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Design Considerations to Optimize Monitoring for Canada's Pacific Region Fisheries

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Prepared for: **Pacific Region Monitoring and Compliance Panel**
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Executive Summary

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This paper is intended for the broad community of stakeholders who are involved in the design, implementation, operation, and evaluation of fishery monitoring programs. Although we focus on Canada's Pacific Region as a case study for this paper, the methodology and observations we present apply to any fishery that is attempting to improve their catch monitoring systems. It is important to clarify that this paper is not intended to judge the adequacy of existing fishery monitoring systems, as we recognize that the choices made are often a trade-off between many factors. Instead, we seek to promote a more informed understanding of fishery monitoring design considerations, and to assist practitioners in determining if monitoring systems are achieving their goals.

Canada's Pacific Region fisheries contain a diverse array of capture species, harvest groups and fishing methods; and the information systems that are built around these fisheries are equally diverse in structure and content.

Catch reporting has been defined in terms of an assortment of methodologies, called 'catch reporting tools' that provide data to an integrated information system, called the 'catch monitoring system'. At a basic level, the tools are separated into two categories; those that acquire data supplied directly by fishery participants, termed 'self-reporting' tools, and those that involve dedicated investments to independently gather data from the fishery participants, termed 'independent reporting' tools.

The information needs of all fisheries contain data elements that may limit or conflict with the self-interests of the individual fishery participants. Therefore, data collected from self-reporting tools will always be subject to credibility challenges, whether justified or not. Other factors such as the complexity of the data itself and inconsistent methodologies may also create data quality challenges with self-reported tools. However, self-reporting tools are inevitable for many fisheries and therefore, continuous effort is needed to ensure fishery participant compliance with reporting responsibilities.

Independent reporting tools typically provide more credible and higher quality data, but often at a substantially higher cost than self-reporting tools – one or two orders of magnitude higher, in our experience. Because these tools involve methodologies that must align with the operational activities of a fishery, the cost for these tools varies widely from fishery to fishery due to different fishery characteristics and other external factors. As well, there are different service delivery options for these programs that influence cost and efficacy.

Within a fishery there may be multiple tools used to capture the full scope of information required. The integration of these catch reporting tools is a critical design process for a fishery. Several design considerations are presented in this document including the impact of fishery characteristics, efficacy of catch tools, cost factors, compliance issues, and coverage levels. Hence, investments in catch reporting tools should be the result of a deliberate and strategic planning process.

The strength of fishery monitoring systems should be routinely evaluated, and improvements considered. In our view, improvements to fishery monitoring systems lie with new tools, improvements to existing tools, increased integration of existing tools, and measures to strengthen compliance, particularly in fisheries with a high self-reporting component. Most Pacific Region fisheries already use the catch reporting tools most suited to their specific fishery characteristics and information needs and avenues for improvement lie with strengthening existing tools. Several improvement pathways were identified, including reduced timelines, increased coverage levels (e.g., independent monitoring), greater emphasis on participant engagement and the use of technology.

Recognizing that self-reported data are a component for most fisheries, and the only option for some, the level of catch reporting compliance is a key issue that potentially undermines the value of these information systems. With the complex coastal geography of the Pacific Region, increasing compliance through deterrence measures is likely to be very costly and ineffective. We believe that a strategy is needed to strengthen the 'social contract' for participant compliance with their catch reporting obligations. In particular, more attention should be given towards the participant's normative motivations – measures that strength a fishery participant's willingness to comply by reinforcing values such as the legitimacy of the regulations and management process, the importance of fishery information systems, the importance of participant contributions, and overall fairness across different user groups.

The methodology attempted in this paper – taking a whole region approach to characterize fisheries and associated catch reporting systems – points to the lack of a consistent, timely process for making basic Pacific Region fishery information available to the public. We believe that this methodology would be useful for any fishery jurisdiction seeking to demonstrate to the public (resource owners) that monitoring systems are sufficient to meet resource management and sustainability objectives.

In terms of Canada's draft fishery monitoring policies, we believe there remains a gap in 'policy to practice' relating to decisions for determining the specific monitoring measures appropriate for each fishery. The high integration dependency among available tools and multiple design elements within specific tools indicates a need for a more systematic approach to monitoring program design. While it is recognized that monitoring needs should be evaluated on a per-fishery basis, some species occur in several fisheries. These "stove-piped" monitoring designs may result in unintended consequences for participant trust and confidence when certain species have poor monitoring in one fishery and adequate in another. Similarly, the siloed fishery by fishery funding approach limits cooperation across fisheries and makes it harder to collectively seek external funding partners.

Catch reporting tools have evolved rapidly over the past few decades with new technology, lower communication costs and improved integration among different tools. Fisheries agencies should foster these advancements by supporting industry and practitioners in developing and implementing new monitoring systems and products. DFO should strengthen its commitment to international fora that focus on improvements to fishery dependent information systems. In our view, Canada has a great deal of knowledge and experience to contribute in this arena.

1 - Introduction

Rationale

Sustainable resource management is a key principle underpinning Canada's fisheries policies. Achieving this requires increasingly more comprehensive information to support resource assessment and to ensure effective management. While the needs of individual fisheries can vary, one of the most common and universal needs is information about resource removals from fishery operations. This information includes fishery participant details, times and locations of fishing activities, descriptions of fishing methods, information on catch composition (including discarded catch), and interactions with other (i.e., non-target) species. Nearly all fisheries have some form of a monitoring system in place for information gathering and compliance enforcement directed to each fishery's policy objectives. Many fisheries utilize one or more information gathering tools such as logbooks, hails, vessel inspections, observers etc., which collectively form the fishery monitoring system. As stewards of these publicly-owned resources, the government of Canada is responsible for ensuring that the fishery monitoring systems are adequate to meet resource management and sustainability objectives.

The Monitoring and Compliance Panel (hereafter referred to as: The Panel) is a multi-stakeholder group formed in 2010 to examine and provide advice on fishery monitoring systems in Canada's Pacific Region. The Panel's mandate applies to all user groups and initially focused on salmon but has broadened to encompass many marine fisheries. The Panel recognized that there is a gap between policy principles and best practices for fishery monitoring systems; nor is it easy to assess the levels of compliance, particularly in fisheries that are heavily reliant on reporting by fishery participants. The Panel has already received background information on the Monitoring, Control and Surveillance (MCS) framework in Canada (Ganapathiraju, 2017a), as well as proposed methodology to examine Pacific fisheries in a MCS context (Ganapathiraju, 2017b). The Panel was interested in further work examining catch reporting methodologies and compliance assessment and therefore commissioned this study from Archipelago Marine Research Ltd. (hereafter: Archipelago). Based in Victoria, British Columbia (BC), Archipelago specializes in the design, development and implementation of fishery monitoring programs, and is a pioneer in the use of electronic monitoring (EM) technologies for fisheries monitoring. Many Archipelago-developed monitoring programs have been instrumental in helping fisheries become more compliant and data rich, and thus providing more opportunity to improve their management.

The Problem

The complexity of fisheries monitoring becomes obvious when considering the many fishery dimensions including (but not limited to): the number of vessels, the isolated nature in which fishing operations occur, the distribution of fishing in time and space, and the detail of information required. The most universal monitoring systems are from fisher-dependent, self-reported data sources such as logbooks, hails, and landing records – which are routine reporting measures conducted by those directly involved with the fishing and offloading activities. Less common are fisheries that have implemented fisher-independent monitoring such as human observers and/or electronic monitoring. When compared to fisher-dependent reporting tools, these options can be much more expensive as they involve dedicated investments of people or technology for collecting, processing, and reporting fishery data. A fishery monitoring system is often an integration of several combined tools to satisfy all the information objectives of a fishery. The way these tools are integrated, along with the timelines and quality control measures in place, also influence the overall strength of the information system. Most fisheries have unique operational characteristics, information needs and financial resources, such that there is no universal approach to implementing monitoring systems across all fisheries. The resulting monitoring system for a fishery is often a trade-off between competing factors.

It is important to acknowledge that with self-reported (fisher-dependent) data, fishers may not have the time, skills or inclination to record their fishing activities accurately. In addition, the information needs of nearly all fisheries require data elements that may conflict with or appear to conflict with the self-interests of fishery participants. These limitations underscore the main challenges with self-reported data in fishery monitoring systems. This is not to suggest that all fishery participants will be non-compliant or misreport, but rather, to make the point that self-reported data will always be subject to credibility challenges, whether justified or not. This is especially problematic because in many instances it is impossible to verify the accuracy of self-reported data, unless coupled with some form of independent verification. Given the vastness of the BC coastline, it is virtually impossible to verify compliance. While it is intuitive that widespread misreporting creates serious information gaps, even low levels can have significant impacts, such as with prohibited and/or protected species. Furthermore, misreporting (or perceptions of misreporting) by some may erode the willingness to comply among normally compliant fishery participants, weakening overall trust in the information system and widening the gap between harvesters, regulators and the public (Battista *et al.*, 2018).

National Fishery Monitoring Policy

In order to provide a consistent framework for evaluating fishery monitoring systems in the Pacific Region, Fisheries and Oceans Canada (DFO) developed a risk-based strategic framework (Fisheries and Oceans Canada, 2012) to achieve the following goal:

"To have accurate, timely and accessible fisheries data, such that there is sufficient information and public confidence for all Pacific fisheries to be managed sustainably and to meet other reporting obligations and objectives."

The framework included several guiding principles - conservation and sustainable use, consistency and transparency, tailored requirements, shared accountability and access, and cost effectiveness – to be applied in the risk-management for different Pacific Region fisheries.

Recently, DFO distributed two documents: a draft National Policy for Fishery Monitoring, and draft Steps to Implement the Fishery Monitoring Policy (Fisheries and Oceans Canada, 2018a). The national policy document identifies three policy principles to ensure that information is dependable, timely and accessible:

1. The levels and frequency of fishery monitoring should respond to the degree of risk associated with the fishery and the complexity of the fishery.
2. A fishery monitoring program should be designed to achieve the fishery and policy objectives and take into account cost-effectiveness and practicality of implementation.
3. Shared accountability and responsibility.

The draft policy document reiterates the requirement for licensed fish harvesters to report data as outlined in their licence conditions and emphasizes that all those involved in fishery monitoring must be committed to meeting requirements for information dependability, timeliness and accessibility.

The draft policy document further outlines cost recovery responsibilities for fishery monitoring programs. With most commercial fisheries, DFO pays for the internal administration costs, whereas the fishery participants pay for direct monitoring program costs. In the past, DFO has contributed to the start up costs for new and emerging programs in commercial fisheries, with the expectation that full industry funding takes place over time. Within recreational fisheries, the costs are borne by DFO, excepting the license fees paid by anglers. Within Aboriginal fisheries, the federal government currently provides funds for monitoring programs but that responsibility may change due to fisheries provisions within new treaties.

The draft implementation steps identify six steps for implementing the fishery monitoring policy:

1. Prioritizing fisheries for assessment,
2. Assessing the monitoring program within an assessment unit (e.g. fishery, fleet, etc.),
3. Setting the monitoring objectives,
4. Specifying the monitoring requirements,

5. Operationalizing the monitoring program, and
6. Reviewing the monitoring program and periodic reassessment.

The implementation document was intended to provide guidance on moving fisheries forward under the framework of the new national monitoring policy.

Purpose

This paper is intended for the broad community of stakeholders who are involved with the design, implementation, operation and evaluation of fishery monitoring programs. While we focus on Canada's Pacific Region as a case study for this paper, the methodology and observations we present apply to any fishery jurisdiction that is attempting to optimize catch monitoring systems. Canada's draft national fishery monitoring policies are specifically referenced and commented upon, yet many of the policy principles and our observations apply quite generally to other jurisdictions. It is important to clarify that this paper is not intended to judge the adequacy of existing fishery monitoring systems with Canada's Pacific Region as we recognize that the choices made are often a trade-off between many factors. Instead, we seek to promote a more informed understanding of fishery monitoring design considerations and assist practitioners in determining if the monitoring systems are achieving their goals and if the right trade-offs were made.

We believe that it is important to select and optimize the catch reporting tools in a fashion that best meets the fishery information requirements, available budgets, and ensures public trust and confidence in the process. We use Canada's Pacific Region fisheries to examine monitoring program design considerations in detail. We begin with an overview of the different fisheries then describe the catch reporting tools currently in place. We then discuss the design considerations affecting the application of the catch reporting tools, recognizing that some tools are not appropriate for certain information needs or certain fisheries. In our view, this approach and conclusions could be applied broadly to many different fishery systems.

With regard to the draft national monitoring policy, the paper builds off implementation Step 4: "Specifying the monitoring requirements". Where monitoring objectives are achieved through different catch reporting tools, Step 4 is informed through a comprehensive understanding of the monitoring tools, their associated cost drivers, and other dependencies.

A note of clarification regarding the term 'monitoring' is in order here. The term is a key element of the United Nations MCS framework (FAO, 1981) and is defined as: 'the continuous requirement for the measurement of fishing effort characteristics and resource yields. Hence, the term includes both active and passive information gathering processes, but as the word 'monitoring' often connotes an active process, we chose to simply refer to different monitoring methods as 'catch reporting tools' and use the term 'fishery monitoring system', to reflect a more active process of using an integrated set of catch reporting tools to form a fishery information system.

2 – Canada's Pacific Region Fisheries

The Pacific Region has a diverse array of marine species and fisheries that depend on them. Herein, we briefly summarize these fisheries, grouping by major user categories of commercial[1], recreational and Aboriginal, recognizing the fundamental distinction and entitlements set out in the Fisheries Act (The Minister of Justice of the Federal Government of Canada, 2016). In providing this summary, we sought fishery information that was publicly available on DFO websites and other sources. DFO produces annual Integrated Fishery Management Plans (IFMP's) for each major species, or species group. These plans apply to all user groups. While attempting to collect the data, it quickly became evident that the available information in the IFMPs varied considerably in terms of the type of information, how it was organized, as well as the release date. We sought to collect the most current information, but the available data and most recent data year varied by fishery. We were able to access 2016 information for most of the commercial fisheries and we used this year for our comparisons, yet the recreational information we were able to locate was only current to 2009 or 2010. In addition, we were not able to find detailed fishery descriptions for Aboriginal fisheries beyond data related to the allocation of communal licenses by DFO. We also recognized that trying to provide a single year coastwide all-fishery snapshot can be problematic because of the interannual variability of some fisheries (e.g. salmon, herring and hake). Finally, it is important to note that the term 'fishery' varies among the different sectors and, in one instance may represent a gear and species focus, while in another it simply represents the use category or catch reporting unit.

Commercial Fisheries

Commercial fisheries in the Pacific Region exploit approximately 100 species, and in 2016 landed about 188 thousand tonnes, with a landed value of about $392.8 million (British Columbia Ministry of Agriculture, 2016). The commercial fisheries are separately licensed, generally according to species, or species/gear categories. Table 1 provides a summary of the main commercial fisheries, excluding minor fisheries such as anchovy, sardine, euphausiids (krill), scallops and clams. The table provides the scope of each fishery in terms of activity (i.e. vessels, trips and days), catch and landed value. Activity information was not consistent across different fisheries for various reasons. For example, dive fisheries track diver hours instead of vessel trips or days fishing.

While not intending to review all fisheries, a few salient features are noteworthy. The fisheries vary widely in terms of the basic unit value of the resource, the quantity

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[1] NAICS Industry Code 1141, defined as *all establishments primarily engaged in the commercial catching or taking of finfish, shellfish and other marine animals and plants from their natural habitat*.

fished, and the level of effort expended in terms of vessels involved and fishing time. Groundfish fisheries represent comparatively fewer active licences and have the highest total catch (87k tonnes, 61% of total), highest value ($156m, 43%) and greatest species diversity landed. Herring and salmon fisheries, both historically iconic species for the BC fishing industry, have declined in recent years, yet are still very significant in terms of catch and value (42.2k tonnes, $85.1m), and unlike the year-round coastwide groundfish fisheries, mostly occur as intense concentrations of effort in time and location. Among the shellfish fisheries, both crab and prawn use trap gear for high-valued catch ($45m and $18m, respectively), involve many vessels, and occur across a large coastal area and an extended fishing season. The shrimp fishery uses mobile gear (bottom or beam trawl), also over a large area and extended fishing season. Most other shellfish fisheries are dive fisheries, with harvest plans that carefully manage the distribution of fishing effort in benthic locations where the species occurs.

TABLE 1. SUMMARY OF PACIFIC REGION COMMERCIAL FISHERIES.[2]

Commercial Fishery	# Active Vessels	# Fishing Trips	Vessel Days	Catch (MT)	Value (000's)
Groundfish Trawl (A)	41	735	3,532	32,557	$66,967
Groundfish Trawl (B)	10	212	318	67	$335
Hake MW Trawl	11	221	700	47,300	$9,107
Halibut	138	455	3,826	3,506	$45,883
Sablefish	22	120	1,003	2,390	$26,483
Lingcod	31	137	1,150	596	$3,417
Dogfish	5	14	118	163	$262
Rockfish (inside)	8	46	386	32	$141
Rockfish (outside)	44	193	1,621	610	$4,334
Herring Roe (Seine)				9,780	$3,234
Herring Roe (Gillnet)				4,717	$3,120
Herring (Food/Bait)				3,044	$861
Salmon (all)	809	16,989	12,135	24,700	$77,900
Albacore	117	702	3,393	1,700	$5,300
Shrimp	50	1,600	2,550	710	$2,200
Dungeness Crab	199	18,109	17,114	3,600	$45,600
Geoduck	39		492	1,400	$34,818
Prawn	152	3,648	6,232	1,100	$18,000
Green Urchin	13		165	136	$459
Red Urchin	40			3,605	$6,750
Sea Cucumber	32		751	620	$7,516

Recreational Fisheries

Tidal water recreational fishing in the Pacific Region is world-famous, notable for the spectacular outdoor experience and opportunities to angle for salmon, halibut, lingcod, many groundfish species, as well as crustaceans (crabs and prawns) and shellfish. The fishery is coastwide and year-round but more intensely concentrated in southern coastal waters during the summer months. Most of the recreational fishery effort occurs from private or chartered small boats, to a lesser extent from shore (15%), and a small amount (3%) by diving (Fisheries and Oceans Canada, 2010). Table 2 provides catch and effort data for the 2009 fishing year (Fisheries and Oceans Canada, 2016). These results estimate that most of the catch (40%) comes from west coast Vancouver Island, followed by the North and Central Coast (32%), while the majority of effort is from the Strait of Georgia, followed by the west coast of

[2] Source: DFO IFMP's (Fisheries and Oceans Canada, 2018d) were consulted for most fisheries except groundfish fisheries, where information is derived from Archipelago client reports. We used data from the 2015/16 fishery year except for herring which is from 2017. Catch values were obtained from the BC Ministry of Agriculture (2016).

Vancouver Island (North coast effort data are not shown). Additionally, this source reports a total of 291,250 tidal water angler licenses sold in 2009 (20% non-resident), with license revenue of about $6.1 million. The nationally-led five-year national survey for 2010 (Fisheries and Oceans Canada, 2010), uses different methodology and provides different estimates indicating a BC angler population of about 228 thousand, making 148 thousand trips for a total of 2.05 million days. Their survey estimates a total catch of about 3.3 million pieces, about half of which are kept. The same survey provides economic data, estimating direct expenditures by BC anglers at $367 million and other indirect investments that exceed this number. We were not able to locate any catch information on the sport charter component of the recreational fishery while this 'subfishery' is likely to have very different characteristics. A more detailed analysis of this information is beyond the scope of this paper, the information is intended simply to provide perspective on the overall magnitude of this fishery.

TABLE 2. CATCH AND EFFORT SUMMARY FOR 2009 BC TIDAL WATER RECREATIONAL FISHERIES (Fisheries and Oceans Canada, 2016)

Species	Catch by Region (Pieces)					Pacific Region Total
	North Coast	Johnston Strait	Strait of Georgia	Juan de Fuca	W/C Van Island	
Chinook Salmon	46,407	10,774	20,587	28,558	92,050	198,376
Coho Salmon	118,590	8,562	2,112	12,084	76,434	217,782
Pink Salmon	3,773	13,679	28,984	48,366	6,019	100,821
Sockeye Salmon	20,080	48	0	198	57,926	78,252
Chum Salmon	1,027	101	76	113	310	1,627
Subtotal Salmon	**189,877**	**33,164**	**51,759**	**89,319**	**232,739**	**596,858**
Rockfish (Various)	26,841	4,351	7,563	3,640	50,643	93,038
Halibut	33,749	4,972	4,748	959	27,117	71,545
Lingcod	16,220	1,200	3,086	808	10,671	31,985
Groundfish (Various)		1,187	11,043	2,678	808	15,716
Total All Species	**266,687**	**44,874**	**78,199**	**97,404**	**321,978**	**809,142**
Fishing Effort (# trips)	**n/a**	**16,277**	**75,774**	**48,856**	**70,275**	**211,182**

Aboriginal Fisheries

Indigenous peoples of Canada have a constitutional right to fish for food, social and ceremonial (termed 'FSC') purposes. This right of access supersedes other uses of the resource, excepting resource conservation. Since this right was clarified by the Supreme Court of Canada in 1990, DFO has taken steps to ensure FSC through the Aboriginal Fisheries Strategy, and locally through the Pacific Integrated Commercial Fisheries Initiative (PICFI). PICFI was specifically designed to, among other things, assist Aboriginal groups by increasing opportunity for fishing, enhancing resource management capacity and improving economic self-sufficiency. One of the goals under PICFI was to establish fisheries management agreements with Aboriginal groups that provide funding to develop enhanced accountability through fisheries monitoring and resource management programs. As well, fisheries provisions have been established in modern day treaties with six First Nations groups.

We were not able to find sufficient information to characterize the Aboriginal fisheries in terms of the catch and effort data. The harvest includes most of the same species fished by both commercial and recreational user groups. As well, since the early 1990s, the FSC harvest has broadened to include catch for commercial purposes. The FSC harvest can occur much like recreational fishing, or as a commercial fishery opening (demonstration fisheries). The most notable directed FSC fisheries are commercial salmon fisheries, open for holders of PICFI licenses and operating the same way as commercial fisheries with an allocation under the commercial TAC. In addition, DFO has strengthened Aboriginal involvement in commercial fisheries through license repurchase and transfer programs.

3 - Catch Reporting Tools

Commercial Fisheries

Of the three fishery types in the Pacific Region, commercial fisheries have the most comprehensive catch reporting tools in place. Table 3 provides a summary of the different catch reporting tools used with commercial fisheries in the Pacific Region. Abbreviations used in the table are explained within the text below. It is noteworthy that most fisheries have multiple catch reporting tools implemented, and there may be redundancy with certain types of information.

Table 3. Summary of Catch Reporting Tools Used in Pacific Region Commercial Fisheries (Acronyms are defined in the text).

Commercial Fishery	Catch Reporting Tools							
	Self-Reporting			Independent-Reporting				
	Slips	Logs	Hails	ASOP	EM	DMP	OGM	VMS
Groundfish Trawl (A)	Yes	Yes	Yes	Full		Full		
Groundfish Trawl (B)	Yes	Yes	Yes		Full	Full		
Hake MW Trawl	Yes	Yes	Yes		Full	Full		
Halibut	Yes	Yes	Yes		Full	Full		
Sablefish	Yes	Yes	Yes		Full	Full		
Lingcod	Yes	Yes	Yes		Full	Full		
Dogfish	Yes	Yes	Yes		Full	Full		
Rockfish (inside)	Yes	Yes	Yes		Full	Full		
Rockfish (outside)	Yes	Yes	Yes		Full	Full		
Herring Roe (Seine)	Yes	Yes	Yes	Part		Full		
Herring Roe (Gillnet)	Yes	Yes	Yes	Part		Full		
Herring (Food/Bait)	Yes	Yes	Yes	Part		Full		
Salmon (Seine)	Yes	Yes	Yes	Part			Yes	
Salmon (Gillnet)	Yes	Yes	Yes	Part			Yes	
Salmon (Troll)	Yes	Yes	Yes					
Albacore	Yes	Yes	Yes					Yes
Shrimp	Yes	Yes	Yes	Part		Part		
Dungeness Crab	Yes	Yes	Yes		Full			
Geoduck	Yes	Yes	Yes			Full	Yes	
Prawn	Yes	Yes	Yes					Yes
Green Urchin	Yes	Yes	Yes			Full		
Red Urchin	Yes	Yes	Yes				Yes	
Sea Cucumber	Yes	Yes	Yes					

Self-Reporting Tools

Commercial Sales Slips (Slips)

Commercial sales slips are produced by the first receiver at the time of a vessel offloading event. These records provide basic fishing information by vessel on offloaded species (usually by market categories), quantity, value, days fishing and other information. The sales slips are intended as a census of all commercial offload events, self-reported by the offloading facility. Sales slips are a standard reporting requirement of the Province of BC and have been required in all commercial fisheries for decades.

Logbooks (Logs)

Nearly all commercial fisheries require that the vessel operator keep a record of their fishing activities and catches in a logbook; and provide these reports to DFO according to prescribed reporting intervals. Logbook programs may also stipulate the time duration between the fishing event and when it is recorded. Logbooks vary by fishery, following a format specified in the license conditions. Most logbook programs are contracted to service providers who are responsible for issuing logbooks, collecting completed forms, inputting to a database, and providing finished datasets to DFO. Service providers cost recover these programs from the industry.

Most logbooks are in paper format and are subsequently input to a database. Electronic logs are becoming more prevalent and provide advantages of more structured data entry and wireless communication of entered data.

Hail Systems (Hails)

Hails are a verbal declaration made by the vessel, usually to an answering service, where data entry occurs with a structured, interview-led format. Requirements are often specific to the management requirements of a fishery and may include 'hailing out'- providing notification to start a fishing trip, and 'hail in'- notifying the completion of a trip and intention to land. Most hail programs are provided by a call answering service, coordinated by service providers with catch monitoring experience. Hail programs are usually cost recovered through industry.

Hails are required in most commercial groundfish and invertebrate fisheries, providing notification for dockside monitoring programs (when required) and also alerting DFO of vessel activity status. In fisheries where they are used, hails provide a full census of fleet activity.

Independent-Reporting Tools

At Sea Observer Programs (ASOP)

These programs involve the use of a trained fisheries technician to accompany the vessel on a trip to witness and document fishing operations. Observers are specifically trained for their data collection duties; they have no official enforcement role, the motto 'observe, record and report' is often used to define this role. However, as will be discussed later, there is little question that observers on fishing vessels have a significant deterrence effect. An observer program is complex with many program functions in addition to observers working at sea. This includes training, briefing/debriefing, deployment, data processing, equipment provision, and management services for the operational logistics. Observers are almost always deployed for the full duration of the fishing trip and their data collection is a comprehensive record of fishing operations for management and science purposes, to ensure compliance with regulations, and to collect biological samples.

The groundfish trawl fishery has a compulsory requirement for 100% fleet coverage with at sea observers, a program that requires a pool of about 50 observers for an annual total of about 3,500 sea days. The high coverage level is primarily intended to ensure compliance, but observers are also responsible for the detailed catch accounting, discard estimation and biological sampling required in this fishery. Among other Pacific Region fisheries, observers are also deployed primarily for data collection purposes but not at 100% coverage. For example, observers are required for herring food and bait (usually one observer per fleet group), and salmon net fisheries.

Electronic Monitoring Programs (EMP)

EM includes an integrated array of sensors, usually with video imagery, deployed on fishing vessels for the purposes of providing independent, verifiable fisheries information. EM programs generally include provision of hardware, services for installation and maintenance of EM equipment on vessels, services to retrieve and process image and sensor data, services to compile and report interpreted data to DFO, and management services to coordinate overall program operations.

EMP is often considered attractive because of its potential to provide independent at sea monitoring at a lower cost than with an ASOP but it should be noted that both tools have separate strengths and weaknesses for certain applications. In terms of costs, the main advantage of EM over observers is with the amount of labour required. Whereas an ASOP involves continual deployment of an observer for the entire fishing trip, a much lower labour investment is required for 100% at sea data collection in an EMP. The EMP has a further requirement to process raw image and sensor data after the fishing trip is complete, yet this can often be achieved in much less time than the vessel time at sea. Often, monitoring events of interest are a fraction of the total trip duration. For example, a typical fishing trip may last ten days, while the time required for net retrieval and catch stowage may only be 20 hours for the entire trip. It is usually not practical to place observers for just the monitoring events. An EMP uses productivity tools to efficiently review data sets much faster than real time. For example, fixed gear retrieval can often be reviewed three times faster than real time, and other monitoring objectives (gear deployment, mitigation practices, catch retention, etc.) at a small fraction of the elapsed time. Further, it may not be necessary to analyse 100% of the EMP data set. For example, since the entire trip is monitored, and fishers do no know which events will be reviewed the EM data set can be used as a powerful audit tool to ensure self-reported data meets prescribed quality standards. The ability to measure the quality of self-reported data through an audit process provides the opportunity to provide feedback and incentivize improvement.

EM is used in several of Canada's Pacific Region fisheries. In groundfish fixed gear fisheries, EM systems equipped with multiple cameras are used to 'monitor' 100% of every fishing trip, with the data set analyzed using the audit approach, described previously. The same approach has been used to verify compliance with catch retention requirements in midwater trawl fisheries. In the Dungeness crab fishery, the EM system automatically reads radio frequency identification (RFID) tags embedded on the trap and thereby provides a record of active traps by fishing area, date and time. The northern crab zone, Area A, also uses video to monitor practices associated with gear entanglements. EM is a compulsory requirement while the crab vessel is conducting fishing operations, hence it is a full census data collection effort. Crab fishery EM data analysis is a hybrid where the entire data set is examined for certain information (e.g. data completeness, confirmation of fishing locations), and a portion is examined in detail using an exception-based approach (e.g., examining imagery of trap haul events that have no associated RFID scan).

Dockside Monitoring Programs (DMP)

Involves trained fishery technicians to witness offload events primarily to verify that landed catch is sorted to species/grades and weighed correctly. Like ASOP, dockside monitoring programs include other program elements as well as observers at the dock. For example, programs include observer certification training, field staff deployment logistics, landings data processing and reporting, and operations management.

DMPs exist in many fisheries in BC, mostly those managed by individual quotas or catch shares, where it is important to accurately register landings by species in relation to individual license holder quota holdings. In many fisheries, offloading of catch while vessels are at sea is usually not permitted, hence dockside monitoring programs provide a practical way to independently monitor landed catch by vessel. In some fisheries the DMP also provides services such as biological sampling and product labeling. When required, dockside monitoring is compulsory for all offloads. DMPs not only ensure independent verification of offloaded catch, but also that these data are delivered to DFO in a specified format and timely fashion.

On Grounds Monitor (OGM)

On grounds monitors perform a similar role as observers, but on a fleet level. A few fisheries require an OGM to be present on the fishing grounds to provide direct oversight of fishing operations. These programs involve a chartered vessel, captained by a skilled fishery technician with comprehensive fishery knowledge to effectively coordinate fleet operations, gather and report fishery data and to coordinate with fishery managers.

OGM has been widely used in salmon net fisheries where a concentrated fishing effort takes place usually under fishery openings defined by time and location. The

OGM serves an important role of monitoring fishing location and compiling vessel catch reports. An OGM is also used in the geoduck and red sea urchin fisheries where fishing occurs on a very fine geographic scale. The OGM gathers vessel catch reports and oversees fleet fishing efforts with respect to specific bed locations.

Vessel Monitoring System (VMS)

While not a catch monitoring tool, VMS is a relatively low-cost, tamper proof satellite technology that provides real time reports of fishing vessel location. With higher position reporting frequencies (e.g., hourly) managers can infer vessel activity. This is a 'black box' technology that, once installed, is controlled and monitored remotely, usually by fishery managers or compliance officers. Other similar technologies include Automatic Identification Systems (AIS), a VHF based system reporting vessel positions to satellite and land receivers, then streamed onto public sites (e.g., https://globalfishingwatch.org/map/). Another emerging technology is iVMS, which is a cellular-based vessel reporting system, with the potential for lower costs, capable of larger data volumes, and best-suited for coastal fishing fleets (European Commission *et al.*, 2018).

VMS systems are used in two commercial fisheries, the offshore fishery for albacore tuna (only applies to vessels greater than 24m length, fishing west of 150^{o}), and the prawn fishery. EM systems provide a similar but more comprehensive data stream than VMS. Thus, all fisheries using EM should also be considered as VMS compliant although the EM data may not be available in real time.

Recreational Fisheries

With an angler population of nearly quarter million participants, each catching only a few fish a day, catch reporting tools have evolved very differently from those used in commercial fisheries. DFO has been using population survey methodology, similar to methods as those used in many recreational fisheries in North America. Because of the broad expanse of the fishery, the survey lacks a comprehensive methodology that applies to all species, areas and methods. Importantly in terms of the survey design, all Pacific Region tidal water anglers require an annual license and therefore the overall angler population is known and can be contacted. Also important is the requirement for recreational anglers to comply with catch reporting requests made by DFO. These two features form the basis from which to estimate the recreational fishery catch.

Self-Reporting Tools

Angler Logs

As a condition of license, all anglers are required to keep a written record of recreational catches, but this requirement is very limited in scope. This self-reported information must be recorded at the time of the capture event and is to be produced upon request, such as during inspection by a fisheries officer. Hence, these logs mostly serve the purpose of real-time compliance enforcement for catch reporting (i.e., are fishers recording the catches in their license?), rather than as catch information reported to DFO. Unless requested through the surveys described below, anglers are not required to report their catch information.

Fishing guides and sport lodges may voluntarily keep detailed logs of their activities and report these to DFO. There are also expanded reporting responsibilities for anglers who participate in the experimental halibut license program which enables access to commercial halibut quota. The extent of verification is unknown but likely low. We were not able to establish whether these data are included in the catch databases.

Annual Surveys

Through a contracted service, DFO conducts the Internet Recreational Effort and Catch Survey (iREC) (Fisheries and Oceans Canada, 2018b). Licensed anglers are randomly selected to provide a detailed record of their fishing activities during a specified period (usually a month). iREC data include a daily record of areas fished, fishing method, presence of juvenile anglers, catch, species disposition (kept/discarded) and other information. The information is reported on an online form. These data are unverified but are then assumed to be representative of the entire angler population and expanded to provide estimates of the entire fishery catch.

As a complement to iREC, DFO also carries out the Internet Annual Recreational Catch Survey (iARC) (Fisheries and Oceans Canada, 2018c). Through the same population of licensed anglers (but different from those selected for iREC), a random sample is selected to complete the iARC survey. iARC participants are requested to provide the catch records written on the sport fishing licenses (described above).

Five-Year Recreational Survey (Fisheries and Oceans Canada, 2010)

Separate from the survey noted above, DFO conducts a more comprehensive survey of recreational fisheries of Canada every five years. This nationally-coordinated mail-based survey effort is intended to assess the social and economic importance of recreational fisheries throughout Canada. The most recently published report is 2010; 2015 is listed as pending. No information was found that compares the local and national surveys.

Independent Reporting Tools

Surveys

As a complement to the iREC and iARC surveys DFO carries out creel surveys with trained interviewers to gather detailed fishing information and collect samples from anglers at landing locations during busy times of the season. As well, aerial surveys are conducted over selected coastal areas to provide time/area-stratified counts of recreational fishing boats to complement the catch rate data from creel surveys.

Aboriginal Fisheries

Catch reporting tools for Aboriginal fisheries are not well documented but appear to follow methods in both commercial and recreational fisheries. Under the PICFI program to transfer commercial fishing licenses to Aboriginal groups, catch reporting for commercial activities occurs in the same fashion as any other commercial trip in the fishery. In some instances (e.g. halibut longline) it is permissible to conduct both commercial and FSC fishing (i.e., food, social and ceremonial purposes) during the same trip. In this case, the FSC portion of the harvest is monitored in the same way as the commercial harvest but reported separately. In cases where FSC fishing activities are separate from commercial fishing activities, catch reporting occurs in a variety of ways, depending upon the resource type and governing body. While not known, it is probable that catch reporting tools are largely self-report methods where fishers are obligated to keep fishing records as a reporting obligation within the fisheries monitoring agreements. It is not known what, if any, catch reporting obligation exists with DFO, or if these data are publicly available as is the case with commercial and recreational data. We were not able to locate data on the DFO website from which we infer that no catch reporting data are in the public domain, as with the other fisheries.

4 - Monitoring System Design Considerations

Thus far, we have presented Canada's Pacific Region fisheries and catch reporting systems to highlight the diversity and complexity of the setting. Existing catch reporting tools vary by fishery according to different information needs, fishery characteristics, tool suitability, and available funds. These monitoring systems are the outcome of balancing tradeoffs between the quality, functionality, and cost of the different elements of a fishery monitoring system.

As outlined in the implementation steps, monitoring systems should be periodically reviewed to ensure that the information produced continues to align with the management needs of a fishery. When considering monitoring alternatives, we contend that there are a limited number of options for certain fisheries and there is no single 'cookie cutter' solution for a monitoring program design. This section explores the different catch reporting tools from an efficacy and cost-effectiveness perspective.

As mentioned in the Introduction, it is not the purpose of this paper to evaluate the appropriateness of the catch reporting tools in use, however, such a review should be an integral component in evaluating MCS programs. The premise for this discussion is that the information needs are defined (implementation step three) and the questions revolve around making the best choices to achieve those information needs (implementation step four).

Understanding the Fishery Characteristics

The scope of a monitoring system is often strongly informed by the fishery characteristics. This includes information about the fleet (number of vessels and vessel characteristics), landing patterns (ports of operation and landing characteristics), trip details (gear, catch method, fishing events and trip duration), and catch characteristics (species composition, quantity, retention and discard characteristics). This information helps to inform the program requirements, identify resource levels, and estimate costs. For example, the Pacific Region Option A trawl fishery with 41 active vessels, 735 trips and 3,500 fishing days will have very different logistical requirements than a crab fishery with 199 vessels, 18,109 trips and 17,114 fishing days, other differences aside. As well, fisheries that operate coastwide and land in several ports will have different program infrastructure requirements than those that are more limited in scale. The above information is useful to help determine the monitoring resources required to align with the fishery-specific operations. This level of detail about fishery characteristics enables a more detailed evaluation of a given tool for a fishery. In the example above, the same tool applied to these two fisheries will likely be very different in terms of cost and operational requirements. Similarly, recognizing that recreational fisheries with over 225,000 participants and two-million fishing days will not only define a monitoring program's scope, but will limit the range of feasible catch reporting tools. In addition, the geographic range of a fishery and seasonality of activities is also important to consider. The monitoring systems for a halibut fishery with similar effort and landings over a ten-month season will be very different than a seasonal salmon seine fishery, where 50-100 vessels may be involved in a single area for only a few hours.

Another important fishery characteristic concerns participant perspectives on the monitoring system. While we discuss compliance in a later section, basic cooperation and buy-in is important, even if compliance is high. Participant attitudes around the value of the information and the necessity for the monitoring program strongly affect effectiveness of all catch reporting tools. With self-reporting tools, the level of industry engagement directly determines the quality and timeliness of information. With independent-reporting tools, the level of engagement also affects data quality, but differently. Low industry cooperation can make it more difficult to achieve results, as observers are part of the catching, sorting and stowing process. Similarly, an EMP requires cooperation to ensure that core functions of the EM system remain operational (i.e. system power, cleaning camera lenses, and handling catch within camera views). With at sea monitoring programs, participants may reluctantly accept monitoring as a means to ensure that the non-compliant participants are monitored. For these reasons, the design and use of all catch reporting tools needs to consider participant attitudes and find ways to strengthen engagement and cooperation.

Choosing the Right Tools

As mentioned previously, catch reporting tools have strengths and weaknesses and are suited to different fishery application. Importantly, catch reporting tools vary in the kinds of data that they can provide or vary in the quality of the data they provide. A recent report by the Environmental Defense Fund (Lowman et al., 2013) characterized the capabilities of various tools to meet different information needs in the form of a fishery 'monitoring matrix'. Table 4 follows this format but has been modified to apply more specifically to Canada's Pacific Region fisheries. The matrix compares the different fishery information needs (rows) with the different catch reporting tools (columns), with cell shading to show the tool's ability to meet information needs. Cell shading follows stoplight colours, with green being most suited to red, being least suited. The matrix just considers if such information is possible, not whether it can be trusted. Rows are subdivided to reflect different types of fisheries. The matrix is generalized for both fishery information categories and monitoring methods, yet the approach is helpful in matching needs to their respective tools. For example, EMP and ASOP are the only methods effective across nearly all data needs, yet these two methods differ in their application. The former excels at confirming full retention (all catch loaded into the hold for shoreside validation) or catch composition for low volume catches. ASOP has more strength with higher, more diverse catch volumes where observers are able to subsample and distinguish similar looking species. VMS, while an independent tool, is only effective at providing spatial data, and DMP is very strong at differentiating species and recording weights but this is limited only to offloaded (retained) catch. The effectiveness of the self-reported tools will be conditional on the complexity of the information and the incentives to report accurately.

TABLE 4. FISHERY MONITORING MATRIX ADAPTED FROM LOWMAN ET AL., (2013). COLOURS REFLECT SUITABILITY TO MEET INFORMATION NEEDS USING GREEN TO RED FOR MOST TO LEAST, RESPECTIVELY. TOOL SUITABILITY DOES NOT CONSIDER NECESSITY FOR THE INFORMATION TO BE SELF REPORTED OR INDEPENDENT.

Information Category	Monitoring Objective	Fishery Characteristics/Data Specifics		Type of Catch Reporting Tool Used							
				Self-Reporting			Independent-Reporting				
				Slips	Logs	Hails	ASOP	EM	DMP	OGM	VMS
Discarded Catch	Full Retention	No Onboard Catch Sorting									
	Discarded Catch Composition	Low Volume/Singulated Catch						Singulated			
		High Volume	Single Target Species					Aliquot			
			Multi-species easy to Differentiate				Subsample	Aliquot			
			Multi-Species difficult to differentiate				Subsample	Aliquot			
Retained Catch	Retained Catch Composition	Low Volume/Singulated Catch									
		High volume catch handling	Single target species					Aliquot			
			Multi-species				Subsample	Aliquot			
		Species difficult to differentiate					Subsample	Aliquot			
Protected Species	Seabird, Turtle and Marine Mammal Interactions and Avoidance	Species Encountered									
		Handling Method									
		Release Condition									
		Discarded or Retained									
		Other Interactions									
		Mitigation Device Deployment									
Fishing Effort	Gear and Fishing Information	Spatial/Temporal by Fishing Event									
		Gear Characteristics									
		Trap Limits/Soak Limits						RFID required			
		Bait Characteristics									
		Economic data									
Catch Sampling	Biological Data Collection	Length, Sex (dimorphic)						Crew Required			
		Sex, Viability, Meristics, Reproductive Condition									
		Tissue Samples (age structures, DNA, gonads, stomachs, etc.)									

While Table 4 provides an assessment of tool suitability from the perspective of meeting the information needs, we must also consider a tool's suitability relating to fishery characteristics (fleet size, vessel suitability, catch methods, temporal/spatial aspects, etc.). To show this, Table 5 provides a matrix showing the potential application of each tool by fishery. Again, stoplight colours are used to reflect currently utilized (green), potentially suitable (light green), to low and not suitable (yellow and red, respectively). It is important to note that suitability simply reflects whether the catch reporting tool is an option for a fishery, not whether it is needed. We included both commercial and recreational fisheries, with the latter divided by individual and charter, reflecting the fact that charter operates at a scale where certain tools could be applied. Aboriginal fisheries are not specifically included but the commercial element would apply to the appropriate commercial fishery and the FSC element would more closely align with individual recreational fishing activities.

It is interesting to note from Table 5 that most of the catch reporting tools have already been implemented in fisheries where their application is feasible. There are few cases such as salmon and albacore fisheries where a tool is potentially suitable but has not been implemented. Therefore, with the exception of light green indicators, improvements to catch reporting systems in fisheries are more likely to be achieved through improvements to existing tools rather than application of new tools (when warranted). Again, this is just an assessment of the potential for catch reporting tool use in a fishery, not whether the tool is needed.

TABLE 5. CATCH REPORTING TOOL SUITABILITY IN RELATION TO PACIFIC REGION FISHERIES. SEE TEXT FOR EXPLANATION OF COLOUR SHADING.

Fishery	Catch Reporting Tools									
	Self-Reporting			Independent-Reporting					Angler Surveys	
	Slips	Logs	Hails	ASOP	EM	DMP	OGM	VMS	Creel	Internet
Commercial										
Groundfish Trawl (A)										
Groundfish Trawl (B)										
Hake MW Trawl										
Halibut										
Sablefish										
Lingcod										
Dogfish										
Rockfish (inside)										
Rockfish (outside)										
Herring Roe (Seine)										
Herring Roe (Gillnet)										
Herring (Food/Bait)										
Salmon (Seine)										
Salmon (Gillnet)										
Salmon (Troll)										
Albacore										
Shrimp										
Dungeness Crab										
Geoduck										
Prawn										
Green Urchin										
Red Urchin										
Sea Cucumber										
Recreational										
Individual										
Charter										

Determining Monitoring Program Costs

Second only to aligning the right tools with the information needs, cost is a significant and often primary factor in determining which tools can be employed. As mentioned previously, self-reporting tools are often relatively inexpensive and are already a routine element of fishery operations. Independent-reporting tools can be much more expensive because they involve dedicated investments of either people or technology to coordinate, collect and process catch data. In our experience, the cost difference is significant with independent reporting being as much as two orders of magnitude higher than self-reporting tools. Therefore, investment choices in catch reporting tools need to be strategic and carefully planned.

Once narrowed to the catch reporting tools appropriate to the information needs, there are a number of considerations to understand program costs. Catch reporting tools vary in cost according to their ingredient components, and the tools can be combined in various ways. We believe that this is an iterative design process which examines different tool integrations and their resulting cost, aimed at an optimization that best meets needs. Getting beyond basic 'ballpark' costing involves examining cost influences in the use of a tool for the specific application. Fishery-specific influences can create widely different costs among fisheries. As well, program costs can be strongly influenced by service delivery elements (i.e., the degree of adherence to timeliness, the level of detail and the data quality specifications), the program delivery method, and the cost recovery method. The following sections more fully describe cost influences for various catch reporting tools.

Cost Drivers

Catch reporting tools vary in cost because the program elements may differ from one another. For example, DMP costs are most sensitive to the number of landings monitored, whereas ASOP costs are sensitive to the total days that observers are deployed. Within each program there are usually several other operational elements that need to be considered.

Self-Reporting Tools

Sales Slips (Slips) - The cost is internalized within the commercial offloading entities and government agencies responsible for receiving and compiling these reports and represents essentially zero cost to fishery participants. The cost of a sales slip program is driven primarily by the total volume of offload events, and secondarily by factors such as the complexity of reporting information, the level of compliance by offload entities, and the data quality objectives for the information system.

Vessel Logs (Logs) - The main cost is data entry labour and the scaling element for paper logbooks is the volume of data created. Electronic logs differ since the data entry is made by the vessel operator. In this case, the main costs are the amortised technology cost and the data transmission costs. Both modes of data entry incur cost of data review and quality assurance, which is dependent primarily on volume and data structure complexity.

Hail Systems (Hails) - Hail services primarily involve phone answering and data entry labour, with scale directly related to the call volume. Rates charged vary by total call volume, the number of simultaneous calls, the information complexity, hours of operation and other service related issues.

Independent Reporting Tools

At Sea Observer Programs (ASOP) - The majority of program costs are associated with human observers deployed at sea. Overall program size affects the amortization of fixed costs. Fleet characteristics also influence costs as small, more weather-dependent fleets may have more lay days. Data service processing costs often scale to the number of trips and are strongly influenced by data volume and complexity. Like EM, ASOP program coordination costs are determined by the size of the program and service level requirements. Observer program cost is directly affected by fleet coverage levels; 100% coverage is usually the most costly of all independent catch reporting tools. Typically, an observer program cost is 3-6 times the daily observer wage for every day the observer is deployed.

Electronic Monitoring Programs (EMP) - An EMP, while functionally similar to an observer program, has a very different cost structure. The capital cost of EM equipment is a significant up-front cost, although the equipment tends to last for many years and the daily equipment cost may be a small fraction (<1%) of the total installed purchase price. EM systems are usually permanently installed on vessels as their portability is limited, hence their use is costlier in low coverage applications. EM programs also require technical support in the field, where costs are dependent upon factors such as the number of staff, number of ports, number of service events expected and service levels (response times, hours of service). Data services is a third area of cost, the main driver being the number of data review events, the volume and complexity of data collected, as well as service requirements (response times), percent of data reviewed and the complexity of the data compilation process. Finally, program coordination costs are determined by the size of the program and service level requirements. Given the multiple drivers at play –vessels, trips, active ports, data volume – there are several considerations to optimise costs for a given fishery application. Curiously, EM program cost estimation is often (incorrectly) focused on the capital cost of the EM hardware rather than careful consideration in designing the operational elements where the greater ongoing cost lies.

Dockside Monitoring Programs (DMP) - Dockside monitoring services are similar to an at sea observer program, but costs are tied to landing events and the number of offload hours rather than the days at sea. The main costs are directly related to the number of observer hours required per landing, which is influenced by the complexity of the landing event (size and composition). DMPs also require data processing and program coordination services. The cost for these program elements (per landing event) is determined by the overall program size, the information volume and complexity, the number of active ports, and the service level requirements.

On Grounds Monitor (OGM) - An OGM program is primarily the daily cost for the vessel and operator while OGM duties are performed. As well, there are fuel, communications (satellite phones) and deployment costs to consider. While the daily cost for a vessel and operator may be high, an OGM is usually deployed in areas where the fishing fleet is concentrated, hence the cost is spread across many vessels.

Vessel Monitoring System (VMS) - The largest single cost is the cost of the VMS unit, although, like an EM system, the equipment lasts many years and the daily cost is low. Hence the main cost for an VMS program is the satellite transmission costs which are tied to data volume or service package arrangements. Often the regulatory agency incurs the infrastructure costs of hosting the VMS data reports. Even at high transmission rates to provide hourly reports, the monthly cost for VMS is about $75.

Angler Surveys - It would seem the main cost drivers would relate to the proportion of the population sampled. In the case of iREC, iARC and 5-year surveys, this would relate to the number of reporting requests made of licensed anglers and follow up work needed to receive and process their reports. In the case of the creel survey, the costs would relate to the number of landing ports and hours surveying anglers. In the case of aerial surveys, this would relate to the amount of time spent conducting surveys. Similar to census-based methods there are costs associated with data complexity and follow-up efforts to receive reports. Unlike census methods, survey methodology has a lot more complexity in methodology to properly identify the sample to survey and to analyse and expand the results with minimal bias. Lastly, the issue of unverified self reported data remains for even the most well-designed angler survey if it does not contain a significant angler intercept component. Hence, the consideration of cost drivers for this tool should also include the investment requirements for on grounds inspections and compliance monitoring.

Service Delivery Considerations

As mentioned, there are several cost influences, separate from the tool itself, that must be considered in the application of the different catch reporting tools. Some service elements are intrinsic to the fishery (e.g., vessels, trips, days fished) and cannot be changed while others relate to design choices in how the methodology is applied, with choice to better align with the specific needs of the fishery.

Service Levels - While each catch reporting tool may have a specific methodological approach, there can be a lot of variability in how these tools are applied, or ‘service levels'. Service levels define when and where services are provided within a program, as well as the level of quality and how timely services are performed. For example, an at sea observer program may require that observers be available within six hours of the request in order to ensure that weather-dependent activities of the fleet are unaffected. Similarly, there may be requirements that all data collected from a monitoring deployment be processed and reported within a specific timeframe. In an EM program, there may be performance requirements that the EM system must operate 100% of the time, potentially forcing vessels to cease fishing and come to port when there is an equipment malfunction. These examples serve to illustrate how operational decisions have a direct impact on program operations and cost. Requiring staffing levels to ensure availability of services 100% of the time can lead to overcapacity during low activity periods. Hence it is important to examine service levels when balancing program performance, needs for operational flexibility, and program cost.

Feedback and outreach have been singled out as a key service element because of its importance. All catch reporting tools require the support and cooperation of program participants. It follows that consideration be given to the level of dedicated investments in processes that provide feedback to program participants, follow-up with individuals who have questions or may require assistance, and generally provide information to reinforce the value of their contributions to the overall program. Outreach builds participant support, expands program staff understanding of the fishery, and thereby strengthens the program and the value of the information. These initiatives are separate from operations-driven tasks and must be planned for in a program. The level of outreach or customer interaction is a direct investment within all catch reporting tools, serving to help enforce a standard of program quality, but also connecting to program participants to reinforce the importance and value of the information system.

Service Delivery – The service delivery method relates to the way catch reporting tools are provided to fishery participants. As mentioned, most catch reporting tools are outsourced to companies that specialize in the provision of these services. Fisheries and Oceans Canada has requirements to certify companies for the provision of monitoring services with programs contracted by industry (commercial fisheries), or the federal government (recreational fisheries). There are a wide range of service delivery arrangements and program tenures that influence the way these programs function. For example, tenures of 3-5 years allow service providers to reduce their fees because their infrastructure costs can be amortized with less risk than a similar project with annual turnover. There are many service delivery-related issues beyond the scope of this paper to ensure the program provides high quality data, cost effective service, services that mesh with operational requirements of the fishery, and a business environment that encourages professional monitoring services.

Cost Recovery – Cost recovery is the method by which revenue is obtained to fund the program. In the case of government funded programs, program fees are invoiced and paid on regular milestone payments. Industry funded programs are sometimes funded similarly to agency programs where fees are paid through an umbrella industry association, but more often, fees are paid directly by fishery participants. These different cost recovery methods can result in very different program requirements, sometimes with different behavioural impacts. For example, a program funded with monthly invoices will have much less administrative overhead than a program funded through hundreds of individual invoices for each trip or landing event. Furthermore, fee structures can be used to incentivise efficiencies and reduce costs. For example, DMP services billed at a flat rate per hour of service will have a lower total program cost that one billed at a flat rate per pound of offloaded fish because program users can reduce their costs through more efficient use of the monitoring services (e.g. being on time, having paperwork completed, offloading efficiently, etc.). When services are billed on pounds landed the users are given no incentives to use program services efficiently.

Fishery Compliance Influences

Illegal, Unreported and Unregulated, or IUU fishing is often considered in a high-seas context, conjuring images of pirate-like fishing vessels profiting from illegal operations in international waters. IUU however applies to all fisheries in some form and pertains to activities that corrupt catch reporting activities (Schmidt, 2005). IUU is many things including: fishing by unauthorized persons, intentional incorrect reporting of capture details (i.e. falsified species, amounts, locations etc.) to appear compliant, failure to report catch when required, or fishing when the reporting system is absent or inadequate. Ainsworth and Pitcher (2005) examined IUU for BC marine fisheries and considered factors that influence the discard, illegal and unreported catch, pointing out that there are no direct ways to measure IUU.

Kuperan and Sutinen (1998) provided a useful framework to describe compliance behavior in the context of the New England groundfish fishery. The authors believe that, in general, there are three categories of violators: those that are chronic, those that periodically violate when incentives are high and/or detection is low, and those that fail to comply because of accident or ignorance. In their view (for New England fisheries), the latter category is less common, and fisheries violations are mostly the result of a deliberate choice, rather than by accident. The decision to comply with a regulation is guided by both ‘instrumental’ and ‘normative’ motivations. Instrumental (also known as deterrence) is more of a simple economic motivation where violators seek to maximize return, and opportunities are viewed as a tradeoff between the risks of getting caught and the rewards of violating. In this case, risk incorporates the combined effect of detection, prosecution, and severity of the penalty, while reward can be both monetary (higher value, lower cost) or non-monetary (quality of the experience).

Normative motivations are related to the individual's sense of the legitimacy of the regulations and management process. The underlying elements of this motivation are: whether the rules are perceived as appropriate and fair, an assessment of whether compliance will make a difference, and the influence of peers. Irrespective of a low risk-high reward outcome, people may choose to comply with regulations out of a sense of moral obligation, but the level of compliance directly affects the sense of obligation. Importantly, normative motivations are influenced by perceptions rather than facts. If noncompliance is *believed* to be very high amongst peers, normally compliant people may not feel a strong obligation to comply. In fact, compliant behavior becomes a penalty because those who comply are receiving lower benefits compared to the non-compliant group. Finally, the authors point out that enforcement is a necessary component of all fishery management systems because there is always a small but persistent non-compliant element of the fishing population. In another study, King and Sutinen (2010) showed that the level of enforcement required to achieve compliance is lower if the normative elements have a high positive effect. Therefore, in addition to the deterrence effect, the success of enforcement investments is closely tied to improvements in normative motivations.

We believe that many of the instrumental and normative motivations described for New England also apply for Canada's Pacific Region, and likely most other industrial fisheries. Therefore, the level of participant compliance is a key design issue for many monitoring programs. As mentioned, there are often no direct ways to estimate compliance level, yet the perceptions of both fishers, resource regulators, and others is useful to identify key compliance issues and their associated risk to fishery management objectives. In fisheries reliant on self-reporting, fishers may have little incentive to report their legal or illegal activities if there is a low chance of detection. For this reason, it is important to assess the willingness of participants to comply in these types of fisheries. Fisheries with poor compliance may benefit from strategies to incentivize instrumental and normative behaviors, or through increased investment in independent reporting tools, but this is not always feasible.

In the case of fisheries reliant on independent-reporting tools, it is expected that participants will be compliant when monitored, provided that the tool is appropriate for the monitoring issue. However, it is naïve to assume that compliance will always occur with independent-reporting because human observers cannot be in two places at once, and cameras have blind spots, etc. Yet, in the context of all possible areas of non-compliance, we believe independent monitoring more often results in high compliance. A recent study of the BC groundfish trawl fishery provided an interesting analysis of observer bias and data quality. It indicated that discard data recorded by at sea observers was reliable, and the proportion of misreported discard weights was likely negligible relative to fishery needs (Grinnell, 2010). Independent reporting tools should be routinely examined for quality control purposes to minimize noncompliance effects.

Determining Fleet Coverage Level

Coverage level is defined as the proportion of the fishing activity monitored, with percentage of fishing trips often used as a proxy for activity. Coverage level is a key issue with independent-reporting tools in terms of cost and effectiveness. Overall, there is a direct relationship between total program cost and the coverage level, hence significant savings can be made if sampling can achieve reliable estimates. A partial coverage strategy ('sample-based' approach) is widely applied in many fisheries and it is suggested that coverage levels of at least 20% for common species and 50% for rare species provide reasonable bycatch estimates (Babcock and Pikitch, 2011). Less common are fisheries where 100% coverage is applied such as the BC groundfish fisheries, west coast US groundfish fisheries, and the Alaskan groundfish large industrial fleet (>125-foot vessels). Unfortunately, sample-based approaches may overlook certain aspects of noncompliance.

Many sampling designs attempt to control sample-induced biases (e.g. time, area, fleet segment, deployment logistics, etc.), but it is difficult to control non-sample bias effects, such as those caused by the monitoring method itself. It is widely known that independent monitoring changes the behavior of the vessels monitored. In social sciences this is termed the 'Hawthorn Effect' (Landsberger, 1958), which suggests that people perform differently when they are watched. In the fishery monitoring world this is termed the 'Observer Effect', where vessels are more likely to adopt a risk averse fishing behavior when an observer is present (Sampson, 2002; Benoît and Allard, 2009; Faunce and Barbeaux, 2011). Trawl skippers, for example, can catch vastly different species compositions though subtle changes in depth, time of day, state of the tide, or characteristics of the fishing gear that are not monitored (e.g. rigging of nets and trawl doors). As well, monitored fishing trips can be shorter or exploit low-risk areas to reduce the likelihood of undesirable catches. These differences may be too subtle for algorithms to accommodate which lump sample data at a much coarser scale and still infer that the sample data are representative. Thus, a partial coverage sampling approach only truly works with fisheries where compliance issues are minimal, or where monitoring has minimal effect on the vessel behavior.

In many cases, independent monitoring is specifically intended to improve compliance through the placement of human observers or EM to change the behavior of the monitored vessels. The reasoning being that fishers are more likely to adopt compliant fishing behavior if they are being monitored. The behavior changing effect is real for the portion of the fleet monitored but may have little effect on the unmonitored portion of the fleet. The result is that compliant fishing behavior may be limited to monitored vessels and it becomes difficult to characterize the non-observed portion of the fleet. Concerning discarded catch, not only may the non-observed vessels fail to comply, but the total impact on the resource by the fishery is underestimated because only data from observed vessels are available for discard estimation. Thus, partial coverage may provide unbiased estimates for some elements and very biased estimates for others. Furthermore, ongoing partial monitoring programs can become increasingly difficult to carry out because vessels selected for monitoring 'take the hit' while non-selected vessels are less inhibited in their activities. It is not uncommon that these partial coverage programs have higher rates of observer attrition, less fleet cooperation with observer deployments and poorer working conditions for observers. The observer becomes viewed as an unwanted burden, rather than as an asset for fishery data collection and improved management.

Other Design Considerations

Fishery monitoring systems benefit from a few other design elements that are applicable to many of the catch reporting tools.

Integration – Catch reporting tools are often integrated with one another with synergies greater than a single tool alone. For example, DMP can be coupled with ASOP to improve estimates of retained catch, allowing at sea monitoring to focus on discarded catch or other sampling responsibilities. Similarly, ASOP and EMP can be coupled so that observers are deployed for more strategic activities such as biological or catch composition sampling while EMP provides more cost-effective fleet-wide coverage for issues like catch at area and discard composition. Hail systems are often used to enable scheduling of DMP services but the pre-landing notification of fishing information through hails could also be used to enable spot sampling for those fisheries without a DMP.

Program Quality – Before considering investments in potentially more costly catch reporting tools, it is worth considering investments to improve the quality of the existing tools. For example, fisher logs have a reputation for being low quality, but rather than dismissing the potential information, investments could be made to improve the quality of the information, the timelines for reporting, and the speed with which this information is assimilated. The use of electronic fishing logs provides greater control in data entry format, direct access to time and position data and wireless transmission of these data to the agency. This technology also provides important metadata such as when the observations were reported relative to the event itself. In addition to technology, improvements to program quality can occur through further dialog with fishery participants on the methods used to estimate and record catch, as well as building knowledge in areas such as species identification. These efforts not only improve the quality of self-reporting but also reinforce the importance of these programs and encourage compliance by appealing to the normative motivations of fishers.

Technology – While technology has already been mentioned in the context of EMP and electronic fishing logs, it is noteworthy to mention that the increased availability of all types of technology should be considered in relation to catch reporting tools. Smartphones and tablets are becoming very widely used and provide a powerful data capture opportunity. GPS and gear sensors provide a much more precise definition of fishing activities. Similarly, RFID technology can provide gear specific identification, which can assist in gear inventory management and improved spatial precision. The availability of image capture through digital cameras, smart phones, etc. enables the documentation of all types of events such as unknown and/or rare species. It is important to consider the technology integration opportunities with different catch reporting tools, and how those opportunities could benefit specific fisheries.

Big Data - The information needs for fishery monitoring should be considered in the context of the grander information system that may develop as monitoring programs expand in scope and utilization. We may still be years away from the point where fishing fits into a larger universe of marine data, but many fishing operations have needs beyond catch reporting, such as vessel operations and product marketing (e.g. traceability). It is important to consider the potential broader uses as there may be substantial benefits to a holistic approach to marine monitoring if the information can serve multiple purposes.

5 – Discussion

Fisheries and Catch Monitoring Systems

This region-wide approach to characterize fisheries and their underlying monitoring systems is useful to better define the entire fishery system and the strength of the underlying information systems. Pacific Region fisheries are valuable from an economic, social and cultural perspective and the scope extends across hundreds of thousands of participants, and a large spatial and temporal range. The fisheries also span a wide effort-yield spectrum where commercial fisheries have fewer participants and higher yields, recreational fisheries have over twenty times more participants and lower yields, while Aboriginal fisheries contain traits of both. In addition, previous research contrasting commercial and recreational fishery impacts has shown that the differences between these two fisheries are not restricted to just effort and yield (Cooke and Cowx, 2005).

Our attempt to provide a snapshot of Canada's Pacific Region fisheries and their catch reporting systems was constrained by the availability of public information. Commercial fishery data was more recently updated, but inconsistent for certain types of information, particularly relating to spatial characteristics. Groundfish data were more comprehensive because Archipelago works closely with these fisheries. Recreational fishery data were incomplete and very dated (the most recent we could find was eight years old), with limited information on the underlying catch reporting systems. Recreational catches were reported in pieces while commercial is by weight, further complicating simple fishery comparisons. Aboriginal fishery information was even more challenging. We were not able to locate any publicly available catch or fishery data. The gaps in information could perhaps be filled through information requests to each of the responsible managers but we contend that basic information on these fisheries should be widely available to the public, who are the owners of these resources. Fishery data should adhere to a common standard of timeliness, format, accessibility and quality.

Catch reporting in Pacific Region fisheries is accomplished in various ways and most fisheries use multiple tools. As previously mentioned, the existing monitoring systems vary by fishery according to different information needs, fishery characteristics, tool suitability, and available funds. Commercial fisheries have the most comprehensive systems in place which is understandable given that these fisheries are more likely to achieve cost-effective data collection efforts. This contrasts with recreational fisheries with roughly two million angler days, catching about three million fish, half of which are released. Clearly, many of the monitoring options available to commercial fisheries would be ineffective for recreational fisheries.

Self-reporting tools are almost universally applied across all fisheries and are more common in fisheries where catch volumes are low. Whereas independent tools are more common in the higher volume, mixed species fisheries. Recreational fisheries are unique because scientific survey methods are used to estimate catch, which is common for fisheries with high participation rates.

Observers and EM are the only catch reporting tools available to independently monitor catch from fishing vessels at sea. Observers are suited to a wide variety of monitoring needs, yet issues of cost and vessel suitability to host an observer limits their use. EM is becoming more widespread because of its potential to be less expensive and its suitability across a wider variety of vessels. EM works best where data collection is systematic and with vessels that have high enough activity levels to justify the cost of the equipment. Observers are more adaptive to varying data collection needs and are more suited to low coverage or low activity fleets. As mentioned previously, observer programs carry high labour requirements because of the time observers are deployed at sea.

Independent at sea monitoring with 100% coverage levels occurs in just a few Pacific Region fisheries. As mentioned, 100% monitoring is achieved in the groundfish trawl and fixed gear fisheries using both Observers and EM, and full coverage using EM is also applied in crab fisheries, primarily for effort control. More commonly, fisheries carry out independent at sea monitoring with partial fleet coverage. There are often practical reasons that limit coverage (i.e., cost and logistical) even though coverage may not be representative and there may be information or compliance needs that require higher coverage levels. Without intending to challenge the appropriateness of these monitoring systems, the observation is simply that full fishery transparency through 100% independent at sea monitoring is not prevalent in Pacific Region fisheries, nor is it likely to be in the future.

Options for Improvement

The strength of fishery monitoring systems should be routinely evaluated, and improvement options considered on an ongoing basis. When improvements to the monitoring system are warranted, one or more of the following options should be considered:

- Introduce new tools (i.e., DMP, VMS),
- Improve the performance of existing tools,
- Increase the level of integration among the suite of tools used, and
- Strengthening compliance and participant confidence.

As noted earlier, most Pacific Region fisheries already use the catch reporting tools most suited to their characteristics and information needs, and examples of where new tools could be applied (light green shaded cells of Table 5) appear limited. Thus, improvements to Pacific Region fishery monitoring systems, if warranted, are more likely to be achieved through enhancements to existing tools and improved integration among tools. Several options were identified, including improvements to timelines, increased coverage levels (e.g., independent monitoring), greater emphasis on participant engagement, and the use of technology. With self-reporting being a key component for most fisheries and the only option for some, truthful reporting is essential since there is often little opportunity to verify reports or gather the same data independently. Therefore, self-reporting systems must incorporate a routine assessment of participant response bias and include investments in the instrumental and normative elements that motivate participant cooperation. Routine evaluation of information system quality and improved public access to timely fishery information are examples that could reinforce the trust in reliable catch data and the role that fishery participants have in this.

Technology provides several opportunities for improving catch reporting systems. With self-reporting systems, technology such as electronic logbooks can be used to improve the quality and timeliness of information. However, we note that electronic logs may not improve data quality unless participants have adequate species identification knowledge, follow systematic accounting methods, and are diligent in reporting these data accurately and timely. Otherwise, the electronic log simply becomes a more efficient vehicle for capturing and delivering poor quality data. Self-reported data quality can also be improved with integrated technologies such as gear sensors, GPS, weigh scales, and counting devices.

Technology can also be used to improve independent catch reporting systems. EM programs offer many ways to reduce costs, primarily through deciding where and how much labour is applied. The audit method for EM has fishery participants completing logbooks, and EM is only used to verify the accuracy of self reporting. Thus, the EM becomes a valuable tool for measuring data quality, thereby avoiding high analysis costs, and promoting trust among participants for the catch reporting system. In addition to labour savings, many predict that the cost of implementing EM technology will reduce due to other factors (Michelin *et al.*, 2018). If EM becomes more widespread, the cost of EM technology is likely to decline through economies of scale. Analysis of EM imagery remains one of the larger costs and artificial intelligence is widely seen as a tool to automatically process image data and reduce the cost of monitoring. While we share this view, we note that EM usually involves multiple video streams to monitor multiple objectives, so automation may prove to be more difficult, particularly in instances where there are motivations to misreport.

Separate from cost savings from technology advancements, significant savings to monitoring program costs can be achieved through improved participant cooperation. Based on our experience with the BC groundfish fixed gear fishery, harvesters were able to achieve significant savings by using EM technology and internalizing fishery data collection needs into routine vessel operations. With EM serving as an audit (rather than monitoring) function, analysis and other data processing costs declined. This quality management approach benefits fisheries where participants find value in demonstrating transparency and accountability. Such a motivation is more likely be driven through consumer demand for proof of sustainability, rather than through regulatory or management controls.

In our view, reductions in monitoring costs through these developments are most likely to occur beyond the next 10 years, rather than within the next few years, and these costs are not likely to be reduced by orders of magnitude, the cost difference that currently separates self-reporting from independent reporting tools. More likely, the magnitude of savings will be 40-60%, a level that is still too costly for many of Canada's Pacific Region fisheries, and most fisheries globally. Hence, we believe that cost will remain to be a significant challenge for fishery monitoring systems which can only be addressed holistically where all design options are considered.

Implications for the National Monitoring Policy

With respect to Canada's draft National Policy and Implementation steps (Fisheries and Oceans Canada, 2018a), it appears that there remains a gap between the policy direction and the guidance needed to determine the specific monitoring measures appropriate for different fisheries. A key challenge in maintaining or upgrading catch monitoring systems is their cost. Affordability, cost-effectiveness and risk level are identified as key considerations in determining the most appropriate catch monitoring system for a fishery. In our view, these terms are too subjective to be prescriptive for monitoring program planning purposes. As mentioned, monitoring program costs are usually paid by industry in commercial fisheries and by government in recreational and Aboriginal fisheries. With commercial fisheries, monitoring program costs directly impact their bottom line and fisheries have vastly different landed values (Table 1), yet these values only partially inform affordability and there will be differential impact across different participants. In the case of government-funded monitoring systems, affordability will also be guided by the value of the fishery, but 'value' is likely to be interpreted more broadly to encompass social, economic and political aspects. Therefore, we would predict that securing sufficient funding for catch monitoring systems will be a challenge regardless of whether the source is industry or government.

Another factor to consider is that cost-effectiveness may be difficult to establish because of the way monitoring program costs align with information quality. With independent tools being more costly than self-reporting tools, a doubling of the monitoring program investment may only result in a marginal improvement to data quality. When only partial coverage is applied (e.g. a fishery where 100% coverage is necessary, but not affordable), the increased investment may result in no improvement, and potentially less reliable information. The alignment between cost and benefit is further complicated because some tools depend on others. For example, introduction of at sea monitoring may also require dockside monitoring.

Similarly, risk is difficult to define in a way that informs investment choices in catch monitoring programs. Risk is often assessed in a qualitative manner which doesn't prescribe specific data quality measures. Further, it is not uncommon that resource risk is only evident when revealed through improvements to an information system. Hence, the level of risk may rise as more is learned about a fishery.

In many fisheries there are a limited number of catch reporting options available and the use of independent tools is difficult because of their relatively greater cost. The high level of integration among multiple tools and varying design elements across fisheries points to a need for a more systematic approach to monitoring program design. While it is recognized that monitoring needs should be assessed on a fishery by fishery basis, target and bycatch species in Pacific Region fisheries may span multiple fisheries. This stove-piped assessment approach may result in unintended consequences to participant trust and confidence when certain species have poor monitoring in one fishery and good in another. The approach may also preclude the development of partnerships, including external funding partners, that could assist with improvements to the catch monitoring for a resource group or region.

6 – Recommendations

We offer the following recommendations:

1. Chapters 2 and 3 of this report should be completed with updated information to provide a comprehensive description of Canada's Pacific Region fisheries and their underlying catch reporting systems. This regionwide summary should include all fisheries and user groups, and contain up to date catch information (i.e., within two years). This information should be annually updated, much like the Province of BC's Seafood Report (British Columbia Ministry of Agriculture, 2016). Furthermore, we suggest that this approach be applied across other regions of Canada.
2. Connected with #1 above, we believe that basic information on Canada's fisheries and associated catch reporting systems should be widely available to the public, who are the owners of these resources. Fishery data reporting should adhere to a common standard of timeliness, format, accessibility and quality.
3. As is evident from this report, it can be a difficult challenge to implement effective catch reporting systems in different fisheries – hindered not only by available funds, but also by difficult logistics, participant willingness, and by limited catch reporting tool options. We believe that different fishery monitoring design options, as outlined in Chapter 4, need careful consideration on a fishery-specific basis. Also important is the integration of the tools and building synergies with complementary information. This design work would be aided through the creation of regional catch monitoring working groups with expertise in different fisheries and catch monitoring systems. The Pacific Region's Monitoring and Compliance Panel could aid in enabling this process.
4. Both the Pacific Region and draft National Policy identify obligations of fishery participants toward catch reporting. Given that self-reporting is likely to persist in many fisheries, we believe that a strategy is needed to strengthen the 'social contract' for participant compliance with their catch reporting obligations. As noted in this paper, participant motivations to comply with reporting responsibilities are reinforced with a belief that the information is important and that their contributions matter. Expanding participant involvement with catch accounting not only improves data quality, but also builds participant awareness of resource impacts, strengthening these normative motivations.
5. Both Pacific Region and draft National Policy documents are helpful in a broad sense but offer little specific prescriptive guidance for designing catch monitoring systems. The terms 'risk', 'cost-effectiveness' and 'affordability'

are very subjective and do not provide compelling justification that would lead to either risk reduction or reforms to data poor fisheries. Further work is needed in this area.

6. Advancements in technology are likely to provide many benefits to fishery-dependent information systems. DFO should consider how it can help to foster technology development by supporting industry and practitioners in developing and implementing new monitoring systems and products. A recent report provides several ideas on ways to promote EM technology development (Michelin *et al.*, 2018).
7. Finally, Canada has been widely regarded as a leader at implementing innovative fishery monitoring systems. The leadership is not only with technology such as EM, but also philosophy underpinned by principles of transparency and individual accountability, as well as management using instruments like license conditions to provide flexibility for exigent issues. In 1998, Canada and the US created the International Fishery Observer and Monitoring Conference, a biennial international forum that promotes excellence in fishery-dependent data systems. Canada's support and participation in this conference and similar forums has waned over the last decade and we suggest more emphasis be given to these meetings through increased participation and collaboration.

References

Ainsworth, C. H., and Pitcher, T. J. 2005. Estimating illegal, unreported and unregulated catch in British Columbia’s marine fisheries. Fisheries Research, 75: 40–55. http://www.seaaroundus.org/doc/publications/books-and-reports/2004/Ainsworth-and-Pitcher-Dark-Side-of-Fishing.pdf (Accessed 25 September 2018).

Babcock, E. A., and Pikitch, E. K. 2011. How much observer coverage is enough to adequately estimate bycatch? 37 pp.

Battista, W., Romero-Canyas, R., Smith, S. L., Fraire, J., Effron, M., Larson-Konar, D., and Fujita, R. 2018. Behavior Change Interventions to Reduce Illegal Fishing. Frontiers in Marine Science, 5: 403. Frontiers. https://www.frontiersin.org/article/10.3389/fmars.2018.00403/full (Accessed 4 March 2019).

Benoît, H. P., and Allard, J. 2009. Can the data from at-sea observer surveys be used to make general inferences about catch composition and discards? Canadian Journal of Fisheries and Aquatic Sciences, 66: 2025–2039. www.nrcresearchpress.com (Accessed 5 March 2019).

British Columbia Ministry of Agriculture. 2016. B.C. Seafood Industry - Year in Review 2016. Victoria, B.C. 20 pp. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/agriculture-and-seafood/statistics/industry-and-sector-profiles/year-in-review/bcseafood_yearinreview_2016.pdf.

Cooke, S. J., and Cowx, I. G. 2005. Contrasting recreational and commercial fishing: Searching for common issues to promote unified conservation of fisheries resources and aquatic environments. https://www3.carleton.ca/fecpl/pdfs/Cooke and Cowx Biol Cons 2006.pdf (Accessed 25 January 2019).

European Commission, EU Member States, European Parliament, Council of the European Union, Advisory Councils, and EU Stakeholders. 2018. Outcomes of the workshop on digital tools for small-scale fisheries, Brussels, 4-5 December 2018. Brussels. https://ec.europa.eu/fisheries/press/outcomes-workshop-digital-tools-small-scale-fisheries-brussels-4-5-december-2018_en.

Faunce, C. H., and Barbeaux, S. J. 2011. The frequency and quantity of Alaskan groundfish catcher-vessel landings made with and without an observer. ICES Journal of Marine Science, 68: 1757–1763. Oxford University Press. https://academic.oup.com/icesjms/article-lookup/doi/10.1093/icesjms/fsr090 (Accessed 25 October 2018).

Fisheries and Oceans Canada. 2010. 2010 Survey of Recreational Fishing in Canada. Ottawa, Ontario. 27 pp. http://www.dfo-mpo.gc.ca/stats/rec/can/2010/index-eng.htm (Accessed 25 September 2018).

Fisheries and Oceans Canada. 2012. Strategic Framework for Fishery Monitoring and Catch Reporting in the Pacific Fisheries. 38 pp. http://www.dfo-mpo.gc.ca/fm-gp/peches-fisheries/fish-ren-peche/sff-cpd/overview-cadre-eng.htm.

Fisheries and Oceans Canada. 2016. Fisheries and Oceans Canada Pacific Region Recreational Catch Statistics. http://www.dfo-mpo.gc.ca/stats/rec/pac/index-eng.html (Accessed 25

September 2018).

Fisheries and Oceans Canada. 2018a. Draft Fishery Monitoring Policy Statement (Subject to Change) - Oct 2, 2018.

Fisheries and Oceans Canada. 2018b. Internet Recreational Effort and Catch (iREC) survey. http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/irec-iarc/index-eng.html (Accessed 25 September 2018).

Fisheries and Oceans Canada. 2018c. Internet Annual Recreational Catch (iARC) survey. http://www.pac.dfo-mpo.gc.ca/fm-gp/rec/irec-iarc/iarc-eng.html (Accessed 25 September 2018).

Fisheries and Oceans Canada. 2018d. Fisheries and Oceans Canada Pacific Region Integrated Fisheries Management Plans. http://www.pac.dfo-mpo.gc.ca/fm-gp/ifmp-eng.html (Accessed 25 September 2018).

Ganapathiraju, P. 2017a. Global Evaluation of Fisheries Monitoring Control and Surveillance in 84 Countries: Canada - Country Report. 12 pp. http://iuuriskintelligence.com.

Ganapathiraju, P. 2017b. Developing a Framework for Independent Monitoring of Compliance Data in British Columbia's Fisheries. 18 pp.

Grinnell, M. H. 2010. Evaluating the reliability and equitability of at-sea observer release reports in the B.C. offshore groundfish trawl fishery: Research project submitted in partial fulfillment of the requirements for the degree of Master of Resource Management. Masters Thesis: 111.

King, D. M., and Sutinen, J. G. 2010. Rational noncompliance and the liquidation of Northeast groundfish resources. Marine Policy, 34: 7–21. Pergamon. https://www.sciencedirect.com/science/article/pii/S0308597X09000529 (Accessed 25 September 2018).

Kuperan, K., and Sutinen, J. G. 1998. Blue Water Crime: Deterrence, Legitimacy, and Compliance in Fisheries. Law & Society Review, 32: 309. WileyLaw and Society Association. https://www.jstor.org/stable/10.2307/827765?origin=crossref (Accessed 25 September 2018).

Landsberger, H. A. 1958. Hawthorne Revisited: Management and the Worker, Its Critics, and Developments in Human Relations in Industry. Distribution Center, N.Y.S. School of Industrial and Labor Relations, Cornell University, Ithaca, New York 14850 ($1.75). https://eric.ed.gov/?id=ED024106 (Accessed 9 October 2018).

Lowman, D., Fisher, R., Holliday, M., McTee, S., and Stebbins, S. 2013. Fisheries Monitoring Roadmap: A guide to evaluate, design and implement an effective fishery monitoring program that incorporates electronic monitoring and electronic reporting tools. 74 pp.

Michelin, M., Elliott, M., Bucher, M., Zimring, M., and Sweeney, M. 2018. Catalyzing the Growth of Electronic Monitoring in Fisheries. Building Greater Transparency and Accountability at Sea. Opportunities, Barriers, and Recommendations for Scaling the

Technology. San Francisco, CA. 64 pp. https://www.ceaconsulting.com/wp-content/uploads/CEA-EM-Report-9-10-18-download.pdf (Accessed 22 January 2019).

Sampson, D. B. 2002. Final Report to the Oregon Trawl Commission on Analysis of Data from the At-Sea Data Collection Project. Newport, Oregon. 5 pp. http://people.oregonstate.edu/~sampsond/projects/edcp/.

Schmidt, C.-C. 2005. Economic Drivers of Illegal, Unreported and Unregulated (IUU) Fishing. The International Journal of Marine and Coastal Law, 20: 479–507. Brill. http://booksandjournals.brillonline.com/content/journals/10.1163/157180805775098630 (Accessed 2 October 2018).

The Minister of Justice of the Federal Government of Canada. 2016. Fisheries Act. http://laws-lois.justice.gc.ca/PDF/F-14.pdf (Accessed 28 September 2018).

