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Deliverable 2.4. Inventory of specific opportunities for technology transfer and innovation between Arctic science community and industry

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Executive summary

This report provides the results of the interaction between the Arctic science community and the maritime Arctic industries in identifying opportunities for technology transfer and innovation. An inventory is provided combining science-industry priorities with technology available, along with the technology readiness level and bottlenecks for finalization of the transfer.

A regular science-industry dialog was established in the project making use of dedicated meetings and the regular interaction with the industry liaison panel. A set of topics relevant for the industrial sectors has been identified with sectors including: shipping coating, ice risk assessment, route planning, comply and anticipate regulations within the polar code, ship design and pollution risk management and impact mitigation. Different science initiative contributing to these major areas have been defined and including further research needs (e.g., experimental testing in real conditions, validation of the results and field work, further engagement with stakeholders, development of policy and certification tools, etc.).

A list of research areas, research needs and available scientific/commercial tools – including their assessed technology readiness level – has been compiled for a comprehensive inventory of technology transfer opportunities.

In the short-medium term, important research areas include development on: standard ship interfaces based on data distribution standards, automatic instruments for environmental data acquisition, high bandwidth communications and cloud services for near-real-time data transfer, storage, and analyses, and artificial intelligence methods for autonomous classification of sea ice properties.

In the long-term, promising research and management tools to support sustainable industrial development in the Arctic are identified and further illustrated in detail. These include: methods for integrated ecosystem assessment, new generation end-to-end ecosystem models, operational maps for same risk areas identification, technologies and methods for pollution detection and mitigation, and sea-ice forecast services for short term (e.g., navigation) and long term (e.g., route planning) operations.

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Science industry dialog for ARICE

The ARICE project includes among its targets a regular and sustained interaction between the Arctic science community and the Arctic industry community. This is established via a dedicated work package in the project (WP2). The structured science-industry interaction aims to bring forth opportunities for technology transfer and innovation to address industry challenges e.g. to reduce environmental impacts (noise, emissions etc.) of ships in Polar Regions, and opportunities for collaboration and innovation to develop specialised technology of mutual value, e.g. under-ice sensors. Since early 2018, WP2 has been working towards the development of regular science-industry dialogue through: general outreach, industry liaison panel and focused meetings.

1.1 General Outreach

WP2 Lead World Ocean Council (WOC) has been identifying and reaching out to key representatives of Arctic industries to invite them to participate in regular dialogue with the Arctic science community. These include 20+ industry associations and 85+ companies/individuals from six key sectors with the greatest potential to deploy instrumentation and collect environmental data in the Arctic region: shipping, shipbuilding, oil and gas, tourism, fishing and aquaculture. Outreach has been conducted via emails and news releases to the WOC network in the ocean business community, social media, conference calls and in-person meetings at industry events and other occasions.

1.2 ARICE Industry Liaison Panel (ILP)

In spring 2018, WOC convened an ARICE Industry Liaison Panel (ILP) comprising an initial 7 panellists from a diversity of sectors. In view of in-company personnel changes, the updated list of ARICE ILP panellists is as follows:

- Oceanwide Marine Expeditions: Mark van der Hulst, COO (Elected as ARICE ILP Chair)
- Northern Shipping Company (NSC): Yakov Antonov, General Director
- SINTEF: Karl-Johan Reite, Research Scientist
- TOTAL: Michael Borrell, Senior Vice President, North Sea & Russia
- Fincantieri / Vard Marine: Andrew Kendrick, Vice President Ottawa, Vard
- PONANT: Nicolas Dubreuil, Director of Expedition Cruises
- Stena Bulk: Daniel Edvall, Manager, Fleet Operations

Additional panellists may be added as the need and opportunity arise, in order to comply with a gender balance and to address additional sectors.

1.3 Science-Industry Meetings

To date, WP2 has hosted or partnered on the organization of three high-level science-industry meetings. These are:

- **WOC Sustainable Ocean Summit (SOS) 2018, Hong Kong**

  Hosted in Hong Kong in November 2018, the SOS 2018 convened the first annual meeting between the maritime industry and Arctic science community in a 90-minute session titled "*SMART Ocean-SMART Industries and the Arctic: Advancing Industry-Science Collaboration for Data Collection in Support of Safe and Responsible Arctic Development*". More than 30 participants from science and industry were in attendance. Discussions focused on how industry can better engage in data collection in the Arctic to advance knowledge in support of safe and responsible shipping and other economic activity, as well as the benefits and barriers to closer business cooperation with researchers. Further details on the session are available in D2.2.

- **Arctic Circle 2019, Reykjavík**

  Hosted in Reykjavík in October 2019, the Arctic Circle collaborated with WP2 and other members of the EU Polar Cluster KEPLER, ARCSAR and with Extreme Earth in the organization of a breakout session titled "*Breaking the Ice: Cooperation for Safe and Responsible Exploitation of Arctic Sea Routes*". The session showcased the need for collaborative science-industry approach in addressing accurate sea-ice and weather predictions, information on the status of the Arctic and its marine life, and complex predictions of future scenarios. It also fostered active discussions on how the science community can better address the needs of industry, and to identify opportunities for collaboration between the science community, ice mapping agencies and industry.

- **WOC Sustainable Ocean Summit (SOS) 2019, Paris**

  Hosted in Paris in November 2019, the SOS 2019 convened the second annual meeting between the ARICE ILP, the maritime industry and Arctic science community in a four-hour morning workshop titled "*Industry-Science Cooperation for Safe and Sustainable Arctic Operations*". More than 35 participants from industry (from over ten maritime sectors) and science were in attendance.

The first panel – comprising three industry speakers from the ARICE ILP (Total, Ponant, SINTEF) – provided an overview of industry's current research interests (e.g. fleet sizing, aids to ship navigation in ice, port and channel brash ice management, performance of emergency systems, coverage and accuracy of metocean and ice data for model verification and indicators of climate change), the steps they are taking to advance ships/platforms of opportunity, and the challenges and possibilities therein.

The second panel – comprising three speakers from the WP2 Team (WOC, Arctic Portal, FMI) – discussed ongoing efforts to define "menu of options" for observations and interface requirements, develop principles and platforms for industry data sharing and access, and strengthen existing ships/platforms of opportunity programs.

Further details on the workshop are available in D2.5.

1.4 Major outcomes science-industry dialog

As iterated in D2.3, the science-industry discussions laid the foundation for a "programme of ships and platforms of opportunity", as well as identified key technologies to overcome the bottlenecks that are preventing a large-scale improvement of autonomous measurements in the ice-covered seas.

Specific technological standards and tools that require research and innovation for their development with short-medium term transfer time to market include, amongst others:

- *Standard ship interfaces based on Data Distribution Standard (DDS)*
- *Automatic instruments for data acquisition, e.g. of sea ice and snow variables of interest or atmospheric variables as radiation and cloudiness*
- *High bandwidth communications and cloud-based services for near real-time, high resolution transfer, storage and analysis of data*
- *AI-based methodologies for automatic classification of ice properties from satellite images*

The design and development of the above tools are expected to open new markets for major system architecture and software companies as well as for SMEs developing apps for instrument and data management.

Moving forward, WP2 has in plans at least two annual meetings to support the science-industry dialogue: SOS 2020 (November 2020, host city TBC) and SOS 2021 (November 2021, host city TBC). These meetings will aim to lay down concrete objectives and steps for the design and development of identified technological standards and tools needed to actualize technology transfer opportunities.

1. Technology transfer opportunities

Technology transfer processes can be technology-push or demand-pull. We concentrate here on demand-pull transfer and try to explore important factors enabling it.

2.1 Inventory of technology transfer and innovation opportunities

Demand-pull requires industry priorities. Hence, in the table below, for each specific priority (industry interest) identified by D2.3 we have associated technology requirements as well as the contribution of the science community and included any available *technology*. It is worth noting that we are using here and along the whole report the word *technology* in a very broad sense, including not only systems and related processes but also models. In the table below we also indicate the estimated technology readiness level (TRL) of the solution.

Industry Interest	**Technology need**	**Support science activities**	**Technology available**	**TRL**
Define shipping coating requirements	Mapping biodiversity status along navigation route	Assess changes at different spatial and temporal scales	End to end ecosystem models (see below)	2-3
Risk assessment/tools for ship design and navigation Route planning (short term) Optimal use of infrastructures/shipping resources	Forecast conditions for weather, ocean and ice (short term) Mission planning algorithms and methods	Develop a risk assessment toolbox accessible in near real time. Field campaigns and historical data combined for model validation and development. Framework for optimal use of infrastructures / shipping resources	Weather and sea ice forecast services at different spatial scale, from few hours to 5-7 days (see below)	4-5
Route planning (long-term)	Forecast conditions for weather, ocean	Develop risk assessment methods	Integrated satellite observations and sub-	3-7

Navigation services planning	and ice (monthly, seasonal) Mission planning algorithms and methods	Integrated navigation services Cross validation by ships collecting data of ice and iceberg positions along route(s)	seasonal, seasonal forecast models (see below)	
Respond to POLAR CODE on pollution	Test new technologies for pollution measurements, effects and mitigation in real conditions	Stakeholder engagement and interactions to identify promising technologies, present and (expected) future standards and management strategies	Results on scrubber water, new fuel oils, bilge water, lubricants, cargo residues and treated sewage and food waste, underwater noise. Same risk areas models Multi-Iper-spectral and opto-acustic techniques for atmospheric pollution (see below)	1-4
Prevent new POLAR CODE regulations on waste management and support sustainable tourism growth	Waste management plan Transfer on ships consolidated land technologies On-board detectors to secure and document that waste	Adaptation of existing technologies/development of new methods suitable for ship conditions Transfer of experience acquired in remote areas or space Demonstrations of water treatment	Water and waste systems for separation and compacting, biological treatment, etc. See for example [1] Map same risk areas	5-8

	management policies are in compliance	processes and waste treatment processes Mapping of areas where impact (pollution and 'time presence') is different levels of impact		
Reduce overall risks and support ship design	Effective survival equipment	Test in real conditions Define special certificates on survival equipment	Different equipment including Tents or storm shelters, Thermal protective aids or similar, sleeping bags, Foam sleeping mats, Emergency food, Group survival equipment container etc. reviewed in e.g. [2], [3]	6-9
Ship design to respond to POLAR CODE	New materials for low temperature	Test in real conditions Define special certificates on POLAR materials (e.g. ISO type)	Winterization of materials e.g. [4], [5]	7-8
Respond to POLAR CODE work to improve/ameliorate its standards	Documentations and standards	Stakeholder engagement and interactions to identify management strategies Test present certifications and standards	Integrated ecosystem assessment for the Arctic, including policy tools (see below)	2-3

References

[1] https://www.consorzioproambiente.it/en/competenze/trattamento-acque

[2] Deling, W., Hejun, G., Fuquan, F. and Qingfeng, T., 2019. Research on Special Measures of Safe Abandonment of a Ship in Polar Waters. *Journal of Water Resources and Ocean Science*, *8*(4), pp.44-49.

[3] Jensen, J.E., Solberg, K.E. and Gudmestad, O.T., 2019, November. Survival in cold waters-learnings from participation in cold water exercises-a regulatory perspective related to the Norwegian offshore industry. In *IOP Conference Series: Materials Science and Engineering* (Vol. 700, No. 1, p. 012045). IOP Publishing.

[4] Mejlænder-Larsen, M., 2017. Winterization. *Encyclopaedia of Maritime and Offshore Engineering*, pp.1-5.

[5] Heikkilä, T. and Hakanen, E., 2017, July. Alternative Winterization Design Philosophy for Ships Operating in Polar Waters. In *The 27th International Ocean and Polar Engineering Conference*. International Society of Offshore and Polar Engineers.

2.2 Specific technological standards and tools with short-medium term transfer time to market

Industry Interest	**Technology need**	**Support science activities**	**Technology available**	**TRL**
Risk management and ship design	Standard ship interfaces based on Data Distribution Standards	Test systems on board for real world applications	Research and some commercial products are available (Box 1a)	6-9
Risk management and route planning	Automatic instruments for data acquisition, e.g. of sea ice and snow variables of interest	Test systems on board for real world applications	Use of drone technologies for ice measurements (Box 1b)	5-7
Navigation services planning	High bandwidth communications and cloud-based services for near real-time, high resolution transfer, storage and analysis of data	Define secure protocols	SeonSE platform from e-GEOS and similar. See also ARCSAR project (Box 1c)	
Risk management, route planning	AI-based methodologies for automatic classification of ice	Applications and testing	Products from ESA or national agencies	6-8

and navigation services planning	properties from satellite images		(Box 1d)	

Box 1 References for technological standards and tools
a) Standard ship interfaces based on Data Distribution Standards Commercial products available including applications of the US Navy • https://www.rti.com/hubfs/docs/Lockheed.pdf • https://www.rti.com/industries/other-markets Condition based maintenance system for the US Navy • https://d2vkrkwbbxbylk.cloudfront.net/sites/default/files/cbm-rti-usc-iss15.pdf Research on DDS for AUV applications • https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5579807/ Distributed monitoring and control using DDS • https://www.datarespons.com/distributed-monitoring-control-using-dds/ • https://ulstein.com/a-need-to-upgrade-the-automation-system Navigation data distribution system for surface vessels, an example by Raytheon • https://www.raytheon-anschuetz.com/assets/surface-ship-navigation-systems.pdf
b) Automatic instruments for data acquisition, e.g. of sea ice and snow variables of interest Research "Measurements of sea ice by satellite and airborne altimetry" • https://backend.orbit.dtu.dk/ws/files/80537655/PhD_SKRose.pdf "Estimating Arctic sea ice thickness and volume using CryoSat-2 radar altimeter data" • https://www.sciencedirect.com/science/article/pii/S0273117717307901
c) High bandwidth communications and cloud-based services for near real-time, high resolution transfer, storage and analysis of data SeonSE platform https://www.e-geos.it/#/hub/hubPlatforms/platform/platform-sense) and similar Arctic and North Atlantic Security and Emergency Preparedness Network (ARCSAR) https://arcsar.eu/)

d) AI-based methodologies for automatic classification of ice properties from satellite images

MACHINE LEARNING FOR SEA ICE MONITORING FROM SATELLITES

- https://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XLII-2-W16/83/2019/isprs-archives-XLII-2-W16-83-2019.pdf

Machine Learning Algorithms for Automated Satellite Snow and Sea Ice Detection

- https://academicworks.cuny.edu/cgi/viewcontent.cgi?article=3440&context=gc_etds

Satellite SAR Data-based Sea Ice Classification

- https://www.mdpi.com/2076-3263/9/4/152

ESA

- https://www.esa.int/Applications/Observing_the_Earth/Using_artificial_intelligence_to_automate_sea-ice_charting

3 Description of technologies

Integrated ecosystem assessment. Modern environmental assessments go beyond observing system states. They are a means towards evaluating the status of knowledge on complex problems relevant to society (Mach & Field 2017). Prominent examples of such comprehensive assessments of environmental problems comprise the reports of the Intergovernmental Panel on Climate Change and the Millennium Ecosystem Assessment. These modern assessments are based on experts reviewing or investigating the evidence needed for decision-making and make explicit the trade-offs between different uses and ecosystem services. Such analyses require a suite of methods that range from qualitative (e.g. in data poor situations) to fully quantitative complex modelling approaches. Furthermore, retrospective (time series) analyses of system development need to be combined with risk-based approaches to evaluate potential future scenarios under changing and even unknown conditions. Such modern environmental assessments are cornerstones for implementing ecosystem-based management approaches required for achieving a sustainability use of ecosystem services as called for by e.g., the UN Sustainable Development Goals. Present state of the art knowledge identifies Integrated Ecosystem Assessments (IEAs) as the modern strategy towards implementing ecosystem-based management in the ocean (Levin et al. 2009). A number of consecutive and interacting steps are imposed for an integrated approach: scoping the system and management objectives; developing system indicators and reference levels; evaluating risks posed by human and natural stressors; forecasting system dynamics based on modelling approaches; evaluating management strategies for achieving desired objectives. Furthermore, IEAs also guide approaches to observation and monitoring ocean ecosystems. Importantly, IEAs allow for tailoring the approach and selecting appropriate methodology dependent on ecosystem and management context (regional approach), but crucially relying on data and model availability.

References:

Levin, P.S., Fogarty, M.J., Murawski, S.A. and Fluharty, D., 2009. Integrated ecosystem assessments: developing the scientific basis for ecosystem-based management of the ocean. *PLoS biology*, *7*(1).

Mach, K.J. and Field, C.B., 2017. Toward the next generation of assessment. *Annual Review of Environment and Resources*, *42*, pp.569-597.

End-to-end ecosystem models. The so-called end-to-end models typically combine several sub-models to describe physical-chemical-biological oceanographic processes with descriptors of lower- and higher-trophic-level organisms into a single modelling framework. There are currently several established modelling efforts along this line, including among the others: NORWECOM-E2E (Skogen e t al 2014), Ecospace (part of Ecopath with Ecosim; Walters et al. 2010), ATLANTIS (Fulton et al 2004), SEAPODYM (Lehodey et al 2003), OSMOSE (Shin and Cury 2001); see for a full review Plagányi 2007. Numerical operational models for the hindcast and forecast of marine biodiversity are still under development for the Arctic region and elsewhere. However, the approach followed in the project MiMeMo[1] holds promising in filling this technology gaps. Additionally, the model NORWECOM-E2E[2] is presently developed to become a standard for forecasts in the Norwegian Sea ecosystems and includes other Artic regions.

References:

Fulton, E. A., Smith, A. D. M. and Johnson, C. R. 2004a. Biogeochemical marine ecosystem models, I. IGBEM: A model of marine bay ecosystems. *Ecological Modelling*, 174: 267–307.

Lehodey, P., Chai, F. and Hampton, J., 2003. Modelling climate-related variability of tuna populations from a coupled ocean–biogeochemical-populations dynamics model. *Fisheries Oceanography*, *12*(4-5), pp.483-494.

Plagányi, É. E. 2007. Models for an ecosystem approach to fisheries. *FAO (Food and Agriculture Organization of the United Nations) Fisheries Technical Paper*, 477

Shin, Y. and Cury, P. 2001. Exploring fish community dynamics through size-dependent trophic interactions using a spatialized individual-based model. *Aquatic Living Resources*, 14: 65–80

Skogen, M.D., Olsen, A., Børsheim, K.Y., Sandø, A.B. and Skjelvan, I., 2014. Modelling ocean acidification in the Nordic and Barents Seas in present and future climate. *Journal of Marine Systems*, *131*, pp.10-20.

Walters, C., Christensen, V., Walters, W. and Rose, K., 2010. Representation of multistage life histories in Ecospace models for spatial organization of ecosystem trophic interaction patterns. *Bulletin of Marine Science*, *86*(2), pp.439-459.

1 https://www.changing-arctic-ocean.ac.uk/project/mimemo/description/

2 http://bio.uib.no/te/research/norwecom.php

Sea ice forecast services (short term). There are many initiatives and projects working to improve this topic and produce data for new and more accurate services. KEPLER[3] and ARCSAT[4] EU projects are very good examples, but also the Sea Ice Prediction Network (SIPN)[5] that bring together the community of researchers involved in develop sea ice prediction models for different time scale. Additionally, the **Arctic** Regional Communications small **SATellite** (**ARCSAT initiative**[6]**)** provide significant enabling capabilities in the Arctic for communication, awareness and near real time data extraction from in-situ sensors. Moving from the research to services, there are interesting technology including:

- Current and historic ice charts from national ice centres
- Near real-time data and historic from the Copernicus Marine Environment Monitoring Service and the Copernicus Climate Change Service[7]
- Near real time and historic satellite images from ESA, NASA and other Space Agencies and providers

Moreover, methods to produce ice-related risk maps have been developed in the last years but not yet make operational (e.g. POLARIS[8]). Limit of the risk methodology is that it does not include information on ice dynamics and lack some critical information on ice thickness. It is base essentially sea ice concentration maps and polar code ship classification. Furthermore, dynamic interaction of the ships with ice is poorly understood and should be ameliorate (Faury et al 2016).

Sea-ice forecast (monthly and seasonal temporal scale)

The Polar View initiative[9] has provided a review of User Needs and High-Level Requirements for Next Generation Observing Systems for the Polar Regions. This includes identification of technical needs in relation to seasonal sea ice forecast. There are no services at the moment but extensive research on seasonal to decadal ocean forecast are on-going (Payne et al. 2019, WMO Arctic RCC - https://arctic-rcc.org/).

References:

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[3] https://kepler-polar.eu/

[4] https://arcsar.eu/

5 https://www.arcus.org/sipn

[6] https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20140011670.pdf

7 http://marine.copernicus.eu/

8 https://arcticshipping370project.wordpress.com/data-sources/polaris-system/

[9] http://polarview.org/

Dierking, W., Mäkynen, M. and Similä, M., 2020. Editorial for the Special Issue "Combining Different Data Sources for Environmental and Operational Satellite Monitoring of Sea Ice Conditions".

Faury, O., Fedi L., Etienne L., Cheaitou A., ARCTIC NAVIGATION: STAKES, BENEFITS AND LIMITS OF THE POLARIS SYSTEM, Journal of Ocean Technology 13(4):54-67, december 2018

Payne, M.R., Hobday, A.J., MacKenzie, B.R. and Tommasi, D., 2019. Seasonal-to-decadal prediction of marine ecosystems: opportunities, approaches and applications. *Frontiers in Marine Science*, *6*, p.100

Research areas on pollutants

A ship is a source of different pollutants, including different types of oil compounds, lubricants, heavy metals and nutrients, originating from e.g., scrubber water (if the ship has a scrubber), bilge water, carbo residues and discharges of treated sewage and food waste. Whereas some of these are mentioned in the POLAR CODE and others are regulated by other convention, for some regulations are currently being developed. For instance, whereas the recent IMO Sulphur convention allows for the use of scrubbers as an alternative for a low-sulphur fuel oil, the concerns of the environmental effects of scrubbers have already resulted in local bans of open-loop scrubbers, and larger-scale bans might be following in near future. Similar decisions might be underway for other operational pollutants, particularly concerning the vulnerable arctic environment. However, the concentrations and effects of the operational pollutant mixtures in the arctic environment are largely unknown, which hampers the efforts to prioritize mitigation measures, including both technological, regulatory and operational solutions.

References:

ICES working group: https://www.ices.dk/community/groups/Pages/WGSHIP.aspx

Map same risk areas

The Ballast Water Management Convention (BWMC) came into force in September 2017. The purpose of the BWMC is to ensure that marine invasive species (MIS) do not spread with ships ballast water. The BWMC requires that the ballast water meets certain criteria regarding the presence of organisms before it is discharged into the ambient environment, typically in connection with port calls. This means that most marine vessels *de facto* need to install on-board treatment technology to comply with the Convention. In the BWMC there is an option for applying for an exemption for ships engaged in scheduled operations between two or more ports (and countries). An exemption may be granted by the national authorities of involved countries, and shall be valid for a period of 5 years. A prerequisite for an exemption to be granted is that a risk assessment is carried out. The BWMC's guideline (G7) provides procedures for how an exemption can be granted. In the original edition of G7 instructions are targeted the individual ship route, so that every single ship route and ship had to apply for an exemption individually. In 2017, however, the G7 document was updated offering an option for a more general exemption, a so-called

"Same-Risk Area" (SRA). An SRA is a marine area within which an exemption can be granted to all ships engaged in scheduled operations. An important part of the risk assessment required by a SRA exemption is to assess the potential natural spread of marine invasive species in case of introduction. If a species is expected to spread naturally and relatively quickly in an area, spread through ballast water could be regarded as relatively insignificant while species with limited dispersal potential may determine the size and extent of a possible SRA. Some approach could probably be investigated to define pollution levels in different risk areas.

References:

Hansen F T, Christensen A, 2018. Same Risk Area Case-study for Kattegat and Øresund - Final report. DTU Aqua report no. 335-2018. ISBN: 978-87-7481-254-8

Stuer-Lauridsen F, Hansen F T, Overgaard S B, 2016. Same Risk Area Concept.Procedure and Scientific Basis. Final report. By Litehauz Aps for ITERFERRY and Danish Nature Agency

Stuer-Lauridsen F., Drillet G., Hansen F.T., Saunders J., 2018. Same Risk Area: An rea-based approach for the management of bioinvasion risks from ships' ballast water. Marine Policy. Accepted. https://doi.org/10.1016/j.marpol.2018.05.009