. The wave dynamics reveal that the observed EICs can be explained by the equatorial basin semiannual resonance, where the boundary-reflected waves intensify the directly wind-forced waves. The EICs' trapped structure is consistent with vertically propagating first-meridional-mode Rossby wave at semi-annual period. Among various vertical modes, the second-baroclinic-mode makes the largest contribution, which dominates the EICs' semiannual oscillation and westward propagation.

Keywords: Indian Ocean, Equatorial Intermediate Currents,

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Side Scan Sonar Mosaicking with GeoCoder for Seafloor Feature Detection

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Ocean features can be explored, identified, imaged, and characterized by the use of acoustic devices. Side Scan Sonar (SSS) is an acoustic device that covers a wide range of applications. It enables a more complete and detailed description of the seabed for safer navigation, marine archaeological surveys, oil and gas industry, fisheries research, environmental studies, and dredging operations. From these, seafloor feature detection and classification are undoubtedly important to maintain the keel clearance in the navigable waters. Therefore, the respective authorities like Ports Authority must maintain all the ports and waterways timely. In this study, a comprehensive SSS survey was conducted at the Port of Colombo which is one of the busiest ports in the region. "Imaginex Model 872 Yellowfin" Side Scan Sonar was a side-mounted onboard vessel integrated into the data acquisition system. Acquired data were processed using HYPACK software and seabed classification was done using the GeoCoder tool. GeoCoder calculates the beam pattern using Angular Response Analysis (ARA) of the ensonified seafloor which reveals the actual nonlinearity of the transducer angular response. The final classification of the seabed was done based on the grain size of the various forms of sediment referring classification lookup table provided by GeoCoder. ARA states that the dominant grain size varies from 1 to 2 and is equal to sediment type of gravelly muddy sand. Therefore according to the analysis, 57% of the surveyed area of the port is covered with gravelly muddy sand bottom. The remaining area is covered by slightly deviating forms of sand such as coarse sand and silty sand corresponds to 20.4% and 14.7% of the area respectively. These results were further validated by the collected seabed samples that were randomly collected using the grab sampling method from several locations in the study area. The final seabed classification map reveals, the ARA process of beam pattern extracted at uniform seabed area provides a better mechanism of classification resulting in real seabed texture.

Keywords: Side Scan Sonar, Sediments, Angular Response Analysis (ARA), GeoCoder

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Determination of Shallow Water Depth Using Landsat-8 Satellite Images

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Temptation to determine the bathymetry data goes to the era when humans launched ships to discover the world. In fact, bathymetric data provide an important foundation for the process of generating profiles of the seafloor, charts for navigation, coastal erosion, sea level variations, biological oceanography, and so on. Further, there were several methods that are used for bathymetric data collection, (i) ship-based sensors (single beam echo sounders, multi beam echo sounders, etc.) and (ii) air-born and space-born sensors (light detection and ranging-LiDAR, multispectral scanners--MSS, etc). Furthermore, Landsat multispectral images (available freely online with 15 m and 30 m resolution) can be used to determine bathymetric data applying the nonlinear inversion algorithm which was formulated by Stumpf and his team in 2003 on the Landsat-8 satellite image bands of blue, green, and near-infrared (NIR). The present study was focused on preparation of satellite derived bathymetry (SDB) map based on Landsat-8 satellite image of shallow water area. Further, Landsat-8 satellite images of northern coastal area of Sri Lanka were selected due to the existing bathymetric data (ship-based) for verification process of SDB. In addition, Stumpf's nonlinear inversion algorithm was used to prepare satellite derived bathymetric map in northern area of Sri Lanka. Accordingly, statistical index value which is assessed from obtained values (SDB) and existing values (ship-based) is 0.9151. Moreover, shallow water depth data obtained (SDB) and existing depth data (ship-based) are well compared up to 15 m isobath. Consequently, SDB data of shallow areas can be used accurately for many marine purposes and this method is vital to survey water depths of inaccessible areas by ships.

Keywords: Satellite Derived Bathymetry, shallow water depth, Landsat-8, Non-linear inversion algorithm

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Analyzing Shoreline Changes in Micro Beaches Using Google Earth Pro: Case Study in Pareiwella Beach, Sri Lanka

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Shoreline extraction is a challenging task due to its high dynamic nature. However, many attempts have been made to map shorelines using satellite images. Many of them were derived from medium-resolution images for large beaches and still least attention is being paid to map shorelines in small beaches. Therefore, this study focused on mapping shoreline changes using high-resolution satellite images in Google Earth from 2003 to 2017 in Pareiwella beach which is a major tourism hotspot in southern, Sri Lanka. Water-land boundary was delineated as the shoreline on respective images in Google Earth Pro using freehand digitizing method under three different eye-altitudes (50 m, 300 m, 1000 m). Digitized shorelines were corrected with respect to image shifts in Google Earth. Shoreline change statistics were calculated under 50 m eye-altitude after casting transects at 1m intervals along the shorelines of three different zones (zone 1-northeast, zone 2-east, zone 3-southeast) divided based on the beach geomorphology using Digital Shoreline Analysis System (DSAS) tool in ArcGIS 10.5.1 software. Results revealed that there was a significant difference in overall shoreline change statistics among zones and among eye-altitudes (Two-Way ANOVA: $P \leq 0.05$). Further, it was identified that the zone 1 (northeast) and zone 2 (east) had net erosions of 10.8 ± 3.8 m and 8.5 ± 14 m respectively while zone 3 (southeast) had an accretion (5.6 ± 1.3 m) during the study period. Besides, significant erosion was observed in the zone 1 (37.24 ± 14.61 m) and the zone 2 (51 ± 15.77 m) during the period of 2003 to 2005 due to the impact of 2004 tsunami. However, this was partially recovered in a rate of 23.2 ± 11.66 m year⁻¹ and 38.1 ± 3.63 m year⁻¹ in the zone 1 and zone 2 respectively under natural conditions. The groyne established after 2006 between the beach head (zone 2) and the rocky area helped to get back the beach shape which changed due to the aftermath of tsunami and preserved the shape until now. Present situation and the shape of the beach were also verified using ground truth data. This study concludes Google Earth is an effective source for shoreline change estimation in small beaches, eye-altitude influences on shoreline change statistics and the tsunami caused significant impact on the beach followed by a partial recovery.

Keywords: Shoreline mapping, Micro beaches, Google Earth, Beach erosion, Tsunami impact

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Impact of the Regional Wind Stress Curl on the Sri Lanka Dome

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The Sri Lanka Dome (SLD) is an important upwelling eddy which results in high primary productivity in Indian Ocean. This SLD is a cyclonic eddy which locates in the Northern Bay of Bengal, East of Sri Lanka and develops during the Southwest Monsoon (May to September) period while it matured in July coinciding with the intrusion of Southwest Monsoon Current into the BOB. Present study attempts to examine the impact of wind stress curl for the SLD by analyzing twenty years monthly climatology by Simple Ocean Data Assimilation reanalysis (SODA) 2.0.2. model data and AVISO (satellite derived sea surface height) data. The wind stress curl ($\nabla \times \tau$) and Ekman upwelling were calculated using meridional (τ_y) and zonal (τ_x) component of the SODA 2.0.2. wind stress data. Previous studies have shown that the Sri Lanka Dome positive wind stress curl (SLDPWC) forced Ekman pumping is the governing mechanism of the SLD. As an immersing site of view, present results illustrate that there are three parallel wind stress curl bands propagate towards the Northeast in the western BoB. They arrange as the SLDPWC at the lowest, the negative wind stress curl (NWC) at the middle and the East Indian positive wind stress curl (EIPWC) at the uppermost levels consecutively. Moreover, the results show that the SLDPWC propagation dominates the migration of SLD during the developing stage. The monthly variation of the SLDPWC ($10^{-8} Nm^{-3}$) and 35 m depth-averaged vertical velocity of SLD indicates that there is a strong positive relationship between local wind stress curl and Ekman upwelling of the SLD ($r^2 = 0.93, p < 0.05$). Further, weakening of this SLDPWC is also an important factor for dissipation of SLD in addition to the warm Rossby wave effect for the SLD. During the decaying stage of SLD, the Bay of Benagal Dome (BBD) which locates off eastern coast of India, evolves independently from the SLD, as a result of the Ekman pumping mechanism driven by EIPWC. The regression analysis proves that, the EIPWC has a positive relationship with the Ekman Pumping of BBD ($r^2 = 0.76, p < 0.05$). With dissipation of NWC, the positive wind stress curl becomes dominant in the Southwest BOB and facilitate the merging of BBD and SLD.

Keywords: Sri Lanka Dome, Wind stress curl, Southwest Monsoon, Bay of Bengal, Bay of Benagal Dome

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Overview on the Buoyant Plume Dynamics and Its Morphology Off the Pearl River Estuary Over Northern South China Sea

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The northern South China Sea (NSCS) has a complex energetic circulation, which exerts an important influence on the coastal oceanography outside the Pearl River Estuary (PRE). In the last few decades, various techniques have been adopted into action including in-situ measurements, satellite observations and numerical simulations to investigate the dynamics of plume intensity and the spreading intensity of the buoyant plume off the PRE, to understand the buoyant plume morphology and their associated circulations under different forcing and conditions. River discharge is the dominant factor that influences on the plume intensity while the wind dominating on spreading. In addition, there are many factors such as Ekman transport, Coriolis force, Bathymetry, Currents, Tide and wave action along with seasonal variations is effected for spreading the intensity. In this study, eight morphological plume types were identified over the seasonal cycles, namely East Coastal Jet, characterized by a long, narrow, and turbid strip of plume water over the eastern shelf: East Offshore Spreading, characterized by a relatively short and broad strip of plume water, West Alongshore Spreading, characterized by coastally trapped plume water over the western shelf and limited eastward plume extension off the PRE: Symmetrical Alongshore Spreading, characterized by both eastward and westward extensions of plume water, of which the scale of the alongshore length is larger than its cross-shore counterpart, Offshore Bulge Spreading, characterized by a large amount of plume water accumulating off the PRE with alongshore and cross-shore sizes of plume water of equal scale, East Isolated Patch, characterized by an isolated plume water detached from the main plume over the eastern shelf East Offshore Branch, characterized by an offshore branch bifurcating from the eastward extension of plume water, Offshore Filaments, characterized by coastal alongshore spreading of the main plume with offshore filaments. River discharge and wind are the dominant factors that lead to a unique plume morphology. During the summer monsoon, these two factors become dominant which makes distinct plume morphological patterns over NSCS while during the winter monsoon they remain comparably low.

Keywords: NSCS, PRE, River discharge, Wind, Plume Morphology

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Preliminary Assessment of a Real-Time Forecasting System for Atmosphere and Storm Surge in Eastern Indian Ocean

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A real-time regional forecasting system for the Eastern Indian Ocean (EIO), called the Experimental Platform of Marine Environment Forecasting for EIO (EPMEF-EIO), is introduced in this research. EPMEF-EIO consists of a regional atmospheric and a regional storm surge model, and performs a real-time run for four times a day. Output from the Global Forecast System (GFS) from the National Centers for Environmental Prediction (NCEP) is used as the initial and boundary conditions of two nested domains of the atmospheric model, which can exert a constraint on the development of small- and meso-scale atmospheric perturbations through dynamical downscaling. Then the system outputs the 3-day forecast of 72 km, 24 km, 8 km for Indian Ocean-EIO-Sri Lanka. The forecasted winds at 10 m height from the atmosphere model are used to drive the storm surge model, obtaining the $1/12^{\circ}$ - $1/36^{\circ}$ results for EIO-Sri Lanka. By comparing observation data from the Sri Lanka Station Meteorological Tower of the South China Sea Institute of Oceanology, Chinese Academy of Sciences, Tropical Cyclone (TC) best track data and data from the Colombo tide gauge station, it is found that the daily variations of the model forecasted temperature and relative humidity are smaller than the observations; the overall root mean square error (RMSE) of the air temperature is 1.26° , and the coefficient is 0.8; the overall RMSE of relative humidity is 7.0, and the correlation coefficient is 0.7. The model forecasted wind speed is mostly larger than the observation, with an overall RMSE of 2.3 m/s and a correlation coefficient of 0.65. The forecasted wind direction of the model can grasp the main trend of variation, with an overall RMSE of between 20° - 32° and a correlation coefficient of about 0.65. The average error of model track forecast is 110.5 km, 166.4 km, and 181.0 km at 24-hour, 48 hour, and 72-hour, respectively. In addition, the overall RMSE of the model water level forecast is 0.035 m, accounting for about 5% of the maximum amplitude, and the correlation coefficient with the observation reaches 0.996. This shows that the model has the ability to simultaneously forecast tidal and storm surge processes. EPMEF-EIO, established primarily for research purposes with the potential to be implemented into operations, provides valuable information to the operational forecasters of local marine meteorological agencies or international TC forecast centers.

Keywords: Forecasting, Storm surges, Atmosphere, Indian ocean

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FISHERIES AND AQUACULTURE

Effect of Spirulina Powder on Growth Performance and Color Enhancement and Retention in Cichlids

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Body coloration is a major factor in determining the economic value of ornamental fish. Color fading is a major problem in the ornamental fish industry, especially in Cichlids. Artificial colorants can enhance the color, but have less effect on color retention. Many complaints related to the color fading of cichlids come after about two weeks from the exportation. This is one of the biggest barriers to the development of the exportation industry. This study was conducted by using Spirulina (*Arthrospira platensis*), rich in proteins and carotenoid pigments to test the growth performances, color enhancement and retention. Growth performances were tested by using different concentrations of *A. platensis* powder. Five different concentrations of *A. platensis* powder (0%, 3%, 6%, 9%, 12%) were incorporated with prima fish feed in triplicates. The whole experiment was carried out under two phases as the color enhancing (56 days) and color retention period (30 days). All the feeds tested were given, ensuring 10% of their body weight per day. Photographs of fish were taken once in two weeks and considered Red, Green, Blue (RGB) values of those photos of fish skin. There is an inverse relationship between RGB values and the color intensities. RGB values of fish after 56 days were 184.74 ± 1.59 , 128.36 ± 1.58 , 113.39 ± 2.64 , 75.19 ± 1.63 and 75.05 ± 1.60 respectively with a significant difference ($p = 0$) and RGB values of fish at the end of the color retention period were 184.63 ± 1.48 , 133.58 ± 1.36 , 116.71 ± 2.57 , 77.15 ± 2.23 and 75.71 ± 1.78 respectively ($p = 0$). Specific growth rates (SGR) of fish after 56 days in all treatments were 1.24 ± 0.028 , 1.55 ± 0.025 , 1.79 ± 0.028 , 2.19 ± 0.022 and 2.20 ± 0.023 respectively ($p = 0$). According to the study growth and colors and color retention were enhanced with increase the concentration of Spirulina until 9%. After 9% concentration those factors were recently constant. Finally, according to the study, the most suitable treatment for color retention and growth of *Aulonocara baenschi* is 9% spirulina powder incorporated treatment.

Keywords: Cichlid, Color fading, Spirulina, Color retention, *Arthrospira platensis*

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Current Status of Freshwater Aquatic Plants Export Industry in Sri Lanka

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The aquatic plants export industry in Sri Lanka is growing rapidly in the last few decades due to its ornamental value. According to the IUCN red list, there are nearly 370 freshwater aquatic plant species in Sri Lanka, which holds 40% endemic aquatic plants. This study aims to review the present status and identify potentials to improve the aquatic plants industry in Sri Lanka. Details on international trade of aquatic plants were recorded from Sri Lanka Customs between the periods of 2015 to 2018. Also, a list of companies which export freshwater aquatic plants was prepared using the information gathered from the Export Development Board. A questionnaire was used to collect the data from 49 registered aquatic plants export companies, on aquatic plant exportation, biosecurity measures, management practices and problems related to the industry. The custom data revealed that the aquatic plant exportation from 2015 to 2018, albeit database alone is not adequate to identify the quantities up to species level. Main buyer of fresh water aquatic plants from Sri Lanka was Germany. Currently, only six companies are engaging with freshwater aquatic plants exportation and it is a 57% reduction with compared to 2014. Due to the legal barriers on endemic plant exportation, only two companies out of the six are currently engaged with endemic aquatic plants exportation. Study exposed that *Echinodorus cordifolius* and *Anubias nana* are highly demanded exotic aquatic plant species while *Aponogeton species*, *Cryptocoryne species* and *Lagenandra species* are highly demanded endemic species. Aquatic plants identification problems, unaware of licensing procedures for endemic plants and monopoly of the industry were the major issues identified. The development of a mobile application may address the gaps in the identification and unawareness while proper government involvement will help to transfer the monopoly to free trade.

Keywords: Endemic aquatic plants, Export Development Board, Sri Lanka Customs, Export trade, Mobile application

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Functional Properties of the Crude Extracts From *Ulva Lactuca*

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Oceans provide different nutritional sources to fulfill the growing demand for nutritional compounds. Extremely changing temperature and salinity levels of seawater around Sri Lanka induce the growth of macroalgae with bioactive properties. Green marine macroalgae, *U. lactuca* is a good candidate for different nutritional compounds. The present study focused to compare different methods of extracting crudes and determining the functional properties of extracts of *U. lactuca* harvested from Hambantota, Sri Lanka. Proximate analysis was conducted to determine moisture, ash, and protein and fat contents in the sample. Water, salt, ethanol and alkaline extraction methods were followed to extract crude from the *U. lactuca*. Protein content in the selected best yield ratio of lyophilized crude extracts were determined by using the Lowry method. Antioxidant, antimicrobial and metal chelating properties were observed in each extract. *U. lactuca* contains $58.79\% \pm 0.89$ moisture, $4.43\% \pm 1.22$ crude fat, $22.40\% \pm 0.10$ protein and $12.30\% \pm 1.82$ ash. According to the yield analysis, 1:4 ratio (water, alkaline and ethanol extraction method) and 4% (v/w) concentration (salt extraction method) were selected as the simple, non-toxic, cheap, food-grade and the best process to extract crude from *U. lactuca* ($p < 0.05$). Crude extracts showed higher antioxidant activities concerning TBARs assay and DPPH radical scavenging activity ($p < 0.05$). Salt extract ($62.42\% \pm 0.62$) showed higher DPPH activity and alkaline extract ($0.257\% \pm 0.062$) showed low MDA concentration. Water extract had strong metal chelating activities rather than other extracts ($p < 0.05$). 20,000 ppm and 10,000 ppm concentrations of each extract were showed little higher antibacterial activities with Total Plate Count ($p < 0.05$). The study suggested that the crude extracts of *U. lactuca* is one of the sustainable sources for human nutrition, having good antioxidant, metal chelating and antibacterial properties that can be used in the food industry.

Keywords: *Ulva lactuca* Crude Extracts, Antioxidant, Antimicrobial, Metal Chelating

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Comparison of Bacterial Quality of Packed and Non-Packed Dried Sprats Available in the Local Market, Tangalle, Sri Lanka

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Dried fish is an important and popular protein source in Sri Lankan households. Dried sprats represent a major portion of local dried fish consumption. There is a market stereotype that packed products have a higher quality. Also, as there is a possibility of contamination during all the steps from processing to consumption, assessing the bacterial quality of dried fish is important. Therefore, this study was conducted from January to March 2019 to assess the bacterial quality of packed and non-packed dried sprats available in the local market of Tangalle, Sri Lanka. Total Viable Count (TVC) in nutrient agar was determined using the aerobic plate count method. Also, a qualitative screening of bacteria was done by using selective agar media (Thiosulfate–citrate–bile salts–sucrose agar and MacConkey agar). TVC of packed and non-packed dried sprats were 0.067×10^5 CFU/g and 5.3×10^5 CFU/g, respectively. There was a significant difference in TVC of packed and non-packed dried sprats ($P < 0.05$). Furthermore, both samples indicated the presence of coliforms and *Vibrio*. Also, the TVC of non-packed dried fish was reported over the accepted limit (5.0×10^5 CFU/g) of the Sri Lanka Standard Institute.

Keywords: Total Viable Count, Coliforms, *Vibrio*, Dried fish

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Qualitative Comparison of the Fatty Acid Profile Extracted From Skins of *Thunnus Albacares* and *Lepidocybium Flavobrunneum*

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Fish products consist of considerable amount of lipids, proteins and minerals. *Thunnus albacares* is the most abundant commercial food fish that is generated higher amount of waste while processing. *Lepidocybium flavobrunneum* is low demanded fish because of purgative and hazardous properties. To improve the utilization of fish processing byproducts and underutilized fish varieties; fish oils are extracted. Fish oils are considered as good sources of poly unsaturated fatty acids (Omega 3, Omega 6), used in pharmaceutical and food industries. Objectives of the study were to compare the fatty acid profiles extracted from skin of the selected marine fish species qualitatively and compare physiochemical properties of the extracted oils. Proximate composition of the raw materials was determined by Association of Official Analytical Chemists 2016. Oil extraction was done by using solvent extraction technique (Chloroform: Methanol: Water 2: 2: 1 V/V). The Gas Chromatography – Mass Spectrometry analysis was performed using an Agilent 7890B gas chromatograph equipped with a HP-5MS capillary column (30 m×0.25 mm) connected to an Agilent 5977 mass spectrometer (source temperature: 230°C, quadrupole temperature: 150°C). Structural assignments were based on interpretation of mass spectrometric fragmentation and confirmed by comparison of retention times and fragmentation pattern of authentic compounds of National Institute of Standards and Technology data bases. Physiochemical properties were determined by Iodine value, Peroxide value and Thiobarbituric acid reactive substance assay. Results indicate that *Lepidocybium flavobrunneum* and *Thunnus albacares* contained 50.87±2.14a%, 18.07±0.24a% crude fat content, respectively. Significant difference ($p < 0.05$) in chemical composition were observed between two species. Pentadecanoic acid, Hexadecanoic acid, Docosahexaenoic acid, Eicosapentaenoic acid, Arachidonic acid and Octadecenoic acid were observed as predominant poly unsaturated fatty acids. There were no any significant differences ($p > 0.05$) in physiochemical properties between two species. Thiobarbituric acid reactive substance assay revealed that the rancidity of *Thunnus albacares* oil was higher than *Lepidocybium flavobrunneum* oil. Accordingly both species were contained omega-3 and omega-6 fatty acids in their skins that can be used in industrial levels.

Keywords: Fatty acid profile, Gas Chromatography, Mass Spectrophotometry, Poly unsaturated fatty acids, Solvent extraction

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Gut Content Analysis of Black Sea Urchin (*Stomopneustes Variolaris*) Inhabited in Negombo and Weligama Coasts of Sri Lanka

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Sea urchins are prominent macro grazers inhabited in rocky marine ecosystems. *Stomopneustes variolaris* or black sea urchin is a highly abundant sea urchin species in the coastal waters of Sri Lanka. There is a trend of culturing Sea urchins as gonad of sea urchin known as roe is highly prized culinary delicacy in the world. Lack of knowledge on feeding ecology is one of major constrain to implement sea urchin culture. Hence this study was undertaken to study gut content of *S.variolaris* in Negombo and Weligama coasts of Sri Lanka and find out whether there is a spatial variation in gut content of *S.variolaris* in two regions. Samples were collected using random sampling method and 30 samples from Weligama coast and 20 samples from Negombo coast were selected for the study. Gut content was analyzed using number method. Macro algae, animal materials and detritus in the gut of *S. variolaris* inhabited in both regions were recorded. Length of the demipyramid and test diameter were also recorded. Results of the gut analysis revealed that, macro algae are dominated in the gut and represented 57% of the gut content. Among the 18 species of macro algae reported *Ulva* spp was the most abundant species in the gut content of sea urchin in the both Negombo (14.4%) and Weligama (14.3%) samples. Gastropods (0.05%), bivalves (0.13%) and foraminifera (0.04%) were also identified in Negombo samples and only foraminifera (2.70%) was identified in Weligama samples. According to the results of the Pearson Correlation analysis, the length of the demipyramid was positively correlated with test diameter ($r = 0.904$ for Negombo; $r = 0.705$ for Weligama). In conclusion, the results of the present study indicate that black sea urchin prefer *Ulva* spp. than other food sources. Further studies are designed to identify food preference of sea urchins in Sri Lankan waters.

Key words: Feeding habits, Sea urchin culture, Mariculture, Demipyramid

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Development of a Cost Effective Mass Culture Media for *Spirulina Platensis* in Sri Lanka

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Spirulina platensis is a multicellular and filamentous cyanobacteria with major popularity in the health, food and aquaculture sector due to its high protein availability. *Spirulina* is able to grow in different types of culture media, including decomposed organic and inorganic nutrients rich media. Production cost of spirulina culture is expensive at present Sri Lanka due to limited knowledge on culture techniques. Present study was conducted to formulate a low cost medium using cow dung ash (CDA) along with other cost effective chemicals for the mass production of *Spirulina platensis*. Accordingly four culture media were developed with the controller (Zorrouk media),

Treatment	NaHCO ₃ (g/l)	K ₃ PO ₄ (g/l)	NaNO ₃ (g/l)	K ₂ SO ₄ (g/l)	CDA(v/v)	NaCl(g/l)
T1	16.8	0.5	2.5	1.0	-	1
T2	16.8	0.5	2.5	1.0	20%	1
T3	16.8	0.5	2.5	1.0	40%	-
T4	16.8	0.5	2.5	1.0	60%	1

Pure culture of *Spirulina platensis* were inoculated into to four media and controller with three replicates. The population density was measured by counting the number of cells in each media maintained at 25°, pH 10.5 and light intensity 4000 lux. Data were collected once in three days for 24 days. The population densities of media were (T1 : $6.3333 \times 10^4 \pm 2.404 \times 10^3$, T2 : $1.21778 \times 10^5 \pm 1.7209 \times 10^4$, T3 : $1.16889 \times 10^5 \pm 8.002 \times 10^3$, T4 : $1.10000 \times 10^5 \pm 1.4529 \times 10^4$, control: $1.27000 \times 10^5 \pm 3.512 \times 10^3$) T2 medium was the most favorable media other than the control medium for culturing *Spirulina platensis*. Results indicate the potential of cow dung ash as a fertilizer to provide the effective cultivation medium for growth of *Spirulina platensis*.

Keywords: Cow dung ash, *Spirulina platensis*, Growth, Organic media, Mass culture

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Length–Weight Relationship of *Stomopneustes Variolaris* (Black Sea Urchin) in Mahamodara and Pareiwella of Southern Sri Lanka

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This study was conducted to determine the length–weight relationship and the length and weight frequency of *S. variolaris* from intertidal waters of Mahamodara and Pareiwella in the Southern coast of Sri Lanka. A total of 102 and 87 samples were collected randomly from the Mahamodara and Pareiwella during the time periods from September 2018 to August 2019. The test diameter and bodyweight were measured separately for two sampling sites. The frequency distribution of test diameter and weight of *S. variolaris* reveals that the test diameter (TI) ranged from 3.2 cm to 9.0 cm and 3.0 cm to 8.6 cm, for *S. variolaris* in Mahamodara and Pareiwella respectively. Total weight (Wt) ranged from 27 g to 350 g and 28 g to 340 g, for *S. variolaris* in Mahamodara and Pareiwella respectively. In addition the length weight relationship of *S. variolaris* were $W = 0.97273L^{2.636}$ and $W = 0.98316L^{2.622}$ for Mahamodara and Pareiwella respectively. The present study revealed the b value for Mahamodara (2.636) and Pareiwella (2.622) were less than 3, which concludes that *S. variolaris* shows a negative allometric growth. Results of the present study could be utilized to get an idea about the growth of *S. variolaris* in Southern coast of Sri Lanka for formulating a sound management plan while developing the fishery.

Keywords: *Stomopneustes variolaris*, Southern coast, growth parameter

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Habitat Use and Behavior of Blue Whales (*Balaenoptera Musculus*) During North-East and South-West Monsoon, Off Mirissa, Sri Lanka

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Information on the habitat use of cetaceans is vital to develop conservation efforts and management strategies for particular species. In southern Sri Lanka, Mirissa is a year-long area for blue whales (*Balaenoptera musculus*), but limited information is available on their habitat use of this area. Boat-based survey data collected from 2017 to 2018 were used to analyze blue whale habitat use. The objectives of this research were to; 1) identify habitats that were important to blue whales, 2) determine which behaviors were observed in this area and whether whale groups with calves used the area, 3) fill knowledge gaps on the species' behavioral ecology. The kernel density was used as a standard tool to estimate ecological distribution to identify significant use areas. Critical habitat maps in the southern part of Sri Lanka were generated for feeding, traveling, and whale groups with calves in the northeast monsoon (November–March) and the southwest monsoon (May–September). Traveling was the most commonly observed behavior. It is identified that the region represents an important foraging ground and nursing ground for this population. Further, dense aggregations and foraging blue whales were observed near the shipping lane and several acute injuries recorded during the study period. The results suggest that the southern part of Sri Lanka also serves as a transit route between the Indian and the Arabian sea in all seasons.

Keywords: Blue whale, critical habitat, behavior, distribution, season

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Partial Replacement of *Artemia*-Nauplii by *Moina* Sp. on Growth and Survival of *Poecilia Latipinna* (Golden Sailfin Molly) Larvae

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In global aquaculture, application of live feed has high demand and in most cases, *Artemia* sp. is used as a live feed for the larval stages of aquaculture organisms. Since, *Artemia* sp. is an expensive live feed, replacement would help economically feasible larval industry. In order to replace alternative source, the current study aimed at evaluating the suitable combination of two selected live feeds: *Artemia nauplii* and *Moina* sp. (an economical species) for better survival and growth of Golden Sailfin Molly (*Poecilia latipinna*) larvae. The treatments used were 100% *Artemia* sp. (A100), 75% *Artemia* sp. and 25% *Moina* sp. (A75M25), 50% *Artemia* sp. and 50% *Moina* sp. (A50M50), 25% *Artemia* sp. and 75% *Moina* sp. (A25M75). Three days old *P. latipinna* larvae were introduced to experimental tanks with a stocking density of 80 fish larvae per each tank (5 larvae per 1L of water) and were fed with the above treatments (two times per day) for twenty-one-day period maintaining three replicate tanks for each treatment. The survival and growth, Percentage weight gain (%Weight Gain), Percentage length gain (%Length Gain), Specific Growth Rate (%SGR) and Condition Factor (CF) were computed and statistically analyzed in SPSS software package using separate ANOVA tests. The results revealed that the fish larvae fed on the A50M50 combination (*Artemia* sp. and 50% *Moina* sp.) showed the highest final length, final weight, %length gain, %weight gain, and %SGR than the larvae fed on other combinations (A100, A75M25, and A25M75). The A25M75 treatment (25% *Artemia* sp. and 75% *Moina* sp.) yielded the lowest growth performance to the fish larvae. Therefore, the present study concluded that 50% of *Artemia* sp. and 50% *Moina* sp. (A50M50) treatment was the best among the tested live feed combinations for the larval stages of *P. latipinna*. Use of 100% *Artemia* sp (A100) for feeding the *P. latipinna* larvae is a common practice in aquaculture. However, based on the findings of this study, the *Artemia* sp 50% and *Moina* sp. 50% (A50M50) is the best combination and might have commolcial benefits instead of A100.

Keywords: *Artemia* nauplii, *Moina* sp., Partial replacement, Live feeds, Aquaculture

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Demonstrating the Influence of the Microbiome on Oyster Health Using an Experimental Infection Model in Pacific Oysters (*Crassostrea Gigas*)

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In the recent past, the global oyster industry experienced mass mortality disease outbreaks resulting severe economic losses. Although *Ostreid herpesvirus-1* (OsHV-1) has emerged as an important cause of these disease outbreaks, the oyster microbiome is also thought to play a role in these disease outbreaks. The environment influences the microbiome of oysters owing to their filter-feeding behaviour. This study considered the oyster microbiome as a risk factor for disease susceptibility by evaluating the microbiome of Pacific oysters: (1) from a common hatchery but grown in different estuaries; and (2) in response to OsHV-1 infection. Pacific oysters (n=348) from a single hatchery that were grown in three distinct estuaries were recruited to the laboratory and challenged with OsHV-1. Samples were collected: before (A) and soon after OsHV-1 challenge (B); from moribund oysters (C); survivors of OsHV-1 (D); and from OsHV-1 negative control oysters (E), for microbiome analysis. Total bacterial, OsHV-1 and *Vibrio* genomic DNA were quantified using real-time PCR assays. The microbiome in oysters was identified by sequencing the bacterial 16S rRNA gene (V1-V3). The initial bacterial diversity was significantly different for oysters grown in different estuaries and changed further after OsHV-1 injection. In conclusion, the different microbiome in oysters grown in different locations also had a differential response to OsHV-1 challenge. Further, the higher *Vibrio* load in oysters with increased quantities of OsHV-1 and higher mortality suggested a role of *Vibrio* in the pathogenesis of this disease. This study indicates the role of estuarine environment in shaping the oyster microbiome and the resulting influence on the disease outcome.

Keywords: microbiome, Oyster, *Ostreid herpesvirus-1*, *Crassostrea gigas*

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Ocean Currents and Temperature Variability on Yellowfin Tuna Catch Rates of Sri Lankan Longline Fishery

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Sri Lankan fishermen spend about 2-4 weeks on a fishing trip for longlining targeting for yellowfin. However, uncertainty of catch leads to increase search time and operational cost. Traditional knowledge on fishing is also inadequate to compete with the foreign vessels operating in the Indian Ocean (Rajapaksha et al., 2013). Therefore, more advanced technologies need to be introduced for Sri Lankan longline fishing operations. Ocean temperature and circulation pattern play a significant role in locating tuna fishing grounds. This study focuses on identifying the impact of ocean currents and vertical temperature variability on tuna catch rates with the ultimate goal is to contribute for improvement of an existing fishing ground forecasting system. Ocean currents and vertical temperature data were obtained from Copernicus Marine Environment Monitoring Service. Tuna catch datasets of year 2016 was obtained from the Department of Fishery, Sri Lanka. The catch dataset consisted the data of fishing, the location, the number of hooks and the species wise catch rated in each operation. Temperature and currents data were in 0.25° spatial resolution and averaged over 5-day intervals. Similarly, the catch data records were also transformed into the same grid resolution and averaged over 5-day intervals to match up with temperature and currents data in different depth levels. The matched dataset of current velocity, temperature and catch rates were analyzed using R statistical packages (Gomez-Rubio, 2018). The results show that the high catch rates can be found in the temperatures between 22–25°C that exist around thermocline of mean depth around 100 m. However, seasonal variability of vertical temperature fluctuates the thermocline form about 60 m to 160 m in the study area. This study also shows that the high catch rates fall in the areas where current speed is less than 0.5 ms⁻¹, peak around 0.25 ms⁻¹. Thus, the prediction of fishing depth based on the vertical temperature structure is an essential parameter for successful fishing operations.

Keywords: Indian Ocean, Longline Fishing, Yellowfin tuna, Ocean Currents

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MARINE ENVIRONMENTAL MANAGEMENT

Assessment of Marine Litter in Selected Beaches of Southern and Western Part of Sri Lanka

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Sri Lanka has been ranked at the 5th place in the list of world's most sea waste producing countries. Direct discharge of marine litter is highly influenced by rapid urbanization, poverty, population growth, marine environment related industries and tourism. Land and ocean-based sources are caused for marine litter and land-based pollution is considered as a major threat to the marine environment. The objective of the present study was to evaluate on composition and abundance of marine litter in twelve beaches such as Mirijjawila, Dehiwala, Moragolla, Kalido, Panadura, Moratuwa, Negombo, Hikkaduwa, Dodanduwa, Weligama, Mirissa and Tangalle of the Southern and Western coastal belts. Survey was conducted from April to November in 2019. Twelve samples were collected randomly from each beach within 200 m beach stretch from three zones including back shore, high water strand line and water edge by using quadrats ($1 \times 1 \text{ m}$). Litter particles bigger than 5 mm were identified visually, counted and weighted. Beach litter was categorized as plastics (Polythene, Polypropylene, Polystyrene, Polyvinyl chloride, nylon, fiber glass), organic waste, leather, glass and metal. Statistic was performed and found that mean total litter count and total weight of litter were significantly different with each sampling locations ($P < 0.05$). High weight of total litter ($602.87 \pm 29.83 \text{ g/m}^2$) and total plastic litter ($277.27 \pm 9.31 \text{ g/m}^2$) abundances were reported at Kalido beach. Minimum total litter weight ($58.50 \pm 2.66 \text{ g/m}^2$) and minimum total plastic litter weight ($6.51 \pm 0.37 \text{ g/m}^2$) was reported at Mirijjawila beach. Highest total litter count ($469.86 \pm 20.27 \text{ item/m}^2$) and total plastic count ($169.07 \pm 6.35 \text{ item/m}^2$) were reported at Moratuwa beach. Lowest total litter count and plastic litter count abundances were reported at Mirijjawila beach. Domestic and hotel waste dumping, recreation and fishing activities were identified main sources of marine litter. Take proper mitigation to stop domestic and hotel dumping at the beaches in areas of Western and southern coastal belt is vital. It is suggested to keep billboards in such open dumping locations to enhance the public awareness or implementing penalties on polluters. Also, to reduce the waste from beach visitors, it is advisable to keep public waste bins in well identified locations in study sites where the public frequently gather.

Keywords: Marine litter, Sri Lanka, coastal dumping, plastic, land-based pollution

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Evaluation of Chlorpyrifos Toxicity Under Adsorption and Photo Degradation Using *Daphnia Magna*

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The presence of pesticides in the environment poses adverse effects on health and leads to severe environmental pollution. When a pesticide is applied, it is subjected to different complex process and degradation happens in the environmental conditions. Use of natural absorbent material is cost effective and environmentally friendly approach to water purification techniques. Therefore, main objective of this study was to determine the adsorption and photo-degradation of chlorpyrifos pesticide using different natural absorbent materials to remove pesticide from water. Liquid humic acid, charcoal and a mixture of both humic acid and charcoal were used to test with three different chlorpyrifos concentration, such as 0.5 mg/l, 1.0 mg/l and 2.0 mg/l shaken for 4 hours at 150 rpm for different experiments; adsorption and photo-degradation. The non-degrade chlorpyrifos portion was extracted by solid phase extraction and the concentration was determined by gas chromatography. For the toxicity test, diluted non-degrade chlorpyrifos solution was used. LC50 value of *Daphnia magna* was determined by following the Organisation for Economic Co-operation and Development (OECD) Guidelines for the testing of chemicals and toxicity. Results reveal that, almost 60% of pesticide by humic acid, 85% of pesticide charcoal and 68% of mixture of both and charcoal were removed on the adsorption experiment. Also, more than 95% of pesticide removed with a mixture of humic acid and charcoal mixture, nearly 50% with humic acid and 80% with charcoal were degraded under the photo-degradation experiment including both photodegradation and adsorption process. The pesticide removal rate is higher in charcoal than other two materials on adsorption process. However, the pesticide removal rate on photodegradation is higher in mixture of both humic acid and charcoal than that of other two materials. The result suggested that, LC50 is higher in mixture of both humic acid and charcoal than that of other two materials and toxicity was considerably low. Based on the results, it can be concluded that, the natural absorbent materials degraded considerable portion of Chlorpyrifos and best performance illustrated by the both humic acid and charcoal mixture.

Keywords: Adsorption, photodegradation, chlorpyrifos, charcoal, humic acid

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Status of Plastic Waste Management and Proposed A Circular Economy-Based Policy Framework to Management Plastic Waste in Sri Lanka

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Plastics are inexpensive, lightweight and durable materials, which can be used to develop a variety of products in a wide range of applications. There is no exception in Sri Lanka the use of plastics resulted to generate huge amounts of waste creating the environment socio-economic and health issues. Circular Economy is an alternative concept for the present linear model of make, use and dispose of plastics. Recycling aims to keep resource efficiency to extract maximum value by improving waste minimization strategies. Plastic recycling and required policy to strengthen the circular economy is not efficiently implementing the country since there is no proper circular based policy framework. This paper examines the amount of plastic waste generated and recycled in Sri Lanka, future trend and gap of plastic waste generation and recycling. The primary data were collected using the structured questionnaire from randomly selected 20 recyclers and secondary data were collected from the Department of Customs. The future trend of plastic waste generation and recycling capacities were analyzed by statistical analysis using Minitab and it shows quantities of plastic waste (MT) 11750 LDPE, 3270 HDPE, 60480 PP, 29060 PS, 2200 PET generated in 2019 and it expected to increase (MT) 175000 LDPE, 7800 HDPE, 79800 PP, 50000 PS, 3000 PET in 2025 in Sri Lanka. Plastic waste quantities, gap of waste generated and recycled will further be increased if the proper policies are not adopted. Further this paper suggest that circular economy based policy framework within the concept of reduce, reuse and recycle. Government should be proposed rules and taxes for importing plastic items and regularize the rules for using plastic materials and move to ecofriendly alternatives. Implement a strategic plan to introduce plastic recycling at provincial and municipal council's level and consider about the resale price of the recyclable products. Introducing the process to carry out plastic packages by manufactures by their own way to recycle can avoid waste management issues and mitigate its impact by keeping their value in the economy.

Keywords: Circular Economy, Plastic Recycling, Framework, Waste Management in Sri Lanka

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Nutrients Dynamics in the Water and Sediment and Its Impact to Planktonic Species Diversity in Ratgama Lagoon, Sri Lanka

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Ratgama lagoon is located in the wet zone (WL4) of Sri Lanka, and spreads between latitude 60°72' and 60°55'N and longitude 80°08' and 80°07'E in Galle district in Sri Lanka. Surface area of the lagoon covers around 237.5 ha of which 234 ha is open water, while 3.5 ha accounts for the total area of the islands. There is no proper study conducted to understand the water quality, sediment chemistry, and planktonic species in the Ratgama lagoon. Therefore, the present study was focused to evaluate the water quality, sediment characteristics and plankton community. Water samples and sediment samples were collected from fifteen sampling locations during February, 2018 to December, 2018. Results reveal that, the mean surface water temperature, mean pH value, mean turbidity, mean salinity and dissolve oxygen concentration in study area were 32.27 °C ± 0.41, 7.90 ± 0.08, 5.69 NTU ± 0.91, 21.2 ppt ± 2.79 and 6.10 mg/L ± 0.46 respectively. Also, mean nutrients such as ammoniacal nitrogen, nitrate nitrogen, nitrite nitrogen and dissolve phosphate were recorded as 0.054 mg/l ± 0.04, 0.013 mg/l ± 0.035, 0.008 ± 0.01, and 0.073 mg/l ± 0.13 respectively. The mean chlorophyll_a concentration was recorded as 8.65 mg/m³ ± 12.37. In addition, the mean nutrient (ammoniacal nitrogen, nitrate nitrogen, and dissolve phosphate) concentration in the sediment were varies 2.655 mg/l ± 0.96, 0.041 mg/l ± 0.04, and 0.003 mg/l ± 0.002 respectively. Thirteen planktonic species were recorded and Keratella spp and Chaetocera spp were the most dominant species in the Ratgama lagoon. The highest Shannon diversity index (H) of 1.9642 was recorded in sampling location 3. The principal component analysis and scree plot for nutrients was illustrated that there are two major components (40% and 30% respectively) and also, weak positive and weak negative correlations of water quality and plankton were recorded under correlation matrix.

Keywords: Ratgama lagoon, planktonic species, sediment, water quality, principal component analysis

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Detection of Sea Surface Plastic in the Northern South China Sea Using an End Member Analysis of Sentinel Satellite Reflectance

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Recently, the ubiquitous concentration of marine plastics has significantly increased. However, a well-established methodology to apply in the global extent has not yet been published. This study focused on an innovative approach for finding sea surface plastic using end member spectra derived for the level-2 Sentinel-2 and Sentinel-3 satellite images. The Northern South China Sea (NSCS) and the Great Pacific Garbage Patch (GPGP) were used as the main study area and verification study area respectively. The end member detection was accomplished using bottom of atmosphere spectral reflectance of Sentinel-3 infrared bands (central wavelength 753.75 nm–1020 nm) and Sentinel-2 infrared bands (central wavelength 783 nm–2190 nm). The identified Sentinel end member spectra were compared with the United States Geological Survey (USGS) plastic spectra visually and quantitatively to identify the closely related spectra. The Environment for Visualizing Images (ENVI) spectral library viewer and the spectral contrast angle (θ) method were used for visual and quantitative spectra evaluation respectively. Six different plastic spectra for NSCS and two different plastic spectra for GPGP were identified in the end member analysis. These plastic spectra were used for linear spectral unmixing process of Sentinel satellite images in which generated pixel wise sea surface plastic concentration values from θ to 1. The high plastic concentration values from 0.7 to 1 for the NSCS below the latitude of 22°N, was a significant result because the probability of spectral mixing due to the water turbidity is lower in the seaward area compared to the landward nearshore areas. The accuracy verification was done by cross checking the detected plastic concentration maps of GPGP with an existing plastic model for this area. The overlap area comparison results of the derived concentration maps with the model showed more than 50% similarities in 7 out of 12 images. These validation results concluded the importance of using plastic end member spectra evaluated as strong ($5^\circ < \theta \leq 10^\circ$) and very strong ($0^\circ \leq \theta \leq 5^\circ$) according to the spectral contrast angle (θ) scale because it enhances the accuracy of the plastic concentration results.

Keywords: marine plastics, infrared bands, end member, spectral contrast angle, Northern South China Sea

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Composition of Sessile Benthic Life Forms, Reef Fish With Relation to Water Chemistry and Microbial Abundance of Paraviwella Coral Reef, Sri Lanka

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Coral reefs have suffered from a range of impacts from local anthropogenic influence to global climate change. In recent years these impacts have led to changes in coral community structures from coral reefs dominated by living corals to dominance by fleshy algae, which is called phase-shift. The present study was conducted at Paraviwella reef, Tangalle (06.02152° N , 80.8022° E) from 12 September 2017 to 31 May 2019. The mean water depth was 54 ± 17 cm and the mean temperature was $29.0 \pm 0.3^{\circ}\text{C}$. The objective of the study was to find out the present status and composition of sessile benthic life forms, reef fish with relation to water chemistry and microbial abundance. The main methods for the assessment of benthic composition (i.e., Line Intercept Transects for percentage cover, $n=3$, 20 m each) and abundance of dominant reef fish (Visual fish counts along belt transects to determine percentage abundance, $n=3$, 25 m each) were conducted according to Australian Institute of Marine Sciences procedures. Microbial Abundance of the water column was determined using epifluorescence microscopy and metagenomics sequencing techniques. The results show that benthic composition was dominated by living coral ($57.6 \pm 11.7\%$) and fleshy algae ($22.2 \pm 15.4\%$). Percentage cover of non-living components such as coral rubble, sand and rock were recorded as $20.1 \pm 8.5\%$. *Pocillopora damicornis* and *Caulerpa racemosa* were the dominant sessile benthic life forms represented at the reef site. Fish community represented by herbivores ($46 \pm 7\%$), carnivores ($40 \pm 1\%$) omnivorous ($3 \pm 1\%$) and planktivorous fish ($9 \pm 1\%$). Overall, nutrient levels which had high levels of ammonia and NO_x, at $4.29 \pm 2.00 \mu\text{M}$ and $9.78 \pm 0.18 \mu\text{M}$, respectively. The phosphate concentrations $0.61 \pm 0.01 \mu\text{M}$. At this condition at Paraviwella reef water column mean microbial abundance was $4.5 \times 10^6 \text{ ml}^{-1}$. The metagenomics data shows that Paraviwella reef had abundant Vibrionales and Alteromonadales, which include copiotrophic members. These copiotrophic microbes possess large genomes and are often resistant to heavy metals. These results confirm that the status of health of the reef in a polluted environment and maintained its health by herbivorous fish population, allowing this microbe to thrive in an environment with increased toxicity and nutrients.

Keywords: Bacteria abundance, Microbial metagenomics, Coral, Phase-shift, Reef fish, Water column

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A Preliminary Study on Avifaunal Diversity in the Crow Island Beach Park, Urban Coastal Wetland of Sri Lanka

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Sri Lanka has a wide array of inland and coastal wetland ecosystems that harbor rich biological diversity. One such urban coastal wetland in Sri Lanka is Crow Island coastal ecosystem. The Crow Island Beach Park is a public park located in Colombo (6.9733°N 79.8694°E). The land extent of this park is 7 ha. The beach park consists of rich avifaunal diversity since it is a coastal wetland. The main objective of the present study was to document the avifaunal diversity of the coastal wetland of the beach park. Multiple surveys were conducted through random visits in the area for a period of two months from July to August 2020. Their status was evaluated from the National Red List. Diurnal and nocturnal observations were made through the unaided eye and using a binocular via multiple random walks and point counting method. A total of 28 bird species were recorded belong to 14 orders and 22 families representing 5.69% of the birds recorded in Sri Lanka (492). Of the reported bird families, nine families represented Order Passeriformes while four species of birds found in the park represented family Ardeidae. This park is not only significant for biodiversity conservation but also for its value as a coastal wetland. The local communities of the area are constantly interacting with the area for their living and for leisure. Consequently, these habitats are threatened by irresponsible human activities such as garbage dumping, noise pollution, lighting fires for garbage burning, clearing of natural vegetation in and around wetlands. However, detailed survey has to be carried out to study the abundance, seasonal variation to recommend the conservation and management measures.

Keywords: Coastal wetland, Avifaunal diversity, biodiversity conservation

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Comparative Study on Aquatic Avian Species at Rekawa and Kalametiya Lagoons in the Southern Sri Lanka

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Avian species in Sri Lanka play a vital role in sculpting the country's biodiversity where about 458 species, including residents, migrants, vagrants and waders have been recorded so far in the local context. Among them migratory species tend to visit the island in search of favorable climatic settings. Rekawa and Kalametiya lagoons are considered to be the two major lagoons located in the region and they are significant as they harbor a considerable proportion of resident and migratory aquatic avian species. The information on these lagoon migratory avian species is comparatively less in Sri Lankan context. The broad objective of the study was to determine the abundance of aquatic avian species residing the two selected lagoons (Rekawa and Kalamatiya) in the southern coastline of Sri Lanka. Transect Counts (TC) method was used to survey the two sites and points were delimited at respective 100 m intervals along a single transect. Data were collected from each site (Rekawa and Kalamatiya) utilizing a combined investigating technique of transect and point methods at the 2 hour time intervals for Rekawa site and at the 2 hour time intervals for Kalamatiya site. Three transects have delimited for Rekawa lagoon and six transects have delimited for Kalamatiya lagoon. MINITAB 16 statistical software have used to statistically analyze the collected data and mean abundance to compare data by using a Two-way ANOVA test underlying a post-hoc analysis. According to the One way ANOVA test, the mean abundance of aquatic avian species differed significantly ($P < 0.05$) Kalamatiya lagoon had the highest mean abundance (130 ± 27 SE) and Rekawa had the minimum mean abundance (27 ± 3 SE). The distribution of species at each site have mapped using the Arc GIS 10.1 geo-processing software. According to Two way ANOVA, the highest avian abundance was recorded in Kalamatiya lagoon, also the avian abundance in morning was significantly higher than the evening in both lagoons. Current study will be provide a grounding source in managing and implementing conservation strategies. Also it will indicate the value of these fragile ecosystems.

Keywords: Avian, Migratory, Kalametiya, Rekawa, Southern province, Sri Lanka

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Seaweeds for Bioremediation: Removal of Oil From Seawater

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Oil is a slippery liquid that burns and is not soluble in water and one of the most widespread pollutants in the ocean. Ports and harbors located within urbanized areas are the most affected by oil pollution. This is mainly because of serious damage to the fishery and maricultural resources through physical contamination, toxic effects on stock and disrupting business activities. Seaweeds have showed the ability of surviving in the oil polluted sea waters. The aim of the current study is to check the oil absorbing ability of some selected seaweed species, including the effect of particle size and drying methods of Seaweeds. Three seaweed species (*Gracillaria sp.*, *Ulva lactuca*, *Sargassum sp.*) were collected along the Tangalle coastline in Sri Lanka during May 2019. Solar and Oven drying methods were used to dry each seaweed sample. Dried samples were crushed and separated into three particle sizes including the actual size of dried seaweeds. Crude oil and sea water were mixed in 1:50 ratio and added into conical flasks. Seaweed samples were added into each mixture and left for overnight to absorb oil from the mixture. Separatory funnel technique was used to separate remaining oil. Results revealed that the mean oil absorption ability is significantly varied among the three seaweed species ($p < 0.05$; Two-way ANOVA test) and between different drying methods ($p < 0.05$; Two-way ANOVA test). Solar dried *Gracillaria sp.* had the highest absorption ability (80%) followed by *Ulva lactuca* (76%) and *Sargassum sp.* (75%). The mean oil absorption ability is significantly varied among the three seaweed species ($p < 0.05$; Two-way ANOVA test) and between different particle sizes ($p < 0.05$; Two-way ANOVA test). 0.2mm size of *Gracillaria sp.* had the highest absorption ability (81%) followed by 1mm of *Gracillaria sp.* (74%) and actual size of *Gracillaria sp.* (71%) Thus, the current study clearly revealed that seaweeds have high potential to absorb the oil spread in sea water. Therefore, seaweeds can be recommended to use as a Bio-oil filter. Further, these findings will be useful in implementing bioremediation measures in the oil polluted areas.

Keywords: Seaweed, oil, separatory funnel technique, Tangalle, Sri Lanka

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Preliminary Study on Rehabilitation of Mangroves in Malala Lagoon, Bundala, Sri Lanka

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Mangrove ecosystems are very significant seaside environments in tropical areas, straightforwardly or by implication empowering reliant and business fisheries. They are under risk in an assortment of human exercises. To relieve the misfortunes of mangroves, rehabilitation is near on the preservation plan. Previous studies were not reported about the factors affecting the mangrove rehabilitation and the success or failure of planted mangroves in the Malala Lagoon (Bundala National Park). Therefore the current study is focused to examine reestablish mangroves using suitable species with respect to the environmental conditions; salinity, water depth, and temperature. This program has been conducted for six months; from January to June, 2020. Seedlings have been planted covering roughly 2.5 ha in Malala lagoon. The two sites: site O1 (0.5 ha) and site O2 (2.3 ha) were recognized for the study. Water depths were estimated concerning the sub site estimations. Preliminary studies conducted the one and half month to measure the environmental conditions in Malala lagoon. The environmental data of the Malala lagoon has moderate salinity conditions; 1–5 ppm, low water depths; 25–30 cm and temperature; 28–30°C Three mangrove species (*Rhizophora mucronata*, *Rhizophora apiculata*, *Sonneratia caseolaris*, and *Bruguiera gymnorrhiza*) which can be go in moderate salinity conditions were selected. In both sites 250 seedlings of each species were planted. Results revealed that after four months the growth percentage of *S. caseolaris* (65.2%) is higher than *R. mucronata* and *R. apiculata* (41.6%) and *B. gymnorrhiza* (40.5%). The higher mortality rate showed in *B. gymnorrhiza* (59.2%) that followed by *R. mucronata* and *R. apiculata* (58.4%) and *S. caseolaris* (34.8%). During the study few challenges were faced; drying of the site's tidal creek zone, small scale fishermen making paths to land their canoes, etc. Continues monitoring with proper management plan is recommended to implement in one year. The findings of the study can be used in future rehabilitation projects that surrounded in Sri Lanka.

Keywords: Rehabilitation, Mangroves, Malala lagoon, Bundala

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Apical Grooves in Order Gymnodiniales: History, Diversity, and Taxonomy

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Apical groove is a morphological character in unarmored dinoflagellates that is present as a narrow and shallow structure on the top of the cell. Apical groove is one of the meaningful features in natural classification systems for taxon identification. The relationship between apical groove shape, morphology and phylogeny is poorly studied. Groove like structure in some unarmored dinoflagellates were named as paracingular lines, acrobase and later given the term apical groove. Recently it is renamed as 'Apical Structure Complex' (ASC) with complex morphological features that is categorized into three types as type I, type II, and type III. However, diversity of apical groove among unarmored dinoflagellates has not been systematically studied. In this study we classify a new ASC type as type IV in *Pseliodinium pirum*. Based on our data and historical data, we studied the diversity, morphology and types of apical grooves in order Gymnodiniales. Apical groove's morphological, ultrastructural and molecular phylogenetic studies in unarmored dinoflagellates has enabled to identify, reclassify, and differentiate genera and species such as *Barrufeta*, *Margalefidinium*, *Polykrikos* and *Testudodinium*. Horseshoe-shaped or loop-shaped and sigmoid apical grooves are generally used to describe species that belongs to Gymnodiniales sensu stricto clade and *Takayama sp.* respectively. Most of the *Takayama*, *Karlodinium*, and *Margalefidinium* species have one or two ventral pores appearing as a slit near the apical groove that could be a paleontological evidence of a rudiment or existence structure of another apical groove. Earlier species like *Gymnodinium sp.2* and *Warnowia sp.3* are identified with two apical grooves. *Woloszynskia* dinoflagellates has been identified with the epicone morphology combined with the line like structure called carina or acrobase that is now termed as 'apical line of plates'; because apical groove consisted with many structures of morphological features and sometimes it does not show a groove. Here we suggest the term ASC as the best term to describe 'apical groove'. This study provides an insight to future research to identify the evolutionary relationship in apical groove's shapes, identify different types and morphological features of ASC. Further, we recommend reclassification, changes and erecting new genera in the order Gymnodiniales.

Keywords: Dinoflagellates, unarmored, morphology, apical structure complex, taxonomy

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Comparison of Microplastics Abundance With Special Reference to Their Shapes and Colour at Estuarine and Seaside Areas Near to Nilwala River Mouth, Southern Sri Lanka

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Microplastics can be found floating in water column and some fraction may settled on the sea floor. This study was conducted in February 2019 to record the abundance of microplastics according to their shapes (ie. Line, Fragments, Pellets, and Others) and colours (ie. Red, Blue, Black and Others) and settled in two locations (Nilawala estuary and nearby Sea) in February 2019. There were four sites at the estuary location such as 10 m and 5 m away from the river water line towards the land, and 5 m towards the river water (deep) and right at the river water line. There were four sites at the sea location such as 10 m and 5 m away from the shoreline towards the beach, and 5 m towards the seawater (deep) and right at the shore line. Three replicates of sediments/sand were collected using a quadrat (20 cm × 20 cm × 2 cm heights) in same sampling site. Density separation method was used to extract the microplastics. Florescence microscope was used to examine the microplastic particles. Mean microplastic abundance (microplastics m^{-2}) at sea location (3168.67 ± 2350.81) was higher than river location (1356.28 ± 665.07) showing the highest abundance at shoreline at sea location (6013.11 ± 2968.63). The abundance of microplastics showed that the 5m deep areas of both locations contained comparatively higher abundance. Two-Way ANOVA showed that there was a significant differences in abundance of microplastics between different colours ($p < 0.05$), colours between sites ($p < 0.05$), and the interaction ($p < 0.05$). In addition, two-Way ANOVA showed that there was a significant differences in abundance of microplastics between different shapes ($p < 0.05$), shapes between sites ($p < 0.05$), and the interaction ($p < 0.05$). The mean abundance of microplastics (microplastics m^{-2}) for the colours were; Blue (12.21 ± 10.44) > Black (9.08 ± 12.08) > Others (4.04 ± 2.35) > Red (3.17 ± 2.53) and those for shapes were Lines (24.63 ± 23.84) > Pellets (1.88 ± 3.37) > Others (0.83 ± 1.24) > Fragments (0.63 ± 0.82). They were abundant at shore line resembling that, the decaying nylon treads of fishing nets have significant contribution to microplastics. This study is important to understand the amount of microplastic distribution in the spatial scale in estuarine and sea landscape and identify the source.

Keywords: Microplastics, Shape, Colour, Estuary, Sri Lanka

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Low Light Reduced Seagrass and Subsurface Sediment Carbon Sequestration

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Seagrasses are marine flowering plants, which extend for a large area. Seagrass ecosystems are highly productive and provide vital ecological services. Seagrass beds are an important global sinks for carbon, accounting for an estimated 15% of net CO₂ uptake by marine organisms on a global scale. Underwater light factor is one of the major factors that influence aquatic ecosystem, hence the light regime defines the photosynthesis in the seagrass. Eutrophication induced by high nutrient input can increase the amount of suspended particles in water and epiphyte biomass in the seagrass leaves, thereby reducing the amount of light reaching the seagrass population. This has caused large decline of seagrass, which may reduce the carbon sequestration. The aim of this study was to examine the effect of light intensity on seagrass morphology, biomass carbon and sediment organic carbon, which was helpful for seagrass conservation and management. We cultured the dominant seagrass *Halophila beccarii*, a vulnerable species on the IUCN Red List, under different light intensities (Low light–20 $\mu\text{mol m}^{-2} \text{s}^{-1}$, Mid light–200 $\mu\text{mol m}^{-2} \text{s}^{-1}$ and High light–600 $\mu\text{mol m}^{-2} \text{s}^{-1}$). The results showed that low light decreased leaf length by 17%, root length by 12%, aboveground biomasses by 80% and belowground biomasses by 4% comparing to mid light, indicating that seagrass growth was inhibited. Carbon and nitrogen content in the aboveground tissue was also reduced by 15% in low light. This led to lower seagrass biomass carbon under low light. Interestingly, low light only decreased sediment organic carbon content in the sub-surface by 20% comparing to mid light, which might be caused by less root length and its release of dissolved organic carbon. Therefore, these results indicated that low light would reduce the carbon sequestration in seagrass and sediment. Measures should be taken to reduce the input of nutrients into seagrass bed to maintain the carbon sequestration service by enhancing light penetration into seagrass.

Keywords: Seagrass, Light stress, Carbon dynamics, Sediment carbon

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Diversity, Abundance and Composition of Phytoplankton in Coastal Waters of Off Crow Island Beach Park with Reference to Physico-Chemical Parameters

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The composition and abundance of these phytoplankton are important to assess the health of the coastal waters. The present study was conducted to assess diversity, abundance, and composition of marine phytoplankton in coastal waters of off Crow Island Beach Park with reference to physico-chemical parameters. Sampling was done in nine locations from three sites with different environmental conditions and they are nearby Kelani River mouth, Crow Island Beach Park and the Modera Fishery Harbor. Plankton samples were collected using 50 μ m plankton net and water sample were collected using a surface water sampler monthly from November 2019 to March 2020. Results reveal that, total of 108 species belongs to 50 families of phytoplankton were present during the study. Mean total phytoplankton abundance varied from 177 ± 8.17 to 166 ± 11.06 No./l. Phytoplankton abundance did not varied significantly among months ($p>0.05$), however, site wise variation was significant ($p < 0.05$). The significantly high abundance was reported in Modara Fishery Harbor. Diatom composition was high in phytoplankton assemblage in the area with a range of 61.87% to 67.14% followed by dinoflagellates (31.76% to 23.99%). The Shannon Weiner diversity index was high during the entire study period within mean diversity index of 4.50 ± 0.05 . Species evenness was also high in the study area with the mean value of 0.96 ± 0.01 . Dinoflagellate abundance had positive significant correlation with salinity and silicate concentration at $p=0.001$. Water quality parameters does not show significant site wise or monthly variation at $p=0.001$. Toxin producing dinoflagellates such as *Alexandrium sp.*, *Akashiwo sanguinea* and *Gymnodinium sp.* were also reported with very low abundance. The findings of this study provide the useful knowledge on phytoplankton community structure of the area.

Keywords: Crow Island, Diversity index, Phytoplankton

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Status of the Coral Reefs in Pigeon Island National Park in Sri Lanka

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Pigeon Island has been designated as the seventeenth National Park of Sri Lanka under the Fauna and Flora Protection Ordinance since 2003. Its fringing coral reef teemed with vivid organisms forged the island as a popular tourist destination creating lucrative opportunities to the community. At present, the reef environment is degrading at an alarming rate due to numerous natural and anthropogenic stresses. The recent study was conducted in 2013 and over the past six years, a critical data gap is observed to understand the dynamics of the reef ecosystem. Thus, this study was conducted in August 2019 to determine the present status of the reef and the causes behind its degradation in comparison with 2013. Underwater visual census methods were used to collect primary data. Ten sampling sites at shallow waters around the main Pigeon Island were selected at iso-depth contours. Line Intercept Transect method (15 m) was used to determine the percentage of sessile benthic categories while the belt transect (15×2 m) method was used to quantify reef fish. As the secondary data, information on visitors, boat operations and gross income were collected to understand the impact of visitor pressure. According to the findings, the percentage of live corals and dead corals are about 42.21% and 21.42% respectively revealing a recovery of the coral reef during the recent years. Compare to the 2013 study, 5.38% of increment in macroalgae (*Halimeda* spp) is observed, which smothers corals extensively. During this study period, 9 individuals of *Acanthaster planci* and 4.67% of corallimorpharians were recorded. 48 reef fish species belonging to 17 families were documented indicating a diminishing in species richness in contrast to 2013. There has been a rapid increase in the number of visitors (131.38%) and boat operations (135.38%) generating incomes of 282.28% surplus in 2018 compared to 2013. As observed, coral trampling, bathing, unregulated solid waste disposal, the disturbance caused by boat movements are causing chronic stress on the fragile ecosystem, which is exacerbated by outbreaks of invasive species, intermittent coral bleaching and unusual algal growth. Therefore, there is an urgent need for management interventions and monitoring to safeguard the Pigeon Island environment.

Keywords: Pigeon Island, Line intercept transect, Belt transect, Invasive species

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SOCIO-ECONOMICS AND MARKETING

Analysis of Bottlenecks and Efficiency of the Marine Fish Supply Chain in Sri Lanka

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Marine fish supply chain (MFSC) in Sri Lanka can play a major role in the national economy by exploiting living marines resources in the exclusive economic zone and other resources namely ports, harbors, anchorages and landing sites as a coastal nation, Supply chain as, the integration of key business processes from end-user through the original supplier that provides products, services, and information add value for customers and other stakeholders. The study has used the theory of constraints (TOC) as a management philosophy to analyze bottlenecks and implements the supply chain changing methods. For this purpose, the study used mixed-method, semi-structured interviews and questionnaire surveys for data collection. The population was comprised of MFSC stakeholders and secondary data were collected to strengthen the analysis and findings. The main objective is to identify and analyze bottlenecks of MFSC and recommend preventive measures. 12 major bottlenecks were identified and analyzed. The study discovered that Fisherman Share in Consumer Rupee 48%, it indicates that–MFSC does not assure greater share to fisherman in consumer’s rupee while Wholesalers Average Net Share of the Consumer’s Price is 64% and Retailers Average Net Share of the Consumer’s Price is 76%, this is because of the detrimental effect of the bottlenecks. The study found that the average price is almost double in the retail market as compared to the primary market. Marketing Efficiency Index (MEI) is ($ME \geq 1$) but in MFSC it is 0.88, which indicates that MFSC is inefficient. And also 96% of consumers believe that high price at the retail market because of supply chain-related problems. While 62% of consumers believe that fish price in the retail market is extremely high. 5 major recommendations have been given to minimize the detrimental effect of bottlenecks of MFSC including ensuring security and legal protection at landing centres, overcoming involvement of middlemen, encouraging fish auctions at landing centres, enhance the usage of IT, empowerment of fishermen these measures need to be applied in three stages as a short-term, medium-term and long-term development plan.

Keywords: Marine fish supply chain, theory of constraints, supply chain bottlenecks, Sri Lanka

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An Insight Into the Economic Importance of Wreck Diving in Sri Lanka

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Wreck diving is a popular marine recreational activity in the coastal tourism sub-sector in Sri Lanka. The data and information on this recreational activity are meager due to the lack of available literature. This paper examines the nature and economic importance of wreck diving and its future. This study was performed by administering semi structured questionnaires among domestic and foreign recreational divers and dive operators in four coastal areas namely, Hikkaduwa, Unawatuna, Trincomalee and Batticaloa. A random sample of 70 divers and 16 dive operators were selected for the study which was carried out from January to November 2019. Data analysis was done by using the Microsoft Excel and measured central tendency and percentages. The average number of wreck diving customers arrived per day was 13, 19, 12, and 15 in Unawatuna, Hikkaduwa, Trincomalee, and Batticaloa diving centers respectively and the average charge per wreck dive was US\$ 37, 33, 40 and 39 respectively for the same centers. The highest average expenses per month was recorded in Batticaloa diving centers and that was US\$ 152 and the lowest was recorded as US\$ 133 in Unawatuna diving centers. The average total costs for divers per diving trip in Unawatuna, Hikkaduwa, Trincomalee and Batticaloa were US\$ 363, 324, 226 and 270 respectively and the trip duration varied from 2-4 days. The highest and the lowest average number of customers per month were recorded as 560 and 360 in Hikkaduwa and Trincomalee diving centers thus having the highest and lowest average income per month of US\$ 18000 and US\$ 14850 respectively. A total of 171 people are benefited from job opportunities created by the diving centers. Therefore, there is a remarkable potential for increased in foreign exchange earnings and new employment opportunities through the promotion of wreck diving in Sri Lanka.

Keywords: wreck diving, coastal tourism, recreational divers, diving centers

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Valuing Recreation Benefits and The Willingness to Pay of Crow Island Beach Park In Sri Lanka

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The Crow Island Beach Park is a major recreational site. The site is popular because of its unique ecological and recreational qualities which are a limited resource within the Colombo Metropolitan Area. However, so far there has been no research carried out to estimate the recreational value of the park. Thus, this study aims to estimate the recreational value and willingness to pay (WTP) towards the Beach Park. This study employs the individual travel cost method (ITCM) to estimate the recreational value and the contingent valuation method (CVM) to estimate the willingness to pay (WTP) of visitors. Data were collected from 120 visitors at the Beach Park using random sampling method. The questionnaire survey was conducted to collect the data on socio-economic variables and travel cost variables (such as round trip travel cost, time spent on site and on site trip expenses). Microsoft Excel and SPSS software were used to analyze the data. Results describe that 68% of the visitors live in apartment complexes where there has no space for recreational activities. Average on site expenses are about Rs. 363.00 per visit per person and average round trip cost is about Rs.203.00 per visit per person. The findings indicate that the Crow Island Beach Park generates an annual consumer surplus of Rs. 495 million to people who use the area for recreation. Also, a possible access fee to the beach park of Rs.32.00 was suggested based on the stated willingness to pay (SWTP) of visitors. Municipal authorities may have to consider these values in the management of the park which is located in the congested city limits.

Keywords: Recreation, willingness to pay, visitor characteristics, Crow Island beach Park

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Employability of the Graduates of Ocean University of Sri Lanka in 2010 and 2011

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The Ocean University of Sri Lanka, former National Institute of Fisheries and Nautical Engineering, has been started its degree programs in 2001. Initially, the university offered B.Sc degrees in Marine Engineering and Fisheries and Marine Sciences but later two new degree programs, B.Sc.in Maritime Transportation Management and Logistics and Coastal and Marine Resources Management were introduced. The mandate of the university is to produce requisite manpower for the sustainable management and utilization of fisheries, marine and maritime resources of the country. In addition to that the University has a vocational training section as well, to produce skilled personnel to the sector as fisheries and maritime sector is dynamic and various changes are happening over the time. But the status of the employability of Ocean University graduates is not assessed and updated. Therefore, this study aimed to explore the employability of graduated students during the time period of 2010 to 2014. This study confined mainly to find out whether graduates are employed in relevant fields and their job satisfaction as well as level of earnings. Study was conducted as a sample survey of randomly selected 32 graduates. Results found that 100% employment rate was achieved by them after one year of graduation. Further, it was noticed that the content of degree curriculum is highly relevant with the job opportunities to the graduates and highly implicated the job performance of the graduates.

Keywords: Employment opportunities, graduates, Ocean University, degree programmes

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Use of Participatory Rural Appraisal Tools to Develop Attributes and Levels of a Choice Experiment: A Case Study of Rekawa, Sri Lanka

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Rekawa community is confronted with an issue of declining lagoon fishery, which is their most important livelihood. However, an alternative to compensate the loss of fish yield income is possible with nature-based tourism. The Rekawa has a potential for ecotourism, which has not yet been fully reached. A Participatory Rural Appraisal (PRA) workshop was conducted in Rekawa-Oruwella community building in 2018 to achieve the objective of identifying suitable ecotourism activities for Rekawa. There were 32 participants in the workshop, representing different stakeholders of ecotourism. We used several PRA techniques in the focus group discussion including "resource map", "historic profile", "strengths-weaknesses-opportunities-threats (SWOT) analysis", and "pair-wise ranking method" to identify the ecotourism potential. The resource map helped to identify the geographical distribution of natural resources and places which are suitable for ecotourism activities. The historic profile used to examine the changes in natural resources (turtles, mangroves, corals, and lagoon fisheries), human-made resources (infrastructural development and hotels), climatic changes, changes in management structure, tourists' arrival to Rekawa, and changes in tourism activities in Rekawa over the time. The SWOT analysis provided important information regarding strengths, weaknesses, opportunities, and threats prevailing in Rekawa coastal wetland for ecotourism. A pair-wise ranking was done to identify the most suitable ecotourism activities for Rekawa. The identified ecotourism development activities (i.e. attributes for Choice Experiment) were turtle watching tours, boat trips around the Rekawa lagoon, and beach cleanup. Then, the participants were requested to decide levels for each attribute. The turtle watching tour attribute received four levels; 5, 15, 25, and 35 tourists per visit to the turtle nesting site. The attribute of boat trips around the lagoon had two levels; with and without a guide. For the beach cleanup attribute; 20%, 10%, and no further increase in expenditure on beach cleanup activities were taken as the levels. In addition, a cost attribute in terms of Rekawa coastal wetland fund in rupees was proposed with seven levels; 0, 250, 500, 750, 1000, 1250, and 1500. By varying the levels of attributes, a few alternatives were formulated and presented in choice cards to be used in the Choice Experiment.

Keywords: ecotourism, turtle watching, boat trips around the Rekawa lagoon, coastal recreation, choice cards

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Role of Maritime Universities in Sustainable Development: Trends Around the World

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Maritime universities play a key role in enhancing opportunities for employment in the marine sector. This study investigates the contribution of Maritime universities in the world to implement Sustainable Development Goals (SDGs) that facilitates transformation into a socially inclusive and greener planet. The websites of 19 member universities of the International Association of Maritime Universities (IAMU), with online and language access were considered in this study. AYLIEN Text Analysis Software was used to “text-mine” their websites under four (4) categories namely, Education, Research, Leadership and Operation, to provide descriptive statistics on how they perform SDG related activities since 2015. The number of universities with SDG initiatives under each category was counted and SDG/s related to particular cases were clustered. Out of these 19 universities, 11 universities offer programs with teachings on SDGs. These include modules on sustainable shipping and port operations, fisheries and maritime safety, tourism, entrepreneurship, energy and climate actions, which are directly relevant to one or more SDGs. Themed conferences, workshops, and student discussions are other popular means of integrating SDGs into education. Providing quality education (SDG4) is a top priority in all universities, which applies in securing decent work opportunities (SDG8), introducing industrial innovations (SDG9), establishing sustainable cities and communities (SDG11), combating climate change (SDG13) and sustainable utilization of marine resources (SDG14). 18 universities conduct solution-oriented researches on sustainability issues in the marine sector. Popular areas cover innovation and infrastructure (SDG9), climate action (SDG13), Life below water (SDG14) while many research groups represent international partnerships (SDG17). 15 universities leverage leadership roles in delivering SDG related responses. Training programs for maritime professionals, partnerships for capacity building, establishment of industrial service centers, declaring professional maritime associations, promoting green campaigns and facilitating citizenship education on maritime and ocean sustainability are amongst the common leadership initiatives of maritime universities, which strengthen collaboration and partnerships (SDG17). 8 universities practice governance initiatives such as endorsing SDGs into the strategic plan, formulating sustainability panels and policies, hosting employee dialogues on sustainability issues and adhering to diversity and gender equality policies. This study highlights effective ways to integrate SDGs into visions and missions of maritime universities and set examples for Sri Lankan maritime universities to promote SDGs in the country.

Keywords: Maritime Universities, Sustainable Development, SDGs

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Effectiveness of Training And Development Program for The Management Assistance in The Ocean University of Sri Lanka

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In Sri Lanka, the institutions take a serious view of the human resources development more than any other time in the history, thus understanding its crucial role in the progress of an organization is vital. The senior management of majority institutions in Sri Lanka considers human resource management as a key area in its business and therefore, once this back-office function has come forward to the forefront. In the human resource development realm, the branch of training and development is considered to be a major area which contributes to many factors in an organization such as retention, professionalism, knowledge culture, work environment, business potentials to name a few. As a result, the organizations plan, organize and implement a vibrant annual training schedule that encompasses the entire human capital, in a bid to upgrade their quality of professionalism systematically. In doing so, the institutions adopt many models and methodologies to deliver their human resources products across the board. Therefore, Human Resources Development departments, branches or units plan in-house training, outsourced training and even overseas training for the staff after a carefully orchestrated training need analysis. In this synopsis, it is being evaluated how a state institution like Ocean University of Sri Lanka evolved in the discipline of human resource development and what the university's policy and strategy when it comes to human resources development. In the process, it transpired that the University relies on training for the staff on a regular basis. From the sample that was chosen for the research, almost every staff member was privileged to have varied training experiences although the University is relatively young in its existence as compared to other Universities in Sri Lanka. This research attempted to obtain candid views of the sample staff to ascertain the impact of training that they have been exposed to. Since the remarks have been obtained on a structured questionnaire and the sample staff had the opportunity of giving their views anonymously, majority of the sample have submitted honest opinions. In analysis, this research paper has come with many facts which would inadvertently help the University to adopt a transparent policy on training and development. Besides, the basis of this information is a crucial factor for the University in preparing modalities of selection, post-evaluation and adaption of the new knowledge at office. In an overall development, the University could also formulate a comprehensive human resources policy for the University to sustain for a fair period of time. It is always healthy for an institution to possess a practical human resource policy as it would consolidate the level of contentment among the staff. Otherwise, some staff members would be disgruntled and would complain of many negative aspects as regards training programs. It is believed that research paper has exposed many important facts regarding human resource development spectrum and it would be a value addition to shape policies.

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MARITIME TRANSPORTATION AND LOGISTICS

A Study on Sustainability of Port Operations: The Case of Port of Colombo

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The term "sustainable" as a broadly used phenomenon, consists of three dimensions: environmental, social and economic, which are known as triple bottom lines of the concept of sustainability. All United Nations (UN) Member States adopted the 2030 agenda for achieving Sustainable Development Goals (SDGs) which can be addressed by any industry. The preliminary intention of the International Maritime Organization related to sustainability is "The conservation and the sustainable use of oceans and their resources". Seaports are complex transport nodes in the global transportation network. Further, seaports are disreputable as one of the most polluting industries due to their complex operations as an interface between sea and land. Lack of implementation of sustainability growth-led port policies is an identical problem in the maritime sector in many developing countries. This paper investigates the three dimensions of sustainability in relation to seaport operation selecting the Port of Colombo (PoC) as a case. The main research objective is to determine the extent to which the focused port is aligned with the most relevant 11 SDGs out of all 17 SDGs in UN 2030 agenda from 2015 to 2020. A questionnaire was developed and data were gathered from both operational and management level port employees (n=182). Hypothesis testing and paired sample t-test were performed. Analysis results indicated that PoC is only aligned with 9 SDGs out of the all core 11 SDGs related to port industry. All the 8 Core SDGs (Good health-well-being, Affordable-clean energy, Industry innovation-infrastructure, Sustainable cities-communities, Responsible consumption-responsible production, Climate action, Life below water, Partnerships for the goals) have been developing during the period from 2015 to 2020. However, only one secondary SDG (Gender Equality-SDG 5) has developed well over other 4 Core SDGs. Clean water-sanitation and Decent work economic growth have not been developing from 2015 to 2020 inside PoC. A conceptual model/framework connected with 4 SDGs (Life below water, Industry-innovation-infrastructure, Good health-well-being and Affordable-clean energy) which is specified for sustainability of PoC was derived using Exploratory Factor Analysis and Confirmatory Factor Analysis and Model Fit Analysis. The paper provides policy implications for sustainability policy design in port sector in Sri Lanka.

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Challenges in Implementing Green Port Concept for Jaya Container Terminal in Port of Colombo

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Maritime transport is the backbone of world trade and globalization. It is servicing to the world trade by moving 90% of cargoes to all corners of the world connecting markets in different places in the world. The greatest challenge faced by the current society and economy is the sustainable development and environmental protection. Nowadays environmental issues are becoming a significant factor in sea ports and port activities. Thus the green port concept is based on the idea of making the port operations environmental friendly to reduce the environmental pollution. At present one of the most significant objectives of sea ports in all around the world is the accomplishment of "green port" status. Also green port concept aligns with the international conventions like MARPOL. In the local context, Port of Colombo is very close to the commercial capital of Sri Lanka and container terminal operations are caused to the air pollution in Colombo city. Therefore, this research motivated to study challenges in implementing green port concept for Jaya Container Terminal (JCT) in Port of Colombo. Data collection was performed through semi-structured interview with eleven experts who are involved with container terminal operations. Data were analyzed using coding technique to find out challenges in implementing green port concept at JCT. Findings revealed that huge cost and required initial investment amount is the main challenge for the implementation of green port concept in JCT which further indicates that the latest technologies related to reduction of emission and environmental impacts are very much expensive. Lack of awareness of staff and the unstable government policies on environmental protection and prevention of pollution are some of other identified challenges. However, at the successful implementation of green port concept would generate multiple benefits such as reduction of non-renewable energy consumption, emission and ensure the well-being of terminal employees and other surrounding.

Keywords: Green port, Sustainability, Container Terminal, Renewable energies

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MARINE ENGINEERING AND TECHNOLOGY

Performance Evaluation of Battery Energy Storage for Offshore Solar Power System

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No-stoppable growing demand for global energy needs has been leading towards a path of production of clean energy from renewable energy sources. It is indeed that the ocean, which occupies 71% of the total earth surface, is an immense energy source whereby the available marine renewable energy resources (MRES) can accommodate global present and predicted future energy demands, thereby minimizing dedicated land spaces for power plant constructions. However, due to the intermittent and stochastic nature of MRES, the power quality and reliability of the marine energy harnessing system are questionable facts in the scenario of system establishments, but the integration of an energy storage system is a preferable solution for the improvement of system performance and flexibility. The battery technology is the most common and widely used energy storage technology, especially thanks to simplicity and flexibility thereof in adoption from small-scale to large scale. The current research focused on the performance of an offshore solar power system with the integration of battery energy storage system and presents an investigation of three battery technologies: lead-acid (PbA), lithium-ion (Li-ion), and nickel-cadmium (NiCd), which have been often used in onshore photovoltaic (PV) systems. The battery voltage, State of Charge (SOC) and battery aging characteristics of battery technologies are evaluated for entire year using practical data into an offshore PV system model in MATLAB Simulink. The analysis of battery charging and discharging performance is presented to find the better battery technology for offshore PV system. The battery performance characteristics are shown that li-ion batteries have the most effective performance in state of charge (SOC) and aging conditions while the performance of lead-acid batteries degrades with the lower SOC conditions. NiCd performance is far better than lead-acid and less with Li-ion. From the comparative investigation of battery technologies, Li-ion batteries have the high potential of energy storage integration due to its characteristics; but a proper battery management system must be embedded because of safety issues associated with Li-ion batteries.

Keywords: Renewable energy sources, offshore solar power system, battery energy storage system, state of charge and battery aging

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Application of Hard Coast Protective Structures Along the Western and Northwestern Coasts of Sri Lanka Over Past 15 Years Period

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Coastal erosion is a significant and continuing issue occurring due to both natural and anthropogenic phenomena which cause to degrade coastal lands. Different types of techniques such as soft and hard coastal protection techniques are used to mitigate coastal erosion or allow the shore to recover naturally without any construction process. Though hard structures have been used for immediate coastal issues like coastal degradation, their usage as a sustainable solution has been debatable. Hence, the study focused on the application of hard coastal techniques in the Western and Northwestern provinces of Sri Lanka by delineating and calculating the extent of revetments, groins, breakwaters, and coves over the past 15 years period by geo-processing of high-resolution Google Earth satellite images. The results revealed that at the end of 2019, the extent of the coastal revetment in Kaluthara, Colombo, Gampaha, and Puttalam districts were 7133 m, 9432 m, 2395 m, and 4594 m, and the percentages to total coastal length were 16.85%, 38.81%, 6.90% and 2.88% respectively. The total constructive lengths of breakwaters of the above districts were 1903 m, 702 m, 2175 m, and 4141 m, respectively. The total number of groins in those districts was 19, 2, 29, and 91, respectively. Number of 3 coves in Kaluthara, no coves in Colombo and Gampaha districts, and 2 coves in Puttalam district were recorded by the end of 2019. Generally, the Colombo district had applied more hard structures than other districts. But from 2014 to 2019 it reduced because hard structures around the area that construct port city have removed and the revetments of certain places are got damaged. The Western province has constructed more structures at a higher annual rate than Northwestern province because the Western Province have utilized their coastal zone with respect to mega development projects than Northwestern Province. And after some extent in Northwestern shoreline, there is minimum human influence along the coast, and naturally behaved sandy beach up to Kalpitiya peninsula. These protective methods are based on the utilization and alterations of the shoreline by humans and the adverse effects of natural phenomena but cannot be recommended as a sustainable solution because these hard structures also may cause erosion in another area.

Keywords: Coastal erosion, hard protection, revetments, Groins, coastal protection

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Effect of Lateral Acceleration on Nonlinear Coupled Pitch-Roll Ship Motion in Turning Maneuvers

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Maneuvering characteristics of seagoing vessels are evaluated with respect to angular motions (roll, pitch and yaw) and displacement motions (surge, sway and heave), which concurrently lead to 6DoF (6 Degrees of Freedom) time-domain analyses. Accordingly, complex dynamical motions become a result of the combination of linear displacement and angular motions of each axis of reference system. Due to the unpredictable nonlinearity of ship rolling parameters (inertia, stiffness, damping and excitation), it is considered the most critical motion that can lead to vessel capsizing. Although it is well known that hard and sudden turning maneuvers give rise to critical rolling in sea going vessels, it is almost impossible to avoid those steps in many occasions including, but not limited to, search and rescue operations, collision avoidance maneuvers and naval operations. It is, therefore, vital to assess and improve vessel characteristics for safe maneuvering and ship handling through experimental methods or simulations. Moreover, in the wake of numerous researches in maritime autonomous surface ships (MASS), perfecting maneuvering characteristics of seagoing vessels has become one of the major concerns and thus, importance of assessing critical ship motions, especially the nonlinear coupled pitch-roll motion in turning maneuvers, is emphasized. This study focuses on the nonlinear, coupled pitch-roll motion of a vessel in waves, with respect to its lateral acceleration during turning maneuvers in a continuous time domain. A training vessel with a gross tonnage of 6,500ton was utilized to carry out the experimental study, conducting standard 100/100 and 200/200 zig-zag maneuvers, following the recommendations of the International Maritime Organization (IMO). Rolling and pitching responses of the vessel were recorded using an Inertial Measurement Unit (IMU), two Global Positioning Systems (GPS) receivers and a Global Navigation Satellite System (GNSS) receiver. Results from the experimental study presented an inverse proportionality between the rolling motion and lateral acceleration of vessel, as it was modelled mathematically, thus validating the proposed math model. Moreover, this work intends to expand the earlier work related to mathematical modeling of pitch and roll motions of ships during turning maneuvers.

Keywords: Pitch-roll coupling, ship roll motion, turning maneuver, ship stability, seakeeping performance

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CFD Analysis and Performance Characteristics of Tidal Current Cross-Flow Turbine with Single, Twin and Quad Turbine Setup Utilizing Thin Blades

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The tidal current contains and delivers an immense amount of energy without any cost. This research work focus on numerical investigation of the performance and flow filed behavior of tidal turbine setup which utilizes single, twin and quad cross-flow turbines in an augmentation channel. In the Korean Peninsula, a specific marine region the estimated a tidal flow of 2.5 m/s, the requirement was to numerically analyze the suitability and performance of crossflow turbine to be used as a tidal energy harnessing turbine. With the experience of the previous crossflow turbine studies, initially 6.0 m diameter 3D model of the cross flow turbine was designed using variable design methodologies having 18 number of thin turbine blades as the first stage. With same 3D CAD modeling software, the turbine was incorporated in side an augmentation channel having convergent and divergent nozzles at the inlet and outlet sections. The single turbine was placed inside a square tunnel section faced towards the tidal stream. In the 2nd and 3rd stages, two and four number of turbines were placed inside the same tunnel section with equal spacing, parallel arrangement without disturbing the symmetry. The hydrodynamic simulation of the turbine model setups was done using ANSYS CFX, computational fluid dynamics package. The numerical accuracy of the CFD model was validated using a similar cross flow turbine research papers which are published previously. The aim of the simulations was to numerically assess the maximum amount of power which can be extracted by each turbine setup. Also, the flow behavior of inside and around each turbine setup was examined using CFD post processing. There appears to be an agreement between the numbers of tidal turbines which can be placed in a given tidal stream with a certain corresponding blockage ratio pertaining to their channel opening cross section area. With CFD simulations it was found that single turbine yield maximum of 91 kW at tip speed ratio (TSR) of 0.35, twin turbine setup reached a maximum of 148 kW at tip speed ratio of 0.3 which is above 60% of power gain compared to single turbine setup, and the quad turbine setup yield the least performance due to large blockage in the channel.

Keywords: Tidal Energy, Cross Flow Turbine, Augmentation Channel, CFD

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Designing and Sizing of a Solar System to the Regional Centre at Tangalle of the Ocean University of Sri Lanka

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Solar energy is a good alternative solution to produce the electricity. Photovoltaic (PV) is the direct conversion of the solar energy into electricity. The energy emitted from the sun is converting into electricity by using semiconductors. Hydro power, Coal and gas power generation, wind power, biomass power generation, solid waste power generation and solar energy power are the main sources of producing electricity. Currently, hydro power generation have limited as it fully utilized in the country. So, solar energy is vital as alternative solution to the power crises. The Climate conditions, delayed electricity supply projects for remote areas are the reasons for giving attention on solar energy. Solar energy is a sustainable and very less emission of green gas to the environmental while producing required apparatus and there is no of any harm gas or no effect to increase the global warming. Also, Sri Lanka is consider as rich country of the solar energy with high intensities of the solar radiations along duration of sunshine hours as geographically located close to equator. Purpose of this research is to design and install a PV solar panel system as a solution for increasing of electricity bill in Tangalle Regional Centre of the Ocean University of Sri Lanka. In this project we are introduce the net metering system. As estimated in the solar resources map developed by The National Renewable Energy Laboratory of USA over most parts of the flat dry zone in Sri Lanka which accounts for two-third of land area. Solar radiation varies from $4.0-4.5 \text{ kWhm}^{-2}\text{day}^{-1}$. The study revealed monthly electricity consumption in Tangalle center is 3500 kWh. The results indicated that the size of a solar panel is 65"x39".The required number of panels are hundred and seventeen (117) with 250 W. The inverter size and weight of the panel is 30 kW and 27 kg respectively. The expected output of the research is to reduce electricity bill get zero level of the electricity. However, it is recommended to investigate how much calculations deviate from actual situation.

Keywords: Photovoltaic system, system sizing

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