Marine Policy 73 (2016) 235–243

Contents lists available at ScienceDirect

Marine Policy

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

Historical abundance of juvenile commercial fish in coastal habitats: Implications for fish habitat management in Canada

J. Scott P. McCain [a,*], Robert W. Rangeley [b], David C. Schneider [c], Heike K. Lotze [a]

[a] Department of Biology, Dalhousie University, Halifax, Nova Scotia, Canada
[b] Oceana Canada, Halifax, Nova Scotia, Canada
[c] Department of Ocean Sciences, Memorial University of Newfoundland, St. John's, Newfoundland, Canada

ARTICLE INFO

Article history:
Received 19 April 2016
Received in revised form
9 August 2016
Accepted 14 August 2016

Keywords:
Fisheries policy
Coastal zone management
Nursery habitat
Fish stock collapse
Historical baseline

ABSTRACT

An important component of science-based fisheries policy is the provision of habitat adequate for population renewal. In Canada, the Fisheries Act pays little attention to managing fish habitat, and was further weakened by changes enacted in 2012. Specifically, determining the role of fish habitat in contributing to fisheries and fish stock recovery is challenging when many stocks have severely declined and no longer occupy former habitats. This study compared the abundance of juvenile fish in coastal vegetated habitats before and after collapse or decline of groundfish stocks in Atlantic Canada. This comparison was done by compiling past studies that surveyed juvenile Atlantic cod (*Gadus morhua*) and pollock (*Pollachius virens*) in vegetated habitats across three provinces. Two studies were repeated, and one that already had post-collapse data was analyzed to quantify long-term changes in juvenile abundance. In all three cases substantial reduction in juvenile abundance coincided with declines in adult stocks. However, juvenile fish still occur in coastal habitats and could aid in adult stock recovery. The current version of the Canadian Fisheries Act requires presence of an ongoing fishery to trigger habitat protection. This is problematic as low fish abundance may lead to lowered habitat protection and potentially habitat degradation, with less or lesser-quality habitat for fish in the future. Thus, recommendations are made to repeal the 2012 Fisheries Act changes and enhance current fish habitat legislation. Using a precautionary approach for coastal fish habitat management, particularly in valuing its potential for fish stock recovery, would strengthen Canadian fisheries management.

1. Introduction

Fisheries have shaped global economies and vastly influenced marine ecosystems for centuries. Fisheries are also vital for food security, as fish provides more than 2.9 billion people with ~20% of their average per capita intake of animal-based protein, with the majority coming from marine capture fisheries [1]. Rebuilding overfished stocks could increase capture fisheries production and associated annual value by US$32 billion [2]. Effective fisheries management is therefore imperative. Habitat management is not traditionally seen as an important component of fisheries management, despite the known importance of habitat at various stages of fish life history [3,4]. Specifically, complex habitats mediate mortality of juvenile fish, and therefore play a role in supporting fisheries [5–11]. The protection and management of coastal ecosystems and complex habitats is an integral component of ecosystem-based fisheries management [12].

At a time when many commercially important fish stocks have been depleted [13], protection and restoration of juvenile habitats may be contributing factors for recovery. For example, population recovery of goliath grouper (*Epinephelus itajara*) in the south-eastern United States stemmed directly from their nursery habitat – mangroves [14]. Mangroves functioning as nursery habitat have also been shown to increase local fishery yield in the Gulf of California [11]. Nursery and juvenile habitat conservation can even exceed the effects of no-take reserves in coral reef fisheries [15]. Nursery habitat availability may limit the adult stock size and recruitment for some fish species [16–18], and nursery habitat degradation has been related to population decline of European flounder (*Platichthys flesus*) in the northern Baltic Sea [19]. While there is a wealth of evidence supporting nursery habitat function, directly quantifying the contribution of juveniles to an adult population continues to be challenging [20]. Furthermore, measuring the value of a nursery habitat solely by contribution to adult fish stocks has recently been criticized as an oversimplification [20,21]. Due to the challenges associated with directly quantifying contributions of nursery habitats to fisheries, the value of coastal nurseries in Canada for sustaining fish populations, as well as

* Corresponding author.
E-mail address: j.scott.mccain@dal.ca (J.S.P. McCain).

http://dx.doi.org/10.1016/j.marpol.2016.08.009
0308-597X/

aiding recovery, is largely unknown.

In Atlantic Canada, there have been strong declines of major groundfish stocks, namely Atlantic cod (*Gadus morhua*) and pollock (*Pollachius virens*) [22–24]. Due to the substantial depletion of adult stocks, juvenile abundance may also be low, such that the current value of coastal habitat as important juvenile habitat may be underestimated. This issue was addressed by using a historical approach, which is increasingly important for setting baselines of healthy ecosystems and fisheries for marine management [25–27]. The principal objective of this study was to quantify change of juvenile fish abundance in coastal vegetated habitats during periods of stock decline. Three historical surveys that quantified juvenile commercial fish abundance in vegetated habitats were identified, across three provinces in Atlantic Canada. These studies were then repeated using the same methodology, or analyzed from already available data from post-collapse surveys. The results are discussed in relation to concomitant declines in adult fish stocks and the effectiveness of Canadian fisheries management to protect fish habitat. Canadian fish habitat management is then compared with best practices for managing coastal nursery habitats in the United States, and recommendations are made for how to strengthen management of coastal zones and fish habitat in Canada.

2. Methods

Published studies were identified that quantified juvenile fish abundance of commercially important species in vegetated habitats in Atlantic Canada before the major collapse of groundfish stocks in the early 1990s. Because the goal was to compare juvenile abundances between time periods in which stock collapse or declines occurred, published data on both periods were needed or available past studies had to be repeated. To achieve the latter, detailed descriptions of the methods and results (i.e. raw abundance, or mean and standard deviation) were required. Three possible studies were identified: firstly, a highly resolved data set from beach seine surveys of juvenile cod in coastal habitats along the east coast of Newfoundland in the 1959–1964 and again 1992–1996 (Fig. 1) [28]. Two suitable dive survey studies were identified, one quantifying juvenile pollock in Brandy Cove, New Brunswick in 1989–1990 [29], and a second measuring juvenile Atlantic cod in vegetated habitats in St. Margaret's Bay, Nova Scotia in 1992

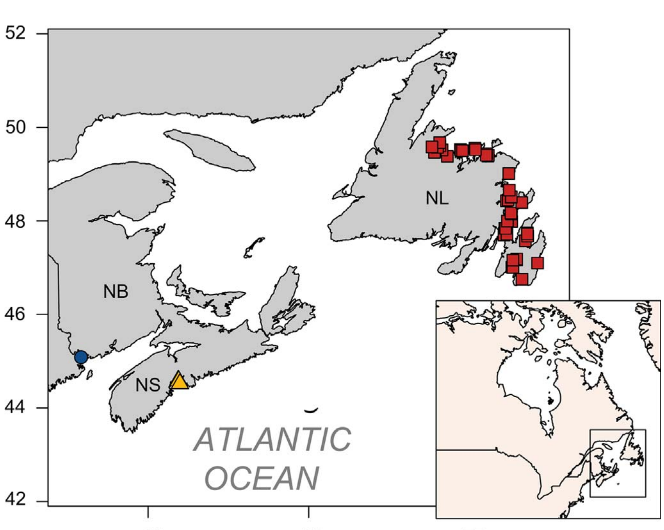

Fig. 1. Sites for case studies in Atlantic Canada: (1) juvenile cod along the east coast of Newfoundland (NL; squares), (2) juvenile pollock in Brandy Cove, New Brunswick (NB; circle), (3) juvenile cod in St. Margaret's Bay, Nova Scotia (NS; triangles).

(Fig. 1) [30]. These case studies are all possible coastal nurseries (e.g. the Newfoundland coast, in which strong year classes in the coastal nursery matched those in the offshore commercial fishery) [31], despite a lack of quantification of their contribution to fish stocks. In the following, there are details for each of the three case studies as well as the statistical analyses required for comparing past and contemporary abundances. A type I error rate of 5% was set as the criterion for statistical significance.

2.1. Case Study 1: Eastern Newfoundland – Atlantic Cod

A systematic series of beach-seine surveys was done along the east coast of Newfoundland from 1959 to 1964, and repeated after the collapse of Atlantic cod from 1992 to 1996 [28]. 84 different sites were surveyed from mid-September to late-October examining juvenile Atlantic cod abundance in coastal bays in the first series, known as the “Fleming survey”. Of the 84 sites sampled, 42 were sufficiently sampled to allow year to year comparisons (this eliminated the first year of the data series, 1959), and in any one year between 17 and 41 sites were sampled depending on weather and ocean conditions. For the purpose of this study, only sites with vegetation (described as “kelp” or “eelgrass” in the field notes) were analyzed, which totaled 35 sites (Fig. 1).

A 25 m bottom seine was used, where one person on land stands holding one hauling rope while the seine is let out 55 m from shore. Then, the seine is let out parallel to shore, and then the other hauling rope is towed into shore. This second hauling rope is received by another person on shore, with 16 m between individuals, and the ropes are simultaneously pulled in. The seine thus censuses 880 m^2 from the shore and the water column up to $\sim$2 m above the bottom. Full specifications, including mesh size, detailed dimensions, and slight modifications between time periods, are described in [32].

In the 1960 s, the number of sets at each site varied; therefore, the data were reduced to 42 sites where there were consecutive sets in many years, removing those years at sites where there were not two consecutive sets. Thus, the comparison of juvenile cod abundance was restricted to the first two sets of beach seines performed at each site. Abundances of cod in the two sets were summed, which represents an index of density. This seining method has high catchability [33], with higher than 95% retention of all fish in the path of the net. Once hauled in, all fish were counted and identified. Here, only the abundances of juvenile cod are used, classified into three age bins: age 0 ($<$97 mm), age 1 (97–192 mm) or age 2 ($>$192 mm), based on annually repeatable modes in the catch curves [28].

The “Resurrected Fleming Survey” (1992–1996) was initiated after the collapse of the Northwest Atlantic cod stocks. The seasonal timing, location of sampling, gear specifications, gear deployment, sampling design, and time of day sampled were all given attention to ensure comparability between the two periods [28,34,35]. Sampling bias was held constant between time periods by close matching of the sampling protocols. Sites that had direct habitat degradation due to development (e.g. wharf building) were not sampled in the “Resurrected Fleming Survey”. It is therefore unlikely that vegetation and habitat within the sites used in this analysis had changed dramatically due to anthropogenic causes.

Generalized linear models (GLMs) [36] were used to analyze changes in juvenile cod abundance. Every GLM used had a common set of categorical explanatory variables: time period (1960–1964 and 1992–1996), and year nested within time period. Year was set as a categorical variable; as temporal autocorrelation of cod abundance counts between years was negligible. Every age group of cod had overdispersed counts, with ages 1 and 2 also exhibiting zero inflated counts. Thus, for age 0 cod, a GLM with negative binomial error structure and a log link function was used.