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Development of data layers to show the fishing intensity associated with individual pipeline sections as an aid for decommissioning decision-making

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Abstract

Numerous pipelines have been installed in the North Sea to support offshore oil and gas extraction. Pipeline decommissioning options include full and partial removal, as well as in situ decommissioning, either with or without intervention. The choice of decommissioning strategy has social, economic and safety implications for commercial fisheries, according to the type and intensity of fishing in the vicinity. Assessing the impacts of decommissioning strategies on fisheries and mitigation options is an essential step in the decommissioning consenting process. It is important that fisheries impact assessments employ the best available data that are capable of resolving the fine-scale spatial patterns that are known to exist in pipeline-fishing overlaps. This paper describes the development of geographic information system (GIS) layers that provide high-resolution fishing intensity data for individual pipeline sections. The layers were created using fishing data extracted from the vessel monitoring system (VMS) for UK vessels operating mobile demersal gear between 2007 and 2015. The layers are freely available to download via the Scottish Government's National Marine Plan Interactive (NMPi). The layers provide a common evidence base for industry, regulators and stakeholders to assess the impacts of different decommissioning options to commercial fisheries during the decommissioning process.

Keywords: pipelines, decommissioning, fisheries, VMS, vessel monitoring system

1. Introduction

The wide-scale deployment of pipelines in the north east Atlantic has facilitated the exploitation of offshore oil and gas reserves since the 1960s. There are ~2500 pipelines in the North Sea, with a

combined length of ~44 000 km (Oil and Gas UK, 2013). Pipelines range in diameter from 2" to 42" (ca. 5 cm to 107 cm internal diameter) and are categorised as 'surface-laid', resting on top of the substratum, or trenched, laid within a subsurface channel that is either back-filled – naturally or artificially – or left open (Oil and Gas UK, 2013). Pipelines are generally constructed from steel, but may have concrete or polymer external coatings (Oil and Gas UK, 2013).

To date, less than 2 % of UK pipelines have been decommissioned (Oil and Gas UK, 2013), but ~7500 km of pipelines are scheduled for decommissioning by 2026 (Oil and Gas UK, 2016). Unlike oil and gas platforms (OSPAR, 1998), there are no international regulations dictating pipeline decommissioning, and individual governments are able to set their own national policies. Options for pipeline decommissioning include full and partial removal, and leaving pipelines in situ, either with or without intervention (e.g. the addition of protective material such as rock placement) (Oil and Gas UK, 2013). The choice of pipeline decommissioning strategy has implications for the environment and other marine industries, including commercial fishing (Love and York, 2005; McLean et al., 2017; Rouse et al., in press).

Commercial fisheries are one of the largest users of the North Sea in terms of spatial footprint and are considered to be major stakeholders in decommissioning decisions (Eastwood et al., 2007; Jentoft and Knol, 2014). Outside the 500 m exclusion zones around platforms, there are no restrictions on fishing in the vicinity of pipelines. Substantial overlaps exist between fishing activity and pipelines in certain regions, including the northern North Sea and east of Shetland, and a number of vessels

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appear to actively target pipelines when fishing (Rouse et al., in press). Under UK regulations, operators must evaluate pipeline decommissioning options in terms of cost, safety, technical feasibility, the environmental consequences and the societal impacts through a comparative assessment process (Department of Energy and Climate Change (DECC), 2011). The comparative assessment is reviewed by government advisors and statutory consultees, who provide feedback and advice to the regulator. The societal impacts that must be considered in the comparative assessment include the consequences of decommissioning to commercial fishers. These include potential snagging hazards from in situ decommissioned pipelines, and loss of access either during the decommissioning process and/or as a result of disused pipelines left on the seabed (de Groot, 1982; Jiexin et al., 2013). Snagging can potentially result in damage to gear, loss of fishing time and/or risk of injuries to crew. Additionally, physical contact between fishing gear and decommissioned pipelines can be a risk to pipeline integrity and, over time, increase the snagging hazard posed by the pipeline (Ellinas et al., 1995; Det Norske Veritas (DNV), 2006). Repeated trawling activity may also disturb any protective material (such as rock placement) which has been added to in situ decommissioned pipelines to mitigate snagging risks.

The implications of any particular decommissioning method to commercial fishing operations will depend on both the type and intensity of fishing in the vicinity. Currently, the majority of operators (and their consultants) use fishing intensity data that are reported at the scale of the International Council for Exploration of the Sea (ICES) statistical rectangles (1° latitude by 1° longitude) as the basis of decommissioning impact assessments (see Canadian Natural Resources International (2017) as an example of the use of ICES-scale data[†]). Integration of effort across ICES rectangles prevents the identification of fine-scale spatial fisheries patterns, and interactions between vessels and individual pipeline sections in particular will not be detectable (Mills et al., 2007; Lee et al., 2010; Rouse et al., in press).

Since 2005, all vessels ≥ 15 m registered in the European Union (EU) have been required to submit their location, heading and speed to the relevant EU competent authority through a vessel monitoring system (VMS) (European Commission (EC), 2002). In 2012, the size of vessels required to fit VMS was reduced to 12 m. Data must be submitted at regular

intervals, and a minimum of every 2 hours (EC, 2002). Data extracted from the VMS can be analysed to provide higher resolution representations of fishing intensity (Mills et al., 2007; Vermard et al., 2010). These data offer significant potential for aiding decommissioning decisions by providing a more accurate representation of spatial overlaps between fishing and specific pipelines or pipeline sections (Rouse et al., in press). VMS data also offer a common evidence base that is available across the entire North Sea region and can be shared between operators, regulators and stakeholders for assessing fisheries-pipeline interactions. This can facilitate timely, consistent and transparent decision-making, as advocated under the Marine Strategy Framework Directive (Flannery and Ó Cinnéide, 2012).

This paper provides details on the development and publication of spatial data layers using VMS data from the UK commercial fishing fleet to show the fishing intensity along the length of North Sea oil and gas pipelines. These data layers represent an alternative source of fishing intensity data that can be used in the evaluation of societal impacts in the comparative assessment framework for decommissioning.

2. Development of geographic information system layers

2.1. Data sources

VMS data were obtained from the Scottish Government's Fisheries Information Network database for all UK commercial fishing vessels that operate dredges, *Nephrops* trawls (otter and pair trawls) and demersal trawls (otter, beam and pair trawls) over the period 2007–2015. VMS records were only included from vessels greater than 15 m in length, with no data from vessels between 12 m and 15 m (for detailed descriptions of fishing gear types, see Montgomerie, 2015). For each VMS record (reported approximately every 2 hours), the following attributes were available: latitude, longitude, date, time, speed, heading and vessel size.

The VMS data were linked to vessel logbooks to obtain gear type information. The location and properties of pipelines in the North Sea were obtained from Oil and Gas UK (Common Access Data (CDA), 2013) and the Norwegian Petroleum Directorate (2016). The pipeline dataset consisted of trunklines (large pipelines transporting oil or gas), flexible and rigid flowlines (transporting oil or gas) and umbilicals (transporting chemicals or hydraulic fluids), as well as cables, mooring lines and anchor chains. Data included the operator, diameter and fluid medium inside each pipeline. Data on whether pipelines were surface-laid or trenched were not available.

[†] Canadian Natural Resources also presented a map of VMS records in the northern North Sea, obtained from the Marine Management Organisation, to complement ICES-scale fishing intensity data.

2.2. Data processing

A unique fishing trip ID was assigned to all VMS records between a vessel leaving and returning to port. For each VMS record, a derived speed was calculated from the distance and time interval between successive records according to fishing trip. The derived speed serves as a second measure of vessel speed, in addition to ‘instantaneous’ speed recorded as metadata for each VMS point, and can be used for quality control purposes. VMS records with any of the following attributes were removed: a latitude or longitude outside the range of possible values, a vessel heading outside the range of possible values or a derived speed of >20 knots (Hintzen et al., 2010). Records within 5 km of a port were also removed to avoid misidentification of fishing activity when a vessel’s speed fell below designated thresholds (see Table 1) around ports (Hintzen et al., 2010).

Individual VMS points were categorised as ‘fishing’ or ‘non-fishing’ (i.e. steaming) using the activity Tacsat function in the R package VMSTools (Hintzen et al., 2012). This function applies a segmented regression to the cumulative frequency distribution of speed profiles for each vessel according to gear type. It returns gear-specific thresholds for delimiting the two peaks (a low-speed peak representing fishing, and a higher speed peak representing steaming), which are typical of mobile demersal gear speed profiles (Bastardie et al., 2010; Hintzen et al., 2012; Natale et al., 2015). The thresholds (Table 1) are then used to label each VMS ping as fishing or steaming according to its associated speed. ‘Fishing’ periods represent occurrences when fishing gear is deployed and expected to come into contact with the seabed, potentially interacting with pipelines. Steaming points were removed from the data. The remaining VMS fishing points were interpolated into fishing tracks to obtain a greater spatial resolution of fishing activity (Lambert et al., 2012; see Fig 1). The interpolation followed the method of Hintzen et al. (2010) using a cubic Hermite spline, which accounts for the heading and speed of the vessel.

Each pipeline was divided into 1 km sections. The section length was chosen based on the median

Table 1: Speed thresholds used to categorise VMS point data as actively fishing or steaming according to gear type. The minimum and maximum speed thresholds that have been used to distinguish between fishing and non-fishing VMS points are shown (see Lee et al., 2010)

Gear type	Speed threshold for fishing (knots)	Minimum speed (knots)	Maximum speed (knots)
Dredging	0.0 to 3.0	0	6.0
Otter trawls (including pair)	≥1.0, ≥4.0	0	6.0
Beam trawls	≥1.0, >8.5	0	8.0

error between interpolated tracks (~500 m for VMS reported at a 2 hour interval for UK trawlers and dredgers) and the true fishing path (Billet, 2016), and previous analysis of VMS data around a Dutch pipeline (Hintzen, 2016). The fishing intensity associated with each 1 km section was calculated as the total number of tracks intersecting the area extending 500 m either side of the pipeline (i.e. in a 1 km by 1 km square containing a pipeline section at the centre). Tracks within the 1 km² were included irrespective of whether the track intersected with the pipeline, based on the assumption that gear may still interact with a pipeline without the vessel crossing over the pipeline. The intensity was calculated for each year and according to four gear categories: (1) dredging; (2) *Nephrops* trawls (pair and otter trawls); (3) demersal trawls (otter, pair and beam trawls); and (4) all mobile demersal boats (dredging, *Nephrops* and demersal amalgamated). The number of fishing tracks for each gear category was joined to the pipeline section attributes to create four GIS layers (one for each gear category). The resulting layers, showing pipelines across the whole North Sea, are available to view via the Scottish Government’s National Marine Plan interactive[†] (NMPi) and can be downloaded from Scottish Spatial Data Infrastructure MetaData portal[§].

The development stages for the GIS layers are summarised in Fig 1, with a sample from one of the final output layers shown in Fig 1d.

3. Applications for layers

The GIS layers showing the intensity of fishing associated with individual pipeline sections have multiple applications for pipeline decommissioning and management. They provide an evidence base for: (1) policy decisions and regulatory guidelines; (2) planning and executing pipeline decommissioning; and (3) optimising oil and gas operations prior to decommissioning. The layers are of particular value for evaluating impacts of different decommissioning options with respect to commercial fisheries (and according to different fishing sectors) during the comparative assessment process. For example, the impacts of decommissioning pipelines in situ on commercial fisheries would be lower for sections identified as having little or no interaction over the last nine years. In these instances, other considerations, such as environmental interactions, could be weighted higher in the comparative assessment processes. Conversely, for the pipeline sections that have a consistently high number of fishing

[†] www.gov.scot/marinescotland/viewpipelines

[§] www.gov.scot/marinescotland/downloadpipelines

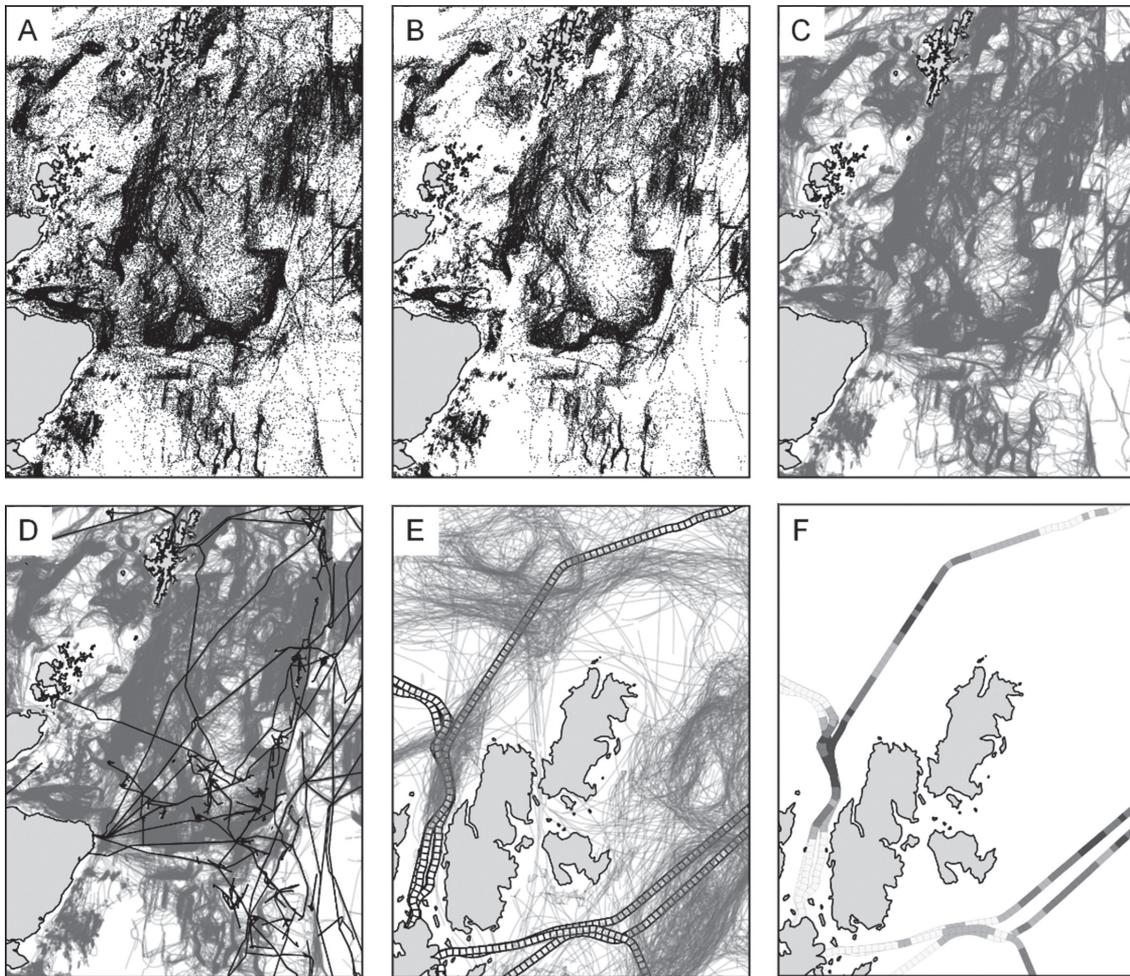


Fig 1: Development stages for high-resolution GIS layers showing fishing intensity associated with pipeline sections in the North Sea. VMS data for all UK vessels were formatted (A), and filtered to remove non-fishing points (B). Fishing points were interpolated into tracks (C). Pipelines (solid lines D) were divided into 1 km sections and overlaid with fishing tracks (E) to provide the fishing intensity associated with pipeline sections – darker sections have a higher fishing intensity (F). Data shown are from 2015 and represent all mobile demersal gear

tracks associated with them, it is important that decommissioning strategies are selected to account for future fisheries interactions and any snagging risks posed by material left on the seabed, in consultation with representatives from the fishing industry.

The pipeline-specific fishing intensity data may also be used to specify the monitoring programme for pipeline integrity and span development, which must be initiated following in situ decommissioning (Oil and Gas UK, 2013). Pipeline sections with little or no fishing activity are likely to maintain their integrity for longer and, as such, could be subjected to a less frequent monitoring regime than those sections of pipelines that are regularly fished over. The adoption of such a risk-based approach to monitoring, informed by the fishing intensity data, could represent a significant cost-saving to the industry and regulators.

By making the layers publically available and accessible to all stakeholders concerned with pipeline decommissioning and management, the transparency

of decision-making can be improved. The explicit linkage of fishing intensity data to specific pipelines within layers enables operators to efficiently extract information pertaining to their own assets using the standard BEIS (Department for Business, Energy and Industrial Strategy formerly Department of Trade and Industry (DTI)) identification nomenclature that is assigned to all UK North Sea pipelines. The higher spatial resolution of the data, compared to intensity data reported at the scale of ICES statistical rectangles, means that greater confidence can be given to the comparative assessment process and proposed mitigation for risks to fishers.

The layers provide an opportunity to gain novel insight into the temporal and spatial variation in interactions between commercial fishing and North Sea pipelines (Fig 2), and this could form the basis of future research. Additionally, the data could be used to understand the impacts of previous pipeline decommissioning decisions (if they are within the available timescale) on commercial fishing

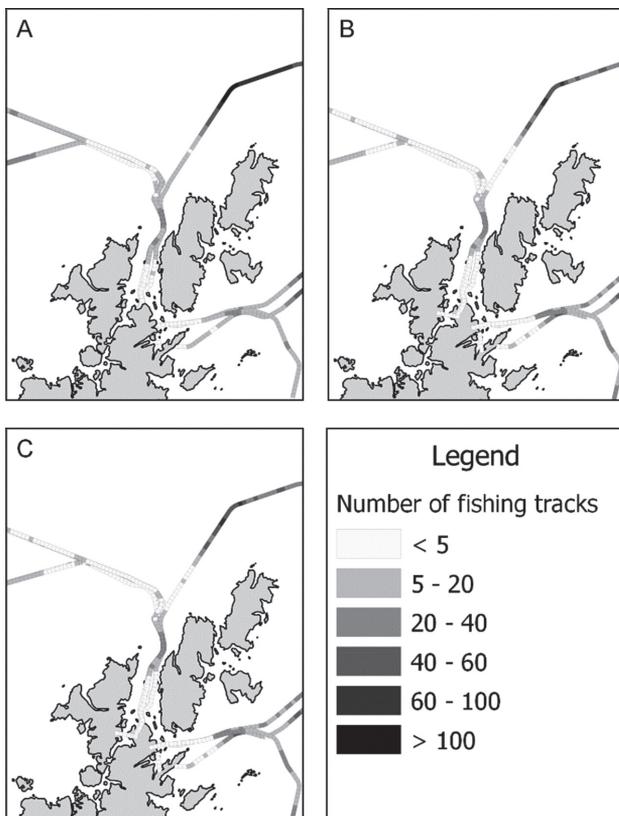


Fig 2: The GIS layers can be queried using the 'Time Aware' function on NMPI to show variations in fishing intensity according to year, e.g. 2007 (A), 2011 (B) and 2015 (C), and at different locations. Darker pipeline sections have a higher number of associated fishing tracks

at local and regional scales. This would serve as a guide for future decommissioning decisions and would allow decision-makers to consider the precedents set by individual pipeline decommissioning cases, including the potential consequences of these decisions at the scale of the UK Continental Shelf. For such an assessment, it would be necessary to collate spatial data on previous pipeline decommissioning practices, which are currently disparate and not readily accessible.

The data layers could also be linked with other data relevant to decommissioning decisions, such as predicted or known associations between pipeline sections and marine species, and in particular species of conservation concern, according to physical environmental drivers (e.g. depth or substratum type). This would further improve the efficiency of decommissioning decisions, by providing a single data source for use in the comparative assessment process to evaluate the impacts of decommissioning to the environment and fishing industry.

The methods used in this study are readily applicable to other marine spatial planning considerations beyond pipeline decommissioning, including the planning, installation and decommissioning of offshore renewable infrastructure and

power cables. Furthermore, the interpolated VMS tracks could be summarised to provide fishing intensity data at a variety of scales (e.g. ICES statistical rectangles, oil and gas licence blocks, renewable licence areas) according to specific management requirements.

4. Recommended steps for using layers

The following recommended steps are provided to guide users in the extraction of data from the layers.

1. Users should download the data to a desktop GIS application via the Scottish Spatial Data Infrastructure MetaData portal. The data are delivered in two formats: an ESRI ArcGIS layer package (which has pre-formatted symbology incorporated) and a standard shapefile (with no symbology information provided). The data consist of a single layer containing 43 770 polygons (each 1 km²) covering UK and Norwegian pipelines. The geographic coordinate system of the layer is WGS84. The attribute table of the layer contains a pipeline identifier field called 'PL_No', a pipeline table field called 'Operator' (representing the operator in May 2016) and 40 fields relating to the number of fishing tracks in each polygon according to year and gear type. The 'AllGear' field shows the total number of fishing tracks per polygon over the nine-year period. The 'AllDredge', 'AllNep' and 'AllDem' fields show the total number of fishing tracks over the nine-year period for vessels operating dredges, *Nephrops* trawls and demersal trawls respectively. The number of tracks for each year is given in the remaining fields for each gear category with field names showing 'AllGear', 'Dredge', 'Nep' or 'Dem' to represent gear type (all gear types, dredging, *Nephrops* trawling and demersal trawling, respectively) and a two-digit year code representing the years between 2007 and 2015. A summary of the attribute table fields is shown in Table 2.
2. After adding the layer to a map, users should select their area of interest either by zooming to the area or building an SQL expression with known BEIS pipeline identification codes contained in the 'PL_No' field.
3. If the ESRI ArcGIS layer package is used, the polygons associated with each 1 km pipeline section will be colour-coded to show the total number of tracks for all years and all gear types. Polygons shown in yellow have the fewest number of tracks associated with them, while red polygons have a higher number of tracks. The symbology will need to be set manually by the user if the shapefile data format is used. Initial inspection of the

Table 2: Summary of layer attribute table fields

Field Name	Type	Description
PIPE_DT	Text	Department for trade and industry pipeline identification code
OPERATO	Text	Pipeline operator as of May 2016. One of fifty operators.
All_Gear	Integer	Total number of VMS tracks per 1 km ² from vessel operating all gear types between 2007 and 2015
All_Dem	Integer	Total number of VMS tracks from vessels operating demersal gear per 1 km ² between 2007 and 2015
All_Dredge	Integer	Total number of VMS tracks for vessels operating dredges per 1 km ² between 2007 and 2015
All_Nep	Integer	Total number of VMS tracks for vessels operating <i>Nephrops</i> gear per 1 km ² between 2007 and 2015
Dem_07... Dem_15	Integer	Total number of VMS tracks for vessels operating demersal gear per 1 km ² according to year (2007 to 2015)
Dredge_07... Dredge_15	Integer	Total number of VMS tracks for vessels operating dredges per 1 km ² according to year (2007 to 2015)
Nep_07... Nep_15	Integer	Total number of VMS tracks for vessels operating <i>Nephrops</i> gear per 1 km ² according to year (2007 to 2015)

data should be done using the 'AllGears' field to identify pipelines sections that are associated with commercial fishing activity. The symbology of the layer can then be manipulated using the remaining fishing fields to identify the type of fishing in the area and any temporal variability in fisheries interactions with the pipeline.

- The number of fishing tracks associated with pipeline sections of interest can be compared to the fishing patterns for other pipelines in the region (e.g. northern North Sea) to provide context to the data, and determine whether the interactions at the pipeline sections of interest may be considered as high or low relative to regional patterns. This can form the basis of permit/licence applications.
- It is important to note that the number of fishing tracks that may be considered 'high' or as representing a 'significant interaction' will depend on numerous factors, including pipeline type, gear type substratum type and burial/exposure status of the pipeline. The fishing intensity data should therefore be considered in consultation with technical experts and pipeline engineers on a case-by-case basis to understand risks to pipeline integrity and rock placement stability from fishing. This is consistent with current practices using lower resolution fishing intensity data.

5. Limitations of data

The risks to pipeline integrity and fishing vessel access and safety (in terms of snagging hazards) occur where pipelines are exposed (permanently or temporarily) on the seabed. Since pipeline burial/exposure data were not available in this study, the current layers are limited in their application to

regional assessments of overall fisheries-pipeline interactions. At the time of decommissioning, individual operators will have access to pipeline exposure data, either from historical records or a pre-decommissioning survey, which can be combined with the developed layers to understand existing and future risks of fisheries interactions.

There are a number of limitations associated with VMS data that must be considered in relation to the pipeline intensity GIS layers. Primarily, the method used to differentiate between fishing and non-fishing VMS records relies on speed as a proxy, yet there are several circumstances – including weather, vessel turning, hauling of gear, and travelling near hazards/port – when the speed of the vessel may fall below the designated speed thresholds. A fishing vessel's speed may also fall below the threshold when conducting 'guard ship' duties around oil and gas infrastructure. Guard ships are fishing vessels contracted by operators to patrol infrastructure during periods of installation or construction to prevent interaction with fishing vessels or other marine traffic. This patrolling occurs at slow speeds, and guard vessels maintain VMS transmissions during their duties. Guard ship duties do occur along exposed cables and pipelines, however, the overall contribution to VMS is considered to be minor, with ~14 vessels conducting guard ship duties on any given day (Scottish Fishermen's Federation, pers. comm.).

The inclusion of VMS records from periods when vessels are operating at low speed, but not fishing, means that for a small minority of trips the total fishing effort may have been overestimated. Despite this overestimate, it can be assumed that the intensity data associated with pipeline sections represent an overall underestimate of the total fisheries interaction.

This is because non-UK vessels were not included in the analysis, even though it is likely that a large number also interact with North Sea pipelines while fishing. Access to European-wide VMS data, including logbooks or other gear type information, would be required to provide the overall fishing intensity associated with pipeline sections.

VMS data for EU vessels could be obtained through the Scottish Government's Fisheries Information Network, but the data only included points when vessels were present within the UK Continental Shelf. This geographical cut-off, along with missing information on vessel heading, meant that the EU VMS data could not be interpolated into fishing tracks using the methods applied to UK data. Furthermore, without access to EU vessel logbooks, gear type could not be assigned to VMS records. Other European VMS, e.g. from Norwegian and Icelandic vessels, could not be obtained through the Scottish Government. Similarly, UK vessels smaller than 15 m are not represented within the current data layers. Since smaller vessels tend to operate closer to shore, the level of fisheries-pipeline interaction will not be accurately represented in coastal areas. When decommissioning sections of pipelines close to shore, operators must consult fisheries representatives and other data sources on inshore fisheries data, such as ScotMap (Kafas et al., 2017).

The inherent error in track interpolation means that it may not represent the true fishing track and this must also be considered when using the data layers. Access to high-resolution plotter data would enable more accurate descriptions of spatial patterns of fishing activities, and centralised initiatives, e.g. the UK Crown Estate Fisherman's mapping project (Crown Estate, 2010), are currently underway to facilitate access to these datasets. Once such data are available, the resolution of fishing intensity data associated with pipelines could be improved even further.

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References

- Bastardie F, Nielsen JR, Ulrich C, Egekvist J and Degel H. (2010). Detailed mapping of fishing effort and landings by coupling fishing logbooks with satellite-recorded vessel geo-location. *Fisheries Research* **106**: 41–53.
- Billet M. (2016). *Using high-resolution vessel movement data to improve accuracy of fishing track interpolation for maritime spatial planning*. MSc Thesis, University of Aberdeen.
- Common Access Data (CDA). (2013) UK Oil and Gas Data [online]. Available at: <https://www.ukoilandgasdata.com> <last Accessed 1 February 2016>.
- Canadian Natural Resources. (2017). *Ninian Northern Platform Late Life and Decommissioning Project*. London: Canadian Natural Resources. 229 pp.
- Crown Estate. (2010). *UK Fishermen's Information Mapping Project*. London: Estate TC, 33 pp.
- de Groot SJ. (1982). The impact of laying and maintenance of offshore pipelines on the marine environment and the North Sea fisheries. *Ocean Management* **8**: 1–27.
- Department of Energy and Climate Change (DECC). (2011). *Decommissioning of Offshore Oil and Gas Installations and Pipelines under the Petroleum Act 1998*. Aberdeen, UK: DECC. 134 pp.
- Det Norske Veritas (DNV). (2006). Interference between trawl gear and pipelines DNV-RP-F111. Det Norske Veritas, Høvik, Norway.
- Eastwood PD, Mills CM, Aldridge JN, Houghton CA and Rogers SI. (2007). Human activities in UK offshore waters: an assessment of direct, physical pressure on the seabed. *ICES Journal of Marine Science: Journal du Conseil* **64**: 453–463. Available at: <http://dx.doi.org/10.1093/icesjms/fsm001> <last accessed 10 October 2017>.
- European Council (EC). (2002) Council regulation 2371/2002 of 20 December 2002 on the conservation and sustainable exploitation of fisheries resources under the Common Fisheries Policy. *Official Journal of the European Communities* L358/59.
- Ellinas CP, King B and Davies R. (1995). Evaluation of Fishing Gear Induced Pipeline Damage. In: ISOPE-I-95-115. Proceedings of the Fifth International Offshore and Polar Engineering Conference, International Society of Offshore and Polar Engineers, 11–16 June, The Hague, The Netherlands.
- Flannery W and Ó Cinnéide M. (2012). A roadmap for marine spatial planning: A critical examination of the European Commission's guiding principles based on their application in the Clyde MSP Pilot Project. *Mar Policy* **36**: 265–271.
- Hintzen NT. (2016). *Fishing intensity around the BBL pipeline*. Wageningen Marine Research Report. Wageningen, NL: Wageningen University. 27 pp.
- Hintzen NT, Bastardie F, Beare D, Piet GJ, Ulrich C, Deporte N, Egekvist J and Degel H. (2012). VMStools: Open-source software for the processing, analysis and visualisation of fisheries logbook and VMS data. *Fisheries Research* **115**: 31–43.
- Hintzen NT, Piet GJ and Brunel T. (2010). Improved estimation of trawling tracks using cubic Hermite spline interpolation of position registration data. *Fisheries Research* **101**: 108–115.
- Jentoft S and Knol M. (2014). Marine spatial planning: risk or opportunity for fisheries in the North Sea? *Maritime Studies* **12**: 13. 10.1186/2212-9790-12-13.
- Jiexin Z, Palmer A and Brunning P. (2013). Overtrawlability and Mechanical Damage of Pipe-in-Pipe. *Journal of Applied Mechanics* **81**: 11 pp.
- Kafas A, McLay A, Chimienti M, Scott BE, Davies I and Gubbins M. (2017). ScotMap: Participatory mapping of inshore fishing activity to inform marine spatial planning in Scotland. *Mar Policy* **79**: 8–18.
- Lambert GI, Jennings S, Hiddink JG, Hintzen NT, Hinz H, Kaiser MJ and Murray LG. (2012). Implications of using

- alternative methods of vessel monitoring system (VMS) data analysis to describe fishing activities and impacts. *ICES JMS* **69**: 682–693. Available at: <http://dx.doi.org/10.1093/icesjms/fss018> <last accessed on 10 October 2017>.
- Lee J, South AB and Jennings S. (2010). Developing reliable, repeatable, and accessible methods to provide high-resolution estimates of fishing-effort distributions from vessel monitoring system (VMS) data. *ICES JMS* **67**: 1260–1271. Available at: <http://dx.doi.org/10.1093/icesjms/fsq010> <last accessed on 10 October 2017>.
- Love MS and York A. (2005). A comparison of the fish assemblages associated with an oil/gas pipeline and adjacent seafloor in the Santa Barbara Channel, Southern California Bight. *Bulletin of Marine Science* **77**: 101–118.
- McLean DL, Partridge JC, Bond T, Birt MJ, Bornt KR and Langlois TJ. (2017). Using industry ROV videos to assess fish associations with subsea pipelines. *Continental Shelf Research* **141**: 76–97.
- Mills CM, Townsend SE, Jennings S, Eastwood PD and Houghton CA. (2007). Estimating high resolution trawl fishing effort from satellite-based vessel monitoring system data. *ICES JMS* **64**: 248–255. Available at: <http://dx.doi.org/10.1093/icesjms/fsl026> <last accessed on 10 October 2017>.
- Montgomerie M. (2015). *Basic Fishing Methods*. Edinburgh: Seafish, 103 pp.
- Natale F, Gibin M, Alessandrini A, Vespe M and Paulrud A. (2015). Mapping Fishing Effort through AIS Data. *PLoS ONE* **10**: e0130746. Available at: <http://dx.doi.org/10.1371/journal.pone.0130746> <last accessed on 10 October 2017>.
- Norwegian Petroleum Directorate. (2016). FactMaps [online]. Available at: <http://www.npd.no/en/Maps/Fact-maps> <last accessed 1 February 2016>.
- Oil and Gas UK. (2013). *Decommissioning of pipelines in the North Sea region*. Aberdeen, UK: Oil and Gas UK, 52 pp.
- Oil and Gas UK. (2016). *Decommissioning Insight 2016*. Aberdeen, UK: Oil and Gas UK, 72 pp.
- OSPAR. (1998). *Summary Record, Meeting of the OSPAR Commission, Sintra, 20–24 July 1998, OSPAR 98/14/1-(A-B)* -E, 20–24 July 1998*. OSPAR archives, London, UK, 99 pp.
- Rouse S, Kafas A, Catarino R and Hayes P. (in press). Commercial fisheries interactions with oil and gas pipelines in the North Sea: considerations for decommissioning. *ICES JMS*. Will be available at: <https://doi.org/10.1093/icesjms/fsx121>.
- Vermard Y, Rivot E, Mahevas S, Marchal P and Gascuel D. (2010). Identifying fishing trip behaviour and estimating fishing effort from VMS data using Bayesian Hidden Markov Models. *Ecological Modelling* **221**: 1757–1769.
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