Using Adaptive and Fisheries Management to Increase MPA Success: A Case Study of the Gilbert Bay MPA

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Submitted in partial fulfillment of the requirements for the degree
of
Master of Marine Management

at

Dalhousie University
Halifax, Nova Scotia

November 2016

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ABSTRACT

The Gilbert Bay Marine Protected Area (MPA) was established in 2005 with the purpose of conserving the genetically discrete Gilbert Bay cod subpopulation. However, following the implementation of the MPA the cod subpopulation has continued to decline. Tagging studies revealed that adult Gilbert Bay cod travel outside of the MPA boundaries during the summer to feed. This coincides with the migration of offshore northern cod into inshore waters, resulting in the mixing of the cod subpopulations. A small commercial northern cod fishery operates adjacent to the Gilbert Bay MPA, in the area where northern cod and Gilbert Bay cod congregate. It is speculated that because of by-catch, the commercial fishery removes adult Gilbert Bay cod from the small subpopulation. One possible method for improving the effectiveness of the MPA is using a combination of management measures both inside and outside the MPA boundaries. This paper evaluates the use of adaptive management inside MPA boundaries and fisheries regulations outside of the MPA boundaries. Adaptive management could be used to strengthen the scientific indicators used to monitor the MPA and guide the development of new regulations. Fisheries regulations could be used to mitigate the impact of the commercial fishery on Gilbert Bay cod. This could be accomplished by implementing regulations to dissuade fishers from fishing near the MPA or encourage them to use fishing methods that minimize impacts on the by-catch. Using these management strategies at the same time could circumvent each of their limitations resulting in a more effective MPA.

Keywords: Gilbert Bay, MPA, Cod, Fisheries Management, Adaptive Management

LIST OF ABBREVIATIONS USED

AOI	Area of Interest
DFO	Fisheries and Oceans Canada
FAO	Food and Agriculture Organisation of the United Nations
MPA	Marine Protected Area
NAFO	Northwest Atlantic Fisheries Organization
R-CPUE	Research Catch Per Unit Effort

ACKNOWLEGEMENTS

Special thanks to my supervisor Dr. Ramon Filgueira, for his invaluable knowledge and guidance.

CHAPTER 1 INTRODUCTION

The need for marine conservation measures has been showcased through a global decline in the abundance of commercially important marine species (Worm et al., 2006; Wroblewski et al., 2007). There are several laws and regulations that afford protection to marine species in Canada including the *Fisheries Act*, *Oceans Act*, *Species at Risk Act*, and general Fisheries Regulations (DFO, 2016a). When marine species meet the criterion for being threatened or endangered they can qualify for protection under these laws and regulations. This protection is also extended to habitats that are deemed unique along with marine areas of high biodiversity or biological productivity (Jamieson and Levings, 2001; Wroblewski et al., 2007).

In 1997, Fisheries and Oceans Canada (DFO) obtained authority to establish Marine Protected Areas (MPAs) following the approval of the *Oceans Act* (Jamieson and Levings, 2001). MPAs are regarded as a key tool in the conservation of marine biodiversity. In Canada, the purpose of MPAs is to conserve commercial species and protect non-commercial species (Wroblewski et al., 2007). The primary objectives of MPAs can be wide-ranging and include but are not limited to protecting pristine environments, endangered species protection, preserving recreational opportunities and developing sustainable fisheries (Jamieson and Levings, 2001). MPAs can include a wide variety of spatial management measures, which can completely or partially protect an area from a multitude of activities, including those of the fisheries (Morris and Green, 2014).

Northern Atlantic cod stocks have been historically, economically, and culturally important to the people living in Atlantic Canada. Europeans were likely fishing in the waters off Newfoundland since the late 15th century, but the earliest documentation of their fishing is from 1507 (Hutchings and Myers, 1995; Hutchings and Rangeley, 2011). Fishing technology advancements in the 1950s-1960s facilitated rapid growth of the commercial fisheries in Atlantic Canada (Hutchings and Rangeley, 2011). During the 1960s and 1970s cod stocks declined as a result of overfishing from distant water fleets from Europe (DFO, 2005). In 1977, Canada implemented its 200-nautical mile exclusive economic zone (Figure 1) (Hutchings and Rangeley, 2011). Following this, quotas were established by DFO for fish caught within Canadian waters. Despite the implementation of stricter fisheries regulations in the late 1970s, the Atlantic cod population continued to decline from the mid 1980s to the 1990s (DFO, 2005). Following this decline, a moratorium was placed on the commercial fishing of northern cod in 1992, which is still in effect today for offshore waters (Hutchings and Rangeley, 2011). A directed fishery within inshore waters was reopened for northern cod in 1998 and has remained opened except for a brief period between 2003-2005 (Hutchings and Rangeley, 2011).

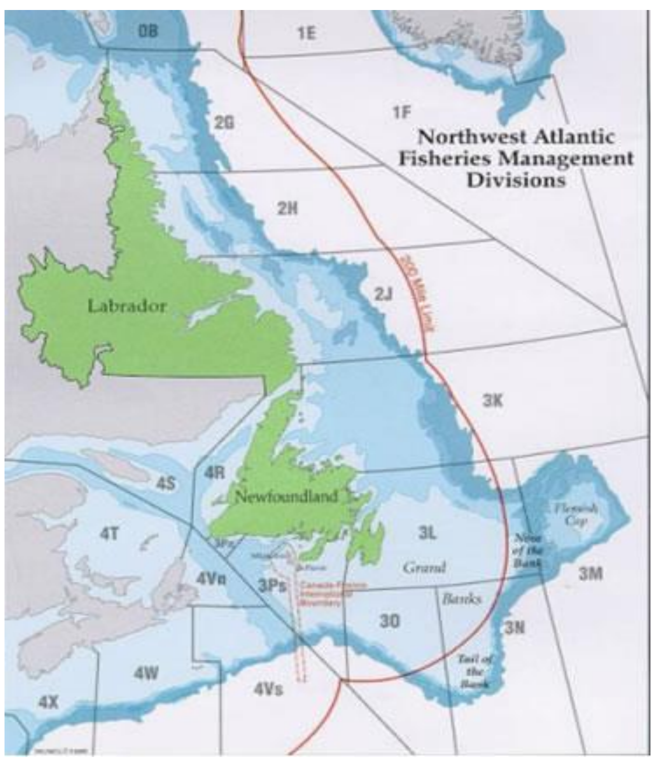


Figure 1. Map of the Northwest Atlantic Fisheries Management Divisions and Canada’s Exclusive Economic Zone (DFO, 2014a).

Northern cod range from southern Labrador, southeasterly along the Northeast Newfoundland Shelf, and include the northern half of Grand Bank (Hutchings and Rangeley, 2011). Templeman (1979) was the first to describe northern cod as the Labrador-East Newfoundland stock complex (Smedbol and Stephenson, 2001). Prior to its collapse in abundance, this stock complex had been identified as the largest cod stock in the north-western Atlantic (Smedbol and Stephenson, 2001). Mark-recapture studies have indicated that this stock was composed of several partially isolated subpopulations (Templeman, 1979; Lear, 1984; Smedbol and Stephenson, 2001). Historically, a large portion of northern cod would migrate from offshore waters into inshore waters off the coast of Newfoundland and Labrador during the summer (Lear, 1984; Morris and Green, 2002). The purpose of this migration was to feed before returning to offshore waters in the fall to overwinter and spawn (Lear, 1984; Morris and Green, 2002). This migration still occurs today but in much smaller numbers off the coast of Labrador (Morris, 2016 personal communication). It was suggested by Templeman (1979) that the small subpopulations would undergo migrations resulting in the exchange of individuals but most cod were retained within their original boundaries or the subpopulation (Smedbol and Stephenson, 2001). In addition to the migrating northern cod, it was suspected that a resident cod subpopulation existed that overwintered and spawned in Gilbert Bay (Figure 2) (Morris and Green, 2002).

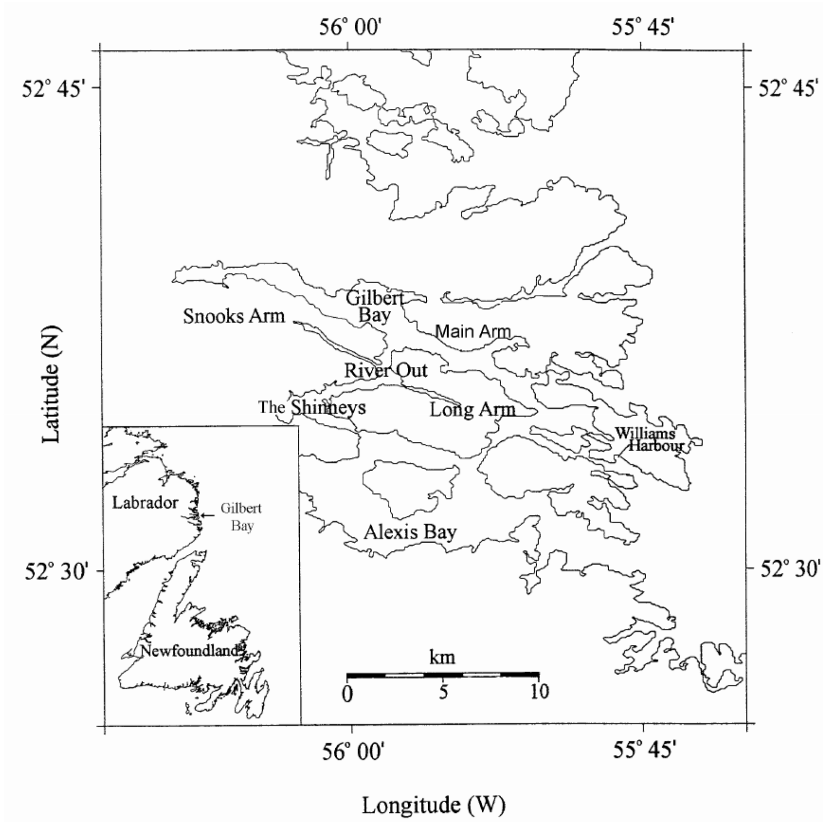


Figure 2. Map identifying the location of Gilbert Bay, Labrador (Green et al., 2004).

Subsequent studies on the movement patterns (Green and Wroblewski, 2000) and biological characteristics (Morris and Green, 2002) of the resident cod subpopulation in Gilbert Bay revealed that they were both visually and genetically distinct from other northern cod populations (DFO, 2013a). Due to their golden/brown colouration these cod are commonly referred to as “golden cod”. Tagging studies indicated that adult Gilbert Bay cod travel outside of the bay during the summer months, mixing with the northern cod in inshore waters (Morris et al., 2014). The resident Gilbert Bay subpopulation never supported a large fishery which at the time rendered them inconsequential from a management perspective (Lilly, 1996; Morris and Green, 2002). However, following the collapse of the northern cod fishery in the 1990s, the largest densities of cod have been identified in a few inshore locations (Shelton and Healey, 1999;

Morris and Green, 2002). This resulted in increased commercial interest and therefore fishing pressure on inshore areas such as ones frequented by Gilbert Bay cod.

The offshore cod populations failure to recover following the moratorium emphasizes the importance of protecting the genetically discrete resident inshore subpopulation (Morris and Green, 2014). Following the re-opening of the inshore cod fishery in 1998, communities and fishers expressed their concern over declining numbers of Gilbert Bay cod (DFO, 2010). In 1998, DFO began their first round of consultations to determine if Gilbert Bay was a suitable candidate for the designation of MPA (DFO, 2013a). In October 2000, Gilbert Bay was officially declared an Area of Interest (AOI) by DFO which provided the area with protective measures under the *Fisheries Act* (DFO, 2010). Biophysical and socioeconomic evaluations were also done to determine the potential for secondary advantages of MPA designation (DFO, 2013a). In accordance with Section 35 of the *Oceans Act*, approximately 60 km^2 of Gilbert Bay was designated as an MPA on 11 October, 2005 (DFO, 2013a). This made it the first MPA in eastern Canada's subarctic coastal zone (Wroblewski et al., 2007). Its purpose is to conserve and protect the genetically unique cod subpopulation in conjunction with providing indirect protection to other species and their habitats (DFO, 2013a). However, after nearly 11 years of being under the protection of the MPA the resident cod subpopulation has been declining (DFO, 2010; Morris and Green, 2014).

1.1 The Management Problem and Research Questions

Despite designating Gilbert Bay an MPA in 2005, the population has continued to decrease (Morris and Green, 2014). Since 1998, five scientific indicators have been used to report on the status of Gilbert Bay cod (Table 1, Morris and Green, 2002).

Table 1. Scientific indicators used to monitor the status of the Gilbert Bay cod subpopulation (Morris and Green, 2002).

	Scientific Indicators Used to Monitor Gilbert Bay Cod
1	Recruitment of age 0 pelagic juvenile abundance
2	Recruitment, relative abundance, and year class strengths based on age 2, 3, and 4 year old Gilbert Bay cod
3	Research Catch per Unit Effort
4	Movement patterns in relation to population demographics and MPA boundaries
5	Localized commercial, recreational, sentinel, and Indigenous catch rates and fishing effort

These indicators are collected on an annual basis and have revealed a loss in reproductive individuals from the Gilbert Bay cod subpopulation (Morris and Green, 2014). This has sparked an urgency for effective management intervention (Morris and Green, 2014). However, making changes to the management strategies in the Gilbert Bay MPA has been a slow process. The management questions that will be addressed in this paper are:

a) "Would an adaptive management framework improve the effectiveness of the Gilbert Bay cod MPA?"

b) "Can Canadian fisheries regulations be used to significantly reduce Gilbert Bay cod mortality when they travel outside of the MPA boundaries?"

Adaptive management is becoming an increasingly important model for commercially valuable fish stocks (Morris and Green, 2014). It creates a structured framework that facilitates effective decision-making while learning about and resolving uncertainties that impact management decisions (Southwell et al., 2016). In this paper, the incorporation of new scientific knowledge into current management strategies for the Gilbert Bay MPA are explored. First, an evaluation of the current management plan for the MPA will be conducted. Based on this evaluation, an adaptive management framework for the Gilbert Bay cod subpopulation will be constructed. This new framework will aim to allow managers to incorporate new scientific knowledge into management strategies within a short period of time.

Tracking research on Gilbert Bay cod implanted with acoustic transmitters confirmed that individuals will seasonally travel outside MPA boundaries (Morris et al., 2014). Therefore, this paper will also review fisheries regulations such as: quota on by-catch, gear restrictions, and changes to the fishing season. The review will help to determine if these regulations could be used to reduce mortality of adult Gilbert Bay cod when they travel outside of MPA boundaries. The pre-existing structure of fisheries management allows yearly decisions to be made in regards to which regulations will be imposed, amended or revoked. This may help to bridge the management gap between the MPA and the fisheries.

CHAPTER 2 MATERIALS AND RESEARCH METHOD

2.1 Gilbert Bay Overview

Gilbert Bay is located on the southeast coast of Labrador (52°34.9’N 56°01.25’W), approximately 300 km from Happy Valley-Goose Bay (Figure 2). It is a narrow inlet with two small channels that open into the Labrador Sea. The two principal communities located in the vicinity of Gilbert Bay which are Port Hope Simpson and William’s Harbour. Port Hope Simpson is located about 20 km from Gilbert Bay and has a resident population of approximately 500 people (DFO, 2013a). William’s Harbour is located at the mouth of Gilbert Bay, about 35 km east of Port Hope Simpson and has a resident population of approximately 17 people (DFO, 2013a).

Gilbert Bay is 25 km long, 1-3 km wide, and the depth of the upper portion of the bay is typically 20 m or less while the outer bay is approximately 80 m (Wroblewski et al., 2007). Two major rivers empty into the bay (Shinney and Gilbert), each contributing to a major inflow of freshwater during spring thaws (Morris and Green, 2002). Two waterways (Winnard Tickle and Williams Harbour Run) join Gilbert Bay to the Labrador Sea. It is the southward flowing

Labrador Current that dictates the oceanographic conditions of the outer bay (Wroblewski et al., 2007). From mid-December until mid-May land-fast ice completely covers the bay (Morris and Green, 2002; Wroblewski et al., 2007). The bay has the geographical features of both a shallow fjord and estuary (Wroblewski et al., 2007). Several key biophysical drivers have been identified in Gilbert Bay. These drivers include, a number of shallow sills with depths of 5m separating sections of the bay, several restricted arms within the bay, a large stratification of temperature and salinity gradients, and a short ice-free season (DFO, 2013a). These biophysical features are speculated to have a strong influence over the life history of the resident cod in Gilbert Bay and are thought to play a critical role in retaining their eggs and larvae within the bay (DFO, 2013a).

A broad range of marine species have been identified in the waters of Gilbert Bay. This includes but is not limited to, shellfish (e.g. Icelandic scallop), demersal fish (e.g. Atlantic cod), pelagic fish (e.g. capelin), anadromous fish (e.g. Atlantic salmon), marine mammals (e.g. harp seals), waterfowl (e.g. common loons) and aquatic plants (e.g. eelgrass) (DFO, 2013a). Numerous coralline algae beds have also been identified within Gilbert Bay, functioning as crucial habitat for several marine species (DFO, 2013a). High levels of biodiversity in addition to the biophysical drivers result in an ecosystem that is complex and challenging to fully understand.

Historically, Gilbert Bay cod were managed as a part of the northern cod stock complex in NAFO Division 2J (Morris and Green, 2014). Within NAFO Division 2J there is a commercial groundfish fishery, a recreational groundfish fishery, and an Indigenous component (food, social, and ceremonial) to the fishery (DFO, 2014a). When the northern cod fishery collapsed in 1992 a moratorium was implemented for all Atlantic cod fishing including fishing within Gilbert Bay (Morris and Green, 2014). In 1996, research on the biological characteristics of Gilbert Bay cod began (DFO, 2010) which were then described by Morris and Green (2002). Resident Gilbert Bay cod were found to be one of the most genetically discrete Atlantic cod subpopulations in the western Atlantic (Morris and Green, 2014). They are rivaled only by the Atlantic cod subpopulation in the meromictic lakes on Baffin Island (Morris and Green, 2014). Since 1998, scientists have conducted annual population surveys on the Gilbert Bay cod subpopulation. During this time a small-scale fishery reopened in Gilbert Bay but was closed in 2000 to prevent overfishing of the resident cod subpopulation (Morris and Green, 2014). The closure in 2000 corresponded with Gilbert Bay becoming an AOI for MPA designation.

2.2 Biological Characteristics and Life-History of Northern Cod

The developmental stages of Atlantic cod include: the egg stage, larval stage, juvenile stage and the adult stage (COSEWIC, 2010). A high degree of variation exists in the duration of each developmental stage depending on the cod population in question (COSEWIC, 2010). Generally, Atlantic cod live for less than 3 decades and can grow up 2 meters in length (Stanley et al., 2015). Generally, sexual maturity occurs when cod reach sizes greater than 35 cm (Stanley et al., 2015). Studies have shown that cod populations inhabiting relatively warm waters (Georges Bank, off the state of Maine) reach maturity at 2 to 3 years of age (COSEWIC, 2010). This is much earlier than the cool water cod populations (Northeast Newfoundland Shelf, eastern Labrador, and the Barents Sea) which reach maturity between 5 to 7 years of age (COSEWIC, 2010). They are broadcast spawners that are reproductive for many years, a large female can release millions of eggs in a single year (Stanley et al., 2015). The number of eggs a female cod produces typically increases with body mass as a power function (COSEWIC, 2010). Spawning typically occurs in the spring and summer at temperatures between 4 and 7°C (Brander, 2005;

Righton et al., 2010; Stanley et al., 2015), but it can occur within a temperature range of -1.5 to 12°C (Brander, 2005; Geffen et al., 2006; Stanley et al., 2015).

Spawning occurs in Atlantic cod over a period of three months or less at depths that range from tens to hundreds of meters (COSEWIC, 2010). Cod eggs develop in the water column and remain pelagic as larvae (Stanley et al., 2015). For the first few days post-hatch, the larvae obtain nourishment from their yolk sac. When the yolk sac is used up the larvae feed on phytoplankton and small zooplankton in the top 10 to 50 meters of the water column (COSEWIC, 2010). When they reach 20-40 mm in length, typically in the summer or fall, they settle to a benthic habitat and are considered juveniles (Stanley et al., 2015). Juvenile cod stay in this benthic habitat for the first 1 to 4 years of their life (COSEWIC, 2010).

Settlement areas have a broad range of characteristics. They vary from being in shallow coastal waters (< 10 m to 30 m) to waters in offshore banks (50 m to 150 m) (COSEWIC, 2010). Sampling cod of different life stages from various depths and areas has indicated that cod habitat requirements change as they age (COSEWIC, 2010). Food availability and temperature have been identified as primary factors affecting habitat suitability (COSEWIC, 2010). Many cod undergo annual feeding migrations when they reach maturity (Stanley et al., 2015). However, the duration and distance of these migrations vary considerably between individuals and populations (Robichaud and Rose, 2004; Stanley et al., 2015).

2.3 Biological Characteristics and Life-History of Gilbert Bay Cod

The resident cod subpopulation in Gilbert Bay have several distinct characteristics that set them apart from other northern cod, including: growth rates, length at age, time of spawning, prey preferences, genetic structure, and movement patterns (Morris and Green, 2002). High levels of antifreeze activity in their plasma provide evidence that they overwinter within Gilbert

Bay. Six months of the year the cod are subject to sub-zero temperatures which has impacted growth rate, time of spawning, and migration (Morris et al., 2014; Stanley et al., 2015). Gilbert Bay cod have slower growth rates than other Atlantic cod. Due to their slow growth, they exhibit a lower fecundity-at-age relationship than other northern cod (Ruzzante et al., 2000). This results in their production and recruitment capacity being lower as well (Ruzzante et al., 2000). They spawn in May and June when land-fast ice clears from Gilbert Bay headwaters (Morris and Green, 2002; Stanley et al., 2015). Eggs are retained with the inner portion of the bay due to oceanographic conditions (Stanley et al, 2015). It is hypothesized by Morris and Green (2002) that these life history characteristics have arisen due to the genetic distinctiveness and restricted movements of Gilbert Bay cod. DNA studies concluded that Gilbert Bay cod are genetically distinguishable from other inshore and offshore northern cod subpopulations (Ruzzante et al., 2000).

2.4 Methods for Analysis

The methodology used for this paper was a combination of literature reviews and SWOT Analysis. Literature reviews were carried out on the following topics:

- Gilbert Bay cod
- Northern cod
- Gilbert Bay MPA
- Scientific indicators used to guide management decisions within the Gilbert Bay MPA
- Fisheries management in Canada
- Adaptive management

The aim of the literature review was to introduce northern and Gilbert Bay cod and the management constraints facing the Gilbert Bay MPA. Identifying the major management constraints could lead to management solutions. A major component used to determine management methods for the Gilbert Bay cod stock is a set of five scientific indicators.

Strengthening these indicators and the management methods used for the MPA could potentially aid in the recovery of the Gilbert Bay cod population.

SWOT Analysis is a commonly used method to identify strengths, weaknesses, opportunities, and threats. Accordingly, strengths and weaknesses (internal factors) of implementing adaptive management to scientific monitoring inside the MPA in conjunction with fisheries management tools outside the MPA were analyzed. Opportunities and threats (external factors) were identified from ecological and social components both inside and outside the MPA boundaries. The purpose of a SWOT Analysis is to identify key factors that support management strategies and decisions (Scolozzi et al., 2014). The SWOT Analysis was used to identify the potential effectiveness of implementing adaptive management within the boundaries of the MPA at the same time as fisheries management regulations outside the MPAs boundaries.

CHAPTER 3 ANALYSIS

Since 1998, numerous acoustic tagging and tracking studies have been undertaken on Gilbert Bay cod (Morris and Green, 2010). These studies indicated that Gilbert Bay cod exhibit foraging movements to areas outside the MPA boundaries (Morris and Green, 2010). Offshore populations of northern cod are known to migrate inshore during the summer months to feed, overlapping with the movements of the Gilbert Bay cod (Lear, 1984; Morris and Green, 2010). This results in the mixing of the two cod populations. A small northern cod fishery exists in NAFO Division 2J (DFO, 2014a), where the mixing of cod populations occurs. If the Gilbert Bay cod subpopulation remains low, there is concern that fishing pressure outside the MPA could impact their recovery (Morris and Green, 2010). Therefore, the viability of Gilbert Bay cod subpopulation relies on management measures both inside and outside the MPA.

3.1 The Gilbert Bay MPA

In Canada, the Fisheries and Oceans Minister has the authority to enhance protection for marine areas by designating them MPAs if they fulfill one or more of the following criteria listed below (Government of Canada, 1996):

(1) the conservation and protection of commercial and non-commercial fishery resources, including marine mammals, and their habitats.

(2) the conservation and protection of endangered or threatened marine species, and their habitats.

(3) the conservation and protection of unique habitats.

(4) the conservation and protection of marine areas of high biodiversity or biological productivity.

(5) the conservation and protection of any other marine resource or habitat as is necessary to fulfil the mandate of the Minister.

The Gilbert Bay MPA was designed to protect key life-history stages of the distinct cod subpopulation inhabiting the bay (Stanley et al., 2015). This included spawning areas, feeding areas, nursery habitats, and areas where many Gilbert Bay cod reside until reaching sexual maturity (Morris and Green, 2014). Approximately 90% of the range and habitat of the population is encompassed by the 60 km^2 MPA boundary (DFO, 2010; Stanley et al., 2015).

The Gilbert Bay MPA has a management plan that has been jointly developed by local community leaders, representatives of Fisheries and Oceans Canada, research scientists from Memorial University of Newfoundland, and marine resource users (Wroblewski et al., 2007). The MPA is not a “no-take” reserve (DFO, 2010). This means that certain fisheries related activities are permitted within MPA boundaries. Gilbert Bay's MPA is divided into three management zones (Figure 3) with specific regulations (Table 2).

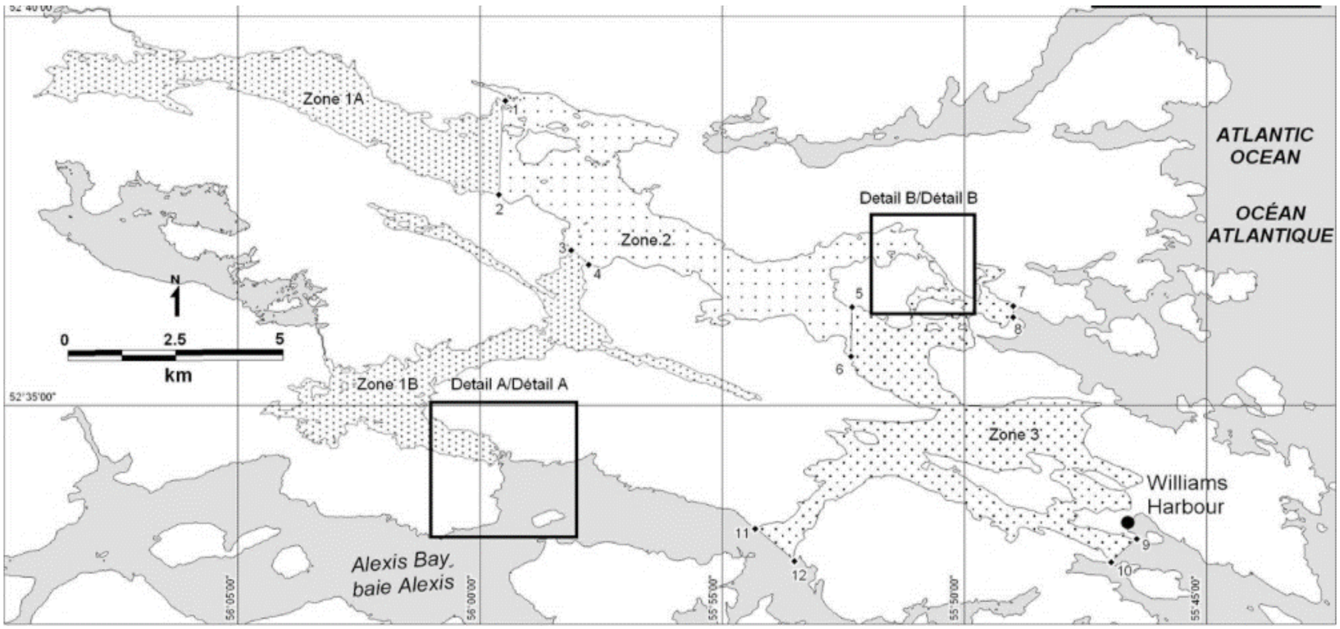


Figure 3. Management zones within the Gilbert Bay MPA (DFO, 2016b).

Table 2. Gilbert Bay Marine Protected Regulations designated management zones (Section 2 in Gilbert Bay Marine Protected Regulations, Government of Canada, 2005).

Management Zone	Description of Zone
Zone 1A	Consists of waters generally northwest of the connecting points of the following rhumb line connecting points: i) 52°38’56” N, 55°59’28” W and 52°37’43” N, 55°59’36” W The area is sea bounded by the low-water line of the bay and by the rhumb lines points of intersection with the low-water line.
Zone 1B	consisting of waters lying generally southwest of a rhumb line connecting points: i) 52°37′00″N, 55°58′07″W and 52°36′49″N, 55°57′45″W The area is sea bounded by the low water line of the bay and by the rhumb line to its points of intersection with the low-water line.
Zone 2	Consists of the area of sea bounded by the low-water line of the bay and by rhumb lines to their respective points of intersection with the low-water line. The rhumb lines include: i) 52°38’56” N, 55°59’28” W and 52°37’43” N, 55°59’36” W ii) 52°37’00” N, 55°58’07” W and 52°36’49” N, 55°57’45” W iii) 52°36’16” N, 55°52’19” W and 52°35’38” N, 55°52’20” W
Zone 3	Consists of the sea bounded by the low-water line of the bay and by the following rhumb lines to their points of intersection with the low-water line: i) 52°36’16” N, 55°52’19” W and 52°35’38” N, 55°52’20” W ii) 52°36’17” N, 55°48’59” W and 52°36’09” N, 55°48’ 59” W iii) 52°33’17” N, 55°46’27” W and 52°32’59” N, 55°46’58” W iv) 52°33’25” N, 55°54’19”W and 52°33’01” N, 55°53’31” W

According to the Gilbert Bay Marine Protected Area Regulations (Government of Canada, 2005), in the three zones, no person is permitted to:

a) Disturb, damage or destroy, or remove from the management zones, any living marine organism or any port of its habitat; or

b) Undertake activities that are likely to disturb, damage, destroy, or remove living marine organisms or any part of their habitat. This can include but is not limited to depositing, discharging, dumping any substance, or causing any substance to be deposited, discharged or dumped.

However, a person can carry out any activity that is excepted or an activity that is scientific or educational when submitted in accordance with and approved by the Gilbert Bay Marine Protected Regulations. Exceptions to the prohibited activities include the following:

a) Fishing activities including:

   i) fishing in accordance with *Aboriginal Communal Fishing Licences Regulations,*

   ii) fishing for seals and any related activity under the *Marine Mammal Regulations,*

   iii) recreational fishing activities carried out in accordance with the *Atlantic Fishery Regulations, 1985* or the *Newfoundland and Labrador Fishery Regulations*, specifically,

      A) angling for Arctic char, salmon or trout, in Zone 1A or 1B

      B) fishing for any species other than Atlantic cod in Zone 2

      C) fishing for any species in Zone 3

   iv) commercial fishing for any species other than Atlantic cod in Zones 2 or 3, that is carried out in accordance with the *Atlantic Fishery Regulations, 1985* or the *Newfoundland and Labrador Fishery Regulations*

b) Activities where approval or authorization is not required by the *Navigable Waters Protection Act* or the *Fisheries Act*, or are carried in in accordance with approval or authorization from either of these Acts, namely,

   i) maintenance, repair or removal of a wharf in Zone 1A or 1B,

   ii) construction, maintenance, repair or removal of a wharf in Zone 2,

   iii) construction, maintenance, repair or removal of a wharf, causeway or bridge.

c) Any activity that addresses public safety, national defence, national security, law enforcement, or in response to an emergency.

3.2 Scientific Indicators Used to Determine the Status of Gilbert Bay Cod

The first management plan for the Gilbert Bay MPA was implemented in 2007 (DFO, 2010). This three-year plan was the first to define the five scientific indicators (Table 1) used to assess the Gilbert Bay cod subpopulation (DFO, 2010) and consequently inform management decisions for the MPA. In 2010, a Canadian Science Advisory Secretariat (CSAS) report was published stating that the five indicators and their respective sampling and analytical protocols were appropriate and sufficient to monitor the MPA (DFO, 2010). However, some of the indicators may not provide the necessary data needed for making direct linkages with the overall status of the cod subpopulation, while others have potential to be strengthened (DFO, 2010). This led to several recommendations that were aimed at strengthening the indicators (DFO, 2010).

a) Recruitment of age 0 pelagic juvenile abundance.

This indicator is based on ichthyoplankton sampling, which is the sampling of the eggs or larvae of a fish (Morris and Green, 2010). Sampling is done using a 1 meter plankton net that is towed horizontally through the water column for 15 minute intervals (Morris and Green, 2010). Approximately 10-30 tows are conducted during the sampling seasons (May-June and August) and are taken from a depth of about 2 meters (Morris and Green, 2010). This indicator has the potential to advance the understanding of juvenile cod mortality, the effects of temperature on juveniles, spawning and settlement time, and feeding areas (Morris and Green, 2010).

Samples taken annually in late May and early June revealed that the majority of cod eggs collected from the Shinnys area (Figure 2) were at the same early stage of development (Morris and Green, 2002; Morris and Green, 2010). Since 2004, large fluctuations in maximum egg density can be seen from year to year (Figure 4). Between 2011 and 2016 a decline in maximum egg density occurred (Figure 4). During the sampling in August, only age 0 pelagic juvenile cod were present in the samples (Figure 5) (Morris and Green, 2010). Similar to maximum egg density, large inter-annual variability can be observed in the number of pelagic juvenile cod sampled. When abundance of age 0 pelagic juveniles was compared to catches with hook and line data, it resulted in weak correlations (Morris and Green, 2010). Therefore, no strong link can be made between age 0 pelagic juvenile abundance and the overall population status of Gilbert Bay cod (DFO, 2010).

Annual sampling of maximum egg density and the number of larval fish per tow do not indicate a direct link with each other or the overall cod population (DFO, 2010). Additional analysis such as spawner per recruit matrices should be carried out to determine the usefulness of this indicator (DFO, 2010). Evidence of age 2, 3, and 4 year old Atlantic cod could also strengthen linkages between age 0 and older age classes (DFO, 2010).

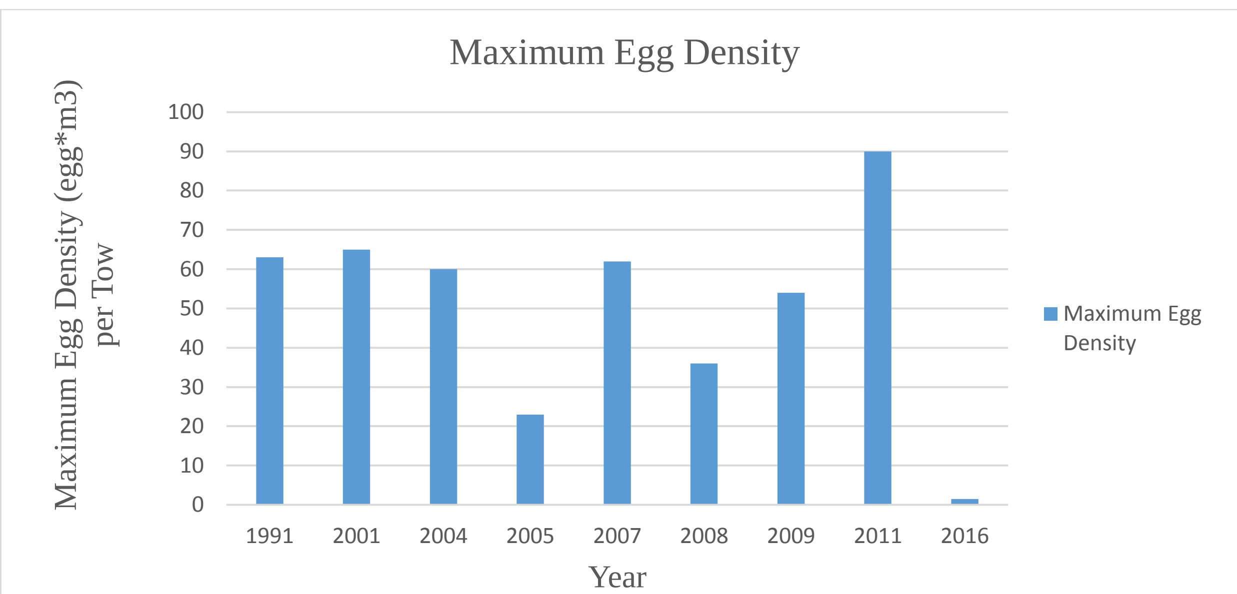


Figure 4. Maximum egg density of Gilbert Bay cod during late May- early June sampling (C. Morris, personal communication, August 19, 2016).

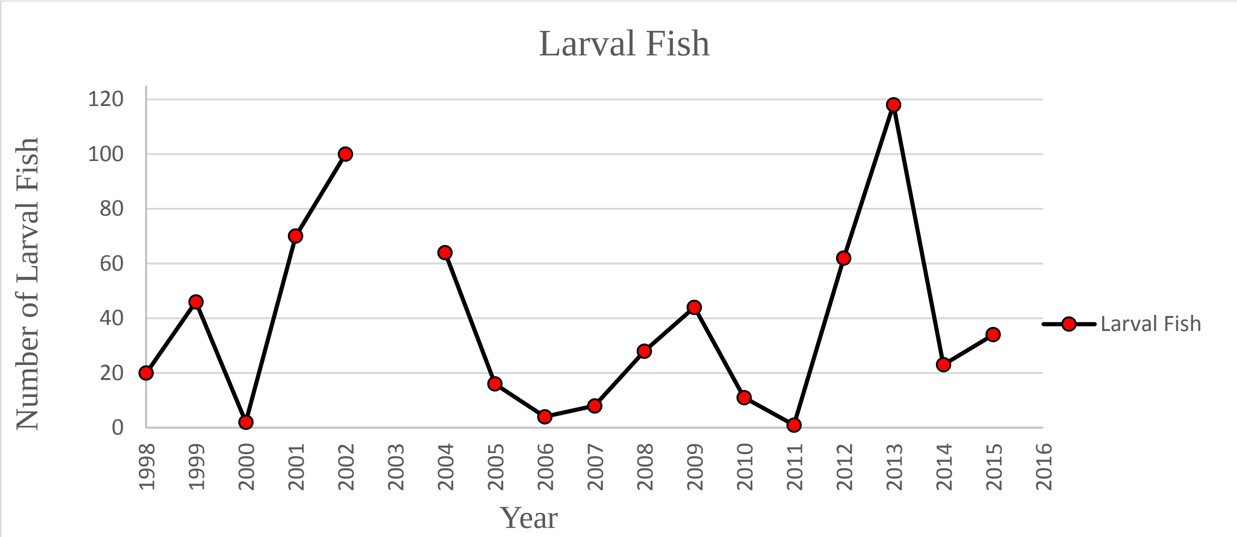


Figure 5. Number of larval fish collected per tow from Gilbert Bay during August sampling (C. Morris, personal communication, August 19, 2016).

b) Recruitment, relative abundance, and year class strengths based on age 2, 3, and 4 year old Gilbert Bay cod.

Recruitment data of ages 2, 3, and 4 year old juvenile cod, is based on relative juvenile year class strengths (Morris and Green, 2010). Year class strength is an index that relates early life history growth rate to survival rate (Campana et al., 1989). The year class strength of juveniles is identified using length frequency distribution (Morris and Green, 2010). This indicator is important for determining the annual length frequency distributions of the cod (Morris and Green, 2010). It can be used for describing trends in population dynamics and identifying periods of poor recruitment (Morris and Green, 2010).

The relative abundance and size distribution of cod in Gilbert Bay (Figure 6) suggests that the strongest cohorts produced since 1996 were in 2000, 2001, and 2006 (Morris and Green, 2010). This is due to the relatively high number of 2 and 3 year olds caught in the following years (Morris and Green, 2010).

Length Frequency Distributions

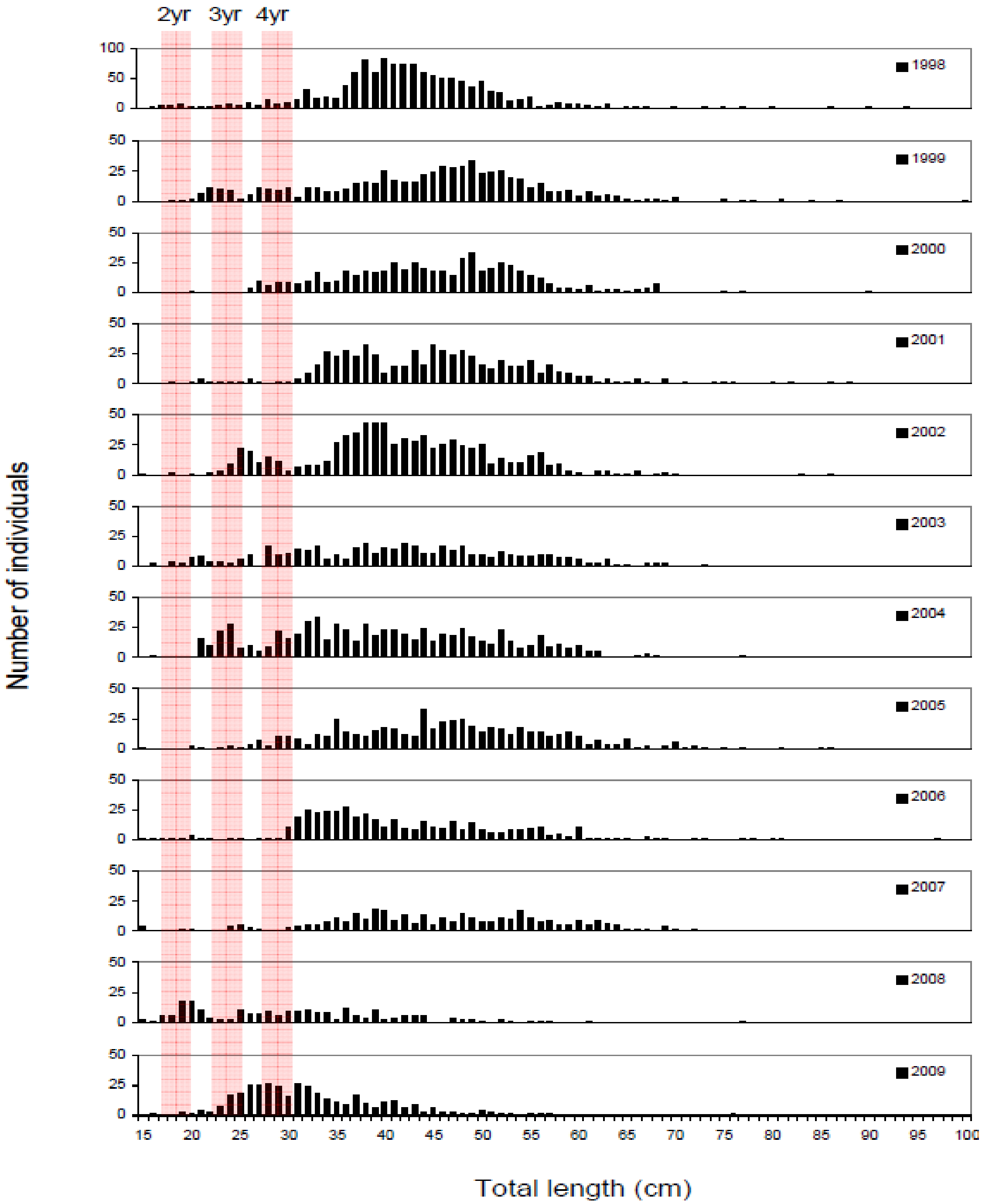


Figure 6. Gilbert Bay cod length frequency distributions. Data was standardized by mean annual spring effort from fish caught in The Shinneys. The graph indicates approximate fish length corresponding to ages 2-5 years. *The Y-axis for 1998 is different from all other years due to higher catch rates. (Figure 5 in Morris and Green, 2010).

Due to limited sampling, uncertainties exist in actual age-classes (DFO, 2010). The indicator could be improved by defining the annual variability in length at age and year class abundance by increasing otolith sampling, which can be used to determine age (DFO, 2010).

c) Research Catch per Unit Effort (R-CPUE).

R-CPUE is calculated by dividing the number of fish caught by the number of people fishing multiplied by the time (hrs) that each individual spent fishing (DFO, 2010). Most of the CPUE sampling done for the Gilbert Bay cod population occurs in the Shinneys (Figure 2) using a hook and line, where the highest abundance of fish is observed during the May-June sampling season (Morris et al., 2003). R-CPUE is one of the strongest indicators for determining the status of the Gilbert Bay cod population (C. Morris, personal communication, August 19, 2016). This indicator can be used to give an estimation of the overall abundance of Gilbert Bay cod (DFO, 2010). However, it is important to keep in mind that there is a possibility that differences exist in the catchability of the cod from one year to the next (Morris et al., 2003).

From the 1970s to the cod moratorium in 1992, commercial fishing occurred within Gilbert Bay (Table 3) (Morris et al., 2002; Morris and Green, 2010). R-CPUE peaked in 1998 (Figure 7), which was six years after the northern cod moratorium (Table 3). In 1998 and 1999, a directed commercial fishery in Gilbert Bay was resumed which resulted in a decline in R-CPUE (Morris and Green, 2010). Despite the fisheries restrictions implemented in 2000 and MPA regulations implemented in 2005, R-CPUE has shown large inter-annual variability and an overall decrease over a 14-year sampling period (Figure 7). After 2008, R-CPUE has remained particularly low (Morris and Green, 2014).

There is potential to strengthen this indicator by providing a measure of R-CPUE variability among sampling sites (DFO, 2010). Providing confidence intervals for annual R-CPUE would increase the reliability of the indicator (DFO, 2010). To reduce uncertainty in these estimates, R-CPUE should include an increased number of samples from the main arm of Gilbert Bay (DFO, 2010).

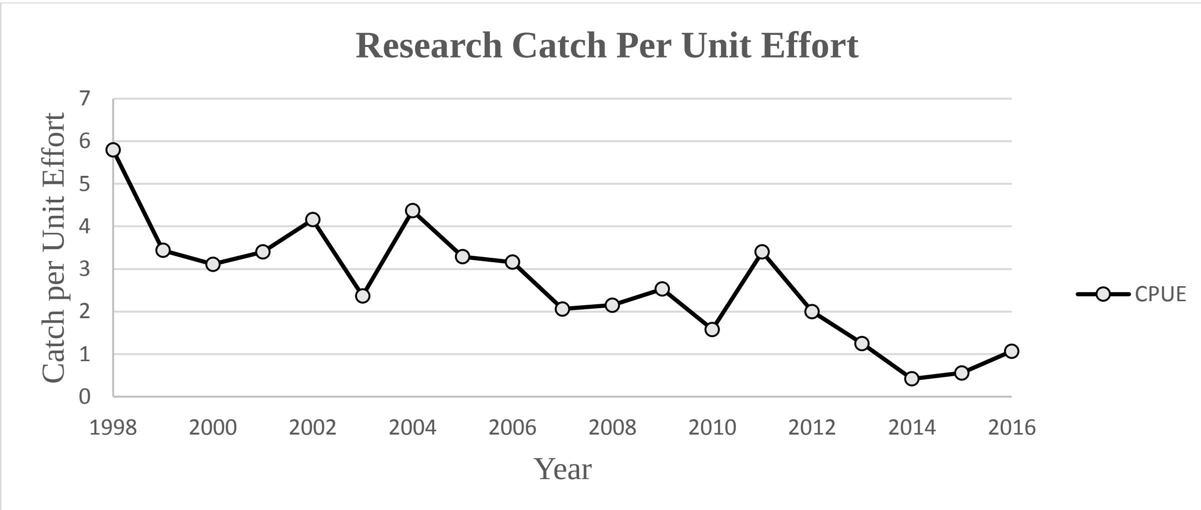


Figure 7. Averaged R-CPUE of Gilbert Bay cod sampled from 1998 to 2016. Each year a total of 40 to 50 sets were fished at 25 separate sites distributed around The Shinneys. R-CPUE was calculated for each set and then averaged for each year. (C. Morris, personal communication, August 19, 2016).

d) Movement patterns in relation to population demographics and MPA boundaries.

This indicator helps determine the movement of the population relative to the MPA boundary and to other spatially variable threats, such as fishing outside the MPA (DFO, 2010). It is based on the recapture of previously tagged Gilbert Bay cod which are sampled using hook and line (Morris and Green, 2010).

This indicator has revealed that the cod exhibit homing behaviour, most being recaptured within a few hundred meters of their initial tagging site (Morris and Green, 2010). However, some individuals have been recaptured by commercial and recreational fishers outside the MPA boundaries in the summer and fall (Morris and Green, 2010). This shows that large cod travel outside MPA boundaries.

The proportion of larger cod travelling outside the MPA in late May and early June is unknown (Morris and Green, 2010). Further genetic and telemetry studies could help to confirm the proportion of cod moving outside the MPA and consequently strengthen the indicator (DFO, 2010).

e) Localized commercial, recreational, sentinel, and Indigenous catch rates and fishing effort.

This indicator uses data obtained from DFO landings and tag returns from multiple sources of fishing effort (Morris and Green, 2010). Tag returns come from a combination of commercial, recreational, sentinel, and Indigenous fishing outside the MPA (Morris and Green, 2010). The data identifies areas where fishers are likely to encounter Gilbert Bay cod (Morris and Green, 2010). It can show the potential for fishing pressure to directly impact the population status of Gilbert Bay cod (DFO, 2010).

Figure 8 reveals the decreasing trend of large Gilbert Bay cod in conjunction with increasing commercial catches. A negative correlation was observed between the year of commercial fishing and R-CPUE sampling years (Morris and Green, 2010).

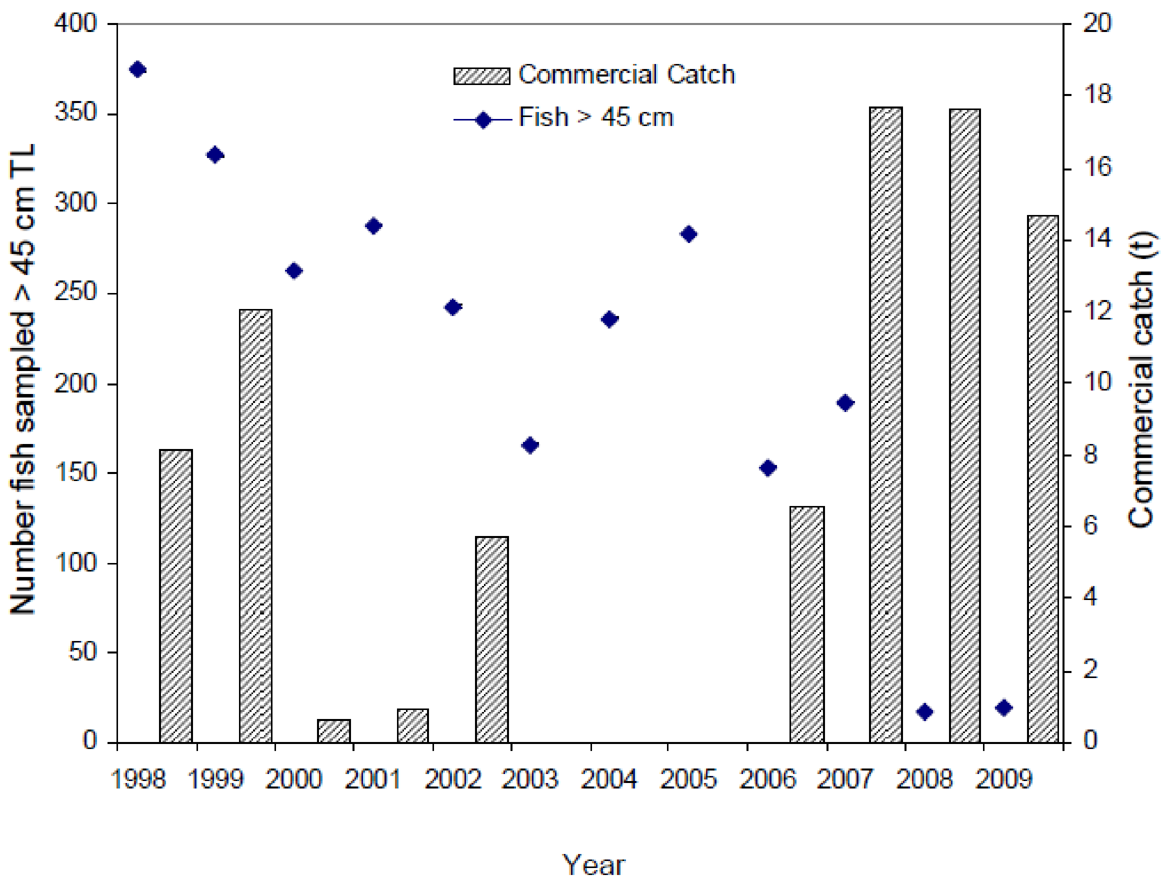


Figure 8. Total standardized catches of Gilbert Bay cod larger than 45 cm (total length) caught during annual spring research sampling in The Shinneys (Primary Y-axis) and commercial catch (Secondary Y- axis). (Figure 9 in Morris and Green, 2010).

There is an opportunity to collect more data from at sea observer programs (DFO, 2010). Establishing a stricter set of regulations for collecting data from the recreational fishery would also increase knowledge of the overall catch rate. Genetic identification tools could potentially improve accuracy in determining the proportion of Gilbert Bay cod being caught in various fisheries (DFO, 2010).

3.3 Alterations to the Gilbert Bay Management Plan

The scientific monitoring program for Gilbert Bay aims to deliver an overview of population dynamics, and describe several generations of cod (Stanley et al., 2015). After the first three-year management plan, the indicators were used to review the efficacy of the plan in

2010. Using recommendations from the review, a revised management plan for 2013-2018 was developed and implemented (DFO, 2013a). Five changes were made to the original management plan which can be found in the Gilbert Bay MPA Management Plan 2013-2018 (2013):

1. September start date for the commercial cod fishery outside the MPA.
2. Expanded science monitoring program including new genetic work, and tagging studies outside the MPA.
3. Steering committee became to Advisory Committee.
4. Annual general meeting.
5. Discontinuation of MPA community coordinator position.

3.4 Fisheries Management in NAFO Division 2J

For management purposes, the Northwest Atlantic Fisheries Organization (NAFO) has separated fisheries in the Atlantic into several divisions (Hutchings and Rangeley, 2011). The area surrounding southern Labrador has been classified as 2J, which includes Gilbert Bay (Figure 1). For the period 1993-2009 the median annual reported catch of northern cod from all fishery sources was 2,918 t (DFO, 2010; Hutchings and Rangeley, 2011). Within this timeframe most cod were caught as a result of by-catch (inshore and offshore), food and recreational fisheries, DFO- industry sentinel surveys, and illegal exploitation (Hutchings and Rangeley, 2011). Since 2006, a directed inshore fixed gear fishery and recreational fishery for cod has been open in NAFO division 2J (Table 3). Commercial fishers had an annual allowance of cod per licence holder ranging from 1,135 kg to 1,475 kg during 2006-2008, 1,700 kg during 2009-2012, and 2,270 kg during 2013-2015 (DFO, 2016c). Total landing reported in 2015 were 4,436 t (DFO, 2016c).

For 2016, a one year management plan was implemented for the Northern Cod Stewardship/ by-catch fishery (DFO, 2016d). The purpose of the Stewardship fishery is to ensure responsible planning and the sustainable management of resources. In 2016, alterations to regulations included: an extended season, weekly landing limits (August 15th -September 4th: 907 kg per week. September 4th to end of season: 1,361 kg per week (DFO, 2016d)), elimination of individual quotas, and removal of the restriction of fishers only fishing within their homeport (DFO, 2016d). In addition to the alterations to the Stewardship fishery in 2J, there are other active management methods that are being utilized by fisheries managers in the area. Some of these methods could be strategically used to reduce Gilbert Bay cod mortality including:

- Gear restrictions and gear limits: restrictions on the amount and type of gear used by fishers (Mateo and Baird, 2015).
- Small fish protocol: control of the capture of juvenile cod by enforcing a minimum size restriction (Mateo and Baird, 2015).
- Monitoring of landings: The Dockside Monitoring Program requires fishers to land their catch at designated ports (Mateo and Baird, 2015).
- Logbook completion: it is mandatory to keep logbooks under Section 61 of the *Fisheries Act.* Fisheries harvester must record catch and effort data, and submit this data as specified in the conditions of their license (DFO, 2014b).
- No Buddy- up: Buddy-up is a partnership arrangement, whereby two license holders fish together on one vessel (DFO, 2016c).

The main fisheries regulations focused on in this paper are: quota on by-catch, gear restrictions, and changes to the fishing season. These management tools were chosen based on their anticipated capacity to reduce Gilbert Bay cod mortality as a result of the commercial fishing industry.

Table 3. Timeline of events and management measures for the Gilbert Bay MPA and Fisheries Management in NAFO division 2J. The color red represents fisheries management measures and cod landings. The color blue represents Gilbert Bay MPA management measures.

Year	Events and Management Measures
1500s	Northwest Atlantic cod fishery began (Lear, 1998).
1600s	Cod catches in NFLD reached approximately 100,000 metric tons (t) per year (Mateo and Baird, 2015).
1700s	Catches increased to about 200,000 t annually (Mateo and Baird, 2015).
1800s	Cod landings ranged between 150,000 and 400,000 t annually (Mateo and Baird, 2015).
1950s	Northern cod catch increased to approximately 300,000 t (Mateo and Baird, 2015).
1968	Cod catches peaked at over 800,000 t (Mateo and Baird, 2015).
1974	All cod stocks were placed under quota regulation (Mateo and Baird, 2015)
1977	Canada implemented its 200-mile limit. Setting the Total Allowable Catch in Canadian waters became Canada's responsibility (Mateo and Baird, 2015).
1978	Catches declined to a low of 140,000 t (Mateo and Baird, 2015).
1980s	Cod catches increased to approximately 240,000 t (Mateo and Baird, 2015).
1990s	Cod catches declined steadily.
1992	Fishing moratorium on northern cod.
1998	Annual studies began on Gilbert Bay cod.
1998	Directed inshore cod fishery reopened (inside Gilbert Bay 1998-1999).
2000	Gilbert Bay declared an AOI.
2003	Directed inshore fishery closed.
2005	Gilbert Bay designated as an MPA.
2006	Directed inshore cod fishery opened (outside Gilbert Bay). Annual allowance of cod per license holder ranged from 1,135 kg to 1,475 kg during 2006 to 2008 (DFO, 2016c).
2007	First MPA management plan implemented
2009	Annual allowance of cod per license holder was 1,700 kg from 2009 to 2012 (DF), 2016c).
2010	MPA management plan was reviewed.
2013	Annual allowance of cod per license holder was 2,270 kg from 2013 to 2015 (DFO, 2016c).
2013	Revised management plan was implemented for 2013-2018.
2016	Extended fishing season, weekly landing limits, elimination of individual quotas, and removal of the restriction of fishers only fishing within their homeport (DFO, 2016d). August 15th -September 4th: 907 kg per week. September 4th to end of season: 1,361 kg per week (DFO, 2016d).

3.5 SWOT Analysis for Using Adaptive Management and Fisheries Management to Strengthen the Gilbert Bay MPA

The SWOT Analysis aims to identify key factors to help increase the success of the Gilbert Bay MPA. The SWOT focused on a hypothetical scenario in which adaptive management is implemented within MPA boundaries and additional fisheries management tools outside MPA boundaries.

	Favourable Outcome	Unfavorable Outcome
Internal	**Strengths** • Facilitates intersectoral partnerships within DFO. • Allows for both short-term and long-term protective measures. • Encourages innovative approaches to management (e.g. genetics, telemetry). • Reduce Gilbert Bay cod as by-catch of the northern cod commercial fishery.	**Weaknesses** • MPA boundary • Potential for insufficient funding to have a intersectoral approach to management. • Ambiguity in leadership roles • Knowledge gaps
External	**Opportunities** • Provide employment opportunities to locals from communities near Gilbert Bay. • Information and research partnerships with new organizations. • Advancing genetic technology.	**Threats** • Fishermen may oppose additional regulations imposed outside MPA boundaries. • MPA not meeting its objectives may result in a loss of stakeholder buy-in. • Loss of key staff • Loss of political will

Figure 9. SWOT Analysis for using adaptive management and fisheries management to increase success of the Gilbert Bay MPA.

Strengths: There are several potential internal strengths associated with implementing adaptive management inside the MPA in conjunction with fisheries regulations outside the MPA. This would include strengthening intersectoral partnerships within DFO. Specifically, the Science Branch, Ecosystems Management Branch, and Fisheries Management Branch. The Science Branch conducts monitoring, surveys, and research that is crucial for making management decisions (DFO, 2015). This branch could work towards strengthening the scientific indicators used to monitor the Gilbert Bay cod subpopulation. Further genetic testing and use of telemetry could lead to innovative approaches to making management decisions. One of the responsibilities of the Ecosystems Management Branch is the designation and management of MPAs (DFO, 2015). As new scientific information becomes available from the Science Branch, adaptive management could be used to incorporate this new information into management decisions. The Fisheries Management Branch is responsible for managing fisheries resources that are harvested for Indigenous, commercial, and recreational purposes in marine inland waters (DFO, 2015). This branch administers licensing for fishing operations and provides conservation and enforcement of fishing activities (DFO, 2015). In waters adjacent to the MPA, fisheries managers can implement fishing regulations that could mitigate the threat of commercial fishing activities on Gilbert Bay cod, such as reducing by-catch. This fisheries management framework could operate in conjunction with an adaptive management framework. Fisheries managers can enact or repeal fisheries regulations within a short timeframe. Therefore, they can implement regulations which could aid in the conservation of Gilbert Bay cod that travel outside of the MPA boundaries. This could provide the cod with some protection while alterations are made to MPA regulations over a longer timeframe. Additionally, increased collaboration between DFO sectors would facilitate the exchange of innovative ideas and human resources strengthening the management of the Gilbert Bay MPA. However, for this to be efficient and effective there must be a formal system developed for information flow between sectors.

Weaknesses: The boundaries of the Gilbert Bay MPA were established before tagging studies revealed that larger sized cod travelled outside the bay to feed during the summer. Data suggests that a spatial scale mismatch occurred which has resulted in golden cod commercial fishing mortality (Stanley et al., 2015). Further scientific studies are needed to determine both the spatial and temporal scale of mixing between Gilbert Bay cod and northern cod. Another weakness that exists is the uncertainty in long-term funding for scientific monitoring and management both within and outside of the Gilbert Bay MPA. In addition, potential conflict could arise from having DFO sectors with different objectives and resources working together on one project. Specifically, having three branches of DFO working on the MPA objective has the potential to create conflict regarding leadership roles.

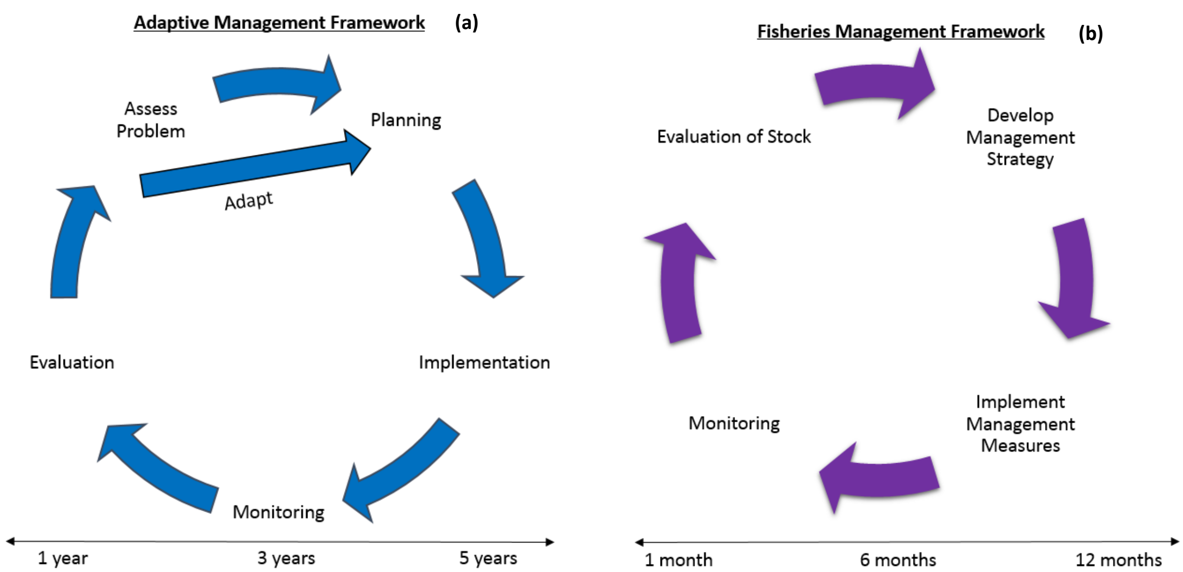
There are several scientific knowledge gaps regarding the Gilbert Bay MPA. Currently, there is not a reliable method for measuring the impact of the recreational fisheries on Gilbert Bay cod. Without accurate data for the recreational fishery, error will exit in the science presented to managers. In addition, genetic analysis of the sampled larval fish from 2015 revealed that not all the fish were Gilbert Bay cod (C. Morris, personal communication, August 19, 2016). The pelagic juveniles have been identified as being a mixture of *G. ogac* and *G. morhua*. These juveniles are both the same Genus but are different species of cod. This issue has arisen because larval *G. ogac* and *G. morhua* are challenging to distinguish visually during their larval stage (C. Morris, personal communication, August 19, 2016). According to C. Morris (personal communication, August 19, 2016) it is possible that the proportion of these two species has fluctuated over time while the overall number of larval fish remained constant. An additional potential issue with age 0 larval cod sampling is that the Gilbert Bay subpopulation may be compensating by changing the reproductive effort with changing population size (C. Morris, personal communication, August 19, 2016). Even if all the larval fish gathered had been Gilbert Bay cod, there is a chance that this data does not have a direct correlation with the R-CPUE data gathered on larger fish (Morris, 2016, personal communication).

Opportunities: There are several opportunities that could arise from combining adaptive and fisheries management frameworks. Increased monitoring efforts outside the MPA boundary could provide employment opportunities for residents in nearby communities. Increasing the number of people that receive hands on training, such as local Indigenous groups, increases the amount of human resources and equipment available to conduct monitoring in the area (DFO, 2010). To effectively enforce new fisheries management regulations, it would be necessary to hire additional At-Sea-Observers. When cod subpopulations mix and disproportionate harvesting takes place on one genetically discrete population, overharvesting and (or) a loss in genetic diversity of the other subpopulation can occur (Laikre et al., 2005; Spies and Punt, 2015). The loss can be amplified when subpopulations have different biological characteristics but are being managed as a single stock (Spies and Punt, 2015). This presents the opportunity to use genetic analysis to distinguish between Gilbert Bay cod and northern cod when they mix in waters adjacent to the MPA. Concentrating on the advancement of genetic technology could result in a real-time method for distinguishing Gilbert Bay cod from northern cod when they mix outside the MPA. Monitoring outside the MPA boundary could potentially generate interest from other non-governmental organizations. This could lead to further funding for Gilbert Bay cod conservation efforts.

Threats: The Gilbert Bay cod subpopulation has declined following the implementation of the Gilbert Bay MPA. There is a risk that stakeholders will perceive the MPA as a failure. This could diminish support for future conservation efforts both inside and outside the MPA boundary, especially when stakeholders are already opposed to increasing the MPA boundaries (DFO, 2010). Therefore, there is a threat that adding additional regulations to the commercial fishery to conserve Gilbert Bay cod may be met with opposition from fishermen. There is also a risk that community members that are trained to monitor may move away for other employment opportunities. It takes a minimum 3 years to train individuals to a point that ensures a reasonable level of data quality insurance (DFO, 2010). It is a major financial loss and loss in human resources when trained individuals move away. Finally, political will could change resulting in a loss of support for the strengthening of MPAs. This could result in a decrease in funding for ongoing scientific research and adding additional at-sea monitoring on commercial vessels.

CHAPTER 4 DISCUSSION

The objective of the Gilbert Bay MPA is to conserve the genetically distinct resident cod subpopulation (DFO, 2010). However, since the establishment of the MPA in 2005 the population has not recovered (Figure 7). An ideal solution to this management problem would be to extend the MPA boundaries to include the summer feeding areas of the adult golden cod. If extending the MPA boundaries is not feasible due to stakeholder opposition, a compromise could be made by coupling adaptive management inside the MPA with fisheries management tools outside the MPA. As such, the management of the Gilbert Bay MPA calls for integrated management between MPA and fisheries managers. However, divisions exist between MPA management and fisheries management. Reasons for these divisions include: inequitable impacts of MPAs on fishing communities, ineffective protection of the marine resources, and a lack of integration between MPA management and other marine and fisheries management institutions (Weigel et al., 2014). Studies have suggested that MPAs with the highest level of conservation and fisheries benefits are: no-take, well-enforced, large, and have a wide variety of management actions associated with them (Edgar et al., 2014; Weigel et al., 2014). In terms of fisheries management, when MPAs are used as the only management measure it is likely that the result will be a displacement of fishing effort. This leads to higher fishing costs but no overall decrease in fishing pressure (Weigel et al., 2014). It is becoming increasingly recognized by managers that protective measures must include entire ecosystems while maintaining the profitability of the fishery (Weigel et al., 2014). As previously stated above, the current management inside and outside the Gilbert Bay MPA is not coupled, jeopardizing this holistic approach to management. In this study, a SWOT analysis has been used to evaluate the use of adaptive management inside the MPA in combination with the use of fisheries management tools outside the MPA. This integrated management approach aims to protect the existing Gilbert Bay cod population and potentially help them recover.



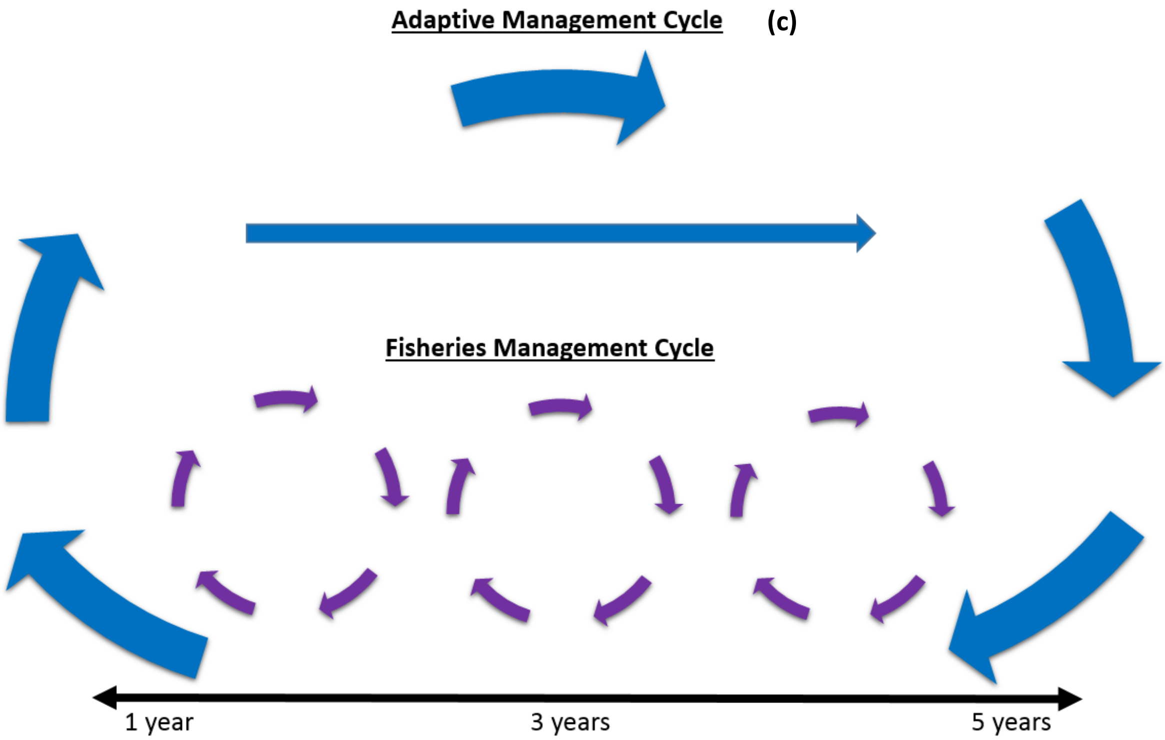


Figure 10. *Top Left (a)*: Typical adaptive management framework and estimated timescale. *Top Right (b)*: Fisheries management framework and estimated timescale. *Bottom (c)*: Image depicting how fisheries management tools can operate within an adaptive management framework in order to provide protection for Gilbert Bay cod both within and outside of MPA boundaries.

4.1 Spatial Scales and Management Problems

In terms of designing and monitoring MPAs, the spatial scale is extremely important (Stanley et al., 2015). Studies such as Edgar et al. (2014) suggest that the most successful MPAs are a large size (>100 km^2). The Gilbert Bay MPA, 60 km^2, is considered a small MPA. A similar case to the Gilbert Bay MPA is the Poor Knights Island Marine Reserve (PKIMR), New Zealand. It covers approximately 24 km^2 which is comparable on a spatial scale to the Gilbert Bay MPA. Despite its small size it has become successful after being established as a fully no-take reserve in 1998, with red snapper undergoing a rapid and sustained recolonization within the reserves boundaries (Sim-Smith and Kelly, 2009; Stanley et al., 2015). It is thought that there are both resident and migratory snappers in the PKIMR (Sim-Smith and Kelly, 2009). Therefore, attending only to the MPA dimension it could be argued that the Gilbert Bay MPA has the potential to be successful even though it only covers a small area. However, it is crucial to understand the spatial scale of the biological processes of cod in order to establish successful management actions. Tagging studies revealed that large golden cod travel outside the MPA and are most likely harvested by the commercial fishery, potentially resulting in the loss of spawning individuals (Morris and Green, 2014; Stanley et al., 2015). This evidences a scale mismatch between the area of the MPA and the biological processes that should be protected, which has resulted in increased mortality due to commercial fishing, compromising the goals of the MPA (Stanley et al., 2015). Using fisheries management tools to decrease Gilbert Bay cod mortality outside MPA boundaries could minimize the impact of this scale mismatch.

4.2 Adaptive Management and the Gilbert Bay MPA

Adaptive management is a framework that focuses on acquiring and incorporating new scientific knowledge in order to improve management practices over time by constant evaluation/adaptation (Figure 10a) (Southwell et al., 2016). Adaptive management is not a new concept in the realm of ecosystem and fisheries management. In fact, this concept has been widely acknowledged as having great potential for achieving sustainable fisheries while maintaining biodiversity (Botsford et al., 1997). Yet successful implementation of adaptive management has been challenging. This is due to the difficulty of altering management practices, as a consequence of "evaluation" and "adaptation" (Figure 10a), due to regulatory procedures and processes (Morris and Green, 2014).

Adaptive management should be thought of as an ever evolving management strategy. Efficient and effective management builds on a framework that has a set structure for decision making while incorporating new knowledge from a broad range of fields (Williams and Brown, 2016). The effectiveness of an MPA as a management tool is dependent on the ability of managers to balance three main factors: (1) the protection of the ecosystem (Devillers et al., 2015), (2) acquiring and maintaining stakeholder support (Roberts et al., 2003), and (3) achieving the conservation objectives (Stanley et al., 2015).

The success of the Gilbert Bay MPA is evaluated using five scientific indicators (Table 1). However, these indicators do not provide a direct link to the status of the adult cod subpopulation, apart from the R-CPUE data. Adaptive management provides an opportunity to redefine the indicators to strengthen their representation the cod subpopulation. There is also an opportunity to develop new indicators based on genetic and telemetry data. For example, telemetry data could strengthen the justification for extending MPA boundaries and genetic analysis could be used to determine the ratio between Gilbert Bay cod and northern cod outside of the MPA, aiding in the understanding of by-catch mortality.

In general, resistance from local communities and stakeholders plays a significant role in the failure to achieve MPA targets (Voyer et al., 2015). A fundamental challenge of designing an effective MPA management plan is creating a balance between stakeholder demands and the protection of ecosystems and species (Stanley et al., 2015). Different perspectives and priorities are encountered when discussing how much protection an ecosystem or species should receive (Stanley et al., 2015). For example, protective measures can easily become secondary to minimizing opportunity loss for stakeholders (Stanley et al., 2015). It has been suggested that the resilience of communities in the vicinity of MPAs is a defining feature in the social acceptability of the MPA (Voyer et al., 2015). Analyzing community composition and local history can provide insight into socio-economic, demographic, and historical factors influencing a community's attitude towards MPAs (Voyer et al., 2015). Other factors that may affect the social acceptability of an MPA include economic reliance on fishing and fishing-related industries (Voyer et al., 2015). There are only a small number of people living in communities located near Gilbert Bay (DFO, 2013a). After the inshore cod fishery re-opened in 1998, community members and fishers expressed their concern over declining numbers of Gilbert Bay cod (DFO, 2010). Arguably, the most effective measure for protecting Gilbert Bay cod would be extending the MPA boundaries. However, stakeholders for the Gilbert Bay MPA strongly oppose any extension of the boundaries because it would impact their fishing areas (DFO, 2010; Stanley et al., 2015). A balance must be struck between achieving the conservation objectives of the MPA and maintaining stakeholder buy-in for the MPA. Therefore, making numerous or frequent changes to an established management plan is extremely difficult from the stakeholder standpoint.

4.3 The Use of Fisheries Management Outside the Gilbert Bay MPA

Fisheries management frequently operates using a framework that includes: developing a management strategy, implementing management measures, monitoring, and stock evaluations (Figure 10b). Pending the outcome of the stock evaluation, the management strategy will either be maintained, altered, or repealed. While it can take several years to alter regulations within an MPA, regulations for commercial fishing occur on a yearly basis. Using different temporal scales could benefit the Gilbert Bay MPA objective (Figure 10c). It would allow for flexibility to accommodate sudden changes to the cod population or commercial fishery. Since the Gilbert Bay cod population is small, being able adapt regulations on multiple time scales is crucial for their conservation. Traditional fisheries management tools such as: effort restrictions, imposing by-catch limits, fishing gear restrictions, fishermen accountability, at sea monitoring and genetic analysis could help achieve this management priority (Stanley et al., 2015).

For example, effort restrictions such as quotas can be established for Gilbert Bay cod by-catch (DFO, 2013b). Current data regarding the movement of adult Gilbert Bay cod suggests that they only travel short distances outside the MPA. Implementing limits and quotas on Gilbert Bay cod could potentially discourage commercial fishing near the MPA boundary. For vessels that continue to fish in the area, once they reach the by-catch limit they would have to move away from the MPA boundary to diminish the risk of catching Gilbert Bay cod. Improved designs and use of fishing gear could also be used as a method for mitigating by-catch. Fishing mortality could be reduced in Gilbert Bay cod if commercial fishermen used cod pots when harvesting in waters adjacent to the Gilbert Bay MPA (C. Morris, personal communication, August 19, 2016). Additionally, fishers can have “individual accountability”. Only a small number of vessels fish near the MPA (DFO, 2013b). Therefore, individual fishers can be responsible for accounting for their catch (directed and non-directed). At-sea monitoring could encourage responsible fishing when it occurs in the vicinity of the MPA, while also providing accurate catch information which could help to determine how many adults are removed by the commercial fishery (DFO, 2013b; Morris, 2016b personal communication). It also presents an opportunity to collaborate with and to train stakeholders (e.g. local Indigenous groups), increasing their personal connection with the MPA. There is also potential to use genetic analysis on fin clip samples to determine the proportion of northern cod versus Gilbert Bay cod caught in the commercial fishery (Morris, 2016b, personal communication). Additionally, implementing adaptive and fisheries management could strengthen intersectoral partnerships and information flow between DFO sectors. This would be crucial for achieving adaptive management within the MPA and effective fisheries management outside of it.

4.4 Using Genetic Analysis to Distinguish Cod Subpopulations

Fisheries management becomes more complex when subpopulations of commercially fished species overlap. Mixed-stock fisheries are made up of individuals from distinct stocks (subpopulations) of a single species (Ovenden et al., 2015). When subpopulations mix and disproportionate harvesting takes place on one genetically discrete population, overharvesting and (or) a loss in genetic diversity of the other subpopulation can occur (Laikre et al., 2005; Spies and Punt, 2015). As previously stated, Gilbert Bay cod and northern cod mix during the summer months outside of the MPA boundary. Genetic testing can reveal the composition of mixed-stock fisheries by comparing reference gene frequencies from the subpopulations (Ovenden et at., 2015). Genetic population structure has been studied in many marine fish species (Ruzzante et al., 2000; Spies and Punt, 2015). Yet there are not many documented cases of this information being included in management plans. One of the biggest challenges is the cost associated with mixed-stock analysis (Ovenden et al., 2015; Spies and Punt, 2015). They require personnel with a high level of expertise and costly equipment. However, advancements in technology allow for high through put automation, meaning that specimens can be screened at hundreds of genetic loci quickly (Ovenden et al., 2015). Another of the reasons that genetic population structure may not be prevalent in fisheries management is that there is no clear framework for how to incorporate it (Carvalho and Hauser, 1994; Spies and Punt, 2015). Adaptive management would facilitate rapid integration of this new knowledge into the scientific monitoring aspect of Gilbert Bay management plan. Genetic testing of larvae could be used to estimate the proportions of *G. ogac* and *G. morhua* in relation to the total number of larvae in the bay. As previously noted, a strong link cannot be made between age 0 juveniles and the overall population status (DFO, 2010). However, this new information warrants an evaluation of previous years' data on the abundance of age 0 juveniles, improving the current indicators (DFO, 2010).

CHAPTER 5 CONCLUSION

Gilbert Bay has been designated as an MPA for over a decade. During this time, annual scientific monitoring based on 5 indicators has shown that the MPA is failing to achieve its objective of conserving Gilbert Bay cod. Subsequent to the establishment of the MPA boundaries, tagging studies revealed that commercial sized cod travelled outside the boundaries of the MPA to feed. As a result, Gilbert Bay cod mix with offshore northern cod in inshore waters during the summer months. A consequence of this has been the removal of spawning adults from the Gilbert Bay cod subpopulation via the commercial fishery. This highlights a mismatch between the spatial scales of the MPA and critical biological processes of the Gilbert Bay cod subpopulation. The ideal solution to this problem would be to extend the boundaries of the Gilbert Bay MPA to include the cods summer feeding areas. However, due to stakeholder opposition it is unlikely that the boundaries will be extended. A combination of adaptive and fisheries management tools could be used to help recover the subpopulation while maintaining stakeholder buy-in.

Adaptive management could be used to guide decision-making inside the MPA. The dynamics of adaptive management allows for the incorporation of new scientific knowledge into management decisions as it becomes available. This is especially critical in Gilbert Bay given the uncertainty of the current scientific indicators that are used to monitor the status of the cod subpopulation. As science resolves uncertainties surrounding Gilbert Bay cod, the new knowledge must be incorporated into management decisions and regulations. However, there are threats for this MPA that may not be circumvented by the implementation of adaptive management alone.

Fisheries managers have several tools to regulate fishing activities in Canadian waters. Establishing limits and quotas on by-catch of Gilbert Bay cod can minimize the removal of spawning individuals from the subpopulation. It is important to have management tools that can be implemented on various time scales. This is because the declining Gilbert Bay cod subpopulation may require rapid management responses from year to year in order to protect them while MPA regulations are altered. Managers can implement and repeal these tools on an annual basis, which results in an efficient mechanism for protecting Gilbert Bay cod. Being able to repeal regulations within a short period may be more acceptable to stakeholders than changing MPA regulations.

Following the SWOT Analysis, it was concluded that the Gilbert Bay MPA is not conducive with an exclusively adaptive management framework. This conclusion arose due to the threat from stakeholder opposition to extending the MPA boundaries to include the feeding areas of adult Gilbert Bay cod. There is a possibility that decisions derived from adaptive management could be frequently opposed by stakeholders. A solution to this threat could be to couple regulations inside the MPA with fisheries management tools used outside the limits of the MPA. Regulations within an MPA typically take years to implement or change, while fisheries managers can set, alter, or repeal regulations on an annual basis. Combining management strategies allows for both long and short term protective measures to be implemented. This strategy could help to resolve the mismatch in the spatial scale between the MPA boundary and the movements of the adult cod.

In conclusion, to improve the effectiveness of the Gilbert Bay MPA, a combination of management measures could be implemented both inside and outside the MPA boundaries. Adaptive management could be used to strengthen scientific indicators within the MPA, leading to changes in the regulations to better protect the Gilbert Bay cod subpopulation. Changing an MPA area can be slow process and perhaps not suitable for attending to the fine balance between MPA goals and stakeholder buy-in. These limitations could be circumvented by adjusting fisheries management outside the limits of the MPA. Regulating tools available to fisheries managers provide a viable method for implementing protective measures for Gilbert Bay cod without compromising stakeholder buy-in.

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