ARTICLE IN PRESS

Marine Policy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Marine Policy

journal homepage: www.elsevier.com/locate/marpol

Small-scale fisheries in Canada's Arctic: Combining science and fishers knowledge towards sustainable management

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ARTICLE INFO

Keywords:
Small-scale fisheries
Traditional ecological knowledge (TEK)
Stock assessment
Productivity-susceptibility analysis (PSA)
Arctic char
Data poor fisheries management

ABSTRACT

In remote and data-limited situations such as encountered in Arctic regions, traditional ecological knowledge (TEK) is an important and valuable information source. TEK from local fishers (fishers knowledge, FK) is highly relevant to fisheries management. The integration of FK in fisheries assessments remains complicated by the lack of tools to combine scientific and FK observations. This study implements a productivity-susceptibility analysis (PSA) for assessing the risk from fishing to fish stocks and incorporate FK in the assessment process. The PSA method consists of scoring productivity attributes of fish populations and susceptibility attributes affecting fisheries exposure and intensity. The method can be adapted to incorporate FK on two levels: (1) in the validation of biological data (indirect inclusion); and (2) in the definition and scoring of independent FK attributes (direct inclusion). Risk scores measured along the productivity-susceptibility gradient serve to identify areas and populations most vulnerable to fishing activities and formulate science advice for prioritisation and management. We apply the method to small-scale fisheries for Arctic char *Salvelinus alpinus* in Cumberland Sound, Baffin Island, Nunavut. These fisheries are key to food security and economic growth in Canada's Arctic territories, yet management remains complicated by data paucity; by the widespread distribution and biological complexity of Arctic char stocks; and by growing uncertainties related to climate change impacts on Arctic fish and ecosystems. This paper demonstrates the usefulness of the method for combining science and FK information to improve management advice for Arctic char stocks, and applicability to other small-scale, data-limited fisheries.

1. Introduction

Traditional ecological knowledge (TEK) has extensive value for developing sustainable resource use and conservation strategies [1–5]. This is especially true in remote Arctic regions, where TEK is often the most abundant and valuable information source. Small-scale fisheries for Arctic char *Salvelinus alpinus* are key to food security and economic growth in Canada's Arctic communities, yet their assessment and management remains complicated by data and accessibility constraints. Inuit fishers have detailed knowledge of Arctic char resources and their environments. This knowledge is readily available, generally exceeds the available scientific data in sample sizes and recurrence of observations, and requires to be integrated in stock assessments and management practice to ensure sustainable resource use and conservation.

Arctic peoples depend on ecosystem services for their subsistence and livelihoods, and maintain a detailed knowledge of natural resources and their environments. TEK in Arctic regions is implemented in various life sustaining activities and its validation has been based on the persistence of both people and culture in harsh Arctic environments [6,7]. In Canada's Arctic territories, the incorporation of TEK in environmental assessments and natural resources management is a policy requirement established by treaty or land settlement agreement and implemented in shared-management frameworks and responsibility between government, resource users, local communities and aboriginal groups [1,8,9]. As a result, TEK integration mainly occurs via representation by "bridging" organisations in the context of participatory, collaborative frameworks [10,11]. Direct integration remains marginal. Examples of studies that have engaged both TEK and science to understand aspects of Arctic ecosystems and environmental change include assessments of polar bear [6], migratory seabirds [12,13], fish [14] and marine mammals populations [2,15–19] – looking at seasonal movements, distribution, habitat preferences, abundance trends and/or incidence of disease. Other examples include the evaluation of long-term changes in snow and ice conditions as related to reindeer herding practice [20], and changes in local weather patterns [21]. In all cases,

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https://doi.org/10.1016/j.marpol.2018.01.016
Received 24 November 2016; Accepted 16 January 2018

Please cite this article as: Roux, M.-J., Marine Policy (2018), https://doi.org/10.1016/j.marpol.2018.01.016

qualitative TEK information was used to corroborate or invalidate empirical data and trends derived from independent scientific surveys (with a focus on describing similarities and differences between the two types of information); or to broaden research outcomes by introducing scientists to alternative perspectives. To our knowledge, practical examples of TEK inclusion in the science frameworks and quantitative tools used to inform species and environmental management decisions, are still lacking.

TEK and scientific data provide independent sources of information that can be combined to increase confidence and depth of knowledge [22]. Like scientific knowledge, TEK consists of evidential (empirical) observations and experimental information (i.e., interpretations of observations through testing and validation or refutation) [4,6,8]. Scientific knowledge is held to be neutral and objective (even despite increasing advocacy and potentially related bias), while TEK is framed within the cultural context that developed and holds it [6]. For this reason, TEK is commonly described (and erroneously dismissed) as anecdotal and subjective [3,4]. Combining the two forms of knowledge is feasible and highly desirable, but requires a clear definition of TEK relative to the study aims [23], and the identification of TEK components compatible with scientific process (i.e., the distinction between knowledge that has an empirical basis, versus knowledge potentially substantiating artefacts, and knowledge beyond time and space linked to identity, values, ethics, worldviews and philosophy [8,11]).

In this paper, we focus on fishers knowledge (FK) defined as the TEK held by Inuit fishers, which "has evolved through adaptive processes and has been handed down through generations" [24]. In this context, FK consists of factual, empirical and pragmatic (experience-based) observations on the biology and ecology of fish species, populations and ecosystems, as well as past and present exploitation patterns and management. This definition includes TEK categories 1 and 2 as proposed by Usher [1], but is exclusive of beliefs and values about fisheries and the environment and the knowledge system used to define them (Usher [1] TEK categories 3 and 4). In fisheries science, this type of FK information is increasingly recognized as an important class of knowledge that has yet to become successfully integrated within scientific practice [5,25,26].

Anadromous Arctic char is an abundant and predictable food source in Arctic environments, with historical and present-day cultural and economic importance to circumpolar Arctic peoples [27,28]. In Canada's Nunavut Territory, Arctic char populations are subject to non-negligible levels of subsistence harvest [29] and increasing opportunities for commercial fisheries development [30]. Emerging commercial fisheries allow for economic expansion in Inuit communities while sustaining traditional cultural ties to land- and harvest-based activities. Fisheries assessment and management processes to ensure sustainability however, remain complicated by several factors. These include (1) incomplete harvest statistics (mainly due to subsistence harvests being unreported); (2) problems of scale (owing to the larger number, widespread distribution and biological complexity of Arctic char stocks); and (3) growing uncertainties related to climate change impacts on Arctic fish and ecosystems. For these reasons, conventional approaches relying on estimates of population abundance and the setting of harvest levels are often impractical, both in terms of feasibility and applicability. Alternative risk assessment methods such as the productivity-susceptibility analysis (PSA) can provide useful tools to inform management decisions [30].

The PSA evaluates risk to a species or population as a function of its productivity (as this determines resilience and recovery potential) and susceptibility (as this determines exposure and the relative intensity of a threat). The method has been developed and applied to evaluate the risk from commercial fisheries to numerous and diverse bycatch species and targeted fish stocks [31–38]. Multi-species PSAs serve to rank species relative to one another and prioritise high risk species for management. Roux et al. [30] developed and applied a single-species PSA to 86 anadromous Arctic Char stocks from across Nunavut. Sufficient contrast in life history traits was available to differentiate stocks productivity. The method was useful for distinguishing between fishery areas having higher and lower risk (on a broad spatial scale) and between higher and lower risk stocks at the regional scale. Preliminary outputs however, were limited by incomplete and/or outdated biological information and a set of proxies for susceptibility attributes unlikely to capture the full complexity/adequately index fishery exposure and intensity. One way to refine PSA assessments of Arctic Char stocks is via the inclusion of FK information.

To this day, failure to incorporate FK data in fisheries assessment and management systems is in part due to inertia in favour of established scientific paradigms [2], but mainly also because the tools and guidance required to effectively combine FK and scientific data are still lacking [5,8,25]. In data-limited situations, the PSA method provides a flexible framework for data synthesis and integration that can incorporate region-specific information on fishery and management activity [34]. In this paper, we demonstrate how the PSA framework can also be used to combine FK and scientific knowledge in the evaluation of risk from commercial and subsistence fisheries to targeted fish populations.

We implement PSAs with FK in a case study of small-scale Arctic char fisheries from the Cumberland Sound Area, Baffin Island, Nunavut Territory, Canada. The PSA framework is used to directly incorporate FK data in the definition and scoring of a set of FK susceptibility attributes; and indirectly via the validation and weighing of productivity attributes based on correspondence between FK and scientific observations. A scenario-based approach is used to compare outcomes between PSA assessments performed with and without the inclusion of FK. The aims of this paper are to (1) demonstrate the value of the PSA method for incorporating FK in the assessment and management of a fishery resource; (2) evaluate and compare risk outcomes between science-based and combined science/FK assessments in small-scale fisheries; and (3) formulate recommendations for application in other data-limited, small-scale fisheries.

2. Methods

2.1. Case study area

Cumberland Sound is a large inlet approximately 300 km long and 65 km wide (on average), located in southeast Baffin Island, Nunavut Territory, Canada (Fig. 1). The Sound opens into Davis Strait and the Labrador Sea and is a rich habitat for marine mammals influenced by both Arctic (i.e. Baffin Island Current) and Atlantic (i.e., Greenland Current) water masses [39]. Its shoreline consists of several, deeply indented fjords and numerous river/lake systems that provide abundant habitat for Arctic char. Residents of Pangnirtung (population 1400), the only Inuit hamlet in Cumberland Sound, have a long tradition of traveling the fjords, following the migration of marine mammals, caribou and fish, and the making and breaking of the huge ice sheets that offer highways across the Sound [40]. Arctic char is the main food fish for the community, and was traditionally caught using stone weirs during the August migration from salt to freshwater, and in inland lakes during winter. Anadromous Arctic char spawn and overwinter in freshwater lakes and migrate to marine environments every summer for feeding. Details on the biology and ecology of Arctic char in the Canadian Arctic are available from Johnson 1980 [41]. Commercial fishing for Arctic char began in the early 1990s with the opening of *Pangnirtung fisheries Ltd.,* the community-owned and operated fish processing plant established in 1992. Nowadays, both subsistence and commercial fisheries for Arctic char are conducted using 140 mm mesh nylon gillnets set in fjords, coastal areas or near river mouths in late summer and under the ice in freshwater lakes during winter. Fisheries management for anadromous Arctic char in Nunavut follows a waterbody-by-waterbody strategy, whereby fish overwintering in headwater lake(s) of a given river/fjord system are assumed to represent a distinct biological stock.