LCA Analysis: Case Study of Ring Seine Fishing Systems of Kerala

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Introduction

Fish capture technology encompasses the process of catching any aquatic animal, using any kind of fishing methods, often operated from a vessel. Use of fishing methods varies, depending on the types of fisheries, and can range from a simple and small hook attached to a line to large and sophisticated large fishing vessels. The targets of capture fisheries can include aquatic organisms from small invertebrates to large whales, which might be found anywhere from the ocean surface to 2000 meters deep. The large diversity of target species in capture fisheries and their wide distribution requires a variety of fishing gear and methods for efficient harvest.

In recent decades major improvements in fiber technology, along with the introduction of other modern materials, have made possible, for example, changes in the design and size of fishing nets. The mechanization of gear handling has vastly expanded the scale on which fishing operations can take place. Improved vessel and gear designs, using computer-aided design methods, have increased the general economics of fishing operations. The development of electronic instruments and fish detection equipment has led to the more rapid location of fish and the lowering of the unit costs of harvesting, particularly as this equipment becomes more widespread. Developments in refrigeration, ice-making and fish processing equipment have contributed to the design of vessels capable of remaining at sea for extended periods.

Although these technologies are largely available, those actually introduced in many small-scale fisheries may amount to no more than motorizing a dugout canoe, use of modern and lighter gear or introducing the use of iceboxes to ensure the quality of the product landed. The impact of such changes, however, has considerably increased landings and the earnings of fishers, and underlines the need for effective management to prevent excessive fishing effort. The emphasis of much recent technical innovation has been focused on greater and more appropriate selectivity of fishing gear so as to reduce negative impacts on the environment.

Impact on Fisheries

Most of the environmental concerns with respect to commercial fishing mainly focus on direct impacts to targeted species (Pauly et al., 2002; Christensen et al., 2003; Myers & Worm, 2003), bycatch and discards (Alverson et al., 1994; Glass, 2000), alterations to benthic communities (Johnson, 2002; Chuenpagdee et al., 2003), and modifications to trophic dynamics (Jackson et al., 2001). These concerns do not cover all aspects related to the environmental impacts of fishing activities (Iribarren et al., 2010a and Iribarren et al., 2011). In this background, LCA has arisen as a suitable methodology to undertake the environmental assessment of products through a life-cycle approach (Pelletier et al., 2007). LCA is recognized worldwide as a useful tool for assessing environmental aspects and potential impacts associated with products or processes

(ISO 2006a, 2006b), and can be a suitable methodology for the analysis of the environmental performance of fisheries (Pelletier et al., 2007; Vázquez-Rowe et al., 2010a; 2010b). LCA is a compilation of the inputs and outputs and evaluation of potential environmental impacts of a product throughout its lifecycle (ISO 2006a, 2006b; Pelletier et al., 2007). LCAs are used to identify environmentally preferred products or methods and to provide insight into the main causes of the environmental impact of a product or process and for determining design priorities. LCA can be used as a support tool for policy and decision-making or as a methodology for benchmarking in terms of eco-efficiency (Vázquez-Rowe et al., 2010a). In India, till now no study has taken place related to LCA for trawl fishing wherein impact categories such as Global warming potential, Abiotic depletion potential (fossil), Acidification potential, Eutrophication potential, Marine aquatic ecotoxicity potential, Ozone layer depletion potential and Photochemical ozone creation potential are considered. The Carbon Footprint (CF) is just one output from the life cycle assessment. The Carbon Footprint is a measure of the amount of CO_2 and other GHG emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product. This is usually expressed in kilograms of CO_2 equivalents (Gerber et al., 2010). CO_2 equivalents represent the equivalent concentration of CO_2 that would cause the same warming effect on the atmosphere.

LCA allows for comprehensive evaluations to be made on the environmental impacts related to products over their whole life cycle, encompassing infrastructure, energy provision, extraction of raw materials, manufacturing (cradle-to-gate), distribution, use and final disposal (cradle-to- grave) (ISO, 2006b). LCA is thus a tool aimed to, among other purposes, identify opportunities for improving environmental performance and inform decision makers on the environmental performance of products, product systems and even their alternatives (ISO, 2006a). Energy analysis are relevant in relation to fisheries due to the accepted importance of fuel consumption in fleet operations (Tyedmers, 2001) and associated environmental impacts (Thrane, 2004a; Schau et al., 2009; Driscoll & Tyedmers, 2010). Carbon footprint is often considered as a sub-set of LCA (EC/JRC, 2007) and is closely associated to fisheries LCA due to the strong impact of fuel consumption (Avadi & Freon, 2013). LCA was first introduced in the late sixties in the United States and was first used to compare resource consumption and environmental impact associated with containers of beverages (European Environment Agency, 1997). In 1992, at the UN Earth Summit, LCA methodologies were announced to be the most promising tool for environmental management tasks (European Environment Agency, 1997). Studies by Thrane (2006) points out that if all flatfish in Denmark is caught by Danish seine nets or gillnets it would theoretically be possible to save 30 million litres of fuel per year within the Danish fishery or 15% of their total fuel consumption in a year. Pioneering studies on LCA and CF applied to Indian fisheries include Ghosh et al. (2014) has studied carbon footprint of marine fisheries of Visakhapatnam with targeted species and fishing methods. Ravi (2015) studied the structural changes and life cycle assessment in mechanised trawl fishing operations of Kerala. Das and Edwin (2016) conducted the LCA analysis of Kerala Ring Seine Fishery in a cradle to grave approach. Motorized fishery impact studies were conducted by Edwin and Das (2016).

In recent times, significant changes have taken place in capacities of the fishing craft, installed engine horse power, fish handling equipment and fishing gear. The increasing oil price, growing environmental consciousness and the change in availability of fish catch necessitates the reduction in energy use and hence there is a need for re-estimation of energy requirement of fishing systems by application of modern approaches like Life Cycle Assessment and Carbon Footprint. Fish harvesting systems are dependent on fossil fuels which are non-renewable and releases high levels of carbon dioxide to the atmosphere contributing to greenhouse effect. In this scenario, energy analysis are relevant in relation to fisheries Life Cycle Assessment (LCA) due to the accepted importance of fuel consumption for fleet operations and associated environmental impacts.

In this study, LCA analysis for individual ring seine fishing unit (vessel and gear) and its operation was conducted using a cradle to gate approach. The post-harvest processes have been excluded from the system boundary as the use of catch varied with the different fishing units. So in this study system, boundary has been limited to the point at which the catch reaches the harbour.

Collecting quantitative and qualitative data for every unit process in the system was the most cumbersome part of LCA analysis. PE- Gabi LCA software was used for analysis of the data (ISO: 14040, 2006). As per the requirements of this software the data for each unit process can be classified as energy inputs, raw material inputs, ancillary inputs, other physical inputs, products, co-products, wastes etc.

A case study of ring seine fishing system of Kerala

System boundary

All major actives associated with the inputs for assessment of LCA are depicted in the system boundary chart comprising of three sub systems is given in Fig.1. The system boundary defines which processes will be included in, or excluded from, the system and describes the processes and their relationships. In this study LCA analysis for individual fishing unit (vessel and gear) and its operation was conducted using a cradle to gate approach. The post-harvest processes have been excluded from the system boundary as the use of catch varied with the different fishing units. So in this study system boundary has been limited to the point at which the catch reaches the harbour.

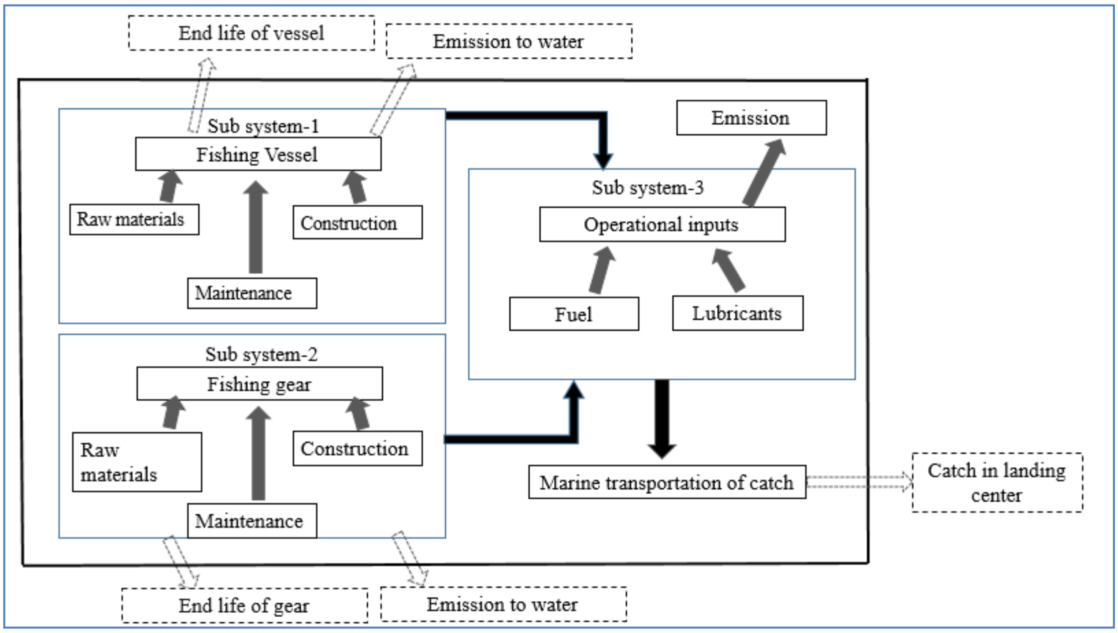

Fig.1. Block diagram of the studied system. Dotted line represent the system boundary

Functional Unit

LCA is generally organized into a four step process viz. goal and scope definition, inventory analysis, impact assessment and interpretation of results. The functional unit taken for the study is one ton of ring seine catch. The functional unit (FU) is a quantified definition of the function of a studied system and it provides a reference to which the inputs and outputs can be related (ISO:14040, 2006). The major operational inputs and outputs associated with fishing activity of mechanised and motorised ring seine system in the south east Arabian sea was collected and analyzed.

As per CML 2001 methodology ten environmental impact categories, namely abiotic depletion potential elements (ADP elements), abiotic depletion potential fossil (ADP fossil) acidification potential (AP), eutrophication potential (EP), global warming potential (GWP), human toxicity potentials (HTP), marine aquatic eco-toxicity potentials (MAETP), stratospheric ozone depletion potential (ODP) and finally photo-oxidant formation potential and terrestrial eco toxicity potential (POFP and TETP) were chosen to quantify the environmental impacts associated with the activities.

Data acquisition: - Fishing Craft

Details of materials used for construction of fishing vessel were collected from local boat building yards by interviews with boat builders, skippers and log books maintained at boat yards and vessels. Quantity wise data on materials like steel (for hull, engine, propeller shaft etc.) welding rod, electricity for welding, grinding, light (unit kwh) plywood for deck, wooden material, alloy for propeller, fiber glass mat, resin, other ingredients (accelerator, catalyst, etc.) material, details of primer, paint, antifouling paint, transportation etc. were collected. Collected quantitative vessel characteristics were amortized with the life span of the fishing vessel and calculated for one ton landings. Inventory data is given in Table-1

Table 1. Inventory for ring seine gear (data for one ton of catch)

Particulars	Mechanised ring seiner	Motorised ring seiner
Paints (surface primer, paint, antifouling paint, etc.)	1.79E-01	1.31E-01
Electricity	1.43E-01	1.92E-02
Electrodes	8.82E-02	6.42E-04
Fiber reinforced plastic	4.48E-02	8.03E-01
Gunmetal Material	2.56E-02	-
Hard wood log mix	8.82E-02	4.81E-01
Limestone	1.92E-02	1.05E-02
Plywood board	9.62E-03	1.40E-01
Steel	2.03E+00	2.57E-01

Fig. 2. Inventory network of ring seine gear

Data acquisition:- Fishing Gear

Quantity of polyamide multifilament webbing, high density polyethylene webbing, polypropylene rope, plastic floats, lead sinkers, brass rings were collected from net fabrication sites and net making factory. In fishing gear webbing life span is considered as Two year and the quantitative inputs were expressed in teams of per ton sardine landings. Inventory data for Ring seine gear is given in Table-2

Table 2. Inventory for ring seine gear (data for one ton of catch)

Particulars	1000 m Mechanised ring seine gear	750m Motorised ring seine gear
Polyamide Webbing Material	1.42E+00	9.16E-01
HDPE Webbing Material	3.16E-01	2.62E-01
Polypropylene Rope	4.34E-01	3.40E-01
Lead Sinker	9.87E-01	5.24E-01
Brass	1.03E-01	1.05E-01
Plastic float	3.16E-01	2.88E-01

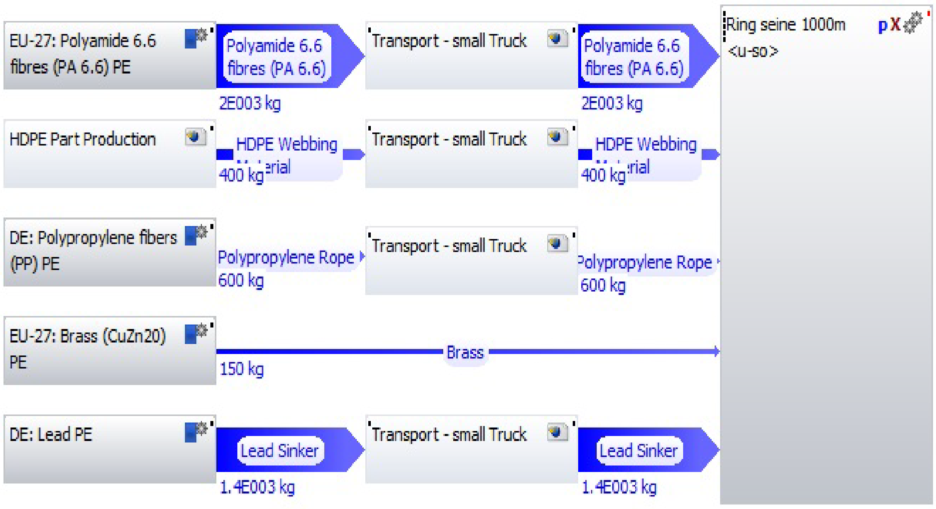

Fig. 3. Inventory network of ring seine gear

Data acquisition:- Fishing Operation

Details of engine and its horsepower, number, types and size of fishing gear, details of fishing operations including the number of fishing days in an year, time of shooting the net, time of hauling, number of hauls, fuel used (diesel, petrol, kerosene and lubrication oil) were collected from skippers and fishing vessel owners and species wise catch details were collected from fishermen cooperative societies which maintained the daily landing log books (Table-3).

Table 3. Inventory for ring seine operation (data for one ton of catch)

Particulars	Mechanised ring seine operation	Motorised ring seine operation
Diesel	89.50684	
Petrol	4. 945890	8.114803
Kerosene	32.44179	141.9945
Lub oil	1.316277	

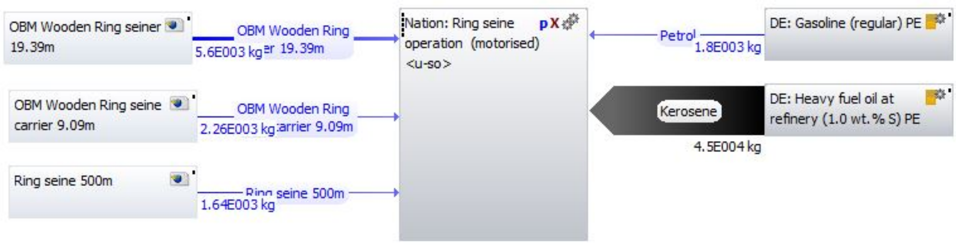

Fig. 4 Inventory network of motorised ring seine operation

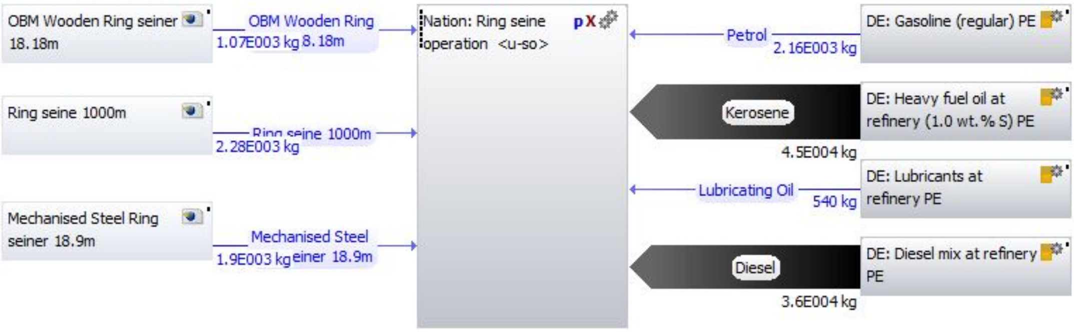

Fig. 5. Inventory network of mechanised ring seine operation

Inputs excluded from system boundary

Harvest loses during transfer of catch at the landing center, solid and liquid waste generated in the fishing vessel, discharges of such matter into the sea were not taken into account the study due to insignificant quantity and lack of data. Quantitative data on electric wiring circuits, navigational equipment also do not come under the purview of this study.

Environmental performance of Ring seine fishery

Results show that fish catch landed by motorized ring seine fleet is having higher impact when compared to mechanized ring seine fleet except ADP element and ODP it due to the high use of lead weight and polyamide webbing in mechanized fleets. While comparing motorized fleets (Table-8), impact of ADP fossil, AP, EP, GWP, HTP and POCP shows more than 20% higher impact than mechanized fleet with a higher value of 24% in GWP.

Table 5. Combined environmental performance and Mass allocation of impact categories in terms of one ton of ring seine landing

Impact Category	Mechanised	Motorised	% difference motorized / mechanized landings
ADP elements	3.50E-03	1.94E-03	-80.24%
ADP fossil	4.97E+03	6.45E+03	22.89%
AP	1.24E+00	1.57E+00	21.02%
EP	5.97E-02	7.51E-02	20.41%
GWP	3.95E+02	5.22E+02	24.26%
HTP	2.83E+01	3.56E+01	20.60%
MAETP	1.06E+04	1.12E+04	4.96%
ODP	3.20E-09	2.47E-09	-29.95%
POCP	8.92E-02	1.13E-01	20.71%
TETP	2.14E-01	2.38E-01	10.08%

Different hot spots have been identified in the study of ring seine fishery through motorized and mechanized activities. Through this study some important interventions can be proposed for the improved efficiency of the fishery. The reduction of fuel through reduction of speed can bring about a major change. Gulbrandsen (2012) has opined that 10% reduction of engine rpm will reduce 20% fuel consumption and 20% reduction in rpm will reduce 40% fuel consumption. Proper maintenance of vessel hull also contributes a major role in fuel use. In tropical conditions hull fouling increases fuel consumption at 7% in first month of operation and up to 44% after six month of operation if antifouling paint is not used (Gulbrandsen, 2012). Vessel drag reduction through improvised hull shape will help in energy efficiency up to 20% (Schau et al., 2009). In motorized fleets, replacement of high energy consuming 2-stroke out board engine to inboard engines will reduce the fuel usage. According to Gulbrandsen (2012) when compared with 2-stroke out board petrol engines inboard diesel engine consume 62% less fuel at same speed. Ring seine operations are conducted based on the occurrence of small pelagic fish shoals. The chance of occurrence of fish as small pelagic shoals mainly depends on the sea surface temperature and chlorophyll concentration (Pillai and Nair, 2010). Boopendranath and Hameed (2012) observed that Kerala ring seine fuel consumption per kg fish landed varied with lower fuel consumption during the month of May to December and higher in January to April. The high fuel consumption during this period is due to the movement of pelagic shoals towards deeper depth, because of distortion caused by direct sunlight (Pillai and Nair, 2010) which make the fishing more difficult and increase the total fish shoal searching time and leads to the wastage of fuel. During the study period it is observed that an average ring seine fishing trip takes 12.28 ± 2.06 hours of operation, including the cruising time to the fishing ground and the fishing operation takes less than 45% of the total fishing time and major time was spent for searching the fish shoals for which maximum fuel is consumed. Knowledge about the spatial distribution of fish over the time and the effective use of Potential Fishing Zone (PFZ) forecast based on sea surface temperature and or surface chlorophyll concentrations can help to reduce the searching time and environmental impact.

Replacement of low durable polyamide webbing with highly durable Ultra-High Molecular Weight Polyethylene (UHMWPE) will help to increase the life span of webbing (Thomas and Edwin, 2012) which will lead to reduction in detrimental effect on environmental impact factors. Appropriate use of lead sinkers will reduce the number of sinker per meter of sinker line which will also reflect in environmental factors like ODP. Compared to mechanized and motorized ring seine units, traditional ring seine units are least contributing to the environmental factors. L_{OA} of motorized ring seine units restricted to 15m for near shore operation with smaller size of ring seine gear and mechanized ring seine units with optimized gear for off shore operation will help to reduce the environmental impacts.

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