Energy use in fishing

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Introduction

Fisheries sector is promising way for employment and income generator to huge chunk of the society. Global fish production peaked at about 171 million tonnes in 2016, with aquaculture representing 80.3 million tonnes and 90.9 million tonnes of the total capture production (FAO, 2018). Fishing has been an occupation since time immemorial. Fish harvest is one of the oldest forms of food production; it directly contributes approximately 10% of the total animal protein intake by humans. In per capita terms, food fish consumption grew from 9.0 kg in 1961 to 20.2 kg in 2015, at an average rate of about 1.5 percent per year. Preliminary estimates for 2016 and 2017 pointed to further growth to about 20.3 and 20.5 kg, respectively (FAO, 2018). All over the world diverse range of fish catching methods with different fishing gears are used by small-scale artisanal to large-scale industrial systems. Small-scale fisheries contribute about 50% of global fish catches which leads to generation of employment for more than 90% in world's capture fisheries. Worldwide about 59.6 million people are directly or indirectly involved in fisheries and aquaculture (FAO, 2018) Out of which about 37% people are directly dependent on fishing and rest are in other allied activity like processing and marketing activities (Matthews et al., 2012).

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 how of the stock health in fisheries sector. The fisheries sector is highly external energy dependent sector which is mainly on fossil fuels. 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) (Clark and Tilman, 2017). Global greenhouse gas emissions would be significantly higher if inland fisheries had to be replaced with other forms of animal protein production (Lymer et al., 2016b; Ainsworth and Cowx, 2018)

Energy Inputs to Fisheries

In the year 2017-18 the marine fish landings of India was 3.88 million tonnes which is 6.9% more than the preceding year (CMFRI, 2018). There are 1,99,141 fishing vessels operates in marine fisheries sector of India out of which mechanised, motorised and traditional artisanal vessels contributes about 36.5%, 36.9% and 26.6% respectively. Where as in terms of total catch landed during year 2017-18, mechanized, motorized and artisanal contributed around 75%, 23% and 2% respectively (CMFRI, 2012b, 2015, 2018). 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). A few studies have been conducted in Indian context for energy analysis of fishing systems and operations (Edwin & Hridayanathan, 1997; Boopendranath, 2000; Boopendranath & Hameed, 2009; Boopendranath & Hameed, 2010; Vivekanandan, 2013; Ghosh *et al.,* 2014). In Indian marine fisheries, the boosted fishing effort and efficiency in the last five decades has led to in considerable increase in fuel consumption, which is equivalent to CO_2 emission of 0.30 million tons (mt) in the year 1961 to 3.60 MMT in 2010. The CO_2 emission has increased from 0.50 to 1.02 t for every tone of fish caught during the period. Large differences also reported by authors in CO_2 emission depends upon craft types and age. In 2010, the larger mechanized boats (with inboard engine) emitted 1.18 t CO_2/t of fish caught, and the smaller motorized boats (with outboard motor) 0.59 t CO_2/t of fish caught. Author reported that among mechanized craft, trawlers emitted more CO_2 (1.43 t CO_2/t of fish) than the gillnetters, bagnetters, seiners, liners and dolnetters (0.56–1.07 t CO_2/t of fish). (Vivekanandan, 2013). Many authors studied and reported effect on environment by capture fisheries using life cycle assessment method. Tyedmers (2001), Ziegler *et al.* (2003), Thrane (2004, 2006), Ellingsen & Aanondsen (2006), Ziegler & Valentinsson (2008), Vázquez-Rowe *et al.* (2010a and 2010b), Ramos *et al.* (2011) and Svanes *et al.* (2011). Gulbrandsen (2012) reported 10% and 20% reduction of engine rpm will reduce 20% and 40% fuel consumption respectively. He also opined that, compared to 2-stroke out board petrol engines inboard diesel engine consume 62% less fuel at same speed. Boopendranath (2009, 2010) also advocated use of four-stroke fuel-efficient diesel engines compared to two-stroke engines as it is fuel efficient. He also mentioned fuel consumption drastically increases as maximum speed is approached and a reduction of 10% in speed could lead to 35 % savings in fuel. Study revealed the technical efficiency of the different types of ring seines using lesser horsepower engines performed well with respect to the catch per adjusted horsepower (Edwin & Hridayanathan, 1997). Energy requirement have been used to evaluate the performance of food production systems for over a hundred years in terms of energy input and carbon footprint.

After Gerald Leach's handbook "Energy and Food Production" published in 1976 which included data on the major culturally mediated energy inputs to six fisheries from four continents. Since then researchers in various parts of the world have started working on energetics of fisheries from different perspectives. 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. In most fisheries energy inputs are required to propel fishing vessels and deploy fishing gears. 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. Human animate energy inputs remain part of the production equation, they are generally counter coursed by the inputs of wind energy. Unlike fisheries sector, preindustrial agriculture scenario where a wide variety of animals were domesticated to provide important secondary sources of animate energy.

Wind Energy

For as long as people have sailed, it is likely that wind energy has been used to support fishing activities. Wind energy 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. It started in England at late 1800s, when coal-fired steam engines installed on trawl fishing vessels for propulsion and net hauling first time. With the advantages of improved power and speed, also ability to operate against of the wind more efficiently, it expanded rapidly. Up to late 20th century the coal- and oil-fired steam engines were in use on fishing vessels, subsequently it shifted towards internal combustion engine. 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. Motorised and mechanised fishing is based on fossil fuel, which is non-renewable and scarce. 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 (Endal, 1989b; Hill *et. al.,* 1995; TERI, 1999). The escalated oil prices may severely affect the economic viability of fishing.

The Relative Importance of Direct and Indirect Energy Inputs

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 composed with 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. But squid jigging is extreme example of interesting fisheries 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-fuelled 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 aluminium and steel as compared to wood or fiberglass.

Boat constructed with aluminium or steel found that the embodied energy inputs are higher than fiberglass & wood. Mostly energy analyses of fisheries are on evaluating the direct fuel inputs to fishing. It somehow narrow the focus which reflects the facts that fuel inputs dominate the energy profiling of fishing and also analysis of indirect energy input which is actually labour intensive and time consuming. Therefore, in order to ease the comparison in fisheries sector, only the direct fuel energy inputs to various fisheries is considered. The energy intensities of various fisheries are expressed in terms of the litres of fuel burned per live weight tonne of fish or shellfish landed. The significance of energy and fuel in the fishing sector and its vulnerability to changing energy supplies and prices has highlighted the importance to review the sector's energy and fuel needs. In the holistic context, energy and fossil fuel relations in food production have been subject to notable interest for some decades. These have developed towards detailed analyses of energy and the carbon footprints of various food commodities. Energy use is now important in comparative resource-use analysis, potential trade trends, and in carbon and related greenhouse gas (GHG) impacts in climate change and its mitigation (FAO, 2012).

Related terms linked to fuel and energy use

Energy used in the fisheries sector either directly or indirectly, commonly converted to work in the form of motive and propulsive hauling and other allied work. Energy is also used in producing various capital items and raw material inputs.

Carbon footprint assessments

Which connect the energy use in terms of total set of greenhouses gases that are emitted at different stages of a product's life cycle. The most recognized methodologies used for a carbon footprint assessment are based upon the ISO 14044 standard and the PAS 2050. This can be done with modern software application like SimaPro, GaBi etc.

Climate change processes and impacts

Where use of fossil fuels may add to GHG production, where mitigation features of various aspects of the aquatic supply chain could become important (potentially changing economic incentives), and where impacts of climate change will result in changing energy requirements in various parts of the fishery sectors.

Capture fisheries systems and structural descriptions

In different systems the input levels can be significant, and changing fuel costs are likely to different in each class of fishing activity viz. small-scale, artisanal and inshore fisheries, Coastal industrial fisheries, Distant-water fisheries

Energy use can be defined and measured in a number of ways as:

Direct fuel use

Primarily liquid petroleum products (diesel, petrol, kerosene, liquefied natural gas [LNG], petroleum and materials such as wood or coal – defines the specific usage of a product by quantity or calorific value of fuel.

Total direct energy use

It is broad system of measurement where the total of fuel, electricity and other sources of energy input are taken in consideration. This gives a more comprehensive picture of use and comparison when fuel use is not the only energy element.

Industrial energy use

Assesses the energy required to manufacture basic element which acts as a row material for capital input or operating inputs in the process, e.g. steel, timber, synthetic fibres, plastics in vessels, gear. This total is then related to the outputs.

Embodied energy

It takes a more holistic approach, in addition to industrial energy it also includes photosynthetic energy input for biological processes of ecosystem and food chain supply in fisheries resources.

Renewable and non-renewable energy use

In any of the above categories, the specific sources of energy is renewable (solar, wind, tidal, hydropower) or non- renewable (derived from fossil fuels).

Key energy elements and linkages

The primary energy elements are fuel for propulsion, and for larger vessels, power supply for a range of ancillaries. The relationship between fishing effort, fishing methods, distance to fishing grounds, vessel speed and fuel efficiency of hulls, engines and propulsion systems are all key factors. Linking with stock conditions and market values, these are all reflected in operating costs, the profitability of fishing and the level and choice of activity. In most forms of fishing activity, fuel costs have direct implications for viability. Types of fishery, conditions of fishing and market prices will all determine the impact of fuel prices, as will specific conditions of the fishing enterprise. Impacts of rising fuel prices and reduced profitability, including the value of capital assets used in the sector, can extend widely. Shorter-term changes can be accommodated by scrapping older or more inefficient vessels, selling and writing down capital values (and hence financing and depreciation costs),. Poor profitability will inhibit the building of new fishing vessels, and decrease fleet size even at global level. In the absence of external actions, such as fuel subsidies or market interventions, rising fuel prices will drive out unprofitable fishing businesses, and will tend to reduce fleet size. Depending on the nature of the fishery, this may reduce output, or improve vessel yields and overall economic and fuel-use performance. However, various forms of inertia – time lags in market responses and shorter-term support actions – might delay these changes.

Current estimates of fuel use and cost

Tyedmers et al., (2005) proposed annual fuel use of about 50 million m^3, 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. There is large differences in CO_2 emission among the types of craft which made of different material. In 2010, mechanized and motorized boats emitted 1.18 t CO_2/t and 0.59 t CO_2/t of fish caught respectively. Among the mechanized craft, the trawlers emitted higher CO_2 (1.43 t CO2/t of fish) than the gillnetters, bagnetters, seiners, liners and dolnetters (0.56–1.07 t CO2/t of fish). (Vivekanandan, 2013).

Conclusion

Global fishing practice is highly varied. Harvest is a process in which capture of aquatic animals takes place using a variety craft and gear, mostly vessel-based fishing gears. The major forms and quantities of energy inputs used in fishing operation also vary extensive. Most of the fisheries, particularly large-scale fisheries, over the past half-century, input of energy/fossil fuel dominate energy profile. Cost and use of fuel is a significant issue in the capture fishery sector. It represents significant input cost in most of the fishing operations, except for non-motorized sector. Impact of fuel price is verifying with economic conditions and location, generally developing countries, distant-water fishing and poorer market conditions will have and greater impacts. The data on fuel consumption can be extrapolated to get the idea about fleet, levels of fuel used, its cost and also help in better management of fishing fleets along with resource and efficiency considerations.

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