Irish Fisheries Investigations No. 12 (2004)

Bionomics of brown crab *Cancer pagurus* in the south east Ireland inshore fishery

Project funded by the Irish Government and part financed by the European Union under the National Development Plan 2000-2006 through the programme for Innovation and Sustainability in the Fisheries Sector

by

Edward Fahy[1], John Hickey[2], Nicoleta Perella[2], Antonio Hervas[2], Jim Carroll[1] and Carlos Andray[2]

[1]Fisheries Science Services, Marine Institute, Abbotstown, Snugboro Road, Dublin 15

[2]Bord Iascaigh Mhara, Stella Maris Centre, Kilmore Quay, Co Wexford.

ISSN 0578 7467

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SUMMARY

The south east inshore brown crab fishery is delimited by the boundary of longitude - 6.3, within a coastal band of approximately 18 km (10 nm) in width and it extends along the south coast of Co Wexford for a distance of approximately 55 km; evidence for the stock extending into the inshore fishery west of the Waterford Harbour estuary is sparse.

The fishery, whose maximum extent is calculated at 427 km^2, yielded up to 700 t per year during the 1990s. In 2002 annual landings of 959 t accounted for 8.2 % of the national catch. The average overall LPUE was 0.87 kg per pot lifted in that year. Brown crab were landed whole or as claws, for human consumption, and clawed or, of poorer quality, with claws, to provide bait for the whelk fishery. This fishery is not considered to have any discard of legally sized crab and, in consequence, a large percentage of the landings is poorly conditioned.

The stock is intensively fished; the amount of gear in use increased almost 5 fold since the mid 1970s. Landings per boat declined since the late 1980s although this may be as a result of sharing among a greater number of vessels. In 2002 an estimated 60 – 69 vessels fished brown crab in the peak autumn months.

In 2002 and early 2003, 3,674 crabs were tagged in the inshore fishery; of these 14.4% were recaptured (12.8% of tagged females and 20.7% of tagged males). Observations made during tagging operations in 2002 only were used to clarify sex ratio and the incidence of recently moulted animals.

The crab stock consists of a migratory female component which moves into shallow waters during the summer months probably to moult and mate. The male component is more sedentary. Both sexes move at speeds which slow during the summer months and increase again as the year advances; maximum speeds of 2 km/day were recorded for both sexes in the autumn. Movements by male crab were random while females adopted a south west trajectory. The greatest distance recorded for a tagged female crab was 136 km after 287 days at liberty. Other tagged females, reported by French vessels, were recaptured in ICES division VIIg which may be the over-wintering area for the stock. These animals had moved between 69 and 75 km from their release point.

Tag reporting by the industry is considered to have been low. Based on the rate of tag recovery, the estimated rate of exploitation was lower than expected in an intensely fished stock. Population estimates were attempted using the Petersen formula and on the basis of assumptions about mortalities which recognized the phenomena of moulting and migration. The south east crab stock moves with the current which is westerly along the southern Irish coast. Recorded migrations were also short when compared with those of brown crab in the northern stock and in several other documented fisheries. The Nymphe Bank which adjoins the south east fishery has a water current pattern which retains larvae and it is known to have a high density of brown crab in the plankton. The existence of retaining currents may make the kind of long migrations which characterise others unnecessary for this stock.

The status of the south east fishery is not known. LPUE indices provided by the Roscoff super-crabber fleet for ICES statistical division VIIg remained fairly stable between 1987 and 2002 but the quantity of crab captured by those vessels has declined considerably in most years since 1995.

1.Introduction

Although the south east coast of Ireland has provided substantial landings of brown crab for the past thirty years – more than 700 t a year to 55 km of coastline in the mid-1990s – little is known of the status of this inshore fishery whose catches have been under-stated by as much as a factor of 2-3 in the official statistics in some years.

In the 1970s the number of pots fished per km of south Co Wexford coastline was 50; in 1998 it had increased to 191; the latest census, prepared for 2002, provided an estimate of > 292 pots per km (Source J H). Increasing pot numbers is a conservative estimate of fishing power, technological innovation also having contributed much in the interim.

Fahy *et al* (2002), found no reliable indicators of the status of the south east brown crab stock. The length frequencies of males and females sampled in spring and summer contained larger individuals in the later 1990s than in the 1960s. In the absence of log books, sales data were scrutinised in an attempt to ascertain whether consignment size delivered to buyer had altered during the 1990s. Apparently, during the later 1980s and early 1990s it declined, then stabilized, but the significance of this in a fishery which does not always deliver an individual day's landings to a buyer but instead accumulates catches in keep-boxes, is open to interpretation.

The south east inshore brown crab fishery has a marked seasonal pattern, crab becoming more abundant closer to shore as the year progresses, so its inter-relation with an offshore stock (a component of which moved into coastal waters in the summer) was believed to be crucial to its survival. LPUE indicators cited from the Roscoff super-crabber fleet in the 2002 appraisal of the south east fishery suggested that the stock in ICES divisions VIIe-h had increasing LPUE, and this provided some reassurance.

In 2002, another approach to ascertaining the status of the south east inshore fishery was adopted: a mark-recapture trial was undertaken to ascertain exploitation levels in the fishery. In the course of it other aspects of the biology and behaviour of brown crab in this fishery were clarified. This paper describes these in the course of re-examining the broader question concerning the sustainability of a fishery of this kind against a background of increasing fishing effort.

2. Materials and methods

Brown crabs were tagged using individually numbered plastic electrical cable-ties placed on the carpus or the merus of the right cheliped. The trailing end of the cable tie was trimmed back so as not to inhibit movement of the animal.

Animals were taken at random from commercial catches coming on board. The maximum carapace width of each tagged animal was measured to the nearest mm; the sex of each crab was noted as was whether the animal appeared to be "white", "pale" or recently moulted.

Tagging commenced on 18 December 2001 when 40 crabs were marked and it continued on 18 further occasions until 4 October 2002. Tagging was opportunistic, taking place during commercial fishing operations, the skippers of the vessels on which it took place were paid for each crab tagged and released. The maximum number of crabs tagged on any one day was 244. In all 3,060 crabs were tagged and released in 2002 at positions shown in Fig 1.

Coverage of the early months of 2002 was poor because of adverse weather conditions so the work was extended into the following year when a further 614 crabs were tagged in March to provide more data on migrations during the early months of the fishing season within the fishery.

Tagged crabs were stored in individually compartmentalised boxes on deck and released in batches of approximately 20 – 100 at a noted longitude/latitude.

A reward was offered for the return of marked crabs with associated details of the fishery operation: the GPS of the recapture, how many tagged crabs were taken on the day in question and how many boxes of crab were landed as well as the number of pots lifted.

GPS data indicating the point of release and of recapture of individual crab were converted to decimalised longitude and latitude and used to calculate the direction of movement (the bearing) adopted between release and recapture and the minimum distance travelled (km) in the interim using the aplet “geofunc” in Microsoft Excel. Mapping of the results was undertaken using Surfer 8 and Map Viewer 5 packages.

Estimates of population size were made using the Petersen formula (1896), also known as the Lincoln index:

$$\hat{N} = \frac{rn}{m}$$

Where N is the size of the whole population before the first visit, *r* is the number of tagged individuals released, *n* is the number of unmarked individuals captured and *m* the number of tagged animals which were recaptured.

The standard error of this estimate is given by the formula:

$$\sqrt{\frac{r^2 n}{m^3}}$$

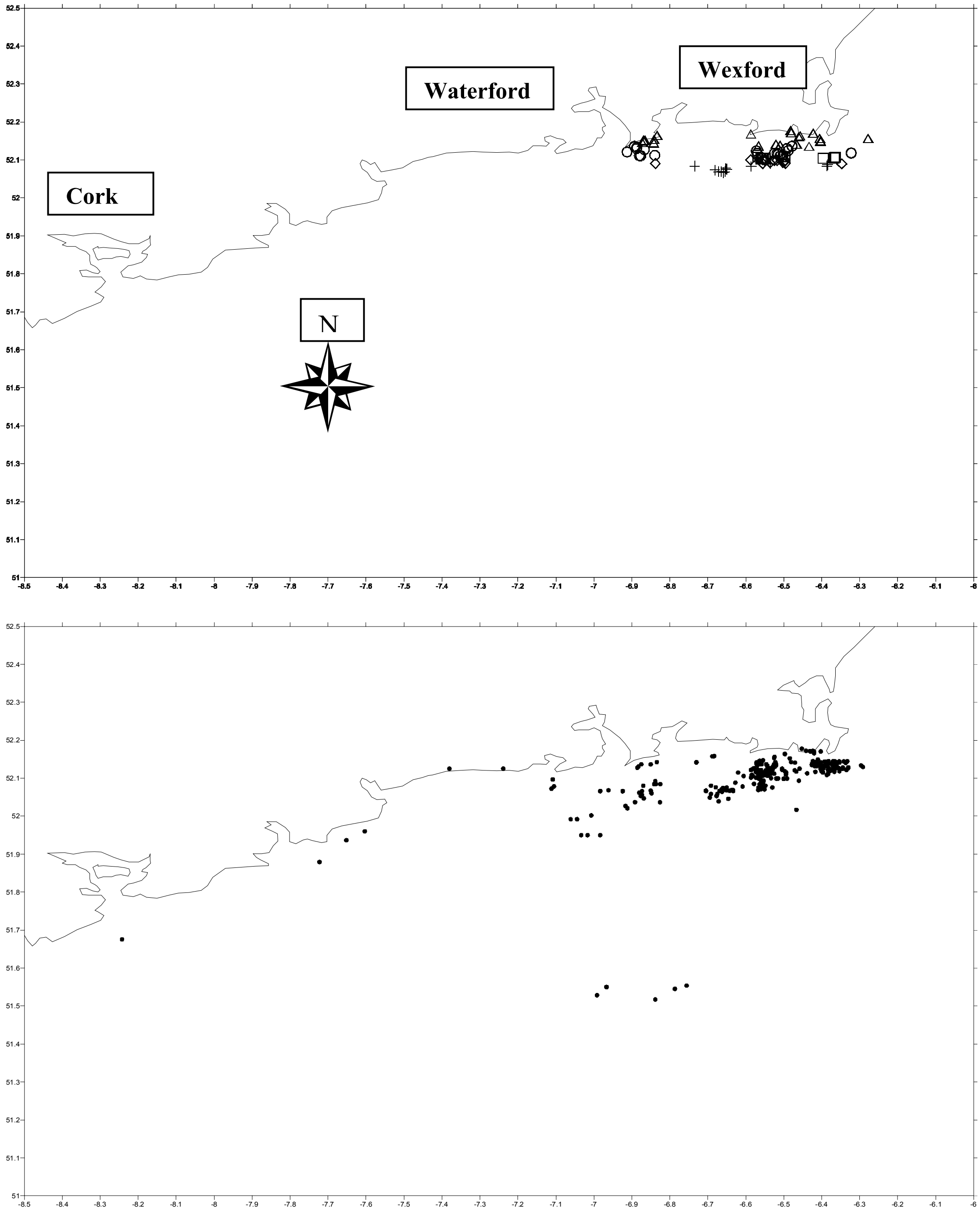

Fig 1. Distribution of tagged brown crab released into the south east inshore fishery in 2002 and 2003 (above) and of recaptures up to August 2003 (below).

3. Results

3.1 Tag returns

Of a total of 3,674 brown crab tagged in 2002 and early 2003, (2,893 females and 775 males) 516 (14.4%) had been recaptured before 10 August 2003 by 37 fishermen. Four individual fishermen reported more than 50% of all recaptures and one fisherman alone within this group accounted for 19%. Despite attempts to standardise data reported by fishermen, the quality of information was not consistent. Few reports were accompanied by carcass and tag, as requested, fewer contained associated LPUE data. Tags from which sufficient data were gleaned to model the population numbered 469 in 2002 and the population estimates are based on work undertaken in 2002 because it covered most of a fishing year: 92% of the landings in 2002 were covered by the mark-recapture experiment.

For the duration of the work (up to 10 August 2003), 20.7 % of tagged male crabs were recaptured as against 12.8 % of females. The time at liberty between mark and recapture did not differ significantly between the sexes, males being free for an average of 49.0 days (s.d. = 53.64, N = 160) and females for 50.7 days (s.d. = 70.6, N= 366. P>0.05).

The carapace width frequencies of tagged crabs are presented on a quarterly basis in Fig 2. During the first quarter the average carapace width had its lowest value, increasing thereafter. Increasing carapace width as the year progressed is due in some measure to the decreasing incidence of male crab, as shown in the sex ratios of crabs tagged on particular dates (Fig 3) and of undersized individuals.

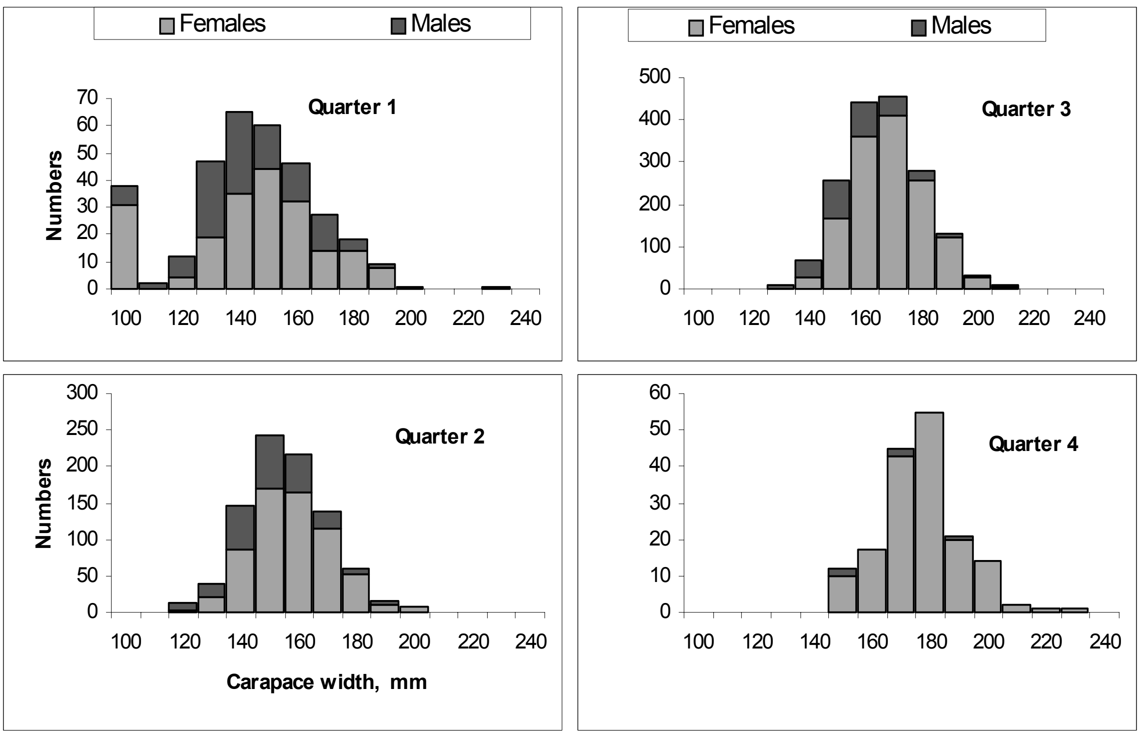

Fig 2. Length frequency distribution of male and female brown crab tagged, by quarter, in 2002.

Average carapace widths of three categories (all tagged animals, all recaptured animals and those recaptured after 200 days) are provided by sex in Table 1. Tagged females which were recaptured after 200 days at liberty were larger, though not significantly so ($P>0.05$) than the average size tagged or the average size recaptured.

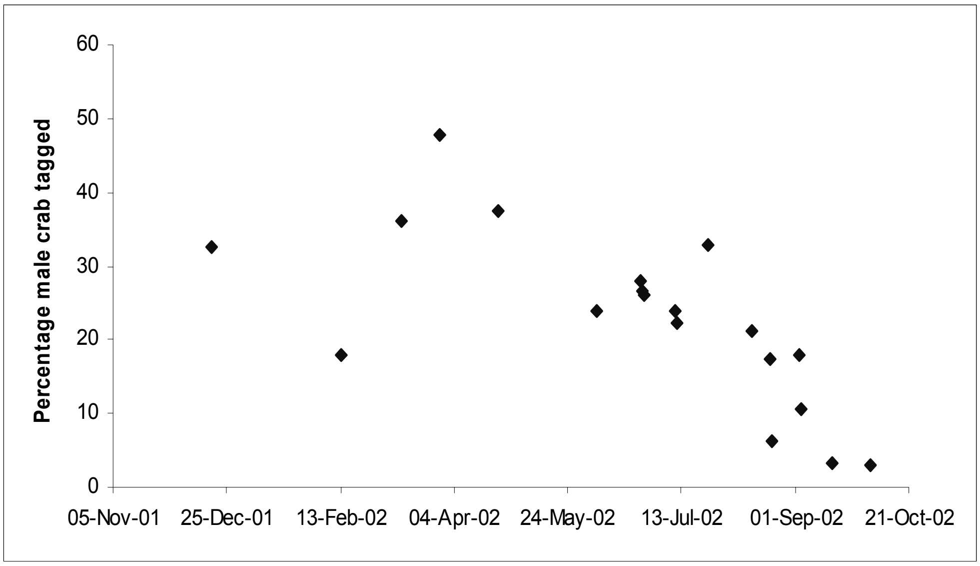

Fig 3. Percentage male crab tagged throughout the mark-recapture experiment in 2002.

The sexes displayed different movement patterns: females moved along-shore in a south westerly direction, while males did not display any preference for a particular bearing. To examine seasonal alterations in direction these results were expressed over the greater period in which tags were recovered (Fig 4). For female crab there are several notable clusters of data: one indicates the northward movement of crab into the fishery, a second, suggests some easterly along-shore movement in September 2002 but the largest grouping adopted a south-westerly direction from May to September. Although data from 2003 are sparse, this migration pattern is evident in the second year also. The data are grouped in a compass rose in Fig 5 which demonstrates the south westerly tendency in female crab and the random nature of movement in the males.

Table 1. The carapace width of three categories of brown crab: all animals tagged, all recaptured and those recaptured after 200 days

		Average (mm)	Standard deviation	Number
General population tagged	Females	160.5	15.15	2,376
	Males	148.9	15.97	678
All recaptures	Females	159.8	13.70	342
	Males	151.7	15.51	151
Recaptured after 200 days	Females	163.6	11.50	23
	Males	150.8	12.30	4

Measurements of distance moved between release and recapture are noted in accordance with the GPS readings recorded and reported, some allowance must be made for the possible drifting of released crab in the current before they settle on the sea bed. Latrouite (pers comm.) proposes these should be +/- 0.1 km.

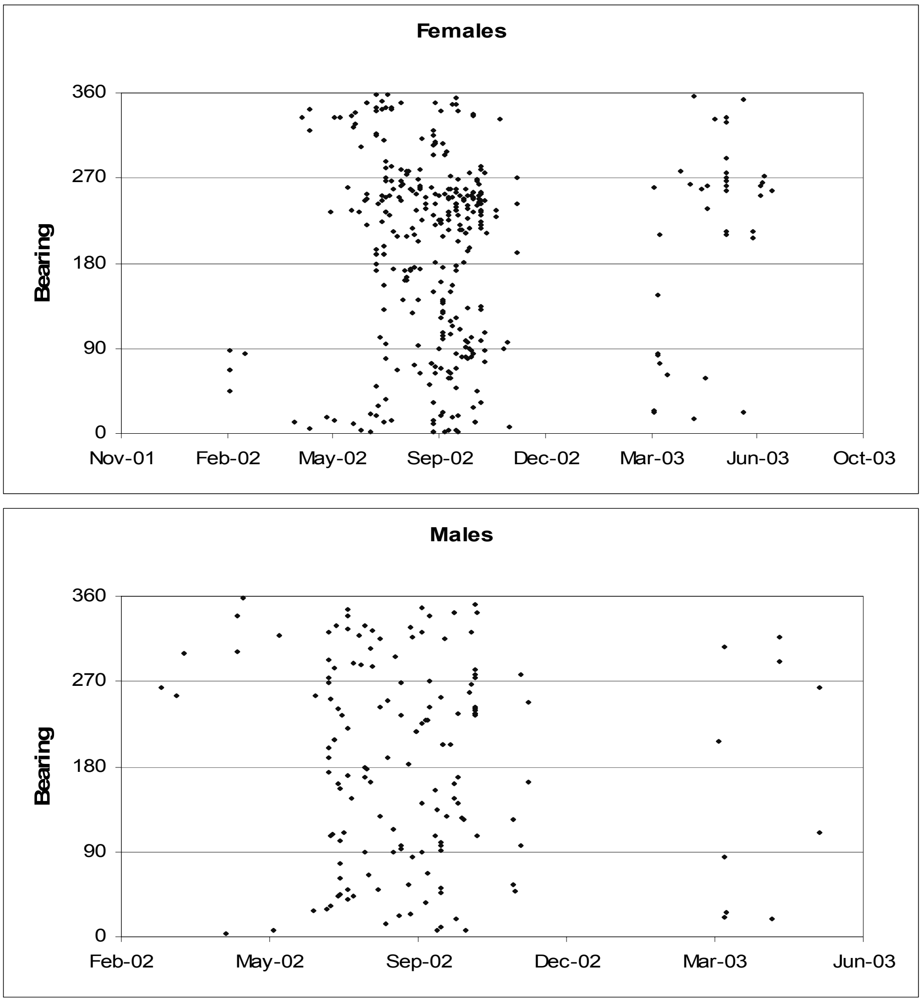

Fig 4. The bearing adopted by female and male crab between places of release and recapture during the course of the mark-recapture experiment, 2002 – 2003.

Approximately 50% of female and male crab had moved a minimum distance of 5 km between mark and recapture (Table 2) although females made the longest migrations. In terms of distance moved per day, females averaged 0.64 km (st dev = 1.8473, N=360) while males covered only half that distance (Average = 0.36 km; st dev = 15.829, N=159).

Speed of movement, defined as the averaged minimum distance moved per day was compared in female and male crab which had been at liberty for 0-21 days over the period in which observations were made (Table 3). Similar trends were observed in both sexes: in spring the rate of movement could be relatively high, compared with the summer months. Lowest rates of movement were recorded in June after which they increased to a maximum in September/October, falling again in the following spring.

The longest minimum distance moved by males was considerably shorter than by females; three individuals made distances of between 36 and 38 km, their liberty ranging from 6 to 269 days. Distances in excess of 40 km were achieved only by females; 22 made minimum migrations of this length and greater. The longest was 136 km by a female in 287 days, another moved 98 km in 29 days. A female migrated 80 km in 380 days and one of the fastest speeds was achieved by a female which moved 68 km in 18 days.

Table 2. Minimum distance (km) moved by female and male crab between mark and recapture.

Km	Females %	Males %
0.1	0.3	1.3
0.5	3.3	13.3
1.0	5.5	11.4
5.0	48.4	53.2
10.0	19.7	13.3
15.0	7.4	3.8
20.0	2.7	0.6
25.0	3.3	1.3
30.0	1.6	0.0
35.0	0.8	0.0
70.0	4.4	1.9
140.0	2.7	0.0
Totals	**366**	**158**

Six tags together with recapture details were passed to us by IFREMER from the Roscoff super-crabber fleet. All were females and all were captured in June 2003. All had adopted a bearing of between 170 and 279° from their place of release; the minimum distance they had achieved ranged from 69 – 75 km.

Table 3. Minimum distance (km) moved per day by female and male crab at liberty for <21 days

	Period	Average distance	St dev	Number of observations
Females	February - May '02	0.66	1.13	8
	June	0.33	0.19	9
	July	0.40	0.36	43
	August	0.55	0.67	32
	September/October	2.14	3.80	59
	March - April '03	1.43	4.29	9
Males	March - May '02	0.62	1.00	4
	July	0.22	0.26	35
	August	0.49	0.36	10
	September/October	2.22	4.68	13
	March '03	0.26	0.45	5

3.2 "White", "pale" or apparently recently moulted crab

Observations on the incidence of white (recently moulted) crab as recorded in the course of tagging operations, are summarised in Fig 6 which suggests that in 2002, they reached a peak in July, indicating that most moulting had taken place before that month.

3.3 Additional information on the south east fishery in 2002

3.3.1 Weight of individual crab landed

Because of the close association of the south west Irish Sea whelk fishery with the fishery for brown crab, due to the fact that crab carcasses are used as whelk bait (Fahy, 2001), the south east crab fishery is considered to have no discards of brown crab above the size limit of 130 mm imposed by EU Council Regulation 850/98 Annex xii. Sub-legal sized crab are occasionally included among whelk bait, particularly in the early months of the year (Fig 2). The fishery is conducted closer to shore at that time and both small crabs and male crabs tend to frequent these waters in larger numbers (Fahy *et al*, 2002). In order to convert lengths (carapace width) to weight, a regression of LNweight on LNlength of crab (sexes combined) sampled in 2000, had the following outcome:

$$W = 3.5129 L^{1.704}$$

(N= 897, $r^2 = 0.5786$, $P < 0.001$).

Latrouite (pers comm) remarked that this formula provides very low weights for brown crab and these are probably due to the harvesting of poorly conditioned animals which had recently moulted to be used as whelk bait. Tully *et al* (1998) have demonstrated the association of low meat yield with poor condition in brown crab.

The length frequencies in Fig 2 were converted to weights on the basis of this regression in Table 4.

3.3.2 Total Landings

Landings data were supplied by month by the principal buyers and processors taking product from the south east fishery in 2002. The recent history of this fishery suggests that official figures for landings can be underestimates so that an account of how total landings are compiled is appropriate at the outset.

Brown crab may be landed whole, for human consumption, directly after capture or following a period of retention in a keep box. Alternatively the carcasses might be landed without claws for use as bait in the whelk fishery, in which case a factor (*1.25) was used to raise this statistic to live weight. Or, crab claws were landed separately, in which case a factor (*5) was used to raise this figure to live weight. According to Council Regulation 850/98, Annex xii, it is prohibited to land crab claws which exceed 5% of the weight of whole crab but this measure is not enforced.

One processor who purchases both carcasses and claws, would have reported similar live weights for each which would be a duplication if both were included in total landings. In 2002, the raised weights of crab claws were considerably heavier than those of crab carcasses and the landings weights were based on these claw weights, the raised weights of carcasses being ignored in the calculations. In another case, waste from crab processing which might otherwise be diverted into crab bait, was generated by a purchaser who is located too far from a whelk processor to make the reuse of this by-product financially viable; instead the waste was disposed of in land-fill; in this case a waste figure of 15% was added to the processed product to calculate the full tonnage of exploited crab by the processor in question.

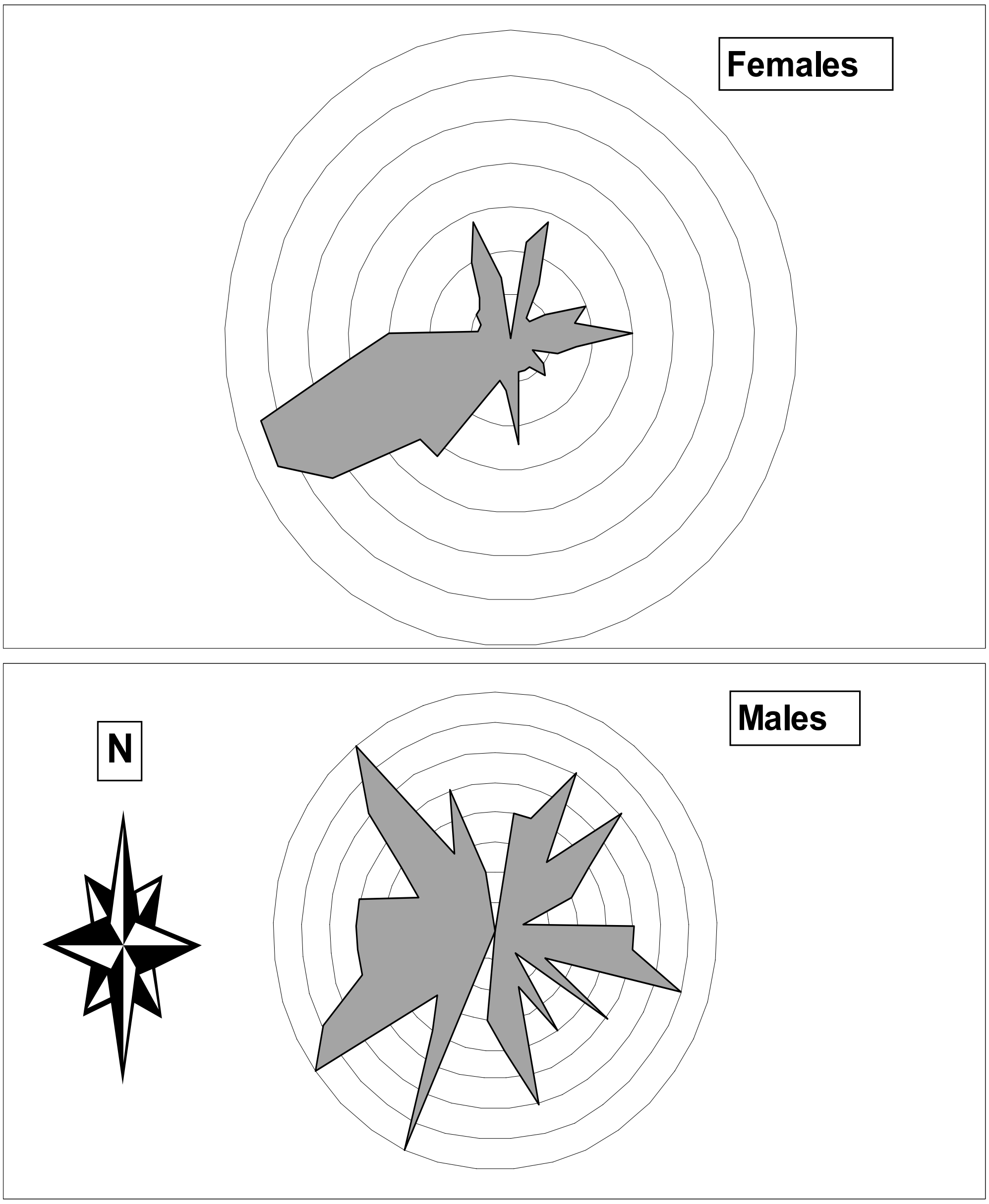

Fig 5. Rose diagrams of bearings adopted by male and female crab between release and recapture during the course of the mark-recapture experiment, 2002 – 2003.

All crab landed from the approximately 55 km of Co Wexford coastline between Carne in the east and the border with neighbouring Co Waterford were included in the landings total for 2002. Half of the crab landed into Dunmore East in Co Waterford, as reported by one buyer, was attributed to Co Wexford although this tonnage was very low (approximately 4 t). Thus, the total landings in 2002 were 959 t (Table 5).

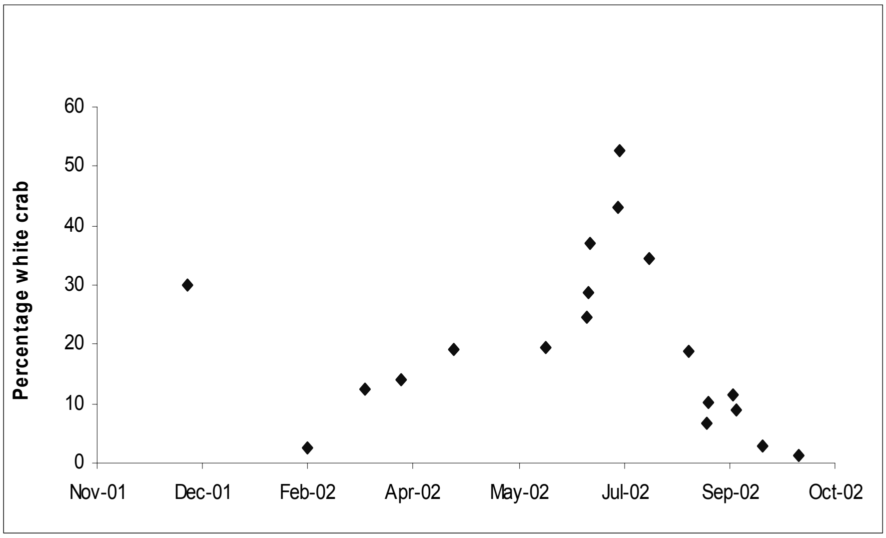

Fig 6. Percentage “white”, “pale” or apparently recently moulted crab in the course of tagging operations, 2002.

The monthly percentage distribution of total landings in 2002 is shown in Fig 7 where they are compared with averaged landings over a five year period in the mid-1990s (1992-1997, excluding 1995 (Fahy *et al*, 2002)). A similar pattern of monthly landings was observed, a greater than usual quantity being taken in the month of October when more than 20% of the annual landings were made in 2002.

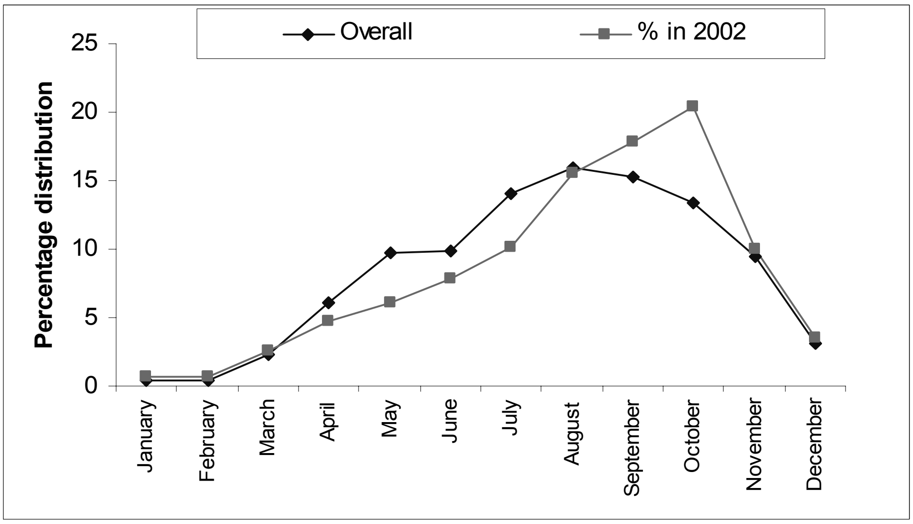

Fig 7. Monthly percentage distribution of crab landings from the south east inshore fishery: the overall pattern was established in the 1990s and is shown for comparison with the landings in 2002.

3.3.3 Catches and landings

Previous work on the performance of this fishery (Fahy *et al*, 2002) examined the variation in size of consignments delivered to processor. The method provides good data when landings are delivered to or collected by a buyer on a daily basis but it is devalued by the use of keep boxes which accumulate landings from several days' effort. The approach provides good data which are comparable over a short period, provided that the behaviour of the fishermen does not change in that time. At its best, the landing from a single day's effort does not quantify such criteria as the amount of gear used or the soak time of the pots. On the other hand, those details are virtually impossible to obtain where logbooks are not compulsory and the quality of the data is not monitored.

Table 4. Percentage length composition and corresponding weights of crab tagged in each of the four quarters of 2002

Averages		**Percentage representation**			
Length, mm	**Weight, g**	**Quarter 1**	**Quarter 2**	**Quarter 3**	**Quarter 4**
100	178	11.7	0.0	0.0	0.0
110	209	0.6	0.1	0.0	0.0
120	242	3.7	1.4	0.0	0.0
130	278	14.4	4.4	0.6	0.0
140	315	19.9	16.4	4.0	0.0
150	354	18.4	27.6	15.4	7.1
160	395	14.1	24.6	26.2	10.1
170	438	8.3	15.8	27.1	26.8
180	483	5.5	6.9	16.6	32.7
190	530	2.8	1.8	7.7	12.5
200	578	0.3	0.9	1.8	8.3
210	628	0.0	0.1	0.5	1.2
220	680	0.0	0.0	0.1	0.6
230	734	0.3	0.0	0.0	0.6
240	789	0.0	0.0	0.0	0.0
Average weights		336	381	426	471
		Average overall weight		430	

The best quality of catch/effort data is a weight or number statistic compiled from the known number of pots fished in a certain soak time. As part of the tagging release and recapture programme in 2002, these data were sought. Landings per effort were noted whenever the information was available, during tagging operations for example. Fishermen were also asked to provide similar details (not in this instance soak time) when they completed claims forms when submitting details of a recaptured tagged animal. Few observations were made outside the summer and autumn months. During the summer and autumn of 2002 BIM (Bord Iascaigh Mhara, the Irish Sea Fisheries Board) also conducted a survey of catch effort and the results of this were kindly made available to us by Oliver Tully.

The south eastern fishery is a mixed one for large crustaceans, brown crab being the principal species captured. Lobster is also a valuable target species and pots may be set on ground which is frequented by it and by relatively few brown crab; alternatively and to a lesser extent, gear may target spider or velvet crab. In every instance some brown crab will be captured but the diversion of effort towards any other species invariably means a lower yield of brown crab. The BIM survey emphasised this point in relation to lobster (Table 6 – see also Appendix Tables 1-3). Because of some uncertainty about the definition of catches in the BIM investigation, the LPUE data used in further calculations here are derived mainly from the data obtained in the course of the mark and recapture exercise. Soak times were mainly those reported in the BIM survey. The overall statistic for brown crab LPUE on an annual basis was 0.87 kg per pot lift in the south east fishery.

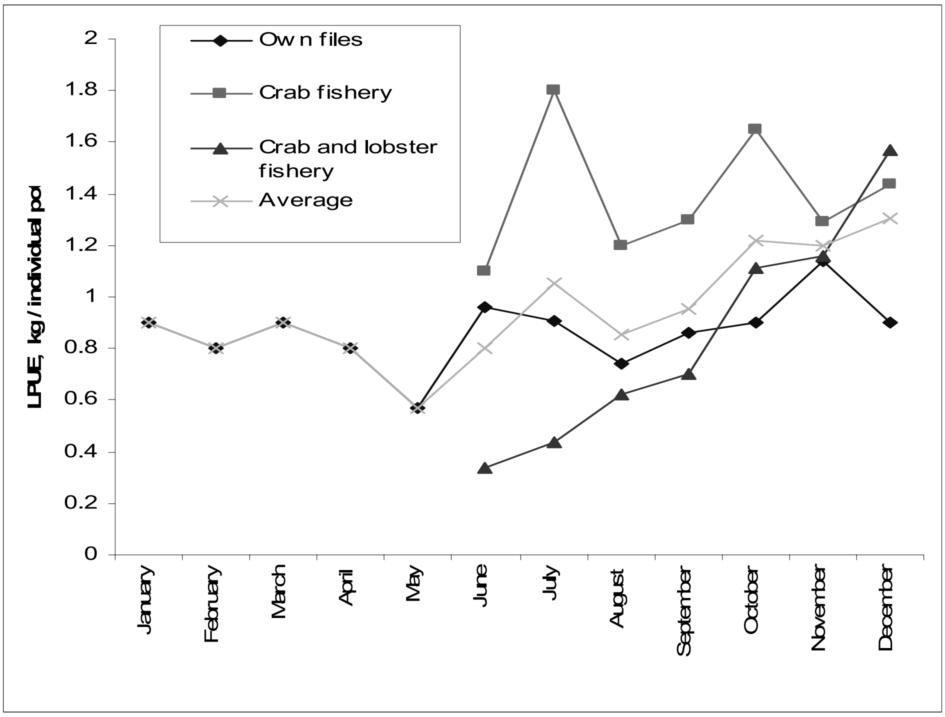

Fig 8. LPUE estimates for the south east inshore fishery in 2002. "Own files" refers to data collected in the course of the mark-recapture experiment, "Crab fishery" to pots targeting crab, "Crab and lobster" to some pots targeting lobster. "Average" is of all the foregoing.

3.4 An offshore survey

Coincidentally, a survey by a super-crabber took place offshore of the south east fishery in June and July 2002. It was conducted between latitudes 50.50 and 51.50 N approximately, beginning in the east, at longitude –5.30 in June and working west to –7.10 towards mid-July.

In June landings ranged between 12 and 384 kg (to a string of 150 pots) and averaged 147 kg per string lifted (standard deviation = 74, N = 117; the total number of individual pot lifts in June being 26,550). In July the landings ranged between 24 and 118 kg per string lifted and averaged 68 kg (standard deviation = 24, N = 72; the total number of individual pot lifts being 10,800). This represented a significant deterioration ($t = 2.10$, $P<0.05$) on the month before. The results of this work were kindly made available to us by Martin Robinson of the Zoology Department, Trinity College, Dublin.

3.5 Indices of offshore stock abundance collected by the Roscoff super-crabber fleet

This fleet is highly mobile, ranging over the Celtic Sea. On this occasion LPUE data – reported on the basis of a 24 hour soak time - gathered by the fleet from ICES statistical division VIIg was considered most appropriate to the investigation (Fig 9). These data were kindly made available to us by Daniel Latrouite of IFREMER. LPUE shows a downward tendency since 1987 although it is it has been stable in the recent past (1990 – 2002) but the amount of fishing effort dedicated to this statistical division has fallen off since 1998.

Table 5. Monthly landings of brown crab components into the south east fishery in 2002. Weights are in kg.

Month	Bodies (For processing)	Raised claws (For human consumption)	Raised carcasses (For whelk bait)
January	6,772	0	0
February	3,767	2,815	1,938
March	6,649	17,390	6,313
April	13,252	30,430	27,500
May	17,231	39,208	26,250
June	17,494	57,170	33,313
July	28,594	67,553	30,000
August	45,919	102,150	33,344
September	43,648	87,545	40,000
October	44,319	69,198	33,750
November	24,288	31,670	22,125
December	6,379	19,925	13,125
Total	258,312	525,053	267,656
	Total of above		1,051,020
	Actual total live weight landed		958,843

3.6 The operation of the south east inshore fishery in 2002

A simple model of the south east inshore brown crab fishery was devised using the data provided above in order to compare calculated aspects of the way it functioned in 2002 with observed and verified features of its operation.

In Table 7 data on LPUE (column 1) number of pots per boat (column 2), soak times (column 3) [from Table 6] and the monthly landings (column 4) [from Fig 7, Table 5] are the inputs from which the remainder of Table 7 is obtained.

The number of fishing operations per boat per month (column 5) is derived by dividing the soak time into the time available each month. Landings per boat per month (column 6) is the product of columns 1, 2 and 5. The number of boats operating in the fishery (column 7) results from dividing column 4 by column 6.

The number of pots lifted each month in the fishery (column 8) is the product of columns 2, 5 and 7. Pots lifts/day (column 9) is obtained from column 8 divided by the number of days in the month and the number of pots fishing on any day is the data in column 9 multiplied by 2, on the basis that a 48 hour soak time is general in this fishery [Table 6]; soak times tend to be longer in winter, early spring and autumn when prolonged by adverse weather conditions which prevent fishing from taking place; these would however, be unlikely to encourage fishermen to increase the amount of gear in the water in such circumstances.

The maximum number of vessels working in this fishery has been observed at approximately 60, the estimated total in column 7 of Table 7 was 69, a difference of 15%. A second point of corroboration in 2002 was the number of pots in use. Fahy *et al* (2002) provided counts of 10,500 along part of the south coast of Co Wexford in 1998 since when their number has continued to increase. A more recent census in this fishery, updated to 2002 by one of us (JH) provided detailed counts amounting to 16,075 pots to which might be added perhaps 1,000 more from adjoining Co Waterford. It is not feasible to state how many of these were in use at any time. However, the most likely time for maximum usage would have been in the autumn when crab are in their best condition and when the heaviest landings are made in this fishery. The estimated number of pots in the water on any day in October 2002 (Table 7, column 10), was 14,235, which is a difference of 13 – 20% below the most comprehensive and recent census of gear.

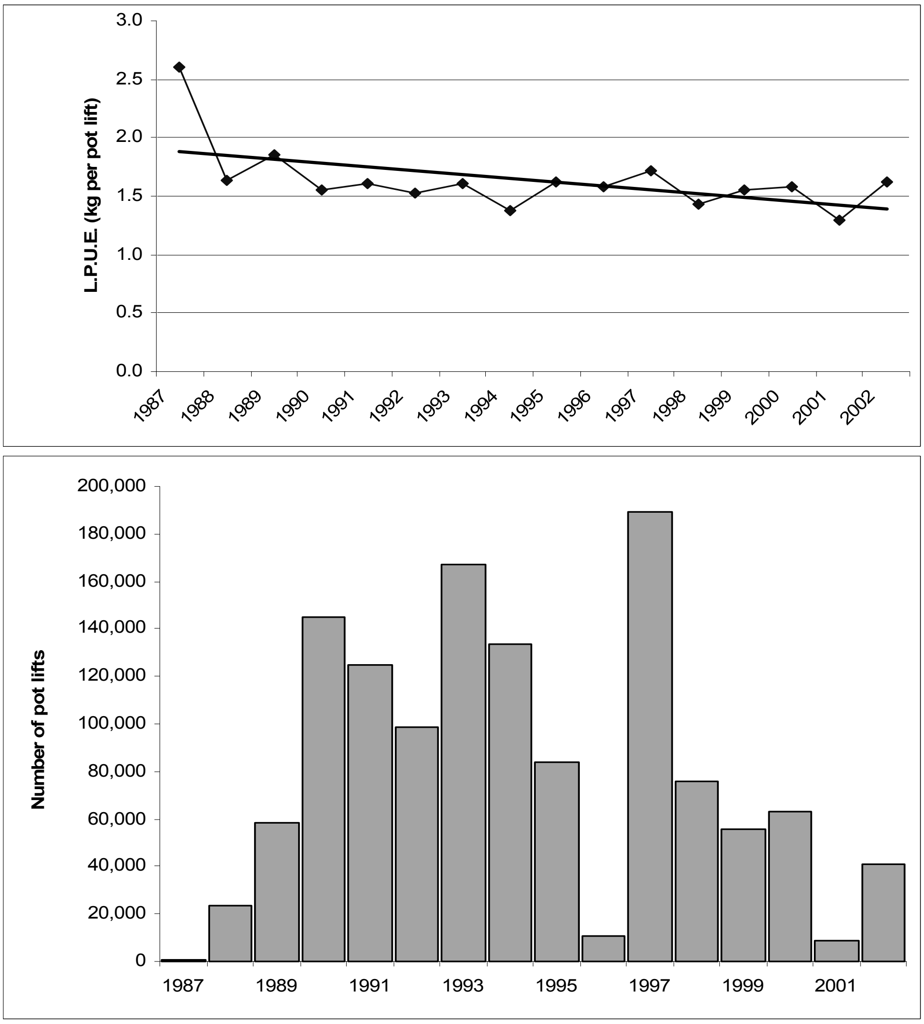

Fig 9. LPUE data for brown crab captured per pot hauled following a 24 hour soak time by the Roscoff super-crabber fleet in the period May – November from 1987 to 2002 in ICES statistical area VIIg (above) and fishing effort by that fleet in the area (below).

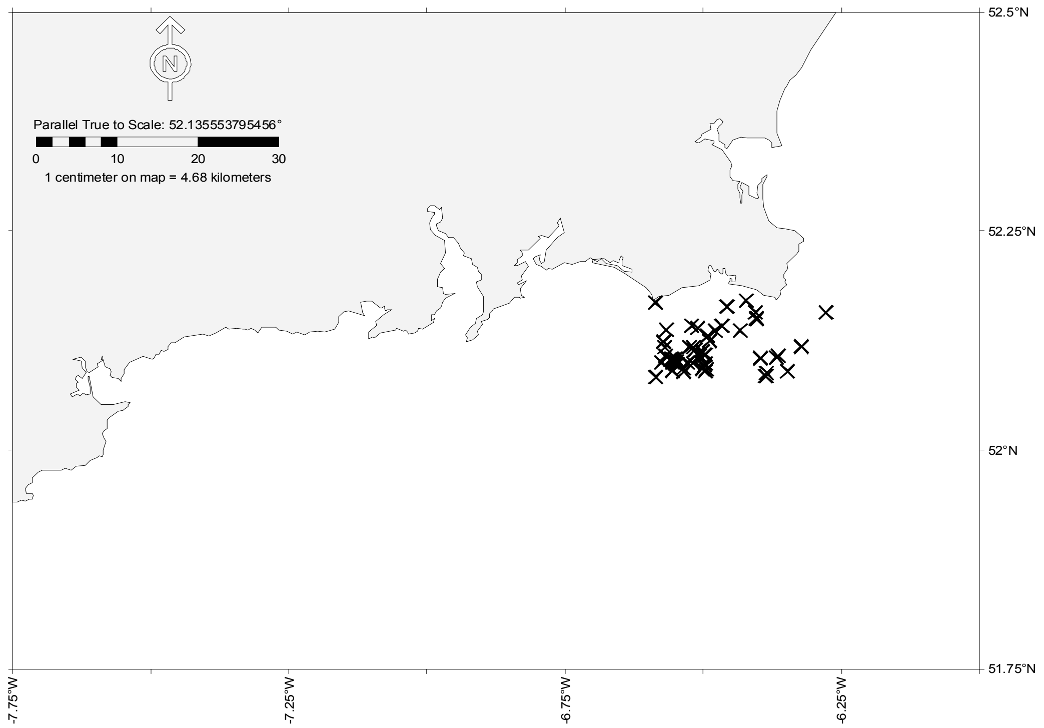

Fig 10. Release points for crab tagged during the mark-recapture experiment in 2002 only.

3.7 Population estimates of brown crab in the inshore fishery

Changes in the population of brown crab in the south east fishery as the 2002 fishing season progressed were estimated from tag returns and commercial landings. The Petersen formula was used because this, or some variant of it, is the basis for all such calculations (Began, 1979). However, the exercise is valid in rare circumstances where certain assumptions can be made. Almost all were violated in the current exercise:

1. a. *All tags should be permanent for the duration of the exercise.* The marks used were affixed externally and would have been lost if the animal had shed a marked cheliped. Loss of the exoskeleton complete with tag through moulting is a more likely problem particularly in the period up to July; for much of the early season approximately 20% of crabs had moulted and this incidence of white (recently moulted) crab peaked sharply in July 2002 (Fig 6).
   b. *All tags must be correctly noted on recapture*. Of a possible total of 60 vessels only four skippers surrendered details of more than 50% of all crab returns. Not all vessels were active throughout the year (Table 7) but details of those returning tags suggested that only a proportion who fished participated in the exercise. This, combined with the submission of data which were incomplete or inaccurate, compounded the problem. It is not feasible to be precise about the degree of under-reporting.

2. A second assumption is that, having been caught did not affect an individual crab's subsequent chance of recapture and there is no reason to believe it did. Eight crabs were recaptured on the same day as they had been released, ten the day afterwards and 25 within 48 hours.
3. It is assumed that in an exercise of this kind, that capture and release did not promote emigration or induce mortality. While there are no data to assume either

occurred as a result, capture took place as part of a commercial fishing operation which is likely to have caused some level of morbidity.

4. It must be assumed that all individuals - tagged or not – have an equal chance of being caught and the observation in point 3 above is apposite here.
5. It must also be assumed that all individuals – tagged or not – have an equal chance of dying or emigrating and the comment in point 3 is apposite.
6. The Petersen estimate assumes there are no births or immigrations and/or no deaths or emigrations. In fact it is likely that female crabs were moving into the fishery in the spring and early summer. This is suggested by the observations on sex ratio (Fig 3) and by the fact that an offshore survey recorded a fall in catches of crab in July which could have resulted from the population having largely moved inshore at that time. The minimum observed distance travelled by both male and female crab per day (Table 3) had fallen to its lowest recorded level in June and July but it increased steadily after that and it is likely that female crab were moving south-westwards out of the fishery in September and October.
7. The final assumption is that sampling periods are short in relation to total time. The discontinuous and limited nature of tag returns would have made selection of such small periods of this kind unworkable; instead the duration of the experiment was divided into five periods. Each was treated as a single sampling event and, to enhance numbers to reproduce some of the phenomena described above, the raw data were transformed by application of a number of partial annual mortality coefficients. The outcome is intended to provide a model of the way in which the population behaved, rather than an estimate of its size.

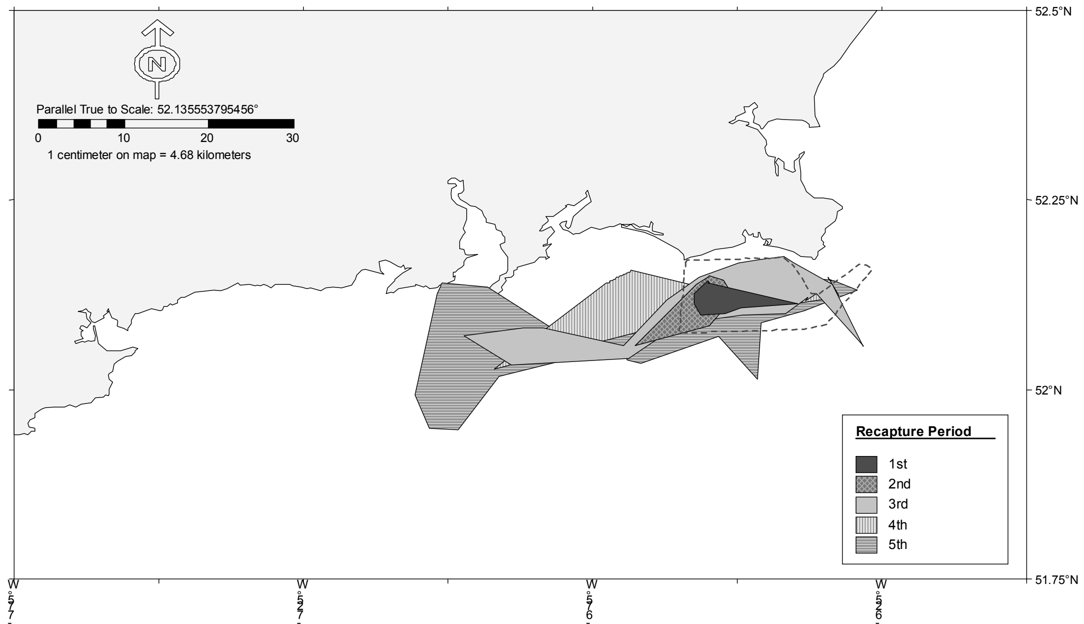

Fig 11. Areas in which tagged crab were recaptured from the south east inshore fishery in 2002 during five periods into which the fishing season was divided. The area in which releases took place is enclosed by the dashed line (from Fig 10).

3.8 Treatment of the data

The tagging and recapture exercise was divided arbitrarily into five periods whose limits, mid- dates and duration are set out in Table 8. The number of crabs landed are estimated from the monthly landed live weights and averaged individual weights (Fig 7, Table 4), and for calculation purposes, the numbers landed in an average month in each period is used as the basis of the population estimate. The area of the fishery in each period is determined by the area from which tagged crabs were recaptured (Fig 11). The distribution of tagged recaptures among the five periods is set out in Table 9.

Table 6. Details of fishing operations in the south east crab fishery in 2002 which are used to elucidate aspects of the bionomics of brown crab. "Own files" refers to data gathered mainly in the course of the mark and recapture exercise and to data used in further calculations. Data for pots targeting crab ("crab fishery") and lobster ("crab and lobster") were provided by BIM. Italicised figures were collected by the authors from other sources. Soak time figures in bold italics are averaged from data collected by BIM. Greater detail is supplied in Appendix Tables 1-3.

Number pots hauled per boat	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Own files	*100*	*150*	*150*	*191*	*168*	186	166	259	287	281	125	140
Crab fishery						97	103	125	118	164	149	131
Crab and lobster fishery						93	136	129	149	172	159	138
Landings, kg/haul	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Own files	*90*	*120*	*135*	*153*	*118*	148	143	183	272	265	142	150
Crab fishery						115	131	140	150	256	188	188
Crab and lobster fishery						51	68	82	106	172	172	199
LPUE/CPUE, kg/pot hauled	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Own files	*0.9*	*0.8*	*0.9*	*0.8*	*0.57*	0.96	0.91	0.74	0.86	0.9	1.14	0.93
Crab fishery						1.1	1.8	1.2	1.3	1.65	1.29	1.44
Crab and lobster fishery						0.34	0.44	0.62	0,7	1.11	1.16	1.57
Soak time, (hrs)	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Own files	*140*	*120*	*100*	*48*	*40*	***38.5***	***51.5***	***53***	***43.5***	***65.5***	***72***	***68.5***
Crab fishery						31	55	56	41	70	90	79
Crab and lobster fishery						46	48	50	46	61	54	58
No. of observations	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Own files	*2*	*3*	*1*	*5*	*6*	7	24	30	40	15	3	3
Crab fishery						10	41	51	59	35	17	8
Crab and lobster fishery		1				24	151	151	133	50	24	10

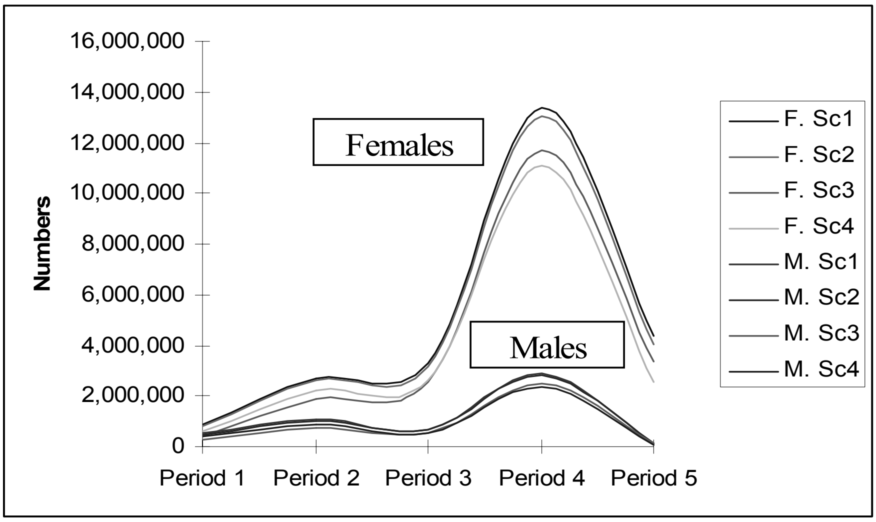

Fig 12. The modelled population of brown crab in the south east inshore fishery in 2002. M=male, F=female, Sc=scenario, further explained in the text.

The interpretation of mark-recapture data was undertaken in each of four scenarios:

Scenario 1. Assumed that the raw data represented a closed population without emigration, immigration, births or deaths; all tagged animals at liberty remained in the fishery until captured. These were clearly not the circumstances in which the fishery in 2002 took place and the following three scenarios adjusted the recapture data to reflect phenomena observed in the course of collecting the data.

Scenario 2. Envisaged some natural mortality and morbidity resulting from handling of the animals during tagging. An annual mortality coefficient (Z) of 0.2 was applied, divided into partial annual mortality coefficient values according to the duration of each sampling period. The number of recaptures *m* made within each period was raised according to the formula:

$$m_{periodX} * \exp(Z_{periodX})$$

Partial annual mortality coefficients were summed horizontally across the periods during which crabs were at liberty. Numbers of animals still at liberty (*r*) were altered according to the adjusted numbers which had been recaptured. The calculations for scenario 2 are set out in Table 10.

Scenario 3. Mortality coefficients of 0.5 were applied to periods 1-3 to take moulting into account; in periods 4 and 5 these were reduced to values of 0.1 respectively. These values were added to the annual mortality values used in Scenario 2 and they were summed for the duration of the experiment until 14 November 2002.

Scenario 4. Envisaged that animals moved out of the fishery during periods 4 and 5. Annual mortality values of 0.2 in period 4 and 0.5 in period 5 were added to the others in

Scenario 3 and the cumulative values were applied to the raw data as in the previous scenarios.
Values of the mortality coefficients used to transform the data are summarised in Table 11. Table 12 provides population estimates (with standard errors), values for the density of crab and exploitation rates in the fishery in each of the five periods of the four scenarios. These are summarised in Table 13. Release points for the population estimate are shown in Fig 10; the distribution of the population throughout the mark recapture exercise (outlining the positions of tagged recaptured animals) is shown in Fig 11. Finally, a simple model of the inshore crab population, numbers divided between sexes according to the proportions of each encountered during tagging, is shown in Fig 12.

Table 7. Operation of the south east inshore crab fishery in 2002

	Column 1	Column 2	Column 3	Column 4
	LPUE: kg/pot	**No pots per boat per lift**	**Soak times (hours)**	**Landings, kg / month**
Jan	0.90	100	140	6,772
Feb	0.80	150	120	6,582
Mar	0.90	150	100	24,039
Apr	0.80	191	48	43,682
May	0.57	168	40	56,439
Jun	0.96	186	39	74,664
Jul	0.91	166	52	96,147
Aug	0.74	259	53	148,174
Sep	0.86	287	44	172,781
Oct	0.90	281	66	198,584
Nov	1.14	125	72	97,928
Dec	0.90	140	69	33,053

	Column 5	Column 6	Column 7
	Fishing operations/boat/ month	**Landings per boat per month (kg)**	**Number boats operating**
Jan	5.3	478	14
Feb	5.6	672	10
Mar	7.4	1,004	24
Apr	15.0	2,292	19
May	18.6	1,781	32
Jun	18.7	3,339	22
Jul	14.4	2,182	44
Aug	14.0	2,690	55
Sep	16.6	4,085	42
Oct	11.4	2,873	69
Nov	10.0	1,425	69
Dec	10.9	1,369	24

	Column 8	Column 9	Column 10
	No. of pots lifted/month in the fishery	**Pot lifts/day**	**Number pots fishing on any day**
Jan	7,524	243	485
Feb	8,228	294	588
Mar	26,710	862	1,723
Apr	54,603	1,820	3,640
May	99,015	3,194	6,388
Jun	77,775	2,593	5,185
Jul	105,655	3,408	6,816
Aug	200,235	6,459	12,918
Sep	200,908	6,697	13,394
Oct	220,649	7,118	14,235
Nov	85,901	2,863	5,727
Dec	36,726	1,185	2,369

4. Discussion

The south east brown crab fishery has an eastern boundary: brown crab do not frequent the south west Irish Sea in any numbers, probably because the currents there are too strong. Only about 1% of the national catch was landed from the Irish Sea in 2002 (source DCMNR) and the whelk (*Buccinum undatum*) fishery there is populated by thin shelled animals, an indication that the seabed is not shared with large numbers of crustaceans; in contrast, whelk patches in the vicinity of Kilmore Quay, in the midst of heavy crab numbers, consist of heavily armoured individuals (Fahy *et al*, 2000). In recent years exploratory attempts have been made to seek crab inshore further east of the area in which tagging took place in 2002 (Fig 1) but these are understood not to have been fruitful.

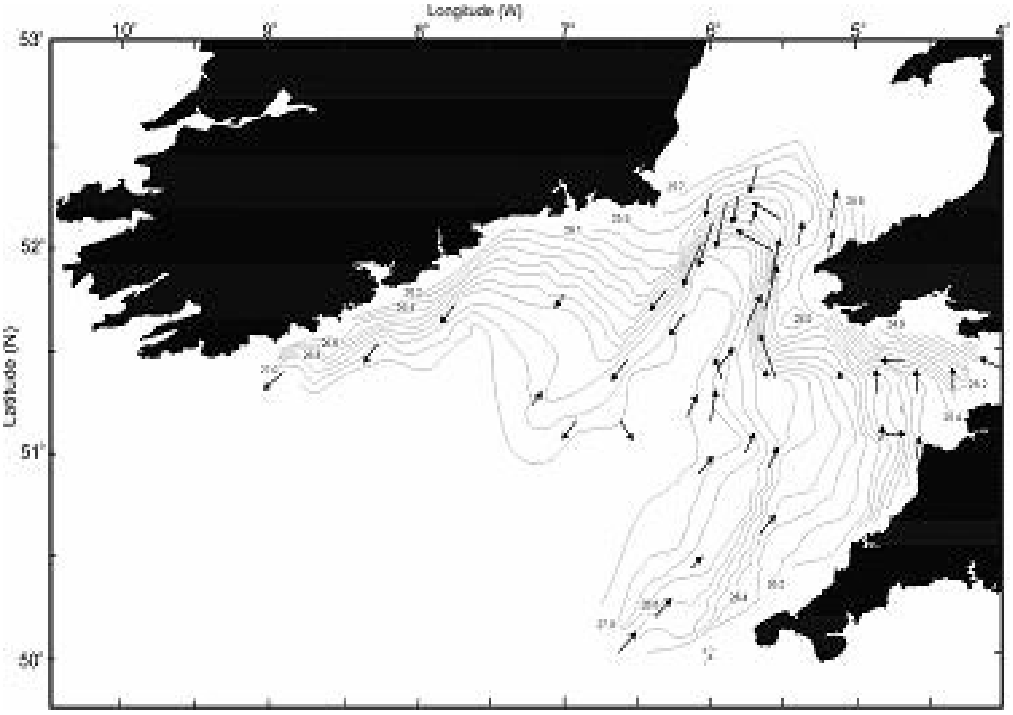

Fig 13. Summer water current circulation in the Celtic Sea (from Brown *et al*, 2003). This modification of the original Figure contains water density isolines and arrows showing the direction and speed of currents.

The off-shore boundaries of the inshore fishery, approximately 10 nm from the coast, are as set out in Fig 11. When they migrate, the animals are presumed to move rapidly (>1.5 km per day) and there is no tradition of targeting them as they travel to and from inshore grounds. The westerly boundaries of the inshore fishery are not known although the furthest west that a recapture took place was offshore of Cork Harbour. Crab potting takes place all along the south coast and in 2002, approximately 6.0% of the national landings were made between Hook Head and the Old Head of Kinsale. Whether crab from the south east fishery move on westwards into this inshore fishery is not known and it remains an open question whether the south coast fishery is stocked with crab which move north from more westerly parts of ICES statistical division VIIg. In the course of the mark and recapture experiment in 2002, fishery personnel were alerted to the likelihood of tagged animals being taken along all parts of the south coast up to and including Co Kerry and the trade press carried notices of the mark-recapture experiment in order to promote reporting of recaptured animals. The longest migrations were made by females, moving in a south westerly direction but few were recaptured beyond Helvic Head (longitude *c* –7.53) and it is possible that most had sought greater depths and moved in a more offshore trajectory before reaching this longitude.

Table 8. Details of the five periods into which the tag recovery programme of 2002 was divided

	From	To	Mid-period date	Duration, months	Area of the fishery (km2)	Numbers of crabs landed	Number landed/month
Period 1	1-Jan-02	6-Jun-02	19-Mar-02	5.2	29	413,266	78,968
Period 2	7-Jun-02	9-Jul-02	2-Jul-02	1.1	48	222,299	202,090
Period 3	10-Jul-02	20-Aug-02	6-Aug-02	1.4	214	384,575	274,697
Period 4	21-Aug-02	4-Sep-02	22-Aug-02	0.5	182	166,280	356,315
Period 5	5-Sep-02	2-Jan-00	5-Oct-02	2.3	427	856,639	367,131
			Total landings (in numbers) during the five periods of the fishery in 2002			2,043,060	(92% of landings for 2002)
			Total landings for year			2,231,143	

The mark and recapture experiment provided good data on several aspects of brown crab biology but the return of tags was poor. There is no way of estimating under-reporting but the data, whether interpreted raw or after alteration in accordance with assumptions which are in line with evidence on moulting and migration, conform to a pattern: female crab immigrate seasonally and leave shallow waters as winter sets in. Males are more sedentary and their numbers do not so dramatically change in the course of the fishing season. The apparent increase in the population estimate for male crab in period 4 (Fig 12) is not in accordance with expectation and, because it is derived as a percentage of the total number of crab, it is possible that the population estimate for the stock numbers at that time was too high.

Table 9. Table of number of crabs tagged and recaptured during the five periods into which the experiment in 2002 was divided.

		Recoveries						
Release period	**Releases**	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**	**Total recoveries**	**% removal**
Period 1	499	26	15	9	1	3	54	11
Period 2	715		45	42	4	46	137	19
Period 3	743			70	22	53	145	20
Period 4	585				23	70	93	16
Period 5	518					40	40	8
Totals	**3060**	**26**	**60**	**121**	**50**	**212**	**469**	**15**
Crabs remaining at large		473	1128	1750	2285	2591		

The south east inshore crab fishery is intensively exploited; its yield of up to 1,000 t to 55 km of coast line is probably comparable with that of the most productive inshore inshore crab fishery, that at Malin Head in Co Donegal. Robinson *et al* (2002) remarked that in five weeks of a tagging experiment there in 2001, approximately 25% of the population had been removed in fishing operations. Exploitation rates in the south east fishery are believed to be equally high although estimates made from the recovery of tags (15% overall, Table 9) and from the landings as a percentage of the estimated population size (1 - 63%, Table 12) or indeed the tag returns according to scenario 2 in Table 10 (1.2% a month in period 1 and 5.2% a month in period 3) are all considerably lower and they are most likely a consequence of under-reporting.

Table 10. Alteration of data estimating the number of crabs which would have been recaptured and those still at liberty (from Table 9) had certain assumed mechanisms not reduced their numbers to those actually recaptured. Numbers actually recaptured and released are presented in Table 9. This is scenario 2.

M = 0.2, which is 0.0166666667 per month					
M	0.0167	0.0167	0.0167	0.0167	0.0167
Months	5.2333	1.1000	1.4000	0.5000	2.3333
	Period 1	**Period 2**	**Period 3**	**Period 4**	**Period 5**
Period 1	0.0872	0.0183	0.0233	0.0083	0.0389
Period 2		0.0183	0.0233	0.0083	0.0389
Period 3			0.0233	0.0083	0.0389
Period 4				0.0083	0.0389
Period 5					0.0389

Cumulative mortality	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**
Period 1	0.0872	0.1056	0.1289	0.1372	0.1761
Period 2	0.0000	0.0183	0.0417	0.0500	0.0889
Period 3	0.0000	0.0000	0.0233	0.0317	0.0706
Period 4	0.0000	0.0000	0.0000	0.0083	0.0472
Period 5	0.0000	0.0000	0.0000	0.0000	0.0389

New numbers recaptured	**Period 1**	**Period 2**	**Period 3**	**Period 4**	**Period 5**
Period 1	28	17	10	1	4
Period 2	0	46	44	4	50
Period 3	0	0	72	23	57
Period 4	0	0	0	23	73
Period 5	0	0	0	0	42
Totals recaptured	28	63	126	51	226
Remaining at large	471	1123	1740	2274	2566

Summary, scenario 2	**At large**	**Nos recaptured**	**Nos recatpured / month**	**% recaptured /month**
Period 1	471	28	5	1.2
Period 2	1123	63	57	5.1
Period 3	1740	126	90	5.2
Period 4	2274	51	110	4.8
Period 5	2566	226	97	3.8

There are few studies of brown crab in Irish waters with which comparison is possible. Most work has hitherto been undertaken on the northern crab fishery (Edwards and Meaney, 1968 Edwards and Potts, 1968, Fox, 1986a-d, Cosgrove 1998 , Tully *et al*, 1998, Robinson *et al*, 2002). The terminology used to describe fishery performance has not always been consistent and this hinders comparison, CPUE and LPUE being used interchangeably to refer to the same data. Tully *et al* (1998) reported that LPUE in the offshore Donegal fishery declined from 2.8 kg per pot hauled in 1991 to 1.85 kg in 1997 and stabilised between 1994 and 1997; this term is also used in Anon (2003) but Robinson *et al* (2002) label the same phenomenon CPUE. No estimate of CPUE is presented in this account of the south east inshore fishery. It is highly variable, depending on substratum and depth (Fahy *et al*, 2002) but, more significantly, discarded undersized crab are rejected immediately from the pots and they are not quantified before being returned to the water. The overall LPUE value of 0.87 kg per pot lift in the south east fishery in 2002, approximately half the value of the inshore fishery in Co Donegal, is one of its most distinguishing features; in fact, it may be even more significant because LPUE in the south east fishery includes poor quality crab carcasses which may well be discarded elsewhere and this is proposed as the reason for the low condition of crab landed by the south east fishery.

Table 11. Summary of Mortality coefficients used in the analysis of tag returns

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Period 1	Raw data	0.0872	0.3489	0.3489
Period 2	Raw data	0.0183	0.0733	0.0733
Period 3	Raw data	0.0233	0.0933	0.0933
Period 4	Raw data	0.0083	0.0133	0.1133
Period 5	Raw data	0.0389	0.0622	0.7622

Sinclair (1988) pointed out that many marine species, especially those with complex life cycles and a planktonic phase, are subject to severe spatial constraints at critical stages of the life history. The mechanism envisaged was the release of a egg or larva which is carried by tidal drift to nursery grounds some distance away, the strategic positioning of the adult at spawning being crucial to the location of settlement. Hill (1995) chose as specific example, the edible crab in which westward migration of adults is thought necessary to offset a generally eastward drift during the pelagic larval phase. Robinson *et al* (2002) and predecessors working in the northern crab fishery described a westerly migration of female adult crab against an easterly current and, presumably, the release of larvae close to the continental slope. Off the north east coast of England, tagging experiments by Edwards (1965, 1966) suggested a northerly and offshore tendency in migrations by mature females. Nichols *et al* (1982) suggested that the release of zoea larvae in this fishery took place 70 km offshore after which the females moved inshore again. Mathematical models indicated that the larvae drifted southwards after release, metamorphosis from megalopa taking place in the vicinity of or on the Norfolk coast, after which the juveniles migrated gradually northwards as they grew (Anon, 2003). Although their full geographical range is not known, crab in the south east fishery appear to make much shorter migrations than their northern counterparts.

In another respect also, the south east crab are unusual in that their principal direction of migration is with the current rather than against it. The currents in the Celtic Sea are anti-clockwise and the movement of female brown crab is westerly (Fig 13). The fact that the area around the Nymphe Bank is one of retention, as has been suggested from plankton surveys (Anon, 2003) may obviate the necessity for gravid animals to strategically position themselves elsewhere. The vicinity of the Nymphe Bank has also been reported to have heavy concentrations of brown crab larvae which lend support to the hypothesis for the operation of a different migratory mechanism in the case of the south east crab stock.

Table 12. Estimated population size, N (with standard error), density (m2/crab) and percentage exploitation of brown crab in the south east fishery according to four scenarios.

Scenario 1	N	s.e.	Density (m2/crab)	% exploitation
Period 1	1,436,610	644,507	20	29
Period 2	3,799,300	514,358	13	6
Period 3	3,972,886	427,277	54	10
Period 4	16,283,611	1,572,910	11	1
Period 5	4,486,963	470,673	95	19
Scenario 2				
Period 1	1,310,019	413,266	22	32
Period 2	3,631,427	222,299	13	6
Period 3	3,804,146	384,575	56	10
Period 4	15,810,592	166,280	12	1
Period 5	4,174,760	856,639	102	21
Scenario 3				
Period 1	660,124	413,266	45	63
Period 2	2,669,892	222,299	18	8
Period 3	3,066,650	384,575	70	13
Period 4	14,237,884	166,280	13	1
Period 5	3,460,224	856,639	123	25
Scenario 4				
Period 1	990,229	413,266	30	42
Period 2	3,134,174	222,299	15	7
Period 3	3,177,661	384,575	67	12
Period 4	13,465,053	166,280	14	1
Period 5	2,631,499	856,639	162	33

It should however be noted that westerly movements by brown crab along the south and west coasts of Britain and Ireland and from the west coast of Northern France, are not uncommon (Bennett *et al*, 1976, Latrouite *et al*, 1989).

The inshore migration of female *Cancer pagurus* in summer is reported over much of the species's range although the explanation for it varies. Two theories have been proposed concerning the release of larvae by *Cancer pagurus*: Williamson, 1904, Pearson, 1908, and Edwards, 1979 all suggested that females move inshore in spring and early summer to release their larvae and Nordgaard (1912) made similar claims for brown crab in Norwegian waters.

It is more likely from the evidence presented here that female brown crab move inshore in order to moult and to mate. That inshore migration appears to begin in April or May but the evidence from offshore surveys in 2002 suggests that it may not be completed until July.

Table 13. Range in total population estimates and density of crab in the south east fishery in 2002.

	Total population million			Density m2/crab		
Period 1	0.6	to	1.4	20	to	45
Period 2	2.7	to	3.8	13	to	18
Period 3	3.1	to	3.9	54	to	70
Period 4	13.5	to	16.3	11	to	14
Period 5	2.6	to	4.5	95	to	162

The status of the south east brown crab fishery remains, at the end of this investigation, uncertain. Landings are still high and the fall in LPUE as described on the basis of crab purchasing figures indicating a decline (Fahy *et al*, 2002) might well represent simply an intensifying competition for the resource. On the other hand, the inshore fishery is a seasonal aggregation in which the density of the animals might be misleadingly high. The offshore super-crabber fleet from Roscoff could provide a better indication of abundance but its interest in crab stocks which adjoin this inshore fishery has been declining in more recent years (Fig 9). Tully *et al* (1998) demonstrated that a mobile offshore fleet in Co Donegal obtained consistently high LPUE but over a declining area between 1991 and 1996 and that could well be the phenomenon shown in Fig 9.

Acknowledgements

Among the many people who contributed to the work described here are the fishing community of County Wexford and particularly that of Kilmore Quay. The following buyers and processors provided landings data for brown crab landed in 2002: Sofrimar, Kilmore Quay, Carr & Sons, Curraglass, Co Waterford, Saltee Shellfish, New Ross, and Atlantis, Wexford. David Stokes of the Marine Institute prepared Figs 10 and 11 and Glenn Nolan, also of the Marine Institute, prepared Fig 13. Additional data were supplied by Oliver Tully of BIM and Martin Robinson of Trinity College Dublin. The authors are particularly grateful to Daniel Latrouite of IFREMER who read through and commented on an early draft of the paper. The work was part financed by NDP funds (project number 01.SM.T1.03).

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Appendices

Appendix Table 1. Details of performance of the south east crab fishery in 2002 from data collected in association with tagging and tag recovery.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pots hauled per boat per day										
Average	150	191	168	186	166	259	287	281	125	
Standard deviation		50	49	35	81	128	124	129	9	
Number of observations	1	5	6	7	24	30	40	15	3	
Weight of landings, kg/day										
Average	288	192	118	148	143	183	272	265	142	
Standard deviation	53	148	72	99	77	228	191	158	14	
Number of observations	2	6	7	16	34	19	32	15	3	
LPUE, kg/pot										
Average	2.2	0.8	0.57	0.96	0.91	0.74	0.86	0.9	1.14	
Standard deviation		0.64	0.2	0.6	0.56	0.61	0.35	0.19	0.19	
Number of observations	1	5	6	7	24	19	32	15	3	

Appendix Table 2. Details of brown crab landings in the south east crab fishery by pots targeting brown crab; Source, BIM.

	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pots hauled per boat per day										
Average				97	103	125	118	164	149	131
Standard deviation				19	41	36	43	41	34	32
Number of observations				10	41	51	59	35	17	8
Weight of landings, kg/day										
Average				115	131	140	150	256	188	188
Standard deviation				85	67	69	81.6	90	95	48
Number of observations				10	41	52	59	35	17	8
CPUE, kg/pot										
Average				1.1	1.8	1.2	1.3	1.65	1.29	1.44
Standard deviation				0.62	2.99	0.53	0.64	0.66	0.57	0.25
Number of observations				10	41	51	59	35	17	8
Soak time, hours										
Average				31	55	56	41	70	90	79
Standard deviation				16	53	79	20	43	50	53
Number of observations				10	41	52	59	35	17	8

Appendix Table 3. Details of brown crab landings in the south east fishery where some gear targeted lobster; Source, BIM.

	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pots hauled per boat per day											
Average	200				93	136	129	149	172	159	138
Standard deviation					72	74	74	72	56	47	65
Number of observations	1				24	151	151	133	50	24	10
Weight of landings, kg/day											
Average	350				51	68	82	106	172	172	199
Standard deviation					75	73	71	91	110	74	72
Number of observations	1				24	151	151	133	50	24	10
CPUE, kg/pot											
Average	1.75				0.34	0.44	0.62	0.70	1.11	1.16	1.57
Standard deviation					0.43	0.43	0.52	0.58	0.72	0.52	0.48
Number of observations	1				24	151	151	133	50	24	10
Soak time, hours											
Average	46				46	48	50	46	61	54	58
Standard deviation					35	40	52	29	34	36	49
Number of observations	1				24	151	151	133	50	24	10