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MPA regulations should incorporate adaptive management—The case of Gilbert Bay Labrador Atlantic cod (*Gadus morhua*)

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ABSTRACT

Although an important conservation tool, Marine Protected Areas sometimes fall short of intended goals; however, adaptive management can potentially improve their effectiveness. Efforts to develop an MPA in Gilbert Bay, Labrador, Canada, began in 1998 to protect the genetically distinct population of Atlantic cod (*Gadus morhua*) and its habitat. Population monitoring and research conducted in Gilbert Bay during 26 research trips over 14 years have documented significant population declines. The biomass declined by as much as 83% and research catch rates by 54% since Gilbert Bay became a MPA in 2005. Commercial fishing in adjacent waters was strongly correlated (Pearson correlation $r=-0.87$, $p=0.002$), with the declining trend in research catch rates. Tag recaptures from the commercial fishery ($n=105$) confirmed that fishing removed large adult Gilbert Bay cod that seasonally move outside the MPA. Evidence of the production of strong year classes even at low adult population levels indicate that the Gilbert Bay cod population has the potential to increase rapidly under appropriate adaptive management; thus improving MPA effectiveness. A relatively small change in the timing of commercial fishing in waters adjacent to the MPA would likely produce this result; however, inflexible MPA regulations, and poor co-ordination and agreement among differing fishery management processes and stakeholders has delayed the implementation of such a change.

1. Introduction

Marine Protected Areas (MPAs) represent a potentially important conservation and fisheries management tool worldwide [1–3], garnering significant international commitments [4,5] that ensure their continued implementation into the foreseeable future. The term "MPA" can include a variety of spatial management measures that completely or partially protect an area from a variety of activities, including fisheries. Because ill-considered MPAs may be detrimental e.g., [6] it may be misleading to promote them as approaches which are always likely to improve yields [7]. As Marine Protected Areas become increasingly popular, evidence suggests that not all will be successful [8], emphasizing the importance of improving MPA effectiveness through adaptive management when problems are identified. Adaptive management refers to the systematic acquisition and application of reliable information to improve natural management over time, which has been promoted as essential to management under uncertainty [9]. Adaptive management can however be hindered if regulatory procedures and processes act as a barrier to expedient implementation when problems are identified and changes are necessary.

Gilbert Bay, Labrador, Canada supports a local (resident) Atlantic cod population [10,11] which historically was managed as part of the northern cod stock complex in NAFO subdivisions 2J3KL [12]. Gilbert Bay was closed to commercial fishing for Atlantic cod in 1992, when the northern cod fishery collapsed and a moratorium on all fishing for Atlantic cod in NAFO Subdivisions 2J3KL was implemented. A small scale northern cod fishery reopened in 1998, but in 2000 fishing activities in Gilbert Bay was again stopped to prevent overfishing of the local cod population, and the bay was considered an area of interest to become a MPA. In 2005, Gilbert Bay became a MPA regulated under Canada's Fisheries Act and Oceans Act to protect the resident cod population and its habitat. Research on Gilbert Bay cod began in 1996 and the biological characteristics of the population was described by Morris and Green [11]. Gilbert Bay cod comprise the most discrete Atlantic cod population among those investigated in the western Atlantic [13–15], with the exception of relict Atlantic cod populations inhabiting meromictic lakes on Baffin Island [16]. Ongoing ultrasonic tagging studies that began in 1996 have investigated the movement patterns of cod in Gilbert Bay [10,11; Morris and Green, Unpublished data]. These studies identified size-specific migratory

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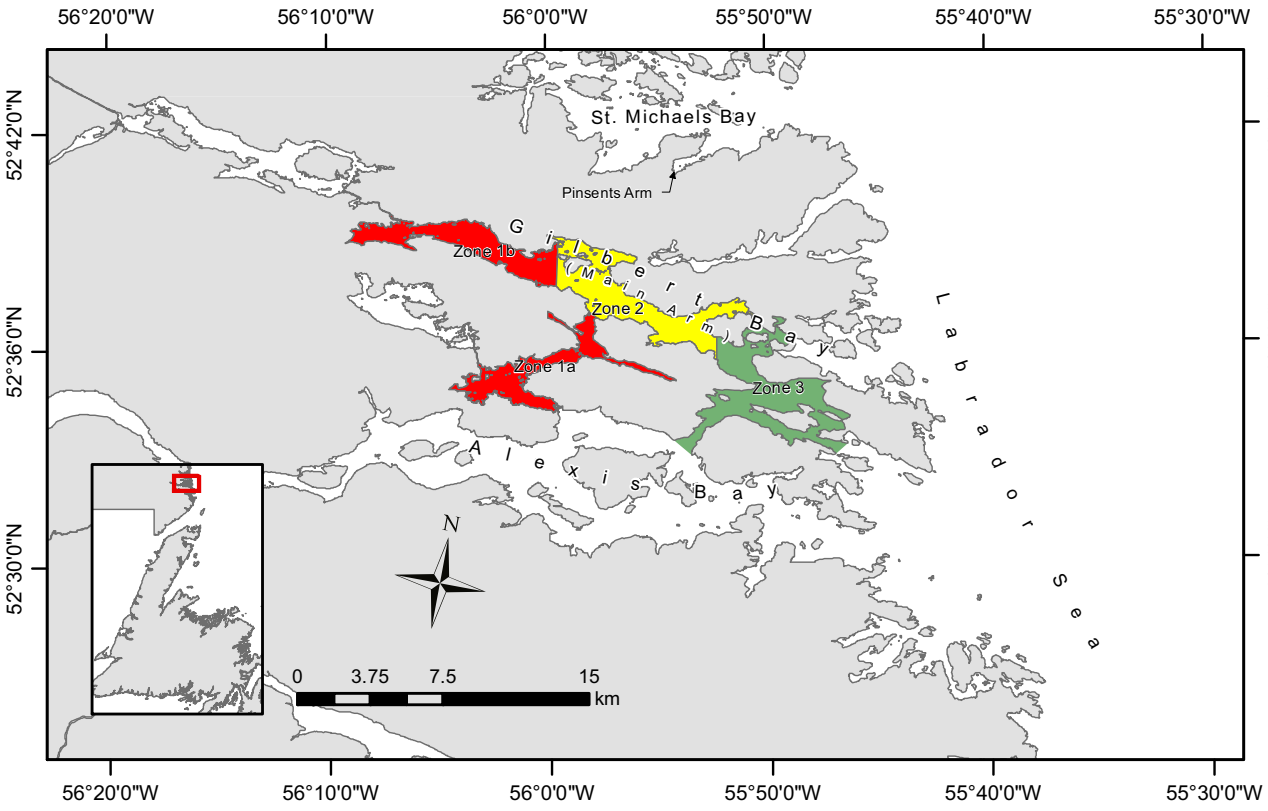

Fig. 1. Map of study area showing the Gilbert Bay MPA. Colors represent different MPA zones established for different regulations (see Canada Gazette [24] for regulatory details).

behavior and annual movements of Gilbert Bay cod, including into waters outside of Gilbert Bay, and their seasonal return to overwintering and spawning areas at the head of the bay. A very localized distribution spatially and temporally separated from other spawning populations of Atlantic cod is thought to explain their genetic distinctness [10,11]. Here we present the long-term (1998–2011) population trends in abundance, size distribution, and recruitment, and consider the effect of commercial fishing near Gilbert Bay on this population's biomass and size distribution. A case is made for implementing adaptive management decisions early in the MPA establishment process, to enable MPA improvements should management changes be necessary to reach conservation objectives as new information becomes available. The well-being of Gilbert Bay's distinctive cod population, and the current regulatory framework that impedes this, is discussed.

Table 1
Summary of angling research data collected in zone 1a, within Gilbert Bay during spring sampling periods, from 1998 to 2011.

Year	Sampling period	Rod hrs	Fish caught
1998	June 1–10	88	439
1999	May 20–June 2	168	598
2000	June 10–22	148	447
2001	May 29–June 7	84	306
2002	June 11–19	162	679
2003	June 4–10	128	333
2004	June 1–8	126	498
2005	June 1–19	222	675
2006	June 1–10	224	602
2007	June 1–10	224	457
2008	June 2–12	284	418
2009	June 2–11	274	491
2010	June 3–10	231	366
2011	June 1–9	165	408

2. Methods

This study was conducted within the Gilbert Bay Marine Protected Area and adjacent waters (Fig. 1). Annual sampling methods used to study population dynamics are described by Morris and Green [11]. Sampling spanned 26 research and monitoring trips to Gilbert Bay from 1998 to 2011 (Table 1), during which Gilbert Bay cod were sampled annually in late May-early June (spring), and again in early August (summer) from small boats 4–7 m in length. Spring monitoring targeted the spawning season, at which time most Gilbert Bay cod are concentrated at overwintering locations in MPA zone 1a (Fig. 1) [11,17]. Summer monitoring targeted a period after some Gilbert Bay cod (particularly adults) are dispersed from their overwintering area in zone 1a, but prior to their return.

Research catch data were collected by hook and line sampling, using a straight one ounce jigging lure (Gibbs Minnow Jig™). This method captured nearly all size classes of Gilbert Bay cod (fish greater than ~15 cm, and ages 2–18 yrs) from 33 sampling locations in zone 1a during each trip. Upon capture, each cod was measured for total length (TL) to the nearest millimeter and further examined by gently squeezing the abdomen to check for sexual maturity (identified by the presence of eggs or milt) and generally assessing overall fish condition. Healthy fish larger than 30 cm were marked with an external, individually numbered tag (Floy® t-bar tag) and released ($n=8213$) at the location of capture. This sampling provided relative trends in specific size classes at defined locations. Fish length was converted to weight based on relationships provided by Morris and Green [11]. The largest fish caught were comparable to commercial sizes, and commercial