A Two-Stage Approach to Integrate Vessel Geo-Tracking Data and Logbooks for Monitoring Fishing Activity of Coastal Fisheries in Waters off Northwestern Taiwan

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RESEARCH ARTICLE

A Two-stage Approach to Integrate Vessel Geo-tracking Data and Logbooks for Monitoring Fishing Activity of Coastal Fisheries in Waters Off Northwestern Taiwan

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Abstract

Catch and fishing effort data are fundamental information to stock assessment and fisheries management, but difficult to obtain without the support of administration and sound fishery data collection system. This study integrated various sources of data from a simplified vessel geo-tracking system and logbooks from interviews with captains of coastal gillnet fisheries. We developed a two-step approach based on hierarchical cluster analysis to characterize the operation patterns and infer the fishing activities of the fishery. Results showed that the fishing effort in terms of operation duration could be estimated precisely for various vessel sizes, with catch composition and harvest information from logbooks incorporated in the analysis. We then demonstrated how to monitor the geographical extent of fishing effort and the fishing intensity by vessel size and fishing season. The method developed in this study could benefit to understand the fleet dynamics and fishing pattern, and thus could potentially overcome the difficulty regarding to fisheries management due to the complexity of operation pattern in seasonal changes on target species and various strategies to fishing.

Keywords: Fleet dynamics, Fishing pattern, Vessel tracking, Cluster analysis

1. Introduction

Marine spatial planning (MSP) has become more and more important nowadays, and has been considered an effective management tool to compromise the utilization of marine areas and fisheries development [16]. Through the mapping of human activities and species interaction with fisheries, the implementation of MSP could potentially reduce the conflicts among authority, fishermen, developers, and stakeholders, and lower the impact on marine ecosystem function and services [8]. One of key elements to the success of MSP is the participation of various fishery sectors into the management framework. Several studies have demonstrated that management objectives may be difficult to achieve without the incorporation of fishery information into the decision making in multiple aspects of ecology, conservation, economy and society comprehensively [5,15].

Information on catch and fishing effort is essential to stock assessment and fisheries management. However, it would be a challenge to obtain such information without the support of sound data collection system and administrative cooperation [18,35]. For example, data on operation duration are
regarded as fundamental information to infer fishing effort for trawl and gillnet fisheries. Unfortunately, such kind of information is not always easy to reach, without the submission of logbook from captains [12,13].

Development of vessel tracking technology based on geographic information system, such as vessel monitoring system (VMS) or automatic information system (AIS) serves as alternative approaches to understand operation characteristics, and thus could be used to estimate fishing effort in terms of fishing intensity and geographical extent [28,29]. Satellite-based geo-tracking systems can promptly provide near-time vessel position data to the administrative authority. However, high cost of data transmission and equipment installation prevents the popularization of this technique in, particularly, the coastal and inshore small-scale fisheries in Taiwan [6].

To implement fuel subsidy policies for fishing vessels, an alternative simplified geo-tracking device, called voyage data recorder (VDR), is developed and forced to be installed in vessels larger than 20 GRT in Taiwan. This approach can provide high resolution data on vessel position, speed, and heading angle at 3 min intervals, which forms the basis to characterize operation patterns and infer the fishing activities at sea for fishing vessel fuel subsidies (see [7]. However, little studies have focused on the application of this source of information to derive spatial distribution and intensity of fishing effort, combining with logbooks and catch reports, for assessment and fisheries management purposes.

The objectives of this study were to integrate two sources of data from VDR and logbooks based on vessel tracking technology and interviews with captains from a coastal and inshore gillnet fishery in waters off northwestern Taiwan. Fishing trips with information available on VDR, operation characteristics, and catch composition were classified by group to infer the fishing intensity and spatial distribution of the effort. Results derived from the analysis were presented by vessel size and fishing season, which aims to provide basic scientific knowledge as management tools to effectively monitor the fleet dynamics and fishing pressure for small-scale fisheries.

2. Materials and methods
2.1. Data collection

The study area off northwestern Taiwan (120.7°–121.0°E and 24.6°–24.8°N) is shown in Fig. 1, where the Formosa 1: the Taiwan’s first commercial-scale offshore wind farm is located. The coastal gillnets is the major fishery in this area; however, they may suffer the impact of turbine operation during the demonstration phase. Two data sets relating to this fishery were therefore collected for analysis (Table 1).

We collected VDR data for auxiliary information and comparison with logbooks. VDR is a fishery management system widely used in Taiwan to monitor the fleet dynamics of coastal and inshore fisheries, which provides information of vessel

<table>
<thead>
<tr>
<th>Source</th>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Logbook</td>
<td>Vessel</td>
<td>Registered number of fishing vessel to link with VDR</td>
</tr>
<tr>
<td>Date</td>
<td>Operation date</td>
<td></td>
</tr>
<tr>
<td>Latitude</td>
<td>Operation location in latitude</td>
<td></td>
</tr>
<tr>
<td>Longitude</td>
<td>Operation location in longitude</td>
<td></td>
</tr>
<tr>
<td>Catch</td>
<td>Landing by species in weight (kg)</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>Vessel size in GRT categorized using 5 levels: CTR (fishing raft), CT0 (&lt;5 GRT), CT1 (5–10 GRT), CT2 (10–20 GRT), CT3 (20–50 GRT), CT4 (50–100 GRT)</td>
<td></td>
</tr>
<tr>
<td>VDR</td>
<td>Vessel</td>
<td>Registered number of fishing vessel</td>
</tr>
<tr>
<td>Speed</td>
<td>Sailing speed of fishing vessel</td>
<td></td>
</tr>
<tr>
<td>Latitude</td>
<td>Reported location in latitude</td>
<td></td>
</tr>
<tr>
<td>Longitude</td>
<td>Reported location in longitude</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 1. Map showing the study area and the location of the offshore wind farm off northwestern Taiwan.
location every 3 min. Data from this system could be used to estimate the fishing effort in terms of duration and location for each registered vessel. However, the VDR information consists of both vessel cruising and operating, and the data need to be separated to present the fishing effort correctly. Methods based on speed criterion to define fishing activities have been demonstrated in numerous previous studies (e.g., [2,3,22]. A speed criterion following [14] was applied by vessel size to infer the fishing effort in hours and distribution of fishing intensity by spatial grid in 1 min for this coastal gillnet fishery in this study.

Fishing vessels larger than 20 GRT are forced to install VDR system in Taiwan, but this is not mandatory for small coastal and inshore fishing vessels. Even so, some captains show their willing to be volunteers and provide voyage information to the management system. We collected VDR data for vessels operating in coastal waters off northwestern Taiwan (Fig. 1) for potential evaluation of impacts from offshore wind farms on the marine ecosystem and fishery resources. In addition, through interview with captains, logbooks were collected at major fishing ports every month from 2013 to 2017, which include information on fishing date, operation location in latitude and longitude, operating hours (starting and ending time) and species caught in weight and/or number. We then matched the VDR data with logbooks to cross validate the information from two sources, in order to better estimate the fishing effort with associated harvest and location.

2.2. Data analysis

Due to complexity of coastal and inshore fisheries, such as seasonal targeting shifts and changes in fishing strategy and operation patterns, a hierarchical cluster analysis (HCA) was applied to group the fishing trips according to vessel sizes (tonnage) and operation location in latitude and longitude of the fishing effort. HCA was used once again to separate the fishing season by trip group determined at the first HAC based on monthly targeting shift and catch composition in species. This two-stage based approach could substantially benefit the understanding of fishing strategy and fleet dynamics over time and through the fishing ground [17,21,30].

The HCA was conducted using “hclust” function in software R [25] based on the Gower distance [9] and Ward’s grouping algorithm [33]. The optimal number of clusters was determined based on the Elbow method. Spatial distributions of fishing effort were accordingly mapped by vessel size and fishing season for each year from 2013 to 2017 to examine the annual variation. Fishing intensity and catch amount from the coastal gillnet fishery were also plotted by vessel size and season to further examine the shift in fishing effort associated with fishing strategy and resulted changes in catch composition.

3. Results

In total, 911 fishing trips with operation location and reported catch information from 116 gillnet vessels were separated into 3 groups based on hierarchical cluster analysis (Fig. 2). Fishing vessels smaller than 5 GRT (as known as vessel classification in Taiwan, CTR) were assigned to the first group, while the other two groups consist of vessels between 5 and 100 GRT (vessel classification CR1 to CT4). Very few fishing trips for the vessels larger than 5 GRT (<0.5%) were grouped into the first group based on operation location and catch
composition information (Fig. 3). The small fishing vessels (<5 GRT) mainly operated around the area of offshore wind farm, but large vessels fished in two major fishing grounds northern and southern the wind farm area (see right panels in Fig. 3). The small-scale coastal gillnet fishery was therefore divided into 3 categories according to the vessel size.

The hierarchical cluster analysis was applied once again to determine the fishing season for each vessel size class. Three fishing seasons (summer, spring, and winter) were found for the small fishing vessels (<5 GRT), while two fishing seasons (March–October and November to the next February) were shown for the vessels between 5 and 20 GRT (Fig. 4). However, December, besides the two major fishing season, were decided for the large fishing vessels (20–100 GRT) operating in this area owing to the seasonal change in catch composition. In that season (December), large amount of mullet (Mugil cephalus; 98%) was caught by the vessels larger than 20 GRT (Table 2). Sharks, bonitos, and seer fish (i.e., Scomberomorus commerson and Scomberomorus niphonius) were the main harvest from February to November. For fishing vessels between 5 and 20 GRT, sharks and mullets were major catch for summer fishing season (March–October) and the winter (November to February), respectively. A variety of harvest species, including cephalopod (23%), mullet (16%), croaker (14%), stingray (13%), and sea bream (11%) were caught by small fishing vessels during the three different fishing seasons (Table 2).

In general, the small fishing vessels operated around the area of offshore wind farm during various fishing seasons. They fished in the southern part of the coastal waters from 2015 to 2017. Seasonal variation in fishing effort distribution was not evident for the small vessels (Fig. 5). However, the major harvest species varied seasonally, from cephalopod and stingray in spring, croaker in summer, and mullet and sea bream in winter (Table 2). For vessels between 5 and 20 GRT, spatial distributions of fishing effort changed seasonally and decreased year by year (Fig. 6). Sharks and mullets were the dominant species in summer and winter, respectively. The spatial distributions of fishing effort for fishing vessels larger than 20 GRT differed seasonally. Fishing intensity was low between January and August, increased from September to...
November, and reached a maximum in December (Fig. 7). Sharks were the major species harvested by the large vessels from February to November, but large amount of seer fish caught in fall and mullets dominate the catch in December for vessels larger than 20 GRT (Table 2).

The fishing effort remained relatively stable during 2013–2017 for small fishing vessels operating in coastal and inshore waters off northwestern Taiwan, and the catch showed a slightly decreasing trend during the same time, except for 2017 with high catch around 4 mt (Fig. 8). Different patterns were shown for vessels between 5 and 20 GRT. Annual variation was higher in the first fishing season than the second. Extremely high fishing effort and resulted catch presented in 2015, but decreased thereafter from November to near the next February). In contrast, the fishing effort for large vessels increased year by year, with the mullet catch dramatically reached to around 60 mt in 2014 and decreased thereafter to 2017 (Fig. 8).

### 4. Discussion

The need to reduce fishing pressure for coastal and inshore fisheries has been raised urgently in recent years due to overexploitation of fishery resources and degradation of marine ecosystem. However, adequate management for the small-scale artisanal fisheries is always not an easy task because a large number (more than 10,000) fishing vessels operate in complex fishing strategies in waters around Taiwan. For example, the fishermen may use various mesh sizes of gillnets to target different species by season in a so-called single coastal or inshore fishery, resulting in bias estimates of fishing intensity potentially. To overcome this, a two-stage quantitative approach combining hierarchical cluster analysis was demonstrated to be able to regularly monitor the fishing activity and fleet dynamics by vessel size and fishing season (operating strategy) based on VMS and logbook data combining.

Many studies have used vessel position data (VMS or VDR) to resolve the fishing activities at a higher spatial and temporal resolution, and precisely estimate the fishing effort (e.g., [10,34]). However, most of them were carried out for trawlers, and relative few ones aim to analyze data for other fisheries, such as gillnets. This is probably because the speed of trawling remains relatively constant when operating, making them easy to predict the fishing behavior. In contrast, the speed characteristics of gillnet fishery, as those in present study, could be complicated during the steaming to fishing grounds and multiple phases of setting and retrieving under the current condition that may impact the speed of vessel. Results from this study showed that the fishing effort could be determined correctly when the location to shore and the time after leaving the fishing port were served as vessel speed criteria in the analysis [26].

Effectively monitoring fishing effort in small-scale fisheries is essential and vital to understanding their
Table 2. Summary of major catch species from a small-scale gillnet fishery in coastal and inshore waters off northwestern Taiwan. Information is shown for three vessel sizes and different fishing season identified by hierarchical cluster analysis. The numbers in parenthesis indicate the percentage of total catch in weight.

<table>
<thead>
<tr>
<th>Vessel size</th>
<th>&lt;5 GRT</th>
<th>5-20 GRT</th>
<th>20-100 GRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>CTR, CT0</td>
<td>CT1, CT2</td>
<td>CT3, CT4</td>
</tr>
<tr>
<td>Fishing season</td>
<td>Major fishing</td>
<td>Major fishing</td>
<td>Major fishing</td>
</tr>
<tr>
<td>February-June</td>
<td>Cephalopod (23)</td>
<td>Shark (34)</td>
<td>January-August</td>
</tr>
<tr>
<td></td>
<td>Stingray (13)</td>
<td>Seer fish (10)</td>
<td>Bonito (12)</td>
</tr>
<tr>
<td></td>
<td>Sea bream (7)</td>
<td>Cephalopod (6)</td>
<td>Seer fish (7)</td>
</tr>
<tr>
<td></td>
<td>Croaker (6)</td>
<td>Grouper (5)</td>
<td>Stingray (6)</td>
</tr>
<tr>
<td></td>
<td>Shark (5)</td>
<td>Stingray (4)</td>
<td>Tuna (2)</td>
</tr>
<tr>
<td>July-September</td>
<td>Croaker (14)</td>
<td>Mullet (42)</td>
<td>September-November</td>
</tr>
<tr>
<td></td>
<td>Scad (8)</td>
<td>Anchovy (9)</td>
<td>Bonito (8)</td>
</tr>
<tr>
<td></td>
<td>Stingray (5)</td>
<td>Seer fish (9)</td>
<td>Scad (7)</td>
</tr>
<tr>
<td></td>
<td>Sea bream (5)</td>
<td>Bonito (8)</td>
<td>Anchovy (5)</td>
</tr>
<tr>
<td></td>
<td>Mackerel (2)</td>
<td>Pomfret (5)</td>
<td></td>
</tr>
<tr>
<td>October-January</td>
<td>Mullet (16)</td>
<td>December</td>
<td>Mullet (98)</td>
</tr>
<tr>
<td></td>
<td>Sea bream (11)</td>
<td>Scad (0.3)</td>
<td>Scad (0.3)</td>
</tr>
<tr>
<td></td>
<td>Croaker (6)</td>
<td>Bonito (0.2)</td>
<td>Bonito (0.2)</td>
</tr>
<tr>
<td></td>
<td>Scad (4)</td>
<td>Pomfret (0.2)</td>
<td>Pomfret (0.2)</td>
</tr>
<tr>
<td></td>
<td>Bonito (3)</td>
<td>Hairtail (0.1)</td>
<td>Hairtail (0.1)</td>
</tr>
</tbody>
</table>

Impacts on fish stocks and marine ecosystems. There are several approaches available in the literature, among which the analysis of logbook data is the commonest method to estimate the fishing intensity (e.g., [31,32]). However, approaches based on logbooks solely are intrinsically limited by several drawbacks. For example, logbooks are not always publicly accessible vessel tracking systems (e.g., satellite-based automatic identification system) serve as another potential source of data to infer the fishing effort for fisheries management and marine planning in the future as suggested by [20].

Previous studies of fishing activities in small-scale fisheries have been usually based on interviews with fishermen. However, limited by short duration of survey or insufficient spatial resolution of vessel location, these approaches provide imprecise information in determining fishing effort [23]. VMS/VDR was thus developed to be used for monitoring fishing activity, and has increasingly been applied in fisheries management and ecology research in recent years owing to the advantage of being immediately available precisely and continuously for a long-term of monitoring fishing effort at a finer spatial and temporal resolution [19,24].

Another issue to be addressed is the technology to integrate vessel position data and catch information from logbooks because there is no direct way or system to collect catch and effort data simultaneously. Catch reports from this small-scale fishery may be assigned to a fishing location uncertainly because the fishermen could operate more than once during a single fishing day by coming back to the fishing ground again for good harvest. Therefore, it is important to identify fishing activity from non-fishing movements and allocate catch to separate operation location in multiple trip scenarios. We successfully applied a set of criteria to the vessel tracking data for filtering the fishing ground. Results could be improved and refined by means of spatial models or artificial intelligence technique to
Fig. 5. Spatial distributions of fishing effort by fishing season (left to right) for small vessels (<5 GRT) of a small-scale gillnet fishery in coastal and inshore waters off northwestern Taiwan. The area of offshore wind farm is shown in the maps.
Fig. 6. Spatial distributions of fishing effort by fishing season (left to right) for vessels between 5 and 20 GRT of a small-scale gillnet fishery in coastal and inshore waters off northwestern Taiwan. The area of offshore wind farm is shown in the maps.
Fig. 7. Spatial distributions of fishing effort by fishing season (left to right) for vessels between 20 and 100 GRT of a small-scale gillnet fishery in coastal and inshore waters off northwestern Taiwan. The area of offshore wind farm is shown in the maps.
differentiate vessel tracks where fishing gears are being deployed. The approaches implemented by [11,27] were demonstrated as cases to reduce error rates in characterizing fishing trips efficiently.

In conclusion, characterizing fishing activity and using them to inform fishery indicators (CPUE) represents a challenge in fisheries science since logbooks and vessel tracking technology is still developing. In the present study, we proposed a cost-effective method to monitor seasonal patterns in fishing effort and targeting changes for a small-scale fishery. With modifications by incorporating cluster analysis, one could expect that this approach to be used to overcome some deficiencies in logbooks or reports by fishermen and observers.

Conflict of interest

The authors declare that there is no conflict of interest.

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References


