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BOOK OF ABSTRACTS

“Aquatic Research to Nurture the Nation”



26th July 2019





**National Aquatic Resources Research
and
Development Agency**

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“Aquatic Research to Nurture the Nation”

26th July 2019

**National Aquatic Resources Research and Development
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Colombo 15
Sri Lanka**

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Fisheries and Aquaculture

Abundance and reproductive seasonality of *Stomopneustes variolaris* (Black sea urchin) in East and South coasts of Sri Lanka

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Sea urchins are one of the most common macro-grazers found in rocky shore systems. The gonads of the sea urchins known as roe are a culinary delicacy prized in many countries. To study spatial distribution, abundance and biology of edible sea urchins found in Sri Lanka, a study was conducted from February to December 2018 in the East (Pulmudei and Trincomalee) and South (Midigama, Kottegoda, and Nilwella) coasts. The study was carried out using random transect sampling method and transects were laid vertical to shoreline with the length varying from 5 m - 20 m. At the field, a quadrat of 0.5 m x 0.5 m was laid along transects and all the sea urchins were counted within the plot. A total of 13 sea urchin species belonging to six families were identified in this survey and among these species, black sea urchin (*Stomopneustes variolaris*) was identified as the most abundant species in both these regions. The highest black sea urchin abundance was recorded at Midigama (20 individuals/m²) and the lowest was recorded at Sallikovala (Trincomalee) (8 individuals/m²). Total body wet weight and gonad wet weight were recorded. Gonado Somatic Index (GSI) was calculated to identify the spawning seasonality. The GSI of black sea urchins was found to vary periodically suggesting an annual cycle of reproduction. But they have peaks in November to December in Matara and April and August in Trincomalee. This type of variation could be due to the difference of populations of the same species and environmental variability. Length-weight relationship of black sea urchin shows a negative allometric growth. Exploitation of the wild stock of black sea urchin could be attempted while ensuring the sustainability of the resources. Results of the present study could be utilized for formulating a sound management plan while developing the fishery.

Keywords: sea urchin, GSI, Sri Lanka

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Preliminary study on development of a protocol for the acclimatization of *Kappapycus alavarezii* (seaweed) in laboratory conditions

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Kappapycus alavarezii (Family Solieriaceae) is an important source of the industrial gel carrageenan. It is one of the important commercial species cultivated in Southeast Asia. Tissue culture techniques were applied for micropropagation of *K. alavarezii*, in order to select the best strain and develop an experimental system for *in vitro* culture. The acclimatization of seaweed explants (thallus) was a difficult task as it showed high mortality rate. Thus, several experiments were conducted to minimize the mortality rate in the laboratory. This study was carried out in order to increase the survival rate of *K. alavarezii* thallus explants in the laboratory. Thalli were cut into 5.0 cm length pieces and washed with 0.5% (W/V) Betadine solution for 1 minute. Thereafter, it was washed several times with sterilized seawater and washed with an antibiotic solution for 24 hours. (Antibiotic Solution: Penicillin G, 0.02 g/L, Kanamycin 0.30 g/L, Polymyxine B Sulphate 0.001 g/L). Afterward, the thalli were washed with sterilized sea water and 10 pieces were transferred to each conical flask and globular shaped glass container with 1.0 L of sterilized ½ PES medium and proper aeration was provided. After one week percentage of survived thalli pieces were observed. Each type of container had 3 replicates and was repeated 5 times. According to the observations, it was found that globular shaped container was better to get a higher survival rate (mean of 65.4%) compared to the conical flask (mean of 27.6%). Thus, it could be suggested that the globular shape glassware would be the most suitable method to acclimatize *K. alavarezii* explant in the laboratory.

Keywords: *Kappaphycus alvarezii*, tissue culture, acclimatization

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Study on development of captive breeding technology for endemic fish species *Pethia melanomaculata* (Cyprinidae) in Sri Lanka

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Ten endemic Cyprinid species are popular in the tropical ornamental fish industry and are being exported to over 25 countries. *Pethia melanomaculata* is an attractive endemic Cyprinid which is hitherto underutilized. Since the spawning males develop brilliant fire red colour, this species has a high potential to become a good candidate in the tropical ornamental fish industry. The specific objective was to introduce a new endemic ornamental fish species for the tropical ornamental industry. The present study therefore, was carried out from January to December 2018 to develop culture and breeding technologies and to explore its biology and ecology to seek possibility in sustainable utilization of *P. melanomaculata*. In March 2018 a total of 35 individuals of *P. melanomaculata* (2.0 - 2.8 cm in total length) were collected from the Manampitiya flood plains, were transported to NARA, and reared for four months period. In June 2018, fish (3.5-3.8 cm TL) were bred successfully adopting environment manipulation procedures. The water stress, under which brooders are introduced to a low water environment, was used to induce spawning. The sex ratio of 1 male to 2 females was used and breeding substrate was *Hydrilla verticillata*. Present study indicated that fecundity of *P. melanomaculata* is low with an average of 34. It lays small eggs (average egg diameter 2.5 mm) in batches within a single spawning period, indicating it is a serial spawner similar to other *Pethia* species. The egg hatching period varied from 48 to 72 hours and the larval survival was 89%. The field study showed that this species has a limited distribution in intermediate to dry zone and prefers to inhabit swamp forest and flood plains. They were found to prefer to live and spawn in slightly alkaline water of low DO >2.98, pH ≥7.56, hardness 73.4 CaCO₃ mg/L and alkalinity 36.6 CaCO₃ mg/L at 27 °C to 33 °C water temperature. Present study clearly showed that *P. melanomaculata* can easily be bred under captive conditions using water stress. Relatively low fecundity and poor colour development in F1 offspring are the major challenges confronted in the study.

Keywords: endemic fish, *Pethiamelano maculata*, breeding technology, ornamental fish.

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Historical changes in demersal fish stock abundance and distribution of Sri Lanka

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To observe the changes in demersal fish stocks after 40 years, data of the historical RV Dr. Fridtjof Nansen surveys (1978-1980) was compared with the results of the survey in 2018. For the comparisons of CPUE (kg/nm²) in 20-100 m depth, the coastal area was divided into six regions i.e. North East, Central East, South East, South, South West and North West. From the bottom trawls conducted, CPUE (kg/nm²) was calculated combining all the historic surveys and comparing the average catch rates from those surveys with the 2018 survey. The results indicated that decline in total catch rates are oblivious in all the regions, especially profound along the West coast. Relatively strong decline in the catch rates of several important demersal fish families was noted between the two survey periods, notably Lutjanidae, Carangidae, Lethrinidae and Serranidae, where species are commercially very important, commonly larger in size, long lived and higher trophic level predatory fish. In contrast, it also shows that catch rates of some families such as Acanthuridae, Leiognathidae, squids, Balistidae, Gerreidae, Mullidae, Nemipteridae, Scaridae, Synodontidae and Siganidae have increased between two periods. Those groups are normally considered as lower trophic level species in marine food webs and have lower commercial value than the first group. Furthermore, the situation seems to be more dire in the West coast than the East, and the Southeast seems to have the best survival of large long-lived demersal species. Various measures such as gillnet ban on reefs, marine protected areas, civil war, shifting in fishing effort from demersal fish to small pelagic are believed to have had some positive effect to better preserve the demersal fish stocks. For the long-term goal of sustainable harvesting, it is important not to jeopardize this situation and to further develop and implement adequate fisheries management.

Keywords: RV Dr. Fridtjof Nansen survey, CPUE, historical changes, demersal fish

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Abundance, distribution and species composition of ichthyoplankton in surface coastal waters of Sri Lanka

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Eventhough the knowledge on ichthyoplankton (fish eggs and larvae) is important for fisheries management, such information are often lacking in Sri Lanka waters. The aim of this study was to find out the abundance, distribution and diversity of ichthyoplankton in six coastal regions (North East, Central East, South East, South, South West and North West) of Sri Lanka. Ichthyoplankton samples were collected by continuous underway fish egg sampler (CUFES) method during the Ecosystem Survey conducted in Sri Lankan waters by RV Dr. Fridtjof Nansen from 23 June 2018 to 16 July 2018. Fish eggs and larvae were separated from other plankton and identified to the lowest possible taxonomic level. A total number of 3735 fish eggs belonging to 33 morphological categories and 146 fish larvae belonging to 32 families were collected from 49 stations. The most abundant larval families were Bregmacerotidae (16.7%), Engraulidae (11.1%), Pomacentridae (11.1%), Microdesmidae (7.4%) and Leiognathidae (7.4%). An average abundance of 50/100 m³ eggs and 1.64/100 m³ larvae were recorded. According to the Kruskal-Wallis test, the abundance of both fish larvae ($P=0.057$) and eggs ($P=0.891$) were not significantly different among the regions. However, the diversity of fish larvae was significantly different ($P=0.001$) while the fish eggs were not significantly different ($P=0.792$) among the regions. The highest abundance of fish eggs and larvae recorded from a single station was found in the Central East region, having 225 eggs (6% of total eggs) and 42 larvae (29% of total larvae), an area bordering the mouth of Kumbukkan Oya. This study concludes that there was a high abundance, diversity and variation in the distribution of pelagic, demersal and mesopelagic ichthyoplankton in Sri Lankan waters. Since this was a preliminary study, continuous studies are recommended to be carried out especially within the aim of studying the spatial and temporal variation in the abundance and diversity of ichthyoplanktons in Sri Lankan waters. Results of such studies could be integrated for conservation and management of marine resources in Sri Lanka.

Keywords: ichthyoplankton, fish eggs, fish larvae, Sri Lanka, Dr. Fridtjof Nansen Ecosystem Survey

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The effect of locally available carbon sources on zero water exchanged guppy (*Poecilia reticulata*) growing system

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The environment friendly aquaculture system based on *in situ* heterotrophic microorganism in order to assimilate toxic nitrogenous waste is called Biofloc Technology (BFT). This study was conducted to identify the effect of locally available C sources on water quality management in the guppy (*Poecilia reticulata*) growing system. Twenty-seven glass tanks (21 L) were used for the experiment using completely randomized design for 60 days. Ten male guppy fish were stocked in each tank (mean weight 0.16 ± 0.02 g and standard length 2.0 ± 0.1 cm). Four different treatments with three carbohydrate sources were formed as Wheat Flour (WF), Rice Bran (RB), Molasses (MOL) and 1:1 mix of RB: MOL were applied in two patterns; Single dose (S) and Split (SPL) dose with three replicates. Control (CON) was maintained without the addition of external C source. C/N ratio was maintained to 15. Water quality parameters of the fish tanks were assessed daily. Water in the system was not exchanged except in the CON. Mean DO concentration, pH and temperature ranging from, 8.02 ± 0.02 to 8.20 ± 0.01 mgL⁻¹, 6.99 ± 0.08 to 7.35 ± 0.06 and 25.6 ± 0.1 to 25.7 ± 0.1 °C were within the favourable range for tropical fish culture. Total ammonia nitrogen concentrations in the CON and in the WF treatments were significantly high whereas in the other treatment, it showed no significant difference ($p > 0.05$) and more stable and lower than the CON, WFS and WFSPL. Mean nitrite concentration was below 0.1 mgL⁻¹ except for CON. Nitrate concentrations were also significantly different; however, all the values are below 0.5 mgL⁻¹. The lowest and more stable nitrate concentrations could be seen in the tanks except for CON, WFS and WFSPL treatments. Lowest survival (63%) was recorded with WFS and all others showed over 90% survival. The study revealed that the performance of the C sources used to assimilate the toxic nitrogenous wastes is more effective than the CON. According to this study, RB, MOL and the MIX treatments were equally effective in maintaining the water quality, whereas wheat flour cannot be recommended as a good source to maintain the water quality in the BFT system.

Keywords: biofloc technology, carbohydrate sources, guppy, *Poecilia reticulata*

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Survival and growth of the sea cucumber *Holothuria scabra* farmed in two selected sites in Puttalam Lagoon, Sri Lanka

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Sea cucumbers are highly diverse and exclusively marine invertebrates that play crucial roles in the recycling of nutrients and bioturbation processes in the marine benthic environment. It is a nutritious seafood with high protein and low lipid content and rich in gluten, nitrogen, iodine and other nutrients. Aquaculture production of sea cucumbers, particularly sandfish (*Holothuria scabra*), has gained momentum in recent years and the industry is forecast to expand rapidly. Therefore, this study was carried out to evaluate the growth and survival of *H. scabra* cultured in two selected sites, Serakkuliya and Illipantivu in Puttalam Lagoon with the active participation of the community. Hatchery reared juveniles ($n=150$) in the size range of 10.0 ± 3.48 g were stocked into two pens (size 15 m x 15 m each) at the rate of 1.5 juveniles per m^2 in April 2018. Water temperature and salinity were measured bi-weekly whereas weight and length of each individual was obtained once a month. Community people maintained the facility and looked after juveniles for a period of ten months culture period. Mean growth of *H. scabra* recorded for Serakkuliya (520.37 ± 31.34 g) is significantly higher than Illipantivu (410.37 ± 46.57 g, ANOVA; $p < 0.05$). Maximum body weight of *H. scabra* cultured in Serakkuliya and Illipantivu pens were 570.86 g and 432.68 g respectively. Average growth rate of sandfish in Serakkuliya was 0.91 ± 0.08 g day^{-1} whereas that of Illipantivu site was 0.58 ± 0.09 g day^{-1} . But the particular months in which minimum and maximum daily growth rates were recorded, did not coincide for two sites. A higher survival rate of *H. scabra* was reported in Serakkuliya (75%) than Illipantivu (40%). The mean salinity and mean water temperature were 31 ± 2.26 ppt and 29.9 ± 2.94 °C for Serakkuliya site. Those values for Illipantivu site were 28 ± 3.00 ppt and 28.2 ± 3.65 °C respectively. Significant low growth rate beginning from October at Illipantivu could have been due to high fluctuations of salinity during that period. These preliminary results reveal that the Serakkuliya site is more suitable for sea cucumber farming in Puttalam Lagoon.

Keywords: sea cucumber, *Holothuria scabra*, pen culture, survival rate

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Distribution and diversity of benthic macro invertebrate fauna in mangrove soils of Puttalam Lagoon

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The aim of the study was to assess benthic macrofauna in mangrove soils at Puttalam Lagoon in view of environmental assessment. Occurrence and spatial distribution of species composition of macrobenthos in Northern part of the mangrove areas in Puttalam Lagoon were carried out by taking core samples along 08 selected belt transects (10 m x 50 m). Three core samples (10 cm x 10 cm x 10 cm) were taken from each 10 m x 10 m plot. Based on records from all the samples (120) in the study sites, 11 species belonged to Gastropods and only one species in Flabelligeridae (Polychaete) were detected. Shannon-Weiner Diversity Index was used to assess the diversity levels. Higher range of organic matter was detected in the two transects studied (92% to 98%) in the locations while the pH value of sediments ranged from 3.12 to 7.01. There was no clear correlation between macro faunal density with pH or organic matter percentage. Species density among the study plots within the transects did not show statistically significant dissimilarity. Shannon Diversity Index in the waterfront study plots were in narrow range from 2.2-2.3. Species diversity was also highest in waterfront area of all transects while species diversity in whole transects ranged from 1.1 to 3.2. Species density among five plots within the transect was not statistically significant while the species density in MT3 was significantly higher than MT4, MT5, and MT7 transects. All other transects showed no significant variations regarding species density. Most predominantly found species in the study transects were *Cerithidea spp* and *Nassariidae (Bullia sp.)*.

Keywords: benthic macro invertebrate, mangrove soil

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Gillnet selectivity pattern of *Amblygaster sirm* (Clupeidae) in the West coast of Sri Lanka

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The coastal fisheries exploitation in Sri Lanka has shown some alarming signals as many small pelagic fish resources including *Amblygaster sirm* are being threatened. *A. sirm* is one of the key species available in commercial landings and are mainly harvested by using small meshed gillnets. The presence of higher percentages of immature *A. sirm* in gillnet catches can severely impact the fish populations. The present study on gill net selectivity for *A. sirm* was conducted in the west coast of Sri Lanka from January to December 2017, in order to determine the optimal fish lengths of each gillnet with respect to length at maturity and to provide mesh size regulations towards the sustainability of the resource. Mesh-wise total lengths of fishes were collected at the main fish landing sites of Beruwala, Negombo, Chilaw and Kandakuliya. Maturity studies were also carried out using randomly selected fish samples. The study revealed that seven stretched mesh sizes (2.54, 2.70, 2.86, 3.02, 3.33, 3.65 and 3.81 cm) are being used to catch *A. sirm*. The size of recorded *A. sirm* ranged between total lengths of 8.5 cm to 22.0 cm. The optimum selections of lengths of above mesh sizes were 13.04, 13.13, 14.48, 14.97, 16.38, 18.84 and 18.52 cm respectively. According to the maturity studies, it was confirmed that the length at maturity of *A. sirm* was 15.25 cm. Therefore, it can be determined that gillnets with mesh sizes of 2.54, 2.70, 2.86 cm are mainly targeting fish below 15.25 cm and are not suitable for the fishery of *A. sirm*. This study further revealed the necessity of restricting some of the existing small meshed gillnets in order to control the overfishing.

Keywords: gillnet selectivity, maturity, fishery, *Amblygaster sirm*

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Specific growth of *Kappaphycus alvarezii* (Doty) in the Southern coastal waters of Sri Lanka

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Seaweed cultivation is a major source of livelihood among coastal communities worldwide. The *Kappaphycus alvarzii* culture industry in Sri Lanka was mainly concentrated in the Northern coastal area, but recently several attempts have been made to culture this species in the Eastern province. Therefore, optimizing the growth conditions is a major concern and therefore, this study was conducted to determine the Specific Growth Rate (SGR) in different seedling densities and the culture durations needed for optimized growth. The study was conducted in floating net cages from March to November in 2018 at Dondra in the Southern coastal area in Sri Lanka. The *Kappaphycus alvarezii* growth depends on different factors, such as environmental factors, propagule density, self-shading effect and initial density. Different initial seedling densities of 100 g, 150 g, 200 g were used for the entire culture period; to perform SGR, 9 replicates were used. The highest average SGR (7.95%/day) was recorded in the first 14 days with 100 g initial weight and a gradual decline was recorded after 14 days of growth. Therefore, in 200 g, trial SGR of 29.3% deviates from the initial phase and final phase when compared to the initial weight of 100g trial. When the analysis was conducted in ANOVA (analysis of variance) between groups, there were significant differences among initial weight groups and the weights recorded in different times in the growth cycle ($p \leq 0.05$). It was revealed that the growth of shoots significantly depends on the culture period and self-shading effect. To minimize the effects on the growth, shoot density should be managed to overcome self-shading.

Keywords: *Kappaphycus alvarezii*, specific growth, propergules

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Assessment of the status of abandoned, lost or otherwise discarded fishing gear (ALDFG) in Southern Coastal waters of Sri Lanka: fisher' perspectives

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Abandoned Lost or otherwise Discarded Fishing Gear (ALDFG), otherwise known as “ghost gear” has now become a global concern and assessments on the sources, types and impacts of ALDFG are extremely rare at local level. A survey was conducted in eleven fishing sites in the Southern coastal region to assess the status, of ALDFG generated from the three fishery types; offshore, coastal and artisanal. Forty five fishermen of offshore, 26 of coastal and 14 of artisanal fisheries were interviewed taking convenient samples and they were given a pretested semi-structured questionnaire to assess their experiences on the origin, types, encountering and impacts of ALDFG. Based on the number of respondents and their answers, “percentage respondents (%)” were calculated to determine the frequency of the particular incident. In all cases, fishing nets become the major source of the ALDFG, followed by hooks and lines. Fishing gear happened to be damaged and therefore, abandoned mainly due to poor weather conditions in coastal fisheries (61.5%) and in artisanal fisheries (78.6%). This cause it not common in offshore fisheries (35.5%), as in many cases, gear becomes damaged and abandoned when they become snagged on other large objects such as whales (95.5%). In lesser incidents of coastal fisheries (57.6%) and artisanal fisheries (71.4%), gear has to be abandoned due to natural disturbances. Most common reason for gear to be lost in coastal fisheries (92.3%) and artisanal fisheries (100%) is poor weather conditions, while in offshore fisheries, the most common reason is becoming entangled with passing vessels (91.1%). In both coastal and offshore fisheries, the most vulnerable groups to become entangled in ALDFG are turtles (100%), followed by marine mammals. Both anthropogenic and natural causes may result in ALDFG that ends up ghost fishing and a robust system of recovering and managing ALDFG has to be implemented.

Keywords: abandoned, discarded fishing gear, derelict fishing gear, ghost fishing, marine debris

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A comparative indoor trial study for evaluating plant based formulated feed vs non plant feed for tilapia fingerlings

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As there are no proper formulated feed for tilapia aquaculture in Sri Lanka, an experimental growth trial was conducted in 12 indoor cement tanks (1.5 x 1.2 x 0.3 m) for evaluating three newly formulated feeds for tilapia fingerlings. All treatments with three replicates and all male Tilapia fingerlings (ave. total weight = 89.96 ± 5.31 , 98.06 ± 4.8 , 91.7 ± 6.4 , and 94.0 ± 3.4 g) were stocked at the density of 87.5/m³. Three formulated feed [feed 1- incorporated with 30% dry weight of *Pistia stratiotes* (water lettuce), feed 2- incorporated with 30% dry weight of *Eichhornia crassipes* (water hyacinth), feed 3- non plant and feed 4- a commercial feed used by some tilapia farmers as control (C)] were tested using growth parameters of the fishes. The % protein of feeds 1, 2, 3 and control feed were 27%, 25%, 35% and 38% respectively while the cost for 1 kg of 3 experimental feeds was approximately LKR. 115 and the control feed was LKR. 175. Feeding rate was adjusted to twice daily at 5% body weight and the pH, temperature, DO and un-ionized ammonia measured in all tanks were in acceptable ranges. The trial lasted for 60 days. The average final weight of the fish fed on feed 1, 2, 3 and feed-C were 181.16 ± 1.2 , 193.7 ± 2.6 , 183.86 ± 3.9 and 183.5 ± 2.9 g and specific growth rates were 1.17 ± 0.10 , 1.13 ± 0.06 , 1.16 ± 0.09 and 1.11 ± 0.03 respectively. Percentage weight gains were 102.90 ± 13.02 , 98.27 ± 7.6 , 102.06 ± 11.08 and 95.51 ± 4.1 g ($p < 0.05$) respectively and the Food Conversion Ratios (FCR) were 3.70 ± 0.39 , 3.70 ± 0.22 , 3.6 ± 0.25 and 3.88 ± 0.16 , while the Food Efficiency Ratios (FER) were 0.27 ± 0.02 , 0.27 ± 0.01 , 0.27 ± 0.01 and 0.25 ± 0.01 ($p < 0.05$) respectively. As all the results did not show a significant difference, these aquatic plants incorporated feeds can be suggested as economically feasible feed for tilapia food fish culture. Further, the present study revealed that, 25% crude protein is sufficient for growth of Tilapia all male fingerlings for 60 days period.

Keywords: tilapia fingerlings, plant based feed, *Pistia*, *Eichhornia*, growth

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Introducing near-shore Fish Aggregation Devices (FAD) to artisanal fishery in Sri Lanka: A preliminary study

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Fish Aggregating Devices (FADs) are objects placed in the ocean to attract and capture fish. There are two main types of FADs, drifting and anchored. Anchored FADs are identified as an important tool for development of sustainable artisanal and small-scale commercial fisheries, in facilitating the growth in coastal communities. Few research investigations have been published on the ecology and catch rates of FADs in Sri Lankan coastal waters. The current study focused on the catch composition and Catch Per Unit Effort (CPUE) as an abundance index in the area of anchored FADs in the North Western coastal waters of Sinnamon Island. Sixteen experimental purse-seine fishing trials were conducted at four fixed locations (station A was closest to FADs while rest extended away) in proximity to forty anchored FADs during the period January 2018 to March 2019. Shannon-Weiner diversity index of catch was highest closest to the shore (station A; $H=1.6917$), while lowest was at a location further away from the coast (station D; $H=1.1206$). CPUE values of the experimental fishing showed a positive correlation between the distance of locations with FADs within the study area (up to 1.5 km distance) and the period ($R^2 = 0.91$ and $p < 0.05$), with highest at location D (133.91 kg per boat per person) and lowest at location A (24.35 kg per boat per person). Clupeidae, Balistidae, Carangidae and Engraulidae were the most abundant families that contributed to the catch in the area. *Amblygaster sirm* was dominant in all the stations, followed by *Decapterus russelli*, *Caranx ignobilis* and *Balatoides* sp. The present study showed the increased fish diversity and CPUE in areas where FADs were anchored. Further studies need to address the succession and seasonal variation of the species composition and CPUE within the FADs development programme for the sustainable coastal fisheries.

Keywords: fish aggregating devices, diversity, CPUE

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Spiny lobster fishery in Hambantota District, Sri Lanka: An update

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Spiny lobster fishery in the South coast of Sri Lanka plays a very important role in the rural economy. With the increasing demand for lobsters in foreign markets, growing fishing effort and violation of the existing regulations were reported having adverse impacts on the sustainability of the stocks. Current status of the fishery is of utmost importance to revise the present regulations, which are implemented through the fisheries co-management mechanism. Spiny lobster catch data was collected by the samplers attached to the CENARA project from March to November, 2017 from major lobster landing sites and collecting centers in the Hambanthota district except in the closed season. The scalloped spiny lobster (*Panulirus homarus*), the major species found in the landings, contributed 85.57% (n=1957 from 2287) of the total catch while four other species (*P. versicolor* 5.99% - n=137, *P. penicillatus* 5.77% - n=132, *P. longipes* 1.26% n=29 and *P. ornatus* 1.39 % n=32) contributed 14.43%. Among the three different craft types used by the fishermen, Non-Motorized Traditional Canoes (NMTC) are the most popular craft type (61%, n=504) operated with the 3½'' - 4½'' mesh size bottom set gill nets. The estimated CPUE for the gill net used in three craft types were 0.213 for FRP boats, 0.216 for NMTC and 0.182 kg/day/craft/net pieces for motorized traditional crafts and also correlation between the number of gear units and catch was significant ($R^2=0.379$, n=177, p=0.001) at $\alpha=0.05$. Among the two gear types used by the lobster fishermen, 92% of them used bottom set gill nets and 8% used lobster rings. There is no significant difference in the catch between craft types or gear types (p=0.64 and 0.13, $\alpha=0.05$). Length frequency analysis of *P. homarus* revealed that the modal length class 6.5-6.9 cm (CL) is also the medium length class mature enough to harvest (minimum legal harvestable size 6 cm). During the study, recovery trend in the depleted stock was noted. Since the bottom set gill net has been identified as a destructive gear, introduction of eco-friendly fishing gear is of utmost important.

Keywords: spiny lobster, *Panulirus homarus*, South coast

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Efficacy of selected plant extracts as anesthetic agents during packing of *Oreochromis niloticus* and *Cyprinus carpio*

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Transportation exposes fish to a series of stress stimuli which cause fish mortality. Anesthetic agents are used in aquaculture to reduce the stress in fish. Plant materials as anesthetic agents have a great avenue in aquaculture sector. The study was focused to evaluate the efficiency of *Derris scandense* (Kalawel), *Tephrosia vogelii* (Fish-poison bean) and *Barringtonia racemosa* (Medella) as anesthetics during transportation of a food fish (*Oreochromis niloticus*) and an ornamental fish (*Cyprinus carpio*). Extracts of each plant were prepared by grinding 50 g of plant material with 500 mL of water and filtering. Complete Randomized Block Design and one way ANOVA were used. Two experiments were conducted each with three replicates. First experiment was on induction time, recovery time and water quality parameters when packing of fish with five concentrations of each plant extract, *D. scandense* - 1.5, 2, 2.5, 3, 3.5 mL/L; *T. vogelii* - 0.25, 0.5, 0.75, 1, 1.25 mL/L; *B. racemosa* 45, 46, 47, 48, 49 mL/L. Ten fingerlings of each species/treatment/replicate, *O. niloticus* (3.54±0.49 g and 46.05±2.72 cm) and *C. carpio* (3.92±0.52 g and 49.61±2.02 cm) were used. Most effective anesthetic concentration of plant extracts were compared with MS222 (65 mL/L) and clove oil (3 mL/L) in second experiment. Lowest induction time was 7.39±1.22 min at 1.25 mL/L and lowest recovery time was 19.41±1.5 min at 0.25 mL/L were exhibited by *T. vogelii* for *O. niloticus*. Highest induction time and recovery time periods for *C. carpio* was exhibited by *B. racemosa* with 77.29±1.61 min at 45 mL/L and 130.37±0.77 min at 49 mL/L respectively. Water quality parameters were within the acceptable range for aquaculture. The anesthetic properties of *T. vogelii* were similar to that of clove oil at 3 mL/L and MS222 at 65 mL/L. Induction time and recovery time of *D. scandens* and *B. racemosa* were longer than that of clove oil and MS222. Anesthetic properties of *T. vogelii* and *D. scandens* were capable of sedating the fish. *T. vogelii* could be identified as the most effective anesthetic agent at a dosage of 1.25 mL/L. *B. racemosa* can be categorized as a slow anesthetic agent as it exhibited longer induction and recovery time duration and it could be used when transporting fish.

Keywords: induction time, recovery time, anesthetic properties

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Development of sustainable fish culture in two selected floodplains of Nilwala river basin Sri Lanka

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Floodplains of the world's large rivers are highly suitable areas for development of aquaculture. Some of the favourable factors for utilizing flood plain areas for aquaculture are availability of large extents of land, availability of water, suitability of soil types and easy accessibility. On the other hand, these sites may be vulnerable to floods, which need to be taken into consideration in locating aquaculture farms. This study was conducted to investigate the feasibility of undertaking productive and viable fish culture in two selected floodplains in Nilwala river basin. Fingerlings of GIFT tilapia (26- 40 g initial weight and 6.2-9.4 cm in initial length) reared in six mud ponds each 200 m² area at Nadugala (N 5.979500° E 80.550870°) and Diyagaha (N 5.974950o, E 80.562800°) areas. Fingerlings were fed with formulated fish feed (crude protein 35.2%) thrice a day at a rate of 1-2% of the biomass from 1st of August to 31st December 2018. Water quality parameters in fish rearing mud ponds were recorded every fortnight. Growth rate, specific growth rate, survival rate, feed conversion ratio and total fish production ranged between 1.88-1.89 gday⁻¹, 3.68-3.68, 80-83 %, 1.43-1.47, 6811-7069 kg hec⁻¹ respectively. There were no significant differences between growth rate, specific growth rate, survival rate, feed conversion ratio and total fish production between each replicate ($p < 0.05$). Water temperature, water pH, water transparency, dissolved oxygen, unionized ammonia, total alkalinity, soil pH ranged between 28-30 °C, 6.36-7.88, 24-35 cm, 4.8-6.5 mg/L, 0.01-0.02 mg/L, 20-165 mg/L, 6.61-6.80 respectively and these values were within acceptable ranges suitable for fish growth and survival. It was concluded that growth performance of fish is very satisfactory and the water quality parameters and soil quality were suitable for development of GIFT tilapia culture in Nadugala and Diyagaha floodplains of Nilwala river basin Sri Lanka.

Keywords: GIFT tilapia, floodplain, fish culture, Nilwala river, water quality

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Exploring the wellbeing factors and pathways for improving the wellbeing of Mannar fishing populations of Sri Lanka

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Despite looking the possible ways to increase the technical efficiency very few researches have been carried out to find means of improving the wellbeing of the fishing communities in Northern Sri Lanka. As the majority of the population is engaged in fishing activities either full time or part time, improving the fisheries wellbeing is of paramount importance. Hence a study was undertaken, which focused on finding out the factors affecting the wellbeing of the Northern fishing communities, the impact of conflicts on their wellbeing and strategies needed to be adopted to improve their wellbeing. This study was carried out (during 2015) in Pesalai, a fisheries village in Mannar District of Northern Sri Lanka. Methodology employed consisting of a pretested structured questionnaire administered to a sample of fishers and focus group discussions with selected groups of men and women from the fishing community. Results indicated that good income, ownership of a house and maintaining good social relations were the most significant wellbeing factors of women while food, maintaining good physical health and having a good wife was the most important wellbeing factors of men. Use of drugs by the spouse, impact of communication technology on children's education and poor facilities in hospitals were the main problems faced by the women in the study area while illegal fishing by Indian trawlers, the use of destructive fishing techniques and drug addiction were the major problems faced by the men in the particular study area. Further results revealed that their expected changes include banning alcohol, collecting centers and increasing the job opportunities in different sectors. Shifting to new employment, facilitating professional education for their children and temporary transformation to another sector were the suggestions to recover the wellbeing loss and banned Indian trawling, controlling destructive fishing techniques usage and controlling price of fish were the expected changes. The study provides insights for loss of wellbeing of fishing communities can be minimized through bottom-up approach and distribution of inputs among them in Northern Sri Lanka when making appropriate policy changes to uplift their wellbeing.

Keywords: fisheries, Mannar, Northern Sri Lanka

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A comparative study on beach seine fishery in the North West coast and North East coast of Sri Lanka and impacts due to the introduction of a new hauling device (winch) in beach seine fishery

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This study was carried out with the aim of identifying the present performance of beach seine fishery in the North Western region and North Eastern region of Sri Lanka. Twenty manual beach seine operations and 30 winch operations from the North West coast were monitored from January to April and October to December in 2008 and 14 manual operations and 27 winch operations from the North East coasts were monitored from April to October 2018. The selected beach seine landing sites were visited twice a month to collect information on fish catch, fishing gear details and species composition of the catches. *Rastrelliger kanagurta* and *Sardinella gibbosa* were the main contributors in both North West and North East coasts. The present study revealed that the mean operation time of a manual operation (1.98 ± 0.44 hours and 2.18 ± 0.75 hours in North Western region and North Eastern region respectively) was significantly lower than the mean operation time of the winch operation (4.08 ± 2.06 hours and 3.78 ± 0.62 hours in North Western region and North Eastern region respectively) (t-value=5.41, $p < 0.001$ and t-value=6.84, $p < 0.001$ respectively). The estimated mean operation distance from the coast of a manual operation (1.15 ± 0.16 km and 1.27 ± 0.50 km in the North Western region and North Eastern region respectively) was significantly lower than the operation distance of a winch operation (2.60 ± 1.75 km and 2.73 ± 0.53 km in North Western region and North Eastern region respectively) (t-value = 4.53, $p < 0.001$ and t-value = 8.67, $p < 0.001$). The estimated mean catch per haul per square kilometer of manual operation in the North Eastern region was 1310 ± 1226 kg haul⁻¹ km⁻² and this value was significantly higher than the estimated mean catch per haul per square kilometer (368 ± 385 kg haul⁻¹ km⁻²) of winch operation (t-value 3.28, $p < 0.01$). The mean catch per haul per square kilometer of a manual operation in the North Eastern region was 612 ± 1086 kg haul⁻¹ km⁻² and no significant difference was noted with the estimated mean catch per haul per square kilometer (556 ± 547 kg haul⁻¹ km⁻²) of winch operation (t-value 0.18, $p = 0.859$). As the introduction of a winch for hauling the beach seine net, gear operation time has increased while gear operation area also has been significantly extended more from shore.

Keywords: beach seine fishery, North Western region, winch operators, manual operators

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Biotechnology and Animal Health

Genetic divergence of two *Axix* species found in Sri Lanka revealed by two mitochondrial gene regions

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The two *Auxis* species found in Sri Lankan waters, *Auxis thazard* (frigate tuna) and *Auxis rochei* (bullet tuna), have very similar morphological features and are frequently misidentified. The present study was initiated to identify these *Auxis* species accurately by molecular methods and to study their phylogenetic relationship. Samples of *A. thazard* and *A. rochei* were collected from the Western, Northwestern, Southern and Eastern provinces of Sri Lanka. The mitochondrial cytochrome oxidase I (COI) region was amplified and sequenced for 95 *A. thazard* samples and 56 *A. rochei* samples. The sequences were identified with 99.25% similarity for *A. thazard* and 98.9% similarity for *A. rochei*. DNA barcodes for *A. thazard* and *A. rochei* found in Sri Lanka were determined using the mt COI sequences (700 bp) obtained for the two species. In addition, partial mitochondrial D-loop sequences (500 bp) were also obtained for 84 *A. thazard* and 81 *A. rochei* samples for the phylogenetic study. The phylogenetic trees derived for the mt COI and mt D-loop sequences showed *A. thazard* samples in one clade and *A. rochei* samples in a separate clade, with the *A. rochei* clade being ancestor to the *A. thazard* clade. Tajima's D values, -1.88173 for mt COI and -1.39850 for mt D-loop sequences showed recent population expansions of both populations. The nucleotide diversity for the COI sequences of *A. thazard* was 0.02886 and for *A. rochei* it was 0.03541. As nucleotide diversity is higher in older populations, it can be suggested that *A. rochei* is the ancestral species out of the two *Auxis* species, which is also confirmed by the branching pattern of the phylogenetic trees.

Keywords: *Auxis thazard*, *Auxis rochei*, mitochondrial, phylogenetic

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Stock structure of *Amblygaster sirm* (Walbaum, 1792) distributed in the coastal waters in Sri Lanka

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Amblygaster sirm (Spotted Sardinella) is one of the most important fish in small pelagic gill net fisheries in Sri Lanka. Due to its high nutritional value, affordable price and taste, it is a popular protein source among Sri Lankans. At present, the high demand for the fish has caused overfishing and the fish stocks are in a declining trend. To maintain and manage healthy fish stocks, stock identification is essential. As such, genetic stock identification can be used as an efficient alternative to conventional stock identification methods. Sri Lanka faces two distinct monsoons namely South East and North West which process different ocean currents in different directions. Since *A. sirm* is a migratory fish with oceanic currents, there is a doubt whether the stocks of *A. sirm* distributed in the West and East coast of the country belong to a single stock or two stocks. This is a very vital aspect to manage the fishery and present study was carried out to discover the stock structure of *A. sirm*. Samples were collected from ten landing sites around Sri Lanka to represent the coastal area around the country. Further, samples from around the country collected by the RV Dr Fridtjof Nansen Ecosystem Survey were also included. Total DNA was extracted by using Qiagen's DNeasy Blood and Tissue kit. The portion of the mitochondrial cytochrome b (cyt-b) gene was sequenced. Sequences were analyzed by using MEGA, Bioedit and DnaSP softwares. Multiple sequence analysis results showed a conserved nature of cyt-b sequence region among individuals. In addition, fifteen single nucleotide polymorphism (SNPs) sites were recorded with sixteen haplotypes. The individuals were clearly divided into three phylogenetic groups. However, in all groups individuals collected from East and West coastal regions were grouped together. Therefore, study concluded that *A. sirm* population distributed in Sri Lanka should be considered as one stock in future management decisions.

Keywords: *Amblygaster sirm*, genetic stock identification, SNPs, RV Dr. Fridtjof Nansen Ecosystem Survey

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Preliminary genetic evidence on the presence of two stocks of *Lethrinus nebulosus* (Forsskål, 1775) in Sri Lankan waters

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Lethrinus nebulosus (spangled emperor) is a demersal non-migratory reef-associated fish which is having a high global demand as a food fish. Population reduction of *L. nebulosus* has been observed in the recent past due to overfishing. Hence, management plans are needed for immediate action. Mitochondrial COI sequence data provides a preliminary idea about the existing genetic stock structure of a fish population. Samples were collected from around the country during RV Dr. Fridtjof Nansen Ecosystem Survey in 2018. Total DNA was extracted by using Qiagen's DNeasy Tissue Kit following the manufacturer's protocol. PCR was carried out with FishF1 and FishR1 primers. Sequences were analyzed by using MEGA, Bio edit and DnaSP software. Two phylogenetic groups were clearly separated. Individuals from South East and South West regions were clustered in group I and individuals from North and Central East regions were clustered in group II. Among two groups high nucleotide divergence was observed with 116 single nucleotide polymorphic sites and four haplotypes. Average number of nucleotide differences between the groups is 84.182, in group I it is 5.727 and in group II it is 0.000. The results revealed the preliminary evidence of presence of two stocks of *L. nebulosus* inhabit in Sri Lanka; one stock in North and Central East regions and the other stock in other coastal regions. This study has provided foundation for future genetic studies. In conclusion, the *L. nebulosus* population in Sri Lanka consist of two genetically variable groups, may be two cryptic species, however, to confirm it morphological data should be analysed in parallel with genetic analysis.

Keywords: *Lethrinus nebulosus*, haplotypes, fishery management, genetic stock, RV Dr. Fridtjof Nansen Ecosystem Survey

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A preliminary genetic study of the mitochondrial COI gene sequence variation of *Lethrinus lentjan* (Lacepède, 1802) species found in Sri Lankan waters

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Lethrinus lentjan (Pinkear emperor) is a reef associated dimersal non-migratory finfish found in sandy bottoms in coastal areas, deep lagoons and near coral reefs. Due to high demand as a food fish and a sport fish, the populations have been declined in the recent past. There has been no previous study on the nucleotide level variation of *L. lentjan* distributed in Sri Lankan waters. This preliminary genetic study uncovered the hidden nucleotide level variation and opened a new path in the view of fishery management. Fish samples collected during RV Dr. Fridtjof Nansen Ecosystem Survey 2018, were used for the analysis. Total DNA was extracted by using Qiagen's DNeasy Blood and Tissue Kit following the manufacturer's instructions. PCR was performed using FishF1 and FishR1 primers. Sequences were analyzed by using MEGA, Bioedit and DnaSP softwares. Phylogenetic trees were constructed using Neighbor Joining method. The individuals were clearly separated into two groups. Individuals collected from different regions were clustered within group I. However, some individuals collected from South East region was sub grouped within group I. A phylogenetically distinct group from the group I was separately classified as group II with individuals from Central East region. Average number of nucleotide differences between the group I and II was 66.125. Average number of nucleotide differences within the group I is 17.61 and 0.00 within group II. In multiple sequence analysis total of 81 Polymorphic sites and seven haplotypes were recorded. The results of the present study confirmed the presence of high nucleotide level variation within mitochondrial COI region within the *L. lentjan* populations in Sri Lanka. Further, extensive morphological characterization with and more samples in several locations and sequencing of COI and cyt-b regions can be used to confirm the existence of cryptic species of *L. lentjan* in coastal waters.

Keywords: *Lethrinus lentjan*, COI sequence variation, cryptic species, nucleotide variation, RV Dr. Fridtjof Nansen Ecosystem Survey

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Socioeconomic and Marketing

Should Sri Lanka increase the number of fishing boats?: Modelling of fish supply to understand the impact of boat quantity for fish supply of Sri Lanka

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The open-access nature of the capture fisheries encourage more and more fishermen to enter the fisheries sector, which leads to overexploitation of the resources, dilapidation of the economic rent, and finally impoverishment of wellbeing conditions of the fishing community. The Fisheries statistics of Sri Lanka have shown that the number of boats has increased with time. The purpose of this paper is to assess the factors that affect the supply of fresh fish in Sri Lanka and use that supply equation for simulation in order to understand the fish supply response for the number of registered fishing boats. The time series data of number of registered boats, annual average fish and fuel prices and annual fish production for 35 years (1982-2017) were collected from statistic reports of the Ministry of Fisheries and Aquatic Resource Development (MFARD), annual central bank reports and socio-economic statistics books of central bank. The data were analyzed by using STATA (version 11). The nominal values of price data were converted in to real value under the base year of 2010. The autoregressive lag model in linear-log functional form was used as the most appropriate model to estimate the fish supply. Pearson Correlation test result showed that there was a moderately inverse relationship ($p = -0.564$) between annual per capita fish production of boats and number of boats ($p = 0.035$). Weighted average fresh fish price, number of boats registered for the fishing purpose and previous year fish harvest were found to be the motives for fishermen to catch more fish. Under the *ceteris-paribus* condition, the quantity of boats was changed to estimate the series of supply quantities. With the increased number of new boat entrances, the total fish production has been increased at a decreasing rate and has reached a constant at present, which means further entering of new boats will not boost the marginal fish supply significantly. The average annual fish production has been drastically declined from 11 to 7 MT per boat when the number of boats has increased from 27,000 to 60,300.

Keyword: elasticity, annual fresh fish supply, determinants, partial-equilibrium,

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Edible fin fish exports in Sri Lanka: performance in the global market

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This study explores performance of edible fin fish exports of Sri Lanka in the global market. Annually published fish import and export data from 2001 to 2017 collected from the United Nations Commodity Trade Statistics Database (COMTRADE) were analysed to estimate the revealed comparative advantage, revealed export advantage, revealed import advantage, relative trade advantage, revealed competitiveness and Herfindahl-Hirschmann index in the study. The data showed that during the time period, the highest quantity of exports for edible fin fish of Sri Lanka was recorded in 2013 but the highest value was recorded in 2014. The highest drop of quantity exports was recorded in 2016 by indicating the adverse effect of the European Union (EU) ban on Sri Lankan sea food imports. The United States of America was the main importer of Sri Lanka's edible fin fish products. During the EU ban period Sri Lanka had increased its market share of edible fin fish in Canada, United Arab Emirates, Switzerland, Israel and Saudi Arabia as a counter act. Sri Lanka had a revealed comparative advantage for edible fin fish than for other fish products. The competitiveness of Sri Lanka's fin fish at global market was very low because of the narrow product portfolio and high concentration in very few markets. Since the high market concentration, Sri Lanka sea food export industry is vulnerable to the dynamics at the international markets. Introduction of high-tech aquaculture, adding of value to the existing resources, implementation of innovative marketing strategies and institutional arrangements to penetrate into potential lucrative international markets are recommended to minimize the vulnerability and increase the competitiveness of Sri Lankan fin fish at international markets.

Keywords: comparative advantage, edible fin fish, exports, competitiveness, performance of global market

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Owners' perception on mechanization of beach seine fishery in Sri Lanka

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Beach seine fishery (Madal), one of the oldest fishing techniques that has been introduced from India, has been practiced in coastal waters of Sri Lanka. This fishery which was legalized in 1985 through the Madal (Beach seine) Fishing Regulation and section 33, has given provision to seine operations which should be done with manually operated boats and nets which should be gradually dragged or pulled ashore manually by two groups of people. This study explores owners' perceptions on mechanization of seine fishery and its implications. A total sample of 30 seine owners were interviewed during the period May to July, 2018. Descriptive statistics as well as independent t-tests were used in data analysis. Traditionally used wallam, coir net and manual hauling has been changed to the use of mechanized boats, nylon nets and the operation of a winch in present operations. Lack of skilled labour, material and high time consumption were major factors affecting the evolution of seine fishery. Although mechanization has generated an economic efficiency in operation, about 20 percent of owners perceived that negative environmental impacts could be expected.

Keyword: beach seine fishery, mechanization, winch

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Fisheries and its implications on fishing community in Deduru Oya of Sri Lanka

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Deduru Oya originates from the Central hills of Sri Lanka and it mainly runs through the North Western Province and is fed by a catchment of over 2600 km². It emerged as a venue for fisheries due to the construction of the Deduru Oya reservoir in the recent past. Although fisheries were newly introduced to the reservoir, it plays an important role in the village economy. This study explores the fisheries and its implications on fishing community in Deduru Oya reservoir. The total sample size was 21 fishermen who registered in fisheries cooperative societies. Data were collected using semi-structured questionnaire and interviews and analysed using SPSS software package. Inland fishing activities were operated using non-mechanized fiberglass canoes which were approximately 6 m in length. Out of the total sample, 81% of fishers had fiberglass fishing crafts and 57.1% of them were received free from the government for the establishment of the fishing industry in the reservoir. Two fishermen were on board at a time. Gill net was the main fishing gear of the reservoir and fishermen were able to use 6-12 net pieces per craft. Tilapia (*Oreochromis mossambicus*), Nile Tilapia (*Oreochromis niloticus*), Catla (*Labeo catla*), Rohu (*Labeo rohita*) and freshwater prawn (*Macrobrachium rosenbergii*) were the major species in the catch composition. The average catch per fisher/day was in the range of 13-16 kg and the monthly mean income of a fisher was LKR 44,047. Fisheries cooperative society plays an important role in the industry by engaging in different activities related to fisheries management and marketing. All fishers have to engage in a minimum of 15 days per month to activate their membership in fisheries cooperative society. Scavenger problem, lack of technical know-how and training were major issues with fishers. It is important to strengthen the fisheries cooperative societies for the sustainable management of fishing community in the Deduru Oya reservoir.

Keywords: cooperative society, Deduru Oya, fisheries, socio-economics, welfare

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Insights of fresh water giant prawns (*Macrobrachium rosenbergii*) fishery in North Central Province of Sri Lanka

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Fresh water giants prawns (*Macrobrachium rosenbergii*) are highly nutritious and popular in seafood baskets of local consumers especially in the North Central Province of Sri Lanka. This paper explores economic and marketing aspects of the fresh water giant prawn fishery and its importance in the regional economy of Sri Lanka. A survey was administered with randomly selected samples of 40 stakeholders in the fishery in the North Central Province of the country in 2018. This fishery was totally dependent on the releasing of Post Larvae (PL). The capital investment of the fresh water giant prawn fishery was LKR. 85,000. The average annual operational cost was LKR. 156,210 while net income was LKR. 104,556 per unit respectively. Marketing of prawns are totally handled by the cooperative societies and assemblers and retailers. They are the middlemen in the value chain. An assembler collects prawns from 2-3 tanks per day. Prawns with weight >500 g fetched a higher price than others. An assembler earned an annual average net income of LKR. 275,000. Irregular releasing of PL and lower survival rate of PL were the issues raised in the fishery.

Keywords: cost of production, fresh water giant prawns, marketing, net income, North Central Province

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Oceanography and Hydrography

Turbulence and mixed layer depth characteristics in the interior of Sri Lanka Dome

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Sri Lanka Dome (SLD) is a cyclonic feature form in the East of Sri Lanka due to Ekman pumping, generated South West monsoon wind. The phenomenon is formed in July and disappears at the end of September each year. Though, limited investigations have been carried out on SLD, this is the first field effort on the study of small scale dynamics in the Dome. Vertical micro-structure profiler was used to investigate small scale dynamics and surveys were conducted on July 15th to 16th (night) and 16th to 17th (night) at 20 stations along a so called cyclonic eddy. The total length of survey line was about 90 nautical miles. The results indicated that the temperature at the west of SLD is 29.1°C, which decreased towards the center and was 28.4 °C at the east end of the SLD. Salinity was around 34.05 psu at the West end (-45 m) and however, the salinity decreased towards the center of the dome reaching 33.95 psu. The development of upward doming structure of the pycnocline toward the SLD center could be observed, leading to substantial shallowing of the Mixed Layer (MLD). MLD estimation was done based on the density profiles obtained through seabird sensors attached to the micro-structure profiler. MLD is about 40 m at the west end of the dome (-45 m) and decreases towards the middle reaching approximately 20 m. However, MLD is lowest (10 m) at the east side of the dome. Strong density stratification could be observed in the potential density variation along the survey line. The halocline and pycnocline appears to be sloping towards the western part of the dome. Cyclonic circulation during South West monsoon associated with SLD generating an upwelling area of halocline at the SLD center with an average slope of about 30 m over 100 km. Doming of the sharp density interface between surface mixed layer and stratified water interior led to substantial shallowing of the mixed layer depth from around 40 m outside the SLD to ~10-15 m closer to its center. The TKE dissipation rate was found to be substantially higher at VMP stations presumably occupying the inner periphery of SLD, that is about 10-25 nautical miles away to the west from the expected SLD core.

Keywords: dome, cyclone, mixed layer

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Computation of Luni-tidal interval in East and West coasts of Sri Lanka

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Luni-tidal interval is the time lag between the moon transit time over a particular meridian and the immediate high/low tide occurrence. Usually, this interval spatially varies due to the nature of the coastal configuration, bathymetry and various other oceanographic conditions. Apart from that, luni-tidal interval temporally varies at a location due to the relative position of the moon. Because of having different bathymetric and oceanographic alignments in East and West coasts of Sri Lanka, Colombo and Trincomalee ports exhibit a completely opposite tidal pattern which is almost a 180 degree phase out. For example, when Colombo experiences high tides, Trincomalee experiences low tides and vice versa. This leads to completely different luni-tidal intervals in Colombo and Trincomalee. In this study, luni-tidal intervals for Colombo and Trincomalee were analyzed by using 2017 tidal data. The average luni-tidal intervals computed at Colombo and Trincomalee are 4.8 h and 7.7 h, respectively. However, the actual transit time difference of the moon at Trincomalee and Colombo is just 5-6 minutes. Therefore, the reasons for this nearly 3 hour luni-tidal gap were explored in this study. Here, the main diurnal components (K1 & O1) are not showing much variation in the phase between Colombo and Trincomalee while the main semi-diurnal components M2 & S2 are showing nearly 180 phase shift. This is due to the two amphidromic points situated in the Indian Ocean around Sri Lanka.

Keywords: luni-tidal interval, tide, tidal analysis

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Long term and short term coastal erosion in South Western coast of Sri Lanka

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The ever-increasing economical and environmental considerations of the South Western coast of Sri Lanka have provoked further studies on ongoing coastal erosion and future shoreline changes due to wave climate and sea level rise. The issue of shoreline changes over the next century has increasingly become a major social, economic and environmental concern where it poses a serious problem to the environment and future developments. In the current study, pre-defined coastal cells from Matara to Puttalam was considered for evaluating the corresponding long-term (1956-2005) and short-term (2005-2014) erosion/deposition rates and sand volumes. Digital Globe satellite images in Google Earth Pro and aerial photographs were used in the period between 1956 and 2014. Shoreline changes were detected using Digital Shoreline Analysis System in ArcGIS. The relative uncertainties due to coastline positions that were affected by tidal phase at the moment of the images were also calculated using Bruune rule. Results showed that the erosion rate was more intense towards the northern part of the study area whereas the Southern cells were relatively protected by revetments and small groins. During the period between 2005 and 2014, the coastal belt between Marawila and Chilaw was subjected to severe erosion, with the amount of 186 000 m³/year and that was 20 times greater than the erosion volume recorded in 1956 to 2005. The coastal cell from Chilaw to Udappu showed the second largest increase of erosion rate, with the amount of 96 000 m³/year and it was four times higher compared to the erosion volume in 1956 to 2005. The reduction of sand supply from rivers due to extensive sand mining and coastal structures could be the contributory factors that governed the ongoing sea erosion in the area.

Keywords: coastal erosion, Bruune rule, ArcGIS, sand mining, aerial photographs

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Sedimentary characteristics of Hikkaduwa and Beruwala fishery harbours in Sri Lanka

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Two fishery harbours, namely Beruwala and Hikkaduwa in South Western coast of Sri Lanka were studied for depth and sedimentary properties. The main objective of this study was to identify the possibility of using the bottom sediment of the harbours for filling and construction purposes by determining the particle size and other related properties. Thirty-six and twenty-one of sediment samples were collected systematically using a grab from Beruwala and Hikkaduwa harbours respectively and analyzed for grain size. The mean grain size of the Beruwala harbour varied from 1.83 to 4.19 and the average was 3.08 in phi scale indicating that most of them belonged to the fine to very fine sand range. The mean grain size of sediment samples in the Hikkaduwa harbour varied from 0.74 to 2.6 and the average was 2.09 in phi scale indicating that most of them belonged to the medium to fine sand range. The results revealed that, the particle sizes of sediments in both harbours were not in the range of the sand used for construction. However, the sediments in the Hikkaduwa harbour could be used for plastering after purification if the chemical and physical properties are suitable for the purpose. The average sorting, skewness and kurtosis values were 0.84 (moderately sorted), -0.027 (Coarse skewed), 1.05 (mesokurtic) and 1.22 (poorly sorted), -0.056 (coarse skewed), 1.07 (mesokurtic) in phi scale for Hikkaduwa and Beruwala harbours respectively. Since, the sediment was in well sorted to moderately well sorted range and all sediment particles were derivatives of quartzite with same density, it could be concluded that wave energy was generally constant in the Hikkaduwa harbour.

Keywords: mean grain size, sorting, sediment, Hikkaduwa, Beruwala

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**Marine and Coastal Environment
Pollution, Aquatic Environment
Conservation and Management**

Assessing potential toxicity of drinking water from selected dug wells in Medawachchiya, Anuradhapura District, Sri Lanka, using plant and fish bioassays

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Chronic Kidney Disease of Unknown aetiology (CKDu) is prevalent in the Medawachchiya area in Sri Lanka. This study was aimed at assessing potential toxicity of waters in the selected dug wells (drinking water sources) in Medawachchiya area using *Allium cepa* (common onion) root based and *Cyprinus carpio* (common carp) erythrocyte based bioassays. During prolonged dry period in 2016, water from eight dug wells were sampled for assessments which included four drinking water wells of CKDu affected families and four reference wells which had been used by the families with no clinical signs of CKDu. Bioassays were carried out following standard protocols with aged tap water and mineral water as negative controls. Onion bulbs were exposed to well waters and negative controls (n=5) for two days and root growth, mitotic index and nuclear/chromosomal abnormalities in meristematic cells were determined to evaluate potential toxicity. Concurrently, fingerlings of *C. carpio* were exposed to the different exposure media for five days and erythrocytes from peripheral blood and head kidney were used for erythrocytic abnormality tests. The results of plant bioassay indicated potential toxicity associated with water in the dug wells used by CKDu affected families based on root growth retardation and mitotic index depression effects compared to the negative controls (Mann-Whitney U test; $p < 0.05$). Significant induction of chromosomal and nuclear abnormalities in the root meristems was also noted. Fish bioassay showed potential toxicity associated with water in the dug wells used by CKDu affected families and reference dug wells in some cases based on apoptosis of erythrocytes of the fish exposed to well water compared to those of negative controls (Mann-Whitney U test; $p < 0.05$). Both plant and fish bioassays revealed potential toxicity associated with the drinking water of the dug wells used by CKDu affected families.

Keywords: bioassay, CKDu, drinking water, dug wells, toxicity

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Assessment of microplastics contamination in marine protected areas in Southern Sri Lanka

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Microplastics (MPs) are ubiquitous in the marine environment and they cause various detrimental impacts on organisms from lower trophic level to higher trophic levels. Hydrodynamic processes and ocean currents affect wide dispersion of MPs even into remote areas. In order to evaluate abundance, composition and distribution of MPs in coastal sand and water, two Marine Protected Areas (MPAs) were selected and sampling was conducted during South West monsoon period. To acquire better understanding of contamination level, sub sites were also selected from each MPAs. MPs were reported under two main size classes; 0.5 – 1.0 mm and 1.1 – 5.0 mm. Average abundance of MPs in coastal sand of BNP and HNP, ranged from 39 ± 3 to 196 ± 13 MPs/m² and 52 ± 4 to 234 ± 11 MPs/m², respectively. Average abundance of MPs in coastal water of BNP was 107 number of MPs/1000 m² and in HNP, it was 203 number of MPs /1000 m². Fragments and filaments were the most common shapes. FTIR and Raman analysis showed that polyethylene, polypropylene and polystyrene were the major polymer types and about 40% of MPs were oxidized. The particles smaller than 1 mm were stained using Nile Red to confirm visually identified MPs were in fact plastics. The result of this study indicate the presence of MPs in MPAs in Southern Sri Lanka at considerable high levels. This research is the first to survey MPs contamination in MPAs in the Southern coast and provides baseline information for further research at species level.

Keywords: microplastics, plastics, marine protected areas, pollution

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Effect of different nitrogen sources on growth performance of marine phytoplankton *Nannochloropsis* sp. and *Cheatoceros* sp.

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Nannochloropsis sp. and *Chaetoceros* sp. are marine phytoplankton/microalgae that belong to phylum Ochrophyta. They are important in the aquaculture field as a live feed for larval stages of finfish and shellfish. The present experiment was conducted to identify the effect of nitrogen sources on growth performance of *Nannochloropsis* sp. and *Chaetoceros* sp. For this study, F/2 culture media was used as a medium in control culture which contained NaNO₃ as the source of nitrogen. The culture media were also prepared by using KNO₃ (9 gL⁻¹), CH₄N₂O (urea) (27 gL⁻¹) and NH₄Cl (47.3 gL⁻¹) as the sources of nitrogen. Algae cultures were prepared in triplicates for all treatments in *Nannochloropsis* sp. and two replicates were prepared for *Chaetoceros* sp. and cultured under the indoor condition, maintaining a constant temperature (27.0 °C) and salinity (25.0 ppt) with continuous aeration. The results of ten days experiment revealed that there were significant differences for cell density and chlorophyll-*a* (chl-*a*) with the sampling day and nitrogen source (Two-way ANOVA: $p < 0.05$). Significantly high cell density and chl-*a* content were reported in the culture treated with nitrogen source as urea than that of other cultures treated with NaNO₃ (control culture), KNO₃ and NH₄Cl. The significantly high cell density and chl-*a* were reported in second sampling (3rd day for *Nannochloropsis* sp. and 4th day for *Chaetoceros* sp.) from cultures than that of the other sampling. Urea can be recommended as a more effective source of nitrogen for F/2 culture media to obtain high biomass of both species of microalgae. This study provides the information on effectiveness of nitrogen source on growth performance of marine microalgae which can elevate the biomass of *Nannochloropsis* sp. and *Chaetoceros* sp.

Keywords: *Nannochloropsis* sp., *Chaetoceros* sp., nitrogen sources, cell density, chlorophyll-*a*

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Present status of the water quality in Beruwala Fishery Harbour, Sri Lanka

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Fisheries industry plays an important role in the economy of Sri Lanka by providing livelihood for more than 2.5 million coastal communities and more than 50% of animal protein requirement of the people in the country. Beruwala fishery harbour contributes highly to the fish landings in Kalutara District of the country. However, there are limited studies conducted to identify the pollution status of the Beruwala fishery harbour. Therefore, the objective of this study was to identify the pollution status of Beruwala fishery harbour with special reference to the water quality. Sampling was carried out from January to July, 2015 by selecting six sampling locations using judgmental sampling techniques. Surface and bottom water samples were collected and analyzed for sixteen physico-chemical parameters. Dissolved oxygen, water temperature, pH, electrical conductivity, total dissolved solids, total suspended solids, salinity and turbidity were determined in situ and water samples collected were subjected to laboratory analysis for nutrients, oil and grease, chemical oxygen demand, biological oxygen demand and chlorophyll-a, using standard methods for the examination of water and waste water. Data analysis was carried out using MINITAB 14 statistical software. Results revealed that, average pH, electrical conductivity and salinity were within the standard limits of the water quality for harbour waters. However, high oil and grease (84.17 ± 40.69 mg/L) content, biochemical oxygen demand (52.83 ± 20.29 mg/L), total suspended solids (52.27 ± 21.60 mg/L), chlorophyll-a (55.71 ± 47.45 µg/L), ammoniacal-nitrogen (1.22 ± 0.65 mg/L), ortho-phosphate (0.73 ± 0.55 mg/L) and chemical oxygen demand (925.00 ± 64.55 mg/L) were recorded and these values exceeded the standard limits for the harbour water quality. Therefore, it can be concluded that, the water quality of the Beruwala fishery harbour has degraded and is subjected to severe organic pollution, chemical pollution and oil pollution.

Keywords: Beruwala fishery harbour, water pollution, physico-chemical parameters

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Enumeration and categorization of marine debris on Kadolkele mangroves in Negombo Lagoon, Sri Lanka

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Marine debris is recognized as one of the most prevalent pollution problems at present. Coastal litter surveys can focus on the standing crop of litter on a coastline or coastal ecosystem which serves as a snapshot of the level of pollution in a region. The aim of this survey was to assess litter pollution on Kadolkele mangrove ecosystem in Negombo Lagoon. The survey was conducted for a four months period during the South West monsoon from May to August 2017 on a monthly basis. The three blocks of 100 m² in size were selected at the site and the 100 m² block was divided into 1 m² quadrats and 20 quadrats were sampled from each block for macro debris (>2.5 cm in size on the longest dimension). A total of 80 quadrats were sampled in each month. The collected debris particles were counted and classified by material type such as plastic, metal, glass and ceramics, rubber, cloth, wood, paper and cardboard and other. The collected plastic items were categorized into packaging items, fishing items and consumer items. Overall mean (\pm SD) abundance of marine debris in Kadolkele was 2.57 ± 1.37 items/m² and debris accumulation varied significantly among months (Kruskal-Wallis test; $p=0.03$), showing lowest abundance in August. Among eight categories of marine debris, plastics were dominating with 73% followed by glass & ceramics (7%) and rubber (6%). Among plastics, packaging items were dominating with 68% followed by fishing and consumer items. Among different factors that affect debris accumulation, the areal root system of mangroves may retain large plastic objects, leading to high plastic mass estimates in mangroves of Negombo Lagoon.

Keywords: mangroves, Kadolkele, Negombo Lagoon, marine debris, plastics

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Enumeration of microplastics in Sri Lankan waters: Preliminary findings from the RV Dr. Fridtjof Nansen Ecosystem Survey, 2018

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Over the past decades, plastics, as a marine litter have become an emerging issue across the world. Plastics have been used without proper recycling, but with a dramatic increase in production where plastic wastes often end-up into oceans. Plastics fold into several categories with numerous physicochemical properties which determine their fate and impact. Micro-plastics (size <5.0 mm) are generated from various sources, and are the most perilous due to their buoyancy, dispersion, and persistence. Microplastics can cause issues due to their ubiquity, bio-availability and transportability of toxins. This study assessed microplastics in Sri Lankan waters during the Ecosystem Survey (June-July, 2018), conducted onboard RV Dr. Fridtjof Nansen. The sea surface was sampled (n=38), using a *Manta-trawl* (opening: 19×61 cm²; mesh: 333 µm), hauled horizontally (~1.5 ms⁻¹; 15 minutes) with flow-meter readings. The samples were cleansed over a sieve (180 µm) and, particles were examined under a stereo-microscope, photographed, measured and described. Samples were examined against controls (sea water & fresh water), whereas against known contaminants accumulates in the control samples to reduce contamination. The preliminary results reveal that waters in the West coast are more polluted with microplastics compared to the East-coast, due to the highest abundance in the North West (0.85 particles/m³). The Central East is slightly more polluted (0.27 particles/m³), compared to the North East (0.18 particles/m³) and the South East (0.25 particles/m³). Microplastics found in the Southern waters were low as 0.12 particles/m³. The overall average abundance of micro-plastics in Sri Lankan waters was estimated to 0.31 particles/m³ of surface water. The majority of microplastics were fragments whereas the second and the third most abundant contaminants were thread-like microplastics and foams respectively. Notably, a large

amount of fragments was recorded from the Central East and the North West. The average size of particles: 1.23 ± 1.18 mm, reveals the diversity in size. Most particles were 0-0.5 mm in width, and 0-4.1 mm in length, with a few lengthy particles (>28 mm). Most particles (62.67%) had rough surfaces, hard structures, and uneven shapes (74.13%). The profusion of secondary microplastics, indicates the association of industrial applications to pollution. Since the study covered a particular season, further research is recommended on spatial/ seasonal variations and distribution patterns.

Keywords: microplastics, marine pollution, RV Dr. Fridtjof Nansen Ecosystem Survey

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Zooplankton biomass variation in relation to temperature and salinity for upper 30 m around Sri Lanka

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Zooplankton play a vital role in the marine environment by transferring the energy to higher trophic levels through the food web. However, the studies on zooplankton in the coastal waters of Sri Lanka are deficient. The present study was conducted from 23rd June to 16th July, 2018 as a part of a marine ecosystem survey using the Research Vessel RV Dr. Fridtjof Nansen. Twenty seven zooplankton samples were collected by vertically hauling the WP2 plankton net with 180 µm mesh size. The net was taken from 30 m to surface from ten transects in six regions. Each zooplankton sample was divided into two equal halves using a Motoda splitter. The first part of the sample was size fractionated successively by using three sieves with mesh-sizes of 2000 µm, 1000 µm and 180 µm. The content on each screen was rinsed with freshwater to remove salt and transferred to pre-weighed Aluminum trays. The trays were dried at 60 °C for 24 h and frozen on-board. These samples were dried once more and weighed for estimation of biomasses. Among six regions, the highest zooplankton biomass (0.0596 gm⁻³ dry wt) was observed in South West region followed by South region (0.0452 gm⁻³ dry wt). The lowest average zooplankton biomass was recorded in North East region (0.0161 gm⁻³ dry wt). For the upper 30 m of the ocean, the highest temperature was recorded in the North East region and highest salinity recorded in North West region. According to correlation analysis, significant negative relationship was observed between zooplankton biomass and temperature ($r=-0.82$, $p<0.05$) and significant positive relationship was observed between zooplankton biomass and salinity ($r=0.69$, $p<0.05$). This relationship of zooplankton biomass with temperature and salinity are important to understand plankton population dynamics in Sri Lankan waters. Since zooplankton are one of the major food sources for planktivorous fish, this study provides important parameters into models used for predicting fish abundance in Sri Lankan waters.

Keywords : zooplankton, biomass, temperature, salinity, RV Dr. Fridtjof Nansen Ecosystem Survey

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Development of a model treatment system for fish effluent in small scale fish stall

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The small fish stalls release their fish effluent containing waste water into the natural environment without any appropriate treatment. Therefore, the objective of this study was to construct an artificial wetland to reduce pollution from fish waste water by small scale fish stalls. The treatment system consisted of 4 trays with stock tanks (5 L). Control with four different vertical flow types, artificial treatment structures with the flow rate of 1.0 L/hr were used for the experiment with four plant types including medicinal plant species; *Ipomoea aquatica* (Kang kung), *Hygrophila schulli* (Neeramulliya), *Alternanthera sessilis* (Mukunuwenna) and *Bacopa monnieri* (Lunuvila) randomly. Fish wastewater samples were used to treat the 4 structures. Water quality parameters such as pH, Electricity Conductivity (EC), turbidity, Total Suspended Solids (TSS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), nitrate nitrogen, nitrite nitrogen, ammoniacal nitrogen and dissolved phosphate were determined before treating the structure and water samples were obtained after 24 hrs from the outlet from the last tray in each structure using APHA standard methods. Randomized Complete Block Design (RCBD) set as experimental design and Duncan's Multiple Range Test (DMRT) was used to analyzed data using SAS 9.1.3 statistical software and MS-Excel software was used for data analysis. Results revealed that, turbidity and TSS were decreased in all four structures. In addition, mean reduction percentages of BOD, nitrate nitrogen, nitrite nitrogen, ammoniacal nitrogen and dissolved phosphate were $89.20\% \pm 2.17$, $99.81\% \pm 0.12$, $97.03\% \pm 0.19$, $94.70\% \pm 3.63$ and $93.18\% \pm 1.70$ respectively, The best Removal Efficiencies (RE) values were presented in the 4th structure which had a plant sequence of Kang Kung, Mukunuwenna, Lunuvila and Neeramulliya with RE of BOD, phosphate, ammonia, nitrite and nitrate 90.90%, 94.81%, 97.94%, 96.98%, 99.77%, respectively. According to DMRT analysis, there was a significant difference between pH, EC, DO, TSS, turbidity, ammoniacal nitrogen and BOD reduction values in different structures with different plant sequences respectively. The results suggested that, the vertical flow constructed wetland has high removal abilities and best RE values presented in the 4th structure.

Keywords: wetlands, reduction rate, waste water, medicinal plants, fish effluents

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Some biometric parameters of six selected fish species in Sri Lankan waters

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The objective of this study is to determine the Length Weight Relationship (LWR) and the Fulton's condition factor (K) in six commercially important fish species of Sri Lankan waters. Fish samples and their biometric data were collected from RV Dr. Fridtjof Nansen Ecosystem Survey in Sri Lankan waters from 24 June to 16 July, 2018. Six fish species belonging to two families were selected for this study to represent both demersal and pelagic species. Length-weight relationships were estimated using the equation $W = aL^b$ and the Fulton's condition factor (K) was estimated from the relationship $K = 100W/L^3$ to assess the condition of the selected fish. According to the results *Lethrinus nebulosus*, *Lethrinus olivaceus*, *Decapterus macrosoma*, *Decapterus russelli* and *Caranx ignobilis* exhibited negative allometric growth while *Lethrinus mahsena* showed an isometric growth pattern. Considering the K values, *Lethrinus nebulosus* showed the highest K value (1.80 ± 0.37) thus it can be concluded that species is in an excellent condition in Sri Lankan waters. *Decapterus macrosoma* showed the lowest K value which was 1.07 ± 0.43 . Thus it can be concluded that *Decapterus macrosoma* is in poor conditions in Sri Lankan waters. In addition, the resulted K value for *L. olivaceus*, *L. mahsena*, *D. russelli* and *C. ignobilis* were 1.32 ± 0.16 , 1.44 ± 0.21 , 1.14 ± 0.81 and 1.56 ± 0.42 respectively. The findings from this study are useful for comparison with the results of other studies undertaken during different seasons and at different localities to determine the status of the stocks as well as the ecosystem health.

Keywords: length-weight relationship, Fulton's condition factor, RV Dr. Fridtjof Nansen Ecosystem Survey, demersal, pelagic.

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Abundance and distribution of macro-benthos in surface sediments along the North Eastern coast of Sri Lanka

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Benthos are the assemblage of the creatures that live upon, within, or near the bottom sediments and they are generally considered as environmental indicators for aquatic ecosystems. Present study was undertaken to investigate the spatial variations of macrobenthic diversity, abundance and distribution in the North Eastern coastal region of Sri Lanka. Surface sediment samples were collected from nine sampling stations in North Eastern region during the ecosystem survey in Sri Lankan coastal waters by RV Dr Fridtjof Nansen in June-July, 2018. Stainless steel cylinders which were mounted on the foot rope of the bottom trawl to collect sediment samples at nine trawl stations with the depth range of 20 m – 250 m. The benthic samples were subjected to wet sieve and separated the benthic fauna from the substrate. They were identified into possible lowest taxonomic level using literature and percentage abundances of each species were recorded. Also, the Shannon-Wiener diversity index was calculated to each station. A total of 3724 benthic invertebrates belonging to 54 families were recorded during the study and Globothalamea was the highest abundance, contributing 90.77% of the identified specimens followed by Bivalvia (4.91%), Hydrozoa (1.37%), Gastropoda (0.72%) and Anthozoa (0.32%). Results disclosed that total abundance of benthos in each station was not significantly different from each other ($p=0.171$, $p>0.05$) however, the diversity of benthos in each station were significantly different ($p=0.000$, $p<0.05$) probably due to changes in environmental conditions. Also, the abundance of benthos between shallow and deep regions were not significantly different ($p=0.5403$, $p>0.05$). This preprimary study provided an account on benthos abundance and diversity in North East region and showed spatial differences in benthic communities. Further investigations are needed to find out reasons for such variations in species diversity in spatial and temporal scales.

Keywords: RV Dr. Fridtjof Nansen Ecosystem Survey, macrobenthos diversity, spatial variation

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Abundance and distribution of sea snakes in Sri Lanka

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Sea snakes are mostly found in warm tropical waters and play a vital role in the marine food web. There are not much studies done concerning sea snakes in Sri Lanka. Therefore, the objective of this research was to assess abundance, distribution and diversity of sea snakes in Sri Lanka. The data was obtained during an ecosystem survey conducted by RV Dr Fridtjof Nansen Ecosystem Survey from June – July, 2018. During this survey, 85 bottom trawl stations (minimum depth 20 m) were conducted in six coastal regions i.e. North East, Central East, South East, South, South West and North West. The sea snakes caught in trawls were identified, counted and weighed. The results showed that, a total number of 164 sea snakes belonging to 9 species have been recorded in 33 trawl stations with depths of 20-100 m. The highest number (50% of the total) and abundance (403 number/NM²) of sea snakes were recorded in the South East. *Hydrophis* was the most abundant genus (239 number/NM²) and the highest percentage (86.25%) of *Hydrophis* was recorded in South East. In addition, the study revealed that *Hydrophis* was recorded in both day and night while others were present in the trawls either in the day or night. Furthermore, the highest biomass (128.0 kg/NM²) of sea snakes was also reported in South East. Importantly, the aggressive species *Astrotia stokessi* was recorded in North East while *Hydrophis ornatus* was found in all other regions except in the North. The results of Shannon Diversity Index to assess the species diversity, showed that South West had the prominent genus diversity ($H' = 1.21$). The study concluded that *Hydrophis* as the most abundant species and South West region as an important area with high sea snake diversity. These aspects may be considered in formulating marine environmental management plans.

Keywords: sea snakes, RV Dr. Fridtjof Nansen Ecosystem Survey, abundance

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Diversity and distribution of sponge fauna in Sri Lanka

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Sri Lanka possesses an immense marine biodiversity as it is surrounded by the Indian ocean. Sponges (Phylum Porifera) are an important component of coral reef ecosystems and are becoming more prominent in the pharmacological and biomedical industries in the world. However, limited number of studies have been carried out on Sri Lankan marine sponges. Review of previous studies on marine sponges in Sri Lanka carried out by Bowerbank, (1873); Burton, (1930); Carter, (1880); Dendy, (1905), Thomas, (1971) added to results on ongoing research on integrative taxonomy of Sri Lankan shallow water demosponges. In order to get previous information on diversity of marine sponges in Sri Lanka, above mentioned studies were reviewed, and all the species were checked against the World Porifera Database. More than 100 sponge samples were collected around Sri Lanka in the summer (June-August) of 2018 and morphological characteristics were used to identify samples. The review confirmed that 244 species have been recorded during the historical studies: two species in class Homoscleromorpha, 10 species in class Calcarea, 232 species in class Demospongiae. Furthermore, no species were recorded in class Hexactinellida. Newly collected samples include one species of Homoscleromorpha and 56 species of Demospongiae.

Keywords: marine sponges, Sri Lanka, biodiversity, taxonomy, sponge checklist, RV Dr. Fridtjof Nansen Ecosystem Survey

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Determination of *in vitro* antibacterial activity of marine sponges in Sri Lanka

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The rapid emergence of resistant bacteria is occurring worldwide, endangering the efficacy of antibiotics. Development of potential drug leads to overcome this challenge is critically important. In this present study, 20 different sponge species were collected from Sri Lanka for the screening of *in vitro* antibacterial activity using Agar Disk Diffusion Method. Two extracts, organic and aqueous were prepared for each sample and tested against four bacteria. Six out of 20 tested species showed antibacterial activity. Four of the organic extracts and three of the aqueous extracts were active against *Escherichia coli*. Only one organic extract was active against *Staphylococcus aureus* and none of the extracts was active against *Pseudomonas aeruginosa* and *Bacillus cereus*. Almost all the species showed weak activity even at 20 µg/disc compared to the inhibition zone diameter of the positive control (10 µg/disc). Notably both the organic and aqueous extracts of *Xestospongia testudinaria* and *Axinella donani* were active against *E. coli*. The antibacterial active extracts are undergoing further analysis to identify the active constituents.

Keywords: organic extracts, antibacterial activity, *Escherichia coli*, Sri Lankan sponges, RV Dr. Fridtjof Nansen Ecosystem Survey

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Plastic contamination in selected beaches of Sri Lanka with special reference to microplastics

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Microplastics are defined as minute particles of plastic waste (smaller than 5 mm), and these consist of both plastic matter synthesised to be used as small micro particles and particles formed from the weathering and fragmentation of large plastic waste items. This study was conducted in six beaches which were selected based on district population to quantify and characterize the plastics in beach sand. Beach sand were collected from 12 quadrats of 0.5 m x 0.5 m in size in each beach during March and April, 2018 in Western and Southern coasts of Sri Lanka. Sand samples were analyzed for three size classes (>5 mm, 1-5 mm and 0.3-1 mm). A total of 72 sand samples were analysed and found that mean (\pm SE) plastics abundance is 293.67 ± 27.22 items/m² with a 276.66 ± 24.67 items/m² (94%) of microplastics. Total plastics, total microplastics, and two size categories of microplastics (1-5 mm and 0.3-1 mm) varied significantly among the studied beaches at $p=0.05$. All the categories of plastics were seen in significantly higher levels in Bentota beach than that of other beaches at $p=0.05$. Rekawa and Ussangoda beaches had significantly lower abundance of plastics due to the low population density of the area and conservation of the Rekawa beach for turtles. Composition analysis showed that microplastics are dominating in all the beaches with 100% microplastics in Rekawa and Ussangoda beaches. Among two size classes of microplastics, small microplastics in size 0.3-1 mm dominated in each beach with 100% in Ussangoda beach. Composition analysis of six types of shape categories in microplastics revealed that studied beaches are dominated by fibers (37%) and fragments (36%). The major contributing factors for the abundance, distribution and composition of plastics were identified as beach usage for different activities such as recreational and fishing, which suggest that the land-based sources provide major inputs to plastic pollution in these beaches.

Keywords: pollution, microplastics, beaches, Bentota, fragments, fibers, Rekawa

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Assessment of the perception of owners on waste water discharge from their small-scale fish stalls

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In the small-scale fishery, the sellers carry out their business along the roadside or near natural waterways. Waste management and environmental impact from waste of those fish stalls are poorly understood. Therefore, this study is focused to understand the perception on waste management of the fish sellers. Data were collected by personal interviews of respondents. Questionnaires with 30 questions were used to collect information from 35 fish sellers in Gampaha and Kalutara Districts. Data were analyzed using SPSS and MS-Excel software. Results revealed that, in the small scale fisheries sector, majority of the fish sellers are doing their business near the waterways. They directly discharge their waste water, which is used to wash their stalls into the natural environment without any appropriate treatment. 73% used pipe-borne water to wash their fish stalls and minimum of 100 L of water is used to clean their fish stall per day, 67% of sellers are releasing their waste water into natural waterways. From the total amount of waste water, 56% of waste water enters to the natural waterways (67% sellers release the 56% of wastewater to the natural water ways). These waste water causes eutrophication and other environmental problems. 87% of fish sellers are willing to use these waste water for plants/irrigation to reduce environment pollution from this sector.

Keywords: fish sellers, waste water, fish effluents, perceptions, pollution

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Temporal and spatial variability of some physico-chemical and biological parameters in Weligama Bay

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During recent decades, coastal water quality of the globe has altered negatively with the overloaded anthropogenic activities. In the Sri Lankan context, Weligama Bay is such a potentially affected coastal ecosystem with limited information on its water quality. Therefore, this study was focused on revealing spatial and temporal variations in micronutrients (nitrate, nitrite, phosphate and ammonia) and other physicochemical parameters (temperature, salinity, total dissolved solids and pH) and their relationships with biological parameters (chlorophyll and blue green algae) in the bay and two connected streams (Polwatta River and Kapparithota stream). Predetermined 12 samplings points were monitored monthly during October-December, 2018. The presence of significant temporal variations in each nutrient can be linked to the changes in rainfall patterns prior to sampling. The highest nitrate ($52.70 \mu\text{mol/L}$) and nitrite ($0.48 \mu\text{mol/L}$) concentrations in Polwatta River coincide with the daily highest rainfall ($37.3 \pm 16.6 \text{ mm/day}$) in November, which prevailed seven days prior to the sampling day. The significant negative correlation between salinity and micronutrients showed that polluted freshwater discharges from streams, convey high amounts of nutrients into the adjacent bay waters. Chlorophyll-a in Kapparithota stream ($22.11 \mu\text{g/L}$) was higher than acceptable limits ($1-10 \mu\text{g/L}$) indicating it as a eutrophicated stream. Further, its ammonia concentration ($2.981 \mu\text{mol/L}$) doubled compared to the values reported in 2013. Although, nitrate concentration of the entire bay was well over the productivity limiting level ($<0.7 \mu\text{mol/L}$), lower chlorophyll-a concentrations in the eastern side of the bay where the phosphate concentration was lower than the required level ($<0.3 \mu\text{mol/L}$), shows that phosphorous as the limiting nutrient in the system.

Keywords: Weligama Bay, micronutrients, physico-chemical parameters, biological parameters, anthropogenic input

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Water bird diversity and availability of planktonic food sources in Kavutharimunai in the Northern region of Sri Lanka

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Wetlands are important contributors to biodiversity worldwide. In the present study, diversity and abundance of water birds, phytoplankton and zooplankton were investigated to evaluate the importance of Kavutharimunai for water birds in Northern region of Sri Lanka. Three counting blocks in length of 500 m with open width was selected for bird counting. The counting of birds was done once a month from August, 2018 to January, 2019 by ferry. Water bird species were identified and counted using binoculars (10 x 50) and spotting scope (x 60). Concurrent surface water samples were collected and immediately fixed with Lugol's iodine solution for phytoplankton analysis. Zooplankton samples were collected using a zooplankton net with a mesh size of 90 µm by filtering 100 L and fixing in 5% formalin. Phytoplankton and zooplanktons were identified using standard identification guides. A total of 45 taxa were reported in Kavutharimunai, including 26 water bird species, five genera of diatoms, six genera of dinoflagellates and seven groups of zooplankton. The most dominant phytoplankton genera was *Coscinodiscus* sp., which constituted 61.99% of the total population, followed by *Navicula* sp. (16.03%). Diatoms accounted for 96.77% of the total phytoplankton population followed by dinoflagellates (3.23%). Zooplankton taxa was identified under five groups. Zooplankton assemblages consisted mainly of copepod (51.41%), followed by crustacean larvae (24.71%) and molluscs (16.48%). The 26 water bird species belonged to 10 families. The most abundant species was brown-headed gull (13.95%), followed by black-tailed godwit (11.36%), gull-billed tern (10.47%), curlew sandpiper (10.11%), and little cormorant (7.33%). Rare water bird species that breed only within the Northern region and saunders tern (*Sternula saundersi*) were recorded in sandbars. Based on the results it can be concluded that Kavutharimunai offers a suitable habitat for feeding and breeding of water bird species.

Keywords: Water bird, zooplankton, phytoplankton, Northern region, Kavutharimunai

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Water quality monitoring of Ma Oya, Sri Lanka for Water Safety Plan (WSP) implementation of the Galigamuwa urban water supply scheme

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Safety of water is vital for human consumption. Implementation of water quality monitoring programmes in a water safety plan is essential to understand the present status of the suitability of water for the intended purpose. The objectives of present study were to compare the significant differences of water quality parameters in two selected sites (intake; Helamada and reference; Polgahawela) and the comparison of those measured water quality parameters with Sri Lanka Water Quality standards (SLS: 614; 2013) to explore the suitability. Sampling was conducted from April, 2018 to March, 2019 covering 10 sampling occasions. Triplicate samples were composited and onsite and offsite physico-chemical parameters were measured. Samples were transported to the laboratory for offsite parameter analysis. In terms of water quality parameters in Ma Oya, values for colour (Hazen), turbidity, pH, Total Dissolved Solids (TDS), alkalinity (as CaCO₃), total hardness (as CaCO₃), nitrate (as NO₃⁻), total iron (as Fe), total coliform bacteria colonies and *Escherichia coli* bacteria colonies of the water ranged from 10-60 (Hazen), 2.29- 49.00 (NTU), 6.64-9.05 (at 27 °C), 36-96 mg/L, 36-96 mg/L, 36-96 mg/L, 1.76-5.72 mg/L, 0.12-1.21 mg/L, >100/100 mL and >100/100 mL respectively in both Helamada intake and Polgahawela reference sites. There was no significant difference between water quality parameters among the two sites ($p>0.05$, 2 sample t-test, Minitab 17). Results revealed that, colour, turbidity, Fe content, total coliforms and *E. coli* colony count have exceeded with reference to SLS 614: 2013. Fecal contamination, higher turbidity and dissolving of Fe, soil and sediment washing with runoff may be the reasons for an exceeded coliform count, colour and Fe concentration respectively. In conclusion, proper planning and implementation of a WSF should be promoted to protect catchments from soil erosion, solid waste to avoid fecal contamination and sewage discharge in to the water source along with raising awareness of associated communities. Similarly, water treatment plants should be designed to address the Fe and fecal contamination issues.

Keywords: water quality, SL standards, water safety plan, fecal contamination

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Aquatic Post Harvest Technology

Microbiological quality of water from Puttalam Lagoon to find suitability for natural relaying of bivalves

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Bivalve molluscan shellfish feed by filtering large volumes of seawater and accumulating food particles from their surrounding environment. When that environment is contaminated by sewage, shellfish will also accumulate human pathogenic bacteria and viruses during filter-feeding and will present a health risk when consumed raw or lightly cooked. In order to render such shellfish fit for consumption three principal commercial treatment processes have been traditionally used. One process is relocating the shellfish harvested from polluted areas to clean areas (areas free of microbiological contamination) to allow shellfish to cleanse or purge themselves by continuation of their normal filter-feeding and digestive processes. Puttalam Lagoon in Sri Lanka has been identified as a potential site for culturing of bivalves and culturing of oyster has already commenced. The aim of the present study was to evaluate the suitability of Puttalam Lagoon in Sri Lanka for natural relaying of oyster by means of microbiological quality. During the study period 104 water samples were collected from 12 sampling points of the lagoon from January 2017 to March 2019. Total Bacterial Counts (TBC) of tested water samples ranged from 10^1 - 10^3 CFU/mL. All samples were absent for *Salmonella*, *Vibrio cholerae* and *Vibrio parahemolyticus*. Salinity of water ranged from 34 to 45 ppt whereas pH ranged from 6.34 to 8.48. Temperature ranged from 24 to 40 °C. There was no correlation between the salinity ($r=0.54312$ $p=0.4637$) and temperature ($r=0.4285$ $p=0.5281$) of water with total bacterial counts. 67% of samples were positive for total coliform bacteria and ranged from 2 to 225 MPN/100mL while 43% of samples were positive for faecal coliforms and ranged from 2 to 65 MPN/100 mL. *E. coli* was detected only in 32% of samples and ranged from 2-45 MPN/100 mL. It indicated all 12 sampling points were complied with US FDA restricted areas classification standards for microbiological quality and are suitable for natural relaying of bivalves.

Keywords: Puttalam Lagoon, microbiological quality, oysters

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Isolation of histamine producing bacteria from multi-day boats landed at Dikkowita fishery harbour

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Elevated histamine content and physical characteristics such as colour and texture of flesh are the main reasons for rejection of fish when it comes to fish export. Since histamine in fish is formed by contaminant bacteria, this study is aimed at screening histamine formers across different sources. Field samples collected from Multi-Day Boats (MDB) include ice (n= 18) from fish holds and chill transport vehicles (n=21); swabs from fish holds (n=18), decks (n=18); and the skin of yellowfin tuna (n=21). Samples were collected at the Dikkowita fishery harbour. Presumptive histamine forming bacteria were isolated by inoculating the samples on Nivens medium and Violet Red Bile Glucose (VRBG) agar. The histamine forming ability of bacterial isolates were confirmed by measuring histamine levels in broth cultures grown in Trypticase Soy Broth (TSB) supplemented with 1.0% L-histidine. Species of histamine forming bacterial isolates were identified by amplifying and sequencing approximately 1400 bp of the 16S ribosomal DNA (rDNA). Out of 21 ice samples collected from chill transport vehicles, histamine forming bacteria were isolated in 11 instances and they were identified as *Klebsiella aerogenes* (63%), *Pseudomonas* sp. (27%) and *Serratia rubidaea* (9%). While *Bacillus* sp. was found in an ice sample collected from the fish hold of a MDB. From the 18 swab samples collected from boat decks histamine producing bacteria were isolated at three occasions. They are *Pseudomonas* sp. and *Morganella morganii*. One swab sample collected from fish holds of MDB contained *E. coli* which produced histamine. Two swab samples taken from fish surface were positive for histamine producing *Pseudomonas* sp. and *Aeromonas salmonicida*. From the isolated organisms *Klebsiella aerogenes* isolated from ice samples collected from chill transport vehicles, *M. morganii* isolated from boat decks and *E. coli* isolated from a swab samples taken from fish hold formed histamine levels more than 500 ppm in the TSB supplemented with 1% histidine at 15 °C. The information found by this study about sources of histamine forming bacterial contaminations (ice, boat deck, fish hold and fish skin itself), identification of their species and the temperatures at which they produce histamine are important in controlling histamine formation in fish supply chain.

Keywords: histamine forming bacteria, histamine, multi-day boats

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Antibiotic resistance of *Vibrio* species isolated from shrimp culture environment in Puttalam District , Sri Lanka

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In the shrimp culture industry in Sri Lanka financial losses due to the infectious diseases has become a major limiting factor in its development. *Vibrio* species are the most commonly found pathogenic bacteria which cause disease to humans and Vibriosis for shrimps. Occurrence of diseases frequently causes heavy economic losses to the industry. Antibiotics are normally used to prevent or treat disease outbreaks in shrimp farming. However, inappropriate use of antibiotics in shrimp farming can cause the development of antibiotic-resistant pathogens which can infect both cultured animals as well as humans. The aim of this study was to isolate and identify different types of *Vibrio* species from the shrimp culture environment and determine the antibiotic resistance of them. Shrimps (n=12), sediments (n=12) and water (n=12) samples were collected from 6 different shrimp farms in Puttalam District. Vibrios were isolated on thiosulfate-citrate-bile salts-sucrose (TCBS) agar and identified biochemically. Antibiotic sensitivity tests were carried on Mueller-Hinton agar (MHA) plates by disk diffusion method. During the study 146 isolates belonging to the family Vibrionaceae were recorded and identified as, *Aeromonas hydrophila*, *Vibrio metschnikovii*, *V. anguillarum*, *V. parahaemolyticus*, *V. harveyi*, *V. vulnificus*, *V. damsela*, *V. mimicus* and *V. fluvialis*. *Vibrio* isolates were found to be resistant to amoxicillin (68.5%), nitrofurantoin (25.2%), nalidixic acid (21%), tetracycline (5.18%) and chloromphenicol (4.48%). This study showed that *Vibrio* species are more resistant to amoxicillin in comparison with other antibiotics used in this study. Results also indicated that the application of antibiotics for the control of vibriosis in shrimp farms has limited effectiveness due to the development of resistant bacterial strains.

Keywords: shrimp culture, *Vibrio* sp., antibiotic resistance

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Development of seaweed based palmyra (*Borassus flabellifer*) and determination of its quality parameters

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Ceylon moss (*Gracilaria*) is rich in nutrients and contains high amount of agar-agar. The present study was carried out with a view to develop Ceylon moss jam incorporating palmyra pulp as a good source of Vitamin A and C, to improve the sensory properties of the final product. Instead of seaweed pulp and Palmyra pulp, citric acid and sugar was added without pectin. Seaweed pulp was extracted using a different method. Dried *Gracilaria edulis* was soaked in water for 15 minutes, soaked and drained seaweed was steamed for 10 minutes, and ground properly for 10 minutes to obtain the pulp. Different concentrations of seaweed pulp were evaluated based on sensory attributes including flavour, colour, aroma, spreadability and acidity to optimize the content of seaweed pulp in jam, without using Palmyra pulp and 40% was selected. Then seaweed pulp was replaced by incorporating different contents of Palmyra pulp to enhance the colour, aroma and flavour. It was observed that the product containing 24% of seaweed pulp and 16% of Palmyra pulp showed highest score point (5) in sensory quality compared to than other treatments. The pH, titratable acidity and total soluble solid of the seaweed jam were 3.07, 1.045% (w/w) and 65%, respectively. Developed seaweed jam consists of 13.8, 0.59, 5.23, 0.42 and 4.89% (w/w) of moisture, protein, fat, total ash, total dietary fiber, respectively. Finally the shelf life of the product determined more than one year period. The technologies developed, in this study; to extract seaweed pulp from *G. edulis* and to produce Palmyra incorporated seaweed jam has potential to be commercialized as an industry.

Keywords: palmyra, seaweed, sensory properties, pulp

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Microbiological quality of ice at different stages of production in Sri Lanka

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Recently, contamination of fish with pathogenic bacteria has been reported within the supply chain. Such contaminations could result from contact surfaces, water and ice used for postharvest handling of fish. This study, therefore, investigated the microbial quality of ice used for handling of fish. Samples were collected from 72 ice plants located in 13 districts (Trincomalee, Batticaloa, Jaffna, Mullaitivu, Anuradhapura, Puttalam, Mannar, Polonnaruwa, Ampara, Monaragala, Galle, Matara and Hambantota) from March 2018 to April 2019. Ice making water (disinfected water from municipal water supplies, well or tube-well water), ice from cold store (-5 to -10° C) and crushed block-ice which represent three initial stages of ice production line, were sampled from each ice plant, were transported and analyzed in the NARA laboratory for Faecal coliforms, *E. coli* and *Salmonella* using relevant Sri Lanka Standard (SLS) and ISO protocols. The *Salmonella* isolated were identified by serotyping using Kauffmann-White classification method at MRI. In six tested ice plants, the three sample types in the ice production lines were found not contaminated with faecal indicators and *Salmonella*. In 66 ice plants, all or at least one type of samples showed Faecal coliforms and *E. coli* in the range from 1 to >1800 MPN/100 mL. Sixteen samples including ice making water, ice from the cold store and crushed ice across 66 ice plants, found contaminated with different serotypes of *Salmonella* including *Salmonella* Brunei, *Salmonella* Kentucky, *Salmonella* Tananarive, *Salmonella* Edinburg, *Salmonella* Garba VI, *Salmonella* Wilmington and *Salmonella* Agona. This study showed a trend of gradual increase in both number of samples and/or level of contaminants down the three stages of ice production line. Present study showed that urgent need of improving infrastructure facility and handling practices in order to mitigate faecal and pathogenic bacteria contaminations in the production line of ice plants.

Keywords: ice, *E. coli*, *Salmonella* serotypes, fish contamination

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