Energy optimization in fishing systems through material substitution

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Introduction:

Fishing is a process which totally depends on external energy. This process considered as one of the most energy-intensive food production systems globally. Commercial fishing operation mainly utilizes fossil fuels which results in emission of greenhouse gases. Broadly fishing has two processes; the first involves construction of fishing vessel, gear and other accessories and the second involves harvest process. The active cost of fishing is less understood and consequently receives less attention than the direct impact on fishery stock and marine ecosystem. Fishing boat is made up with different components and its construction is a complex process. Certain quantities of greenhouse gases (GHGs) are produced in the process of manufacture, transportation and utilization of these components, which can be converted in terms of equivalent CO_2. Similarly, in harvest process, several reoccurring inputs are required for every fishing operation, viz. fuel, lubricant, ice, fresh water etc. These inputs have their own carbon footprint value for construction/extraction/process, specially fuel contributes more than 95% out of all the components. Despite the fact that prevailing pre-harvest phase of marine capture fisheries lack general detail and standardization about LCA/carbon foot print studies; such studies and their findings can be useful in formulating constructional/operational recommendations to improve environmental performance of fisheries, under the context of ecosystem approach to fisheries along with future certification and different eco-labelling of fisheries. Studies related to pre-harvest, harvest and post-harvest fisheries LCA/carbon foot print analysis would be more appreciated by policy makers for regulation of fishing boat yards and other related fishing ventures.

Energy requirement in different fishing operations

Based on behavior and habitat, there are different methods of fish harvest and on the basis of their operation the quantum of fuel and energy requirement also varies. According to one study of globally large-scale industrial fishing sector consumed about 14-19 million t and small-scale fishing sector consumed about 1-2.5 million t of fuel oil. The production of fish per tonne of fuel was 2-5 t in the industrial sector and 10-20 t in the small-scale sector. As per the study by Parker et al., 2018, the world fishing fleet burned about 40 billion liters of fuel and emitted 179 million tonnes of CO_2 equivalent and other GHGs to the atmosphere. Overcapacity and irresponsible use of fossil fuel leads to increased level of fuel consumption in fishing contributing to climate change in the long run. India contributes 134 metric tonnes (2.7%) of CO_2 emission due to total marine capture fisheries, against 90 million metric tonnes (3.9% of global production) of fish production. The emissions due to fishing were not given importance as compared to other sectors for emission in India, however, the contribution of fisheries sector is negligible which roughly may be <1% to global GHG emission (Tyedmers, 2004). The other associated important environmental parameters by which health of environment, human and resource can be evaluated due to fishing process are; terrestrial acidification, formation of fine particulate matters, Water consumption, Ionizing radiation, ozone formation, human carcinogenic toxicity, fossil resource scarcity, mineral resource scarcity environment deterioration, human health, resource depletion and stratospheric ozone depletion etc. In energy context some of the important fishing methods are listed below:

Trawling: Trawling is one of the most energy intensive fishing methods. It consumed nearly 5 times more fuel compared to longlining and gillnetting (passive fishing methods) and over 11 times to purse seining for every kilogram of fish produced. For large trawlers, 90% fuel consumption accounts during active trawling operation. Percentage of fuel cost in the operational expenditure of trawlers may vary between 45% and 75%, depending on engine power and duration of voyage.

Gillnetting/longlining: Gillnetting and longlining are the passive type of fishing where the gross energy requirement is comparatively lower than trawling. These passive gears are either fixed or drifting in water column which do not require energy for operation process except hauling where it is done by mechanical means.

Purse seining: Purse seining is one of the most aggressive and efficient commercial fishing methods for capture of shoaling pelagic species (Ben-Yami, 1989; Ben-Yami and Anderson, 1985). It is a fishing technique which targets pelagic shoaling fishes. Before actual operation the shoal detection needs more fuel for fish scout, once shoal gets detected the encircling, capture and hauling process is follow-up. Purse seine operations are relatively energy efficient and greenhouse gas (GHG) emissions for small scale mechanized purse seine operations are low compared to trawling, gillnetting and lining operations.

Traps and pots: Traps or pots are gears in which fish are retained or enter voluntarily and will be hampered from escaping. They are designed in such a way that the entrance itself became a non-return device, allowing the fish to enter the trap but making it impossible to leave the catching chamber. It can be baited or non-baited. Generally passive fishing gears like gillnets and trammel nets, tangle nets, longlines, trap nets and pots, and other lift nets consuming very little power in fishing and in some cases no mechanical energy. Although travelling, setting and retrieval of gear may use some energy, target stocks are attracted by bait or are carried to the gear or encounter it by chance and are trapped. Tyedmers (2001) reviewed over an approximately 20-year period (early 1980s to late 1990s) and found about 330 L of fuel used to catch per t of catch in a crab trap.

Other fishing methods: There are several fish harvest practices which require more energy; light fishing is one of them. Fishing using lights has been practiced from historic times, a classic example is 200-year old Chinese dipnet, which use lights (earlier hurricane lamp and now CFL lamps) to attract fish to the net. Chinese dipnets are mostly animate energy based sustainable fishing operation. More than half of the purse-seine vessels, stick-held dipnet and squid jigging boats use artificial light. Report of the ICES-FAO Working Group on Fishing Technology and Fish Behaviour (WGFTFB), 2012, suggests that roughly global marine catches using lights is 1.09 million tonnes (1.6% of global catches) in 2010. Roughly 16% of the light fishing catches comprise of squids, and the remaining >80% are fish species (Mohamed, 2016).

Fuel and emission:

Fishing operation is an external energy-intensive operation which produces emissions mainly due to burning of fossil fuels (Parker et al., 2018). Other related activities which demand energy input, such as net fabrication, fishing gear operation, post-harvest activities etc. Fossil fuel is a dominant energy sources in different fishing methods such as long-lining, gillnetting, trawling, ring seining and purse seining. Mechanized and motorized fishing operations are dependent on fossil fuels which are non-renewable and releases high levels of carbon dioxide to the atmosphere contributing to greenhouse gases (GHGs) to the atmosphere. Due to increased level of fuel consumption in fishing operations, processing and storage of fish, emission of GHGs also increased which finally led to climate change adversely. The energy and material used in the fishing vessels can create negative environmental impacts, mainly due to the consumption of fuel, gear usage and loss, anti-fouling agents, paint and ice consumption. The use of energy is now increasingly important in comparative resource-use analysis, potential trade trends, and in carbon and related greenhouse gas (GHG) impacts in climate change mitigation (FAO, 2012).

The active cost of fishing is less understood and consequently receives less attention than the direct impact on fishery stock and marine ecosystem. During the last decade, the price of fuel and other energy sources was on a rising trend. In 2001, fuel was estimated to account for 21% of revenue from landed catch, whereas in 2008 this increased to about 50%. Fuel use varies usually with type of fishing and level of effort, but as one of the key cost components over which the fisheries sector has no direct control. Profitability and livelihoods are potentially highly sensitive to energy costs (FAO, 2015). The emissions from fisheries were not given importance as compared to other sectors, however, the contribution of fisheries sector is negligible which roughly may be <1% to global GHG emission. Later many studies, research publications and report highlighted its importance. During last 3-4 decades several factors played a pivotal role in increased emission viz. increment of fleet size and number (overcapacity), which resulted higher catch. The major direct and indirect energy inputs can be systematically analyzed using process analysis and input-output techniques. Mostly direct fuel inputs are used primarily for vessel propulsion. On an average direct fuel energy inputs account for between 75 and 90% of the total energy inputs, irrespective of the fishing gear used or the species targeted. Remaining 10 to 25% is generally dependents on vessel construction and maintenance, and the provision of labor, fishing gear, bait, and ice if used which depending on the character of the fishery and the scope of the analysis conducted. The secondary energy-consuming activities, which include on-board processing and storage is negligible compared to primary energy consumption in terms of fuel burned. Here squid jigging is an example in which relatively large proportion of fuel inputs are used for activities other than vessel propulsion. These include mainly batteries of high intensity lamps, automated jigging machines, and on-board storage facility etc. The energy requirement is met by diesel-fueled generators to attract, hook, and preserve the catch while fishing. On an average the non-propulsion energy demands account for 40% of the total fuel burned. Out of total indirect energy inputs, largest fraction account for building and maintaining the fishing vessels. This is mainly due to vessel's major components (hull, superstructure, decks, and fish holds) are fabricated basically from energy-intensive materials such as aluminum and steel as compared to wood or fiberglass.

As far as fishing craft and gear material is concerned, they play crucial role in energy consumption. The nature and texture of material for construction of craft and gear play a crucial role in drag/resistance offered while craft and gear are in operation. The resistance offered is directly proportional to energy requirement by the whole fishing system. ICAR-CIFT is instrumental in developing technologies by using material substitution which have reduced fuel consumption with less environmental burden. Fiberglass canoes and fiberglass sheathed canoes made of rubber wood introduced by ICAR-CIFT have become very popular because of its reduced resistance and fuel consumption. Aluminum boats designs by the institute is another milestone in this series. Aluminum is light weight material, which helps in smooth maneuvering and energy efficiency. ICAR-CIFT has made immense contribution towards the standardization of the netting, netting yarn and netting twine used for fishery purposes, which are mainly focused on reduced physical resistance with greater energy efficiency. These developments have led to an increase in the productivity of the fishing gear and increase in net profits of fishers due to low maintenance and long service life of the implements. Dyneme and platina are some of the material which can be substituted with conventional material in order to achieve energy optimization (Jha and Edwin, 2019).

Some measures for energy optimization:

Energy security and conservation have great significance on account of responsible fishing and also to meet the demand-supply gap of fossil fuel. During the tow, resistance of the vessel is insignificant compared to the resistance of the gear. The gear resistance therefore has a large effect up on overall fuel economy. Fuel cost can be over 50 percent of the total expenses on a fishing trip. Generally, fuel consumption due to floats, sweeps, warp, otter boards, foot rope and webbing are nearly 3%, 4%, 5%, 20%, 10% and 58% respectively. Some of the preventive measures can save fuel in trawling operation are use of knotless netting, thinner twine, large meshes, cambered otter boards, optimal angle of attack of otter boards, slotted otter boards, multi-rig trawling, pair trawling etc. The fuel consumption significantly increases at maximum speed of vessel, this is because of increase in wave breaking resistance. Facts established that reduction of 10-20% speed can lead to save fuel by 35 to 61% fuel. Application of proper vessel technology during construction of vessel is very important for energy optimised vessel. Operation at rated engine rpm helps in reduction in fuel consumption. Selection of right engine with proper periodic maintenance is required for effective energy optimisation. For energy optimisation, proper fleet management, resource conservation and fishery-based geo informatics system like PFZ etc are also very important.

Conclusion:

Different types of vessel and gear combinations are used for fishing to exploit various fish stocks. The important fishing practices are trawling, gillnetting, longlining, dol netting, purse seining etc. One major reason for the substantial increase in eq. CO_2 emission by construction process is the increase in number and efficiency of fishing boats otherwise called overcapacity, which need more inputs and equipment, results in more eq. CO_2 emission.

In modern fisheries the major direct and indirect energy inputs can be systematically analysed using process analysis and input-output techniques. Mostly direct fuel inputs are used primarily for vessel propulsion. On average direct fuel energy inputs account for between 75 and 90% of the total energy inputs, irrespective of the fishing gear used or the species targeted. Remaining 10 to 25% is generally depends vessel construction and maintenance, and the provision of labour, fishing gear, bait, and ice if used which depending on the character of the fishery and the scope of the analysis conducted. The secondary energy-consuming activities, which include on-board processing and storage is negligible compared to primary energy consumption in terms of fuel burned. Study of environmental burden is important in relative resource-use analysis and greenhouse gas (GHG) impacts in climate change mitigation (Gulbrandsen, 2012). It has got emphasis due to the high instability in fossil fuel cost which has potentially lasting impacts on the economic performance of various fishing systems. These impacts, its implications for fish harvest is markedly to fisheries sector, and are likely to have profound aftermaths for resource impacts and for food security across the globe.

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