Impact of various fishery management measures on egg production per recruit in American lobster (*Homarus americanus*)

Louise Gendron and Pierre Gagnon

Regional Science Branch
Department of Fisheries and Oceans
Maurice Lamontagne Institute
C.P. 1000, 850, route de la Mer
Mont-Joli (Québec)
G5H 3Z4

2001

Canadian Technical Report of Fisheries and Aquatic Sciences 2369

Pêches et Océans   Fisheries and Oceans   Canadä

Canadian Technical Report of
Fisheries and Aquatic Sciences

Technical reports contain scientific and technical information that contribute to existing knowledge but that are not normally appropriate for primary literature. Technical reports are directed primarily toward a worldwide audience and have an international distribution. No restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Technical reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is indexed in the data base *Aquatic Sciences and Fisheries Abstracts*.

Numbers 1-456 in this series were issued as Technical Reports of the Fisheries Research Board of Canada. Numbers 457-714 were issued as Department of the Environment, Fisheries and Marine Service, Research and Development Directorate Technical Reports. Numbers 715-924 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Technical Reports. The current series name was changed with report number 925.

Technical reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport technique canadien des
sciences halieutiques et aquatiques

Les rapports techniques contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui ne sont pas normalement appropriés pour la publication dans un journal scientifique. Les rapports techniques sont destinés essentiellement à un public international et ils sont distribués à cet échelon. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports techniques peuvent être cités comme des publications intégrales. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports techniques sont indexés dans la base de données *Aquatic Sciences and Fisheries Abstracts*.

Les numéros 1 à 456 de cette série ont été publiés à titre de rapports techniques de l'Office des recherches sur les pêcheries du Canada. Les numéros 457 à 714 sont parus à titre de rapports techniques de la Direction générale de la recherche et du développement, Service des pêches et de la mer, ministère de l'Environnement. Les numéros 715 à 924 ont été publiés à titre de rapports techniques du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 925.

Les rapports techniques sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement d'origine dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Technical Report

of Fisheries and Aquatic Sciences 2369

2001

Impact of various fishery management measures on
egg production per recruit in American lobster (*Homarus americanus*)

Louise Gendron and Pierre Gagnon[1]

Regional Sciences Division
Department of Fisheries and Oceans
Maurice Lamontagne Institute
C.P. 1000, 850, route de la Mer
Mont-Joli (Québec) G5H 3Z4

[1] Centre Saint-Laurent
105 McGill
Montréal QC
H2Y 2E7

Ce rapport est également disponible en français

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

therefore this 10% threshold has been established somewhat arbitrarily. However, studies by Fogarty and Idoine (1986) and Ennis and Fogarty (1997) indicate that the rising section of the stock-recruitment curve, close to the origin, has a very steep slope, which suggests that lobster populations show fairly strong resiliency at high exploitation rates.

In many lobster fisheries in Atlantic Canada, EPR has been reported at about 1% or 2% of that of an unfished stock (Pezzack and Maguire 1995, Anon. 1995). In many cases, the minimum legal size is less than the size at sexual maturity and the exploitation rates are very high, which explains the low EPR. In its report, the FRCC proposed introducing new conservation measures that would raise the EPR to 5% of that of an unexploited stock. But there is still much uncertainty about the characteristics of an unfished stock, chiefly as regards the growth, spawning frequency, and natural mortality of large females. This is why the stock management policy has been defined in terms of doubling the current EPR in each fishing area, rather than of increasing it as a percentage of the calculated EPR for an unfished stock (DFO 1998).

Over the years, several models for calculating eggs per recruit and yield in weight per recruit have been developed and applied to various Canadian lobster stocks (Attard 1985, Caddy 1977, 1979, Campbell 1985, Campbell and Robinson 1983, Ennis 1985, 1991, Ennis and Collins 1983). These models incorporate every component of the annual cycle of the recruited lobster. Some models account for particularities in the females' reproductive cycle, such as the ability to spawn and molt in the same year, or to spawn more than once during the intermolt period. Fogarty and Idoine (1988) developed an EPR model for US lobster fisheries. This model has been applied by Pezzack and Maguire (1995) to the Canadian stocks to provide the FRCC with an indication of the current level of egg production. In the present study, we describe a new model for calculating EPR. This model, derived from the model of Fogarty and Idoine (1988), has been developed to better reflect the main biological characteristics of the lobster of Atlantic Canada and the distinctive features of the fishery in this region. This model also offers the flexibility needed to account for the uncertainty caused by natural variability in lobster production processes (growth, natural mortality, and recruitment) and by difficulties in determining exact values for biological parameters. We use the Monte Carlo method to generate a set of EPR values whose distribution is the result of the uncertainty in the model's parameters. Consequently, we can formulate probabilistic statements that can be used to assess risk. Risk may be defined as the probability that a negative event will occur, where the probability is the expression of the uncertainty. For example, fishery managers might want to assess the risk of not achieving a given management objective, or of falling below a given biological reference level or warning threshold beyond which the probability of a given stock's collapsing is high. In the former case, we would be looking at a management risk, and in the latter, at a biological risk.

In this paper, we describe our model and present the results of EPR calculations for various management scenarios applied to the lobster fisheries of the Magdalen Islands and the Gaspé Peninsula in Québec. The results of these calculations have been used to develop management and conservation plans that have been implemented in the Québec lobster fisheries since 1997, with the goal of increasing EPR to twice its 1996 level. We

also present an assessment of the management risk—the probability of not achieving this objective of doubling EPR—for a variety of possible management measures. This is the first time a risk analysis has been applied to a lobster fishery.

2.0 MATERIAL AND METHODS

2.1 MODEL

The model presented here is an extension of the biological model developed by Fogarty and Idoine (1988). This model reproduces the lobster's life cycle, incorporating the various biological parameters such as natural mortality, growth, sexual maturity, and fecundity, while also considering the fishing to which the population is subjected. This model simulates the life cycle of a group of male or female lobster with a given initial size distribution until their population has been reduced to nearly zero. In this study, we deal with females only. Each year the sequence of events described below and illustrated in Figure 1 is repeated. For females, the year starts with the fishing season. Fishing mortality is applied only to unberried females. After the fishing season, the surviving females are divided into two groups: those that are going to spawn and those that are not. The spawners may molt once before spawning while the non-spawners may molt once or twice while remaining in the unberried population. Meanwhile, the berried females that are caught are thrown back, sometimes after having been marked (V-notched on the telson). The females incubate their eggs for close to a year. Then, after the eggs have hatched, these females molt, return into the population of unberried females, and thus become vulnerable to fishing in the following year. The V-notched females however, will have additional protection and not suffer any fishing mortality, even if they are not berried. This protection does not continue, however, beyond two molts. Egg production is calculated at the time the eggs hatch.

Natural mortality has two components: mortality of hard-shelled lobster, which occurs throughout the year, and mortality of soft-shelled lobster, which occurs during the short period of increased vulnerability that follows the molt. The probability of spawning in a given year and the number of eggs produced by a female depends on her size. Fishing mortality is also a function of the size of the lobster and is dependent on the minimum legal size. It is independent, however, of the abundance of the population and does not vary from one year to another. It can be reduced through certain control measures (reducing overall fishing effort, protecting berried females, protecting large individuals, and V-notching, which provides further protection for two more molts). The model requires the definition of 19 variables (Figure 1), which may be described by constants or various mathematical functions (Table 1).

3
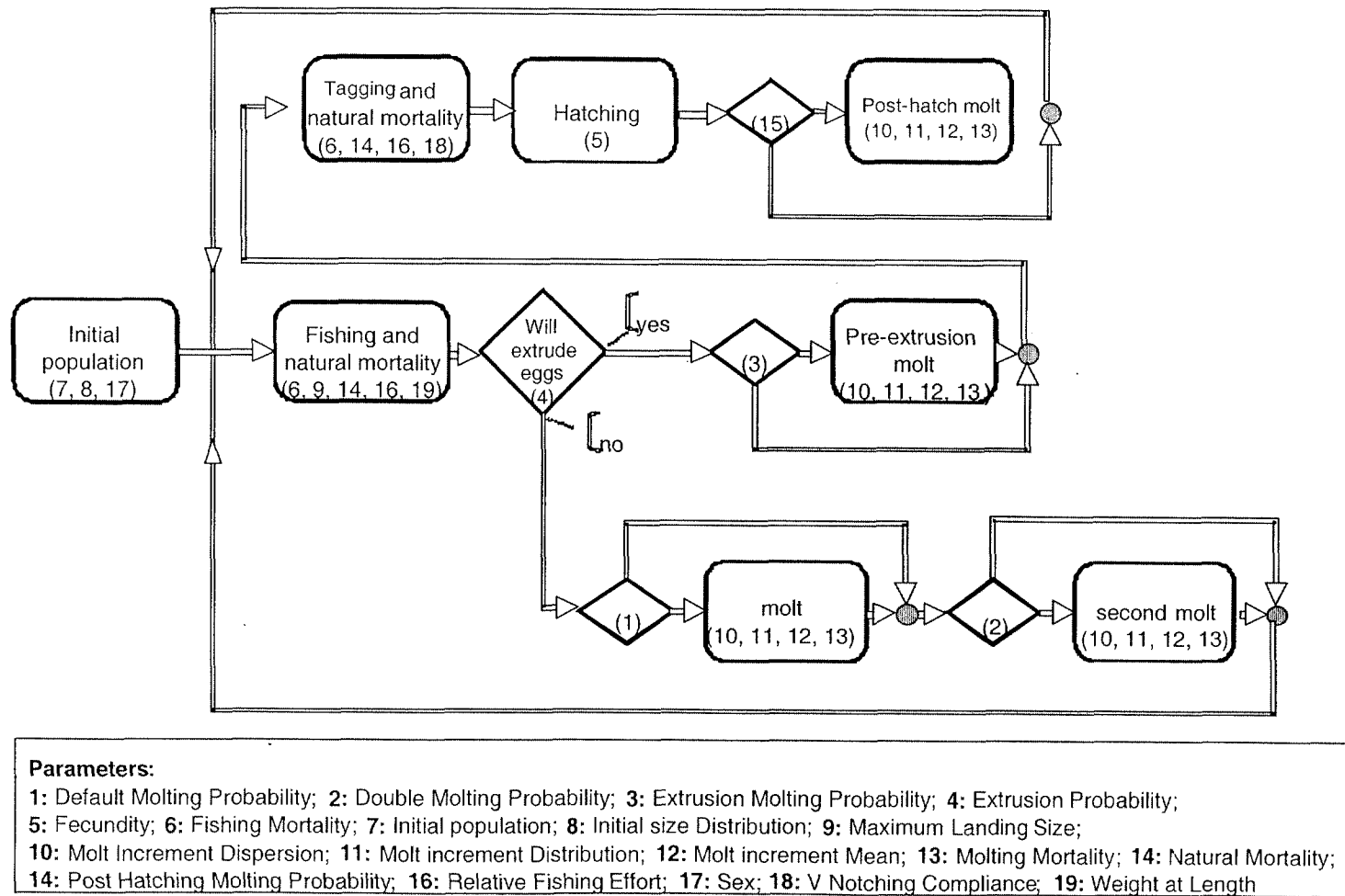
Figure 1. Flowchart of the life cycle of female lobster and list of the parameters used in the model for calculating egg production per recruit (EPR).

Table 1. List of functions that can be used in the model to describe the different variables.

Function	Value for a given size = x (carapace length)
Constant (C)	C
Step (S, L, R)	$\begin{cases} L & \text{if } x < S \\ R & \text{otherwise} \end{cases}$
Two steps (S_1, S_2, L, M, R)	$\begin{cases} L & \text{if } x < S_1 \\ M & \text{if } S_1 \leq x < S_2 \\ R & \text{otherwise} \end{cases}$
Linear (A, B)	$A + Bx$
Quadratic (A, B, C)	$A + Bx + Cx^2$
Cubic (S_1, S_2, L, R)	$\begin{cases} L & \text{if } x \leq S_1 \\ L + (R-L)(2Y^3 - 3Y^2 + 1) \\ Y = \dfrac{x - S_2}{S_1 - S_2} & \text{if } S_1 < x \leq S_2 \\ R & \text{otherwise} \end{cases}$
Logistic (M, Q, L, R)*	$L + \dfrac{(R-L)}{1 + e^{(-2\ln(3)(x-M))/Q}}$
Uniform (S_1, S_2)	$\begin{cases} \dfrac{1}{S_2 - S_1} & \text{if } S_1 \leq x \leq S_2 \\ 0 & \text{otherwise} \end{cases}$
Normal (M, D)	$\dfrac{e^{\frac{-(x-M)^2}{2D^2}}}{D\sqrt{2\pi}}$
Exponential (M)	$\dfrac{e^{-x/M}}{M}$
Power (A, B)	Ax^B

*The logistic function $Y = 1/1+e^{-(a+bx)}$ is expressed here this way to enable the assignment of a distribution of uncertainty to the inflexion point (M) and to the size interval (Q) within which the function goes from 0.25 to 0.75 of its maximum value, or inversely in the case of a negative function. M= -a/b and Q=2ln(3)/b

The computer program developed to implement the model can be used to explore various management measures while taking into account uncertainty in the information available. Every value or every parameter of a function can be described by a probability distribution rather than a fixed value (Table 2). This parameter uncertainty is propagated to the final EPR estimate by means of a Monte Carlo simulation, which iteratively assigns various values to the parameters, chosen randomly within the probability distribution defined for the parameter in question. The program can perform up to 1000 iterations.

This program is a DOS executable written in Fortran. The system reads the data from the files that contain the information on the biological parameters. An application written in Visual Basic 6.0 allows the model to be run under Windows 95.

Table 2. List of probability distributions used to quantify the uncertainty associated with the values or parameters of functions describing various biological variables.

Probability distribution	Parameters to be defined
Uniform	minimum; maximum
Normal	mean; standard deviation
Log Normal	mean normal; standard deviation normal
Binomial	probability of value 1; value 1; value 2
Epanechnikov	minimum; maximum

2.2 DATA

The model has been used to simulate the application of various management scenarios to the lobster populations of the northern and southern portions of the Magdalen Islands and the Gaspé Peninsula. In many cases, the biological data characterising the various populations have been taken from the literature (Table 3).

Table 3. Values and equations describing growth, sexual maturity, and fecundity that were used in calculating egg production per recruit (EPR).

	Magdalen Islands South	Magdalen Islands North	Gaspé
Molt size increment	*Constant, uniform distribution between 8 and 12 mm*		
Molt Probability *Proportion of females molting a given year (Y) as a function of size (CL)*	$Y = 1 / 1+e^{+0.088CL - 7.91}$ $M^* = 90$ mm $Q^{**} = 25$ mm (L. Gendron, unpublished data)		
Sexual maturity *Proportion of mature females (Y) as a function of size (CL)*	$Y = 1/1+e^{-0.314CL + 24.8}$ M= 84 mm Q= 7 mm n=380 Dubé and Grondin (1985)	$Y = 1/1+e^{-0.314CL + 26.37}$ M= 84 mm Q= 7 mm n=361 Dubé and Grondin (1985)	$Y = 1/1+e^{-0.169CL + 14.15}$ M= 79 mm Q= 13 mm n=47 (L. Gendron, unpublised data)
Fecundity *Number of eggs (Y) as a function of size (CL)*	$Y = 0.00256 \times CL^{3.409}$ n=166 Campbell and Robinson (1983)		

*M = inflexion point
**Q = size interval within which the function goes from 0.25 to 0.75 of its maximum value

2.2.1 Growth

The data on growth in size per molt that are used in this model are based on the results of mark/recapture campaigns conducted in the Magdalen Islands by Dubé (1985). In general, the growth in size per molt is a positive linear function of size. However, in the case of females, Dubé (1985) observed that the slope of the regression line between post-molt size and pre-molt size was not significantly different from 1, thus showing that for the sizes considered, growth per molt was constant. An average value of 10 mm has been used in the model, both for the Magdalen Islands and for the Gaspé Peninsula. To account for uncertainty and variability, growth in size per molt has been expressed as a value that is distributed uniformly between 8 and 12 mm and constant for all sizes.

The probability of molting is defined as the proportion of individuals that molt in a given year. It was determined for this model from observations of the proportion of post-molt lobster taken with a trawl off the Magdalen Islands in September 1995, after the molting period. The initial size of lobster that had molted that summer was determined from Dubé's data on growth in size per molt (1985). The percentage of lobster that had molted was then calculated for each 1-mm size class. The probability of molting as a function of size was then represented by a logistic equation in which the minimum value was set at 0.05 rather than at zero, corresponding to one molt every 20 years for very large individuals. We determined that the size at the inflexion point (M) was 90 mm and that the interval (Q) within which the function goes from 0.25 to 0.75 of its maximum value, was 25 mm. The uncertainty in the value of M was represented by a normal distribution with a standard deviation of 4 mm while the value of Q could vary uniformly between 20 and 30 mm.

Though the model can accommodate cases where the same individual molts twice in the same year, we have assumed that the proportion of female lobster that molt twice per year off the Gaspé Peninsula and the Magdalen Islands is negligible. It should be noted, however, that some cases of double-molting—chiefly in lobster smaller than 75 mm—have been reported in the Magdalen Islands in the Grande-Entrée Lagoon, where the water temperature is higher (Munro and Therriault 1983).

2.2.2 Sexual maturity

Observations on sexual maturity were used to determine the probability that an unberried female will spawn in a given year. For the lobster in the Magdalen Islands, sexual maturity was determined from observations of the colour, weight, and oocyte diameter of the ovaries (Dubé and Grondin 1985). Females that had developing ovaries (stages 4 and 5) or mature ovaries (stage 6) during the fishing season, according to the classification of Aiken and Waddy (1982), were regarded as capable of spawning in the course of the year. For the lobster in the Gaspé, on the other hand, sexual maturity was determined from the development of the cement glands, according to the criteria defined by Aiken and Waddy (1982). The females with cement glands in development stages 3 or 4 were regarded as mature and capable of spawning during the current year. Cement gland development stages 3 and 4 are generally correlated with ovary development stages

4, 5, and 6 (Aiken and Waddy 1982). The percentage of mature females as a function of size was determined and a logistic curve was fit to this equation. The size at which 50% of the females are mature is 79 mm in the southern Magdalen Islands, 84 mm in the northern Magdalen Islands (Dubé and Grondin 1985), and 84 mm in the Gaspé (L. Gendron, unpublished data) (Table 3). Standard deviations of 3 mm were associated with all of these means while the 0.25-0.75 intervals of the logistic curve were distributed uniformly between 6 and 8 mm.

The model can accommodate the deviations sometimes observed in the females' usual reproductive cycle, which consists in alternating between molting one year and spawning the next (Aiken and Waddy 1986). Nevertheless, we have assumed that the proportion of females that molt and spawn in the same year is negligible, as is the proportion that spawn immediately after their eggs hatch, without first molting again.

2.2.3 Fishing mortality

Every year, an exploitation rate index is calculated for the lobster populations of the northern and southern Magdalen Islands and the Gaspé, based on weighted size frequency distributions for male lobster. The calculation method is taken from Miller *et al.* (1987) and is based on the abundance of the first two molt classes recruited into the fishery. The instantaneous mortality rate for the first molt class recruited into the fishery is estimated from the following equation:

$$Z = -\log_e (M_2 / M_1)$$

where $M_1 = M_1' / t_{M1}$, and $M_2 = M_2' / t_{M2}$. M_1' is the number of lobster in the first molt class and M_2' is the number of lobster in the second molt class, t_{M1} and t_{M2} represent the period, in years, spent in the molt classes. The molt classes were estimated from data for growth of male lobster in the Magdalen Islands (Dubé 1985). The first molt class comprises individuals ranging from 76 to 86 mm in size and the second comprises individuals ranging from 87 to 99 mm in size. The intermolt period was estimated from the data on molting probabilities calculated for males by Dubé (1985). Thus, t_{M1} and t_{M2} were estimated at 1.13 and 1.52 years, respectively. To avoid any bias due to changes in recruitment, M_1 for a given year is compared with M_2 for the following year, so that the same cohort is followed over time. The catchability of lobsters ranging from 76 to 99 mm in size is assumed to be comparable, which seems reasonable on the basis of the observations by Tremblay *et al.* (1998). Fishing mortality (F) is obtained by subtracting natural mortality (M=0.15, see below) from total mortality (Z). On the basis of these calculations, it was assumed that the value of F was normally distributed (means = 0.9, 1.12, and 1.43 and standard deviations = 0.09, 0.11, and 0.11 for the northern Magdalen Islands, the southern Magdalen Islands, and the Gaspé, respectively).

2.2.4 Natural mortality

We do not have any precise data on natural mortality (M), but by convention, a value of 0.1 has often been used. More recently, on the basis of new observations (Michel Comeau and Manon Mallet, DFO, Gulf Fisheries Centre, Moncton, New Brunswick, personal communication), a higher value (M = 0.15) has been used. A portion of this natural mortality (M = 0.1) occurs at molting, while the remainder (M = 0.05) applies to all lobster, every year. To account for uncertainty and variability, we have assumed that the portion of M associated with molting could vary uniformly between 0.08 and 0.12 and that the value of M not associated with molting could vary uniformly between 0.04 and 0.06.

2.2.5 Fecundity

The equation of Campbell and Robinson (1983) based on a wide range of sizes was used to quantity the fecundity of the females (Table 3). The equations derived from observations made in the Magdalen Islands (Attard 1985) and the Gaspé covered a more limited range of sizes.

2.2.6 Distribution of recruited sizes

The recruitment size was set at 76 mm. The calculations dealt with a cohort whose initial sizes varied uniformly from 65 to 76 mm.

2.3 SIMULATIONS

The model was used to examine the effects of various management measures on the values of EPR in the lobster fisheries of the Magdalen Islands and the Gaspé. Because the southern and northern portions of the Magdalen Islands (from Pointe-de-l'est to Havre-Aubert and from Millerand to Grosse-Île, respectively) have differing values for size at sexual maturity and fishing mortality, these two areas were considered separately. The simulations examined the impacts of increasing the minimum legal size, of reducing fishing mortality, of introducing a maximum legal size, and of combinations of these measures, including V-notching of berried females. Table 4 lists the management scenarios simulated in this analysis. The choice of scenarios for each region reflects specific requests that were addressed to us. For each management scenario, 100 Monte Carlo iterations were calculated. The values for EPR were expressed both in absolute terms and relative to EPR values calculated for a base scenario (before the implementation of the new management measures). The ratio between the two values, referred to as the increment factor, can be used to determine which management scenarios can, at least in theory, achieve the objective of doubling EPR (an increment factor of 2).

10

To make our estimates of the increment factors more accurate, we compared each alternative scenario with a base scenario using the same random selection of parameters. The cumulative frequency distribution of the 100 increment factor values thus calculated, which reflects the uncertainties of our biological model, was used as the basis for assessing the management risk, meaning the probability of not achieving the specified management objective.

The base scenario represents the management regime that was in effect in 1996, before the implementation of the new conservation plan. This regime included a minimum legal size of 76 mm and throwing back of berried females. There was no maximum legal size, and we have assumed that V-notching of berried females was negligible, though it has been practiced to a marginal extent since 1993 in some parts of the Gaspé.

Table 4. List of management measures for which egg production per recruit (EPR) was calculated, for the southern and northern portions of the Magdalen Islands and for the Gaspé Peninsula.

	Magalen Islands South	Magdalen Islands North	Gaspé
Basic scenario			
76 mm	X	X	X
Minimum size			
78 mm	X	X	X
79 mm	X	X	
80 mm*	X	X	X
81 mm**	X	X	X
82 mm	X	X	X
83 mm	X	X	X
84 mm	X	X	X
Minimum size and changes in fishing mortality			
78 mm and reduction of 10 %	X	X	X
78 mm and reduction of 20 %	X	X	
80 mm and reduction of 10 %	X	X	X
80 mm and reduction of 20 %	X	X	
82 mm and reduction of 10 %	X	X	X
82 mm and reduction of 20 %	X	X	X
84 mm and reduction of 10 %			X
84 mm and reduction of 20 %			X
80 mm and increase of 10 %	X		X
Minimum size and maximum size			
78 mm and 121 mm	X	X	X
80 mm and 127 mm	X	X	X
82 mm and 127 mm	X	X	X
84 mm and 127 mm	X	X	X
Combination of measures : **Minimum size, reduction of fishing mortality, maximum size and female v-notching (V)**			
78 mm, reduction of 10 % and 127 mm	X	X	X
78 mm, reduction of 10 %, 127 mm and 10 % V-notching (V)	X	X	X
80 mm, reduction of 10 % and 127 mm	X	X	
80 mm, reduction of 10 %, 127 mm and 10 % V-notching (V)	X	X	

*minimum size in the majority of the fishing areas in the Gaspé Peninsula and on the North Shore in 2001
** minimum size in the Magdalen Islands in 2001

3.0 RESULTS

3.1 EGG PRODUCTION PER RECRUIT

Tables 5, 6, and 7 show the results of our calculations of EPR, both in absolute numbers and in relative terms (as increment factors compared with the production levels observed under the 1996 management regime) for the southern Magdalen Islands, the northern Magdalen Islands, and the Gaspé, respectively. Figures 2, 3, and 4 show the means and standard deviations for the 100 absolute values and increment factors calculated for each scenario for these same three areas.

In 1996, under the management plan then in effect, EPR averaged 3 636 ±1 199 eggs in the southern Magdalen Islands and 3 418 ± 1 097 eggs in the northern Magdalen Islands (Tables 5 and 6). There is thus no significant difference between the two parts of the islands in their initial levels of egg production. Though the size of the lobster at sexual maturity is higher in the northern sector than in the southern sector (84 mm compared with 79 mm), the lower fishing mortality in the northern islands allows egg production to reach equivalent levels. In the Gaspé, on the other hand, because both the exploitation rate and the size at sexual maturity are high, the calculated egg production is much lower than for the Magdalen Islands. The estimated EPR for 1996 averaged 1 433 ± 647 eggs (Table 7), almost three times lower than in the Magdalen Islands.

At present, the measures adopted by lobster fishers to achieve the previously mentioned conservation objective of doubling EPR, both in the Magdalen Islands and in the Gaspé, are basically limited to increasing the minimum legal size. In the Magdalen Islands, this objective could be achieved through an increase of the minimum size to 83 mm in the southern portion and 84 mm in the northern portion (Tables 5 and 6 and Figures 2 and 3). In the Gaspé, because the initial level of egg production per recruit was relatively lower, this doubling could be achieved by increasing the minimum legal size to only 82 mm (Table 7 and Figure 4). In 2001, the minimum legal size in the Magdalen Islands was set at 81 mm, which according to our model should have increased EPR by a factor of 1.60 in the south and 1.53 in the north (Tables 5 and 6). This estimate is based on the assumption that all the other parameters remained constant. But fishing mortality could have increased over the past five years. If it did, then the increase in EPR following an increase in minimum legal size would be smaller than predicted. For example, according to our model, increasing the minimum legal size to 80 mm should have increased EPR by a factor of 1.41 in the southern Magdalen Islands. But if fishing mortality had increased by 10% at the same time, then the increment factor would have been only 1.26 (Table 5).

Table 5. Egg production per recruit (mean and standard deviation) and production increment factor compared with the situation observed in 1996 for the southern portion of the Magdalen Islands.

	Egg Production per recruit		Increment factor	
	Mean	Standard deviation	Mean	Standard deviation
Basic scenario 76 mm	3636	1199		
Minimum size				
78mm	4147	1286	1.15	0.05
79mm	4555	1361	1.27	0.07
80mm	5059	1446	1.41	0.10
81mm	5734	1481	1.60	0.14
82mm	6320	1616	1.78	0.18
83mm	7167	1639	**2.02**	0.24
84mm	7850	1753	**2.24**	0.30
Minimum size; changes in fishing mortality F				
78mm; -10%F	4938	1274	1.34	0.06
78mm; -20%F	5869	1416	1.60	0.10
80mm; -10%F	5907	1414	1.61	0.11
80mm; -20%F	6896	1542	1.89	0.15
82mm; -10%F	7225	1570	1.99	0.19
82mm; -20%F	8277	1684	**2.29**	0.23
80mm; +10%F	4582	1325	1.26	0.09
Minimum size; maximum size				
78mm; 121mm	6326	2851	1.68	0.41
80mm; 127mm	6490	2338	1.74	0.23
82mm; 127mm	8179	2685	**2.22**	0.30
84mm; 127mm	13436	4474	**3.68**	0.74
Combination (minimum size; reduction of fishing mortality F; maximum size and percentage V-notching)				
78mm; -10%F; 127mm	7035	3336	1.90	0.43
78mm; -10%F; 127mm; V10%	9085	4566	**2.45**	0.67
80mm; -10%F; 127mm	8647	3264	**2.33**	0.49
80mm; -10%F; 127mm; V10%	11108	4490	**3.00**	0.76

14

Table 6. Egg production per recruit (mean and standard deviation) and production increment factor compared with the situation observed in 1996 for the northern portion of the Magdalen Islands.

	Egg Production per recruit		Increment factor	
	Mean	Standard deviation	Mean	Standard deviation
Basic scenario 76 mm	3418	1097		
Minimum size				
78mm	3867	1178	1.14	0.04
79mm	4216	1250	1.25	0.07
80mm	4647	1338	1.38	0.09
81mm	5074	1418	1.53	0.12
82mm	5753	1547	1.72	0.16
83mm	6316	1629	1.92	0.20
84mm	7152	1768	**2.16**	0.27
Minimum size; changes in fishing mortality F				
78mm; -10%F	4669	1377	1.38	0.07
78mm; -20%F	5756	1579	1.72	0.12
80mm; -10%F	5504	1531	1.64	0.12
80mm; -20%F	6671	1727	**2.00**	0.18
82mm; -10%F	6666	1718	**2.00**	0.20
82mm; -20%F	7925	1904	**2.39**	0.27
Minimum size; maximum size				
78mm; 121mm	8364	5156	**2.56**	0.90
80mm; 127mm	7565	4146	**2.33**	0.62
82mm; 127mm	9469	4915	**2.95**	0.76
84mm; 127mm	11926	5831	**3.77**	0.96
Combination (minimum size; reduction of fishing mortality F; maximum size and percentage V-notching)				
78mm; -10%F; 127mm	8368	3949	**2.41**	0.65
78mm; -10%F; 127mm ;V10%	10586	5109	**3.05**	0.88
80mm; -10%F; 127mm	9976	4087	**2.92**	0.78
80mm; -10%F; 127mm ;V10%	12205	5115	**3.57**	1.00

15

Table 7. Egg production per recruit (mean and standard deviation) and production increment factor compared with the situation observed in 1996 for the Gaspé Peninsula.

	Egg Production per recruit		Increment factor	
	Mean	Standard deviation	Mean	Standard deviation
Basic scenario 76 mm	1433	647		
Taille minimale				
78mm	1699	739	1.20	0.07
80mm	2223	917	1.59	0.15
81mm	2562	907	1.90	0.20
82mm	2953	1017	**2.24**	0.25
83mm	3538	1162	**2.66**	0.37
84mm	4059	1273	**3.12**	0.46
Minimum size; changes in fishing mortality F				
78mm; -10%F	2056	834	1.47	0.10
80mm; -10%F	2628	1009	1.90	0.19
82mm; -10%F	3407	1084	**2.61**	0.31
82mm; -20%F	4017	1169	**3.11**	0.42
84mm; -10%F	4571	1329	**3.54**	0.54
84mm; -20%F	5253	1400	**4.11**	0.68
80mm; +10%F	1891	739	1.38	0.14
Minimum size; maximum size				
78mm;121mm	2089	1081	1.57	0.34
80mm;127mm	2343	966	1.80	0.16
82mm;127mm	3267	1236	**2.54**	0.29
84mm;127mm	4555	1559	**3.60**	0.53
Combination (minimum size; reduction of fishing mortality F; maximum size and percentage V-notching)				
78mm; -10%F; 127mm	2305	925	1.72	0.22
78mm; -10%F; 127mm; V10%	3238	1453	**2.41**	0.53

In the Gaspé Peninsula, in 2001, the minimum legal size was 80 mm in most areas, except Gaspé-Nord, Gaspé Bay, and La Malbaie, where it was 81 mm. According to the model, increasing the minimum legal size to 80 mm would have increased EPR by a factor of 1.59, and increasing it to 81 mm would have increased EPR by a factor of 1.90. It is important to note that, just as in the Magdalen Islands, an increase in fishing mortality would have negative effects on the expected benefits derived from increasing the minimum legal size. For example, if the minimum legal size was increased to 80 mm, but fishing mortality increased by 10%, the EPR increment factor would be only 1.38 instead of 1.59 (Table 7).

On the other hand, the increase in minimum legal size needed to double EPR would be smaller if this increase was combined with a decrease in fishing mortality. For instance, in the southern Magdalen Islands, the same EPR increment factor—1.60— can be achieved by any of the following three approaches: increasing the minimum size to 81 mm; increasing the minimum size to 80 mm while reducing fishing mortality by 10%; or increasing the minimum size to only 78 mm while reducing fishing mortality by 20% (Table 5). In the northern Magdalen Islands, where fishing mortality is already lower, reducing it further produces a slightly more marked effect. A 20% reduction in fishing mortality combined with a minimum size of 78 mm results in the same EPR increment factor—1.72—as a minimum size of 82 mm (Table 6). In the Gaspé, a 10% reduction in fishing mortality combined with a minimum size of 80 mm provides an increment factor of 1.9, equivalent to what is achieved by a minimum size of 81 mm alone (Table 7).

There would also appear to be some merit in protecting the largest females. According to the model, benefits are obtained from combining a minimum legal size with a maximum legal size of 127 mm (5 inches) or 121 mm (4 ¾ inches). However, these benefits are greater in the northern portion of the Magdalen Islands, because the exploitation rate is lower there, which allows more females to reach larger sizes and thus benefit from such a protection measure. In contrast, in areas where the exploitation rate is very high such as the Gaspé Peninsula, introducing a maximum legal size would affect very few lobster, and the short-term benefits are not very apparent. For example, adding a maximum legal size of 127 mm to a minimum legal size of 82 mm raises the increment factor from 1.72 to 2.95 in the northern Magdalen Islands (Table 6) but only from 2.24 to 2.54 in the Gaspé (Table 7).

Lastly, a doubling of EPR can also be achieved by combining all of the available measures: increasing the minimum legal size, introducing a maximum size, marking berried females, and reducing fishing mortality. Such a variety of measures would allow for a better distribution of the conservation effort among all the lobster fishers. For example, the increase in minimum legal size is felt almost solely by fishers who operate in areas where there are more small lobster, and this situation is often denounced as unfair.
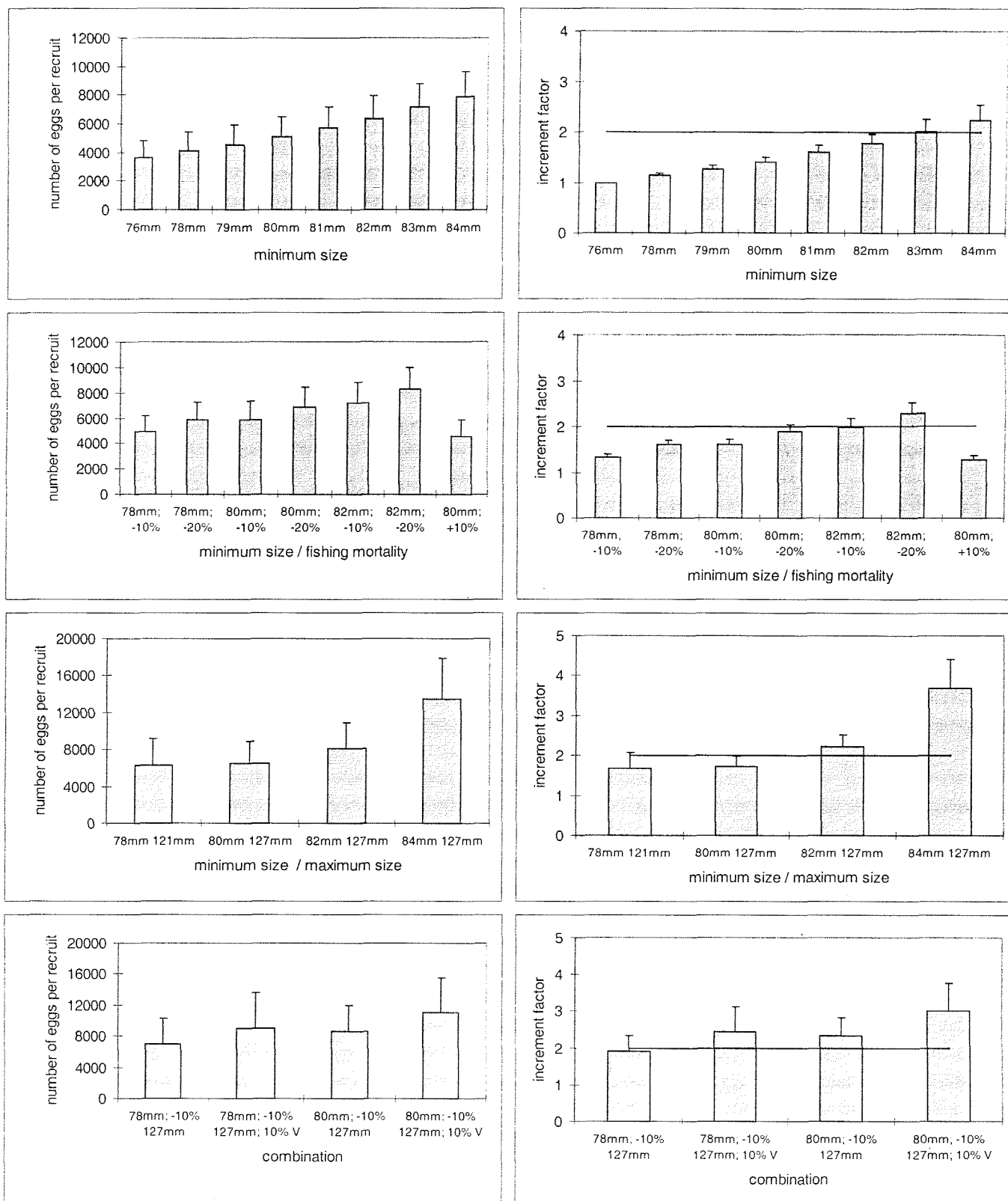
Figure 2. Egg production per recruit (mean and standard deviation) and production increment factor compared with 1996 for the southern part of the Magdalen Islands.
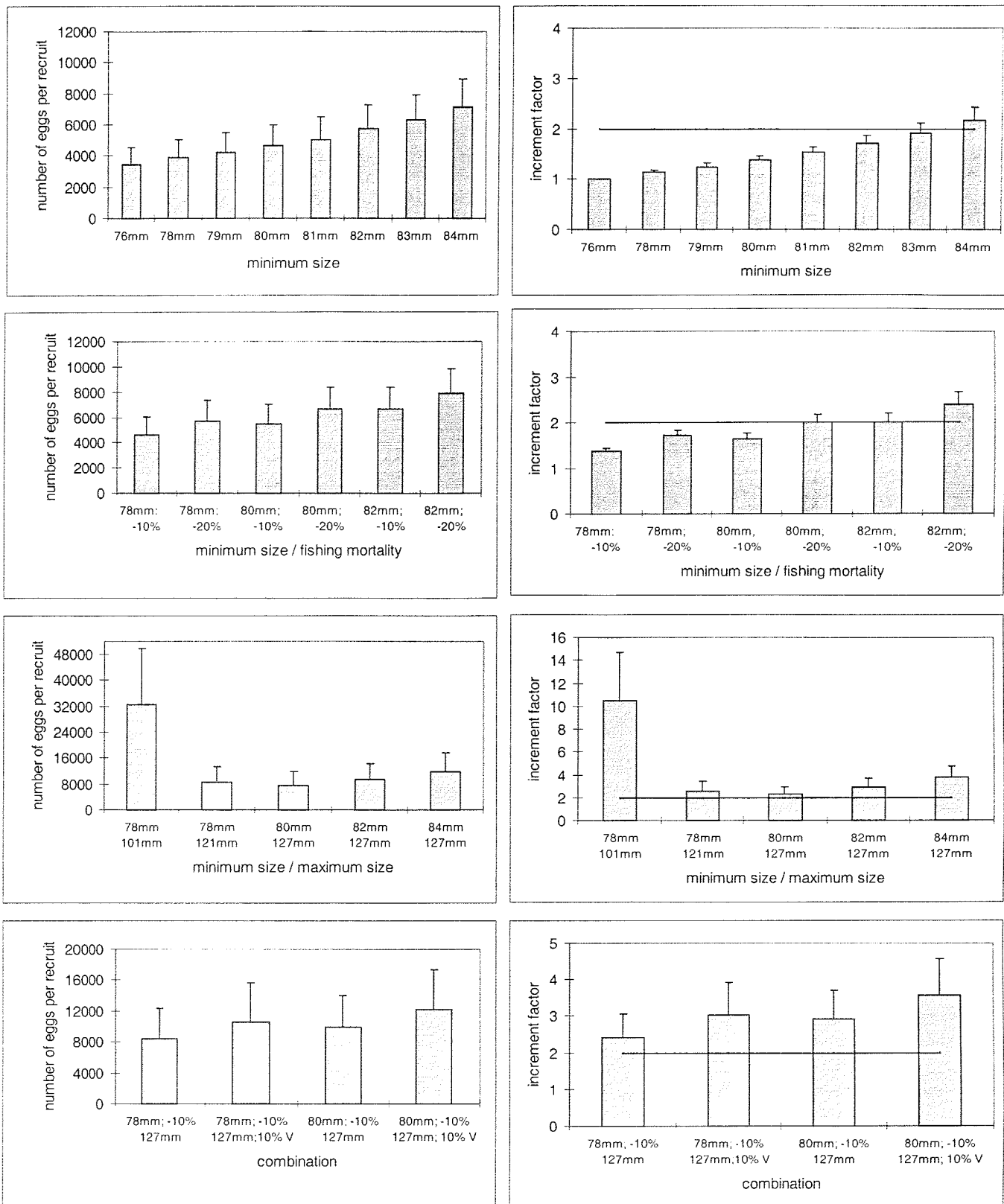
18

Figure 3. Egg production per recruit (mean and standard deviation) and production increment factor compared with 1996 for the northern portion of the Magdalen Islands.
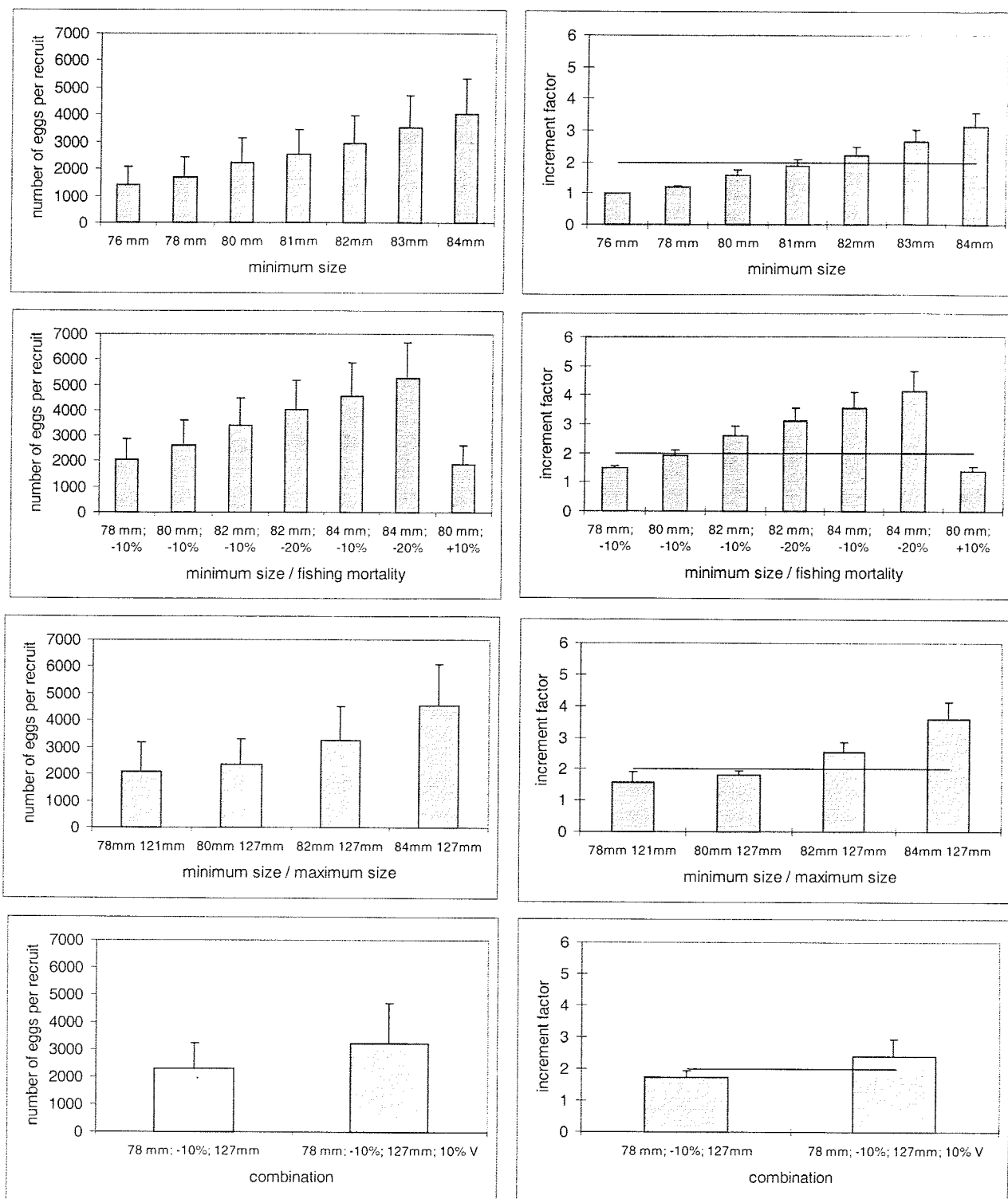
19

Figure 4. Egg production per recruit (mean and standard deviation) and production increment factor compared with 1996 for the Gaspé Peninsula.

3.2. MANAGEMENT RISK

For some years now, there has been growing interest in quantifying the uncertainties involved in fisheries management and incorporating them into recommendations on this subject. In the present study, the uncertainties in defining the parameters for the various biological variables in the lobster's life cycle have been taken into account so that we have been able to generate a range of possible EPR values for each of the management scenarios examined. By plotting the cumulative frequency distribution for the 100 values obtained in the simulation, we can see what percentage of values falls above or below a given target. In the present case, the target is to double the EPR under a given management scenario compared with the EPR before that scenario was implemented—or in other words, to achieve an increment factor of 2.0. Hence it is interesting to see for each scenario, what percentage of values for the increment factor falls below 2.0. This percentage can be interpreted as the risk of not achieving the objective of doubling EPR. When a mean value, such as those considered in the preceding section, equals 2.0, there is in fact about a 50% risk of not achieving the management objective.

The results obtained for the southern Magdalen Islands show that the probability of doubling EPR by raising the minimum size from 76 mm to 81 mm is zero (Figure 5). The risk of not achieving the management objective is therefore 100%. Raising the minimum size to 82 mm reduces the risk to 86%, and raising the size to 84 mm reduces the risk to only 24%. Combining a minimum size of 82 mm with 10% and 20% reductions in fishing mortality results in management risks of 54% and 12%, respectively. Measures to protect large females (such as total protection for female "jumbo" lobster, measuring over 127 mm) and V-notching 10% of berried females captured also reduce the risk of not achieving the management objective. If these last two measures are combined with a minimum size of 80 mm and a 10% reduction in fishing mortality, the management risk becomes almost zero.

The situation in the northern Magdalen Islands is similar (Figure 6), except for management regimes that combine an increase in minimum legal size with a reduction in fishing mortality, a maximum legal size, and marking of berried females. As mentioned earlier, the lower exploitation rate in the northern part of these islands allows a higher proportion of females to reach a larger size, so measures to protect larger females provide greater benefits. The management risks are lower for these combinations. In the Gaspé, the results of the model show that the probability of doubling EPR simply by raising the minimum size from 76 mm to 80 mm is zero (Figure 7). The risk of not achieving the management objective is therefore 100% with these minimum legal sizes. But starting with a minimum legal size of 82 mm, the risk of not doubling EPR becomes very low. When this minimum size is combined with a 10% or 20% reduction in fishing mortality, or with a maximum size of 127 mm, the risk is zero. Marking 10% of the berried females captured, when added to the following measures – reducing fishing mortality by 10%, and enforcing a maximum legal size of 127 mm and a minimum legal size of 78 mm—greatly reduces the management risk, from 92% down to 25% (Figure 7).
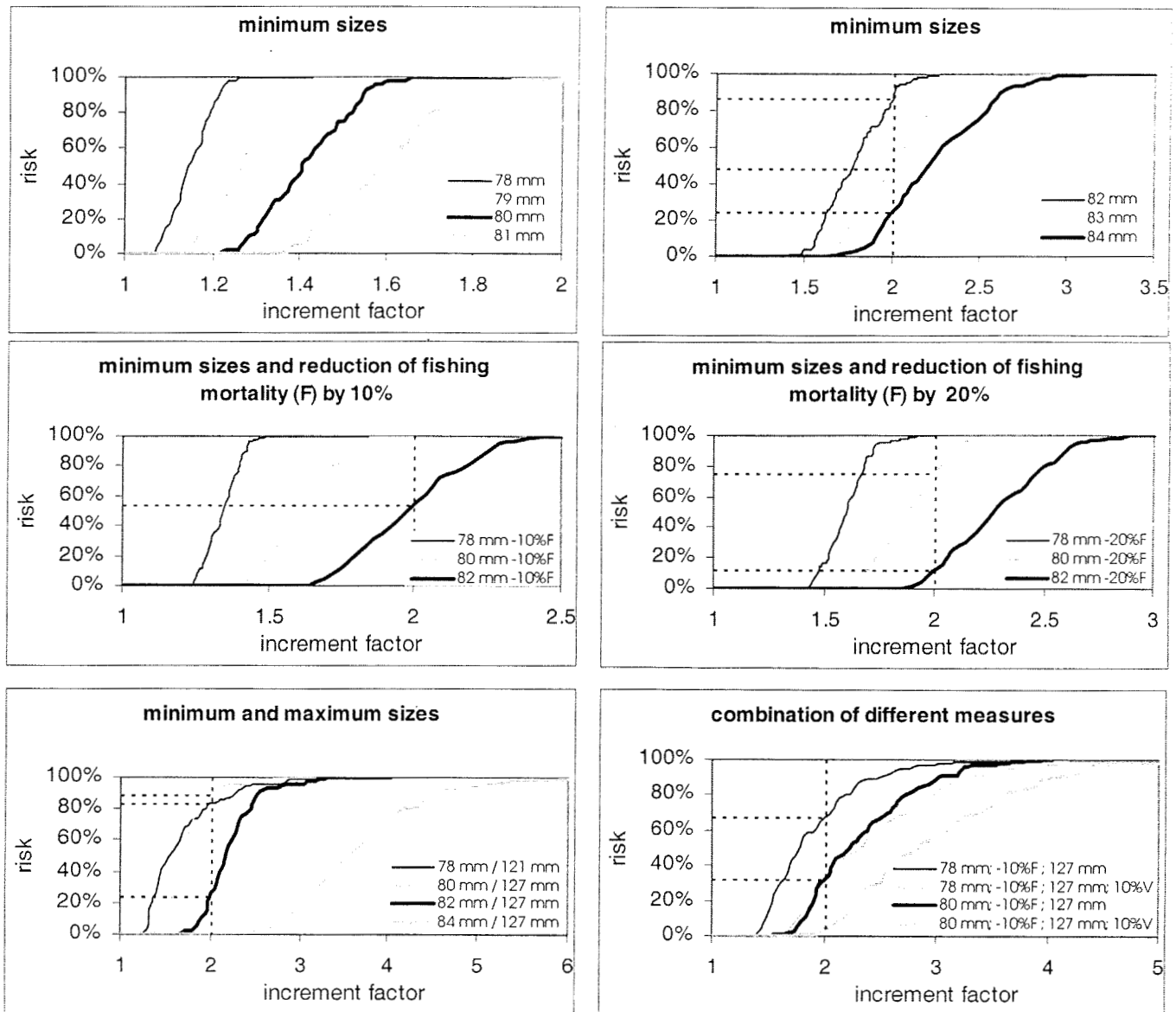
21

Figure 5. Cumulative frequency distribution of the 100 increment factor values obtained with the model, illustrating the risk of not achieving a doubling of EPR under the various fishery management scenarios tested for the southern portion of the Magdalen Islands.

Figure 6. Cumulative frequency distribution of the 100 increment factor values obtained with the model, illustrating the risk of not achieving a doubling of EPR under the various fishery management scenarios tested for the northern portion of the Magdalen Islands.
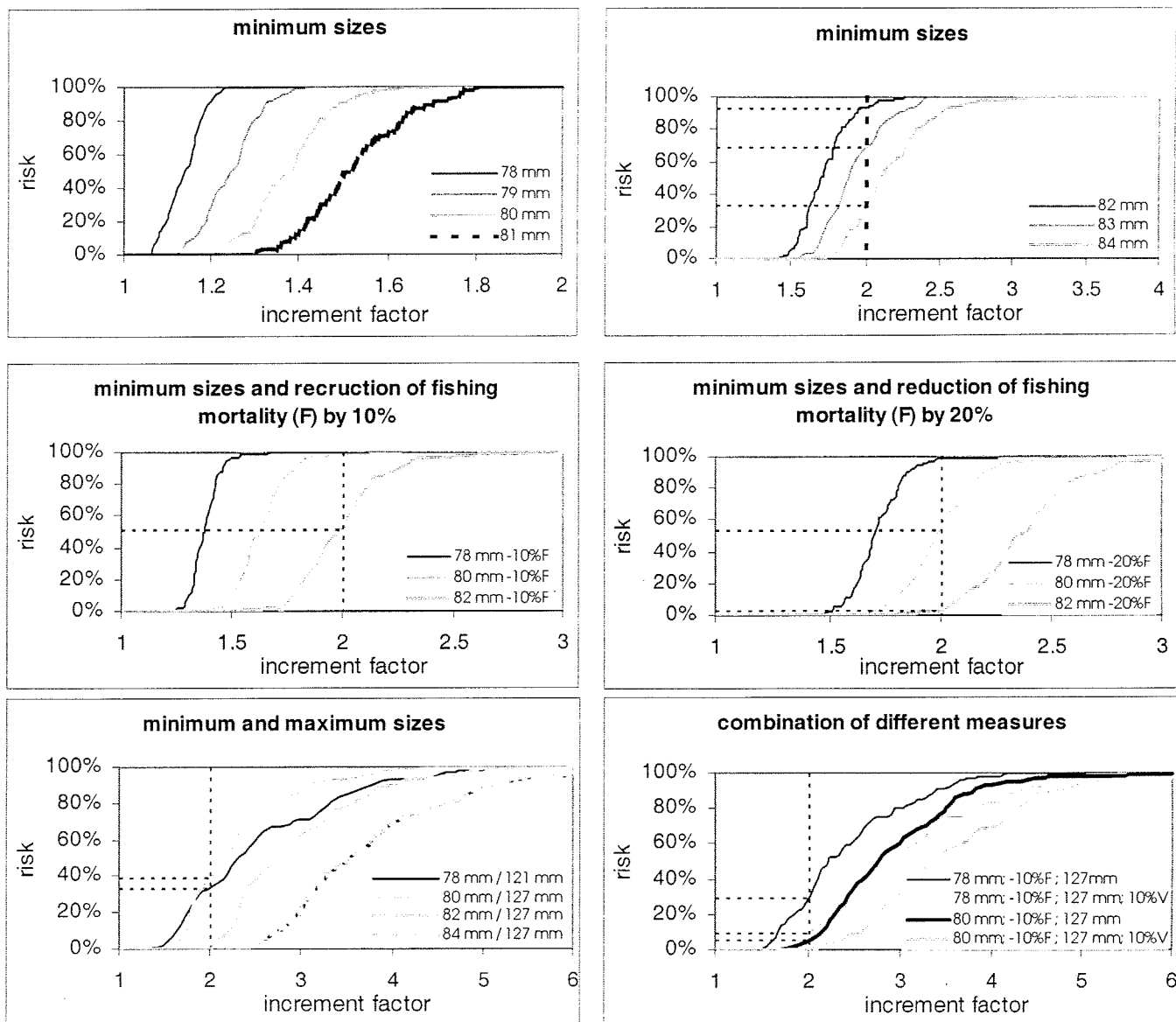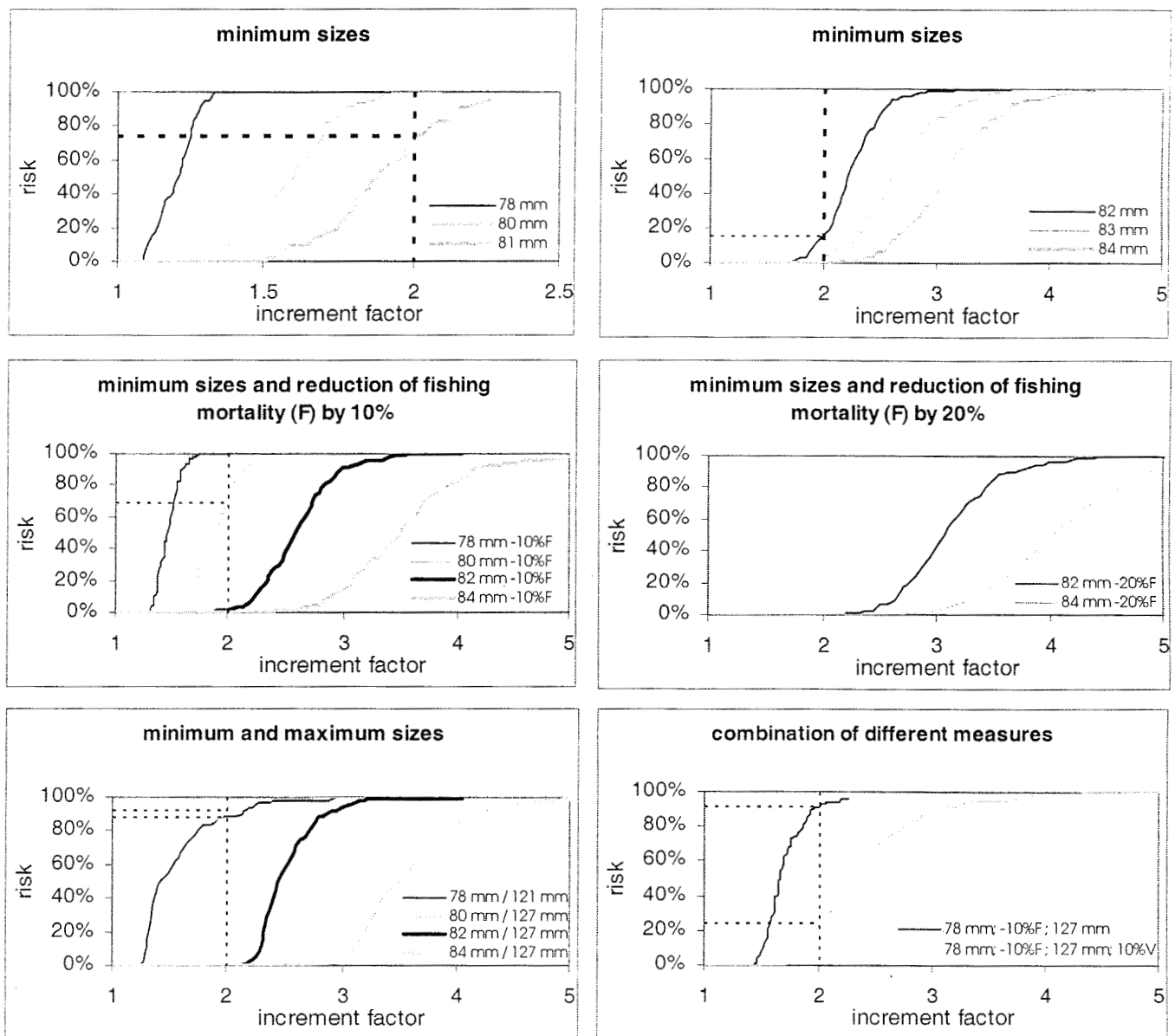
Figure 7. Cumulative frequency distribution of the 100 increment factor values obtained with the model, illustrating the risk of not achieving a doubling of EPR under the various fishery management scenarios tested for the Gaspé Peninsula.

24

4.0 DISCUSSION

The model for calculating EPR has been used to simulate the impact of a wide variety of management measures, applied both separately and in various combinations. Up to now however, in practice, preference has been given to just one of these measures: increasing the minimum legal size. In the Magdalen Islands, the minimum legal size has been increased gradually since 1997, by 1 mm per year. These small increases have gone almost unnoticed by the lobster fishers. A review of the catch composition of the 1996 landings data had shown that lobster measuring 76 to 77 mm accounted for about 4% of the catch in the southern part of the Magdalen Islands and only 2% in the northern part (Gendron and Savard 2000). The situation for the Gaspé was different. There, the policy applied was to increase the minimum legal size by 2 mm every two years. Thus, in 1997, the minimum size was increased from 76 mm to 78 mm. At that time, the average proportion of landings composed of lobster measuring 76 to 78 mm had been calculated at 13.5% (Gendron and Savard 2000). This high percentage is due to the very high exploitation rate for lobster in the Gaspé, which results in a population composed almost exclusively of a single molt class. Landings in the Gaspé were much lower in 1997 than in 1996, partly because of the increase in the minimum legal size. However, other factors, such as changes in the abundance and the catchability of the resource, may also have contributed to this decline in landings (DFO 1998). Nevertheless, the fishers agreed not to increase the minimum size by more than 1 mm per year.

When a program to increase minimum legal size is implemented, the losses in landings that it causes in the first year are offset in the following year, when the lobster thrown back in the first year become available to the fishery. Though their numbers are slightly reduced by natural mortality (estimated at about 15% annually), the lobster are larger, because they have had the chance to molt one more time before being caught. This additional molt results in a weight gain of about 45%. Thus, if recruitment is held constant, increasing the minimum legal size can be expected to reduce the number of lobster taken, but to increase the total weight of the catch. This is true for males and for immature females. For mature females, increasing the minimum legal size will allow a higher proportion of these lobster to spawn before being caught. The number of berried females in the population should increase, and hence the catch of unberried females will decrease. The females that are not accessible to the fishery because they are berried will become accessible the following year, when they have completed their reproductive cycle. They will then be larger because they will have had the chance to go through an additional molt. For these females, the gain in weight may just offset the losses in number (because of the natural mortality over 2 years). Overall, the weight of the catches can nevertheless be expected to increase for a certain time—as long as the minimum size remains below the critical level at which the weight gains in a population exceed the losses in numbers.

Increasing the minimum legal size will reduce the fishing pressure on immature lobster and encourage egg production by primiparous females (those spawning for the first time). Studies now in progress show that even more benefits could be obtained from increasing egg production among multiparous females (those spawning for at least the

second time), because the larvae from larger females are themselves larger and weigh more when they hatch (Plante *et al.* 2001). It has also been observed that larger, heavier larvae grow more rapidly and are larger when they settle on the seabed (James-Pirri *et al.* 1998). All of these characteristics may indicate a better potential for survival.

So far, no steps have been taken to reduce fishing effort and exploitation rates. Measures such as increasing the minimum legal size or introducing a maximum legal size do not necessarily reduce the exploitation rate because this rate is based on the harvestable portion of the population. On the contrary, applying such measures could even increase the exploitation rate if it resulted in a decrease in the harvestable biomass. If fishing effort remains unchanged, and the same level of fishing effort is applied to a smaller biomass, the exploitation rate increases.

To reduce fishing mortality, it is necessary to reduce fishing effort, by reducing the number of licences, reducing the number of traps, or shortening the fishing season. Theoretically, in order to reduce fishing mortality by 10%, fishing effort has to be reduced by the same percentage. In practice, however, a given percentage reduction in fishing effort might result in a smaller percentage reduction in fishing mortality because the fishers can partially offset the reduction in effort by increasing their efficiency. Also, the effectiveness of shortening the fishing season depends on the lobster's seasonal catchability pattern. This pattern depends on many factors, in particular the environmental conditions that affect the lobsters' vulnerability to traps (Miller 1990). In the Magdalen Islands, lobster catchability has been found to peak at the start of the fishing season, but becomes much lower toward the end (L. Gendron, unpublished data). Thus, a greater reduction in fishing mortality would be achieved by opening the lobstering season one week later than by closing it one week earlier.

Until fishing effort is reduced, regardless of what the minimum legal size may be, the fishery will remain just as dependent on annual recruitment. Moreover, in the absence of enhanced measures to control fishing effort, this effort can be expected to grow as fishers increase their efficiency. The results of our EPR calculation model show that the expected benefits of increasing the minimum legal size are attenuated if the exploitation rate increases. A substantial reduction in fishing effort, or even control over catches, will eventually have to be considered to provide better protection for the resource. A reduction in the fishing mortality of the harvestable portion of the stock will enable more individuals to realize their full growth potential, which in turn will result in a population with several modes and more large individuals. Consequently, the fishery will become less dependent on annual recruitment and no longer target only the size classes newly recruited into the fishery. In addition, reducing the fishing pressure on unberried females will increase the number of large females in the population—the ones that may contribute the most to its overall reproductive success.

Doubling the EPR is an interim measure for improving the state of the lobster populations. It does not guarantee that the EPR levels thus achieved will suffice to prevent overexploitation of the stocks. This doubling will be easier to achieve in areas where egg production is currently low than in those where it is already high, so the

benefits may be smaller in those areas that need them the most. In fact, in some areas, the maintaining of demographically sound populations, in which the immature lobster are not harvested, would cause EPR to triple or quadruple.

For some years now, there has been growing interest in quantifying the uncertainties involved in fisheries management and incorporating them into recommendations on this subject. The question of how to combine the risk-acceptance levels of stakeholders who have diverging interests and different attitudes toward risk remains open to discussion. Nevertheless, quantifying the uncertainties also allows an objective assessment of the reliability of the estimates and thus prevents disputes from arising out of subjective assessments of these uncertainties. Probability curves are a useful tool for expressing uncertainty because they provide managers with a direct illustration of the risks associated with their decisions.

There are, however, still some uncertainties that have not yet been incorporated into the model. These uncertainties are associated with the response of lobster populations to the implementation of new conservation measures. The models currently used to calculate EPR assume that there is no compensatory effect in the dynamics of these populations and that implementing new management measures does not alter any aspect of the lobster's biology. It thus assumes that growth rate, sexual maturity, natural mortality, and fecundity do not depend on population density. But any significant conservation effort will obviously increase the populations' density. In light of past studies of other East Coast stocks, the uncertainty created by the absence of this effect in our model is quite real. These studies have found that the shape of the stock-recruitment curve for lobster (Fogarty and Idoine 1986, Ennis and Fogarty 1997) suggests the existence of compensatory mechanisms that depend on population density over the course of the lobster's life cycle (Fogarty and Idoine 1986). If the Magdalen Islands and Gaspé Peninsula stocks also exhibit such mechanisms, then the measures designed to conserve these stocks could have less of an impact on EPR than our model predicts.

Another issue is that measures to encourage spawning by females will afford them greater protection and could result in an asymmetry between the exploitation rates for males and females. As a result, the sex ratio would be thrown out of balance, in favour of females, and the number of large males would be further reduced. Increasing the scarcity of males, and especially of the larger ones, could lead to a problem of sperm limitation, because a small male might not provide enough sperm to fertilize all the eggs of a large female; this phenomenon has been observed previously in rock lobster (*Jasus edwardsii*) and spiny lobster (*Panulirus argus*) (MacDiarmid and Butler IV 1999). Research is currently being conducted on the American lobster's copulatory system to determine whether this species also shows a potential for sperm limitation (B. Sainte-Marie, Maurice Lamontagne Institute, Mont-Joli, Québec, personal communication).

EPR models do not tell us what level of egg production is necessary to maintain populations. However, increasing egg production should ensure that there are always at least enough eggs. When environmental conditions are favourable, higher egg production can result in better recruitment. Most importantly, in bad years, higher egg production will

reduce the risk of the stocks' collapsing. Doubling EPR will not necessarily achieve the levels of egg production that will maintain the stocks despite environmental changes. These levels may vary over time and space in relation to variations in the environmental characteristics that affect the various phases of the lobster's life cycle, such as the survival of the larvae and their success in settling on the seabed.

The present study constitutes a theoretical approach to the problem of egg production in lobster populations. It is essential to implement a process for verifying the effectiveness of the measures recommended for increasing EPR. To perform this verification, natural populations must be monitored, and indices must be developed for determining whether, practically and not just theoretically, we are actually achieving progress toward our conservation objectives.

5.0 ACKNOWLEDGEMENTS

6.0 REFERENCES

Aiken, D. E. and S. Waddy. 1982. Cement gland development, ovary maturation and reproductive cycles in the American lobster *Homarus americanus*. J. Crustacean Biol. 2: 315-327.

Aiken, D. E. and S. Waddy. 1986. Multiple fertilization and consecutive spawning in large American lobsters, *Homarus americanus*. Can. J. Fish. Aquat. Sci. 43: 2291-2294.

Anon. 1977. Report of the working group on *Homarus* stocks. Int. Counc. Explor. Sea. Council Meeting 1997/K:11.

Anon. 1995. A conservation framework for Atlantic lobster. Report of the Fisheries Resource Conservation Council. FRCC95. R.1, Nov. 1995. 49 p.

Attard, J. 1985. Fécondité individuelle et production d'œufs par recrue du homard (*Homarus americanus*) sur les côtes nord et sud des Îles-de-la-Madeleine. Rapp. tech. can. sci. halieut. aquat. 1417 : vi + 14 p.

Caddy, J. F. 1977. Approaches to a simplified yield-per-recruit model for Crustacea, with particular reference to the American lobster, *Homarus americanus*. Fish. Mar. Serv. Manuscr. Rep. 1445. 14 p.

Caddy, J. F. 1979. Notes on a more generalized yield-per-recruit analysis for crustaceans, using size-specific inputs. Fish. Mar. Serv. Manuscr. Rep. 1525. 40 p.

Campbell, A. 1985. Application of a yield and egg-per-recruit model to the lobster fishery in the Bay of Fundy. N. Amer. J. Fish. Manage. 5 : 91-104.

Campbell, A. and D. G. Robinson. 1983. Reproductive potential of three American lobster (*Homarus americanus*) stocks in the Canadian Maritimes. Can. J. Fish. Aquat. Sci. 40 : 1958-1967.

DFO. 1998. Lobster of the inshore waters of Québec. DFO Sciences. Stock Status Report C4-05. 12 p.

Dubé, P. 1985. Croissance du homard (*Homarus americanus*) dans les parties nord et sud des Îles-de-la-Madeleine. CAFSAC Res. Doc. 85/97. 39 p.

Dubé, P. and P. Grondin. 1985. Maturité sexuelle du homard (*Homarus americanus*) femelle aux Îles-de-la-Madeleine. CAFSAC Res. Doc. 85/85. 37 p.

Ennis, G. P. 1985. An assessment of the impact of size limit and exploitation rate changes on egg production in a Newfoundland lobster population. N. Amer. J. Fish. Manage. 5 : 86-90.

Ennis, G. P. 1991. Annual variation in egg production in a Newfoundland population of the American lobster, *Homarus americanus. In* : Crustacean Egg Production. A. Wenner and A. Kuris (eds). pp. 291-299. A. Balkema : Rotterdam/Brookfield.

Ennis, G. P. and P. W. Collins. 1983. A computer program to assess egg production per recruit in a lobster (*Homarus americanus*) population. Can. Tech. Rep. Fish. Aquat. Sci. 1198 : iv + 15 p.

Ennis, G. P. and M. J. Fogarty. 1997. Recruitment overfishing reference point for the American lobster, *Homarus americanus*. Mar. Freshwat. Res. 48 : 1029-1034.

Fogarty, M. J. 1995. Populations, fisheries and management. *In* : J. R. Factor (ed.). The biology of the lobster *Homarus americanus*, p. 111-137. New York, Academic Press.

Fogarty, M. J. and J. S. Idoine. 1986. Recruitment dynamics in an American lobster (*Homarus americanus*) population. Can. J. Fish. Aquat. Sci. 43 : 2368-2376.

Fogarty, M. J. and J. S. Idoine, 1988. Application of a yield and egg per recruit model based on size to an offshore American lobster population. Tr. Amer. Fish. Soc. 117 : 350-362.

Gendron, L. and G. Savard. 2000. État des stocks de homard des eaux côtières du Québec en 2000 et suivi des impacts de l'augmentation de la taille minimale de capture. CSAS Res. Doc. 2000/15. 73p.

James-Pirri, M.-J., J. S. Cobb and R. A. Wahle. 1998. Influence of settlement time and size on postsettlement growth in the American lobster (*Homarus americanus*). Can. J. Fish. Aquat. Sci. 55 : 2436-2446.

MacDiarmid, A. B. and M. J. Butler IV. 1999. Sperm economy and limitation in spiny lobsters. Behav. Ecol. Sociobiol. 46 : 14-24.

Mace, P. M. and M. P. Sissenwine 1993. How much spawning per recruit is enough ? Can. Spec. Publ. Fish. Aquat. Sci. 120 : 101-118.

Miller, R. J. 1990. Effectiveness of crab and lobster traps. Can. J. Fish. Aquat. Sci. 47 : 1228-1251.

Miller, R. J., D. S. Moore, and J. D. Pringle. 1987. Overview of the inshore lobster resources in the Scotia-Fundy region. Canadian Atlantic Fisheries Scientific Advisory Committee. Res. doc. 87/85. 20 p.

Munro, J. and J.-C. Therriault. 1983. Migrations saisonnières du homard (*Homarus americanus*) entre la côte et les Îles-de-la-Madeleine. Can. J. Fish. Aquat. Sci. 40: 905-918.

Pezzack, D. S. and J. J. Maguire 1995. Preliminary examination of egg per recruit estimates in the Canadian lobster fishery. DFO Atl. Fish. Res. Doc. 95/92. 23 p.

Plante, F., P. Ouellet and J.-C. Brêthes. 2001. Maternal size influence on larvae size and growth performance in lobster (*Homarus americanus*). *In :* Tremblay, M.J. and B. Sainte-Marie (eds.) Canadian Lobster Atlantic Wide Studies (CLAWS) Symposium : Abstracts and Proceedings Summary. Can Tech. Rep. Fish. Aquat. Sci. 2328. p. 101.

Tremblay, M. J., M. D. Eagles, and G. A. P. Black. 1998. Movements of the lobster, *Homarus americanus*, off northeastern Cape Breton Island, with notes on lobster catchability. Can. Tech. Rep. Fish. Aquat. Sci. 2220 : iv + 32 p.