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ENERGY USE AND ITS OPTIMIZATION IN INDIAN FISHERIES

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Fisheries sector is highly external energy dependent sector and depend mainly on fossil fuels. Fishing involves the dissipation of energy to accomplish its primary activity i.e. harvesting of fishery resources. While the active cost of fishing is less understood, and consequently receives less attention than the direct impact on fishery stocks and marine ecosystems. It is precisely the availability of fossil energy that enables fisheries to continue even when stocks are in decline. Subsequently, analyses of energy in terms of fuel consumption in fisheries, and changes in energy use over time, can also provide a powerful tool to know the stock health in fisheries sector. Global greenhouse gas emissions would be significantly higher if inland fisheries had to be replaced with other forms of animal protein production. From an energetic perspective, fishing is a set of different process (from fabrication of craft/gear to landing of catch) in which different forms of energy are dissipated in order to capture fish and shellfish. However, as of now very few fishery-specific energy analyses have systematically attempted to account for energy use. Inland fisheries are a low carbon footprint food source compared to marine fisheries. Inland fisheries often use non-mechanized gear that does not require fuel (consumed by boats using active fishing gear in major marine fisheries). The three dominant forms of energy dissipated to these ends include animate, wind, and fossil fuel energy. Animate Energy- Animate energy is common to all fisheries irrespective of their technological sophistication. In traditional artisanal fisheries sector, human muscles is still source of the energy used for propulsion scouting, deploying/hauling the gears and catch handling. Wind Energy- For as long as people have sailed, it is likely that wind energy has been used to support fishing activities. Wind energy not only allowed fishing vessels to be propelled but it facilitates other supporting activities too. Specifically, various trawl or dragger fisheries in which gear are towed were almost all first developed within the context of sail fisheries. Fossil Fuels- Fossil fuels are dominant form of source of energy used in fishing. In the early 1900s Gasoline and diesel based internal combustion engines were first adapted for use on fishing boats. After 2nd world war the size of the global fishing fleet increased along with engine power. In other hand relatively, small engines are also introduced into small-scale fisheries round the globe. These both trend of increasing dominance and size of engines, resulted surprising enhanced fossil fuel consumption for the world's fish harvest sector. Fossil fuels produce carbon dioxide in atmosphere which leads to 'greenhouse effect' and other toxic pollutants which are harmful to the environment and human kind. Greenhouse effect leads to irreversible climatic and oceanographic changes.

Environmental burdens due to construction of fishing vessel

Fishing is one of the energy intensive methods in food production. Energy inputs can be indirect or direct in which indirect energy are linked with building and maintaining fishing vessels and gears. In contrast, direct energy inputs are typically those required to propel fishing vessels and deploy fishing gears mainly in the form of fossil fuels. Combustion of fuels and the release of greenhouse gases to the atmosphere cause environmental impact like climate changes, ocean acidification etc. Fuel consumption rate varies widely according to gear type, materials, shape, fishing practice etc Selection and deployment of energy efficient harvesting technologies suitable for target resources by modifying the existing gears, adoption of alternative fuel-efficient gears are the prime options for fuel conservation. Several technologies evolved over the years in the fishing industry which have improved the fish catch as well as the effort and the related inadequate practices leading to damage to the ecosystem and these ecological impacts were well explained in much of the literature. Hence, this chapter mainly dealt with the environmental impacts of boatbuilding materials and emissions from fishing. Energy analysis are pertinent in relation to fisheries due to the accepted importance of fuel consumption in fishing operations and related environmental impacts. In view of the budding significance of energy use and its impacts on environment, energy inputs in marine fishing and post-harvest operations have been reported by several authors in recent years.

In fishing boat construction, the common materials used in India include wood, fibre reinforced plastic, aluminium, steel, plywood, ferrocement, etc. While selecting a material for boat construction some basic factors to be considered are type, size, speed, the shape of the vessel, availability and suitability of the material, and economic and environmental viability. The performance and efficiency of a boat are directly dependent on the choice of the boat-building material which also has a direct impact on the environment. By taking these facts into account, a boat designer can select the best possible alternative for building a boat of high efficiency and durability. A fishing boat is made up of different components and their 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 CO2. Every ocean has marine debris, and more than 60% of it is plastic that comes from the fishing industry, offshore platforms, recreational shipping etc. At present, the larger class of fishing vessels are made of steel while vessels belonging to the medium and lower categories mostly use wood for construction. Fiberglass, ferrocement, and aluminium are the new substitutes for conventional boat building materials as these can improve the lifespan of the boats. However, traditional fishing boats still play a vital role in this era. Despite its obvious advantages, all boat-building materials are susceptible to the effects of the marine environment, for example, glass fibres are the most selected material for boat construction, which are vulnerable to the effects of sunlight in marine conditions. Fiberglass-reinforced plastic (FRP) is a polyester resin-based composite, reinforced with fine strands of glass filaments. Glass fibre is prone to osmosis, and gelcoat gets faded in sunlight resulting in the attack of UV radiation. FRP fragments have a higher density than seawater and will tend to concentrate nearshore. The polyester resins or epoxy resins in the FRP undergoing physical & chemical degradation lead to the release of microplastics which affects the environment. Marine organisms consume these plastic particles and end up in the human food chain causing severe health issues. Additionally, the deteriorating and peeling paint with high concentrations of tributyltin and lead from the abandoned boats may provide a long-term environmental issue

Fishing and Energy use

Commercial fishing operation mainly utilizes fossil fuels which result in the emission of greenhouse gases. The active cost of fishing is less understood and consequently receives less attention to GHG emissions than the direct impact on fishery stock and marine ecosystem. Similarly, in the harvest process, several reoccurring inputs are required for every fishing operation, viz. fuel, lubricant, ice, freshwater, etc. These inputs have their own carbon footprint value for construction/extraction/process, especially fuel contributes more than 95% out of all the components. Despite the fact that the prevailing pre-harvest phase of marine capture fisheries lacks general detail and standardization about LCA/carbon footprint studies; such studies and their findings can be useful in formulating constructional and operational recommendations to improve the environmental performance of fisheries, under the context of an 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 footprint analysis would be more appreciated by policymakers for the regulation of fishing boat yards and other related fishing ventures. Based on behaviour 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. 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 CO2 equivalent and other GHGs to the atmosphere. Overcapacity and irresponsible use of fossil fuels leads to increased levels of fuel consumption in fishing contributing to climate change in the long run. India contributes 134 million metric tonnes (2.7%) of CO2 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 the fisheries sector is negligible which roughly may be <1% of global GHG emission. The other associated important environmental parameters by which the health of the environment, humans, and resources can be evaluated due to the fishing process are; terrestrial acidification, formation of fine particulate matter, 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.

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. CO2 emission by the construction process is the increase in the number and efficiency of fishing boats otherwise called overcapacity, which need more inputs and equipment, resulting in more eq. CO2 emission.

Energy spent in different fishing operations

Based on behaviour 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 the 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. 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. Reports suggested from south-west coast of India have shown that trawling consumes 6.5 times more fuel compared to purse seining and 1.8 times more fuel than gillnetting, to produce one kg of fish. 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. Among the operational inputs, fuel contributed 95% of the gross energy requirement. A study suggested that the larger mechanized boats emitted 1.18 t CO2/t of fish caught, and the smaller motorized boats (with outboard motor) 0.59 t CO2/t of fish caught. Among the mechanized craft, the trawlers emitted more CO2 (1.43 t CO2/t of fish) than the gillnetters, bagnetters, seiners, liners and dolnetters (0.56–1.07 t CO2/t of fish).

Purse seining: Purse seining is one of the most aggressive and efficient commercial fishing methods for capture of shoaling pelagic species. 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 mechanised purse seine operation is low compared to trawling, gillnetting and lining operations. Some of the energy conserving fishing practices such as large-scale purse seining became possible only with the introduction of synthetic netting material.

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.

Energy intensive illegal fishing: 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. Since light source requires electrical energy which is being produced by main engine/auxiliary engine; this practice is energy intensive. At present in India the light fishing is banned.

Small scale fisheries

Small scale fisheries involves a range of practices, but are typically traditional activities using less capital and comparatively simple gear, commonly with small fishing vessels, making short fishing trips close to shore. Globally 57% of vessels are motorized, of which 79% (2.1 million vessels) are less than 12 m overall. Due to the small size of vessel, the area of operation is limited and operations are mainly on daily basis, which accounts for an average of 1–3 tonnes of fish per person annually. Small scale fisheries require less capital investment and energy for operation. Among all fish harvesting systems, mechanised trawling is the most energy intensive operation and traditional non-motorised gillnetting is the most energy efficient having the lowest gross energy requirement. Out of non-motorised systems, stake nets have comparatively high energy intensive. Among motorised operations, ring seines have a lower gross energy requirement per ton of fish landed. Fishing operations requires scouting of shoal/search of fishing ground which may be distantly located have relatively high gross energy requirement per t of fish landed.

Estimates of fuel use and cost

Annual fuel use is about 50 million m3, 1.2% of total global oil consumption. With marine fish and invertebrate landings at 80.4 million tonnes, global average fuel-use intensity was 620 litres (527 kg) per live weight tonne, or about 1.9 tonnes of catch per tonne of fuel. Fishing vessels released some 134 million kg of carbon dioxide (CO_2) into the atmosphere at an average of 1.7 kg of CO_2 per tonne of live-weight landings. They further noted that these were likely to be serious underestimates, as they did not account for freshwater fisheries or for substantial IUU catches. Global fisheries were estimated to use 12.5 times the amount of fuel energy as their edible-protein energy output, which, although significantly inefficient, compared well with a number of other animal-protein production systems. In context of Indian marine capture fisheries, the substantial increase in fossil fuel noticed due to increased fishing effort and efficiency during the last five decades. Which has resulted in, equivalent to CO_2 emission of 0.30 million tonnes (mt) in the year 1961 to 3.60 mt in 2010. Roughly for every tonne of fish caught, the CO_2 emission has increased from 0.50 to 1.02 t during above said period.

Conservation of fuel as a part of responsible way of fishing

In fish different fish harvesting system different approaches to energy conservation could be one of the ways to conservation of natural asset as well as environment safe. Energy security and conservation have great significance on account of responsible fishing and also to meet the demand-supply gap of fossil fuel. Thus, considering non-renewable nature of fossil fuel, limited availability and effects of its use on environment should be addressed in holistic way. Trawling consumes 0.8 kg of fuel while longlining and gillnetting consumes between 0.15 and 0.25 kg of fuel and purse seining requires 0.07 kg of fuel, to catch one kilogram of fish. Hence most potential for fuel conservation exist in trawling. In trawling typically, a substantial portion of the time is spent on towing the gear. 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. According to a study, fuel consumption due to floats, sweeps, warp, otter boards, foot rope and webbing are 3%, 4%, 5%, 20%, 10% and 58% respectively. Some of the preventive measures can save fuel in trawling operation viz. 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. Generally, two-stroke outboard engine have high fuel consumption compared to 4-stroke petrol outboard engines.

Turbo-charged diesel engines are about 15% more fuel efficient than normally aspirated engines., which have a much better fuel economy and emission standards, are also being introduced in small-scale fisheries.

Summary

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. The remaining 10 to 25% generally depends on vessel construction and maintenance, and the provision of labour, fishing gear, bait, and ice if used which depends on the character of the fishery and the scope of the analysis conducted. The secondary energy-consuming activities, which include onboard processing and storage are negligible compared to primary energy consumption in terms of fuel burned. The study of environmental burden is important in relative resource-use analysis and greenhouse gas (GHG) impacts in climate change mitigation. It has got emphasis due to the high instability in fossil fuel costs which has potentially lasting impacts on the economic performance of various fishing systems.

The effects of fishing and its implications on ecosystems, especially from the boat-building sector or the usage of energy, fuel, and emissions, were not particularly addressed and are anticipated to have significant effects on ecological sustainability and food security globally.

References

FAO (2015) Fuel and energy use in the fisheries sector – approaches, inventories and strategic implications, J.F. Muir. FAO Fisheries and Aquaculture Circular No. 1080. Rome, Italy.

FAO, The State of World Fisheries and Aquaculture 2020, Food and Agriculture Organization, Rome 2020 [Online], http://www.fao.org/documents/card/en/c/ca9229en/

ICAR-CMFRI (2018) Annual Report 2017-2018. 320 p.

Parker RWR, Blanchard JL, Gardner C, Green BS, Hartmann K, Tyedmers PH, Watson, RA (2018) Fuel use and greenhouse gas emissions of world fisheries. Nature climate change 8 (1): 333-337.

Tyedmers PH (2004) Fishing and energy use. In Encyclopedia of Energy (ed. Cleveleand, C.), Elsevier, Amsterdam, pp. 683-693 (42)

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