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Defining value per unit effort in mixed métier fisheries

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ABSTRACT

Value achieved from time spent at sea is a central driver of fishing decisions and fishing behaviors. Value per unit effort (VPUE) is an important indicator of economic performance in itself and a useful metric within integrated mixed fisheries models. A time series of Irish first sale prices and total per trip landings values (VPT) highlight heterogeneity in fish prices and VPTs achieved by the Irish fleet spatially and temporally, as well as variability with species targeting. This investigation compared models to standardize fishing trip VPUE accounting for species targeting (métier groupings), engine power (a kW proxy for vessel size), seasonal and annual variability, fishing effort, and individual vessels (encompassing variability in vessel characteristics and skipper effects). Linear mixed effects models incorporating random vessel effects and within-group variance between métier groupings performed best at describing the variability in the dataset. All investigated factors were important in explaining variability, and thus important in standardizing VPUE. Models incorporating fishing days (days with reported fishing activity) and engine power as separate variables resulted in improved AIC values. Therefore, fishing days were considered to be the most appropriate effort measure to generate VPUE. The effort unit traditionally applied in measures of per unit effort, fishing hours, performed comparatively poorly in relation to VPT.

1. Introduction

Maximizing the value returned from time spent at sea is an important imperative of commercial fishing operations, and a key driver of fishing decisions and behaviors. Value per unit effort (VPUE) is an important indicator of economic performance at various scales. Variation in the first sale landings price (also called ex-vessel prices – Sumaila et al., 2007; Swartz et al., 2013), can alter fisher's behavior (Marchal et al., 2007; Sumaila et al., 2007). The achievable price of a species or group of species will determine the level of investment fishers are prepared to make to catch it (Pinnegar et al., 2002), or whether they attempt to catch it at all (Bastardie et al., 2013). Fishers may adopt alternative strategies that are perceived to be more profitable given species prices and predicted catch value (Marchal et al., 2007).

Normal market drivers, i.e. supply, demand and quality determine price at first sale (Abernethy et al., 2010; Bastardie et al., 2013; Pinnegar et al., 2002). Previous research into price variability suggests that in many fisheries prices are relatively inelastic to supply and vice versa given by weak correlations between catch volume and achieved price (Swartz et al., 2013). Bastardie et al. (2013) also suggest that price more strongly influences fishermen than the prospect of large catch abundance. Fishermen preferentially target the Porcupine Bank[1] for larger *Nephrops* typically caught at lower landings per unit effort (LPUE) because of higher achievable market prices for the larger size grades (ICES, 2013).

The apparent economic importance of price may also be reflected in the total per trip landings value (VPT). It is therefore important to be able to compare the value achieved by individual fishing trips, however, VPT may be influenced by factors including trip duration, species (group) caught and retained, fishing grounds, or fishing season. Direct comparison between trips can therefore be misleading or inappropriate. Standardizing trip values to a 'per unit effort' (PUE) measure removes the influence of variable trip duration and takes account of price variations. Value per unit effort (VPUE) essentially incorporates economic factors into LPUE, reflecting the fisher's objective to maximize profit. At present, discarded catch has no economic value or cost to fishers, something which is likely to change under the upcoming implementation of the European common fisheries policy obligation to land all catches of commercial species. Under this new regulation, fishers will be

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[1] A raised area ~200 m deep between the Porcupine Seabight and Rockall Trough, approximately 110mi off the west coast of Ireland.

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required to land the volumes previously discarded and sold for non-human consumption at a nominal value (EC, 2013).

Whilst CPUE can be a good measure for variability in stock biomass, this is only appropriate if catchability remains constant (Gulland, 1983) and is not always the case (Campbell, 2004; Harley et al., 2001). It is widely acknowledged that processes introducing bias through varying catchability or availability must be accounted for to ensure proportionality between CPUE and total stock size. This is the underlying concept of standardizing catch rates (Campbell, 2004). Fluctuations in catchability and/or availability act to alter supply of fish. Whilst VPUE is an economic performance rather than proxy for abundance, changes in catchability or availability may similarly alter perceptions of CPUE and VPUE.

A variety of factors influence catchability either directly or indirectly by changing the effectiveness of fishing effort (Maunder et al., 2006; van Oostenbrugge et al., 2002). These factors include gear/vessel attributes such as engine power (Rijnsdorp et al., 2000) or gross tonnage (Parente, 2004), increases in gear efficiency through technological innovation (van Oostenbrugge et al., 2002), age- or size-specific selectivity, gear saturation (Maunder et al., 2006), and fuel prices (Tidd, 2013). Other factors include skipper and/or crew skill (Mahévas et al., 2011), changes in seasonal and/or spatial distribution (Campbell, 2004; Mahévas et al., 2011; Tidd, 2013), the targeting behavior of a vessel (Maunder et al., 2006; Quirijns et al., 2008; Tidd, 2013), and management-induced responses (Maunder et al., 2006; Quirijns et al., 2008) such as quota restrictions. Whilst CPUE has been the primary scientific metric for biological stock assessment, VPUE is a more crucial metric for fishers. Fundamentally economic factors drive the decisions and behavior made by fishers whose primary objective is to optimize profit (Squires, 1987; Campbell, 2004).

Factors affecting the effort exerted by fishers, and the way effort is measured can also impact the PUE representation and its standardized forms (Borges et al., 2005; van Oostenbrugge et al., 2002). For example, it is important to ensure effort is accurately enumerated when using commercial CPUE data for stock assessment otherwise it may lead to bias or poor precision in the assessment (Tidd, 2013). Equally, accurate VPUE estimation must reflect the time taken to generate the value obtained to enable comparison among trips.

There is an increasing need to take such VPUE metrics into account within integrated management strategy evaluation models and decision support tools which aim to evaluate the costs and benefits of management measures. VPUE is an input in these models, driving the dynamics of simulated fleets, and an output, indicating the economic performance accruing to fishery segments.

The aim of this study was to: (a) model factors influencing total trip values achieved in the Irish fleet, (b) produce standardized VPUEs, and (c) facilitate direct comparison among trips. The analysis considers the relative influence of target species (métier groups), vessel engine power (in kW as a proxy for vessel size), season (encompassing changing stock availability), annual variability, trip duration (measured using different effort units), and vessel effects which encompasses both variation in vessel characteristics and skipper effects. The analysis generated two additional products: (1) a validated reconstruction of the first sale prices for species landed into Ireland (Euro per kg), and (2) a time series of total first sale values achieved per trip (VPT; Euro).

2. Materials and methods

2.1. Data

The Irish fishing industry exploits a diverse range of species. The fleet consist of ~400 vessels >10 m primarily operating in the waters around Ireland (ICES area VI and VII). Of these, round 23 larger pelagic vessels operate from the West African coast to northern Norway. There are an additional ~650 small vessels (<10 m) fishing inshore waters (these vessels are not considered in this analysis as completion of logbooks is not compulsory for vessels under 10 m in length). The majority of ≥10 m vessels are issued “polyvalent” national fishing licenses. These licenses allow operators a high degree of flexibility in terms of gear and target species. The most widely used gears include: mid-water pair trawls for targeting pelagic species, bottom otter trawls and beam trawls targeting bottom dwelling assemblages, and passive gears such as pots and gillnets. Pelagic fisheries generate the greatest landing volumes, while demersal fishing has the greatest number of vessel involved and can achieve higher catch values. Of particular importance, in value, are the high volumes of *Nephrops* landed. Landings from the ≥10 m fleet in 2011 were around 197 thousand tones, equating to a monetary value of approximately 222 million Euros at first sale.

All vessels ≥10 m in length, fishing in European waters on voyages longer than 24 h must complete a daily logbook of operations and a landing declaration upon return to port (EC, 1993). These records constitute the source of information for this investigation. Irish logbook data from 2004 to 2011 were made available from the Integrated Fisheries Information System (IFIS) database, provided by the Department of Agriculture, Food and the Marine (DAFM). The following data were retained for each fishing trip: landing date, fishing area (ICES division or subdivision), gear type, mesh size, landed weight raised to live weight (applying standard conversion factors when not landed whole), and species declared price per kilo.

The price achieved per kilo is linked to the presentation type (e.g. whole, gutted, fileted, tails) of the species when landed. Prices were scaled to the estimated live weight of landings (using the same conversion factors as above) to remove this variability. Exploratory analyses for each species, or group (e.g. *Rajiformes*), identified price ranges, distribution outliers, and the extent of missing values. The method of recording price appeared to change in 2008 from average value for a species within a port, to a traceable record method known as ‘sales notes’. Under the ‘sales notes’ method, fish buyers are required to submit to DAFM the price and quantity at first sale by species for each consignment (this is mandated in various control and enforcement regulations; EC, 1993, 2008a, 2009). More dynamic price variations were observed since 2008.

Missing prices for one or more species within a trip (20,269 records representing 3% of price records) and outlier prices (3126; <0.5%) were filled in with average prices (fill-ins). Of these, trips containing ≥50% species fill-ins were removed from the analyses (4112 trips) to prevent influencing visualized medians. Trips with less than 50% of species replaced were retained (8779 trips; 7% of used dataset). The following algorithm was used to obtain the most accurate average price for use when replacing missing values:

Landing date, fishing division, landing port, species ID,[2]
Landing year, month, fishing division, landing port, species ID,
Landing year, month, fishing division, species ID,
Landing year, fishing division, species ID,
Landing year, species ID,
Landing year, higher species aggregation.[3]

Trips associated with remaining unfilled prices were removed from the analysis (58 trips). The completed price database was used to calculate the value of each species landed (kg weight x price)

[2] Based on FAO's ASFIS List of Species 3alpha code (last visited 11/04/2013).

[3] Common name/group e.g. monkfish (*Lophius spp* and *Lophius Piscatorius*) and rays (*Raja clavata*, *Leucoraja fullonica*, *Raja brachyura*, *Raja montagui*, *Leucoraja naevus*, *Amblyraja radiata*, *Raja undulata*, *Rajiformes*, *Raja fyllae*, *Raja spp*).