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Evaluation of offshore closed areas as a fisheries management tool, with emphasis on two case studies.

by

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Introduction

The use or potential use of Marine Protected Areas (MPA's) in the management strategies for fish stocks has been receiving an increased amount of attention in recent years. The term MPA generally refers to the managed use of a broad range of types and levels of protection for the marine environment, which would include the use of closed areas, to limit the type and quantity of fishing activity. A definition of a MPA that is often quoted is that of the World Conservation Union (IUCN) and is as follows; " any area of intertidal or sub tidal terrain, together with its overlying water and associated flora, fauna, historical and cultural features, which has been reserved by law or other effective means to protect part or all of the enclosed environment" (Kelleher and Kenchington, 1992).

Although the history of MPA's covers a period of about 60 years, their development has been substantial only since the late 1960's (Wolfe and Hartley, 1996). It has been reported (Paisley, 1996) that up to that time, MPA's had been established in about 30 countries with considerable variation from country to country. Those with the highest numbers were New Zealand, Australia, the United States, Great Britain, South Africa, France, and Belize. The extension of fisheries jurisdictions to 200 miles in 1977 enabled nations to take a number of measures, including those related to regulation of fishing and the protection of living resources of the continental shelf within that area. It provided a legal basis upon which measures for the establishment of MPA's and the conservation of marine resources could be developed. Guidelines have also been proposed (Kelleher and Kenchington, 1992) for establishing MPA's. An additional indication of the increased interest in the use of MPA's has been the passage of Canada's Oceans Act in January of 1997. Section 35 of the Act (see Appendix) states a number of conservation goals that bear on the development of MPA's for incorporation into integrated management plans.

The quality of MPA's throughout the world varies from those in which the marine environment is highly protected and the taking of all marine life is prohibited, to those in which the marine environment is protected in little more than name only. Size of MPA's is also variable ranging from a few hectares to about 350,000 km.^{2} (Australia's Great Barrier Reef Park). A summary by country of existing marine reserves related to the fishery has been described by Bryant et al. (1995).

The increased acceptance of the use of MPA's in fisheries management has undoubtedly resulted from a need for additional measures in view of the general lack of success of traditional management methods. There appears to be an ever increasing number of declining commercial fish stocks along with the associated problems that these situations create. In this context, the value of MPA's has been discussed widely. Most proponents describe the intuitively expected positive gains rather than citing specific studies where the value or effectiveness has been scientifically proven. The reason for the relative paucity of supportive studies is probably linked to the idea that " their benefits are hard to quantify and are often slow to be realized" (Agardy, 1994).

The present paper will provide an evaluation, mainly in the form of case studies, of the effectiveness of the use of offshore closed areas/seasons that have been used as management tools for fish stocks in two different geographic areas. It will look at the history and effectiveness of the use of this type of MPA for; 1) Haddock stocks on the Scotian Shelf and Georges Bank (Fig.1) - International Commission for the Northwest Atlantic Fisheries/North Atlantic Fisheries Organization (ICNAF/NAFO) Div. 4X and 5Z respectively), and 2) North Sea Plaice - International Council for the Exploration of the Sea (ICES) Subarea IV.

Scotian Shelf and Georges Bank Haddock

In the late 1960's the haddock stocks on the Scotian Shelf (ICNAF/NAFO Div. 4VW and 4X) as well as Georges Bank (Div. 5Z) were subject to increased fishing pressure and there were signs of resource declines (4X and 5Z). Georges bank haddock were being depleted by fishing (Hennemuth, 1968) and this had been accompanied by several years of recruitment failure. This stock had yielded an average catch of about 50,000t over the 1935-60 period but was predicted to yield only 13,000t in 1970 at the same exploitation rate. It was thought that a 4-5 year period of no or very little fishing was required to effect recovery (ICNAF, 1969). Div. 4X haddock were still considered to be fairly abundant though fully exploited, but recruitment failure was forecast (Grosslein, 1969). The status of Div. 4VW haddock was similar to that of Div.5Z. It was clear that regulatory measures were necessary to reduce the exploitation rate and reverse the declining stock trends.

At this time, regulation and management of these fisheries was the responsibility of ICNAF. The ICNAF Convention gave it the authority to make certain kinds of proposals to the contracting Governments with the goal of keeping fish stocks at a level permitting the maximum sustainable catch (Halliday, 1988). Under the Convention (Article VIII) there were a limited number of measures allowed which might help in the achievement of the desired goal. These included: 1) establishing open and closed seasons; and 2) closing to fishing, portions of Subareas found to be spawning areas or to be populated by small or immature fish. Until 1969, the only other regulatory measure which had been utilized pertained to the control of mesh size and gear construction (otter trawls) used in the groundfish fisheries. The haddock stock situation at that time required that additional measures be taken. The measures that were proposed for 1970 by Canada and the United States, and accepted by ICNAF, included a total allowable catch (TAC), the first introduced by the Commission of ICNAF, and closure of spawning grounds for the spawning season.

Halliday (1988) states that " the detailed rationale for the choice of measures is not recorded but clearly these countries wanted to do all possible to reverse the declining trends in haddock stocks". He further deduced "from analysis of prevailing circumstances" that the fundamental intent of the regulations was to reduce the high rate of exploitation by the fisheries. When considerating Georges Bank haddock at its 1969 meeting, STACRES considered closed areas/seasons as alternatives to catch limitation. Spawning season and area were also the area and season of peak catch rates and hence closure was expected to impact significantly in reducing catches or, at least, in spreading them more evenly through the year.

It would seem somewhat ironic that the stated intent of the regulations, that of spawning ground and season closure, was accepted by all involved, although the underlying intent was toward the reduction in exploitation rate. The use of spawning season rationale apparently appealed to a fundamental common sense approach that could be accepted by fishermen without the support of 'scientific' fact. Scientific advice at the 1969 ICNAF meeting indicated that benefits from the protection of spawning fish could not be demonstrated and it was never proposed by ICNAF that closures would directly affect spawning success. However, the approach was accepted by both Canadian and USA fishermen who undoubtedly believed that some biological benefits would accrue. Halliday (1988) states that " the insistence of USA fishermen" was responsible for the inclusion of the spawning season closure in the 1969 USA regulatory proposal for Subarea 5 haddock.

The basis for definition of these spawning area and season closures were; the distribution of ripe, spawning, and spent haddock in the commercial and research catches; planktonic egg distributions; and seasonal egg production curves (Halliday, 1988). The seasonal and areal closures were introduced in 1970 (ICNAF, 1969) and included three areas; two in Subarea 5 and one in Div.4X (Fig. 2). The closures covered a period of two months (March and April) and applied to fishing with gear capable of catching demersal species. The details of the coordinates defining the areas and seasons as well as any modifications over the 1970-87 period are described by Halliday (1988). The areal and seasonal closures have since continued to be part of haddock management plans in these areas, although there have been numerous changes since their first introduction. The area currently in use is shown in Fig 3. Most of these have been related to the resolution of conflicts with the fisheries for other species and have involved areal changes. For example, in 1972, the closed area in Div.4X was reduced where it encompassed deeper waters to permit the prosecution of spring fisheries for argentine and silver hake while one area in Subarea 5 was reduced in size to minimize disruption of USA redfish and shrimp fisheries. In Div.4X, months of closure have changed as follows: March-May (1972-74); Feb.-May (1975); March-May (1976-93); March-June 15 (1991-93); and Jan.-June (1994-95) - (see Halliday, 1988; Annand and Hansen, 1995; and Angel et al., 1994). Reasons for these changes have not been documented but are assumed to be a response to database updates.

Similar seasonal changes have occurred with the closed areas in Div. 5Z. In October 1984, the delimitation of the Canada-USA maritime boundary resulted in a division of the closed area on Georges Bank (Area B- Fig. 3). Prior to the resolution of the maritime boundary dispute between Canada and the USA, the closed area seasons on both the the Canadian and USA portions of Georges Bank included the months of March and April (1970-71), and March-May (1972-86). Subsequent to the settlement, seasons on the Canadian side were March- May (1987-93), and January-May (1994-96) while those for the USA side were February-May (1987-93), January-June (1994), and the entire year (1995-96). In 1994 the USA also expanded the size of their portion of Area B (by 15 minutes latitude to the south and 20 minutes longitude to the west) to provide increased protection to haddock concentrations in the area (Gerrior et al., 1994).

Canada had initially proposed the inclusion of a closed spawning area in Div. 4VW but later abandoned the idea because of opposition based on anticipated interference to the silver hake and cod fisheries (Halliday, 1988). A spawning area closure reported (Zwanenburg and Hansen, 1993) for Div. 4VW in 1981 for the period March 1 to May 31, was apparently in error (J.Hansen; pers comm.).

The use of closed areas as a means of protecting haddock nursery areas on the Scotian Shelf was instituted in the late 1980's. The rationale behind closure of juvenile nursery areas is to produce a greater realization of growth potential of recruiting year classes and allow a larger proportion of individuals to reach maturity. An area of the Scotian Shelf was closed to fishing in 1987 (Fig.4) as it was considered an important haddock nursery area. This resulted from an industry recommendation for a closure of haddock nursery areas in Div. 4VW to all groundfish activity (Fanning et al., 1987). The nursery areas were identified using data from; " summer groundfish research surveys, the International Observer Program, published reports, and personal communication" (Fanning et. al.1987). Closure was originally recommended for two areas (I and II - Fig. 4) but was subsequently limited to one (area I). A longline fishery was originally permitted (1987-92) in the closed area but since that time only a scallop fishery gas been permitted (Zwanenburg, pers comm.). The closure also extends for the entire year.

The early years also saw some changes with regard to regulations pertaining to fishing gear restrictions in the closed spawning area. As stated, the initial regulation applied to gear capable of catching demersal species. This was modified in 1972 to permit use of pelagic gears fishing off-bottom and a fishery using large hooks (gape not less than 3 cm.) was also permitted in Subarea 5. The latter closure exemption eventually (1974) applied to only one area of Div.5Z (that closest to shore). However, an amendment to the Canadian regulations in 1981 inadvertently permitted the use of large hooks in a longline fishery on Georges Bank. This error was allowed to persist in the regulations until the early 1990's when the regulations were changed to a closure for all gears .

Evaluation of the effectiveness of the closed areas has had limited success. Evaluation of the spawning area and season closures is dependent on whether the theoretical or practical reasons are to be considered. In considering the theoretical reasons, it would be necessary to prove that the closure produced an increase in spawning success (increased number of fertilized eggs) and a consequent increase in the number of recruits to the fishable stock. While this is an important issue in evaluation of its usefulness as a management tool, it was, and still is, difficult to resolve. There are many factors affecting spawning success and the subsequent survival of recruits, and, unless all factors can be accounted for, it would be almost impossible to determine the effect of each of the variables. It has been generally accepted, however, that there is a tendency for low spawning stock biomasses (SSB's) to be less successful spawners (Shelton and Morgan, 1993) although there is not a precise definition of the threshold stock levels for this phenomenon .

There is little in the scientific literature which provides an evaluation of the success or failure of the spawning area closures on the Scotian Shelf and Georges Bank haddock stocks. The CAFSAC Advisory Doc. for 1981 (81/9) indicated that there was no data available at that time " to suggest that a closed area has either a good or bad effect on spawning success and thus recruitment". It was claimed that a biological interpretation was confounded by the coincidental application of the quota management scheme.

There were no reports found which established a direct link between an increase in the number of eggs produced or the number of subsequent recruits and the existence of spawning area closures. Its persistence in management plans appears to be rooted in a strong belief that it is conceptually sound and that it awaits only the proper evaluation tools and techniques for verification. A recent attempt at assessing closed areas (Mohn, 1996) indicated that traditional models used in estimating fish populations could not assess the contribution of specific areas (eg. closed areas) mainly because the necessary data were difficult to obtain. In the study, an exploratory model was developed which simulated the effects of fishing with and without spawning area closures on long term annual landings, from a management unit having three spawning components, as well as the impacts of differences in fishing methods on their efficiency in exploiting spawning aggregations. Although based on many assumptions, results indicated potential benefits associated with having a closed area in terms of improving population numbers in the protected and surrounding unprotected areas.

As stated, the fundamental intent of the spawning closures was the reduction of the exploitation rate to a low level. To some extent this was successful. For example, in the years following the first spawning area closures, it was claimed (Canada 1974) that the Div. 4X closure was having a greater effect in reducing haddock mortality than the various catch quotas and by-catch limits. Closed areas were thought to be more easily enforced than were TAC's and by catch limits.

Information available on the status of these haddock stocks (FRCC Rep. 1996) indicated dramatic declines since the 1980's. Recent years have seen some improvement, particularly with respect to the above average levels estimated for the 1992-93 year classes, in all areas. As the spawning area closures had been in effect through the period of stock decline which was accompanied by below average recruitment, it might be argued that the closures were not effective. However, it is worthy of note that, as stated below, effective enforcement only occurred after 1990 (Parker, 1996) which is coincidental with the recent period of good recruitment.

An evaluation of the Div. 4VW haddock stock nursery area closure (Zwanenburg and Comeau, 1991) acknowledged that there was no proven link between closed areas and subsequent increases in haddock abundance. However, it was stated that the information presented "was highly suggestive of this being the case". This was apparently based on the continued presence of the relatively large 1988 year class, particularly in Div. 4W in and around the closed area.

During the 1980's, when there was a considerable amount of effort in the groundfish fishery on the Scotian Shelf, illegal fishing within the closed areas was considered commonplace (Parker, 1996) with the net result being no real closure compliance. Enforcement has been conducted by patrol vessels, aircraft, and fishery officers but the results were limited by the technology available. In the late 1980's and early 1990's enforcement became more effective with the acquisition of more sophisticated equipment which improved the speed and accuracy of detection of violations. The cost of enforcement of the two closed areas on the Scotian Shelf was recently estimated (for 1994) at $1.6 million (Parker, 1996).

Areal and seasonal closures have also been used in the management of the silver hake fishery on the Scotian Shelf (Parsons, 1993). In this fishery small-meshed gear had been used and, prior to 1977, it was found to be taking large quantities of juvenile cod and haddock. At that time Canada introduced measures to address the issue. These included establishing an area, which became known as the silver hake box, where hake fishing was permitted only during the period April 15-November 15. Data had indicated that the restrictions would minimize the by-catches of other commercial species while still permitting a silver hake fishery.

The use of closed areas as possible nursery areas was also considered (Sinclair et al., 1991) as a management option for the cod stock in the northern Gulf of St. Lawrence (NAFO Div 4RS3Pn). This stock had also declined substantially and there had been repeated allegations of discarding of small cod. Analysis of survey data did not identify areas with persistent differences in cod size distribution and consequently nursery areas could not be identified which would not have a significant impact on the cod fishery. As well, the Fisheries Resource Conservation Council (FRCC) has recommended in its most recent report (FRCC, 1997. p.31) that time/area closures be established for identified spawning/juvenile aggregations of cod in NAFO Subdivision 3Ps.

North Sea Plaice

North Sea plaice is an economically important flatfish species that is found distributed throughout the central and southern North Sea (Fig.5). The juvenile (15-25 cm) stages are concentrated in shallow inshore waters and gradually move offshore as they grow larger. The nursery areas on the eastern side of the North Sea near the coasts of the Netherlands, Germany, and Denmark contribute about 90% of the total stock recruitment. Spawning occurs in offshore waters during winter. The history of the fishery has shown substantial discarding of undersized plaice, particularly in coastal areas, resulting in high mortality (Rijnsdorp and Pastoors, 1995).

In the late 1980's, assessments of the North Sea plaice stock had determined that exploitation was characterized as being much higher than F_{max} and that it was being concentrated too much on young fish. In 1987 the ICES North Sea Flatfish Working Group was asked to provide advice on measures to improve the exploitation pattern. In doing so, the Working Group analysed data on age distribution from research surveys and commercial catch rates, data on discarding during the year, and considered the effect of possible management measures on other commercial species (Anon, 1987). Two management options were considered; mesh size regulation and the use of closed areas. An increase in mesh size would have greatly improved long term yield, however, the implied mesh increase would have been substantial, from the then legal size of 80-85 mm. to 120-130 mm. The implications would have been severe with regard to the fisheries for other species and consequently this option was not considered feasible. Using the information on juvenile plaice distribution from research vessel surveys and discarding data, an area was proposed for closure to fishing, that would have the greatest impact on reducing the removals of young plaice. The boundaries of these areas were rectangular, and generally based on a minimum of 30 minutes latitude and one degree longitude (Fig. 6).

An evaluation of the impact of the closed area, using a simulation model, concluded that closure for the 2nd and 3rd quarters of the year could raise the apparent recruitment of plaice by about 25%. After discussions with the fishing industry, legislation was introduced in 1989 establishing a closed area or box (thereafter termed the Plaice Box - Fig.7) which was very similar in geographical area to that originally proposed and analysed in 1987 (ICES, 1994). The borders of the Box had been adjusted to account for revised data on the distribution of the juvenile plaice. Detailed coordinates of the Box are presented in ICES, 1994. When introduced, the Box was active from the period April 1 to September 30. In 1994, the regulation was extended to include the fourth quarter and, since 1995, the Plaice Box has been closed for the whole year. However, the regulation did not exclude all fishing from the area. In fact, fishing was only closed to large (>300hp.) trawlers. It was reported (ICES 1996) that the fleet permitted to fish (<=300hp.) had actually increased its capacity and that the larger vessels fished heavily in the closed area after it had reopened on October 1 (1989-1993).

In 1994 ICES set up a Study Group on the North Sea Plaice Box which was mandated to: " investigate appropriate modifications to the plaice box; quantify the expected short- and long termed effects of such modifications on both yield and biomass for plaice and all other relevant species; and identify possible additional regulations associated with the "plaice box"" (ICES 1994). An analysis of the level of discarding by the Dutch beam trawling fleet supported the previous location choice for the closed area. Discard rates inside the plaice box averaged 83% compared with 36% outside the box in the 1976-90 period.

The effects of the plaice box closure were again evaluated with the simulation model first used by the 1987 Working Group (ICES, 1987). Updated effort data along with some breakdown by fleet category (the 1987 simulation had assumed no fishing) were used in the model along with a number of options in which effort was distributed according to different periods of closure of the Box to all or selected fleets. This evaluation suggested that the existing regulated closure (quarters 2 and 3 for selected fleets) would increase plaice recruitment by 8% when compared with that without a closed box. This was much lower than that previously estimated (25% in 1987). The discrepancy was explained by the inclusion of fishing effort in the updated analysis coupled with the heavy fishing that had taken place in the 4th quarter in response to the increased fish abundance built up during the 'closed' 2nd and 3rd quarters. When similar options were compared (closed for the whole year with no discards vs no closed area), both simulations produced comparable results (34% increase in the 1987 analysis and 32% in the 1994 analysis. It was considered possible, as well, that with increased recruitment and the assumption of density dependent growth, changes in growth rate might affect discarding and recruitment to the fishery. One consequent effect might be a reduction in the expected gain from the Box closure.

Analyses also indicated that based on survey results the relative abundance of marketable plaice had increased in 1989-91 compared with pre-Box years and that the relative abundance of undersized age groups had also steadily increased since 1989. Increasing the length of the closed season to include the 4th quarter as well as for the entire year would each increase the total percent recruitment gain. A reduction in fishing mortality in the youngest age groups, as suggested by the Plaice Box simulation studies, was not unequivocally indicated from VPA analysis or from the demersal fish survey results. This was not considered surprising " given the relatively high variance of mortality estimates from VPA and survey data compared to the estimated effect of the Box and the relatively small effect of the box" (ICES, 1994).

A later study (Rijnsdorp and van Beek, 1996) examined further the potential effect of changes in growth rate on evaluation of the Plaice Box closure scenarios. There was also consideration of the survival rates of pre-recruits as well as stock recruitment relationships. In this study the simulation model previously used (Rijnsdorp and Pastoors, 1995) was used with modifications to accommodate the analysis of density dependent growth and stock recruitment relationships. The Plaice Box scenarios used were similar to those in the 1994 study (ICES, 1994). The results from these new simulations showed a similar positive effect of the Plaice Box on recruitment, yield and SSB as had previous studies (ICES, 1987; ICES, 1994). The new predicted gains were somewhat lower possibly because of a revised input parameter value in the new simulation. A decrease in plaice growth rate observed for the late 1980's had resulted in a decrease (14%) in yield. The introduction of the Plaice Box at about the same time reduced the decrease (9%) as would the other options which provided increased closure time. Conversely, an increase in growth rate would increase the yield.

Growth rate analysis indicated significant relationships between both density-dependent (population numbers) as well as density-independent (eutrophication, beam trawl effort) factors. The reduced growth rate of plaice at high population levels implied that a positive effect of the Plaice Box (increased recruitment) might lead to higher population densities and hence reduced growth rates. However, it was noted that the expected recruitment gain from the Plaice Box was much less than the amplitudes of the observed stock recruitment variations. Consequently, it was expected that the negative effect of a reduced growth rate was of lesser degree than the potential gain of improved survival.

While the maintenance of closed areas would be expected to improve recruitment, other factors could influence or cloud the issue. The actual number of plaice recruiting to the fishery could be influenced by variability in environmental conditions during the egg and larval phase as well as survival of the prerecruits until they reach marketable size. Survival until retained by the fishery would be a function of the cumulative natural and possible discard mortalities. Changes in growth rate could also increase these mortalities by effectively increasing the pre-recruit time period.

The potential positive effect of an increased SSB is not clear for this stock. Scatter plots of VPA recruitment and 0-group indices vs SSB did not suggest any threshold SSB level below which recruitment would be impaired and that egg production and survival of eggs and larvae were at an average level despite the historical low level of SSB. The 1996 report (ICES, 1996) indicated that the influence of the Plaice Box on the stock dynamics warranted its inclusion, along with other variables, when considering management advice and medium term predictions for the stock.

The influence of the Plaice Box on other species was considered when each of the studies indicated had been conducted. While it was clear that the area of the Plaice Box covered the most important area of juvenile distribution for plaice it was also determined that it would also impact on cod and sole stocks in the area. High concentrations of sole, including juveniles, were also found within the designated closed area. Sole are caught as part of the general 'flatfish' fishery which historically tended to concentrate its effort in the 2nd and 3rd quarters. Consequently, closure of the Plaice Box area would strongly reduce the catches and fishing mortality of sole. At the time that the closed area was recommended (ICES, 1987), the North Sea sole was considered to be strongly over exploited. It was believed that in addition to the existing TAC regulation, the closed area would help reduce mortality. However the closed area was not the exclusive nursery area for sole as other important areas had been identified. Then projected gains to be accrued for plaice recruitment for the different options showed a similar increasing trend with respect to sole although to a lesser degree. Sole would also benefit from an extension of the closed area to encompass a larger portion of their nursery area.

An examination of the distribution of juvenile North Sea cod (ICES, 1994) indicated that the distribution of 0- and 1-group cod varied considerably within year and quarter in the later years considered. The results of studies simulating the effects of closures for different parts of the north sea indicated that the closed Plaice Box would have no measurable effect on cod SSB. However, it was concluded that the Plaice Box would likely provide protection to juvenile cod in most years. The reports examined indicated (ICES, 1994) that the plaice box might benefit, though not quantifiably, other fish species or benthos. The coastal zone within the Box was also a major nursery area for other fish species (turbot , brill and dab) and had been shown to support a high benthic biomass. It was considered likely that " closure of the box will consequently have wider ecosystem benefits than have been examined in this report" (ICES, 1994).

There was little information published relative to the effectiveness, adequacy, or costs of regulation enforcement relative to the Plaice Box. It has been reported (ICES, 1994) that, based on micro-distributional plots of the fishing activities of some fleets, the box was highly effective as a technical measure. This might imply that there was a high level of compliance either honorably or, as is more plausible, it occurred because of effective enforcement.

Closed areas in other locations

As indicated earlier, closed areas or seasons have been used extensively by countries or management authorities in fisheries management for certain stocks. Some additional areas or stock units for which their use has been documented are:

Iceland: Area closures, both temporary and permanent, have been used extensively for some time (Arnasón, 1994) to protect immature fish as well as spawning grounds. Extensive areas were closed to deep-sea trawlers including most of the fishing grounds within the 12 mile limit as well as a few large areas offshore. Shopka (1994) indicated that closed areas had been used, along with other measures, to protect cod nursery areas and they had been successful in reducing the fishing mortality considerably on the younger age groups.

Arcto-Norwegian cod: Naken (1994) indicated that an area closure system was established in the 1980's to reduce the discarding of young fish and it was indicated that this measure, along with others, was successful in " reducing the influence of fisheries on year class abundance " at young ages.

New Zealand: A network of marine reserves has been established and more are planned (Ballantine, 1994). These are termed no-take areas in that no fishing, no removals, and no disturbance is permitted. The reserves concentrate on providing unexploited areas in the sea as an independent and additional system to that involved with the management of resource exploitation and its inherent problems. Although the benefits of the system have been largely termed potential, it was stated that there was growing evidence supporting their existence.

Discussion

The concept of marine protected areas and their usefulness as conservation instruments is relatively well accepted. This is evidenced by their successful and extended use in countries such as New Zealand (Ballantine, 1994) and Australia (Ottesen and Kenchington, 1994), proposals for increased use by others such as Spain (Suarez de Vivero and Frieyro, 1994), and recent incorporation into Canada's Oceans Act (DFO, 1997). As stated previously, the concept has a wide variety of applications with a large number of marine areas having been designated as marine sanctuaries, parks, and preserves with varied degrees of protection and use. Most have been designed for the preservation of habitats and communities for conservation and research. Only a small number have been designed for the purpose of fishery enhancement. The specific area of MPA's dealt with in the current paper concerns the use of closed areas as tools to be used in fisheries management.

Management of commercial fisheries has generally developed in response to specific fishery related problems which usually fall under the heading 'declining catch rates'. Two main tools that have been used to manage fisheries at the international level were; 1) TAC's, which theoretically limit the amount of a fish stock caught annually, and 2) technical measures such as mesh size, minimum fish size, and closed areas or seasons. The use of closed areas or seasons in fish stock management has not been as extensive as the other methods. The increased interest and advocacy in recent years has resulted from the apparent lack of success of existing management practices for a great number of fish stocks. There have been a number of declining fish stocks in recent years inspite of management efforts to the contrary. In this situation it has been necessary to improve on methods previously used or to try alternatives. One alternative has been to provide protection for the troubled stocks through the establishment of protected or closed areas. The latter have not been considered as replacements for existing measures (Kenchington, 1995; Doubleday, 1993), which mainly attempt to reduce fishing mortality through catch limits, but as a supplementary management tool.

From the literature it is clear that there are a large number of proponents for the establishment of protected areas and for a variety of reasons. Although the basis for, or the concept behind establishment of closed areas is largely intuitive, a determination of their success or failure is generally based on an evaluation of their specific goals. However, the literature is very sparse with respect to evaluations of the success or failure of the protected areas. Dugan and Davis (1993) examined studies of marine parks and reserves, particularly with respect to coastal fisheries management, to assess marine refugia and their potential effect on fisheries yields, through a variety of related effects on target species and ecosystems. The potential effects on target species included: increased abundance, increased individual size and age, increased reproductive output, enhanced recruitment both inside and outside refugia, maintenance of genetic diversity of stocks, and enhanced fishery yields in adjacent fishing grounds. Potential ecosystem effects included: increased species diversity, increased habitat complexity and quality, and increased community stability. It was found that studies relative to potential effects on target species generally indicated positive effects of refugia with respect to abundance and fish size. There was only a small amount of evidence suggesting improvements to fishery yield in areas outside the refugia. There were no studies that suggested enhanced recruitment, increased reproductive output, or influence on genetic diversity. With regard to ecosystem effects there was some evidence of increased species diversity within refugia. In their conclusion, Dugan and Davis (1993) state that, " despite their potential benefits, the efficacy of fisheries refugia in coastal fisheries management is virtually untested".

The latter is true for fisheries management in general in that the expected benefits are generally described as potential. As Shackell and Lien (1995) point out, " MPAs are largely an experiment and should be treated thus". Auster and Malatesta (1995) further state that, "the knowledge base required to justify a reserve, or system of reserves " (for habitat enhancement) " does not yet exist in total. However, like other reserve systems, it is intuitively beneficial". Evaluation of the effect of closed areas is generally a difficult task for a number of reasons. These include; the inadequacy of the specific objectives for establishing the closure and the lack of adequate data necessary for required analyses.

As already stated, even the objectives are not always clear. An example would be that discussed in the case study of haddock on the Scotian Shelf and Georges Bank. These are described as spawning closures although biologically there was no evidence to show that the closure would improve the production of young fish. The latter would be a prime reason for establishing a spawning area closure. The documented reason for closure was to reduce exploitation at a time (spawning season) when catch rates were highest. This closure has persisted to the present day apparently without the support of an evaluation of its adequacy. Determination of success or failure assumes the existence of specific objectives. These are often implicit in their title, i.e. spawning and nursery area closures. However, in some cases, as previously shown (eg. Div. 4X and 5Z haddock) the stated objective is nominal, only, with an underlying objective (i.e. reduction of fishing effort) being of 'primary' importance. The lack of specific objectives obviously affects determination of success of the management measure. The criteria to be used in evaluation has to be related to the objectives established when an area is designated as closed or protected.

Of the many issues or problems that protected or closed areas address, those related to fisheries management can be summarized as follows: improvement of effective spawning; enhancement of juvenile survival; enhancement of fisheries outside the area; protection of habitat; and protecting genetic diversity. These require different and sometimes substantial databases to determine both the extent and the effectiveness of the closed area. In many cases the data necessary to facilitate evaluation are not available. Closed areas are established in response to specific problems such as over-exploitation of specific age groups (eg. juveniles or spawners) and persistent stock declines. Although the determination of these problems usually results from analyses of existing data, the extent of the available database may be narrow with respect to area and time. Areas with a long history of scientific research and monitoring may therefore be desirable when closed areas are being designed or tested.

Difficulties with evaluation of the success of some of the closed areas are also related to their relatively recent origin and constant evolution. The benefits to be accrued are yet technically unproven. It may also be necessary to expect evaluation to be a long term process since many effects may not be detectable on short time scales. Probably the most compelling argument favoring the establishment of closed areas lies in the precautionary approach or 'principle'. The basis for this principle is that; there are uncertainties arising from scientific stock assessments, reliable verifiable data are lacking on ecosystems, and that there are difficulties in extrapolating between laboratory and actual field conditions (Paisley, 1995). In short, if a fisheries management problem exists and persists despite best efforts at correction, then a precautionary closed area is prudent while the uncertainty exists. This concept has strong advocates (Garrod and Shumacher, 1994; Kenchington, 1995; Shackell and Lien, 1995; Brodie, 1996; Paisley, 1995). It could be viewed " in terms of a 'hedge' against uncertainty or of reserving some minimum-acceptable part of the ocean ecosystem beyond human interference"(Kenchington, 1995).

The need to acknowledge uncertainty associated with estimates of abundance was advocated by Hutchings (1995) with respect to the 'Northern' Cod stock and by Brodie (1996) concerning the management of cod and flatfish stocks on the southern Grand Bank of Newfoundland. For Northern Cod a seasonal MPA or closed area was proposed similar to that described in the present paper for haddock on the Scotian Shelf and Georges Bank. It was argued that a fishing ban during the winter-spring spawning season would reflect conditions which existed prior to the introduction of large otter trawlers in the 1950's when it was estimated that the stock was much larger. Similarly, Shackell and Lien (1995) concluded that this stock, and others, were protected in the earlier years before technology permitted fishing at all times of the year.

Management of the cod, American plaice, and yellowtail flounder stocks on the southern Grand Bank of Newfoundland has not been successful as evidenced by the current fishing moratoria for all three species (Brodie, 1996). Part of the difficulty with the management of these stocks has resulted because they occur in two management zones separated by the Canadian 200 mile limit. Catches in the late 1980's were excessive particularly with respect to that for small, immature individuals of all three species (Brodie, 1996). The main reason for this phenomena was that the fisheries occurred in areas coincident with areas where the juveniles were most abundant. The latter had been determined using data from research vessel surveys and the commercial fisheries (Walsh, et al. 1995). The authors recommended that a permanently closed area be instituted to protect juveniles and permit rebuilding of the three stocks. In a further analysis (Brodie, 1996), using additional information from the Canadian commercial fishery, it was again concluded that the use of closed areas would be beneficial to the stocks. It was indicated that, based on distribution data, juvenile yellowtail flounder from the nursery area would subsequently be available as adults to the fishery outside the area. It was also argued that the benefits of a closed area need not to be absolutely demonstrated statistically before implementation as the data required may never be available. The proposed guiding principle in such cases was the reduction of uncertainty.

Conclusions

The apparent lack of success of management goals relative to many commercial fish species using has lead to a considerable amount of support for the use of protected areas as an alternate approach to standard methodologies. Most of the support is intuitive, reflecting the potential benefits of protected areas, as there are few studies providing analytical support for the various objectives. A more detailed look at two specific examples of the use of closed areas in the management of commercial fisheries (Haddock on the Scotian Shelf and Georges Bank and Plaice in the North Sea) indicated some limited success, depending on the objective. In both cases the area closed, the season of closure, and the type and amount of permitted fishing activity changed over time which made evaluation of effectiveness more complex. When conducted on an experimental basis the objectives need to be clear to facilitate evaluation of effectiveness. However, evaluation may be difficult because a relatively long time frame may be required or because all the required data may not be obtainable. It may not always be possible to provide proof of success of a protected area in dealing with a management problem before it can be instituted. Where problems exist despite the best standard management practices, it may be prudent to use a precautionary approach by restricting fishing until the inherent uncertainties of existing procedures can be better understood.

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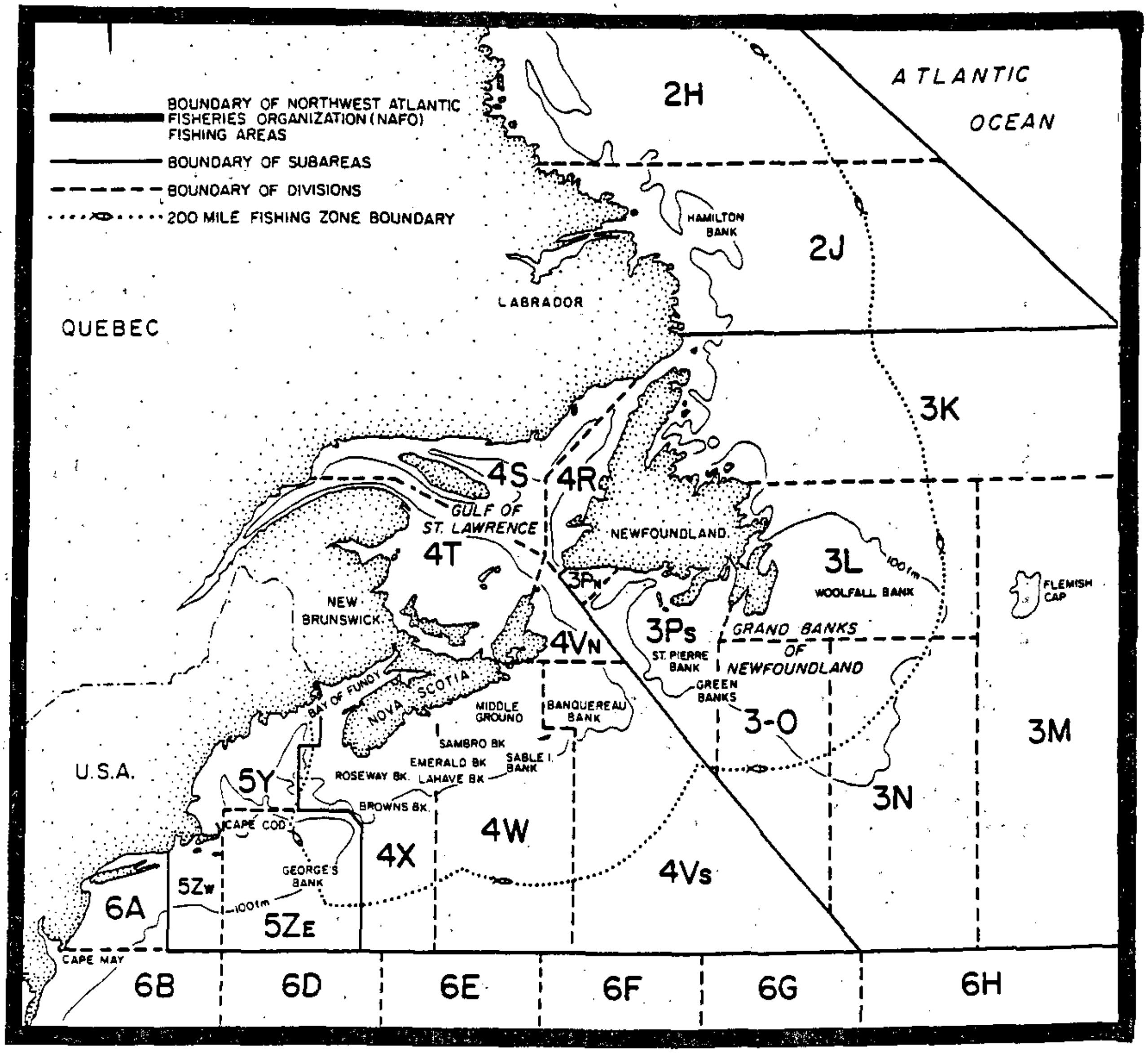

Figure 1. NAFO Subareas and Divisions including the Scotian Shelf (Divs. 4VWX) and Georges Bank (Div. 5Z).

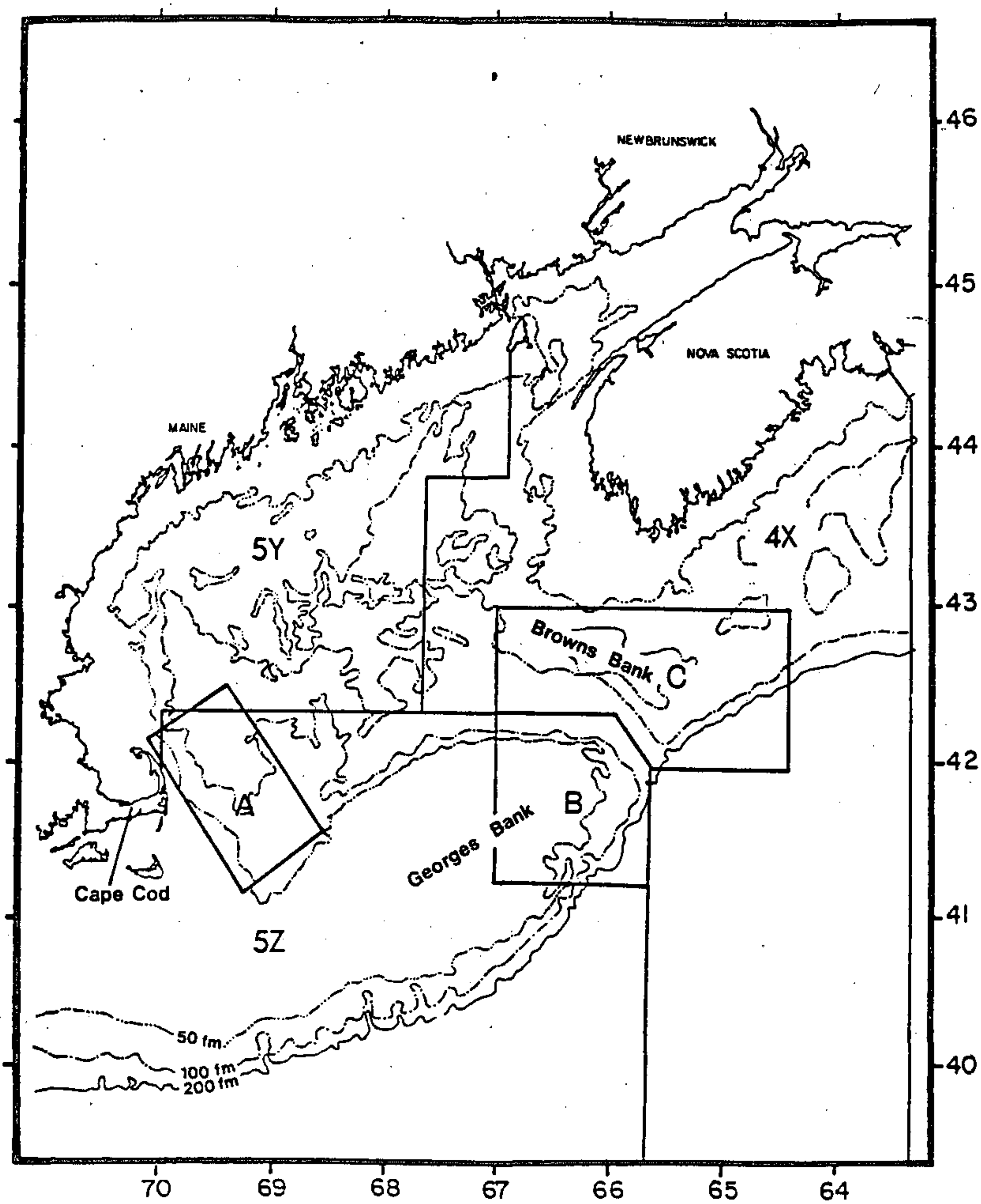

Figure 2. Haddock closed areas in NAFO Div. 4X and 5Z when first established in 1970. (from Halliday,1988).

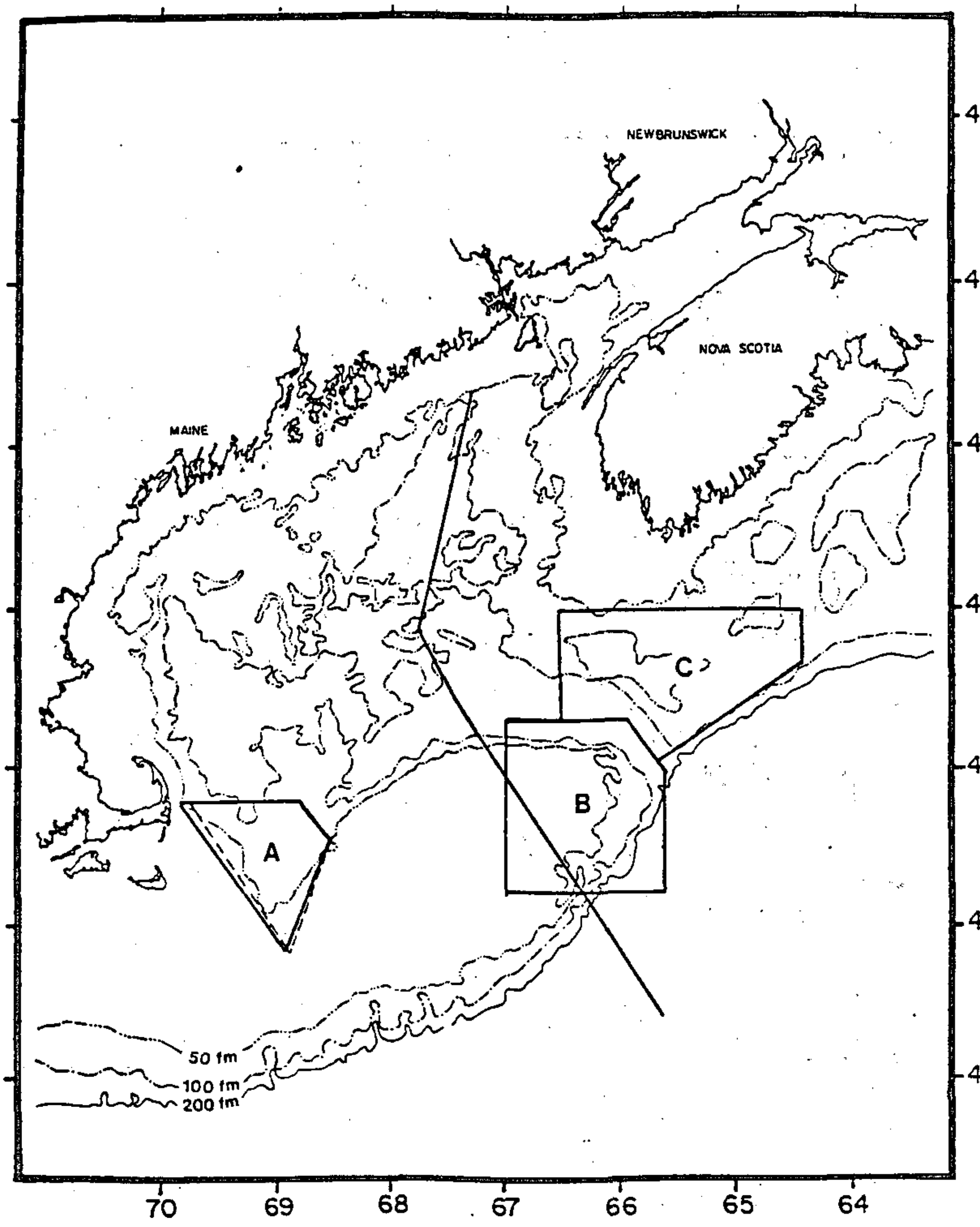

Figure 3. Haddock closed areas in NAFO Div. 4X and 5Z when revised for 1982 and 1987 (dashed line in area A). (from Halliday,1988).

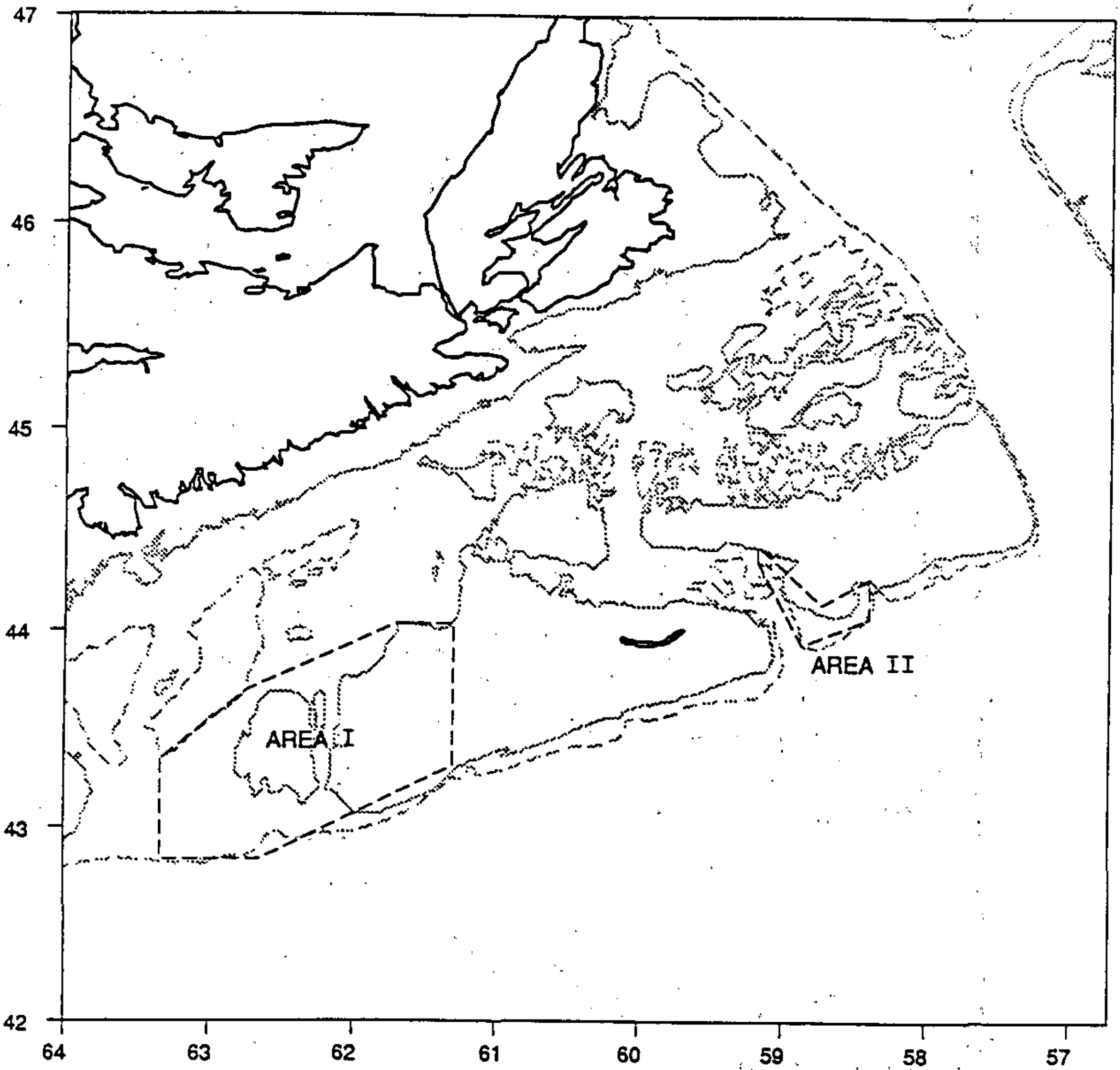

Figure 4. Haddock closed areas (nursery) in NAFO div.4VW as established in 1987. (from Fanning et al. 1987).

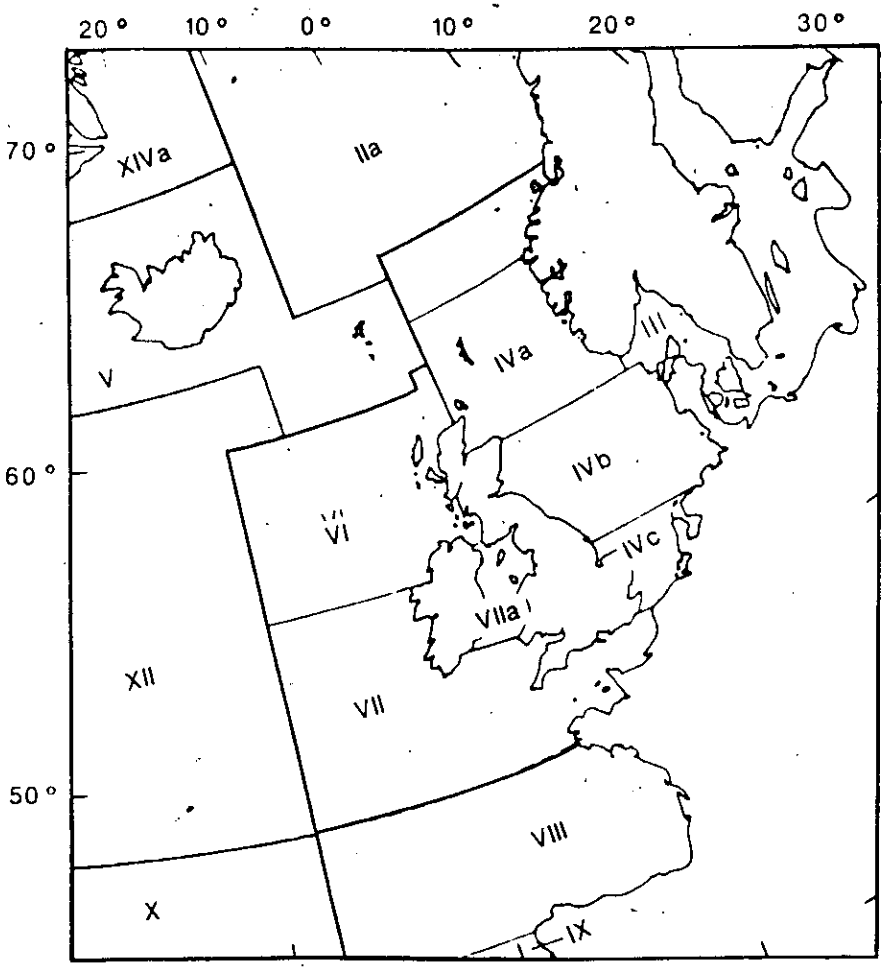

Figure 5. ICES statistical Div. for the north-east Atlantic including the North Sea (Area IV).

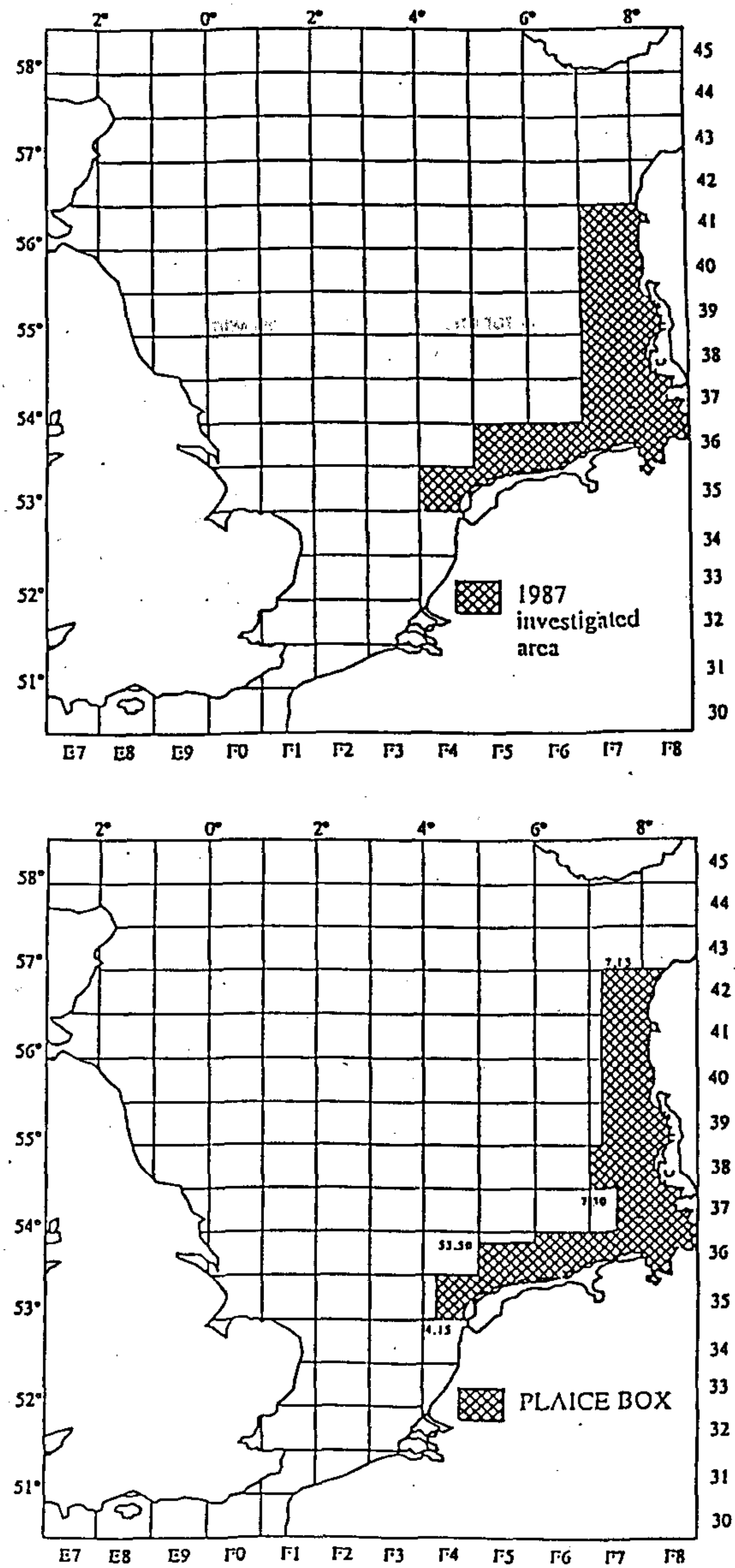

Figure 6. Area of the North Sea proposed (top) and that subsequently designated and regulated (bottom) as a nursery area for plaice - the Plaice Box. (from ICES, 1994).

Appendix

Marine protected areas

35. (1) A marine protected area is an area of the sea that forms part of the internal waters of Canada, the territorial sea of Canada or the exclusive economic zone of Canada and has been designated under this section for special protection for one or more of the following reasons:

(*a*) the conservation and protection of commercial and non-commercial fishery resources, including marine mammals, and their habitats;

(*b*) the conservation and protection of endangered or threatened marine species, and their habitats;

(*c*) the conservation and protection of unique habitats;

(*d*) the conservation and protection of marine areas of high biodiversity or biological productivity; and

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

(2) For the purposes of integrated management plans referred to in sections 31 and 32, the Minister will lead and coordinate the development and implementation of a national system of marine protected areas on behalf of the Government of Canada.