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A Review of Measures to Control Size at First Capture of Groundfish on the Scotian Shelf with Special Reference to Haddock in NAFO Div. 4VW

Examen des mesures visant à assurer une taille minimale à la première capture du poisson de fond de la plate-forme Scotian, en particulier l'aiglefin dans les divisions 4VW de l'OPANO

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Abstract

The Div. 4VW haddock stock, the fishery for which has been under moratorium since 1993, has shown signs of possible recovery. This raises the question of whether the technical measures that were in place when the fishery was closed would still be appropriate in the event of a fishery reopening. A review is provided of the history and the technical basis for measures that control size at first capture in the groundfish fishery in the Scotia-Fundy Region, DFO, i.e. mesh and hook size restrictions, minimum fish size limits and area closures. Emphasis is given to haddock and to cod, which is a likely bycatch species in a directed haddock fishery. It is concluded that present technical measures do not constitute a satisfactory framework within which to manage a directed haddock fishery under current conditions.

Résumé

Le stock d'aiglefin des divisions 4VW, dont la pêche fait l'objet d'un moratoire depuis 1993, montre des signes d'un rétablissement possible. Cela soulève la question à savoir si les mesures techniques qui étaient en vigueur lors de la fermeture de la pêche conviendraient toujours dans l'éventualité d'une réouverture de la pêche. Nous examinons l'historique et le fondement technique des mesures assurant une taille minimale à la première capture dans la pêche du poisson de fond dans la Région Scotia-Fundy du MPO, c.-à-d. des restrictions sur le maillage et la taille des hameçons, des limites de taille minimale du poisson et des fermetures de zones. Nous mettons l'accent sur l'aiglefin et la morue, qui serait souvent capturée accessoirement dans la pêche dirigée de l'aiglefin. Nous concluons que dans les conditions actuelles, ces mesures techniques ne constituent pas un cadre satisfaisant pour la gestion d'une pêche dirigée de l'aiglefin.

Introduction

The Div. 4VW haddock fishery has been under moratorium since 1993. However, the 2001 assessment of the status of this stock (Frank et al., 2001; RAP, 2001) showed signs of possible recovery from the low abundance observed in the 1990s. This has raised the issues of fishery reopening criteria and of what the appropriate measures and procedures are for managing a reopening event (FRCC, 2002). Management measures that control the size at which haddock are first captured, i.e. that minimize the capture of 'small' fish (however small may be defined), are of importance in this regard. An issue ancillary to this is the effect on size at first capture of species taken as bycatch in any haddock fishery that might occur. The Atlantic cod stock in this area is of particular importance in this regard as the fishery for it, as well as haddock, has been under moratorium since 1993.

The present report reviews the history of the size at first capture measures that apply to Scotian Shelf groundfish, with special reference to haddock and associated species in Div. 4VW, and the technical basis for these measures. The most direct control of size at first capture is through regulation of gear construction, primarily mesh size in otter trawls and hook size in longlines. Policy guidelines on the minimum lengths of fish that should be caught provide support to gear restrictions. These minimum length guidelines are operationalized by a system of temporary area closures, as described in the Small Fish and Bycatch Protocols (DFO, 1997). In addition, an area on Emerald and Western banks is closed on an indefinite basis because it contains high concentrations of juvenile (ages 0-3) haddock. Restrictions also apply to the areas that can be fished for groundfish using small mesh trawls. In particular, fishing for silver hake is restricted to spatially and temporally defined 'windows' in Div. 4WX, a primary motivation for their establishment being to minimize bycatches of small haddock.

Gear Regulation

History

Otter trawl size selection has received much attention, as this has been the predominant gear in groundfish fishing generally in the North Atlantic. The first gear regulations that applied to Div. 4VW were promulgated by the International Commission for the Northwest Atlantic Fisheries (ICNAF) in 1957. These required that nets used, when fishing for cod or haddock, must have a mesh size of at least 114 mm. Immediately prior to extension of Canadian jurisdiction in 1977, ICNAF regulations required use of a mesh size in the codend of 130 mm manila equivalent when fishing for cod, haddock or flounders (American plaice, yellowtail, witch, winter flounder) and stipulated the characteristics of the chafing gear that could be used. Equivalency was defined on the basis of 'differentials' in the selectivity of different netting materials from a manila twine standard and, as a result, otter trawls constructed from various synthetic materials were allowed to have 120 mm meshes. There was a differential also for Scottish and Danish seine nets that allowed use of 110 mm mesh netting. These mesh size regulations were established initially to improve yield-per-recruit at prevailing levels of fishing effort by eliminating discards. (Halliday and Pinhorn (1996) provide an extensive history of gear regulation in the North Atlantic fisheries.)

Canada retained the ICNAF trawl regulations for the groundfish fisheries until 1982 when differentials based on net materials, and for seine nets, were dispensed with. This resulted in an increase in mesh size, as only 130 mm mesh could be used regardless of material or gear type. The primary motivation for this change was to simplify enforcement. In contrast to the ICNAF regulations which specified the species and areas to which the minimum mesh size applied, the new Canadian regulations applied to all species and all parts of the Canadian zone unless specific exemptions were given. Thus, pollock on the Scotian Shelf – Gulf of Maine came under mesh regulation for the first time. In March 1991, a further increase in mesh size was imposed in the Scotia-Fundy sector. This raised minimum mesh size in traditional diamond mesh netting to 155 mm and introduced a differential for square mesh netting for which the minimum was set at 140 mm. The short-term effects on catch rates of such a substantial mesh size increase were more severe than the industry was prepared to accept, however, and a reduction to 145 mm diamond and 130 mm square mesh was announced in July of the same year. The original increase in mesh size to 155 mm diamond was introduced because consultations between DFO and fishermen in the Region showed substantial support for an increase in the size of fish caught and landed (Haché, 1989).

In 1993, gear specifications were removed from the Atlantic Fishery Regulations and replaced by specifications in newly instituted annual Conservation Harvesting Plans (CHPs) and operationalized through conditions of licence. This gave fishery managers the flexibility to modify gear requirements as and when needed, in contrast to the many months it took to bring an amendment to regulations into effect. Gear configurations could then be tailored by fleet sector, time, area and directed species. The current situation is summarized in Table 1. Note, however, because no fishing is presently allowed for cod or haddock in Div. 4VW, no mesh sizes are specified for directed fisheries for these stocks.

Regulation of the selection properties of fixed gears has received much less attention than otter trawl selection. Mesh sizes in gillnets has been set largely to keep a rough equivalency with trawl gear mesh size. Longline hook size restrictions were introduced in Scotia-Fundy in 1995. Hook sizes are regulated based on fishermen's opinion on the sizes of fish caught, as are equivalencies between hook types. The reference hook is a 12/0 Mustad tuna circle hook.

Gear Selection - Otter Trawls

The basis for present regulations on mobile gear construction has been established through size selection experiments. There is extensive information for cod and haddock, mainly for diamond mesh netting but including a number of experiments with square mesh netting. These data, along with the rather scant data for pollock, were summarized most recently by Halliday et al. (1999). That study provides the following relationships between the size at 50% selection (L_{50}, in cm) and mesh size (m, in mm) for cod and haddock with diamond and square mesh netting:

HADDOCK	diamond	$L_{50} = 0.461m - 15.051$	($n = 56$, $R^2 = 0.91$)
	square	$L_{50} = 0.416m - 5.902$	($n = 13$, $R^2 = 0.98$)
COD	diamond	$L_{50} = 0.499m - 16.105$	($n = 66$, $R^2 = 0.85$)
	square	$L_{50} = 0.444m - 1.946$	($n = 8$, $R^2 = 0.81$)

The shape of the selection curves was found to be constant and the same for both species but differed between diamond and square mesh netting, the selection curve being sharper for square mesh than for diamond mesh netting. The shape parameter, α, where

$$\alpha = 2 \cdot \ln(3) \cdot L_{50} / SR$$

is 11.4 for diamond mesh and 18.9 for square mesh. (SR, the selection range, is the length range between the 25% and 75% selection points on the selectivity curve.)

These estimates of L_{50} and of the shape parameter allow the selection at any fish length, S(L), to be calculated based on the equation:

$S(L) = 1/(1+\exp(\alpha\,[\,1-L/L_{50}]))$

The mesh sizes that give the same L_{50} for these round-bodied species are roughly 10% smaller for square than for diamond mesh, e.g. a 130 mm square mesh has about the same L_{50} as a 145 mm diamond mesh. Square mesh also has a narrower selection range (higher α) than diamond mesh for roundfish and thus less under-sized fish are likely to be caught with this mesh type.

For flatfish, however, the equivalencies between L_{50}s are inverted. For American plaice, for example, a 155 mm square mesh has about the same L_{50} as a 135 mm diamond mesh (Walsh et al., 1992). However, the selection curve for square mesh is much sharper than that for diamond mesh for plaice, as it is for roundfish. Information is scant for the other flatfish species but selection appears similar to plaice.

Gear Selection - Longlines

Scientific information for cod and haddock indicates that the length composition of longline gear catches is very largely insensitive to hook size, bait size being the primary determinant of sizes caught (Bjordal and Løkkeborg, 1996). However, it has been traditional practice for fishermen to vary bait size with hook size, larger baits being used with larger hooks (McCracken, 1954, 1963). This could be the basis for fishermen's views that larger hooks result in larger fish being caught. However, there are no data to provide objective documentation of the extent of the relationship between bait size and hook size and, in particular, whether this practice was continued after the introduction of hook size regulation.

Escapement Survival

When regulations requiring the use of larger mesh sizes in trawl nets were first introduced, one of the most critical technical issues was whether the fish escaping through the meshes survived. Doubts about this were largely dispelled in the early 1950s by the direct observations of divers, and by underwater films, of fish escaping with ease through codend meshes (Wardle, 1983).

However, new doubts about survival of escapees were raised by experiments in the late 1980s that showed mortalities of haddock and (European) whiting that had escaped from small mesh trawls could be high (Main and Sangster, 1990, 1991). The mortality of haddock in experiments with large mesh nets was lower than with small mesh nets, but data were scant (Soldal et al., 1993; Jacobsen, 1994). Subsequent experiments using improved techniques, for both large and small mesh nets (Ingolfsson et al., 2002; Sangster et al., 1996; Wileman et al., 1999), gave mortality estimates for haddock of 3-50%.

The few experiments done on cod and pollock escapees show escapement mortality to be close to zero (Ingolfsson et al., 2002; Main and Sangster, 1991; Jacobsen et al., 1992; DeAlteris and Reifsteck, 1993; Soldal et al., 1993; Jacobsen, 1994). Scant data for the redfish (Jacobsen, 1994) and for winter flounder (DeAlteris and Reifsteck, 1993) suggested mortalities of 0-6% and 0-15%, respectively. The experiments for these species were almost all conducted with large mesh nets (>125 mm). The exception was that by Main and Sangster (1991) who reported 0-9% mortalities of cod with 90 mm mesh nets.

There are insufficient data to distinguish among alternative explanations of these results. Of particular importance are outstanding issues related to experimental design. Sangster et al. (1996) established that the mortality observed in haddock escapees was essentially restricted to fish less than 25 cm. A recent re-examination of the experimental data for haddock has shown a direct relationship between the time fish are forced to swim in the experimental cover, after escapement from the codend, and mortality (Breen et al., 1998). Swimming ability is a function of fish length, and haddock under 25 cm are the most likely to suffer damage in the cover (Breen et al., 2002). It is possible, therefore, that the high mortalities of small fish observed by Sangster et al. (1996), and more recently by others (Ingolfsson et al., 2002; Wileman et al., 1999), result from the experimental methods rather than from codend escapement. The possibility of another, converse, experimental bias has also been identified by Breen et al. (2002). The presence of a cover reduces the water flow around the codend, thus reducing the likelihood of injury during escape from the codend.

Other factors also are likely to have affected the results reported, particularly the experimental codend mesh size. Sangster et al. (1996) showed that the mortality of haddock of a given length was not related to mesh size (at least within the range of mesh sizes tested of 70-110 mm). Nonetheless, as the escapement mortality observed in haddock is a function of fish length, the proportion of escapees dying will vary with the size composition of escapees. For example, when a small codend mesh is used that only allows haddock that are 25 cm or smaller to escape, it is likely that a high proportion will die. When a larger mesh is used that allows haddock bigger than 25 cm to escape also, most of these bigger escapees (>25 cm) will survive. Thus, even though the same proportion of fish <25 cm die, the proportion of escapees of all sizes that die will be lower. Breen et al. (2002) demonstrate such an inverse relationship between haddock mortality and mesh size for mesh sizes between 70 and 110 mm. As most data for haddock are with small mesh nets (<110 mm) and for cod and pollock (and other species) are with large mesh nets (>125 mm), some of the differences between species in the escapement mortality estimates also may be a result of differences in mesh size used.

The other factor confounding these escapement mortality results is the effect of the size composition of the population being fished. The size composition of the populations being fished likely differed greatly among experiments. Obviously, if the population being fished has few or no fish in the size range susceptible to mortalities, deaths among escapees will be negligible regardless of mesh size.

Further experimentation is required before there can be a definitive answer to the question of post-selection mortality. While the blanket assumption used in the past that post-selection mortality is always negligible no longer seems justified, the extent of such mortality is likely to have been substantially overestimated for haddock in some experiments. Until there is a clarification of what factors are causing the high mortality estimates for small haddock, there are sufficient grounds to be cautious, e.g. by discouraging otter trawl fishing in areas where small haddock less than about 25 cm are abundant.

Minimum Fish Size Limits

History

ICNAF saw no need for regulation of minimum fish size in the Northwest Atlantic groundfish fisheries, even though size limits were popular in the Northeast Atlantic as an indirect way of enforcing mesh size regulations (see below). However, the USA, on extension of its jurisdiction in 1977, instituted a minimum size of 16 inches (41 cm) for cod and haddock caught in its domestic fisheries. The minimum size was increased to 17 inches (43 cm) in 1982 and pollock was added to the regulation in 1986. A further increase to 19 inches (48 cm) was instituted for all three species in 1987, and the minimum size for cod was increased again in 2002 to 22 inches (56 cm). These actions took on significance to the Canadian industry in 1986 when they were applied also to imported fish, as the U.S. fresh fish market is an important outlet for Canadian product. The Province of Nova Scotia also saw minimum fish size controls as important and in 1986 placed restrictions on the buying, selling and transporting of cod, haddock or pollock less than 17 inches (43 cm), which was consistent with USA import regulations at that time.

The Canadian Government first introduced minimum fish size limits for groundfish in 1988 through a regulation that made it illegal to catch or retain or have on board a vessel cod, haddock and pollock less than 41 cm (16 inches)[1]. These minimum fish sizes were intended in part to encourage fishermen to respect the mesh size regulations by making it more difficult to profit from catching small fish, but their introduction was also influenced by U.S. market considerations and Provincial views.

The Scotia-Fundy Groundfish Task Force of 1989 (Haché, 1989) heard many industry representations to increase the minimum sizes, possibly to as large as 19 inches (48 cm). "The intent of these suggestions was the protection of immature cod and haddock, which are generally not more than 17" in length" (Haché, 1989 p35). The Task Force thus chose 17 inches (43 cm) as the appropriate size limit (for cod, haddock and pollock), and proposed adoption of an associated mesh size and type (140 mm square) that would retain only 5% of fish of that size. Based on the Task Force's recommendation, the regulation sizes for cod, haddock and pollock were changed to 43 cm in 1991 (for 4VsWX and 5, 4Vn remaining at 41 cm).

In 1993, the minimum fish size provisions were removed from the Atlantic Fishery Regulations and replaced by "guidelines" documented in the annual Conservation

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[1] Also Atlantic halibut less than 81 cm.

Harvesting Plans. It was made mandatory to retain all groundfish caught (with minor exceptions), regardless of size, to avoid wastage. A system of real-time closures of areas in which there was a high proportion of small fish in catches, referred to as the Small Fish and Bycatch Protocol (DFO, 1997), became the primary vehicle for implementing minimum fish size guidelines. In addition, in areas where there are persistent problems of small fish being caught, longer-term restrictions may be instituted through variation orders and/or licence conditions.

The minimum size for cod, haddock and pollock remains at 43 cm but guidelines have been introduced for several other species, the most important of which, in the present context, are American plaice and yellowtail flounder at 30 cm (Table 1).

In 1996, a preamble was introduced to the small fish protocol section in CHPs for Scotia-Fundy and Newfoundland Region fisheries (but not for Gulf of St. Lawrence fisheries) as follows. "Based on the principle of letting most fish spawn at least once, the approach is to set a target that the harvest consist of at least a specified percentage of the catch being sexually mature fish. Initially, fleets should be moving towards a target of at least 50% being sexually mature." This was a conservation measure raised for debate by the FRCC in 1994 (FRCC, 1994). How this came to be incorporated into CHPs does not appear to be documented. Although it remained in CHPs through 2001, there is no evidence that it has influenced in any practical form decisions on minimum size guidelines for Scotia-Fundy stocks. However, this 'principle' is a quantification of the views expressed by members of the industry to the 1989 Groundfish Task Force, which were already instrumental in having the minimum fish size raised to 43 cm in 1991.

Thus two different philosophical bases for making decisions about minimum fish sizes have developed. The first is the traditional bio-economic one of optimizing net benefits from fishing; meaning, in very general terms, that the growth potential of the resource should be utilized efficiently by catching (as distinct from landing) only fish of suitable size for the market while minimizing harvesting costs. The second is that there is a principle of conservation to be respected that most fish should be allowed to spawn at least once. While the latter doctrine has gained recognition in fisheries circles in Atlantic Canada over the last 10 years, its origins are in folklore and pre-date fishery science. While it has an intuitive appeal (and some theoretical support - Myers and Mertz, 1998) the conservation, economic and regulatory repercussions of its application are not well understood and need closer examination (Caddy and Seijo, in press; Halliday and Pinhorn, 2002).

Technical Basis

The choice of minimum size limits is essentially arbitrary and depends on their intended purpose. Their traditional purpose has been to support observance of mesh size regulations by making it possible to control size at first capture based on inspections of size of fish in landings. This is less costly and logistically more straightforward than boardings for inspection of nets at sea. When this is the purpose of minimum size limits, it has been customary to set the size limit at either the 25% or the 50% selection length of the regulation mesh size, so that fishing with the regulation mesh size should normally result in relatively few undersized fish being caught.

In the case where the minimum size is set in relation to other reasons, such as marketing considerations or allowing most fish to spawn at least once, then it is the minimum size that is being set *a priori.* In this circumstance, it is the mesh size that is to be adjusted to result in the preponderance of fish caught being above that size. Here also, an arbitrary decision has to be made as to the appropriate relationship between minimum fish and mesh sizes. This decision is complicated, in the spawn-at-least-once scenario, a) by the fact that fish maturation, like gear selection, varies with length and is best described by a sigmoid curve, and b) by the variation of maturation schedules over time. Furthermore, in multi-species fisheries, compromises are necessary, as the sizes of the various species caught with a particular mesh size are not likely to correspond to the preferred, or optimum, size for all species.

The Haché (1989) Task Force provides an example of the decision process in the context of allowing most fish to spawn at least once. The information available to the Task Force was that immature cod and haddock were generally not more than 43 cm in length. Thus they chose a mesh size that had only a 5% probability of retaining fish of 43 cm. In other words, it chose a scenario that corresponded to virtually no overlap between the maturity and selection curves for these species. Little was known about the maturity or selection of pollock. However, practicality dictated that a single otter trawl mesh size be specified for the mixed species fishery for haddock, cod and pollock, and there was reason to believe that the same minimum size would be satisfactory for all three species. The issues raised by variation in maturity schedules with time are illustrated well by Div. 4VW haddock. Size at 50% maturity in this stock was close to 40 cm when the Haché Task Force report was written but is now about 30 cm (RAP, 2001). Thus, the Task Force logic would provide a much different answer, at least for Div. 4VW haddock, were it to be applied today.

Minimum fish sizes are used as guidelines in the Small Fish Protocol (DFO, 1997), which is a supplement to gear regulations. Codend mesh size and type, for example, although essentially the only features of an otter trawl that are regulated, are by no means the only elements of a trawl that affect its size selection properties. Furthermore, the size composition of catches is a function not only of the gear configuration but also of the size composition of the population being fished. Thus, if fishing occurs in areas where small fish predominate, it is possible for the actual catches to contain quite large proportions of small fish even though the proper codend mesh size has been used. Thus, the Small Fish Protocol provides regulators with a safeguard of sorts against such eventualities. It does so by requiring the closure of an area in which a high proportion of small fish is occurring in catches for a minimum of 10 days, after which the area is reopened if test fishing shows that the problem no longer exists. Closure areas are predefined and fairly large, e.g. there are eight that encompass all of Div. 4VW. The effectiveness of this procedure in modifying the overall quantities of small fish taken in the fishery likely depends heavily on the frequency and distribution of observer coverage, but its performance has not been evaluated.

The Juvenile Haddock Closed Area

History

A recovery of the Div. 4VW haddock stock in the early 1980s resulted in serious problems with the discarding of small haddock in the predominantly otter trawl fishery. The industry-preferred solution was a closure of haddock nursery areas to all groundfish fishing. In response to an emergency request immediately prior to opening of the 1987 fishery, two areas were identified in which there was persistent occurrence of high aggregations of juvenile haddock. One area encompassed Emerald and Western banks (Area I) and the other was a smaller area on the southwestern edge of Banquereau Bank adjacent to the Gully (Area II). Provisional closures of both areas were implemented for 1987 but more detailed analysis (Fanning et al., 1987) resulted in Area II being dropped and Area I being reaffirmed as appropriate, with minor modification to its southern boundary (Fig. 1). Area I remains in effect, unchanged from its configuration in 1988.

Almost immediately, the conditions of closure were amended to exempt fixed gear boats less than 100 feet in length (DFO, 1987) because these gears were believed to catch relatively older fish than mobile gear (Frank et al., 2000). Access was to be conditional on strict conditions on haddock bycatches and the use of larger hook sizes. However, this access allowed for the development of a much expanded longline fishery centred on the closed area (Frank et al., 2000; Kenchington et al., 1994). As a result, the fixed gear exemption to the closed area was terminated in 1993.

Technical Basis

The haddock nursery closed area in Div. 4VW was based on an analysis of research vessel surveys, observer data and commercial fishery data to identify areas of consistent abundance of juvenile haddock, defined as ages 0-3 (Fanning et al., 1987). It was concluded that Western and Emerald banks were the most important nurseries for haddock. Even so, in winter, juvenile haddock moved onto the slopes of the banks, making the Area I closure less effective at that time. The displacement of fisheries for species other than haddock was calculated to be minimal for cod and redfish but significant for pollock and, of course, haddock. Making the southern boundary of the closed area coincident with the SMGL (see below), eliminated any adverse effects on the silver hake fishery. The closed area is about 4000 nm^2 in area, which is about 25% of Div. 4W and 13% of Div. 4VW (Frank et al., 2000).

An evaluation of the effects of the closed area was conducted in 1998 (Frank and Simon, 1998; Frank et al., 2000). Analyses of distribution, condition, survival and recruitment between the closed area and adjacent areas detected no effects that could be clearly attributed to the existence of the closed area. This is hardly surprising, given the level and distribution of fishing since the closure was implemented. There has been a complete moratorium on fishing for haddock and cod in Div. 4VW since 1993 and the landings of haddock reported as bycatch in other fisheries, which themselves have been operating under strict catch limits, have been no more that 200 t annually. In 1987-93, the fishery was also restricted, although less severely, to bycatch only for boats over 65 feet and to restrictive trip limits for smaller vessels. Landings in that period averaged almost 5000 t. During that earlier period, however, the longline exemption allowed fishing in the closed area and, indeed, that was where the bulk of longline catches were taken (Kenchington et al., 1994). In 1990-92, longline gear accounted for half the catch taken in the entire Div. 4VW management unit. It is probable, therefore, that the effects of fishing were as great or greater within the 'closed area' as outside it. Thus, at no time has the closed area afforded much in the way of protection to haddock that was not available elsewhere in the management unit.

The failure of the present juvenile haddock closed area to provide demonstrable benefits is attributable, therefore, initially to exemptions followed by complete closure of the management unit to fishing for haddock. It cannot be concluded from this that protecting areas of high juvenile haddock abundance is, in general, of no potential value. The question remains as to whether, under different circumstances, the present or some other closed area might offer conservation benefits, should there be a reinitiation of haddock fishing.

There are several factors to be taken into account in decisions on the future use of closed areas to protect juveniles. The most important of these is the extent to which haddock of different sizes are distributed in different areas. It is not possible to protect small haddock using closed areas, unless there is a distinct difference in spatial distribution by size. In making this assessment, seasonal variations in distribution need to be taken into account, as does the fact that growth is now much slower, and thus the size and age of 'juvenile' haddock are lower, than when the present closure was instituted. Analyses of recent research vessel surveys show strong overlap in the distributions of different size classes, which does not encourage the view that area closures can be defined that will protect juvenile haddock (Mohn and Simon, 2002). Certainly, there is no justification for an assumption that the present closed area is appropriate were haddock fishing to be resumed under current conditions.

The Silver Hake Windows

History

The presence of a large-scale foreign mixed-species fishery using small mesh nets over a large part of the Scotian Shelf in the 1960s and early 1970s raised grave concerns about the possible adverse effects on the productivity of fisheries for traditional species conducted with large mesh gear. Bycatch reduction measures were introduced by ICNAF in 1976, and retained by Canada on extension of jurisdiction in 1977. These regulations restricted fishing for silver hake, argentine and squid (which was conducted exclusively by foreign trawlers) to deeper water (>100-150 m) along the shelf edge during 15 April to 15 November (ICNAF, 1977a). This area, extending from 60^0 00' to 65^0 30' W, became known as the 'Silver Hake Box' and its shoreward boundary as the 'Small Mesh Gear Line' (SMGL). An easterly extension to 57^0 00' W was allowed in 1980-83 and to 59^0 00' W in 1984-93.

More restrictive measures were introduced for 1994: the SMGL was moved south to exclude depths less than 190 m, the 'extension' between 59^0 and 60^0 W was eliminated and use of a codend separator grate was made mandatory. In subsequent years, the spatial restrictions were relaxed with the *de facto* distribution of fishing being not greatly different from the pre-1994 period (Branton, 1998; RAP, 1998).

After a number of years of development, a domestic fishery for silver hake showed signs of becoming established in the mid 1990s (Showell and Cooper, 1997). Emerald and LaHave basins were designated as additional areas in which small mesh fishing for silver hake can be conducted (Fig. 1) to meet the need for small trawlers to have fishing grounds close to home ports. Separator grates are mandatory in all areas.

Technical Basis

The initial ICNAF regulation was established based on a comparison of the distributions of other commercially important species with silver hake fishing areas and corresponded to the fishing area where the least overlap occurred (ICNAF, 1977b). An evaluation of the small mesh fishery regulations in 1985 found that the bycatch, mesh size and fishing area restrictions in place were adequate to control bycatches while permitting access to the silver hake stock (Waldron and Sinclair, 1985). The effects on overall yields of cod and haddock of small mesh fishery catches were calculated to be small.

Declines in abundance of cod and haddock in the early 1990s precipitated fishermen's protests about the presence of the foreign silver hake fishery (the Shelburne blockade of 1993) and various allegations were made about high bycatch levels and the role of silver hake in the ecosystem. A review of the fishery by the Panel on the Use of Foreign Vessels in Canadian Waters (the 'Harris Panel') resulted in adoption of revised criteria under which the fishery could be prosecuted. Bycatches of cod, haddock and pollock should be virtually eliminated while still allowing the silver hake fishery to be conducted successfully.

The most successful feature of the regulatory changes made to implement the Harris Panel recommendations for the 1994 fishery was the introduction of separator grates. These released about 90% of the bycatch (by weight) of cod and pollock and 75% of the haddock (Halliday and Cooper, 1999). However, in terms of numbers, only 50% of the haddock were released, as many were small enough to pass through the grate. Cod and pollock in the area were bigger and 80-85% of their numbers was released. Changes to the position of the SMGL to water deeper than about 190 m and elimination of the extension, also implemented in 1994, were expected to reduce bycatch rates (by weight) by a further 40-50% for cod and pollock and by 80% for haddock (Branton, 1998; RAP, 1998). Subsequent adjustments to the fishing area to address the regular complaints of the participants (primarily the Cuban fleet) that they could not conduct the silver hake fishery effectively south of the 190 m contour prevented the benefits from this measure being realized. However, after 1993, fishing effort south of the SMGL was greatly reduced and the average annual tonnages of bycatches over the five years 1994-1998 were low; 50 t of pollock, 25 t of haddock and almost no cod (Branton, 1998). Thus, the precise definition of the SMGL became of little or no practical significance. However, in 2001, the Canadian fleet began to conduct a fishery for silver hake in this area, and the issue of boundaries for the SMGL again becomes an important consideration.

The Emerald and LaHave basin boxes (Fig. 1) were implemented in 1995, the first year of the domestic fleet transition from a developmental/exploratory phase to commercial exploitation (Showell and Cooper, 1997). The boundaries of these boxes were drawn to approximate the 190 m depth contour, i.e. the criterion that had recently been adopted for positioning the SMGL. Observer deployments in subsequent years have confirmed the expectations from the developmental fishing activities that haddock bycatch problems would be minimal in these new boxes. However, there is rather less confidence in bycatch data for the basin boxes than for south of the SMGL as observer coverage of the domestic fleet has amounted to only 1-7% of the catch, in contrast to 100% observer coverage accorded foreign vessels fishing south of the SMGL. In 2001, a 10 nautical mile extension zone around the initial boundaries was evaluated through test fishing but the occurrence of haddock bycatch problems resulted in its abandonment.

A shore sampling program of totes of silver hake to determine bycatch mixtures is in place, as small specimens of other species, particularly haddock, could be mixed in with silver hake. These data, and also industry data on species separation in the processing plant, show the intermixture of bycatch species in landings of silver hake to be very low.

Conclusions

The Scotia-Fundy groundfish fishery is a mixed-species fishery controlled through a complexity of regulations, guidelines and policies. The centerpiece of management is the Total Allowable Catch system, which, along with bycatch controls, limits the overall mortality on groundfish stocks. Protection of small fish is an ancillary element intended to safeguard the productivity of these stocks and to optimize the financial benefits that can be derived from them. The solution to conservation issues does not lie in adopting one particular measure (there is no magic bullet); nor does it lie in adopting all conceivable measures (whether scientifically supportable or not) in the hope that one or more will have a positive effect. Success is most likely to lie in adopting a package of measures that are consistent with each other and that provide an optimal solution in relation to all relevant issues. Relevant issues include the economics of fishing and the practicalities of implementing the measures adopted, i.e. the prospects for obtaining compliance at an acceptable cost.

This review describes the myriad of considerations underlying the adoption of present management measures intended to minimize the mortality of small haddock in Div. 4VW. These have accumulated in an ad hoc way over many years and do not constitute a satisfactory framework within which to manage a directed haddock fishery under currently prevailing conditions. More appropriate formulations of these technical regulations should be an integral part of considerations on fishery reopening.

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Table 1. Summary of the Measures in Place in the Scotia-Fundy Groundfish Fishery to Prevent the Capture of Small Groundfish.

Measure	**Specific Aspect**		**Requirements**
Gear regulations in large-mesh directed fisheries	Mobile gear	Cod/ haddock/ pollock	130mm square mesh except diamond mesh allowed for pollock in 4VW if 155mm
		Flatfish	155mm square mesh except 145mm diamond for Danish seiners in 4VW
		Skates	300mm (codend), 254mm (body)
	Gillnets	4VWX5Y	140mm mesh or larger
		5Z	152mm or larger
	Line gears		#12 circle hook or equivalent (#14 circle for boats over 65' in most areas)
Gear regulations in small mesh fisheries	Silver hake	Directed sp.	55mm square mesh
		Bycatch spp.	Separator grate with 40mm bar spacing
	Redfish		90mm mesh
Minimum size guidelines	Cod, haddock and pollock		<43cm
	White hake		<43cm (fixed gear <45'), <45cm (fixed gear 65'-100'), no guidelines for other categories
	American plaice and yellowtail flounder		<30cm
	Witch flounder		<33cm
	Atlantic halibut		<81cm to be released alive
	Greenland halibut		<45cm
	Redfish		<22cm
Area closures	Protect small haddock		Emerald-Western banks (4W) closed year-round
	Protect small redfish		Bowtie area (in 4Xo) closed to gear with <130mm mesh
Fishing windows	Protect small haddock		Silver hake fishing restricted to defined windows in basins and on shelf slope

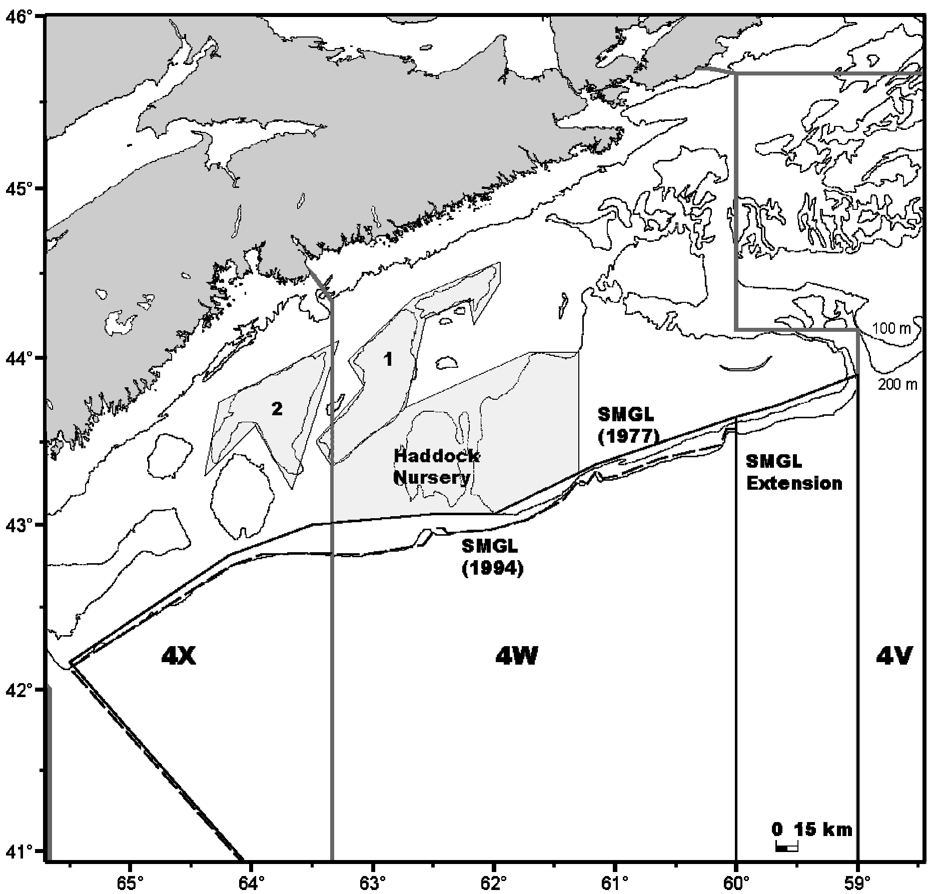

Fig. 1. The Div. 4W haddock nursery closed area, the silver hake Small Mesh Gear Line (SMGL)[1] and the Emerald Basin (1) and LaHave Basin (2) silver hake windows.

[1] The original (1977) and the revised (1994) versions of the SMGL are shown; extensions eastward were in effect in most years, most commonly between 59^0 and 60^0W (shown).