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Effects of a partially closed area in the North Sea ("plaice box") on stock development of plaice

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The "plaice box" is a partially closed area in the North Sea, established in 1989 to reduce the discarding of undersized plaice (*Pleuronectes platessa*) in the main nursery areas, and thereby to enhance recruitment to the fishery. In contrast to the expected positive effects, yield and spawning stock biomass have decreased. The effects of the plaice box are evaluated by analyzing the relevant factors and processes (natural and anthropogenic) that affect recruitment. It is shown that the Dutch beam trawl effort has decreased in two phases. During 1989–1993, when the plaice box was closed only during the second and third quarter, effort was reduced to around 40% of the original level. When the box was also closed in the fourth (1994) and first quarter (1995 onwards), effort decreased to around 6%. The effort reduction would imply a reduction in discard mortality if all other factors had remained constant. However, a reduced growth rate and possibly a higher rate of natural mortality may have counteracted the reduction in fishing effort. The apparent changes in growth and mortality coincided with changes in the North Sea ecosystem that occurred in the early 1990s but may also be related to a response to the change in beam trawl effort.

Key words: marine protected area, plaice, discards, effort, recruitment.

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Introduction

Marine protected areas (MPA) have recently been suggested as necessary tools in marine conservation and precautionary fisheries management (Dugan and Davis, 1993; Roberts and Polunin, 1993; Lindeboom, 1995; Lauck *et al.*, 1998; Pauly *et al.*, 1998). Empirical evidence for positive effects of MPAs, however, is largely limited to tropical reef systems (Alcala and Russ, 1990; Russ and Alcala, 1996). Evidence for the applicability of MPAs in temperate systems is scarce (e.g. Fogarty and Murawski, 1998).

Plaice (*Pleuronectes platessa*) is a flatfish species living in temperate waters. The distribution ranges from the Bay of Biscay to the Barents Sea and the waters around Iceland, but the predominant concentration is in the southern and south-eastern North Sea (Wimpenny, 1953; Harding *et al.*, 1978). The population has been shown to consist of several sub-groups that partially mix on the summer feeding grounds in the central North Sea but split up over different spawning grounds in winter (de Veen, 1978a). The different life history stages are spatially segregated (Wimpenny, 1953; Rijnsdorp and van Beek, 1991). After spawning, the pelagic eggs and larvae drift with the residual current in the open sea. At the end of the larval stage, plaice settle in shallow nursery areas on sandy beaches in estuarine areas. Adult plaice are distributed in deeper offshore waters. During the first years of their life, juvenile exhibit a seasonal offshore–inshore migration and only after maturation do plaice participate in distinct migrations between feeding and spawning areas.

Plaice is a major target species in the commercial trawl fishery. Because the rate of discarding is high (van Beek, 1998) and the undersized fish are confined to coastal waters, a protected area was proposed to improve the exploitation pattern of the stock (ICES, 1987). The likely effects of a closed area have been explored using a static model that estimated changes in yield-per-recruit and SSB-per-recruit under various fishing patterns (ICES, 1987). Using quarterly data on the distribution of fishing effort, the distribution of age groups and the distribution of the proportion undersized plaice per ICES rectangle, the expected gain in recruitment to the

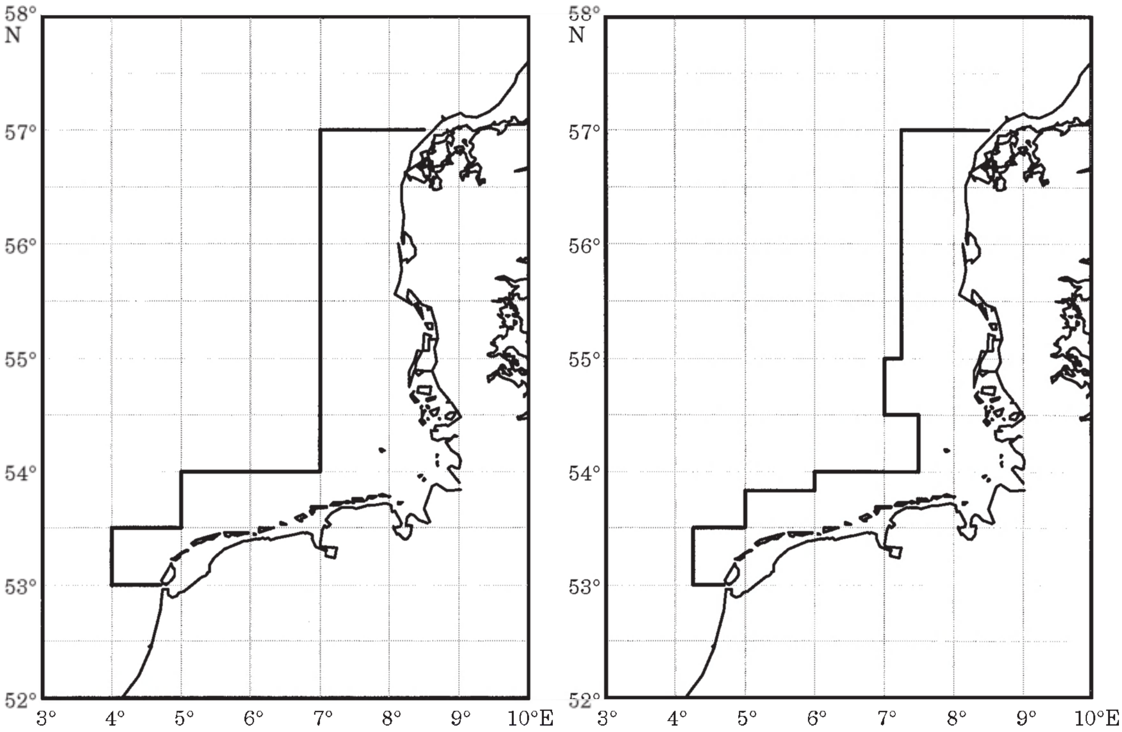

Figure 1. Proposed (left; ICES, 1987) and implemented (right) plaice box.

fishery was calculated for various scenarios, under the assumptions that: (i) the quarterly spatial distribution of each age group was fixed and not affected by changes in fishing patterns or growth; (ii) growth rate was constant and independent of density; (ii) all effort was expelled from the box. Calculations indicated that a closure of the box during the second and third quarter would increase recruitment to the fisheries by about 25%. Additional closure during the first and fourth quarter would further enhance the recruitment by 7% and 2%, respectively (ICES, 1987).

In 1989, the plaice box was established as a partially closed area along the Dutch, German and Danish coast with the aim to reduce discarding of undersized plaice (Fig. 1). Beam and otter trawlers larger than 300 hp were expelled from the area during the second and third quarter. The regulation was extended to the fourth quarter in 1994. Since 1995, the plaice box has been closed during the entire year for vessels larger than 300 hp.

Under the regulation imposed in 1989, the effect of the box was probably less than the 25% predicted originally. The borders were slightly modified from the original proposal (Fig. 1). More importantly, fishing with small vessels (<=300 hp) continued, and in fact the exemption fleet increased in capacity. Also, larger vessels concentrated in the box in the fourth quarter, as soon as they were allowed to fish there.

It is important to note that a protected nursery area has an impact on relative recruitment by reducing discard mortality. The absolute recruitment will be affected by at least four processes: (i) larval influx; (ii) discard mortality; (iii) natural mortality; and (iv) the period during which undersized fish are exposed to discard mortality (Fig. 2). The number of larvae that settle on the coastal nursery grounds annually is affected by environmental factors and is not directly related to fishing. During the juvenile phase, plaice in the nursery areas are subject to natural mortality (predation, diseases) and to discard mortality. Growth rate influences the duration of the juvenile phase. When growth rate is high, more fish are expected to reach the size of recruitment to the fishery, because undersized fish are exposed to mortality factors for a shorter period (other factors being similar).

We review the relevant processes affecting survival of pre-recruit plaice in their nursery areas along the continental coasts. After analyzing changes in beam trawl effort, changes in growth, mortality and recruitment, the dynamic simulation model of Rijnsdorp and Pastoors (1995) is applied to explore interactions between growth rate and discard mortality under different plaice box scenarios.

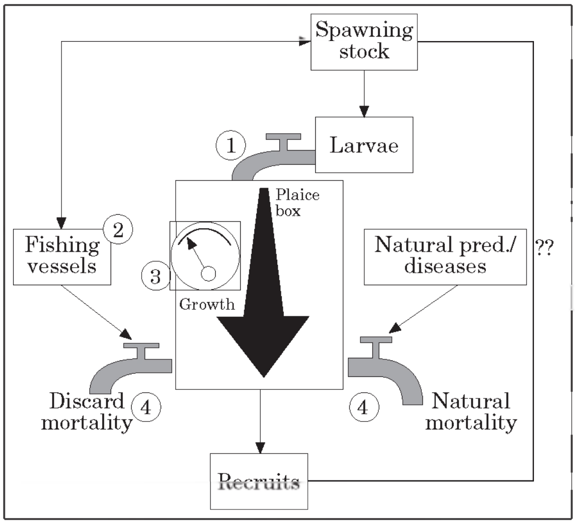

Figure 2. Conceptual representation of the processes affecting survival (and recruitment to the fisheries) of juvenile plaice inside the plaice box. A cohort starts with the number of individuals that survive the pelagic egg and larval phase and settle in the box (1). The duration of their stay in the box is affected by the growth rate (3) and during this time mortality occurs due to natural causes and discarding (4). Fishing effort (2) affects discard rate.

Material and methods

Fleet composition and fishing effort

North Sea plaice is taken in a mixed fishery for plaice and sole. The main fleets are the Dutch beam trawl fleet (44% of 1996 plaice landings), the English beam trawl fleet (17%) and the Danish fleets (15%). In recent years, around 20% of the Dutch vessels fishing for plaice or sole have been re-flagged to England, Scotland, Germany and Denmark. The analysis is based on data for Dutch vessels only. Fleet composition data are available from the vessel registration database (Smit *et al.*, 1997). The data allow for an evaluation of the developments in engine power within the fleet.

We used aggregated Dutch effort data from the mid 1970s to 1989 and trip-level data from 1990 onwards taken from the logbook database (Van Beek *et al.*, 1998). The logbooks contain catch, effort and vessel data per ICES rectangle and per trip. Trips were selected for analysis when they fulfilled the following criteria: (i) beam trawl gear used; (ii) engine power larger than 225 hp (to exclude shrimpers); (iii) landings of plaice and sole reported; (iv) ICES rectangle reported. Effort was calculated as days-at-sea and horse-power days-at-sea. When more than one ICES rectangle was visited during a trip, effort was split according to the estimated value of the plaice and sole landings in each rectangle using the average price by month in Dutch auctions.

No logbook data were available for the years just prior to the establishment of the plaice box. For estimating absolute effort by area in the late 1980s, it was assumed that the spatial and temporal relative distribution of effort was similar to the situation in the mid-1970s, for which data were available. Absolute effort by area was then calculated as the product of a relative distribution of effort times the overall trend in effort (Smit *et al.*, 1997).

Since the plaice box does not always follow the borders of ICES rectangles, effort in those rectangles had to be split into fractions inside and outside the box. We assumed that all effort and landings by large beam trawlers from those rectangles were taken outside the box, during the quarters of closure, and inside the box during the quarters when the box was open. For the exemption fleet (vessels 225–300 hp) in those rectangles, we assumed that they would always fish inside the box.

Recruitment surveys

Three surveys are available for analysis (van Beek, 1997): the Demersal Young Fish Survey (DFS, since 1970) in the nursery areas, the Sole Net Survey (SNS, since 1969) along the coast, and the Beam Trawl Survey (BTS, since 1985) covering both inshore and offshore areas throughout the North Sea, Channel and western waters of the UK (Rogers *et al.*, 1998).

The total instantaneous mortality (Z=F+M) for cohorts during the first years of their life was estimated from the three recruitment surveys (DFS, SNS and BTS) as the log survey catch rate of the same year class in successive years. Estimated mortalities were normalized to an average 0 and standard deviation 1 over the years 1985–1996.

Growth rate was estimated from the mean length of juvenile plaice using pre-recruit survey data. The average size of 0-group was estimated from the DFS and the size of the 1-, 2- and 3-group from the SNS. A second independent data set consisted of otolith back-calculations for female plaice collected between 1948 and 1995 during market sampling programs (Rijnsdorp and Van Leeuwen, 1992, 1996). This data set was used to estimate the mean length at age 1 to 4 for year classes born since 1970. The Von Bertalanffy growth parameter K was calculated from the length (l) at age (a):

$$K = -\ln\{(L_{a+1} - L_{inf})/(L_a - L_{inf})\},$$

where L_{inf} was fixed at 47.3 cm to retain consistency with the simulation model described below (Rijnsdorp and Pastoors, 1995).

Simulation model

The FLATFISH simulation model (Rijnsdorp and Pastoors, 1995; Pastoors *et al.*, 1997a,b) simulates the basic biological processes of growth, recruitment, migration and mortality for North Sea plaice and sole, using a resolution of ICES rectangles (one degree latitude and 0.5 degrees longitude, approximately 30 × 30 miles) and a variable time step of 1 week or less. The simulated population consists of six size classes: pre-recruits (5–14 cm), discards (15–26 cm) and four commerical market categories (27–33 m, 34–37 cm, 38–40 cm and >=41 cm).

Monthly migration vectors (direction and speed) were estimated from conventional tagging experiments. Migration rate increased with the size of the fish. Fishing is simulated by calculating the number of fish caught in each spatial unit in each time step, given the number of fish present and fishing effort by week and ICES rectangle.

The model structure and parameter settings as presented by Rijnsdorp and Pastoors (1995) were slightly modified. Migration rates of the two smallest size classes were reduced to 0% and 50% of the original values to calibrate the model to the observed values of the percentage of discards in the offshore rectangles (see Fig. 10 in Rijnsdorp and Pastoors, 1995). Catchability on recruited size-classes (q2–q6) and growth parameters (K) were calibrated by maximizing the goodness-of-fit between simulated and observed mean length-at-age, and between the simulated exploitation pattern and the VPA-estimated pattern (ICES, 1999a). Because recruitment to the fishery does not start at 15 cm but at 18 cm (van Beek, 1998), the catchability (q2) of the discard size class was reduced artbitrarily to 75% of q3–q6. The modifications in input parameters reduced the percentage discards from 55% in the original run (Rijnsdorp and Pastoors, 1995) to 46%, slightly lower than the estimated 50% in the 1980s (van Beek, 1998).

Routine stock assessment for plaice does not take into account discards, and therefore recruitment is underestimated. The model allows a comparison of the estimated recruitment with and without discards being taken into account based on cohort analysis of the numbers at age in the simulated catches and landings, respectively. The difference between the estimates at age 1 is expressed as the "percentage recruitment" resulting from an assessment based on landings only.

The plaice box scenarios were similar to those explored by ICES (1994). Scenario A reflects the situation in the 1970s and 1980s without a plaice box; scenario B the regulation imposed between 1989–1993 with a plaice box during the second and third quarter; scenario C, a closure during the second, third and fourth quarter; scenario D, a closure during the entire year; and scenario E reflects a total closure, also for the fleet which is presently exempted. The effort distribution for these scenarios as well as the initial distribution of recruits (5–15 cm size class) over the nursery areas were similar to those used by ICES (1987, 1994).

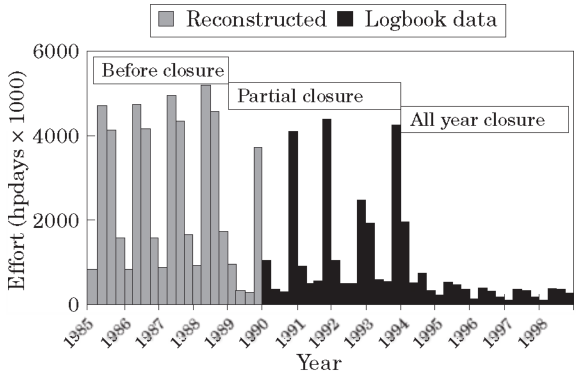

Figure 3. Fishing effort (HP days-at-sea) of the Dutch beam trawl fleet fishing in the plaice box by quarter, 1985–1998. Data for years before 1990 were reconstructed; thereafter logbook data are available.

Results

Fleet composition and fishing effort

Before 1989, effort in the plaice box area was highest in the second and third quarter. After the establishment of the box, effort during the two quarters of closure was reduced, but after reopening the box on October 1st, the fleet of large vessels moved in immediately (Fig. 3). Total fishing effort in the plaice box in the first 5 years diminished to around 40% of the pre-box level and in 1998, effort was only at around 6% (Fig. 4a). Total effort of the exemption fleet (225–300 hp) in the North Sea has remained relatively stable during 1990–1998 (Fig. 4b). However, effort by that fleet in the plaice box showed an increase in 1990–1994, and decline thereafter, even though large trawlers were expelled from the box from 1995 onwards. The large trawlers exerted around 8% of their total effort in the plaice box in the early 1990s. After 1994, the proportion dropped to almost zero (Fig. 4c).

Recruits

The time series of recruitment show annual variations around a general pattern of relatively low abundance in the 1970s, high abundance in the 1980s and again slightly lower abundance in the 1990s (Fig. 5a). This pattern is reflected in the VPA estimates of 1-group abundance (ICES, 1999a) as well as in the survey estimates of 0-group abundance.

Standardized survey mortality estimates for age 0 to 1 (Fig. 5b) and 1 to 2 (Fig. 5c) are available and seem to indicate an upward trend over time in the early 1990s, followed by a sharp decrease in the mid-1990s.

The growth rate of juveniles showed a decrease in the late 1980s as compared with the late 1970s and early 1980s (Fig. 6). Expressed as K, both mean length in

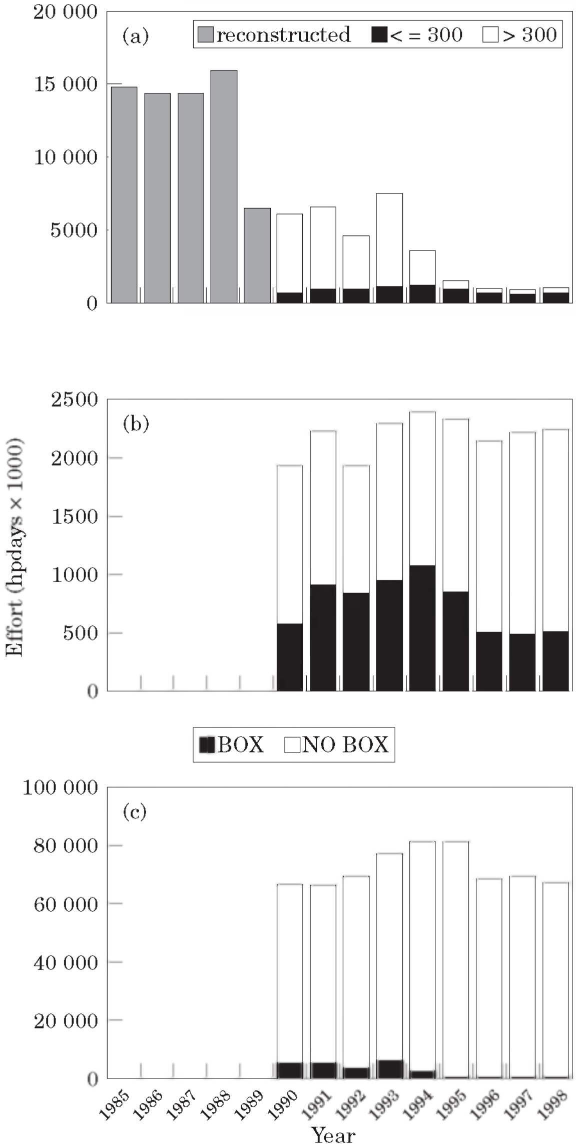

Figure 4. Dutch beamtrawl effort (hp days-at-sea): (a) Inside the plaice box by vessel hp class; total effect for vessels in 225–300 hp class (b) and >300 hp (c) inside and outside the box.

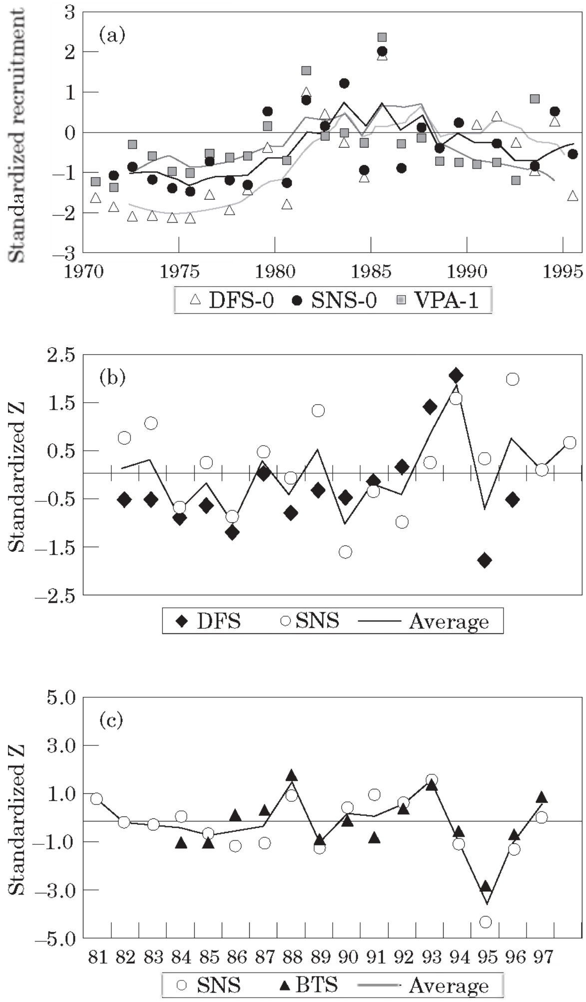

Figure 5. Time series for North Sea plaice, standardized to mean=0 and sd=1: (a) Age-1 VPA recruitment and age-0 abundance from DFS and SNS for year classes 1970–1995 (mean and sd based on year classes 1980–1990); total mortality rate for (b) 0 to 1-group and (c) 1 to 2-group for year classes 1982–1998 estimated from DFS, SNS and BTS indices (drawn line: arithmetic mean over surveys).

recruitment surveys and back-calculated length from market samples show a similar pattern with low growth for the year classes born between 1985 and 1989, although there is a substantial difference in absolute level. For both data-sources the relative decrease in growth rate for the period 1984–1990 compared to 1974–1983 was around 15%. Growth of the year classes born in the early 1990s appears to have recovered to the level of the early 1970s. The drop in growth rate in the late 1980s coincided with an increase in the abundance of juvenile plaice (Fig. 5a).

Simulations

The influence of growth rate (K) on simulated population characteristics (scenario A) is shown in Figure 7a. The percentage discards (defined as the proportion of the total simulated catch that was below the minimum landing size of 27 cm) decreased with increasing growth rate. Recruitment, yield and SSB per recruit showed an increase with growth rate.

The simulation indicated that the incrementally tighter closure of the plaice box represented by the five scenarios (under the assumptions of the model) reduced the percentage discards in the catch and enhanced the landings per recruit and SSB per recruit (Fig. 7b).

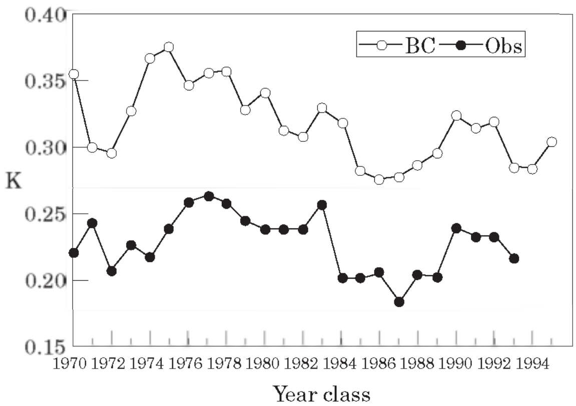

Figure 6. Growth rate (K) estimated from mean back-calculated length (BC) and from mean length at age 0 in DFS and 1 to 3 in SNS (Obs.) for year classes 1970–1995.

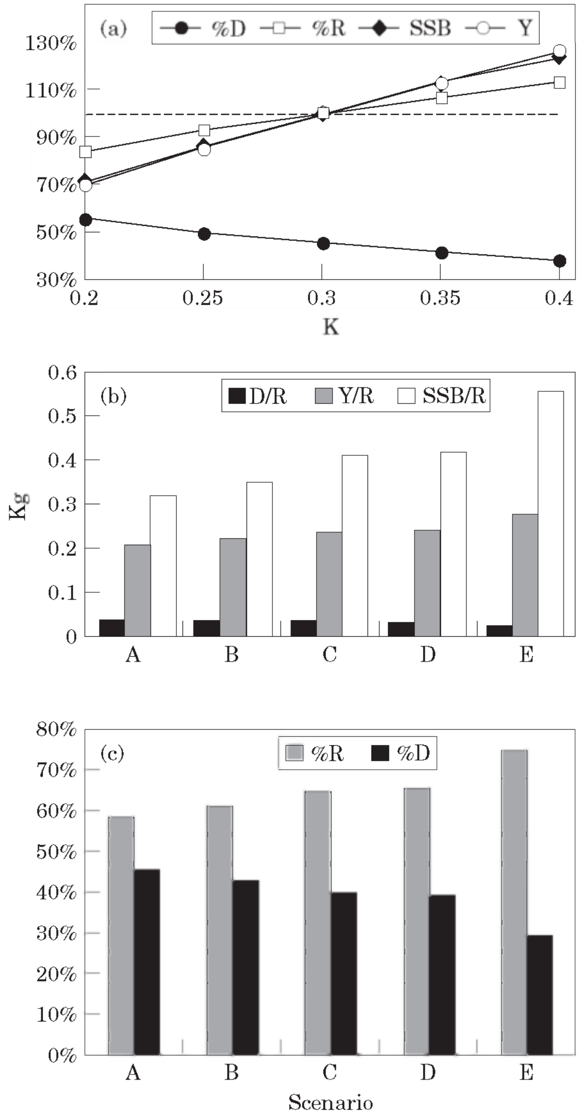

Figure 7. (a) Effect of growth rate (K) on percentage discards in numbers (%D), percentage recruitment to the fishery (%R; the ratio between perceived recruitment based on landings only to simulated recruitment including discards), spawning stock biomass (SSB) and yield (Y), relative to their values at K=0.3 and scenario A; effect of different scenario (b) on discards-per-recruit in weight (D/R), yield-per-recruit (Y/R) and SSB-per-recruit (SSB/R) and (c) on %R and %D in numbers. Scenario B, closure in 2nd and 3rd quarter; C, closure in 2nd, 3rd and 4th; D, closure in all quarters (B–D: only for beam trawlers >300 hp); E, closure in all quarters for entire fleet.

Closure of the box during the second and third quarter (scenario B), reflecting the regulation between 1989 and 1993, gave slight increases in landings and SSB (<10%). Extending the plaice box to the whole year further enhanced landings and SSB. The improvement was mainly due to the reduction in discarding during the fourth quarter, because the fisheries mainly operate on the offshore fishing grounds outside the plaice box. Extending the box by excluding all vessels during the whole year (scenario E) gave the highest landings per recruit and SSB per recruit. Comparing the gain in landings and SSB with that in the percentage recruitment (the ratio between perceived recruitment based on landings only to the simulated recruitment including discards) revealed that the increase was mainly due to an increasing survival of pre-recruits, which resulted in an increase in the recruitment to the fisheries.

Changes in growth rate affect the simulated effects of a closed area for all scenarios significantly. Figure 8 provides a few examples. An increase in K resulted in an increase in the yield-per-recruit for all scenarios (Fig. 8a) and a decrease in percentage discards (Fig. 8b). However, the predicted gain in yield per recruit for scenario D would have been nullified by a reduction of K from 0.3 to 0.25.

Discussion

Recruitment of juvenile plaice to the fishery is affected by several natural processes that determine the level and variability of the number of plaice settling in the nursery areas and their survival until they reach marketable size. Over the historic variations in SSB, there is no evidence that recruitment is impaired at low levels of SSB (Rijnsdorp and Millner, 1996; ICES, 1999a). The number of 0-group settling in the nursery areas is largely determined by the variability in environmental conditions during the egg and larval phase (van der Veer *et al.*, 1992). The time series of survey estimate for 0-group does not suggest a decrease in the number of plaice settling in the nursery areas (Fig. 5a). Our analysis, therefore, focussed on the processes affecting the mortality of demersal pre-recruits between their first autumn after settlement and the time when they recruit

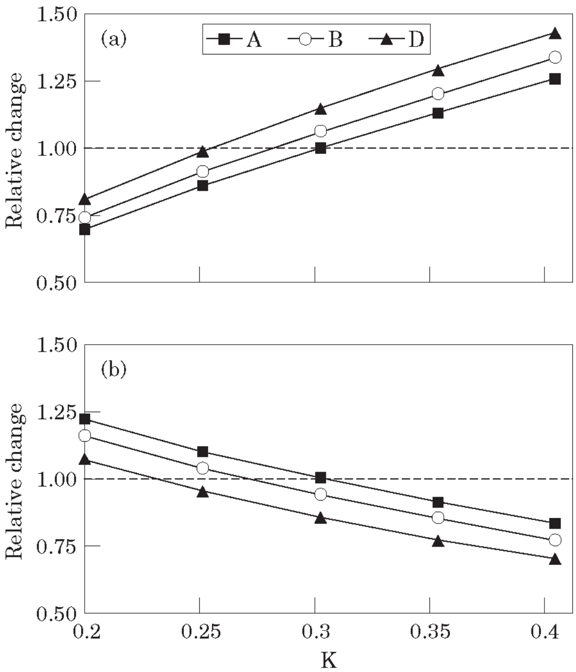

Figure 8. Effect of growth rate (K) on yield-per-recruit (a) and discards-per-recruit (b) for scenarios A, B and D (see Fig. 7), relative to the no-box scenario (A) at K=0.3

to the fisheries. Ultimate survival of pre-recruits will be a function of the cumulative natural and discard mortality.

To evaluate the effects of a partially closed area like the plaice box, it is first necessary to ascertain whether the regulation has been adhered to. A study of the micro-scale distribution of Dutch beam trawl vessels, using an automated position recording system, revealed that the fleet of large vessels heavily exploits the borders of the plaice box (Rijnsdorp *et al.*, 1998), but they rarely entered the box. Therefore, the plaice box has been an effective technical measure to exclude large beam trawlers from the area.

Dutch fishing effort inside the plaice box has decreased in two steps (1989–1993 and 1994–1998). Preliminary attempts to compile international catch and effort data confirmed the trend observed for the Dutch fleet: total international effort inside the plaice box was estimated to be around 15% of the effort in the late 1980s and the effort of exemption fleets (trawlers with engines <=300 hp and fixed gears) in the box had decreased since 1994–1995 (ICES, 1999b).

The reduction in beam trawl effort in the plaice box implies that discard mortality rate in the box area has decreased. This inference is supported by the increase in the relative abundance of larger size classes of a variety of exploited species as observed in the BTS catches (Piet and Rijnsdorp, 1998). However, a reduced discard mortality rate is not reflected in the survival indices estimated from pre-recruit survey indices, which suggest a lower survival of the 1990–1994 cohorts (Fig. 5b and c). This discrepancy may be partly due to the fact that the reduction in beam trawl effort was initially restricted to the second and third quarter. Heavy beam trawling in the plaice box during the fourth quarter in the period until 1994 may have generated a substantial discard mortality which will have affected the year classes 1987–1991. However, this would not explain reduced survival. Other possible explanations may be increased predation (van Eerden and Gregersen, 1995; Leopold *et al.*, 1998), changes in distribution of juveniles (ICES, 1999b) or general changes in the ecosystem during the early 1990s. Corten and Van der Kamp (1996) showed that the abundance of southern fish species increased in the southern North Sea during this period. This change was related to relatively mild winters and an increase in southerly winds, which resulted in an increased transport of Atlantic water through the Strait of Dover. An analysis of the demersal fish assemblage in the south-eastern North Sea also showed significant changes in species composition and abundance (Piet and Rijnsdorp, 1998), which were observed in the plaice box as well as in two reference areas. These results indicate that a change may have occurred in the North Sea ecosystem around the time of the establishment of the plaice box.

A decrease in growth rate will extend the pre-recruit period and hence increase the cumulative mortality. The observed decrease in pre-recruit growth in the late 1980s as compared to the late 1970s and early 1980s corresponds to a reduction in K of around 15%. The simulation model showed that a relative decrease in growth rate by this order of magnitude would confound the effect of the plaice box (Fig. 8), e.g. at K=0.25, the simulated yield of scenario B (closure during second and third quarter) was below the yield at K=0.30 without a plaice box. Even a year-round closure (scenario D) did not show an improved yield if growth rate was reduced by the same amount.

The growth rate of different size classes exhibits statistically significant contributions of density-dependent (population abundance) and density-independent factors (eutrophication, beam trawl effort; Rijnsdorp and van Leeuwen, 1996). The decrease in growth rate in the late 1980s can therefore be (partly) ascribed to the increase in the number of pre-recruits in the nursery following settlement of the strong 1985 year class. The higher growth rate in the 1990s when substantially lower number of pre-recruits were present supports this interpretation.

If growth of plaice is reduced at high levels of population density; the establishment of the plaice box could be causally linked to a reduction in growth rate because increased survival of pre-recruits leads to a higher density. However, the expected gain in recruitment due to the plaice box is much less than the amplitude of recruitment variations. For instance, a strong year class is about two to three times the size of an average year class. Therefore, the degree to which growth may be reduced due to higher density seems insufficient to take away the gain of an improved survival.

The significant relationship between beam trawl intensity and growth rate of plaice and sole (de Veen, 1978b; Rijnsdorp and van Beek, 1991; Rijnsdorp and van Leeuwen, 1996) prompted the hypothesis that beam trawling may improve the food availability by changing the benthic assemblage in heavily trawled areas towards highly productive, small organisms. Thus, the effort reduction in the plaice box may have led to reduced feeding conditions and contributed to a reduction in growth. No time series information on the abundance of relevant benthic organisms is available to test this hypothesis. However, an analysis of the abundance of eight larger benthic species caught in demersal fish surveys in the south-eastern North Sea showed changes that were significantly related both to the changes in the plaice box regime and to gradual changes over time (Piet and Rijnsdorp, 1998).

A related aspect is that beam trawling may affect the spatial distribution of plaice by attracting fish to the rich feeding grounds in heavily trawled areas. Recently, fishermen reported a change in the spatial distribution of small plaice along the border of the plaice box where large beam trawlers are concentrated (Rijnsdorp *et al.*, 1998). In a series of special survey conducted in 1996, 1998 and 1999, there were strong indications that the discard size class was indeed most abundant around the border of the plaice box (ICES 1999b).

At present, the available evidence for an interaction between beam trawling, food availability and spatial distribution of plaice is indirect and at most suggestive. The hypothesis, however, needs careful further examination because it may have important consequences for the effect of area closures for trawl fisheries.

There are many factors that may determine the effect of the plaice box on the population dynamics. Given the short time series of data after the closure and very restricted information to describe the original situation before its introduction, there appears no other option than to resort to a simulation model to disentangle the different processes. Consequently, however, any evaluation will reflect our perception of the important aspects of stock dynamics in this context. The most important features of the model used was that it could separately address the spatial distribution of fish and of fishing effort and cohort dynamics of growth, mortality and migration. The price to be paid for this level of detail is that many parameters must be estimated in order to set the model up, especially for the spatial components. For the current implementation of the FLATFISH model, we used mark-recapture data to estimate migration vectors by month and by ICES rectangle. The model results are very dependent on the spatial dynamics that are generated by this procedure and are therefore intended for improving our understanding rather than for predicting actual outcomes of management scenarios.

Synthesis

After the establishment of the plaice box in 1989, yield and spawning stock biomass have decreased substantially, in contrast to expectations. This phenomenon may be explained by a number of coincidences. First, the positive effect of a reduction in discard mortality was offset by the larger negative effect of the observed decrease in growth rate of juvenile plaice in the late 1980s and early 1990s. Second, the best estimate of settlement of 0-group in the nursery area is given by the abundance of pre-recruits estimated during the autumn research vessel surveys. These data indicate a relatively low number of pre-recruit plaice in the early 1990s compared with the mid-1980s. Third, the changes observed in the demersal fish and epibenthos abundance in the south-eastern North Sea suggest that changes in the ecosystem may have masked the effects of the box. These factors may all have contributed to the decrease in yield and spawning stock biomass since 1989, despite the obvious reduction in fishing effort inside the plaice box. The available evidence suggests that density-dependent growth has a small negative influence on the effectiveness of the plaice box, but not enough to explain the discrepancy. It remains possible that a feed-back mechanism between beam trawling and the spatial distribution and growth of juvenile plaice is responsible for the negative responses at the stock level and that the technical measure of a protected area is by itself counterproductive. However, no direct observations are available to test this hypothesis.

The evaluation of the plaice box is hampered by the lack of representative reference areas, as well as by the lack of a research program specifically designed to study its effects. Given the current debate about the usefulness of MPAs as a tool in precautionary fisheries management and marine conservation (Jennings and Kaiser, 1990; Hall, 1998), it is important that the question is answered as to whether or not the decline in yield and spawning stock biomass is due to the establishment of the plaice box. Without a better understanding, the credibility of the biological advice that led to the implementation of the plaice box, will continue to be negatively affected. The example cautions that MPAs, although intuitively attractive, may be a less straightforward management tool.

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