Fishery closures provide evidence concerning potential measures of MPA effectiveness

Baker, K.D, R.L. Haedrich and A. Williams

Memorial University of Newfoundland
Biology Department, 4 Clark Place
St. John's, Newfoundland
A1B 5S7 Canada

Abstract
Marine protected areas (MPAs) are often created based on measures of biodiversity, abundances and special community composition. These metrics can take years, even decades, to change and therefore may not be useful for measuring the effectiveness of an MPA on the short term. Few large offshore MPAs have been established and even fewer have high-quality time series associated with them. Therefore data to even test what measures might be applied there are rare. We suggest that fishing closures can be used as proxies.

The cod moratorium of 1992 in Atlantic Canada provides an opportunity to study potential indicators that might be used to measure the effectiveness of MPAs. Overall trends in catch per unit effort (CPUE) and mean size of individuals were examined for representative indicator species in scientific fishery surveys conducted from 1978 to 2002. Prior to the moratorium, 11 species showed declines in abundance and 10 showed declines in size. After the moratorium, one species showed an increasing trend in abundance while four exhibited increasing trends in size. The early increasing trends in size rather than abundances are expected in light of the biology of the species involved. For example, the generation time for the deep-water roughhead grenadier (*Macrourus berglax*) is a minimum of 14 years and therefore it is extremely unlikely that significant increases in numbers will be apparent in a short time frame. In fact, CPUE exhibited no significant trend after the moratorium but the trend in size switched from a decline before to an increase afterwards.

The combination of CPUE and mean size can possibly be used to indicate the effectiveness of offshore MPAs on time frames required by managers and planners. This information, however, must be used in conjunction with knowledge of the individual biology of species involved.

Introduction
Marine protected areas (MPAs) can have a wide range of objectives including conserving biodiversity, protecting sensitive habitat, enhancing the production of target species, providing refuge for intensively fished species, or a combination of these goals (Alder 1996, Allison et al. 1998). Specific goals for each MPA must be well defined at the onset of its creation and designation (Day and Roff 2000). The establishment of these goals is necessary for determining MPA success (Halpern 2003) and these goals should be measured in terms of MPA effectiveness regularly.

Baker (2003) used species rich hotspots and critical habitat of species-at-risk to determine high priority areas for potential MPAs in Canada's Atlantic Ocean. There were distinct locations where MPAs could be designated to protect diversity and species-at-risk. High priority areas occurred in the Bonavista Corridor, the northern side of Hamilton Bank, Laurentian Channel, and a portion of the southwest Scotian Shelf. The Bonavista Corridor was considered the highest priority area for an MPA because it was home to abundant populations of all the species-at-risk (except Cusk, *Brosme brosme*) and many hotspots occurred in this region. These sites were also shown to have minimal conflict with on-going trawling and oil and gas stakeholders.

Although protecting regions with high diversity and abundant species-at-risk are common uses for an MPA, metrics such as diversity and abundances can take years, even decades to change. Therefore these metrics may not be useful for measuring the effectiveness of an MPA on the short term. Studies demonstrating the effectiveness of MPAs are few, particularly in the offshore environment. This does not indicate a lack of clear benefits but rather the difficulty of finding areas where comparable results can be monitored (Day and Roff 2000). Most studies examining MPA effectiveness deal with reef or coastal environments.

It has been found that if an area is not fished, the total abundance of fishes, their average size, and their overall egg production can increase over that of an area that is fished (Klee 1999). Halpern (2003) found that with few exceptions, MPAs lead to increases in density, biomass, individual size, and diversity in all functional groups. It was found that density of organisms roughly doubled and biomass nearly tripled in MPAs. As well, the diversity and mean size of organisms within MPAs are between 20 to 30% higher than in unprotected areas. Russ and Alcala (1996) found a significant correlation of both mean density and species richness of large predatory coral reef fish with years of reserve protection. This trend was observed inside and outside the MPA's boundaries. Roberts et al. (2001) also found strong spillover benefits outside a series of MPAs in St. Lucia. The fishery increased 46 to 90% within five years of establishing these MPAs.

Only two official MPAs have been designated by the Department of Fisheries and Oceans Canada (DFO 2004). In 2003, the Minister of Fisheries and Oceans announced Canada's first MPA: The Endeavour Hydrothermal Vents in the Pacific. The Gully was announced as a designated MPA in the Atlantic in 2004. Twelve other sites have been designated as "areas of interest". Areas of interest are designated to facilitate the evolution of the national MPA process, for early protection and management, and to evaluate and demonstrate the effects of MPAs (DFO 2004).

Since very few offshore MPAs have been established in Canada and all have limited time series data, these can not be used to study measures of MPA effectiveness. Instead a proxy must be used to gain insight into these metrics. Although fishery closures do not necessarily offer protection to a specified area, they can relieve fishing pressure. Therefore until significant time series data for offshore MPAs are collected, fishing closures and associated fishery survey results can be used to study potential measures of effectiveness.

On July 2, 1992 the Fisheries Minister announced there would be a two-year moratorium on fishing the Northern cod stock on the north and east coast of Newfoundland (Lane and Palsson 1996, Woodrow 1998). In September 1993, the moratorium was extended indefinitely and spatially extended to include most of eastern Canada's fishing grounds. In fact, this moratorium covered six of the seven Atlantic cod (*Gadus morhua*) populations, ranging from southern Labrador to the continental shelf off eastern Nova Scotia (Myers et al. 1997). This fishery closure remains in place today.

Methods

The data used in our study are the results of scientific survey cruises. These are conducted annually by government fisheries agencies, usually in the spring and the fall, for the purpose of assessing the state of commercial fish stocks. Since the 1970s, and uniformly since 1978, the cruises in our area have followed a random stratified design with Atlantic cod the primary species of interest. Each stratum, characterized mainly by depth, is divided into small fishing units of approximately 2.5` latitude by 2` longitude and survey trawls are conducted within randomly selected fishing units at standard tow speeds and durations (Doubleday 1981). In any one survey year, more than 1000 demersal trawls may be made.

The data for all Canadian and US surveys to mid-1995 have been combined into one, the so-called ECNASAP (East Coast of North America Strategic Assessment Project) Database (Brown et al. 1996). We used a subset of this comprehensive database for the period 1978 to 1994 in our study. Data for 1995 to 2002 were obtained from the Canadian Department of Fisheries and Oceans (DFO). These data were collected and recorded in the same manner as for ECNASAP but the collecting gear was changed in 1995, making direct comparisons between the two datasets impossible. In both datasets, the basic information includes set number, cruise number, vessel, depth, location, date, time of day, bottom salinity, bottom temperature and gear type. The number and aggregate weight of each species caught in each set is recorded under a 6-letter species code.

These scientific survey data have been developed only for the express purpose of assessing stock status and levels in commercial fish populations. Nonetheless, because of their broad distribution in space and time, standardization, comprehensiveness, and the fact that information on all species encountered was recorded, the survey data have proven useful for other types of studies as well. These include trends in size of exploited species (Haedrich and Barnes 1997), biogeography and community structure (Mahon et al. 1998), fish community dynamics (Villagarcía et al. 1999), impacts of deep-water fishing (Koslow et al. 2000, Haedrich et al. 2001), size-based trophic modeling (Martinez-Murillo 2001, 2003), quantifying changes in occurrence (Moss 2002), biodiversity mapping (Baker 2003), and trends within and outside Canada's Exclusive Economic Zone (Williams 2004).

Drawing on this body of work, and because fishery surveys similar to those available to us in Canada have been conducted in many parts of the world, our interest in the present study was to determine whether such data might contain information that could be used to measure the effectiveness of MPAs. In particular, we focused on abundance and mean size, two easily derived metrics that have clear ecological implications.

The two datasets were analyzed independently because of the gear change in 1995, and because the change took place halfway through the year information from 1995 was excluded from the analysis. CPUE was calculated for each species by dividing the total number of individuals caught by the number of tows at appropriate depths for the species that were sampled in that year. Mean size was calculated for each species by dividing the total weight by the total number caught in that year. CPUE and size were then plotted against year and analyzed by linear regression. Trends were considered significant if the trend-line had a slope that differed from zero at the 95% level, i.e. 19 times out of 20. The strength and direction of any trends observed were measured by Pearson's correlation coefficient, r.

Our interest was in trends over time, not absolute values, and so results were scaled to be equivalent for presentation in the graphs. The scaling factor was the value from the Engels net in 1994 divided by the value for the Campelen net in 1996; this factor was applied to all Campelen results (1996-2002). Our study area was the Grand Banks region where the data are the most comprehensive, and stations outside the study area were removed from the data. Thus the area we focused on comprised NAFO divisions 3KLNO inside Canada's 200-mile limit.

Twenty-one species were chosen to study based on data availability and ecological and/or economic importance (Williams 2004). The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) currently recognizes four fish species-at-risk that occur regularly on the Grand Banks: Atlantic cod, Atlantic wolffish (*Anarhichas lupus*), northern wolffish (*Anarhichas denticulatus*), and spotted wolffish (*Anarhichas minor*) (COSEWIC 2004). Three other species

which occur regularly on the Grand Banks and have sufficient available data are being considered by COSEWIC: roughhead grenadier (*Macrourus berglax*), roundnose grenadier (*Coryphaenoides rupestris*), and thorny skate (*Amblyraja radiata*). Seven additional species were considered marine indicator species by Hamilton et al. (2003): American plaice (*Hippoglossoides platessoides*), capelin (*Mallotus villosus*), deepwater redfish (*Sebastes mentella*), golden redfish (*Sebastes marinus*), Greenland halibut (*Reinhardtius hippoglossoides*), witch flounder (*Glyptocephalus cynoglossus*), and yellowtail flounder (*Limanda ferruginea*). Seven other species were chosen as special interest species: Atlantic argentine (*Argentina silus*), Altantic halibut (*Hippoglossus hippoglossus*), common lumpfish (*Cyclopterus lumpus*), goosefish (*Lophius americanus*), haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), and smooth skate (*Malacoraja senta*). These make up the 21 species examined in this study.

Results

Prior to the moratorium, eleven species showed declines in abundance and ten showed declines in size. No species showed increasing trends in CPUE and only one exhibited an increasing trend in size. After the moratorium, one species showed an increasing trend and one a decreasing trend in abundance. Four species exhibited increasing trends in size and one species showed a decreasing trend (Table 1).

Table 1. Summary of trends in CPUE and size for all species examined using Pearson's r.

	CPUE		**Size**	
Species	**Before**	**After**	**Before**	**After**
American plaice	**-0.76**	ns	ns	ns
Atlantic argentine	**-0.51**	ns	**0.71**	ns
Atlantic cod	ns	ns	ns	ns
Atlantic halibut	**-0.75**	ns	ns	ns
Atlantic wolffish	**-0.83**	ns	ns	ns
Capelin	ns	ns	**-0.94**	ns
Common lumpfish	ns	ns	**-0.71**	ns
Deepwater redfish	ns	ns	**-0.59**	ns
Golden redfish	ns	ns	**-0.85**	ns
Goosefish	ns	ns	ns	ns
Greenland halibut	ns	**-0.96**	**-0.92**	ns
Haddock	ns	ns	ns	ns
Northern wolffish	**-0.93**	ns	ns	ns
Pollack	ns	ns	ns	ns
Roughhead grenadier	**-0.83**	ns	**-0.82**	**0.90**
Roundnose grenadier	**-0.75**	ns	**-0.60**	**0.82**
Smooth skate	**-0.83**	ns	**-0.50**	**0.84**
Spotted wolffish	**-0.83**	**0.91**	ns	ns
Thorny skate	ns	ns	**-0.72**	**0.96**
Witch flounder	**-0.72**	ns	**-0.75**	ns
Yellowtail flounder	**-0.61**	ns	ns	**-0.88**

Bold values represent significant trends (95% confidence level). (ns) represents a non-significant trend.

These findings must be examined in conjunction with the life-history traits and on-going fishing pressure of the fish species in question. We focused on six species with varying life-history traits and fishing history to examine changes in these metrics.

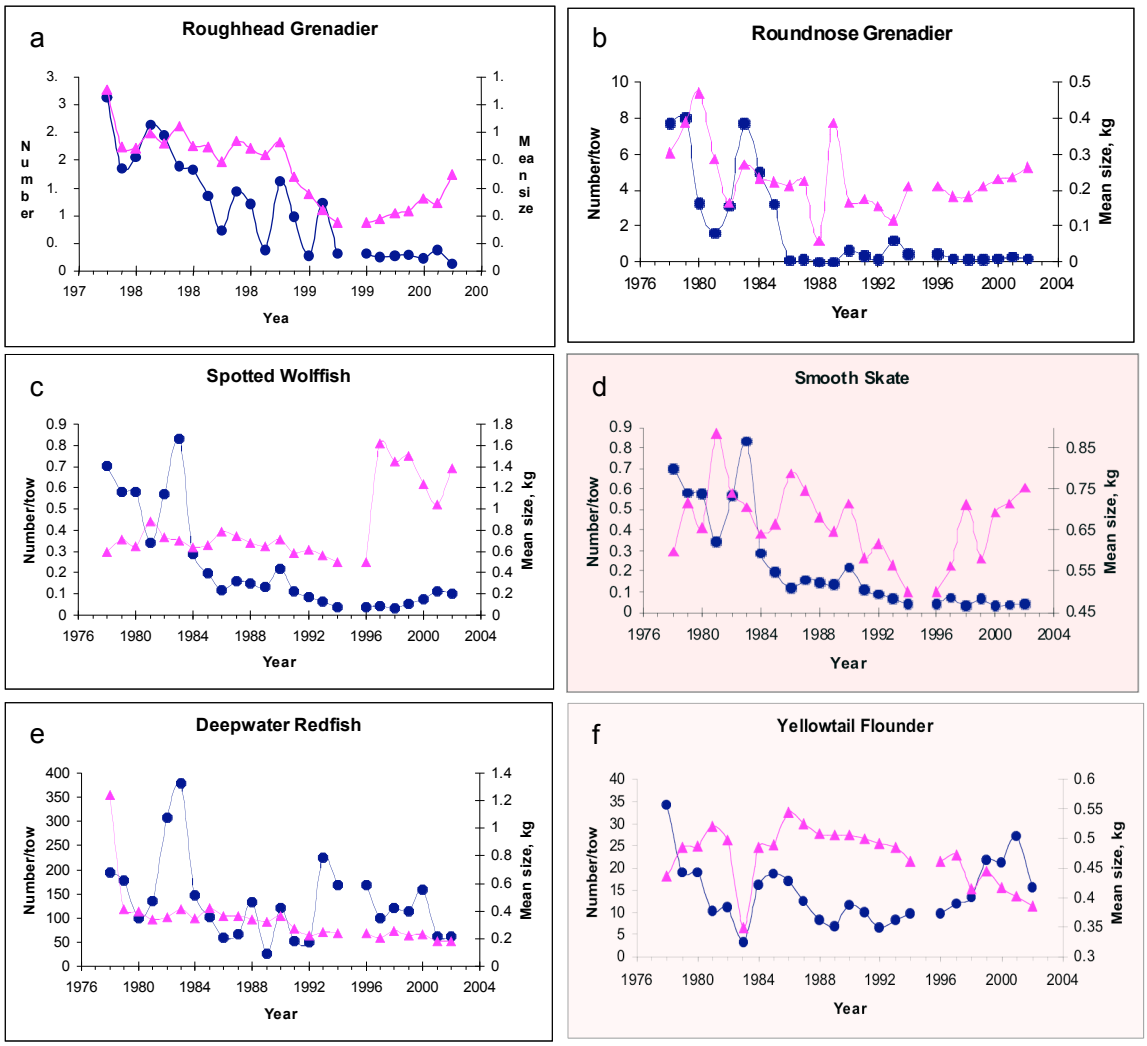

Figure 1(a-f): Trends in CPUE and size of roughhead grenadier (a), roundnose grenadier (b), spotted wolffish (c), smooth skate (d), deepwater redfish (e), yellowtail flounder (f). Triangles represent mean size in kilograms and circles represent CPUE.

A long-lived fish with low productivity would be expected to take years, even decades to reach its prior abundance after being subjected to on-going fishing pressure. The roughhead grenadier lives up to 25 years, matures at approximately 14 years, and is known to have relatively low productivity when compared to shelf gadoids (Cohen et al. 1990, Murua and Motos 2000). Before the moratorium, this species exhibited a decreasing trend in CPUE ($r = -0.83$, $p<0.05$) and size ($r = -0.82$, $p<0.05$). After the moratorium, CPUE showed no distinct trend and average size exhibited an increasing trend ($r = 0.90$, $p<0.05$). Roundnose grenadiers live up to 60 years, mature at 8 to 10 years of age, and are also known to have relatively low productivity (Bergstad and Isaksen 1987, Kelly et al. 1997). CPUE exhibited a decreasing trend before the moratorium ($r = -0.75$, $p<0.05$) and no distinct trend after the moratorium. Although average size showed a decreasing trend ($r = -0.60$, $p<0.05$) before the moratorium, afterwards average size began to increase ($r = 0.82$, $p<0.05$).

Spotted wolffish and smooth skate are thought to be more resilient to change (Froese and Pauly 2004). Species which show higher resilience to change would be expected to exhibit increasing trends in size and/or CPUE in the later data (after the moratorium). Recruitment could improve

to a point where many small individuals enter the system and therefore the average size would begin to exhibit a decreasing trend, while CPUE continued to increase. Little is known about smooth skate maturity and growth (Scott and Scott 1988). Smooth skate exhibited decreasing trends in CPUE ($r = -0.83$, $p<0.05$) and average size ($r = -0.50$, $p<0.05$) in the early data. In the later data, CPUE showed no trend and size began to increase ($r = 0.84$, $p<0.05$). Spotted wolffish mature near 7 years of age and although fecundity is not considered high, survival of well-developed eggs is considered successful (Scott and Scott 1988). CPUE of spotted wolffish declined steadily from 1978 to 1994 ($r = -0.83$, $p<0.05$), but from 1996 to 2002 it exhibited a strong increasing trend ($r = 0.91$, $p<0.05$). Average size showed no distinct trend before and after the moratorium.

Fish species that continue to be the target of direct fishing pressure would be expected to show no or very few signs of recovery. Deepwater redfish are known to be slow-growing and long-lived (Scott and Scott 1988). This species is generally fished using both bottom and mid-water trawls to allow for a 24-hour fishery. They exhibited no trend in CPUE before and after the moratorium. Size exhibited a decreasing trend before the moratorium ($r = -0.59$, $p<0.05$) and no significant trend after the moratorium. Yellowtail flounder became an important commercial fish on the Grand Banks in the early 1970s and since then it has become a substantial addition to the commercial fishery there. There is a directed fishery for this species by Canadian otter trawlers and they are also caught as by-catch when fishing for American plaice (Scott and Scott 1988). Yellowtail flounder are thought to be highly resilient. They mature at 5 to 6 years of age on the Grand Banks and one mature female can lay millions of eggs (Froese and Pauly 2004). This species exhibited a decreasing trend in CPUE between 1978 and 1994 ($r = -0.61$, $p<0.05$) and no significant trend in CPUE between 1996 and 2002. The average size of yellowtail flounder showed no significant trend before the moratorium and a decline after the moratorium ($r = -0.88$, $p<0.05$).

Discussion

The results of this simple research suggest that fishing closures in combination with associated fishery survey data can be used to examine potential measures of offshore MPA effectiveness. The results indicate that average sizes of fish in combination with changes in abundance are appropriate measures of effectiveness. Size may be a more appropriate short-term measure of effectiveness, whereas changes in abundance may take many years to develop. Nevertheless, life-history and current fishing pressure must be taken into consideration while examining trends in these measures. It is extremely unlikely that significant increases in numbers will be apparent in a short time frame for species with late maturation and low productivity. Species which are more resilient to change, such as smooth skate or spotted wolffish, may show changes in size and CPUE over a shorter period of time.

These results are similar to those found near or within tropical MPAs; decreases in fishing pressure can cause increasing trends in size and abundance of fish species affected by the fishing activity. Regardless of the exact goals of the specified MPA, an increase in the average size of fishes is a good sign.

The fishes chosen in this study are influenced by many factors that were not examined in this paper. Although fishing on the Grand Banks decreased substantially after the moratorium, minimal fishing still takes place (Kulka and Pitcher 2002). Therefore, some of these fish are still subjected to a directed or by-catch fishery. This may be limiting the ability of some fish species to exhibit changes in size and abundance. The Grand Banks is not a closed system and therefore our results may have been influenced by immigration. For example, larger grenadiers from deeper areas where there is no fishing could have moved to the sample area. We recognize that

fishing closures are not the perfect scenario for studying measures of offshore MPA effectiveness, but nevertheless using these data we were able to gain some insight about potential metrics of effectiveness.

In the future, more appropriate areas may be found to study the effects and/or effectiveness of offshore MPAs in Canada's Atlantic Ocean. In September 2002, a 20 by 20 nmile portion of the Hawke Channel was closed to all otter trawling and gillnetting. In 2003, this area was increased to cover 50 by 50 nmiles to protect spawning juvenile cod (Rose pers comm. 2005). It is currently protected from all forms of commercial fisheries (except crab traps) and other invasive activity such as seismic exploration (FRCC 2003). It was created based on a joint effort made by independent researchers, Labrador crab fishermen, shrimp fishermen, industry and DFO management (Rose pers comm 2005). A similar "codbox" (The Bonavista Box) is still under consideration by DFO. These will create future situations where more direct comparisons of measures of effectiveness can be made between distinct areas.

It must be highlighted that many variables contribute to the success of an MPA. MPAs subjected to uncontrollable external stressors from atmospheric, terrestrial and ocean sources are likely to be ineffective (Jameson et al. 2002). Maliao et al. (2004) found that adequate enforcement and investment of funds by local government in monitoring activities were necessary to achieve MPA objectives. As well, it is widely recognized that adequate protection and thus success depends on both compliance and enforcement (Roberts 2000). These factors and many others must be taken into account before an MPA is established to heighten the potential for an effective MPA.

Acknowledgements
We thank the Social Sciences and Humanities Research Council of Canada (SSHRC), and the Natural Sciences and Engineering Research Council of Canada (NSERC) who have provided the major funds for the "Coasts Under Stress" Project through the SSHRC Major Collaborative Research Initiatives (MCRI) program. Host universities (Memorial University of Newfoundland and the University of Victoria) also provided funds for this research. Funding was also provided through the North Atlantic Arc Project (NSF). We thank the North American Commission for Environmental Cooperation and the North American Marine Protected Areas Network for the opportunity to present this work.

Literature Cited

Alder, J. 1996. Have tropical marine protected areas worked? An initial analysis of their success. Coastal Management 24: 97-114.

Allison, G.W., J. Lubchenco and M.H. Carr. 1998. Marine reserves are necessary but not sufficient for marine conservation. Ecological Applications 8: S79 – S92.

Baker, K.D. 2003. Potential sites for marine protected areas in Canada's North Atlantic. Masters of Environmental Science Thesis. Memorial University of Newfoundland. 73pp.

Bergstad, O.A. and B. Isaksen. 1987. Deepwater resources of the Northeast Atlantic: distribution, abundance and exploitation. NAFO SCR Doc. 87/85, Serial No. N1388, 40p.

Brown, S.K., R. Mahon, K.C.T. Zwanenburg, D. B. Atkinson, K. R. Buja, L. Claflin, G. D. Howell, M. E. Monaco, R. N. O'Boyle and M. Sinclair. 1996. East coast of North America demersal fishes: initial explorations of biogeography and species assemblages. National Oceanic and Atmospheric Administration Silver Spring, Maryland, and Department of Fisheries and Oceans, Dartmouth, Nova Scotia. 109 pp.

Cohen, D.M, T. Inada, T. Iwamoto and N. Scialabba (eds). 1990. FAO Species Catalogue, No. 5 (10): Gadiform fishes of the world. Food and Agriculture Organization of the United Nations, Rome. 442 pp.

COSEWIC. 2004. Canadian species at risk, May 2003. Committee on the Status of Endangered Wildlife in Canada, Environment Canada.

Day, J.C. and J.C. Roff. 2000. Planning for representative Marine Protected Areas: A framework for Canada's Oceans. World Wildlife Fund, Toronto. 147pp.

DFO. 2004. Canadian waters, ocean management, marine protected areas. Url: http://www.dfo-mpo.gc.ca/canwaters-eauxcan/oceans/mpa-zpm/index_e.asp, version (05/2004).

Doubleday W.G. (ed) 1981. Manual on groundfish surveys in the Northwest Atlantic. NAFO Scientific Council Studies 2: 7-55.

FRCC. 2003. Press Release: March 27, 2003, FRCC recommendations for northern cod. Url: http://www.frcc-ccrh.ca/eindex.htm, viewed April, 2003.

Froese R. and D. Pauly. 2004. Fishbase. www.fishbase.org, version (12/2004).

Haedrich, R.L. and S.M. Barnes. 1997. Changes over time of the size structure in an exploited shelf fish community. Fisheries Research 31: 229-239.

Haedrich, R. L., N.R. Merrett and N.R. O'Dea. 2001. Can ecological knowledge catch up with deep-water fishing? A North Atlantic perspective. Fisheries Research 51: 113-122.

Halpern, B.S. 2003. The impact of marine reserves: Do reserves work and does reserve size matter? Ecological Applications 13(1): S117-S137.

Hamilton, L.C., R.L. Haedrich and C.M. Duncan. 2003. Above and below the water: Social/Ecological transformation in Northwest Newfoundland. Population and Environment 25(2): 101-119.

Jameson, S.C., M.H. Tupper and J.M. Ridley. 2002. The three screen doors: can marine "protected" areas be effective? Marine Pollution Bulletin 44: 1177-1183.

Kelly, C.J., P.L. Connolly and J.J. Bracken. 1997. Age estimation, growth, maturity and distribution of the roundnose grenadier from the Rockall trough. Journal of Fish Biology 50:1-17.

Klee, G.A. 1999. The coastal environment: toward integrated coastal and marine sanctuary management. Prentice Hall, New Jersey. 281pp.

Koslow, J.A., G.W. Boehlert, J.D.M. Gordon, R.L. Haedrich, P. Lorance and N. Parin. 2000. Continental slope and deep-seas fisheries: Implications for a fragile ecosystem. ICES Journal of Marine Science 57: 548-557.

Kulka, D.W. and D.A. Pitcher. 2002. Spatial and temporal patterns in trawl activity in the Canadian Atlantic and Pacific. ICES CM 2001/R:02. 57pp.

Lane, D.E. and H.P. Palsson. 1996. Stock rebuilding strategies under uncertainty: The case for sentinel fisheries. Pp 61-90 in Gordon, D.V. and G.R. Munro. Fisheries and Uncertainty: A precautionary approach to resource management. University of Calgary Press. Calgary, Alberta.

Mahon, R., S.K., Brown, K.C.T. Zwanenburg, D.B. Atkinson, K.R. Buja, L. Claflin, G.D. Howell, M.E. Monaco, R.N. O'Boyle and M. Sinclair. 1998. Assemblages and biogeography of demersal fishes of the east coast of North America. Canadian Journal of Fisheries and Aquatic Sciences 55: 1704-1738.

Maliao, R.J., E.L. Webb and K.R. Jensen. 2004. A survey of stock the donkey's ear abalone, *Haliotis asinine* L. in the Sagay Marine Reserve, Philippines: evaluating the effectiveness of marine protected area enforcement. Fisheries Research 66: 343-353.

Martínez-Murillo, María de las Nieves. 2001. Size structure and production in a demersal fish community. Deep-sea Fisheries Symposium (NAFO conference). Havana, Cuba. 12–14 September. NAFO SCR Doc. No. 134, Serial No. N4529, 16p.

Martinez-Murillo, María de las Nieves. 2003. Size-based dynamics of a demersal fish community: Modeling fish-fisheries interactions. PhD thesis (Biology), Memorial University. 216pp.

Moss, Andrew. 2002. Change in abundance and extent of occurrence of demersal marine fishes: quantitative assessments based on research survey data. Master of Environmental Science project report, Memorial University. 29 pp. + appendices.

Murua, H. and L. Motos. 2000. Reproductive biology of roughhead grenadier (*Macrourus berglax* Lacepede, 1801) (Pisces, Macrouridae), in Northwest Atlantic waters. Sarsia 85: 393 - 402.

Myers, R.A., J.A. Hutchings and N.J. Barrowman. 1997. Why do fish stocks collapse? The example of cod in Atlantic Canada. Ecological Applications 7(1): 91-106.

Roberts, C.M. 2000. Selecting marine reserve locations: optimality versus opportunism. Bulletin of Marine Science 66: 581-592.

Roberts, C.M., J.A. Bohnsack, F. Gell, J.P. Hawkins and R. Goodridge. 2001. Effects of Marine Reserves on Adjacent Fisheries. Science 294: 1920-1923.

Rose, G.A. Personal Communication. 2005. Professor and Chair of Fisheries Conservation, Fisheries and Marine Institute. Memorial University of Newfoundland. St. John's, Newfoundland.

Russ, G.R. and A.C. Alcala. 1996. Do marine reserves export adult fish biomass? Evidence from Apo Island, central Philippines. Marine Ecology Progress Series 132: 1-9.

Scott, W.B. and M.G. Scott. 1988. Atlantic Fishes of Canada. Can. Bull. Aquat. Sci. 219: 713 p.

Villagarcía, M.G., R.L. Haedrich and J. Fischer. 1999. Groundfish assemblages of eastern Canada examined over two decades. Pp 239-259 in Newell, D. and R.E. Ommer (ed). Fishing Places, Fishing People. University of Toronto Press, Toronto.

Williams, A. 2004. Where to draw the line? A preliminary analysis of the 200-mile limit as a tool for conservation on the Grand Banks. Master of Environmental Science Thesis, Memorial University of Newfoundland. 58pp.

Woodrow, M. 1998. A case study of fisheries reduction programs during the Northern Cod Moratorium. Ocean & Coastal Management 39:105-118.