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Implications of energy use for fishing fleet—Taiwan example

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ABSTRACT

Commercial fisheries rely heavily on fossil fuel combustion and contribute heavily to the emission of atmospheric pollutants and greenhouse gases. Propulsion output of fishing vessels has continually increased from 30 kW in 1959 to nearly 320 kW in 2000, indicating that the Taiwanese fishing fleet tended to voyage farther and faster, and to adjust for the heavier loads demanded by more powerful fishing gear. Daily emissions from Taiwanese fishing vessels were estimated using output method. The marine fishery is unlikely to grow in the future as the government is implementing measures to ensure the development of sustainable fishing practices. There has been a rising trend in pollution to production ratios during the study period between 1959 and 2008. The ratio increased by 47% in the first decade, followed by fluctuations within the range of 50%–58% for the remainder of the statistical period. There is a need to investigate the possibility of reductions in all categories of fishing with regard to energy use and emissions through the subsidization of fishing vessels to encourage operators to switch to more energy efficient equipment and cleaner fuels.

1. Introduction

Taiwan has access to one of the most important fishing industries in the world, with 269 ports of various sizes, and a total of 13,470 fishing vessels in 2005 (FA, 2008). The production of the Taiwanese fishery reached US$2.9 billion, employing nearly 400,000 people in 2008 (FA, 2010). However, overexploitation of resources and declining fish stocks are compounded by concerns with the environmental impact of air pollution from fishing vessels (Haward and Bergin, 2004).

1.1. Atmospheric emission from fishing vessel

The environmental impact of fishing goes well beyond the direct effect on targeted stocks and the associated ecosystems, components, and functions (Wildman, 1993). The volume of atmospheric emissions from ships is increasing rapidly (Corbett and Koehler, 2003; IMO, 2006), and dominates the international maritime agenda regarding environmental protection (LR, 2010). Fuel combustion on ships releases mainly carbon dioxide (CO_2), sulfur oxides (SO_x), nitrogen oxides (NO_x), particulate matter (PM), and hydrocarbons (HC) into the atmosphere. Several studies concerning marine diesel engines and their atmospheric emissions have led to the development of a first emission database (Foltescu et al., 1994). However, fishing vessels have been generally overlooked with regard to their contribution to air pollution even though early studies have shown that air pollution from ships has a direct impact on local (Isakson et al., 1995; LR, 1995; Isakson et al., 2001; Saxe and Larsen, 2004; Schrooten et al., 2009; Kowalski and Tarelko, 2009; Tzannatos, 2010), regional (EU, 1999; EU, 2002), and global human populations and environment (Endresen et al., 2003; IMO 2006).

Following the ratification of Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78), the International Maritime Organization (IMO) enforces regulations for the Prevention of Air Pollution from Ships, which went into force on May 19, 2005 (LR, 2010). In Taiwan, the Exhaust Gas Standards of Air Pollutants from Mobile Vehicles (Article 33, Chapter 3) of the Air Pollution Control Act is the major instrument for the regulation of air pollution from ships (EPA, 2009). However, it is complicated by the policies of fisheries subsidization by the Taiwanese government, which exempts fishing boat fuel oil (FBFO) from commodity taxes, business taxes, and air pollution control fees, and results in a nearly 50% lower price over premium diesel fuel (PDF) (Lin et al., 2006). To move global fisheries towards sustainability, members of the World Trade Organization (WTO) have taken two extremes on this policy (Bailey and Solomon, 2004).

In Taiwan, SO_x is the highest component of air pollution attributed to shipping, followed by NO_x, PM, and HC (Hua, 2005). A percentage of the SO_x and NO_x emitted into the atmosphere is transformed into secondary inorganic aerosols, such as

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ozone (O_3), which are major local pollutants (EPA, 2009). For example, the atmospheric concentration of O_3 and HC increased by 29% between 2001 and 2005 in one of the busiest international ports, Keelung, located 30 km northeast of Taipei (EPA, 2009).

1.2. Reduce energy use and emission

In addition to typical air pollutants, greenhouse gases (GHGs) emitted from ships is another important issue under international scrutiny. The IMO estimated that approximately 2.7% of the world's total CO_2 emissions in 2007 came from international shipping (Deniz and Durmuşoğlu, 2008; LR, 2010). Taiwan in total emitted 270 million metric tons (MT) of GHG in carbon equivalent in 2004, making it at number 22 in the world in terms of volume (Bureau of Energy, 2009). As of 2007, Taiwan's per capita carbon emissions (3.18 MT) had more than tripled since 1980 ranking Taiwan second in East Asia (including Japan, Mongolia, North Korea, South Korea, China, Hong Kong, Macau, & Taiwan) for carbon emissions.

Energy use has been of great concern within fisheries due to associated energy costs and environmental impact (Schauer et al., 1996; Driscoll and Tyedmers, 2010). Results from recent research indicate that management decisions can strongly influence energy use and the resulting emissions of fisheries vessels (Driscoll and Tyedmers, 2010). Because fishing crafts are known to make up a significant portion of the marine vessels in Taiwan, their operations and emissions must be better understood before approaches to the remediation of air quality and economics can be effectively assessed.

Controlling the expansion of fishing capacity has been a major challenge for fisheries management in Taiwan, and around the world. On the other hand, more effective fishing vessels and gear have increased catch capacity and caused environmental problems such as the overexploitation of fish stocks (Utne, 2008). For environmental and economic efficiency, as well as marketing reasons, it is becoming increasingly important that food is produced in an environmentally sustainable and transparent manner (Ziegler et al., 2003). Despite focused attempts in recent years to reduce overcapacity in various jurisdictions, the capacity of fishing vessels has continued expanding as a whole (Johnsen, 2009). Taiwan has implemented a voluntary fishing vessel reduction program, by offering fishing companies compensation to scrap their vessels (World Fishing and Aquaculture, 2009).

Due to a lack of data or methodology with which to address fishery-specific environmental issues (such as emissions from fishing vessels), major obstacles must be overcome in the assessment of the environmental impact of current fishing activities. This study examines the sustainability of fishing activities in terms of energy use and environmental impact. We estimated the trends of atmospheric emissions from Taiwanese fishing vessels using the engine output method. The study also explores the characteristics of the Taiwanese fishing fleet and production for the period between 1959 and 2008.

2. Methods

2.1. Survey of fishing vessels

The Taiwan Fishery Agency (FA) registers all commercial fishing vessels, fisherpersons, fish businesses, and passenger fishing boats in Taiwan. The data from fisheries statistics (FA, 2010) includes all fish landings reported to the FA between 1959 and 2008. It provides complete information, including the names of vessels, owners, and operator contact information. We used this database to identify categories of fishing vessels.

To explore details regarding fuel use and emissions for fishing vessels, we surveyed 358 members of fishery around Taiwan. A questionnaire was developed to permit an analysis of the key players in Taiwan's fishing industry. We designed the survey instrument to cover as many types of fishing vessels and activities as possible, to ensure that answers were based on professional judgment, and to enable statistical element analysis with regard to the operation of Taiwanese fishing craft.

To ensure a proper representation from different perspectives, the sample includes both owners and operators. We received 268 usable responses (a response rate of 74.87%) of which 27 were from "owner only" and 241 from "owner and operator", representing approximately 380 fishing vessels of various categories. Three trained graduate students distributed questionnaires between November 2007 and December 2008. Following the initial distribution, a reminder letter and second copy of the questionnaire were passed out one week after the initial request to all samples that had not responded.

2.2. Fuel consumption

We determined fuel consumption by distributing a questionnaire to randomly selected fishermen from various areas of Taiwan, and by converting official energy statistics (Bureau of Energy, 2010). The questionnaire covered characteristic information including home port, type and age of vessel, primary use of vessel (commercial or recreational), type of main and auxiliary engines onboard, fuel storage, annual fuel use, and general vessel operating area. It also included questions regarding vessel fuel consumption during different modes of operation. We compared survey results to available information in official energy statistics and recent studies.

Total amount of fuel consumed annually (F) by fishing vessels can be calculated using the following formula:

$$F = \Sigma\Sigma p_{ij} = \Sigma\Sigma C_j\, tr_{ij}$$

where p is the vessel category total of the annual fuel consumption of each fuel type, C is the vessel population in each category, tr is the average annual fuel consumption per fuel type per vessel, i is the fuel type (PDF or FBFO), and j is the vessel category.

2.3. Emission estimate

We used the engine output (kiloWatt, kW) method to estimate emissions for diesel engines associated with fishing vessels. The survey collected information concerning propulsion and auxiliary engines powering the vessels. Auxiliary engines generally supply power for equipment, such as capstan systems for trawling, lighting systems for fish attraction, and freezer units for harvests.

Based on the survey, individual engine profiles were developed by combining specific information regarding engines. That information included engine use, engine type, make and model, horsepower, annual hours of operation, typical engine load, "wet" or "dry" engine exhaust, and a number of engine-specific specifications used for emission factor elements. The numbers of propulsion and auxiliary engines associated with each fleet in each district were estimated by multiplying the numbers of vessels in specific categories by the average numbers of engines per vessel category. Average numbers of engines by engine type and vessel category were estimated using the results from the survey.

For emission estimation purposes, two of the key inputs included the annual hours of operation (maneuvering and at sea) and the typical engine load. The survey collected engine-specific annual use values to estimate cumulative engine use. Cumulative