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The Lobster (*Homarus gammarus* L.) Fishery: Analysis of the resource in 2004-2005

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Fisheries Resource Series

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Fisheries Resource Series

Foreword

Since its inception, Bord Iascaigh Mhara (BIM) has regularly reported on the work it undertakes as the agency responsible for the sustainable development of the Irish seafood industry at sea and ashore. The ***Resource Records Series,*** which ran for many years, is a notable example of this and admirably fulfilled the Board's remit to print and circulate bulletins, periodicals, pamphlets, and other literature, as the Board deemed advisable, in the interests of the sea-fishing industry. Building on this tradition, whilst also recognising the challenges and opportunities that face the sea-fishing industry today, the ***Fisheries Resource Series,*** produced by the Fisheries Development Division of BIM, is intended as a professional, broadly based, peer reviewed publication.

The content of the *Fisheries Resource Series* reflects a synergy of resources and expertise between BIM and the Irish fishing industry, national academic institutions, international partners, other state and semi-state agencies and provides a vehicle for the dissemination of the results of the Board's innovative, technical and applied research and development activities.

Technical and scientific contributions to the *Fisheries Resource Series* are invited, from internal and external sources, which primarily promote the sustainable development of the Irish sea fisheries sector and, in addition, support its diversification in the coastal regions so as to enhance the contribution of the sector to employment, income and welfare both regionally and nationally.

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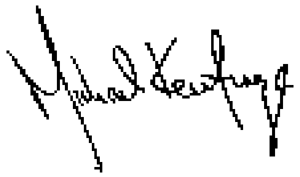

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The Lobster (*Homarus gammarus L.*) Fishery: Analysis of the Resource in 2004/2005

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This document was reviewed and approved by the committee listed below.

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Preface

The Management Framework for Shellfisheries was established in 2005 to oversee the sustainable development and management of the shellfisheries sector in Ireland. The Framework is a co-operative management model between state and industry centred around four Species Advisory Groups (SAGs). In June of 2005 the Lobster Advisory Group requested that a report on the status of lobster stocks and fisheries in Ireland be prepared prior to development of a Management Plan for the fishery. This report has been compiled for the Lobster Advisory Group and its constituent Local Advisory Committees (LACs) and outlines the current status of lobster stocks and fisheries in Ireland at the end of the 2004 fishing season. The report is a working document, which will be developed periodically as the appropriate data and assessment methods become available. It specifically points to areas where data and research programmes are required in order to do this. The report makes specific conclusions relevant to management in order to assist the Lobster Advisory Group to develop a management plan for the fishery that is based on the best *available* scientific advice.

Bord Iascaigh Mhara
Irish Sea Fisheries Board

NATIONAL DEVELOPMENT PLAN

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Summary

1. The true stock structure of lobster in Ireland is unknown. However, for the purpose of issuing management advice the lobster fisheries were assessed separately in four coastal regions of Ireland.
2. Landings in all regions in 2004 were higher than at any time in the past resulting in a national total of 853 tonnes.
3. Fishing effort is known to have doubled on the south east coast over the period 1995-2005. Information on trends in effort elsewhere is poor but effort per vessel is known to have increased.
4. There is significant interaction between lobster and crab fisheries on all coasts. By-catch rates of lobster in crab fisheries is typically 20-25% of the targeted lobster catch rate.
5. Landings per unit effort (LPUE), standardised for season and soak time effects, declined in the southeast and southwest fisheries from 2002-2004. LPUE increased in County Clare. No catch rate data are available for the lobster fishery in the north west.
6. Catch rate of pre-recruit (undersized) lobster declined in the south east and south west but increased in Clare over the period 2002-2004.
7. Length cohort analysis indicated that the annual rate of fishing mortality (F) was between 0.4-0.6, depending on assumptions relating to natural mortality and growth. F in the period 2002-2004 was lower than during the 1990s although this trend is uncertain given the assumptions of the assessment model.
8. Fishing mortality was lowest in the north west and highest in Galway on the mid west coast.
9. Lobsters are fully recruited to the fishery at 95mm carapace length (CL) or one moult above the minimum landings (MLS) size of 87mm.
10. The mean size at maturity is 95mm CL varying from 93-96mm regionally.
11. Relative egg production per recruit ($R_{E/R}$), or the egg production relative to that expected in the absence of a fishery, was less than 10% in all areas. The limit reference point, or the lower safe limit for egg per recruit, is defined at 10%. Regional estimates of ($R_{E/R}$) did not include egg production by v-notched lobsters.
12. V-notching of lobsters has been undertaken in some coastal regions since 1995 and continues in most areas.
13. Catch rates of v-notched lobsters was highest in Clare and lowest in the north west although the data in the north west were poor.
14. Because of natural mortality and repair of the v-notch, the number of v-notched lobsters in the stock was estimated to be substantially lower than the number released.
15. The catch rate of v-notched lobsters was highly correlated with the mortality/loss discounted numbers of v-notched lobsters estimated to be in the stock. This suggests that the catch rates are an effective indicator of the abundance of lobsters.
16. The proportion of the legal sized stock that was v-notched, and estimated from the ratio of catch rate of legal lobsters to the catch rate of v-notched lobsters, varied by region. In the southeast it was 10-15% while in local areas of Clare it was 25%.
17. Very substantial reductions in fishing effort are required to achieve the 10% lower limit for egg production under current technical measures.
18. If the Minimum Landing Size (MLS) was increased to 95mm CL, an ($R_{E/R}$) of 10% would be achieved by a 10% reduction in effort.
19. An ($R_{E/R}$) of 10% would be achieved in most areas by introduction of a maximum size between 120-130mm CL.
20. If the MLS was increased to 95mm CL and a maximum size of 120mm was introduced, effort on the remaining legal lobsters, between 95-120mm, could increase.
21. Parallel optimisation of egg and yield per recruit reference points is not always feasible because of the particular growth and reproductive characteristics of the stock.

Introduction

Lobster (*Homarus gammarus*) fishing is an important economic activity in coastal fishing communities on the coast of Ireland. Over 850 tonnes are landed per annum with an approximate first sale value of €13m. Up to 1400 vessels (vessels under 12m in length on the Irish Register of Sea Fishing vessels in 2004) participate in the fishery between April and October on all coasts and lobster fishing is the mainstay of the artisanal small scale coastal fisheries sector. It is both a high value (€14-28 per kg) and a reasonably high volume species for the Irish industry and it is critical to the future viability of the inshore fleet that lobster stocks are adequately conserved. The fishery supports ancillary industries such as gear manufacturers and bait suppliers and a significant number of merchants and haulage companies who export the live product to the European continent. The market price is highly seasonal and highest from December to April due to constraints in supply at that time and an increase in demand especially in December. The French wholesale price is at a minimum during the production season in Ireland (May-Sept).

This report is the first to compile all available data, relevant to assessment of the lobster resource and the fishery, in Ireland. The objective is to provide reliable information on the status of the stocks and fisheries that will assist in the sustainable development of the fishery. In this context the report is produced for the national Lobster Management Advisory Group, which is part of a co-management advisory framework that provides recommendations to government (The Department of Communications, Marine and Natural Resources) on matters relevant to the management of shellfisheries. Lobster stocks have not been the subject of any particular management regime to date, other than minimum size and v-notch technical conservation measures. Significant investment has been allocated to the v-notch technical measure and during the 1990s there were commercial scale releases of hatchery reared juvenile lobsters in an attempt to increase stock levels. These and other measures were introduced in the absence of stock assessment or management advice.

In this report catch rate data are presented for each stock/region where available. In some regions, such as the south east, these data go back to 1995 but for other areas the series extends back only to 2002. The regional breakdown of the data may or may not reflect the stock structure. A length cohort model is used to estimate fishing mortality rates from data collected on the size composition of the landings. Using data on growth, maturity and fecundity this analysis is extended to yield (Y/R) and egg per recruit (E/R) assessment using current fishery selection patterns and to model the effect of various options for effort control and/or change in technical conservation measures in relation to potential limit and target reference points for the fishery. Data on the v-notch programme and its possible impact on egg production are presented. It has not been fully possible to assess the effect of this measure on population egg production or egg per recruit. This is, however, identified as a priority area for modelling and will be undertaken in 2006-2007.

The Biology of Lobsters

1. Commercial distribution

Lobsters are distributed throughout coastal areas of the northeast Atlantic from mid-Norway to the North Sea, south to the north African coast and into the eastern Mediterranean. However, their 'commercial range' is currently limited to northern France, Britain and Ireland. In Norway and Shetland stocks have declined significantly or collapsed. In the Mediterranean and off the Iberian peninsula, north to the Bay of Biscay, lobsters are rare and generally well below commercial levels. Their stronghold, therefore, is a relatively small proportion of their previous commercial distribution.

2. Biology

Lobsters live for at least 20 years and possibly to 50 years of age. Lobsters at the minimum landing size may vary in age from 4-8 years. Growth rate is variable and the growth increment at each moult generally increases with lobster size but, typically, commercial sized lobsters increase in CL by 8-10mm at each moult and moulting may occur each year or more probably, and especially in the case of larger lobsters, moulting may occur on alternate years or even less frequently. Adult lobsters have few natural predators, octopus being one, and most of natural mortality occurs during moulting when the shell is soft and cannibalism may occur. However, natural mortality rates are probably low. Lobsters may produce eggs every year but again this is size related and depends on the frequency of moulting. Eggs are carried externally from September to April or May when hatching occurs. Moulting cannot occur when the female lobster is carrying eggs as the eggs will be lost. The growth and reproductive cycles are, therefore, antagonistic and the ability to complete both cycles in one year depends on timing and a sufficient energy budget.

Lobster larvae swim freely in the water column for about 30-40 days depending on temperature. Larvae occur mainly close to the sea surface where they can be preyed upon by seabirds and fish, such as garfish, which live at the sea surface. They are the largest crustacean larvae in temperate waters and have a strong swimming ability. They descend to the seabed after they have developed to stage IV and can actively seek the appropriate seabed habitat. The biology of juvenile lobster is largely unknown but they are thought to inhabit cobble and stony ground in shallow water. Juvenile or adult lobsters do not undertake any significant migrations and juveniles in the first 3-4 years of life may be particularly cryptic and sedentary.

3. Biology and Management

The biology of lobsters has implications for management of the fisheries. The time between larval settlement and recruitment to the fishery is 4-8 years. New fisheries management measures designed to increase recruitment will, therefore, take 4-8 years to impact on the stock and the fishery. As there are no extensive migrations, and larvae may be retained locally, stocks may be local in structure. Local management measures are likely to have greatest impact locally but also 'downstream' to a distance depending on larval dispersal rates. Relatively high growth rates and low natural mortality suggest that any short term losses brought about through new management measures will quickly return benefit at least in terms of yield and egg production if not absolute recruitment. No relationship between spawning stock size and recruitment has been demonstrated and environmental conditions during the larval phase are likely to have a strong bearing on recruitment to the stock in any given year. Nevertheless, given the highly developed larvae and the relatively low fecundity, increases in spawning biomass would be expected to have a beneficial effect on recruitment to the stock provided that there are no density dependent bottlenecks during early life history. Density dependence in larval or juvenile survival is highly unlikely to be the case today given the low levels of egg production in the stocks. Patterns of recruitment to the fishery will be smoothed functions of the more variable recruitment to the stock because the former reflects the average recruitment strength of a number of year classes.

Lobster Fishing in Ireland: The Historical Context

Browne *et al*. (2001) recently reviewed the history of lobster fishing in Ireland. This provides a useful historical context for the management of lobsters today and points to the potential benefit of better management and the possible limits of that potential.

In 1876 the number of boats fishing lobsters was over 5000, crewed by more than 23000 fishermen. Nineteen of 62 locations surveyed at that time reported diminishing catches. From 1900-1912 landings rose from 128 to 228 tonnes. By 1927 this had increased to 430 tonnes. By the early 1940s catch had declined to 135 tonnes. Effort appeared to be stable from 1947-1967 and in 1959 landings peaked at 350 tonnes. A dramatic decline of 44% followed until 1963. Catch rates in the southeast fishery in 1959 were about 30 lobsters per 100 traps. This declined somewhat during the 1960s. This was the only information on catch rates that existed in Ireland until 1995 when a voluntary logbook scheme was initiated by the South Wexford Lobster Co-operative.

Post 1990 landings were higher than at any time previously and as reported below in 2004, the most recent year for which data are available, landings were the highest on record at 853 tonnes.

Management Measures

Lobsters are currently managed in Ireland through four points of legislation

1. A polyvalent fishing licence or a pot fishing licence must be held to enter the commercial lobster fishery
2. There is a minimum landing size of 87mm CL. This legislation is transposed from EU legislation (2001) and is the absolute minimum size used throughout Europe. Prior to 2001 the MLS was 85mm
3. It is illegal to land lobsters with any visible damage on their tails ('mutilated tails'). This is to protect v-notched lobsters. This legislation was introduced in 1995.
4. Lobsters cannot be captured in either the commercial or recreational fishery by SCUBA.

Lobsters can be captured in the recreational fishery without licence. This catch cannot be sold commercially.

Research and Monitoring Activity

Ireland has had a poor record of research on lobster stocks. Gibson (1959, 1961) published a limited amount of information on stocks off the southeast coast in the early 1960s. No new research, directly relevant to stock assessment and monitoring, was undertaken between 1970-1995 when work began with the South Wexford Lobster Co-operative to evaluate the impact of the v-notch programme in the Wexford fishery (Tully 2001). In the early 1990s emphasises was on hatchery production and a significant commercial scale hatchery was opened at Carna in Co. Galway and a smaller scale hatchery was operated by the South Wexford Co-op (Browne 2004). Research on the early life history of lobster was undertaken in 1996-1998 and a study of the genetic structure of stocks was completed in the year 2000.

Trinity College Dublin (TCD) and Taighde Mara Teo. (TMT) completed a significant monitoring programme, directly relevant to assessment of the resource, in 1998 and 1999 (Tully *et al*. 2001). The first estimates of size at maturity and fecundity were obtained during this project. The size distribution of the landings was also sampled over two years. No work was undertaken in 2000-2001. The BIM voluntary Fishing Activity Record (FAR) scheme was initiated in 2002 and a new v-notch programme was also launched in that year.

In 2003 and 2004 tagging programmes were undertaken as part of the v-notch release project. This was initiated in a number of areas but particularly in County Clare where a proportion of the fleet returned valuable information on size increase at moult and the reproductive status of recaptured lobsters. This continued in 2005 and 2006. Size sampling of the landings was re-initiated in 2005 in the north west and west. This report synthesises all of the data that has been generated between 1995-2005 and is a base from which future research and monitoring programmes can be developed.

Data sources

1. Landings

Data on lobster landings are recorded for each port by the Department of Communications Marine and Natural Resources (DCMNR). Generally vessels fishing for lobsters, most of which are under 10m in length, do not maintain official landings records. It is mandatory for vessels greater than 10m in length to complete an EU logbook. Vessels registered in the UK or other EU member states and fishing in Irish waters must also report daily landings.

The majority of data on lobster landings are compiled, by the DCMNR, from information supplied by merchants on volumes of lobster purchased annually.

2. Fishing effort

Data on the number of boats active in the fishery and the number of pots were compiled by interviewing skippers known to be active in the fishery. This work was undertaken in specific regions and does not represent a census of effort in the fishery nationally. In some cases it was possible to show trends in fishing effort over a number of years. In most cases the data, when available, are snapshots in time and are incomplete. Although it is possible to obtain effort data from the relationship between catch and CPUE the catch data may not be sufficiently reliable to do this.

3. Catch rates

Catch rate data were obtained from BIM's voluntary Fishing Activity Records (FAR) programme. These data were collected between 2002-2004, with a longer time series of data going back to 1995 (from TCD) for Wexford and to 1998 in north Kerry (from TMT). The following data are recorded in the fishing activity records

- Date
- Location (place name, port)
- Pots hauled per day that were targeting lobster and the lobster catch
- Pots hauled targeting crab and the lobster by-catch
- Soak time (hours) of the gear used to target lobster and crab
- Undersized lobsters caught per day in gear targeted at lobster
- V-notched lobsters caught per day
- Lobsters v-notched at sea per day
- Tagged lobsters caught including the tag number, size and reproductive condition of the tagged lobster

The quantity of data and the number of vessels complying with the FAR programme is limited and varies regionally. There are also a number of continuity problems in the data mainly relating to changes in the vessels participating in the scheme and identification of those vessels. For instance the data from Wexford from 1995-2001 were given anonymously so it is not possible to trace vessels through years. This is also, to some extent, the case with the 2002-2004 data for other areas. The main consequence of this is that it is not possible to standardise catch rates for vessel effects between years. Secondly, prior to 2002 catch rate records did not distinguish between targeted lobster catch rates and by-catch rates of lobster in the crab fishery. Individual vessels can target both species on the same day and, although these two fisheries are mixed, individual strings of traps may be strategically targeted at one species or the other. It is not possible, therefore, to compare directly the absolute catch rates pre and post 2002, although the trends in catch rates can be compared. Distinguishing targeted and by-catch information is, however, important and the switch to this strategy in 2002 was necessary despite the loss of continuity in the time series.

4. Size distribution of the landings

The size distribution of the landings potentially contains information on total mortality and exploitation rate, which can be estimated by length based assessment methods.

Size distribution data were collected annually in south Wexford between 1995-2004 and in other areas in 1997-1998 and again in 2005. The data were collected mainly at the premises of lobster buyers, co-operatives and private companies, at various locations around the coast. Typically, monthly or more frequent samples were taken from consignments of lobsters delivered to a buyer from a coastal region or collected by a buyer from that region. A region in this case could be an entire county or counties or more usually a number of ports in the vicinity of the buyer. The samples taken were large, consisting of 100s of lobsters, and usually the entire stock of lobster collected by the buyer over a period of one week and collected/delivered to the premises in the previous 1-7 days was measured. The following data are available by month and region

- CL
- Weight
- Sex
- Stage of egg development

The sampling programme was opportunistic rather than strategic. In other words there was no control over how many vessels or ports were sampled or how frequently they were sampled. The samples are in effect pre-aggregated samples of an unknown number of boats from a general area/areas and there is, therefore, no strategy for sample aggregation. Given the profile of the industry, in which hundreds of vessels land small volumes daily, there would seem to be no alternative strategy to the current programme. The samples are nevertheless large and are regarded as unbiased and representative of the size structure of the commercial stock for a number of reasons: all lobsters over the MLS are landed so there is no selective grading at sea; it is unusual for a fisherman to grade the landings or to sell different size grades to different buyers. Changes in fishing locations during the sampling period could affect the size distributions; for instance increased fishing offshore or increased targeting of crab may increase the proportion of large lobsters landed. No significant changes have occurred and instances (mainly in the north west) where it does occasionally occur are clearly detectable.

5. V-notched lobsters

BIM, in collaboration with the lobster industry, have operated a lobster v-notch programme since 1994. The primary objective of the programme is to give legal protection to a proportion of the spawning stock over the MLS by marking the tail fan of the lobster with a v-notch. These v-notched lobsters contribute to egg production and are a separate component of the population not subject to fishing mortality. Evaluation of their contribution to egg production is an important assessment objective but data arising from this programme are also relevant to the assessment of lobster stocks generally. The following data were collected

- V-notch release data: Date, location, tag number, CL, weight, reproductive condition
- V-notch recapture data: Date, location, tag number, CL, reproductive condition, catch rates of v-notched lobsters during commercial fishing

Approximately 10000 lobsters were released annually between 2002 and 2004 under the current funding programme (2002-2007) and over 70000 lobsters were released nationally prior to 2002. Not all lobsters released were tagged but almost all were measured. Although this gives size distribution data it is biased because particular lobsters were selected for v-notching. In some areas these were usually berried females only. Lobsters presented for v-notching were, on average, larger than lobsters sampled from the landings.

6. Growth and reproduction

Data on size at maturity and fecundity by region was collected in 1998-1999 (Tully *et al*. 2001). The maturity indicators used in the study corresponded to those used to assess maturity in the American lobster *(Homarus americanus)*. These were

- Ovary wet weight
- Ovary colour indicating the stage of vitellogenesis
- Cement gland stage (indicating preparedness of the pleopods to receive eggs)
- Moult stage
- Egg size
- Evidence of previous spawning as shown by yellow colouration of the distal oviduct

Spawning frequency is largely unknown but some information was derived from the recapture of tagged lobsters in 2004-2006.

Very little information on growth is currently available. Moult increment and frequency data was collected from recaptured tagged lobsters mainly in Clare and Galway in 2004-2006.

Assessment Methods

1. General Linear Modelling of catch rate data

The use of catch per unit effort (CPUE) data to monitor fisheries assumes that changes in the index are proportional to changes in the actual abundance of the stock. This might not be the case for a multitude of reasons some of which can be controlled for by statistical methods. Bias in the catch rate data could be inherent in a time series of such data for the following non-exhaustive list of reasons

1. Vessel performance: Varying performance of a vessel over time due to crew or skipper effects.
2. Soak time: Changes in the frequency of hauling traps will affect CPUE as catch rate is related to the frequency at which gear is hauled at least for frequencies between 2 and 4 days.
3. Fishing area: Vessels may change the location of fishing due to depletion of traditional fishing grounds. Such depletion will not be detected in the annual aggregated catch rate index.
4. Fishing season: If CPUE varies seasonally and the proportion of effort in each part of the season changes over time then the unadjusted time series of annual estimates will be biased.
5. Environmental effects: The catchability of lobster may change due to tidal and weather conditions. Changes in fishing strategy to concentrate on conditions that give better catches will bias CPUE upwards.
6. Gear development: Any changes in the type or configuration of gear that changes the rate of entry and exit of fish to the trap could affect catch rates.

The potential biases listed above mean that it would be unsafe to interpret the data, in terms of stock trends, without first accounting for known sources of variation. Generalized linear modelling (GLM) was used to derive standardized CPUE indices after accounting for variation due to seasonal, soak time and, where possible, vessel effects. Various GLMs of lobster catch rates were run in the R Statistical package. A log(normal) distribution of catch rates was assumed. Log transformation of catch rate data allowed for the development of an additive effects model incorporating both categorical and continuous variables.

Trap soak times are likely to be very important in determining realised CPUE, but there is unlikely to be a linear relationship between CPUE and soak time at the scale of days, i.e. trap-days are probably not a good measure of fishing effort. Over this time-scale it is reasonable to suppose that CPUE has an asymptotic relationship with soak time, whereas CPUE potentially could decline over longer soak times owing to escapement and cannibalism. The relationship was modelled as:

$$1n(CPUE) = \alpha - \beta \frac{1}{\text{soak time}}$$

where α is the value of ln(CPUE) after infinite soak time (effectively an asymptote) and β is related to the rate of trap entry. This approximates to a truly asymptotic relationship, but can be used within a GLM framework without the need for non-linear regression techniques.

Catch rates of lobster are highly seasonal mainly because catchability changes with the moult cycle and environmental temperature. Below 10ºC lobster activity is directly related to temperature (McLeese and Wilder 1958). The seasonal pattern may vary between years, therefore, because of variability in the timing of the moult and because of temperature effects. To account for these effects a year * month interaction was included in the GLM.

The GLM model, therefore, predicted standardised annual catch rates after accounting for vessel (where the vessels could be identified), soak time (where this effect was thought to be important), month to account for the seasonal effect and a month*year interaction to account for annual variation in the seasonal pattern in catch rates.

The following catch rate indices are reported in nominal (observed) and GLM standardised (where possible) forms.

- Monthly and annual landings per unit effort by region (LPUE).
- Undersized lobsters caught per unit effort (a pre-recruitment index, UPUE)
- V-notched lobsters caught per unit effort (an index of the proportion of the spawning stock protected in each area by v-notch legislation, VPUE)

Annual standardised index values and scaled data values were obtained by averaging the monthly averages because of the month*year interaction in the GLM model was usually significant (Maunder and Punt 2004). Nominal annual averages are reported as averages of the raw data.

2. Length Cohort and Egg per Recruit Analysis

It is not possible to estimate the age of lobsters. The fate of individual age classes or cohorts cannot, therefore, be traced as they pass through the fishery. The size structure of the landings, however, does contain information on fishing mortality. Length Cohort Analysis (LCA) can be used to estimate instantaneous rates of fishing mortality (F) on each length class of lobster if other information on growth and natural mortality is known. Its major assumptions are that the fishing mortality signal is reflected in the shape of the size frequency distribution of the landings and that the sample size distribution is an unbiased estimate of the size structure of the stock. The population is assumed to be in equilibrium with constant recruitment (or, at least, that that recruitment and fishing mortality vary around stable average values over the assessed period) as in this model lobsters in the population are in effect treated as a single cohort. This is a significant weakness and is unlikely to be valid in reality over extended periods of time.

The Egg Per Recruit (E/R) assessment calculates the number of eggs a lobster, exposed to a particular value of fishing mortality (F) or over a range of F values, will produce before it is captured in a fishery or dies from natural causes. This can be compared to the number it would produce if there were no fishery to estimate the relative egg per recruit ($R_{E/R}$). This egg production potential is affected by many factors. If the minimum landing size is below the size at which lobsters are mature and capable of reproducing and if F in that fishery is very high (i.e. there is a high probability of capture) then the opportunity to reproduce will be limited. The E/R can be estimated, therefore, for many combinations of different conservation measures or fishing mortality regimes. In particular the ($R_{E/R}$) can be estimated for the current value of F produced by the LCA model.

Separate to the estimation of E/R the yield, in weight, per recruit (Y/R) can also be estimated for different combinations of F and technical conservation measures by the same procedures.

The length cohort model, as described by Jones (1974) and Sparre and Venema (1993), was used to estimate annual mortality rate and mortality at length. The model used the VPA 'exact' algorithm rather than Pope's (1972) approximation as outlined in Darby and Flatman (1993).

3. Reference Points and Performance indicators

This is the first report, in a proposed series, on the status of lobster fisheries in Ireland that will support and facilitate the development of management plans for lobster fisheries. This and future reports will evaluate the status of the fishery in relation to particular stock performance indicators and reference points outlined in the management plan. A number of performance indicators and reference points, in relation to the type of data that are available and the assessment methods that it is possible and realistic to use, are indicated in this report. These may or may not be taken forward to the management plan. The plan would outline its objectives and its management responses in relation to at least some of these indicators however.

Stock indicators and reference points

1. Annual landings: The annual landings reflects the overall level of fishing activity relative to the past
2. GLM standardised catch rates of legal lobsters: This provides an index of the abundance of legal sized lobsters in the stock
3. GLM standardised catch rates of pre-recruit lobsters: This index provides an indication of recent recruitment to the stock and the likely strength of the fishery in the near future
4. Mean size of lobsters in the landings: This provides some information on stock structure. For example a reduction in mean size may indicate fewer large lobsters in the landings due to increasing levels of fishing mortality or alternatively may indicate higher numbers of smaller lobsters entering the fishery. The previous two indices would clarify which was true.

5. Proportion of lobsters > 120 mm CL: The proportion of large lobsters in the stock is itself a reflection of previous recruitment and fishing mortality rates but also, as these lobsters are proportionally of higher reproductive value, their abundance is a useful indicator of egg production.

6. The proportion of the female stock that is v-notched: If a high proportion of lobsters in the stock are v-notched and protected from fishing the fishing mortality on the remainder of the population becomes less of a conservation priority.

7. Annual estimates of fishing mortality (F) on male and female lobsters: These provide an indication of the level of exploitation and can be used to estimate Y/R and E/R corresponding to the current status of the fishery and stock.

8. Relative egg per recruit ($R_{E/R}$): In order to avoid recruitment overfishing the ratio of the E/R at current fishing mortality ($F_{current}$) to the E/R when there is no fishing (F_0), or the relative egg per recruit ($R_{E/R}$), should not fall below a given value. This reference point value will depend on the parameters of the stock recruitment (S-R) relationship and more precisely on the slope at the origin of the relationship. Species that are resilient to high fishing pressure have a higher slope at the origin of S-R i.e. they produce a higher number of recruits per spawning unit. Mace and Sissenwine (1993) estimated the appropriate E/R ratio for 91 stocks of fish in Europe and North America where the S-R relationship was known. Resilience was positively related to body size, which is a proxy for fecundity, longevity and low M. These species require a lower $R_{E/R}$ to maintain their populations than small sized short lived species. On average the lower limit for $R_{E/R}$ was 0.2. Mace and Sissenwine (1993), Clark (1991) and Goodyear (1989) variously recommend precautionary default values for $R_{E/R}$ of 0.2-0.35 when the S-R is unknown. On the other hand the limit for $R_{E/R}$ in the American lobster, where recruitment is strong, is 0.1. The following limits and targets for $R_{E/R}$ are used in this report. These may be refined as information on spawning and recruitment becomes available.
   a. The limit for $R_{E/R}$ is set at 10%. The fishery should not drive egg production below 10% of the production that would occur if the stock was unfished
   b. The target for $R_{E/R}$ is set at 25%. Management measures should allow the stock to produce 25% of the egg production that would occur if the stock was unfished

9. Yield per recruit (Y/R): Y/R is calculated in a similar analysis to E/R but is a proxy for yield in weight rather than egg production. The fishing mortality reference point at maximum Y/R is referred to as F_{max}. From the point of view of stock conservation Y/R is not as relevant as E/R as it does not reference reproductive output or potential. Although optimising Y/R is a management objective it may or may not correspond to parallel optimisation of E/R. In this case priority should be given to E/R and to the protection of egg production.

Limit and target biological reference points for $R_{E/R}$ and Y/R can be identified and the current position of F with respect to these reference points can be established from the LCA. Such reference points identify limits and targets for management in terms of conservation and fishery benefits.

Management options

To achieve egg production limit and target reference points of $R_{(E/R10\%)}$ and $R_{(E/R25\%)}$, respectively, three main strategies are possible. The effect of these three strategies, and the various options under each of them, with respect to achieving egg production limits and targets are presented separately for each geographic region. The strategies are

1. Retain the current technical measures (MLS) and reduce fishing mortality (effort).
2. Change the current technical measures and maintain fishing mortality (effort).
   a. Change MLS and/or
   b. Introduce a maximum landings size (MaxLS) somewhere at or above 120mm.
3. Make combined changes in technical measures and fishing effort.

The following results are presented for each geographic region

1. Values of F that achieve limit and target egg production reference points.
2. The value by which current values of F need to be adjusted to achieve the limit and target egg production reference points (i.e. the F-multipliers).
3. Values of F at different MLS and MaxLS that achieve limit and target egg production reference points.
4. F-multipliers to achieve egg production limits and targets under different combinations of MLS and MaxLS.

Fishery indicators

In addition to the stock indicators and the options available for management to achieve biological targets, indicators of the performance of the fishery are also presented. These relate more to the economic and social objectives that may be set out in the management plan and provide information on the value of the public lobster resource to the Communities that rely on it. The following is a non-exhaustive list of such indicators. Data are not available in all cases and the list will be added to over time.

1. The number of participants in the fishery.
2. The number of pots in the fishery.
3. The concentration profile of pots among vessels, i.e. how are the pots distributed among the vessels.
4. By-catch in crab fisheries.
   Generally the total amount of fishing gear and fishing effort in crab fisheries is greater than in lobster fisheries but there is a significant by-catch of lobster in crab fisheries. Crab fishermen can also easily target lobster fisheries for periods of time as the distribution of crab and lobster overlap substantially on all coasts. Growth in crab effort will also increase the exploitation on lobster.
5. The market price of lobster in the period May-September.
   Market prices are useful indicators as the combination of effort x catch rate x market price determines gross earnings and the profitability in the industry. The price is highly seasonal and is lowest during the peak fishing season.
6. The market price of lobster in the period October-April.
   Prices are highest during this period when landings are lowest. Strategies to increase profitability might involve transferring summer production to winter markets.
7. The proportion of the landings sold by fishermen in the period October-April.
   This indicator identifies any trends in the shifting of summer lobster landings to winter markets in holding systems. This indicator could be used to drive investment in onshore facilities and marketing and research on condition and quality of lobsters in storage.
8. Compliance with regulations
   As the regulations are in place to protect the stock and the fishery lack of compliance with such regulations is an indicator that performance of the stock or fishery may be below targets set out in any management plan.

Analysis of variability in lobster catch rate data

Annual and monthly catch rate indices in this report are used to indicate changes in the abundance of the stock. Many factors, other than abundance, can affect this index. Sources of variability include seasonal effects, weather, tide, temperature, the type of gear, the type of bait, soak time and the knowledge of the skipper. All of these factors affect the probability of catching a lobster in a trap. These effects on lobster catchability can seriously bias annual indices of abundance if they are not accounted for. General Linear Modelling (GLM) is used in this report to statistically control for these effects and to provide an unbiased standardised index of abundance.

The most comprehensive dataset on catch and effort is available for Wexford and Waterford from 1995-2004. Analysis of variance of the data, shown below, shows where most of the variability in catch rate lies and what factors may need to be taken into account in a standardised annual index of abundance.

The data from the southeast for 2002-2004 indicates that the dominant source of variability in catch rates during these years are the vessels (Table 1) rather than month or year. Earlier years were not included in this analysis because traceability to the vessel was not possible. Year and month of fishing are also significant as are the interactive terms between vessel, year and month. This means that catch rate not only depends on the year but also on the vessel that is fishing and the month in which it is fishing. To detect true changes in annual abundance the vessels participating in the voluntary fishing activity record scheme should either be the same in all years or the data should be standardised for the effects of vessel. However, if the data set is sufficiently large this effect may also average out across years. If the vessel effect cannot be accounted for then the annual abundance index should be interpreted with caution.

Table 1. Analysis of variance of lobster catch rate data from the south east for 2002-2004. All interaction terms are included.

Factor	df	SS	MS	F-ratio	Prob
Year	2	1.3	0.7	3.5	< 0.05
Vessel	12	44.0	3.7	19.0	< 0.0001
Year * vessel	15	11.0	0.7	3.8	< 0.0001
Month	7	6.9	1.0	5.1	< 0.0001
Year * Month	12	5.0	0.4	2.2	< 0.05
Vessel * Month	67	56.6	0.8	4.4	< 0.0001
Year * Vessel * Month	45	45.5	1.0	5.3	< 0.0001
Error	1838	353.8	0.2		
Total	**1998**	**959.3**			

The variability due to vessel and month of year in which fishing takes place is described in more detail below.

Seasonality in catch rates

Lobster catch rates vary throughout the season in any given year as indicated in Table 1. This seasonal pattern is not similar in all years (the year * month term in Table 1) suggesting that there are differences in monthly catchability in each year (Fig. 1). Catch rates in winter are generally low as is fishing effort. Catch rates increase in spring and reach a peak in June-September. During those summer months there is usually a decline, some time between July and September, due to increased prevalence of moulting in the stock. Catch rates usually decline in the autumn, although this is not always the case, due to the combined effects of fishing mortality and declining temperatures.

Monthly variability in catch rates and the varying monthly patterns in catch rate in different years could bias the annual non-standardised index if the reported data originated from different months in different years.

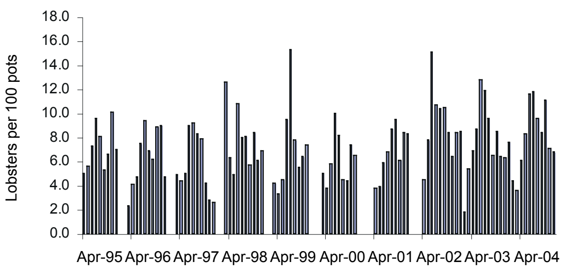


Figure 1. Non-standardised monthly catch rates of lobster between 1995-2004 in Wexford and Waterford.

Vessel effects

Different fishing vessels achieve different catch rates (Fig. 2). This is due to a number of factors related to the specific location of fishing, the type of traps used, the time of year during which the boat is fishing among other factors. Most of the effect is probably due to local variability in the abundance of lobsters i.e. some vessels fish better grounds than others. Each vessel generally performs similarly each year although the (Year * vessel) term in Table 1 was highly significant. This was due mainly to a small number of vessels, which performed differently in 2002 and 2003.

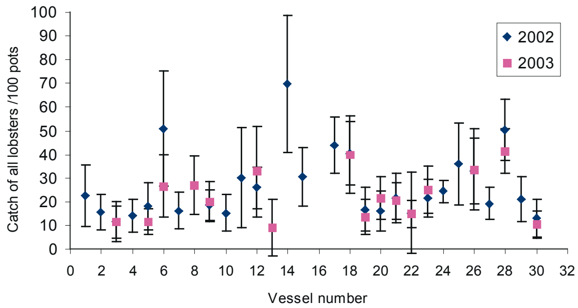


Figure 2. Average (±s.d.) catch rate of different lobster fishing vessels in the south east in 2002 and 2003.

Gear soak time effects (all areas)

The majority of lobster gear is soaked for 1 day. Catch rates in relation to soak time are highly variable (Fig. 3, Table 2). It is not possible to obtain consistent trends in catch rate in relation to soak time within areas, months or years. Data from all years and counties combined or regional data from all years combined generally show a positive relationship between soak time and catch rates. The slopes of these relationships indicate the net rate of entry to traps (i.e. rate of entry minus rate of escapement). The effect of soak time appears to be different in each month. For instance, during May and September-October the effect of soak times 3 days or longer is negligible compared to the positive effect of soak time on catch rates during the period June-August suggesting a higher rate of entry and a higher catchability during summer months (Fig. 4). This is reflected in the overall pattern of monthly catch rate data.

Table 2. Relationship between catch rate (lobsters per 100 pot hauls) and soak time in regional lobster fisheries (all data from 1995-2004 combined for months April to September).

	All areas		South east		SW, W and NW	
Soak days	**N**	**Mean**	**N**	**Mean**	**N**	**Mean**
1	7175	17.39	5924	16.10	1211	23.28
2	3481	23.50	2272	18.21	1091	33.70
3	1515	27.08	721	17.31	703	36.62
4	541	28.02	216	18.26	286	35.33
5	241	30.53	82	21.46	143	35.03

Monthly differences in catch rate may not therefore indicate changes in abundance of lobsters but changes in catchability. These effects are probably mediated through increases in lobster activity and appetite associated with higher seawater temperatures. Soak time and month effects, therefore, need to be accounted for in annual indices of stock abundance.

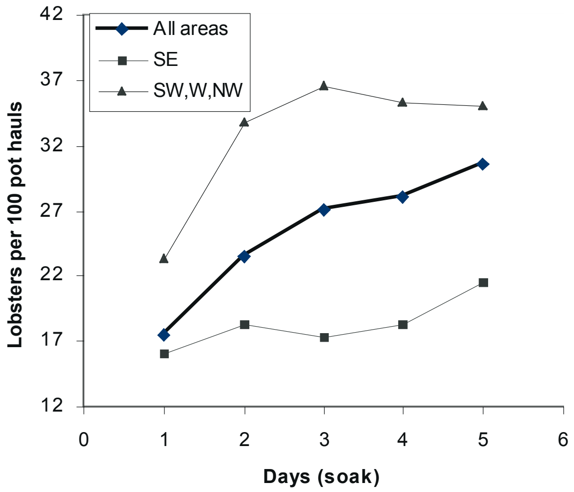


Figure 3. Relationship between catch rate and soak time in regional lobster fisheries (all data from 1995-2004 combined for months April to September).

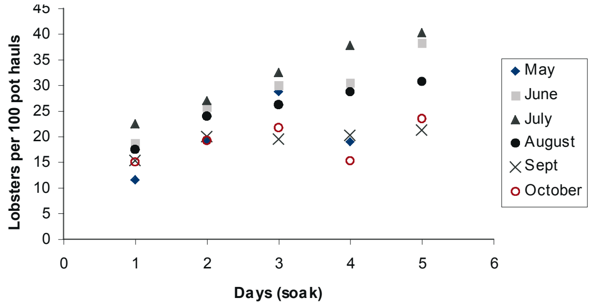


Figure 4. The relationship between soak time and catch rate of lobsters in different months (all regions combined)

Gear type effects

Although the majority of lobster gear used in Ireland is the standard soft eye creel, other types of trap such as the top entrance (inkwell) and parlour pot are also used. Gear type is not currently included in the fishing activity records and little information on comparative performance of each gear type exists. No controlled trials have been carried out. One vessel contributed good quality data by gear type in Wexford in 2000-2001. The data are shown below (Table 3, Fig. 5).

Analysis of variance of these data indicates that catch rates are affected more by the pot type than by month but also that different pot types perform differently at different times of year.

Table 3. Analysis of variance of the effects of time of year and pot type on catch rate of lobster

	df	SS	MS	F-ratio	P
Month	6	11.21	1.87	3.69	<0.01
Pot type	2	9.66	4.83	9.53	<0.0001
Month * pot type	10	14.22	1.42	2.81	<0.01
Error	668	338.58	0.51		
Total	**686**	**428.31**			

Catch rates are higher in soft eye creels than in parlour pots, which have higher rates than inkwells (Fig. 5).

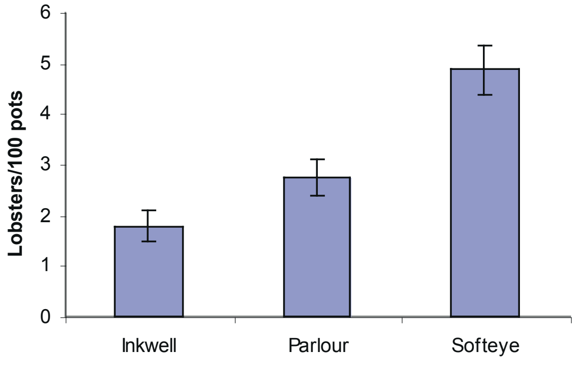


Figure 5. Catch rates (means±s.d.) of lobster in three different types of pot in Wexford in 2000 and 2001.

The South East Fishery (Wexford and Waterford)

1. Landings

Landings of lobster into ports in Wexford and Waterford (Fig. 6) averaged 42.5 tonnes per annum between 1990-2005 (Fig. 7).

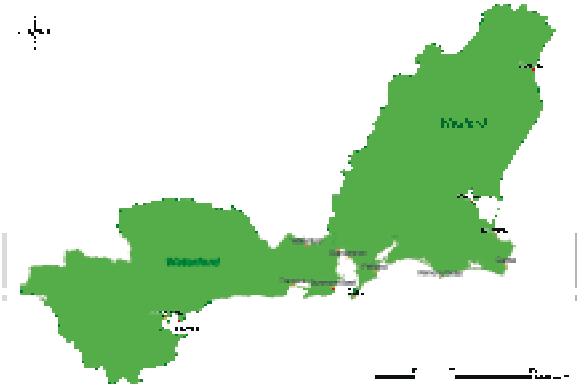


Figure 6. The area of the Wexford and Waterford fisheries and the main lobster landing points.

On average 25.2 and 17.1 tonnes were landed annually in Wexford and Waterford respectively during the 1990-2005 period. Landings in Waterford were less than 15 tonnes between 1990 and 1994, increased to approximately 30 tonnes in 1995 and 1996 and declined to pre 1995 levels by 2001-2004. In Wexford landings varied between 10-28 tonnes in 1990-1994, increased in 1996 to over 30 tonnes but then declined and reached a low of 16-17 tonnes in 1999-2000. Between 2001-2004 landings increased to outside of the range of the previous 1990-2001 period and reached 47.6 tonnes in 2004.

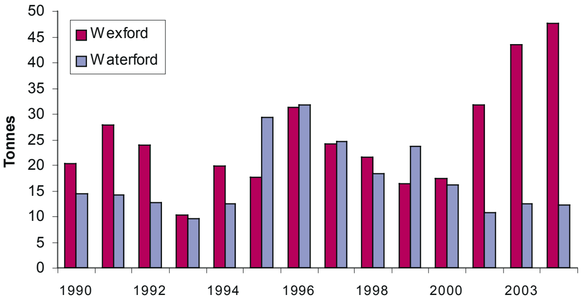


Figure 7. Annual landings of lobster into Wexford and Waterford from 1990-2004.

2. Catch rates

General Linear Modeling (GLM)

The 1995-2001 data were standardised for year and month and a month * year interactive effect. Soak time was not included as its effect was not significant in preliminary model runs. Year and month were included as discrete factors. The 2002-2004 data were standardised for vessel effects in a separate GLM model. Seven out of over 20 vessels were selected for inclusion in the analysis. These were vessels that had submitted the highest number of catch records. Data for January and February were excluded because of the low level of fishing in these months.

Monthly predictions were standardised to a particular vessel. Expected and observed estimates were scaled to the average of the time series involved.

The GLM models generally explained 20-25% of variability in the data. Year, month, vessel and the month * year interaction were significant.

Landings per Unit Effort (LPUE) 1995-2001

Annual observed catch rates (all lobsters including undersized) and catch rates of legal and undersized lobsters and the number of records (boat days) on which these estimates are based are shown in Table 4. There are two discontinuities in the 1995-2004 data; from 1995-2001 data do not discriminate between target and by-catch catch rates while from 2002 only targeted catch rates are included. By-catch rates of lobster in pots that were designated by the skippers as targeting crab were 26% and 25% of targeted rates in 2002 and 2003 respectively. Secondly, data are not available for Waterford prior to 2000 while post 2000 data from both counties are combined. Pre and post 2002 data were treated separately.

Monthly catch rates of legal lobsters show the expected seasonal pattern. Catch rates usually peaked in June and July and were lowest in early spring and late autumn (Fig. 8). Observed and standardised monthly catch rates were similar (Fig. 9).

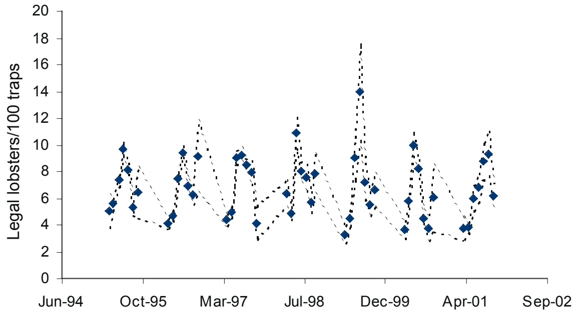


Figure 8. Monthly catch rates of legal lobster off the south east coast from Apr 95 – Oct 01. Dotted lines are 95% confidence limits.

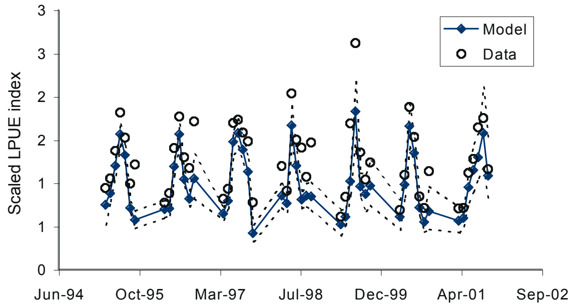


Figure 9. Monthly scaled index of catch rate of legal lobsters off the south east coast in 1995-2001. Dotted lines are 95% confidence limits for the model.

Annual standardised indices for legal sized lobsters increased from 1997-1999, declined from 1997-2000 and increased in 2001 (Fig. 10).

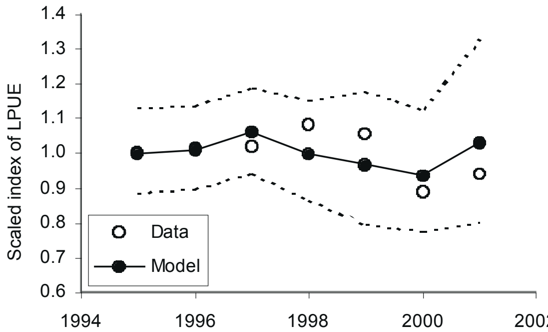


Figure 10. Scaled annual average and standardised scaled annual index of the catch rate of legal sized lobsters off the south east coast between 1995-2001. Dotted lines are 95% confidence limits for the model.

Undersized catch rates (UPUE) 1995-2001

Catch rates of undersized lobsters followed a similar seasonal pattern to that of legal lobster (Fig. 11, 12). Monthly catch rates peaked in 1998-1999 but subsequently declined.

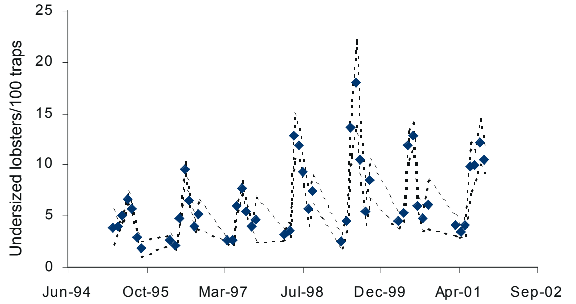


Figure 11. Monthly catch rate of undersized lobsters off the south east coast between Apr 95 and Oct 01. Dotted lines are 95% confidence limits

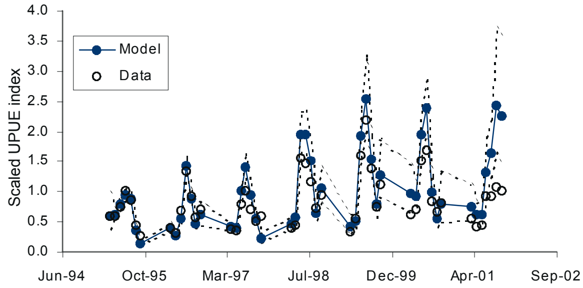


Figure 12. Standardised and scaled monthly observed and predicted catch rates of undersized lobsters off the south east coast between Apr 95 and Oct 01. Dotted lines are 95% confidence limits for the model.

Annual observed catch rates of undersized lobsters doubled between 1997-1999 but declined by approximately 30% between 1999-2001 (Fig.13). There was poor correspondence between the standardised index and the observed catch rates in 2000 and 2001. The model predicted stable catch rates of undersized lobsters between 1998-2001.

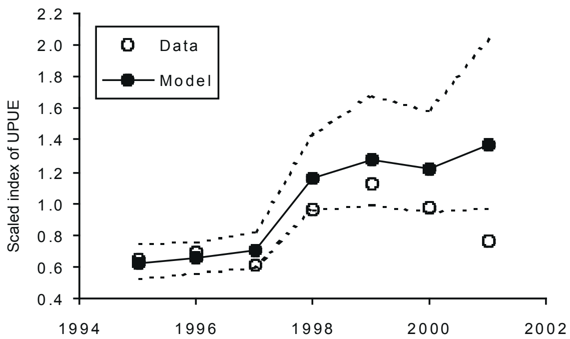


Figure 13. Annual observed and standardised scaled indices of the catch rate of undersized lobster in the south east fishery in 1995-2001. Dotted lines are 95% confidence limits for the model.

Table 4. Annual catch rate (mean±s.d per 100 pots) of lobsters in Wexford and Waterford 1995-2001. N= number of boat days reported per year. CPUE = all lobsters, LPUE = legal lobsters, UPUE = undersized lobsters.

		CPUE		LPUE		UPUE	
Year	**N**	**Mean**	**S.d.**	**Mean**	**S.d.**	**Mean**	**S.d.**
1995	1926	12.70	8.44	7.57	5.17	4.95	4.95
1996	1983	13.51	9.60	7.23	5.30	5.70	5.90
1997	1536	12.60	8.00	7.06	4.65	4.79	4.48
1998	1042	16.40	12.76	7.75	5.92	7.71	9.11
1999	577	19.32	22.33	8.06	9.27	10.55	15.27
2000	662	16.20	10.10	6.86	4.63	8.75	7.08
2001	401	13.99	9.51	6.24	4.24	7.14	5.96

Landings per unit Effort (LPUE) 2002-2004

Monthly average targeted LPUE peaked at 10-12 lobsters per 100 pots in summer although the patterns varied in each year (Fig. 14, 15).

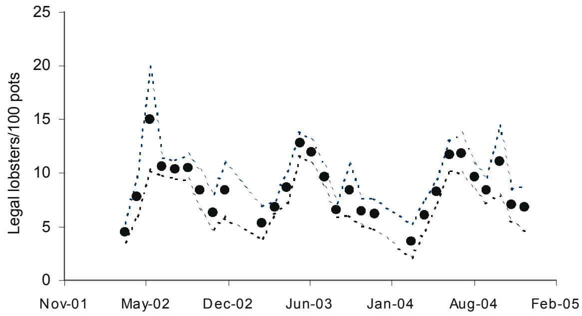


Figure 14. Monthly catch rates of legal lobster from Apr 02 – Dec 04 off the south east coast. Dotted lines are 95% confidence limits.

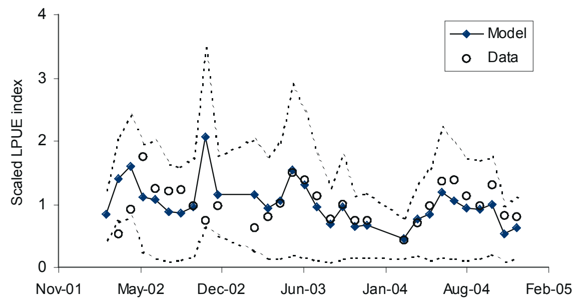


Figure 15. Monthly scaled indices of the catch of legal lobsters in 2002-2004 off the south east coast and scaled data estimates. Dotted lines are 95% confidence limits for the model.

The annual average targeted LPUE declined from 9 to 8.5 between 2002-2003. The index from the GLM model, standardised for vessel effects, declined from 1.19 to 0.83 between 2002-2004 (Fig. 16).

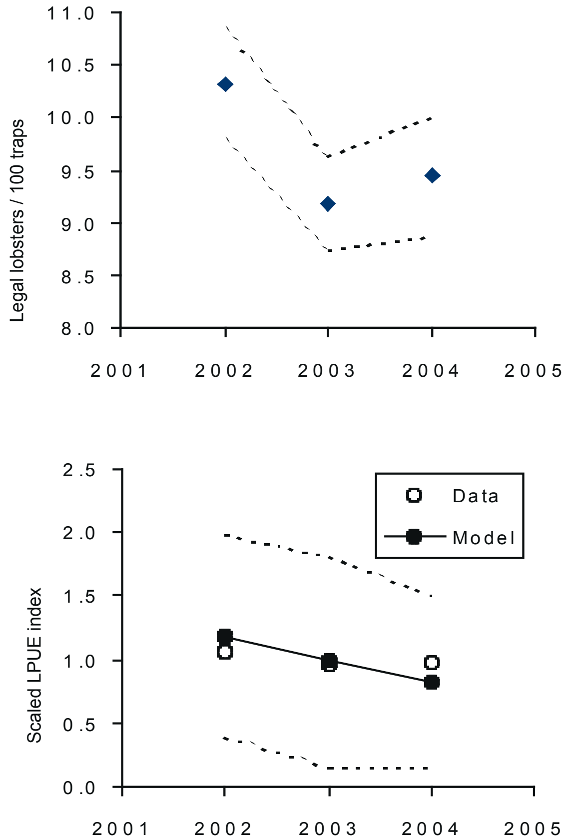


Figure 16. Average annual observed and annual scaled modelled indices of catch rates of legal lobsters in the Wexford fishery in 2002-2004. Dotted lines are 95% confidence limits (for the model in the scaled plot).

Undersized catch rates (UPUE) 2002-2004

The standardised indices and the observed monthly estimates declined between 2002 and 2004 (Fig. 17, 18). The annual GLM estimate and the annual observed mean declined from approximately 14 to 10 lobsters per 100 pots (Fig. 19, Table 5).

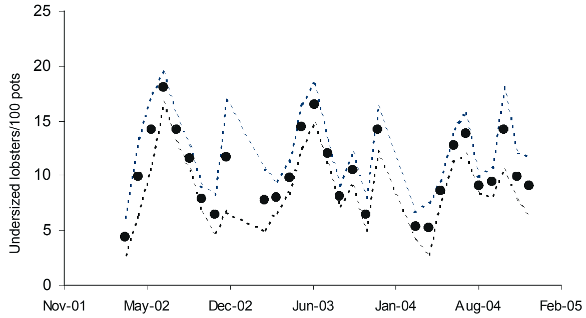


Figure 17. Monthly catch rates of undersized lobster from Mar 02 – Dec 04 off the south east coast. Dotted lines are 95% confidence limits.

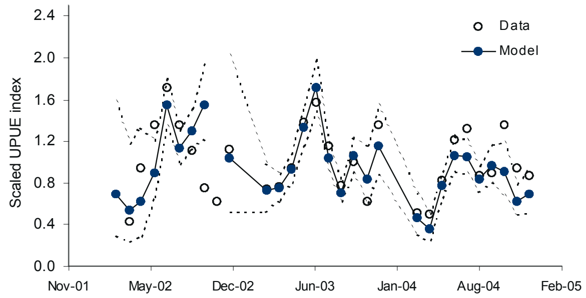


Figure 18. Monthly scaled indices of the catch of undersized lobsters in 2002-2004 off the south east coast and scaled data estimates. An outlying point (value of 2.8) for November 2002 is removed. Dotted lines are 95% confidence limits for the model

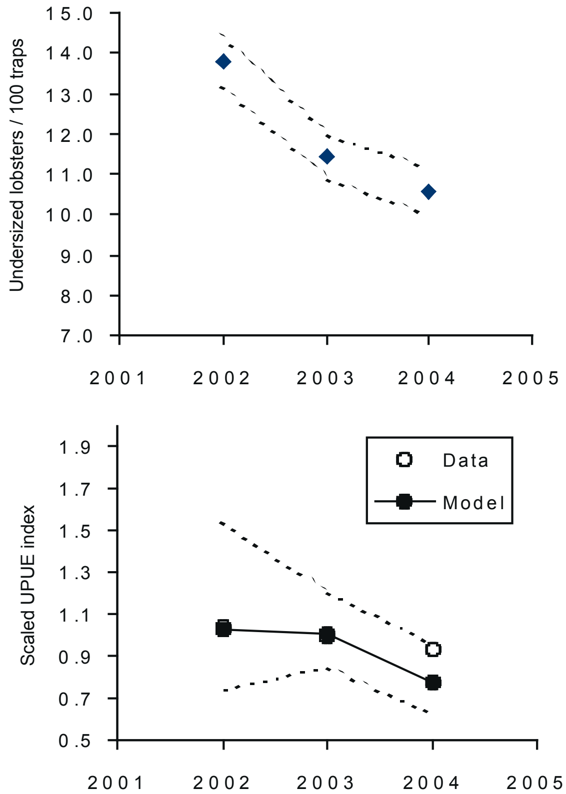


Figure 19. Annual scaled observed and modelled indices of catch rates of undersized lobsters off the south east coast in 2002-2004. Dotted lines are 95% confidence limits (for the model in the scaled plot).

Table. 5. Annual catch rates (mean±s.d. per 100 pots) of lobsters in the south east in 2002-2004. N= number of boat days reported per year. CPUE = all lobsters, LPUE = legal lobsters, UPUE = undersized lobsters.

		CPUE		LPUE		UPUE	
Year	N	Mean	S.D.	Mean	S.D.	Mean	S.D.
2002	1368	25.33	17.59	10.31	9.67	13.81	11.91
2003	1287	21.43	14.27	9.19	7.98	11.44	10.09
2004	640	20.23	12.06	9.44	7.09	10.58	7.18

3. Biological Data

Size distributions

The average size of lobsters landed into Wexford and Waterford between 1995-1999 remained relatively constant but increased in 2002-2004 (Table 6). In particular the proportion of lobsters greater than 120mm CL increased from less than 2% in the mid 1990s to between 4-10% in 2002-2004.

Table. 6. Annual (mean±s.d.) size of lobsters landed into Wexford and Waterford between 1995-2005. The proportion of lobsters over 120 mm CL is also indicated

Year	N	Mean	s.d	%>120
1995	3927	94.90	11.24	3.13
1996	2250	92.94	8.90	1.73
1997	918	94.16	8.71	1.20
1998	1523	94.49	8.63	1.38
1999	2280	94.69	9.93	2.76
2002	1629	101.30	11.30	6.02
2004	2499	97.54	11.90	4.24
2005	465	101.06	14.50	10.75

The size distributions of the landings show that the majority of lobsters are within one moult (<95mm CL) of the MLS when landed, although in some years there is a higher proportion of larger lobsters in the catch (Fig. 20,21). These distributions are used, with other information on growth, to estimate fishing mortality rates in the length cohort analysis (LCA) described below.

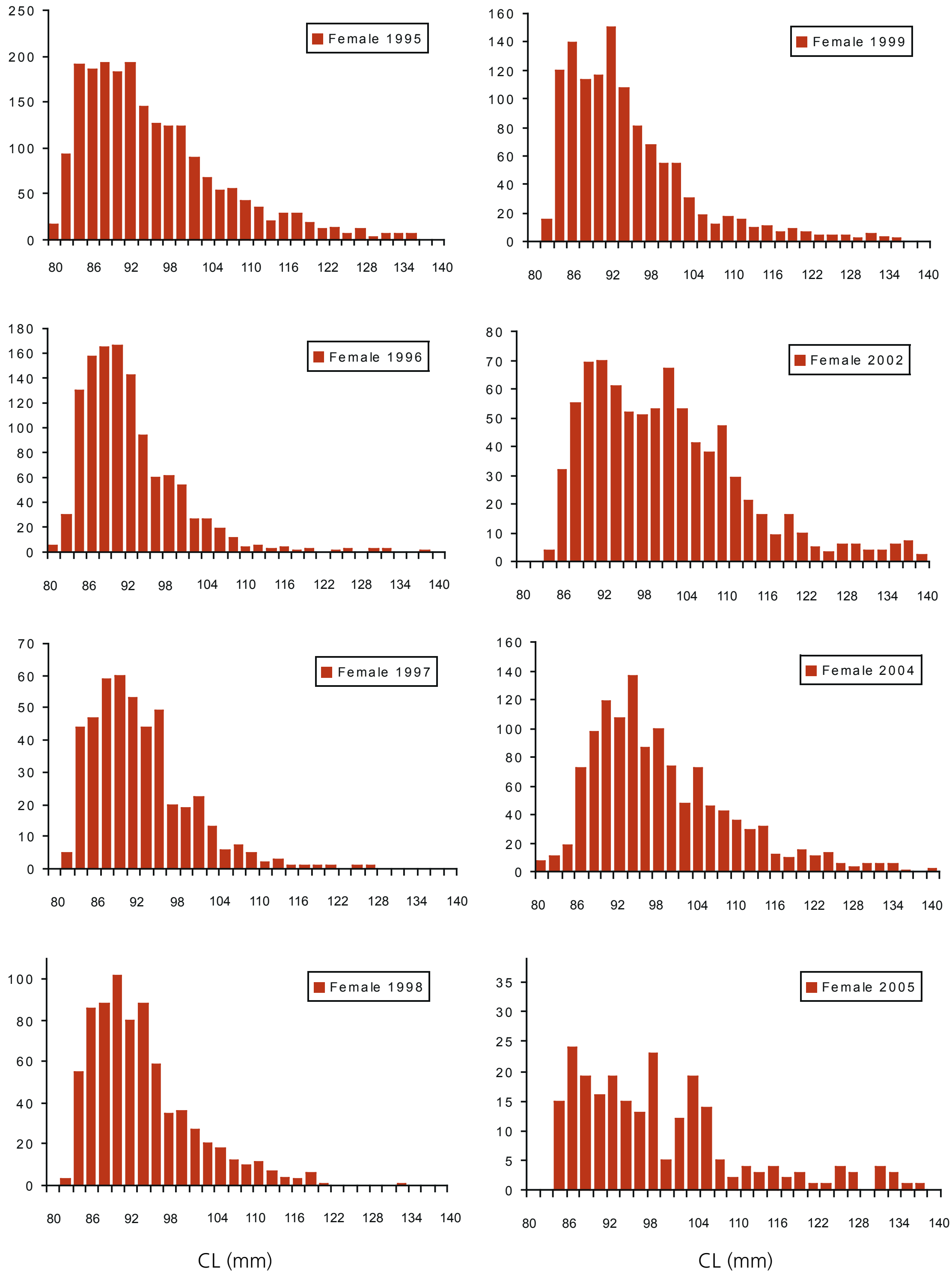


Figure 20. Annual size distributions of female lobster landed into Wexford and Waterford in 1995-2005. Note the different sample sizes.

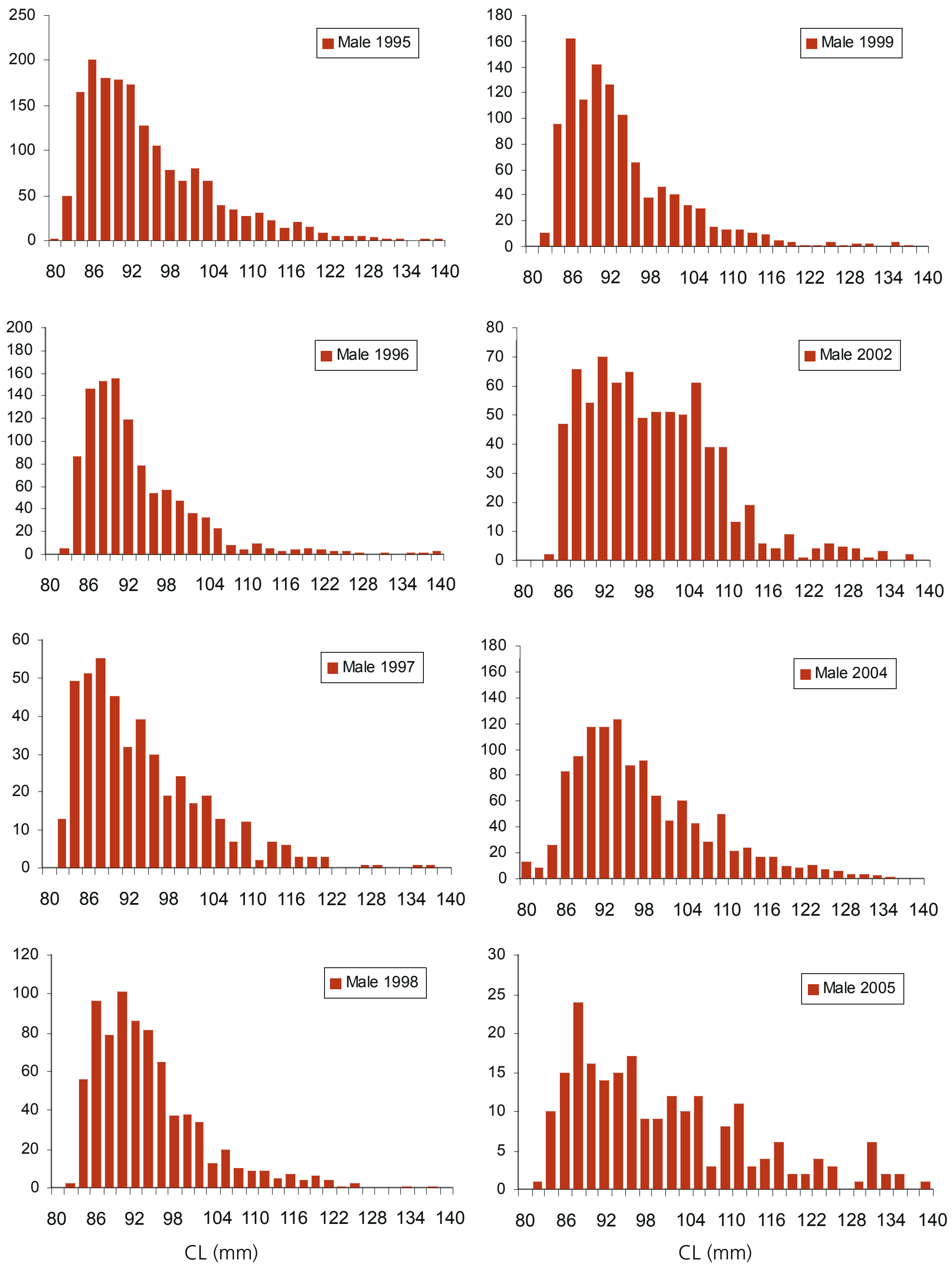


Figure. 21. Annual size distributions of male lobster landed into Wexford and Waterford in 1995-2005. Note the different sample sizes.

Size at maturity

The size at maturity of lobsters in the southeast was evaluated in 1999 (Tully *et al*. 2001). Although the minimum size at maturity may occur below 80mm CL the mean size at maturity, or the size at which 50% of lobsters are expected to be mature, is 95mm (Fig. 22). The maturity ogive expressing the relationship between proportional maturity and size is

$$P_{mature} = \frac{1}{1+e^{15.5-0.163CL}}$$

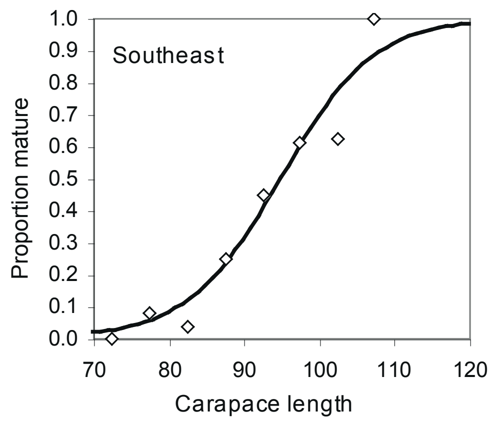


Figure 22. Size at maturity of lobsters off the south east coast showing data and the fitted logistic model (from Tully *et al*. 2001).

4. Assessment and Management

Length Cohort Analysis

Model conditions

Length Frequency Distributions (LFDs) for each year were converted into percentage frequencies in 4mm CL groups and an aggregate plus group at 124mm CL. LCA was performed for each year and for male and female lobsters separately and for average LFDs for each sex for the periods 1995-99, 2002-2004 and 1995-2004. Time periods 1995-99 and 2002-04 were chosen to best comply with population equilibrium assumptions. Terminal F was refined to be the same as that of the adjacent size class, except for 1998, where this gave anomalous results.

Growth and mortality parameters used to drive the LCA were as follows:

- Growth: L_{∞}=172, k=0.12 (representing male and female growth)
- Mortality (M): 0.1, 0.15 and 0.2;
- Length weight: Coefficients of the, combined sex, length weight function a=0.0013, b=2.8476 (monthly sampling from landings in Ireland 2002-2004)
- Length fecundity: Coefficients for the allometric power function relationship between length and fecundity were a=0.000004 and b=3.1554 (Tully *et al*. 2001)
- Size at maturity: Relationship for female lobsters given above.

LCA results

Annual Fishing Mortality (F)

Average values of F for the 1995-1999 period were higher than for the 2002-2004 period. Overall average F for the 1995-2004 period varied from 0.43-0.50 for female lobsters and 0.44-0.51 for males depending on the rate of natural mortality (M) assumed (Fig. 23).

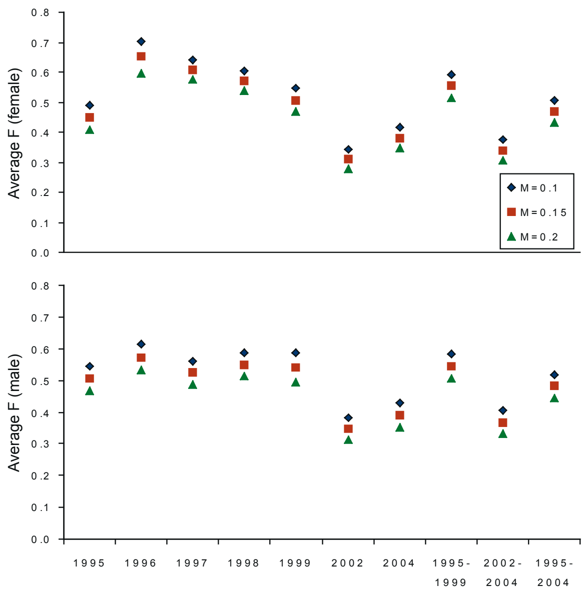


Figure 23. Annual fishing mortality (F) on male and female lobsters between 1995-2004 in relation to natural mortality (M). Estimates are based on LFDs for individual years and for groups of years – note that the individual year estimates are not the same as annual estimates relating solely to that year.

F at Length

Fishing mortality (F) varied from 0.1-0.5, depending on year and sex. Below the MLS of 87mm CL F > 0 because a proportion of lobsters in the 84-87mm size class were landed. Lobsters are fully recruited to the fishery at approximately 95mm, which is 8mm above the MLS and approximately equivalent to one moult increment.

Yield per recruit

Yield per recruit curves, for male and female combined, using an unweighted average F of male and female lobster, were practically identical for input LFDs for 1995-1999, 2002-2004 and overall for 1995-2004. This means that for any particular value of fishing mortality yields would have been similar given the size distribution of the landings during the respective periods. At low values of M higher gains would result from moving from $F_{current}$ to F_{max} but little or no Y/R would be gained if M was as high as 0.2. The position of $F_{current}$ on the Y/R curves differs substantially depending on the set of years used to estimate it and the chosen value of M (Fig. 24).

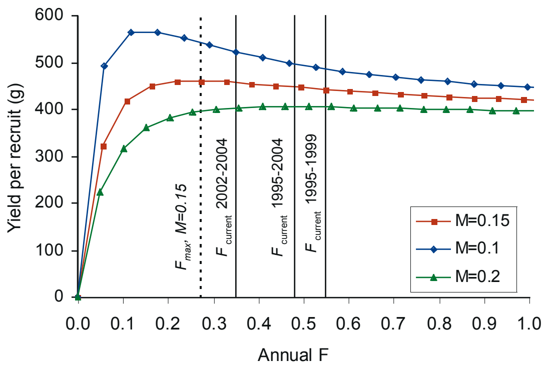


Figure 24. Y/R analysis for south east coast lobsters, sexes combined, in relation to F for 3 values of M and input length frequency data from 1995-1999 in the south east lobster fishery. $F_{current}$ for 3 time periods for M=0.15 and F_{max} for M=0.15 are shown.

Eggs per recruit

E/R declines monotonically with increasing F. E/R curves for different sets of years in relation to F were almost identical. As was the case for Y/R this means that for any particular value of fishing mortality, given the size distribution of the landings during the respective periods and the egg production represented by such a size distribution, egg production at any given value of F would be similar for each period. However, the position of $F_{current}$ (average of male and female F) varied depending on the set of years for which the estimation was made (Fig. 25). Absolute E/R depends on the value of M chosen.

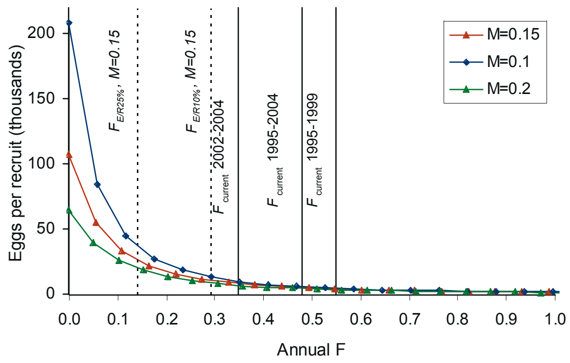


Figure 25. E/R for different sets of years and at M of 0.15. The current position with respect to fishing mortality rate (F current) for different sets of years is indicated.

The limit and target reference points for $R_{(E/R)}$, or the E/R relative to that of an unfished stock, are 0.1 and 0.25 respectively (see above). High values of M give a more optimistic $R_{(E/R)}$ output. At high M the $R_{(E/R)}$ curve is to the right of the curves at lower M i.e. predicting a higher $R_{(E/R)}$ for each value of F and $F_{current}$ at high M is to the left of or lower than F current at lower values of M. The position with respect to the limit and target reference points for $R_{(E/R)}$ is, therefore, doubly optimistic the higher the level of M. However, irrespective of the value of M or F current the $R_{(E/R)}$ is less than the limit reference point of 10% (Fig. 26).

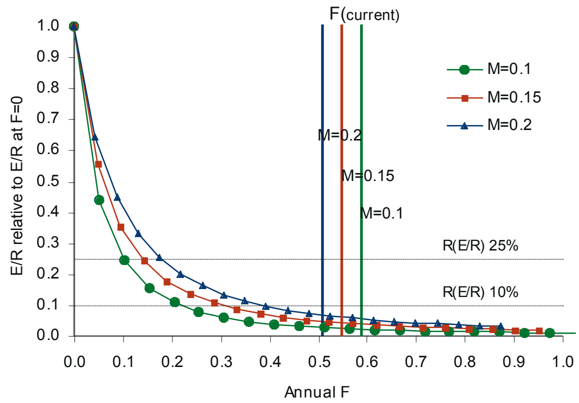


Figure 26. The proportion of potential egg production per recruit at different values of F (unweighted average for male and female). Results are presented for 3 values of M for aggregated 1995-1999 length frequency data. Limit ($R_{(E/R10\%)}$) and target ($R_{(E/R25\%)}$) reference points of 10% and 25% of egg production respectively are indicated.

Management options

F at $R_{(E/R)}$ reference points (no change in selection pattern)

Values of *F* that achieve E/R reference limits and targets are more-or-less independent of the years used to estimate the *F*-at-length (1995-1999, 2002-2004 or 1995-2004), but the relationship with $F_{current}$ is very different. Very low *F* is required to achieve 25% of maximum egg production. Higher values of *M* allow for higher values of *F* for a given reference point, and give lower estimates of $F_{current}$. They are thus doubly optimistic (Table 7).

Table. 7. Fishing mortality rates in relation to E/R reference points

$F_{current}$ **(sexes combined):**			
M	1995-1999	2002-2004	1995-2004
0.1	0.59	0.39	0.51
0.15	0.55	0.35	0.48
0.2	0.51	0.32	0.44
$F_{R(E/R)}$ **10%:**			
M	1995-1999	2002-2004	1995-2004
0.1	0.21	0.2	0.22
0.15	0.29	0.29	0.3
0.2	0.37	0.39	0.38
$F_{R(E/R)}$ **25%:**			
M	1995-1999	2002-2004	1995-2004
0.1	0.1	0.09	0.1
0.15	0.14	0.13	0.14
0.2	0.17	0.17	0.18

F-*multipliers for E/R reference points (no change in TCMs)*

If 1995-2004 is taken as the reference period, and 0.15 is taken as the most likely value of *M*, then reductions in fishing mortality of 40-50% would be required to preserve at least 10% of egg production potential. Target egg production potential (25%) would require a 70% reduction in fishing mortality (Table 8).

Table. 8. F-multipliers for EPR reference points at current fishing selection patterns

***F*-multiplier for $R_{(E/R)}$ 10%**			
M	1995-1999	2002-2004	1995-2004
0.1	0.37	0.52	0.42
0.15	0.53	0.83	0.63
0.2	0.72	1.23	0.87
***F*-multiplier for $R_{(E/R)}$ 25%**			
M	1995-1999	2002-2004	1995-2004
0.1	0.17	0.23	0.2
0.15	0.25	0.36	0.29
0.2	0.34	0.52	0.4

F at $R_{(E/R)}$ reference points (with changes in TCMs)

In this analysis the effects of a maximum legal landing size (MaxLS) of 120, 125 or 130mm CL, applied to females only and/or changes to MLS, applied to both sexes, are explored. The shaded cell in each table represents *status quo* on the effective MLS (where F=0, not the current legal MLS of 87mm) and no MaxLS. Results are presented for 1995-2004 aggregated length frequency data, with M=0.15 (Table 9).

The level of effort reduction required to achieve $R_{(E/R)\ 10\%}$ or $R_{(E/R)\ 25\%}$ is less as MLS increases and at lower MaxLS (Table 9).

Table 9. Current F modified for different technical measures and corresponding F for E/R reference points

$F_{current}$ **(sexes combined, current effort levels):**				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.45	0.46	0.47	0.48
85	0.42	0.44	0.44	0.45
87	0.39	0.4	0.41	0.42
90	0.34	0.35	0.36	0.37
95	0.26	0.27	0.28	0.29
$F_{R(E/R)}$ **10%**				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.44	0.4	0.37	0.3
85	0.43	0.39	0.36	0.29
87	0.41	0.37	0.34	0.28
90	0.39	0.35	0.32	0.27
95	0.37	0.33	0.31	0.26
$F_{R(E/R)}$ **25%**				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.25	0.23	0.21	0.14
85	0.24	0.22	0.2	0.13
87	0.23	0.21	0.19	0.13
90	0.22	0.2	0.18	0.12
95	0.2	0.18	0.16	0.1

F-*multipliers for E/R reference points for F with changes in TCMs*

To achieve $R_{(E/R)\ 10\%}$ with no changes in technical measures requires a reduction in F of approximately 40%. However, increasing MLS to 95mm CL would achieve 10% $R_{(E/R)}$ if F was reduced by about 10%. Substantial increases in effort could be sustained if a combination MLS of 95mm and MaxLS of 120-130mm was introduced but the target egg production would not be achieved (Table 10).

Increases in E/R would occur by increasing MLS and introducing MaxLS at current levels of effort. Relatively small benefits would occur with increases of MLS up to 95mm because of the large size at maturity and the shallow slope of the maturity ogive and $R_{(E/R)}$ would not reach the 10% limit even at 95mm MLS. $R_{(E/R)\ 10\%}$ would be attained at MLS of 85mm and MaxLS of 120mm CL.

Table. 10. F-multipliers for different E/R reference points under various combinations of MLS and MaxLS.

***F*-multiplier for $R_{(E/R)}$ 10%**				
	MaxLS (mm CL)			
MLS	120	125	130	none
80	0.99	0.87	0.79	0.63
85	1.01	0.89	0.81	0.64
87	1.05	0.92	0.83	0.67
90	1.14	1	0.9	0.72
95	1.44	1.24	1.1	0.91
***F*-multiplier for $R_{(E/R)}$ 25%**				
	MaxLS (mm CL)			
MLS	120	125	130	none
80	0.57	0.49	0.44	0.29
85	0.58	0.5	0.45	0.3
87	0.6	0.52	0.46	0.3
90	0.65	0.55	0.49	0.32
95	0.78	0.65	0.56	0.36

5. V-notched lobsters

Releases of v-notched lobsters

Approximately 13180 v-notched lobsters were released into the southeast stock between 1994-2004. Almost all lobsters were released between May-September from each of the main fishing ports in the area.

The catch rate of v-notched lobsters

As more v-notched lobsters are released into the stock the rate at which they are captured in pots should increase. Demonstrating this relationship is important for a number of reasons.

1. It validates that the v-notch conservation programme is succeeding in building a stock of protected lobsters in the release areas.
2. It can be used to verify if catch rate data in lobster fisheries can provide an effective index of stock abundance.
3. The ratio of v-notched lobsters and legal sized female lobsters in the catch should be indicative of the stock size as the total number of v-notched lobsters, discounted for mortality and repair of the notch, is known approximately.

Catch rates of v-notched lobsters were highly correlated with the cumulative numbers of lobsters released during 1994-1998 (Fig. 27). A decline in catch rates occurred for the first time in 1999. Following a temporary cessation of notching in 2000 and 2001 catch rates declined by about 40% compared to the 1998 level. V-notching recommenced in 2002 and continued to 2004. There was a parallel increase in catch rates. The 2002-2004 catch rates may be biased upwards relative to the pre 2002 catch rates as pre-2002 data include by-catch rates on v notched lobsters in the crab fishery. Overall catch rates were not proportional to the cumulative numbers released during the 1995-2004 period, i.e. there was a less than expected increase in catch rate as the cumulative number released increased. This may be due to mortality and repair of the v-notch as described below.

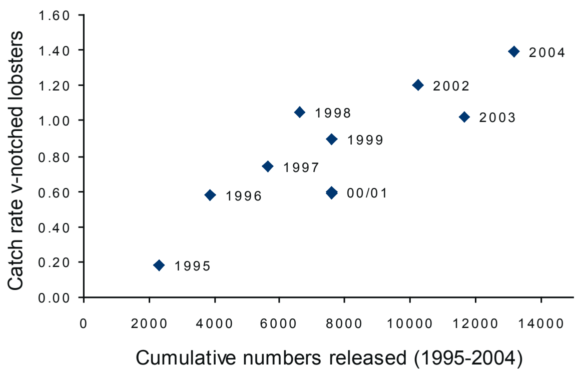


Figure 27. Catch rates (per 100 pot lifts) of v-notched lobsters off the south east coast in relation to the cumulative number of lobsters v-notched and released in the stock

The number of v-notched lobsters in the stock

Mortality and repair of the notch

The number of v-notched lobsters in the stock at any given time (t) is a function of

- the numbers released up to time t (N_{rt})
- the annual rate of natural mortality (M) on v-notched lobsters
- the annual rate of repair of the v-notch due to moulting which is given by the
- annual moult probability (P_m)
- probability of repair at moult (P_{rm})
- the rate of voluntary re-notching of lobsters at sea that have partially repaired the notch (P_{rc})

- the encounter rate or recapture rate of v-notched lobsters (E).
- the annual illegal fishing mortality (F) on v-notched lobsters

giving a predicted number of v-notched lobsters in the stock at time (t) of

$N_{vt} = (N_{rt} * e^{M*t+F*t+R*t})$

where R is the annual rate of repair of the notch as follows

$R = (P_m * P_{rm})-(P_{rc}*(P_m*P_{rm}*E))$

The annual rate of repair of the v-notch is a function of the moulting rate, the number of moults required to repair the notch, the rate at which lobsters, which have partially repaired the notch, are re-notched at sea and the recapture rate of v-notched lobsters. The annual rate of moulting is size related and is less than 1 in most commercial sized female lobsters. In the American lobster it is estimated at 0.5 for lobsters under 120mm and 0.3 in female lobsters greater than 120mm CL. The number of moults required to repair the notch is 2-3. The proportion of v-notched lobsters recaptured at sea that are re-notched is unknown. Although some data related to this is reported in the logbooks it is not sufficient to estimate the rate.

V-notched lobsters in the stock

The lack of proportionality between catch rates and the cumulative numbers released shown in Fig. 28 can be accounted for due to natural mortality and repair of the notch as described above. Catch rates and predicted number of lobsters in the stock are proportional if mortality and processes leading to repair of the notch are used to discount the numbers released. Mortality and notch repair rates used to predict the numbers of v-notched lobsters in the stock are given in the legend of Fig. 28.

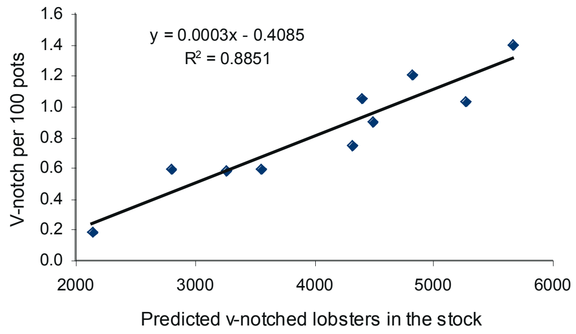


Figure 28. Catch rates of v-notched lobsters in relation to predicted numbers of v-notched lobsters in the stock. Numbers released were adjusted for natural mortality (M=0.15), an annual rate of moult of 0.5, probability of fully repairing the notch during moulting 0.33, rate of re-notching of partially repaired notches at sea 0.2 and a annual recapture rate of 0.5 (equivalent to the estimated F on the stock from length cohort analysis). No account was taken of any illegal landings that might have occurred, i.e. F on the v-notched individuals was assumed to be zero.

The estimates are subject to a high level of uncertainty as the rates of notch repair and natural mortality rate are largely unknown. M and R are applied for the year following release and do not account for losses due to M and R in the season of release. There is an unknown annual fishing mortality (F) on v-notched lobsters but here it is assumed to be zero.

The numbers released and the estimated number of v-notched lobsters in the stock depart over time (Fig. 29). This is due to the accumulating effects of natural mortality and repair of the notch. This relationship could be stabilised by releasing a number of lobsters annually to counteract losses due to mortality and repair of the v-notch.

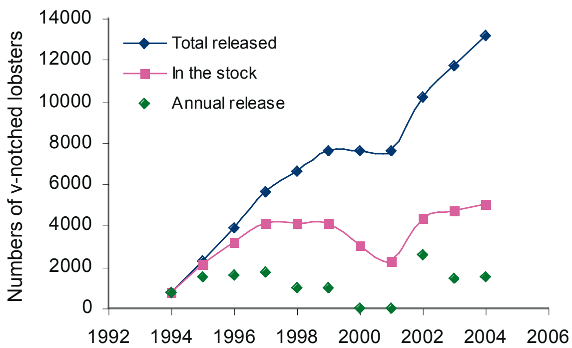


Figure 29. Annual and cumulative number of v-notched lobsters released and the numbers estimated to be in the stock off the south east coast.

V-notched lobsters and total stock estimates

Estimates of the total number of lobsters in the stock could be obtained from information on v-notched lobsters if

- The total number of v-notched lobsters in the stock is known (see above)
- The catchability of v-notched lobsters is the same as non v-notched lobsters.

The number of lobsters in the stock (N_t), over the MLS, could then be estimated as follows

$$N = C/C_v * Nv_t$$

Where C is the total catch of lobsters, C_V is the catch of v-notched lobsters and N_{Vt} is the number of v-notched lobsters predicted to be in the stock during the re-capture period as described above. This is the standard Petersen estimate and requires that the population is closed with no immigration, emigration or recruitment during the period of the estimation. Although the total numbers of v-notched lobsters captured or the total number of lobsters captured in the fishery in each season is unknown the ratio of the catch rates of v-notched and legal lobsters could also be used to estimate the population size.

The catch rates of v-notched lobsters are approximately 10-15% of the catch of legal lobsters (Table 11). Using this ratio, however, to estimate the population size gives unrealistically low population estimates and they have not been included here.

The population estimates may be unreliable for a number of reasons including

- the ratio of LPUE:VPUE is highly variable (Fig. 30) implying that any population estimate based on these data would have a high variance
- the estimated number of v-notched lobsters in the stock could be higher than estimated if M and R (the rate of repair of the notch) were in fact lower than the rates used
- the number of v-notched lobsters could be higher due to unaccounted notching of lobsters with damaged tail fans at sea. This would drive up the VPUE index
- catchability of v-notch lobsters may be higher because they are not randomly distributed in the population especially during the days or weeks after release. Repeated re-capture may also increase catchability – i.e lobsters can become habituated to entering traps.

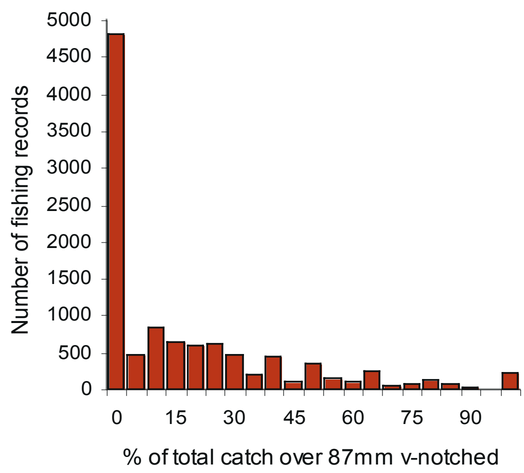


Figure 30. Distribution of catch rates of v-notched lobsters as a percentage of legal lobsters in the southeast fishery between 1995-2004. The graph is truncated at

Table 11. Catch rates(lobsters per 100 trap hauls) of v-notched and legal lobsters in the south east lobster fishery 1995-2004.

		VPUE		LPUE		Ratio
Year	**N**	**Mean**	**S.d.**	**Mean**	**s.d.**	**VPUE/LPUE**
1995	1930	0.18	0.41	7.57	5.17	0.02
1996	1984	0.58	1.02	7.23	5.30	0.08
1997	1537	0.75	0.96	7.06	4.65	0.11
1998	1061	1.05	1.21	7.75	5.92	0.14
1999	590	0.89	1.09	8.06	9.27	0.11
2000	662	0.59	0.68	6.86	4.63	0.09
2001	401	0.59	0.72	6.24	4.24	0.10
2002	1368	1.20	1.78	10.31	9.67	0.12
2003	1259	1.03	1.32	9.19	7.98	0.11
2004	419	1.39	1.52	9.44	7.09	0.15

100%.

Reproductive potential of v-notched lobsters

The v-notch programme is designed to increase population egg production and recruitment of lobsters. The annual reproductive potential (RP) of these lobsters can be estimated as follows

$$RP = \sum_{i=1}^{N\ Sizes} N_v(i) \times P_{mature}(i) \times P_{spawn}(i) \times fecundity(i)$$

where $N_V(i)$ is the number of v-notched lobsters in size class i, $P_{mature}(i)$ is the proportion of lobsters in the size class that are mature and $P_{spawn}(i)$ is the probability of annual spawning.

The egg production in 2005 from v-notched lobsters released in 2002-2004, discounted for mortality and repair of the notch, was 11.6 million eggs (Fig. 31). The reproductive value of lobsters in the large size classes is higher relative to the numbers released because of higher fecundity and proportional maturity. Given unknown stock size (see above) the proportion of total eggs provided by the v-notched females is unknown.

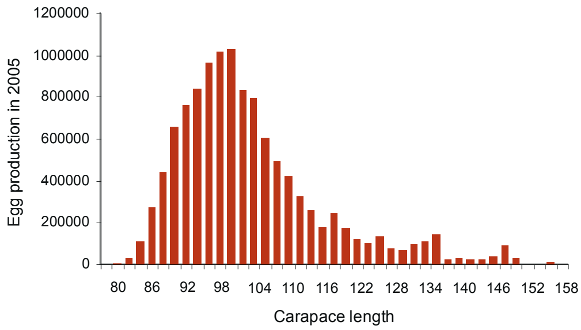
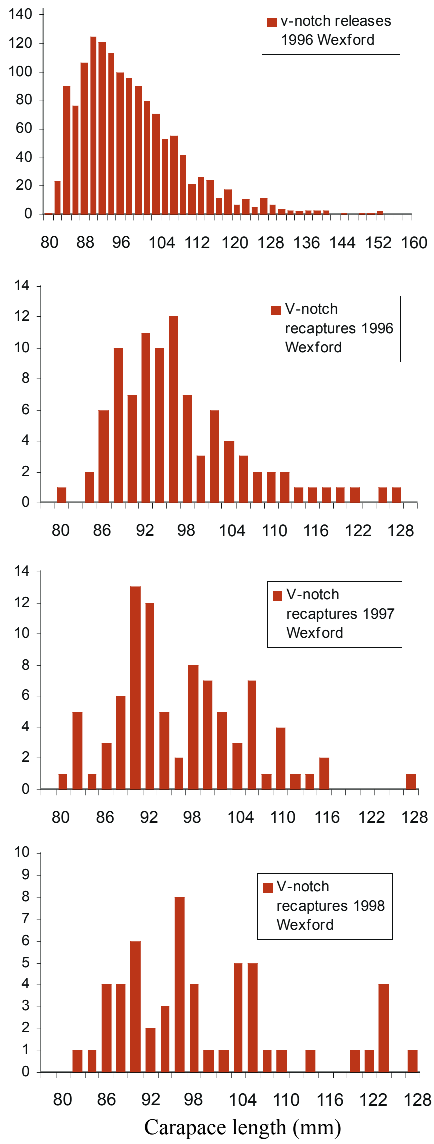


Figure 31. Estimated egg production in 2005 from v-notched lobsters released during the 2002-2004 period. Numbers released were discounted for mortality and notch repair as described above.

Size distribution of recaptured v-notched lobsters

V-notched lobsters in the stock are not exposed to fishing (F=0). The size distribution of these lobsters will, therefore, change relative to the rest of the stock and, as maturity and fecundity are size related, their individual contribution to egg production will increase.

The size distribution of v-notched lobsters recaptured in the fishery shows that they are on average larger than non v-notched lobsters (Fig. 32). Annual moult probability and increments in relation to size, however, are unknown but data on growth is being collected in County Clare and Galway as part of the v-notch and tagging programme.



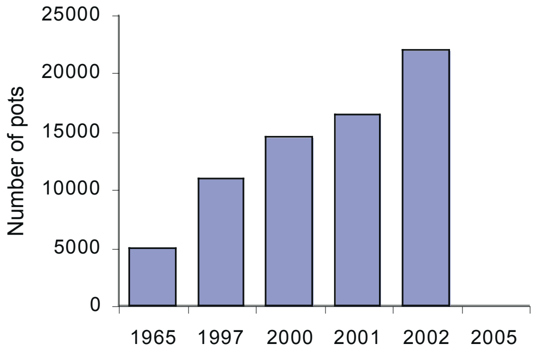


Figure 32. Size distributions of v-notched lobsters released in 1996 and the size distribution of recaptures in 1996-1998 in the Wexford fishery.

6. Lobster fishery indicators

Number and profile of vessels

In 2001 55 vessels, with more than 100 pots, and a further 12 with less than 100 pots fished from ports in south Wexford between Duncannon in the west and Rosslare in the east. The number of vessels with >100 pots in 2005 was approximately 50 or 5 less than in 2001.

Fishing effort potential

Although the number of vessels is stable or declining the effort potential (pots owned) probably doubled between 1997-2002. The current effort potential is at least equal to if not greater than that in 2002 (Fig. 33).

Figure 33. Fishing effort potential in the south Wexford fishery between 1965-2002.

Interaction with crab fisheries

By-catch rates of lobster in the southeast crab fishery were 2.77±2.54 and 2.33±2.08 lobsters per 100 crab pots in 2002 and 2003 respectively. These are approximately 25% of the targeted catch rates for lobster.

The South West Fishery (Cork and Kerry)

1. Landings

Landings of lobster in Cork and Kerry (Fig. 34) averaged a combined 210 tonnes annually between 1990-2004 and peaked at 310 tonnes in 2004 (Fig. 35).

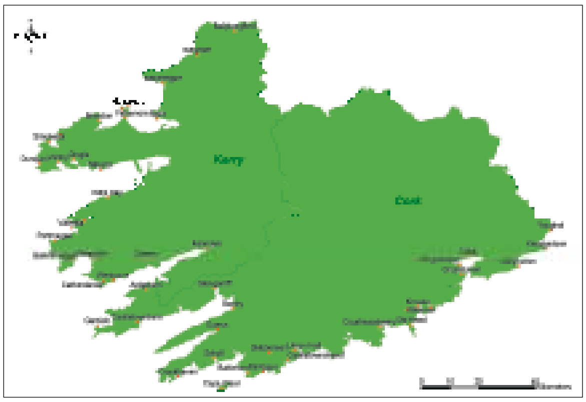


Figure 34. The area of the Cork and Kerry fishery and the main lobster landing points.

In Cork landings declined annually between 1990-1994 and increased from 1996-1999. They declined significantly in 2000 but increased annually between 2000-2004. Landings in 2004 were the second highest in the 1990-2004 period. Landings in Kerry fluctuated between a low of 82 tonnes in 2003 and a high of 163 tonnes in 2004 during the period 1990-2004 (Fig. 35).

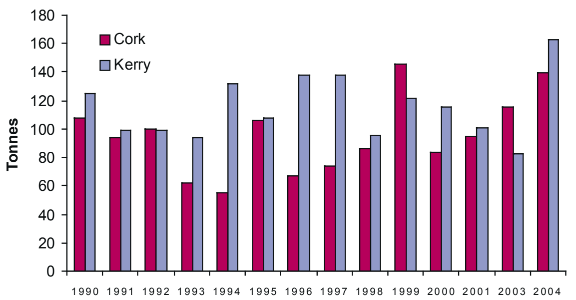


Figure 35. Annual landings of lobster into Cork and Kerry from 1990-2004

2. Catch rates

Kerry

Legal lobsters 1996-1999

Logbook data were collected by Taighde Mara Teoranta in Kerry in 1996-1999. These data are similar to the pre 2002 Wexford data in that they combine targeted and by-catch catch rates. They cannot therefore be combined with data collected in 2002-2004. A GLM model was fitted only to the 2002-2004 data.

Monthly catch rates peaked in May-June. The annual non-standardised index declined from 13 to 8 lobsters per 100 pots between 1997 and 1999 (Fig. 36).

Undersized lobster 1996-1999

Catch rates of undersized lobsters showed the opposite pattern to that of legal lobsters. Catch rates declined from 1996-1998 but increased substantially in 1999 (Fig. 36).

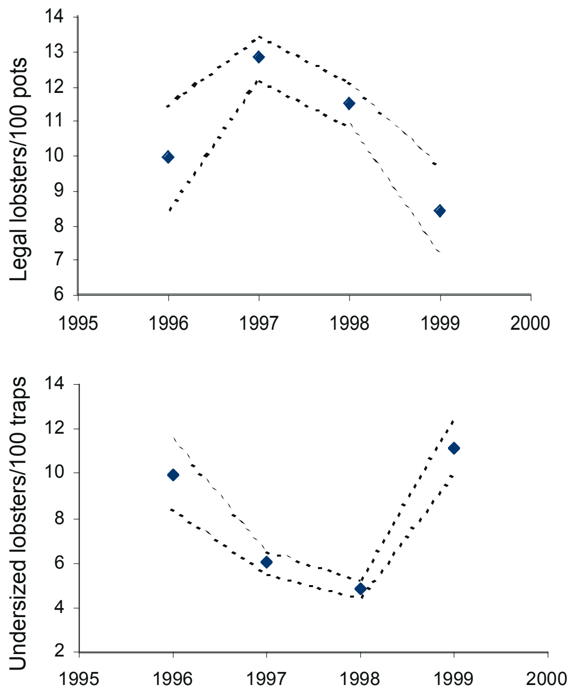


Figure 36 Catch rates of legal and undersized lobsters off the Kerry coast in 1996-1999. Dotted lines are the 95% confidence limits.

Legal sized lobster 2002-2004

Monthly catch rates in Kerry peaked in May-June of each year. Linear declines in monthly catch rates were apparent in 2003 and 2004 as the season progressed (Fig. 37). The annual non-standardised index of catch declined from 16.5 to 13.3. The index for undersized lobster was relatively constant (Fig. 38).

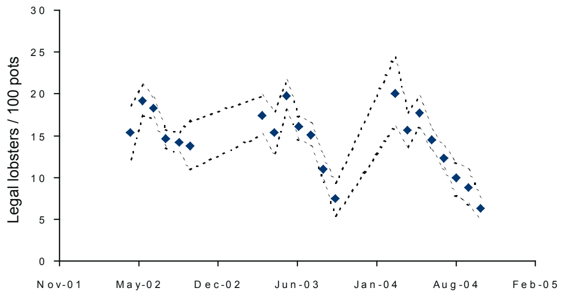


Figure 37. Monthly catch rates of legal lobster from Apr 02 – Dec 04 off the Kerry coast. Dotted lines are 95% confidence limits.

Standardised (GLM) catch rates

Year month interactions, although statistically significant, accounted for a relatively small proportion of the variance in the 2002-2004 data and was not retained in the GLM. March to December data and data from six vessels, which submitted most data, were included. Year, month and vessel were incorporated as factors in the model. The index was standardised to one vessel and month.

The model accounted for 25% of the variance in the data. The annual non-standardised index from the fishing activity records showed a decline from 16.5 to 13.2 lobsters per 100 pot hauls between 2002-2004. The standardised scaled index showed a decline from 2002-2003 but an increase in 2004 (Fig. 39).

There was an overall decline in the catch rates of undersized lobsters

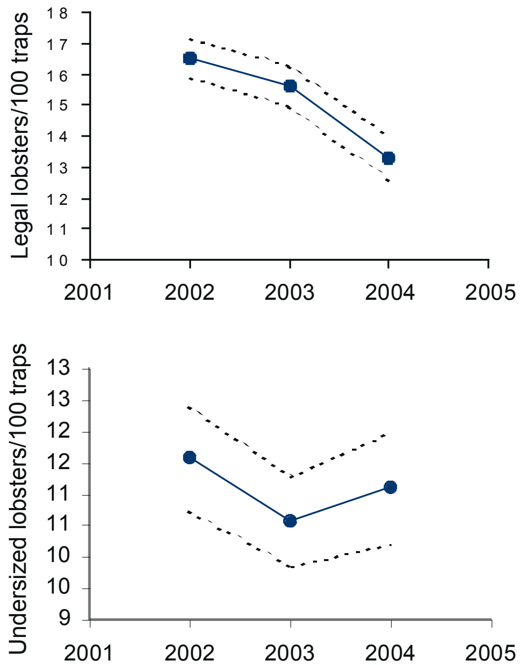


Figure 38. Annual non-standardised catch rates of legal and undersized lobsters off the Kerry coast in 2002-2004. Dotted lines are 95% confidence limits.

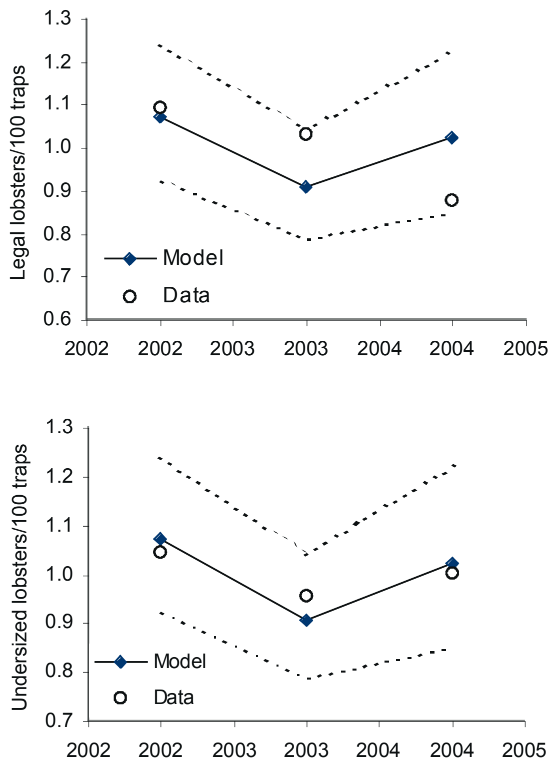


Figure 39. Annual scaled indices of catch rates of legal and undersized lobsters off the Kerry coast in 2002-2004. Dotted lines are 95% confidence limits for the model.

Cork

The catch rates of legal sized lobsters increased substantially between 2002-2004 from 10 to 17 lobsters per 100 traps (Fig. 40). Catch rates of undersized lobsters were highest in 2003 at approximately 21 lobsters per 100 traps. These estimates are based on a total of 469 boat fishing days over the three years or an average of 156 boat days per year. No models have been fitted to these data.

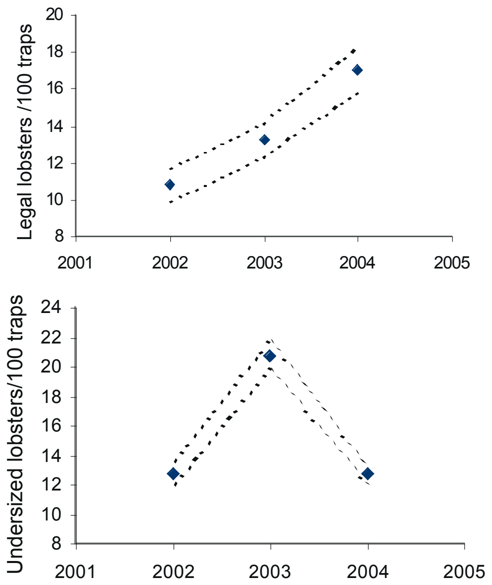


Figure 40. Catch rates of legal and undersized lobsters off the Cork coast between 2002-2004. Dotted lines are 95% confidence limits

3. Biological Data

Size distributions

Taighde Mara Teo. collected data on the size distribution of the landings in Cork and Kerry in 1998-1999. The MLS was 85mm CL at that time. Modal size ranged from 86-92mm. The size distributions for male and female lobsters were largely similar (Fig. 41).

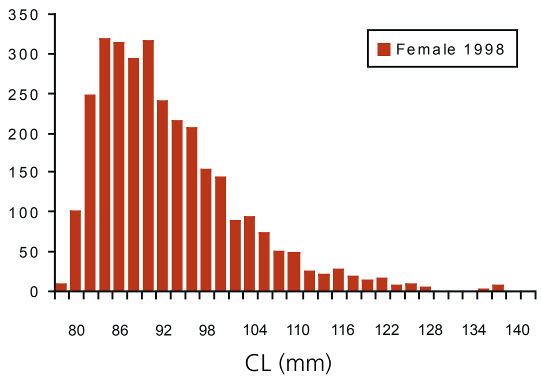
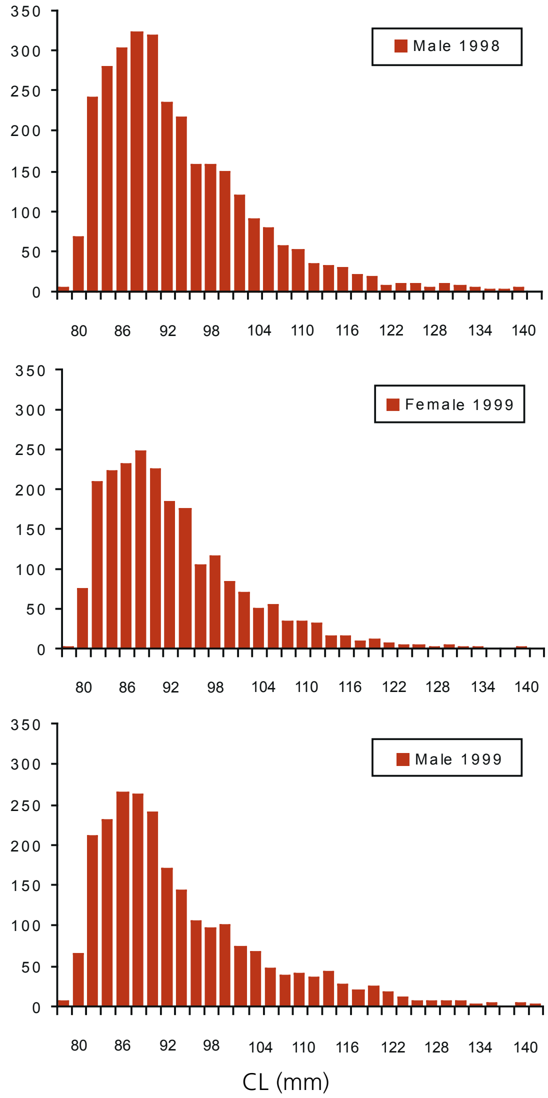


Figure 41. CL distributions of male and female lobsters in the landings in Cork-Kerry in 1989 and 1999.



Size at maturity

The size at maturity of lobsters in the southwest was evaluated in 1999 (Tully *et al*. 2001). The size at which 50% of lobsters are expected to be mature is 95 mm (Fig. 42). The maturity ogive can be described by the function

$$P_{mature} = \frac{1}{1+e^{11.6-0.126CL}}$$

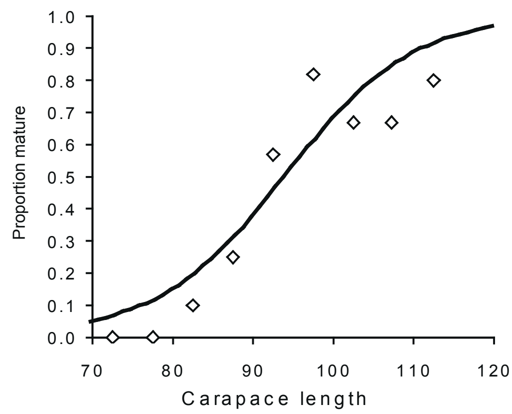


Figure 42. Size at maturity of lobsters in the southwest (from Tully *et al*. 2001).

4. Assessment and Management

Length Cohort Analysis (LCA)

Model Conditions

LFDs for each year were converted into % frequencies in 4mm CL groups and an aggregate plus group at 124mm CL. LCA was performed for each sex separately for average LFDs for the period 1998-99. LFDs for 1998 and 1999 were almost identical. Terminal F was adjusted to be the same as for the adjacent size class, except for 1998, where this gave anomalous results.

Biological parameters were the same as for the southeast analysis except for the size at maturity relationship (see above).

LCA results

Annual Fishing Mortality (F)

Estimates of annual fishing mortality (F) varied between 0.4 and 0.55 depending on M. Mortality of female lobsters was higher than that of males (Fig. 43).

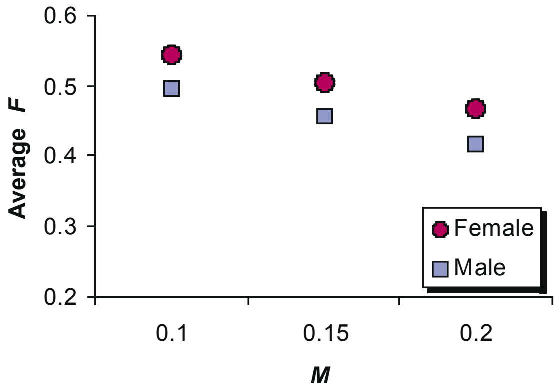


Figure 43. Annual average fishing mortality, F, for male and female lobsters, using 1998-1999 data, at three levels of natural mortality

F at length

MLS during 1998 and 1999 was 85mm CL. Fishing mortality occurred on size classes down to 80-84mm. Lobsters were fully recruited to the fishery at 95mm, which is 1 moult increment above the MLS. F at length was similar for males and females although the male curve is lower above 95mm. M acts as a scaling factor for the curves with higher F at lower M.

Yield per recruit

The benefit in yield per recruit from changing from $F_{current}$ to F_{max} depends on M. Gains are greater at low values of M but are negligible at M=0.2 (Fig. 44).

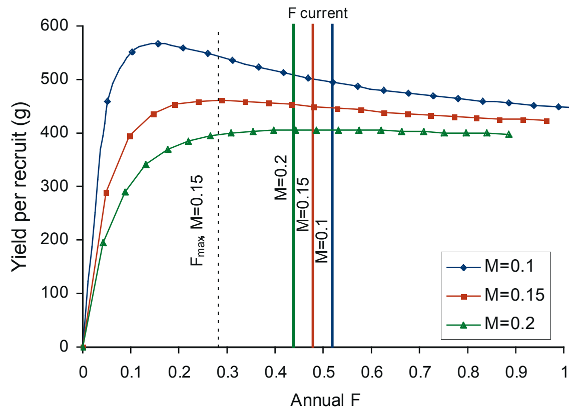


Figure 44. Y/R curves for male and female lobsters combined in relation to F at three values of M using 1998-1999 length frequency data. $F_{current}$ for each value of M and F_{max} for M=0.15 are shown

Egg per recruit

E/R for a given F declines as M increases and declines monotonically as F increases. At current F E/R is a fraction of the egg production at F=0 (Fig. 45).

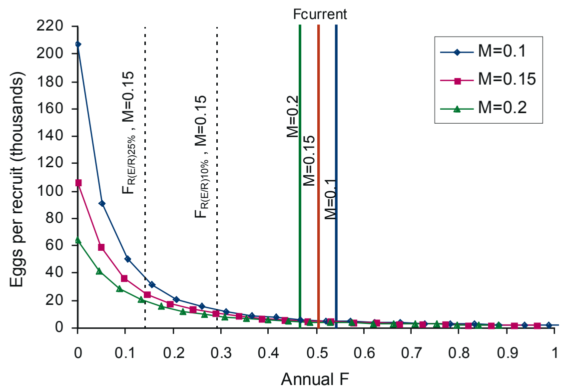


Figure 45. E/R of lobsters in the southwest as a function of F and M for input length frequency data from 1998-1999. $F_{current}$ for 3 values of M and F at 10% limit and 25% target E/R are shown.

R (E/R) F relative to F=0 is shown in Fig. 46.

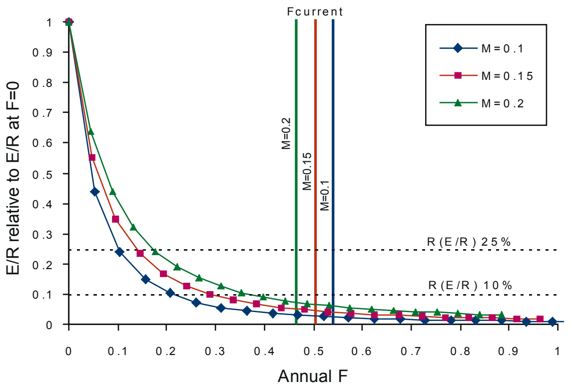


Figure 46. The proportion of potential egg production per recruit at different values of F. Results are presented for 3 values of M for aggregated 1998-1999 and 2005 length frequency data. Limit R(E/R10%) and target (R(E/R25%) reference points of 10% and 25% of egg production respectively are indicated.

Management Options

F at $R_{(E/R)}$ reference points (no change in TCMs)

Current fishing mortality is likely to be in the range of 0.44-0.52 depending on M. Between 17-59% reductions in F are required to achieve E/R limits and 61-81% reductions in F are required to reach the E/R target depending on M (Table 13).

Table 13. Reference points for F at current fishing patterns

Reference points for F no changes to TCMs			
M	$F_{current}$	$F_{R(E/R)\ 10\%}$	$F_{R(E/R)\ 25\%}$
0.1	0.52	0.21	0.1
0.15	0.48	0.29	0.14
0.2	0.44	0.37	0.17
***F*-multipliers for reference points no changes to TCMs**			
M	$F_{current}$	$F_{R(E/R)\ 10\%}$	$F_{R(E/R)\ 25\%}$
0.1	1	0.41	0.19
0.15	1	0.6	0.28
0.2	1	0.83	0.39

Reference points for F with MLS and MaxLS, 1998-2005 data, M=0.15

Fishing mortality at E/R reference points could be higher under a new selection pattern of MLS and MaxLS than with the current selection pattern (Table 14).

Table. 14. Reference points for F with different MLS and MaxLS. Shaded cells indicate the *status quo* or current size selection pattern in the fishery

$F_{current}$ (sexes combined, current effort levels):				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.46	0.47	0.47	0.48
85	0.42	0.44	0.44	0.45
87	0.39	0.4	0.41	0.41
90	0.34	0.35	0.35	0.36
95	0.26	0.27	0.27	0.28
$F_{E/R\ 10\%}$:				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.41	0.38	0.36	0.29
85	0.4	0.37	0.34	0.28
87	0.38	0.35	0.33	0.27
90	0.36	0.33	0.31	0.25
95	0.34	0.31	0.29	0.25
$F_{E/R\ 25\%}$:				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.24	0.22	0.2	0.14
85	0.23	0.21	0.19	0.13
87	0.22	0.2	0.18	0.12
90	0.2	0.18	0.17	0.11
95	0.18	0.16	0.15	0.1

F-multipliers for reference points with MLS and MaxLS, 1998-2005 data, M=0.15

Substantial increases in effort could occur at various new combinations of MLS and MaxLS for an E/R limit of 10% (Table 15). Target E/R of 25% would require new MLS, a MaxLS and reductions in effort of 20-30%. Current E/R is below 10% and under current effort regimes would reach 10% only with some combination of MLS up to 95mm and a maximum size of at 130mm or lower.

Table 15. F-multipliers (relative to current F) under new MLS and MaxLS. Shaded cells indicate the status quo or current size selection pattern in the fishery

***F*-multiplier for maximum Y/R (sexes combined):**				
		MaxLS (mm CL)		
MLS (mm CL)	120	125	130	none
80	1	0.89	0.81	0.57
85	1.06	0.94	0.84	0.59
87	1.13	0.99	0.89	0.62
90	1.27	1.11	0.98	0.68
95	1.66	1.4	1.21	0.84
***F*-multiplier for E/R 10%:**				
		MaxLS (mm CL)		
MLS (mm CL)	120	125	130	none
80	0.91	0.82	0.75	0.6
85	0.94	0.84	0.77	0.62
87	0.98	0.88	0.8	0.65
90	1.07	0.95	0.87	0.7
95	1.33	1.17	1.05	0.87
***F*-multiplier for E/R 25%:**				
		MaxLS (mm CL)		
MLS (mm CL)	120	125	130	none
80	0.52	0.46	0.42	0.28
85	0.53	0.47	0.43	0.29
87	0.55	0.49	0.44	0.3
90	0.59	0.52	0.47	0.31
95	0.71	0.61	0.54	0.35

5. V-notched lobsters

V-notched lobsters have been released in the Cork and Kerry fishery since the mid 1990s. No length frequency data are available for these and the total numbers released were not compiled for this report. From 2002-2004 all releases were measured and total numbers recorded. The length distribution of lobsters released in 2002-2004 is shown in Fig. 47. There are insufficient data on the size distribution of recaptured v-notched lobsters to report here.

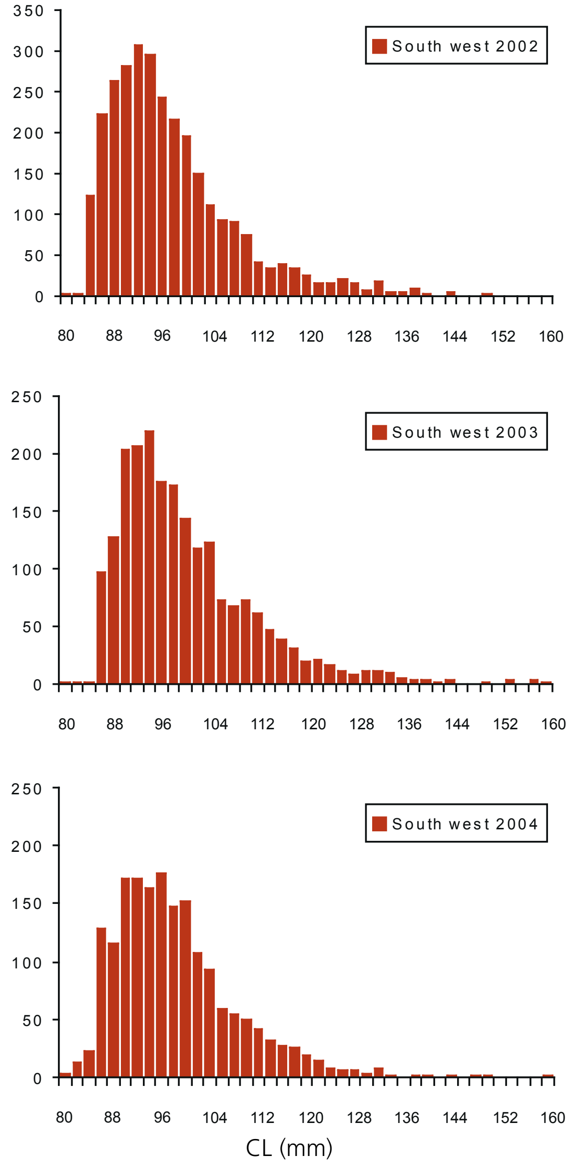


Figure 47. LFDs of female lobsters released in Cork and Kerry in 2002-2004.

Catch rates of v-notched lobsters

The catch rate of v-notched lobsters in 2004 was 2.33 lobsters per 100 pots or 14.4% of the catch of legal lobsters. A progressive increase in the % of the catch that was v-notched occurred in 1996-1998 before falling slightly in 1999 (Table 16). This percentage declined to 12% by 2002 as notching activity declined or stopped in 2000-2001.

Table 16. Comparison of catch rates of v-notched and legal sized lobsters in the Cork and Kerry fishery. Data prior to 2002 is from Kerry only and includes by-catch data from the crab fishery.

Year	N	LPUE		VPUE		%VPUE
		Mean	s.d.	Mean	s.d.	
1996	130	9.93	8.52	0.90	1.47	9.1
1997	350	12.82	6.00	2.37	2.15	18.5
1998	478	11.48	6.87	2.81	2.19	24.5
1999	101	8.40	6.05	1.80	1.87	21.5
2002	815	15.31	7.95	1.84	1.85	12.0
2003	932	15.25	8.98	3.12	4.55	20.4
2004	792	14.06	8.78	2.03	2.33	14.4

6. Lobster fishery indicators

Number and profile of vessels

Thirty one vessels fished for lobster in northwest Kerry in 2005. These vessels fished for a variety of species but in most cases (24 vessels) their primary species was lobster. Crayfish and spider crab were also important.

Soft eye creels are used to target lobster and top entrance inkwell or D-shaped hard eye pots are used for spider crabs but also lobster when the spider crab season is over. Tangle nets are used for crayfish. The mix of potting gear is unique to northwest Kerry as this area has the largest spider crab fishery in the country. Over 4000 hard eye top entrance pots and 3000 soft eye creels are fished in the area.

In west Kerry 41 vessels fished for lobster in 2005. As in northwest Kerry, a number of species are targeted but lobster is the primary target species for approximately 25 of the 41 vessels. A number of gears are also fished but the main type of pot is the soft eye creel of which there are over 4100. Approximately 900 hard eye top entrance pots are used to fish for spider crabs and lobsters.

Data for south Kerry was not available at the time of writing this report.

Interaction with other fisheries

Brown Crab

Lobsters are caught as a by-catch in the targeted crab fishery in the southwest. By-catch rates varied from 2.5-4.0 lobsters per 100 crab pot hauls in 2002-2004 (Table 17). These are approximately 20-25% of targeted lobster catch rates in the lobster fishery. The total number of lobsters caught in the crab fishery or the total crab effort in the area is unknown

Table 17. By-catch rates (per 100 pot hauls) of lobster in the brown crab fishery in Kerry and Cork in 2002-2004.

Year	N	Mean	S.d.
2002	218	3.96	3.91
2003	208	2.50	3.40
2004	126	3.36	2.98

Spider crab

The spider crab fishery in northwest Kerry is an early summer fishery. Top entrance hard eye pots used in this fishery have an unknown by-catch of lobster. This gear is also transferred to the lobster/brown crab fishery during the summer.

Crayfish

Tangle nets are used to target crayfish off the south and southwest coasts. There is an unknown by-catch of lobsters in the tangle net fishery.

The Mid West Fishery (Clare and Galway)

1. Landings

Landings of lobster in Clare and Galway (Fig. 48) averaged a combined 211 tonnes annually between 1990-2004 and peaked at 273 tonnes in 2004 (Fig. 49).

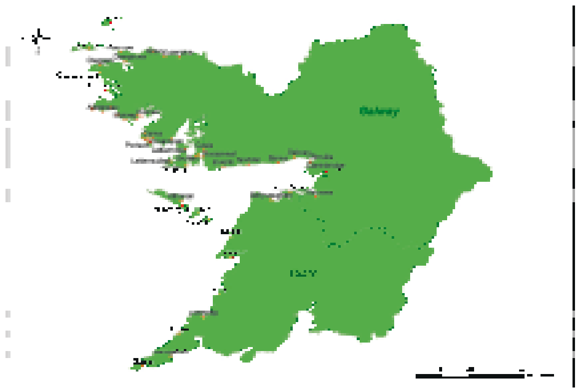


Figure 48. The area of the mid-west lobster fishery and the main lobster landing points

In Clare landings fluctuated between 36 and 164 tonnes during 1990-2004. The years 1994, 1998 and 2001 were peak years with substantially higher (>150 tonnes) landings compared to other years (<100 tonnes). Landings in Galway ranged between 89-189 tonnes between 1990-1994, were stable at 90-100 tonnes between 1995-2000 and increased to 160-180 tonnes in 2001-2004 (Fig. 49).

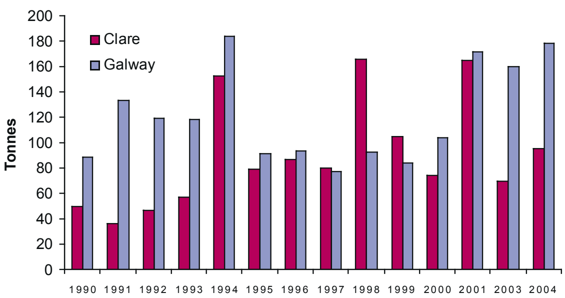


Figure 49. Annual landings of lobster into Clare and Galway from 1990-2004

2. Catch rates

Galway

No data are available for 2004. Catch rates of legal lobsters were higher in 2003 (16.2±10.1, n=105) compared to 2002 (14.8±7.4, n=222) although the catch rate of undersized lobsters was higher in 2002 (18.2±14.5) compared to 2003 (16.3±10.8).

Clare

Catch rates of legal and undersized lobsters increased substantially in the period 2002-2004. However, the data were relatively poor in 2002 and 2003 (averaging less than 100 boat days) compared to 300 days in 2004 (Fig. 50).

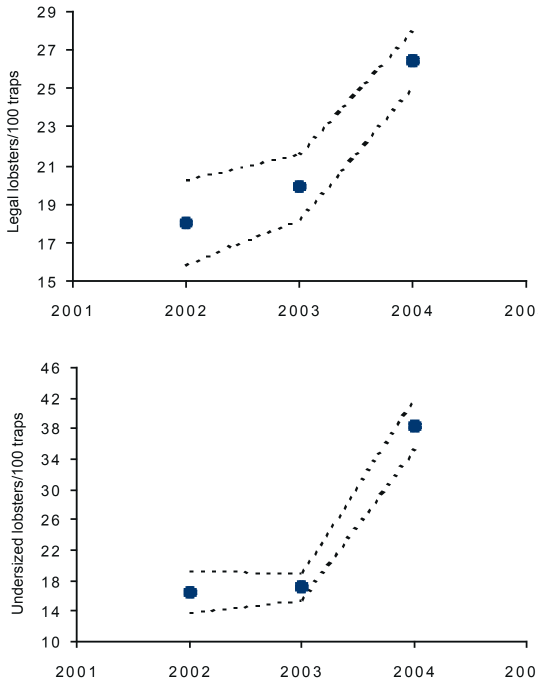


Figure 50. Catch rates of legal and undersized lobsters off the Clare coast in 2002-2004. Dotted lines are 95% confidence limits

3. Biological Data

Size distributions

Data on the size distribution of the landings were collected in 1998, 1999 and 2005 at buyers' premises in Galway and Clare. The mean size of lobsters in the landings varied between 94-96 mm CL or one moult above the MLS. Larger lobsters over 110mm CL were relatively less common in the landings in 2005 compared to 1998-1999 (Fig. 51).

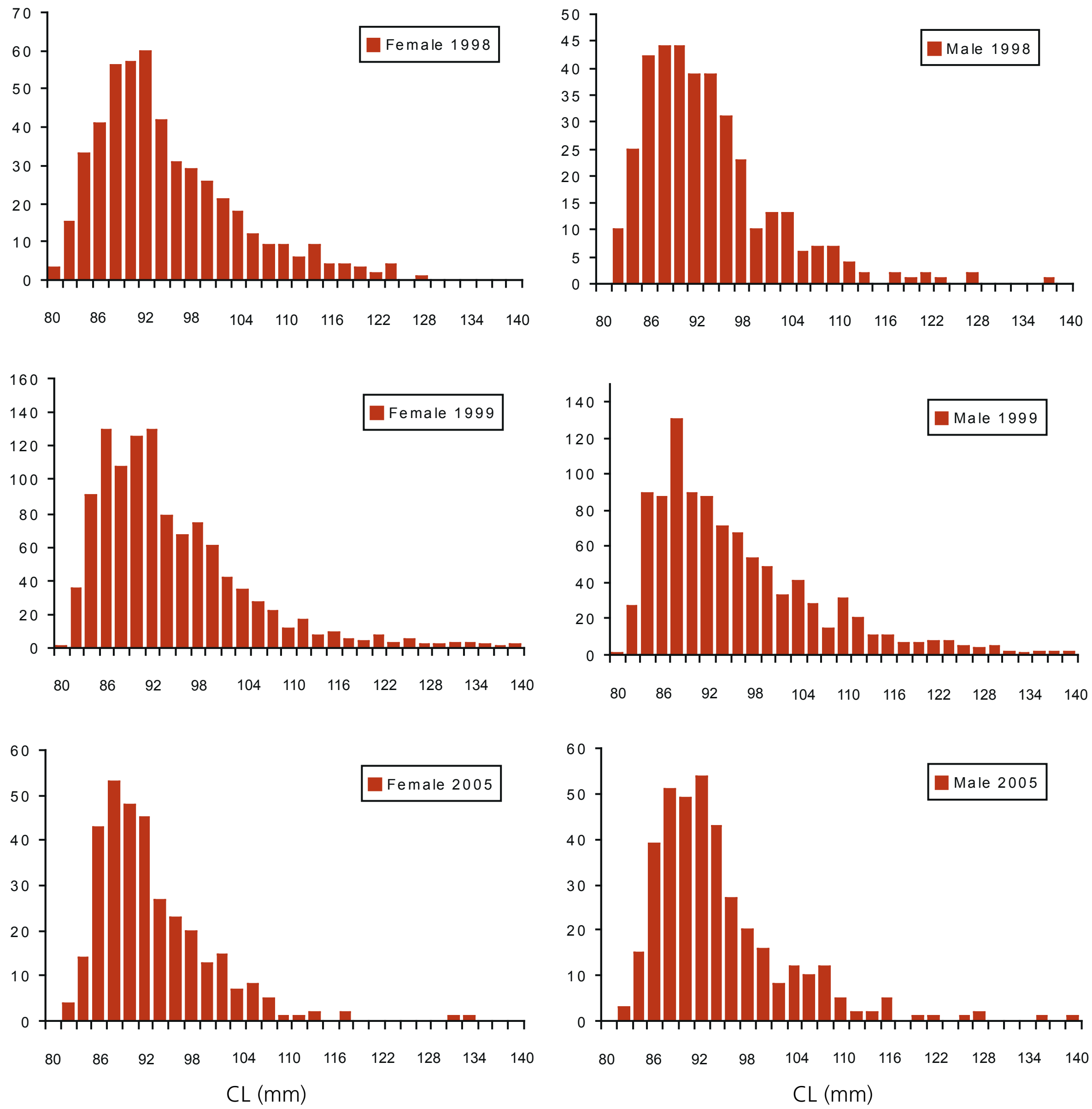


Figure 51. LFDs of the landings of male and female lobsters in Galway and Clare in 1998, 1999 and 2005.

Size at Maturity

The size at maturity of lobsters in Galway and Clare was evaluated in 1999 (Tully *et al*. 2001). The size at which 50% of lobsters are expected to be mature, is 93mm. The maturity ogive can be described by the function

$$P_{mature} = \frac{1}{1+e^{30.6-0.330CL}}$$

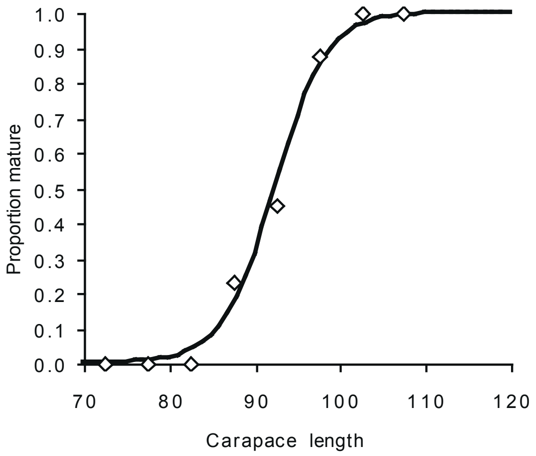


Figure 52. **Size at maturity of lobsters in Galway and Clare (from Tully *et al*. 2001)**

4. Assessment and Management

Length Cohort Analysis

Model conditions

LFDs for each year were converted into % frequencies in 4mm CL groups and a plus group at 120mm CL. LCA was performed for each year and sex separately and for average LFDs for each sex for the periods 1998-99 and 1998-2005. Terminal F was refined to be the same as for the adjacent size class.

Model parameters were the same as those for the southeast except for the maturity ogive (see above).

LCA Results

Annual F

Annual average levels of fishing mortality ranged between 0.5 and 0.6 (Fig. 53). F is higher in 2005 because the proportion of large lobsters in 2005 was lower.

F at length

Full selection by the fishery occurs at about 95 mm CL or approximately 1 moult above the MLS. There is some decline in selection at larger sizes.

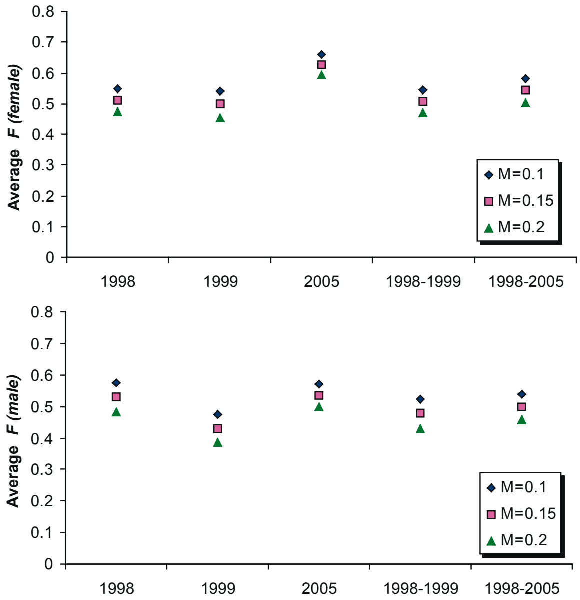


Figure 53. **Annual fishing mortality (F) on male and female lobsters between 1995-2005 in the mid-west fishery in relation to natural mortality (M). Estimates are based on LFDs for individual years and for groups of years – note that the individual year estimates are not the same as annual estimates relating solely to that year.**

Yield per recruit

The shape of the Y/R curve is sensitive to the rate of natural mortality. Peaks in Y/R, however, occur at values of F substantially lower than current values of F (Fig. 54). Reductions in F of 35-50% are required to reach F_{max} for a Y/R gain of approximately 8% if M=0.1.

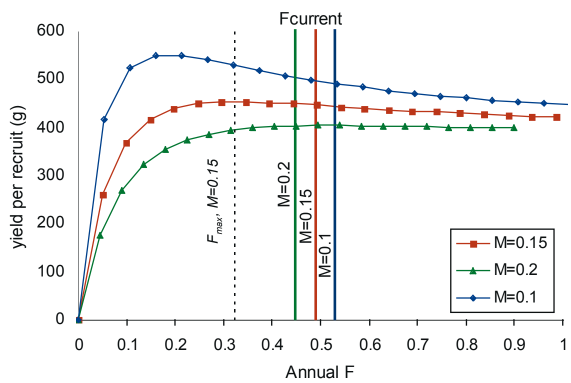


Figure 54. **Y/R curves for the mid-west fishery for male and female lobsters combined in relation to F at three values of M using 1998-1999 length frequency data. F current for each value of M and F_{max} for M=0.15 are shown.**

Egg per recruit

E/R depends on the value of natural mortality but the shape of the curves are consistent and independent of the length data used to derive them The position of F current was higher based on 2005 data than from 1998-1999 data (Fig. 55).

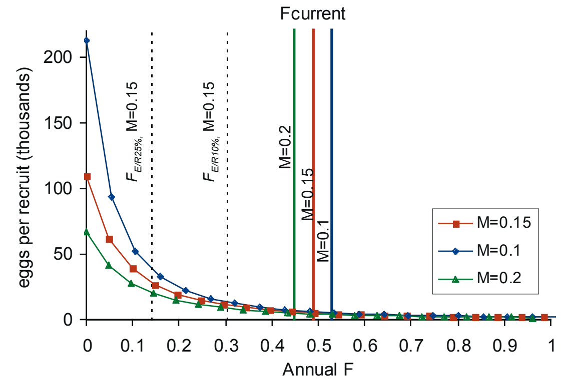


Figure 55. E/R curves for the mid-west fishery in relation to F at 3 values of M for length frequency data 1998-1999. F current for 1998-99 in relation to M and limit (10%) and target (25%) E/R reference points are shown.

E/R is below the E/R limit and target reference points at F current estimated for 1998-1999 and for M between 0.1-0.2 (Fig. 56).

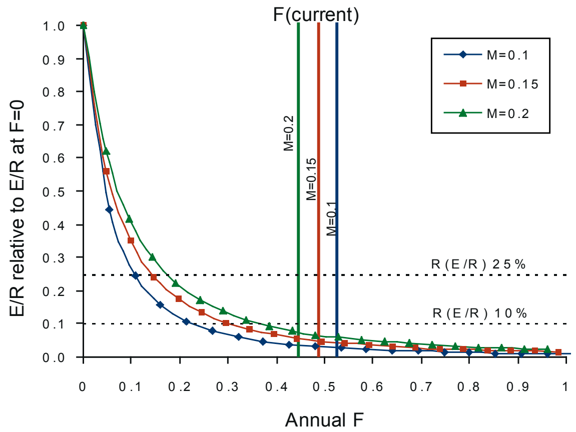


Figure 56. R(E/R) at different values of F and in relation to $F_{current}$. Results are presented for 3 values of M for 1998-1999 length frequency data. Limit R(E/R10%) and target R(E/R25%) reference points of 10% and 25% of egg production respectively are indicated.

Management Options

F at $R_{(E/R)}$ reference points (no change in technical measures)

Values of F based on 2005 data were in the range 0.55-0.62 depending on M. Substantially lower values of F are required to achieve E/R of 25% of egg production (Table 18).

Table. 18. $F_{current}$ and F at E/R reference points

$F_{current}$ (sexes combined):			
M	1998-1999	2005	1998-2005
0.1	0.53	0.62	0.56
0.15	0.49	0.58	0.52
0.2	0.45	0.55	0.48
***F* E/R 10%:**			
M	1998-1999	2005	1998-2005
0.1	0.22	0.17	0.22
0.15	0.3	0.24	0.29
0.2	0.38	0.3	0.37
***F* E/R 25%:**			
M	1998-1999	2005	1998-2005
0.1	0.11	0.08	0.1
0.15	0.14	0.11	0.14
0.2	0.18	0.14	0.17

F-multipliers for E/R reference points (no change in technical measures)

For the period 1998-2005 and M of 0.15 reductions in F of around 40% would be expected to achieve $R_{E/R\ 100\%}$ (Table 19). Almost 70% reduction in F is required to achieve target $R_{E/R\ 25\%}$.

Table. 19. F multipliers for egg production reference points

***F*-multiplier for E/R 10%**			
M	1998-1999	2005	1998-2005
0.1	0.42	0.28	0.38
0.15	0.62	0.41	0.56
0.2	0.84	0.56	0.76
***F*-multiplier for E/R 25%**			
M	1998-1999	2005	1998-2005
0.1	0.2	0.13	0.18
0.15	0.29	0.19	0.27
0.2	0.4	0.25	0.36

F at $R_{(E/R)}$ reference points (with changes in technical measures)

Substantial reductions in F would be required to reach E/R reference points even with changes in MLS or introduction of MaxLS (Table 20).

Table 20. Reference points for F with different MLS and MaxLS. Shaded cells indicate the status quo or current size selection pattern in the fishery

$F_{current}$ (sexes combined, current effort levels)				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.51	0.52	0.52	0.52
85	0.47	0.47	0.47	0.47
87	0.44	0.44	0.44	0.44
90	0.37	0.37	0.38	0.38
95	0.28	0.28	0.28	0.28
$F_{E/R\ 10\%}$				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.42	0.39	0.36	0.29
85	0.4	0.36	0.33	0.27
87	0.39	0.35	0.32	0.26
90	0.36	0.33	0.3	0.25
95	0.35	0.31	0.28	0.24
$F_{E/R\ 25\%}$				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.24	0.22	0.2	0.14
85	0.23	0.2	0.19	0.13
87	0.22	0.2	0.18	0.12
90	0.2	0.18	0.16	0.11
95	0.18	0.16	0.14	0.1

F-multipliers for E/R reference points for F with changes in TCMs

Effort could be retained at current levels or could increase with an increase in MLS and the introduction of a MaxLS (Table 21).

Table 21. F Multipliers for E/R reference points under different

MLS and MaxLS

***F*-multiplier for E/R 10%**				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.83	0.75	0.69	0.56
85	0.85	0.77	0.71	0.58
87	0.88	0.8	0.73	0.6
90	0.97	0.87	0.79	0.65
95	1.25	1.1	1	0.85
***F*-multiplier for E/R 25%**				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.48	0.43	0.39	0.27
85	0.49	0.43	0.39	0.27
87	0.5	0.45	0.4	0.28
90	0.54	0.48	0.43	0.29
95	0.67	0.57	0.51	0.34

5. V-notched lobsters

V-notched lobsters have been released into the fishery in the mid west since the mid 1990s. Size composition data for these releases are available from 2002 onwards (Fig 57). These distributions are generally similar to those of the landings.

V-notch recaptures

All lobsters released in Clare in 2004-2006 were tagged with an individually numbered streamer tag. Recapture data, recorded by fishermen in fishing activity records most of which comes from south Clare, for these lobsters shows the individual increases in size one or two years after release and also the reproductive condition relative to that on release.

The mean size of lobsters recaptured was 102mm and 105mm CL in 2004 and 2005 respectively. This is approximately 8mm and one moult above the average size of lobsters in the stock (Fig. 58). Tag recapture data for 2005 (n=828) and 2006 (n= 1039) indicates the annual probability of moulting, double moulting and spawning. A size increase of between 4-9mm is interpreted as one moult and increases of 10-14mm or greater than 15mm as two moults. Negative increments (smaller size at recapture relative to release) are regarded as errors in measurement and increments of 0-3mm as no growth. Following this interpretation 60% and 51% of lobsters moulted once during one year at liberty in 2004-2005 and 2005-2006 respectively. Twelve and 14% moulted twice during these years while 12% and 19% did not moult (Fig. 59).

The proportion of lobsters spawning annually appears to be 25% while 52% of lobsters with eggs at release had no eggs when recaptured the following year. While 5% without eggs on release still had not spawned the following year (Fig. 60).

The annual probabilities of moulting and spawning and the resultant growth and egg production are higher than the estimates for these parameters used in the E/R and Y/R models in this report. The estimates given, however, are sensitive to the date of release and recapture relative to the timing of moulting and spawning and need to be analysed further to give unbiased estimates of annual probability of moulting and spawning.

Catch rates of v-notched lobsters

Catch rates of v-notched lobsters increased from 1.37 per 100 pots in 2002 to 5.15 in 2004. The proportion of legal sized lobsters in the catch that were v-notched peaked at 26.8% in 2003 (Table 22).

Table 22. Comparison of catch rates (numbers per 100 traps hauls) of legal and v-notched lobsters in the Galway and Clare fishery in 2002-2004.

Year	N	LPUE		VPUE		%VPUE
		Mean	S.D.	Mean	S.D.	
2002	301	15.68	8.28	1.37	2.76	8.7
2003	281	18.54	10.91	4.97	5.08	26.8
2004	301	26.41	12.85	5.15	4.89	19.4

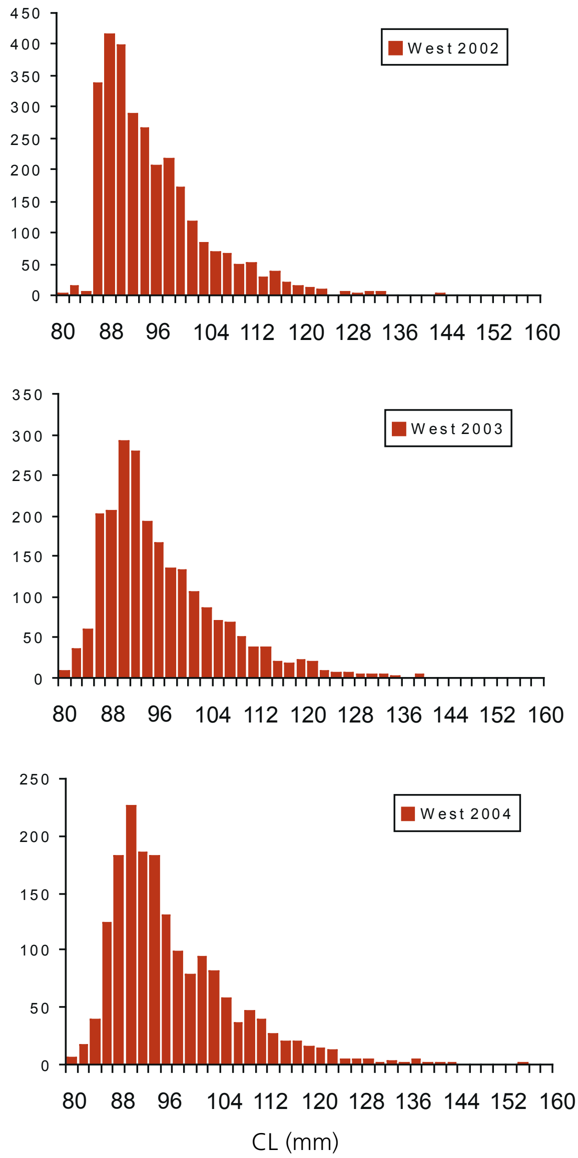


Figure 57. Size distribution of v-notched lobsters released into the fishery in Galway and Clare in 2002-2004. The majority of releases occurred in southwest Clare.

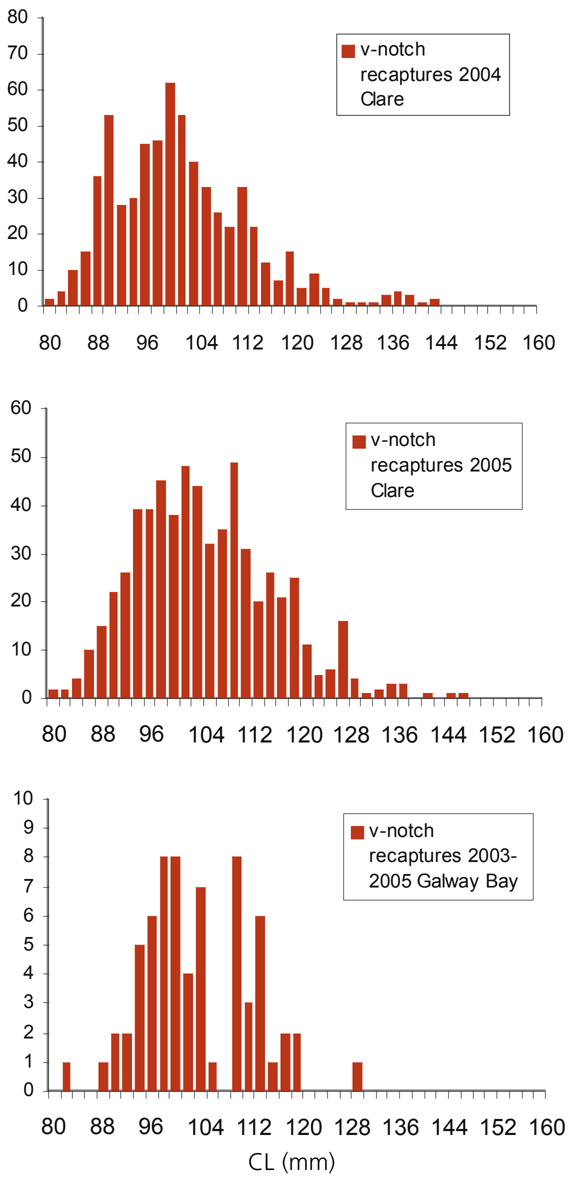


Figure 58. LFDs for v-notched lobsters re-captured during 2003-2005 off the Clare coast and in Galway Bay.

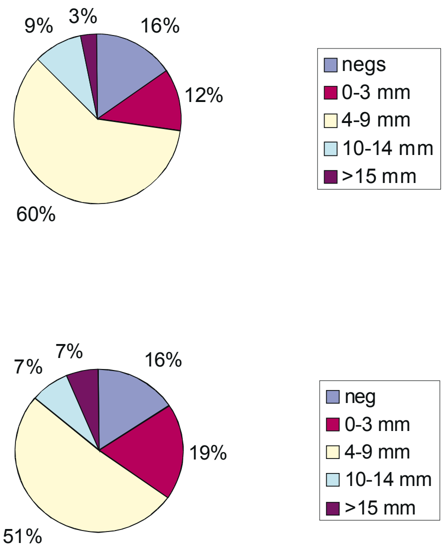


Figure 59. Growth of lobsters released in 2004 and recaptured in 2005 (top) and released in 2005 and recaptured in 2006 (bottom).

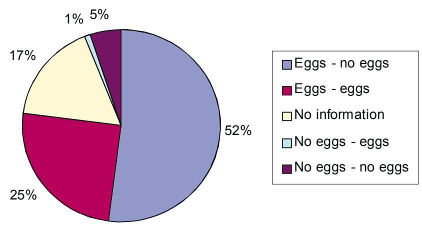


Figure 60. Reproductive condition one year after release (data for 2004–2005 and 2005–2006 combined). 1=Eggs when released, no eggs when recaptured; 2=eggs when released, and when recaptured; 3=no information provided when recaptured; 4=no eggs when released, eggs when recaptured; 5= no eggs when released or recaptured.

The North West Fishery (Mayo, Sligo and Donegal)

1. Landings

Landings of lobster in Mayo, Sligo and Donegal (Fig. 61) averaged a combined 123 tonnes annually between 1990-2004 and peaked at 200 tonnes in 2004 (Fig. 62).

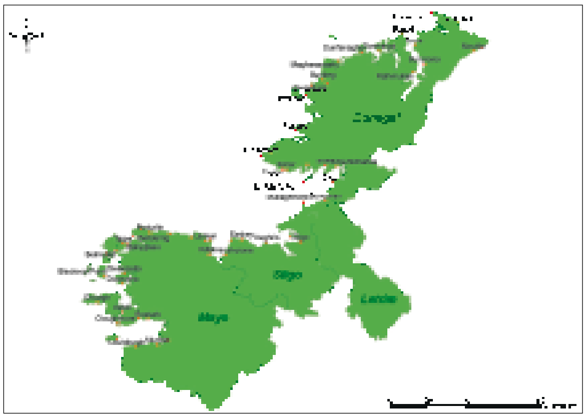


Figure 61. The area of the northwest lobster fishery and the main lobster landing points

In Mayo annual landings were less than 60 tonnes prior to 2000. Between 2000-2004 landings ranged from 85-121 tonnes. Landings in Sligo were generally less than 10 tonnes prior to 2003. In 2004 they were 21 tonnes. Landings in Donegal were generally stable between 1990-1999 averaging 51 tonnes per annum. This increased to an average of 70 tonnes between 2000-2004 (Fig. 62).

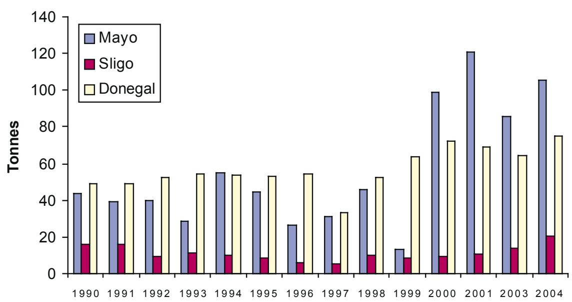


Figure 62. Annual landings of lobster into Mayo, Sligo and Donegal from 1990-2004

2. Catch rates

Catch rate data for the northwest region are quite poor. In Mayo in 2002 LPUE was 15.3±11.65 (n=301) lobsters per 100 traps.

Data compiled by the N&W Lobster Fishermen's Co-operative in 1998 and 1999 show significantly higher catch rates than those above. The cause fo these differences are unknown. A catch summary logsheet was distributed by the Co-op in 1998 and 1999 as part of their funding programme at the time. The data covered the main fishing months for a number of regions such as Sligo Bay, south Donegal, north Donegal, north Mayo (Table 23)

Table 23. Average catch rates of lobster (numbers per 100 pot hauls) in Sligo-Donegal in 1998-1999.

	UPUE	LPUE	VPUE
Donegal Bay	25.9	33.5	7.8
North Donegal	19.4	29.1	4.0
North Mayo	20.9	16.4	2.3
North Sligo	24.9	27.8	8.7
Sligo Bay	28.9	27.9	1.8
South Donegal	13.7	22.2	1.5
Average	22.3	26.1	4.3

3. Biological Data

Size distributions

Size distribution of the landings were collected at buyers in 1998, 1999 and 2005 (Fig. 63). Higher proportions of lobsters >120mm CL occured in the Donegal landings especially in north Donegal than in other areas. This was particularly so in 1998 and 1999 due to offshore fishing activity by some of the vessels. The mean size of lobsters in the landings was 97.8mm, 95.3mm and 95.1mm CL in 1998, 1999 and 2005 respectively.

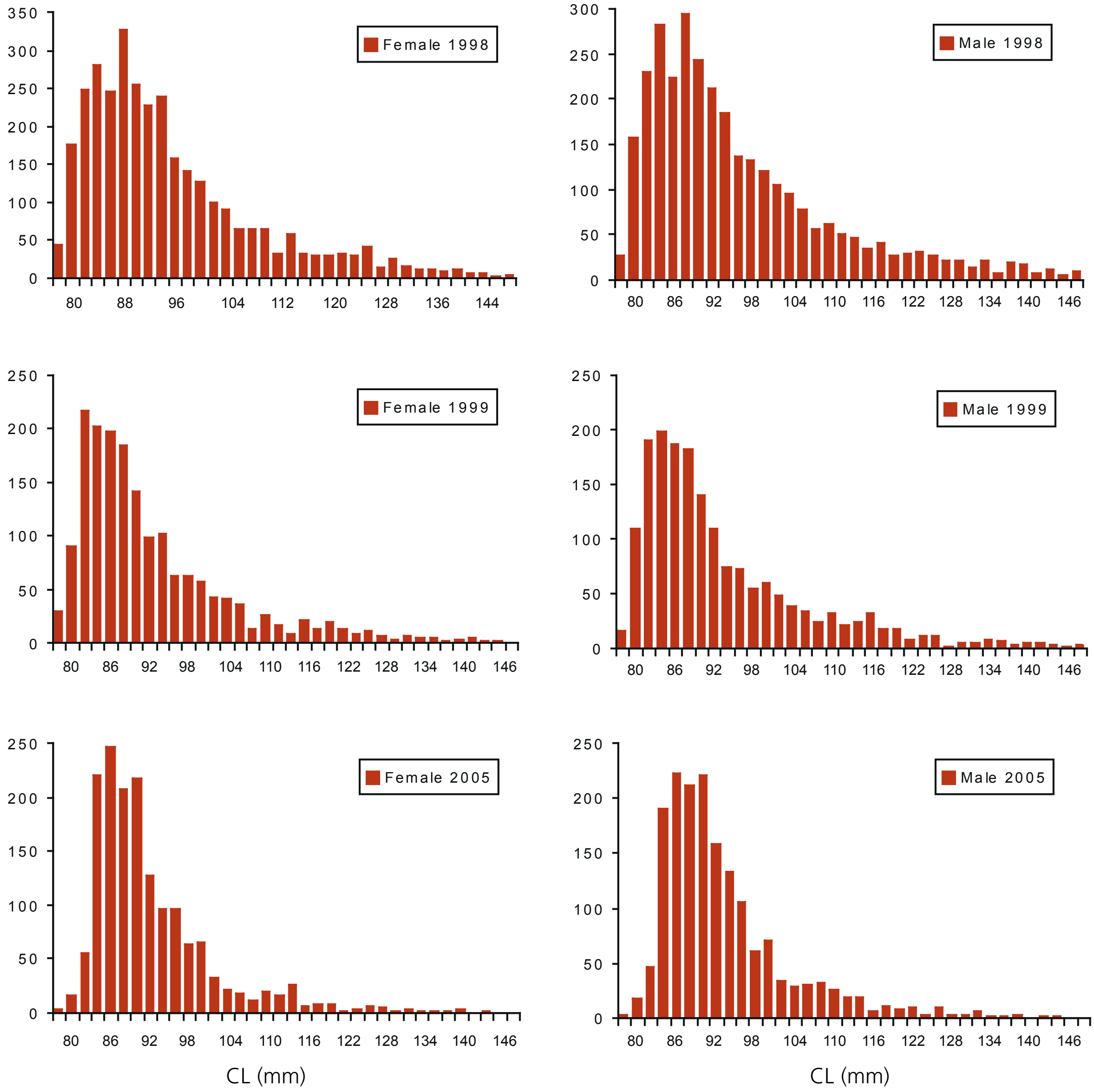


Figure 63. LFDs of the landings of male and female lobsters in Donegal, Sligo and Mayo in 1998, 1999 and 2005.

Size at maturity

Average size at maturity of lobsters off the northwest coast is 96mm CL. The maturity ogive is described by the following equation (Fig. 64).

$$P_{mature} = \frac{1}{1+e^{30.6-0.178CL}}$$

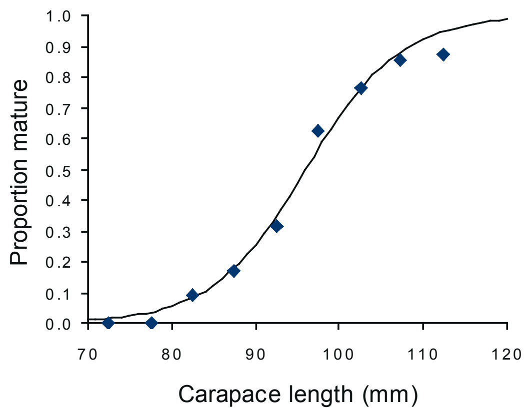


Figure 64. Size at maturity of lobsters in Mayo-Sligo-Donegal.

4. Assessment and Management

Length cohort analysis

Model conditions

LFDs for each year were converted into % frequencies in 4mm CL groups and a plus group at 124mm CL. LCA performed for each year and sex separately and for average LFDs for each sex for the periods 1998-99 and 1998-2005. Terminal F was refined to be the same as for the adjacent size class.

Biological parameters were the same as the southeast except for the maturity ogive (see above).

LCA results

Annual Fishing Mortality (F)

Fishing mortality was similar for male and female lobsters. Apparent trends in F from 1998-2005 may in fact be due to changes in recruitment. These estimates should not be interpreted as the value for the particular year because of equilibrium assumptions (Fig. 65).

F at length

Lobsters are fully recruited to the fishery at 95mm CL or one moult above the MLS.

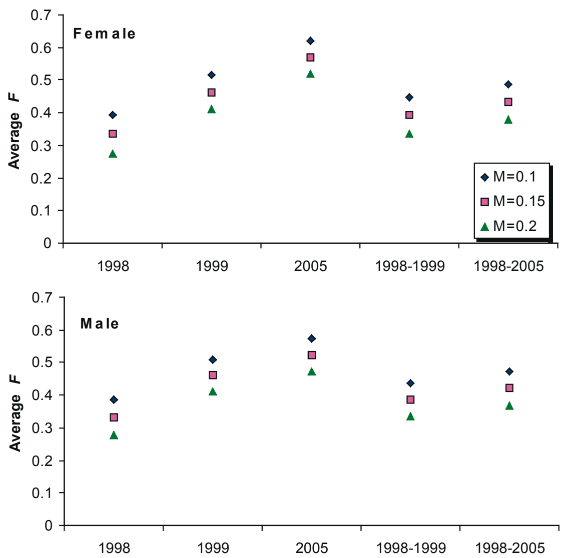


Figure 65. Annual fishing mortality (F) on male and female lobsters between 1995-2005 in the north west fishery in relation to natural mortality (M). Estimates are based on LFDs for individual years and for groups of years – note that the individual year estimates are not the same as annual estimates relating solely to that year.

Yield per recruit

The shape of the Y/R curve is sensitive to M. Curves for both 1998-1999 and 2005 are very similar but current position of F on these curves are different and higher in 2005 (Fig. 66). At M=0.15 small gains in Y/R would result from a reduction in F.

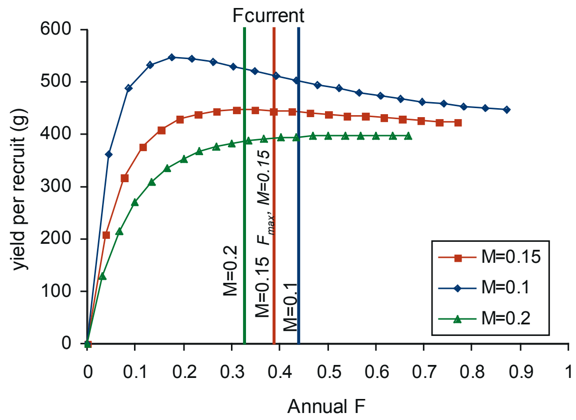


Figure 66. Yield per recruit curves for male and female lobsters combined in relation to F at three values of M using 1998-1999 length frequency data. F current for each value of M and F_{max} for M=0.15 are shown.

Eggs per recruit

The shape of the E/R curves are similar for all years but the current position with respect to F is higher in 2005 (Fig. 67). $R_{(E/R)}$ production is above the limit reference point of 10% if M=0.2 (Fig. 68).

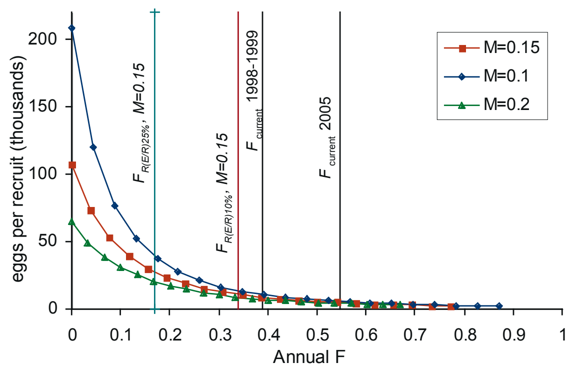


Figure 67. Egg per recruit as a function of F at M=0.15 and the current position of F in 1998-1999 and 2005.

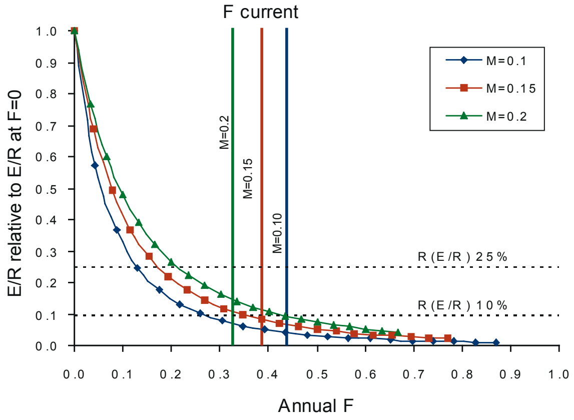


Figure 68. $R_{(E/R)}$ at different values of F. Results are presented for 3 values of M for aggregated 1998-1999 and 2005 length frequency data. Limit R(E/R10%) and target (R(E/R25%) reference points of 10% and 25% of egg production respectively are indicated.

Management options

F at $R_{(E/R)}$ reference points (no change in selection patterns)

Values of F(1998-2005) were in the range 0.37-47 depending on M. Substantially lower values of F are required to achieve E/R of 25% of egg production (Table 24).

F-multipliers for E/R reference points (no change in selection patterns)

If 1998-2005 is taken as the reference period, and 0.15 is taken as the most likely value of M, then reductions in fishing mortality of 20% would be expected to preserve at least 10%, but not as much as 25%, of the maximum egg production (Table 25).

Table 24. Reference points for F with no changes in TCMs.

$F_{current}$ (sexes combined)			
M	1998-1999	2005	1998-2005
0.1	0.44	0.54	0.47
0.15	0.39	0.5	0.42
0.2	0.33	0.45	0.37
$F_{E/R\ 10\%}$			
M	1998-1999	2005	1998-2005
0.1	0.26	0.23	0.26
0.15	0.34	0.3	0.33
0.2	0.42	0.37	0.41
$F_{E/R\ 25\%}$			
M	1998-1999	2005	1998-2005
0.1	0.13	0.11	0.13
0.15	0.17	0.15	0.17
0.2	0.21	0.18	0.21

Table 25. F multipliers for reference points at current selection pattern

F-multiplier for E/R 10%			
M	1998-1999	2005	1998-2005
0.1	0.6	0.43	0.55
0.15	0.89	0.61	0.8
0.2	1.24	0.81	1.1
F-multiplier for E/R 25%			
M	1998-1999	2005	1998-2005
0.1	0.3	0.21	0.27
0.15	0.45	0.3	0.41
0.2	0.64	0.41	0.56

F at $R_{(E/R)}$ reference points (with changes in TCMs)

Fishing mortality would decline as MLS increased. The effect of MaxLS on F would be negligible (Table 26). To reach 25% of egg production changes in MLS and introduction of MaxLS would need to be combined with effort reduction in almost all cases.

Table 26. Fishing mortality at reference points for F and different combinations of MLS and MaxLS.

F current (sexes combined, current effort levels)				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.41	0.41	0.42	0.42
85	0.36	0.37	0.37	0.37
87	0.33	0.34	0.34	0.34
90	0.28	0.28	0.29	0.29
95	0.2	0.21	0.21	0.21
***F* E/R 10%**				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.49	0.45	0.42	0.33
85	0.45	0.42	0.39	0.31
87	0.44	0.41	0.38	0.3
90	0.42	0.38	0.35	0.28
95	0.41	0.37	0.34	0.27
***F* E/R 25%**				
	MaxLS (mm CL)			
MLS (mm CL)	120	125	130	none
80	0.29	0.26	0.24	0.17
85	0.27	0.24	0.22	0.15
87	0.26	0.23	0.21	0.15
90	0.24	0.22	0.2	0.13
95	0.23	0.2	0.18	0.12

Table 27. F multipliers for E/R reference points in relation to MLS and MaxLS.

***F*-multiplier for E/R 10%**				
	MaxLS (mm CL)			
MLS	120	125	130	none
80	1.21	1.1	1.01	0.8
85	1.27	1.15	1.06	0.84
87	1.33	1.21	1.11	0.88
90	1.5	1.35	1.23	0.98
95	2	1.76	1.58	1.27
***F*-multiplier for E/R 25%**				
	MaxLS (mm CL)			
MLS	120	125	130	none
80	0.71	0.64	0.58	0.41
85	0.74	0.67	0.61	0.42
87	0.78	0.7	0.63	0.43
90	0.87	0.77	0.69	0.47
95	1.11	0.96	0.85	0.55

5. V-notched lobsters

The size distributions of v-notched lobsters released during 2002-2004 are similar to those of the landings and confirm the reduction in the proportion of large lobsters in the catch in more recent years (Fig. 69).

Catch rates of v-notched lobsters

Data on catch rates of lobsters in the northwest are poor. In 2002 and 2003 the average catch rate of v-notched lobsters was 0.76±1.34 and 0.62±1.74 lobsters per 100 pot hauls in 2002 and 2003 respectively. This is about 3% of the catch rate of legal sized lobsters.

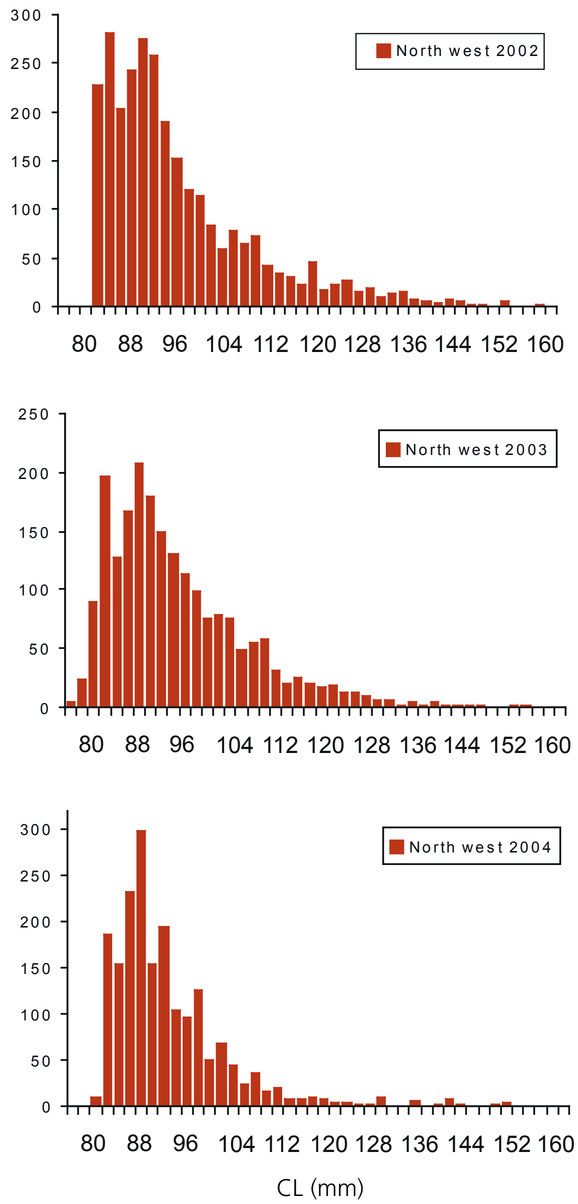


Figure 69. Size distribution of v-notched lobsters released in 2002-2004.

6. Lobster fishery indicators

Effort

No data

Number and profile of vessels

Approximately 35 vessels target lobster on the north west coast of Mayo. Probably over 150 vessels target the fishery in Donegal.

Trends in participation

No data

Interaction with other fisheries

There is a strong interaction between crab and lobster fishing in the early months of the year off north Mayo and potentially in other areas where a number of vessels, which usually target crab, may fish for lobster in early spring when the smaller lobster vessels are still ashore. There are, however, no quantitative data on these interactions.

A Regional Comparison of Lobster Fisheries

Biology

The biological characteristics of lobsters in all coastal regions are quite similar. In particular the average size at maturity may vary regionally by only by 3-4mm. This similarity in maturity, fecundity and annual egg production does not necessarily extend to the stock recruitment relationship nor to the benefit expected to recruitment from different levels of spawning under particular sets of conservation measures. The efficiency by which egg production is translated into lobster recruitment may vary regionally and locally depending on environmental conditions, such as temperature, predation, and dispersal during larval development

The size composition of the landings is comparable across regions suggesting that fishing mortality rates are also similar although fishing mortality in the north west appears to be lower than on the south west or south east. Fishing mortality appears to be highest in the west. The pre-aggregated samples obtained at buyers, however, undoubtedly hide local variability in the size composition of the stock that has not yet been identified. The lower fishing mortality estimates from the north west arise because there is a higher proportion of large lobsters in the catch but these come from offshore patches of ground off the northwest coast of Donegal. There may also be, as yet unrecognised, regional variations in growth rates that would affect the size composition data and estimates of fishing mortality.

Catch rates

Catch rates of legal lobsters are lower in the south east than in the south west fishery. The ratio of legal lobsters to undersized lobsters in the catch fluctuates but is usually about 50:50.

Catch rate data for the west and north west regions are poor.

To obtain reliable catch rate data a large number of vessels need to submit records as there are large differences in the catch rates of individual vessels.

V-notching

V-notched lobsters occur in all stocks. The percentage of the legal sized catch that is v-notched varies regionally and is lowest in the north west. In other areas it is up to 26% of the legal catch and may represent a significant contribution to egg production in these areas. Maintaining the v-notched stock requires continued notching annually to replace losses due to natural mortality and repair of the v-notch. The catch rates of v-notched lobsters decline quickly when v-notching is discontinued.

The individual reproductive potential of v-notched lobsters is greater than that of non-v-notched lobsters because they are larger in size. This will offset, to some degree, the loss in egg production from v-notched lobsters due to natural mortality and repair of the notch.

Egg production reference points

Egg production in all stocks is below the minimum recommended limit of 10% of the egg production of unfished stocks (Fig. 70).

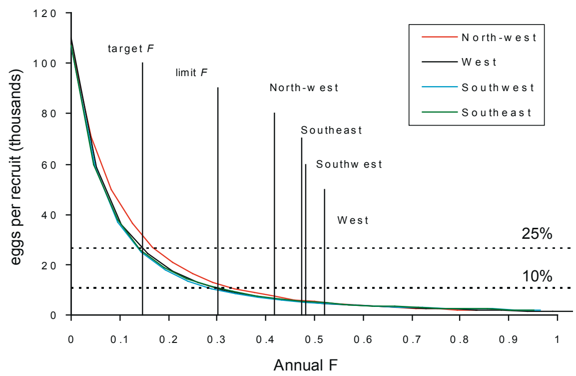


Figure 70. Summary of E/R in each of 4 regional lobster fisheries and the current position with respect to fishing mortality in relation to limit and target reference points for egg production.

Because the average size at maturity is about 8mm above the MLS of 87mm CL and because the slope of the maturity ogive is relatively shallow it is difficult to increase egg production with small increases in MLS although increases in MLS would also result in small increases in Y/R. In addition some fishing mortality occurs on lobsters between 80-87mm in all regions. The reproductive value of large lobsters is substantially higher than smaller lobsters. Lobsters over 120mm CL are

100% mature, produce high numbers of eggs relative to body length and may spawn more frequently than smaller lobsters which invest more energy in growth. Although no data are presented, the egg quality of large lobsters may also be higher leading to higher rates of larval survival with positive benefits to recruitment.

If there are no changes to the current technical measures (e.g. minimum size) substantial reductions in fishing mortality are required to achieve even the limit reference point for egg production. This limit could also be achieved by introducing various combinations of minimum and maximum size. If these technical measures were sufficient, fishing effort on the remaining lobsters, between the minimum and maximum sizes, could increase in some cases. On the other hand the higher the level of fishing mortality then the more stringent the technical conservation measures need to be as the effects of technical measures can generally be negated by increases in effort. It would be difficult to sustain a cycle of increasingly stringent technical measures in response to increasing effort. This would result in a decline in profitability as the technical measures required more and more discarding. The best current option to achieve egg production targets appears to be a combination of effort rationalisation and a maximum size somewhere between 120 and 130mm CL. A maximum size limit will result in small reductions in Y/R since these large lobsters would be lost to the fishery. These fish are, however, of lower market value.

The egg production levels estimated do not include that of v-notched lobsters. In stocks where the proportion of legal sized female lobsters notched is as high as 25% they probably contribute significantly to total population egg production. This will be evaluated further in 2006-2007. Nevertheless as described below the v-notch measure gives only temporary protection to lobsters and their contribution quickly falls away if notching is stopped. Management should not rely solely on v-notched lobsters for egg production because of this. Each v-notched lobster is protected for about three moults and probably for 4-6 years after which it becomes part of the legal stock again. During that time the lobster increases in CL by about 24-27mm given an individual moult increment of 8-9mm. The average size of lobsters that are v-notched is approximately 95mm CL. After three moults, when they are again susceptible to fishing, they measure on average 120mm. Introducing a maximum size would permanently protect the investment in v-notched lobsters and, as described above, also allow the minimum egg production limits to be achieved.

Attaining the target egg production of 25% of egg production of an unfished stock is difficult and would require substantial reductions in fishing effort in combination with technical measures. This is not a feasible target in the short term although the contribution of v-notched lobsters has yet to be evaluated fully. The required target of 25% is not based on direct scientific evidence from Irish lobster stocks but is extrapolated from other fisheries and species. It may or may not need to be this high to maximise the recruitment of lobster to the stock. Monitoring of undersized catch rates in relation to progressive changes in technical measures and effort rationalisation will eventually give an indication of trends in recruitment at particular levels of egg production.

Fishing effort

On the south east coast fishing effort potential doubled between 1995-2005, although some of this increase may be targeted towards brown crab. Trends in effort are unknown in other areas although there are some snapshots of the actual effort in some areas. Individual vessel effort is known anecdotally to be increasing. The number of small vessels in the fishery in some areas may be declining.

A summary of stock and fishery indicators

Suggested indicator and reference points for the monitoring and management of lobster stocks and fisheries were given earlier in this report. Analysis of the available data and assessment of the state of the stocks indicates the current position and trends in these indicators and reference points.

1. Landings: Landings are increasing in all regions. Although this may indicate strong recruitment the available catch rate data shoes that the landing increase must be due to effort increase and that this trend represents a risk to recruitment.
2. Landings per unit Effort (LPUE): LPUE is stable or declining in most areas although there are some local increases in catch rate. No data is available for the north west.
3. Pre-recruit index (UPUE): Trends in the catch rate of undersized lobsters are similar to those of legal sized lobsters; declining in the southeast, stable in the south west and increasing in local areas of the west coast.

4. Eggs per recruit
    a. Limit reference point: Egg production is below the limit reference point of 10% of an unfished stock in all areas although this does not account for the contribution of v-notched lobsters.
    b. Target reference point: Egg production is below the target reference point of 10% of an unfished stock in all areas although this does not account for the contribution of v-notched lobsters.
5. Mean size of lobsters in the landings: The average size of lobsters in the landings is stable and about 1 moult above the MLS. Changes in average size might be due to changes in levels of fishing mortality or changes in recruitment.
6. The proportion of lobsters over 120mm: This proportion has increased since the late 1990s. The reason for this is unclear as fishing effort has also increased. The proportion would increase if the numbers of lobsters recruiting to the fishery declined and also if new grounds were fished.
7. Catch rate of v-notched lobsters: The catch rate of v-notched lobsters is stable although some local increases have occurred in the west cost.
8. The proportion of lobsters v-notched: The proportion of the stock that is notched is stable or increasing although like the previous index this depends on continuation of the v-notch programme.
9. Individual vessel effort: Although the data are poor, when combined with anecdotal information, it is clear that in all areas individual vessel effort is increasing.
10. Number of vessels: The number of vessels active in the fishery is declining in the south east and is stable in the south west. Anecdotal information suggests that the number of new entrants to the fishery is low although the fishery is essentially in open access
11. The market price: the market price is stable although trends in price have not been related to increases in costs.
12. Strategic seasonal marketing: There has been some increase in strategic marketing by storing of summer caught lobsters, when prices are low, for winter market (when prices are high). This is likely to increase in the future because of state grant aid to install storage facilities
13. Interactions with crab fisheries: There is an increase in fishing effort for crab on all coasts. As lobster is a significant by-catch in the crab fishery the impact of the directed crab fishery on lobster is likely to be increasing. In addition crab fishing gear may be targeted at lobster during spring in some areas.

Research and monitoring priorities

The current data collection programmes have significant potential to provide information relevant to assessment of lobster. There are at least three useful indices in the fishing activity records

1. catch rate of legal lobsters
2. catch rate of undersized lobster. This is an index of lobster abundance prior to recruitment to the fishery
3. catch rate of v-notched lobsters. This validates that the v-notch programme is being implemented but also potentially gives an index of the size of the stock and the contribution of v-notched lobsters to egg production

In addition the information on tagged v-notched lobsters provided by some, albeit few, vessels is unique and valuable and will provide the first information on moult frequency and spawning frequency for the species.

The following priorities are identified:

1. Increase the number of vessels submitting fishing activity records. This matter should be discussed by the management advisory group
2. Work closely with groups of fishermen to ensure that the following information is collected
    a. Rate of re-notching of v-notched lobsters at sea
    b. Reproductive condition of recaptured lobsters
    c. Size of recaptured lobsters
3. Develop a national programme to sample the landings and evaluate if the current sampling methods in buyers premises is giving unbiased information. This will require a comparison of samples taken in this way and samples take at sea
4. Develop an individual based egg per recruit model to allow the integration of information on v-notched lobsters into the egg per recruit assessment
5. Continue research on the following topics
    a. The efficacy of escape panels in releasing undersized lobster
    b. The morphology of the v-notch in relation to moulting
    c. Size at maturity of lobsters
6. Effort potential and participation in the lobster fishery in all regions will need to be quantified.

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