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The inshore pot fishery for brown crab (*Cancer pagurus*) landing into south east Ireland: estimate of yield and assessment of status

by

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ABSTRACT

Although it is regarded as an important focus of brown crab *Cancer pagurus* landings, the fishery in south east Ireland is poorly documented and the official statistics are believed to under-record the species by a factor of *2-3. This appraisal of the south east Ireland brown crab fishery is based on >22,000 records of sales transactions from the 1990s and a comparison of the biological characteristics of landings in the late 1960s with thirty years later, in the context of increasing fishing effort. The three buyers who gave access to their books inwards for periods of the 1990s, purchase from the same fishing community and they compete for product but they occupy slightly different market niches: a *vivier* truck operator exports to Spain, a processor concentrates on autumn purchases of female crab for vacuum packing while the third buys crab claws for human consumption and crab bodies which are used as bait for whelk *Buccinum undatum*. Only the first sales of crab from 55 km of coastline are considered. In this area fishing effort doubled between 1972 and 1988 but expansion accelerated in the following decade by at least 128%; a single operator increased his effort by 80% between 1988 and 1998. In the 30 years after 1968, the number of pots per km of coastline rose by 241%.The sale of brown crab is recorded in consignments which are raised to live weights in the analysis. Consignment size fell steeply in the late 1980s and early 1990s after which it stabilised; adjusting the figures to allow for increasing effort accentuated the trend; at the same time consignment number rose. Allowing that a decline in consignment size was accompanied by an increase in pot number, consignment number should have risen by 310% to maintain landings at the level recorded in 1990; the largest recorded increase in consignment number was by 230% and while it is accepted that all sales transactions have not been obtained, it is likely that LPUE has been declining over the 1990s in real terms in this fishery. Increasing fishing effort during that time is seen as a product of better technology, stimulated by a desire to compensate for falling LPUE. Comparison of size and sex composition of the landings recorded in the late 1960s and the late 1990s are inconclusive. Depth of water and type of substratum are likely to influence the composition of inshore landings. An argument is presented that the south east inshore crab fishery is fully or over-exploited. It is likely to have an offshore component and such occasional data as are available on brown crab further south suggest that the offshore is an under-exploited fishery. In which case, the rate of interchange between the two components is likely to be crucial to the continued performance of the inshore fishery.

1. Introduction

When he reviewed the biology of the edible crab in British waters in 1979, Edwards described it as having only minor fisheries around the Irish coast. He reported landings of 605 metric tonnes (t) to Ireland in 1969, increasing to 953 t four years later. In 1999, 7,774 t of edible crab were landed in Ireland (source: Department of the Marine and Natural Resources).

Although south east Ireland has been recognised as an important focus for brown (edible) crab (*Cancer pagurus*) landings, which come from a pot fishery targeting larger crustacean species, over the past thirty years, only occasional observations on the fishery are available in the literature. In recent years a pioneering lobster (*Homarus gammarus*) management programme has become established there, introducing the possibility of a managed crustacean pot fishery. An appraisal of brown crab, its most abundant target species, is appropriate, Irish crustacean fisheries generally having expanded and intensified over the past thirty years.

Fisheries for the larger crustaceans in western European waters [lobster, crawfish (*Palinurus elephas)*, brown and spider crabs (*Maja squinado*)] have received scientific scrutiny proportional to their economic value (see Fahy, 2001 on spider crab). Some data on the conduct of fisheries for other crustacean species are relevant to brown crab and these are assembled here, together with information from fishermen, sales data from processors and biological information on the catches gathered between 1997 and 1999).

Literature sources consist of a number of papers prepared by scientific staff in the government department responsible for fisheries and in the Irish Sea Fisheries Marketing Board (Bord Iascaigh Mhara, BIM). Gibson conducted various investigations on the lobster fishery centred on Kilmore Quay and published a series of annual reports on fishing effort which are relevant. He regarded the fishery for edible crab as a by-catch of the lobster fishery and having a season from May to the end of November (Gibson, 1973a). Edwards (1979) also provided some biological data on the biology of brown crab in the vicinity in the 1960s as did Edwards and Meaney (1968) and Edwards and Potts (1968).

The objective of this work is to ascertain the performance of the fishery in recent years on the basis of the effort currently exerted and the landings made. Biological samples are examined to ascertain what, if any, demonstrable consequences the expansion of this fishery has had for the stock.

The area under consideration extends from Rosslare, on the east coast, south through Carne, west through Kilmore, Bannow Bay then south along the Hook Peninsula through Fethard and Slade, further west into Waterford Harbour, ending at Dunmore East, a distance of 55 km (Fig 1).

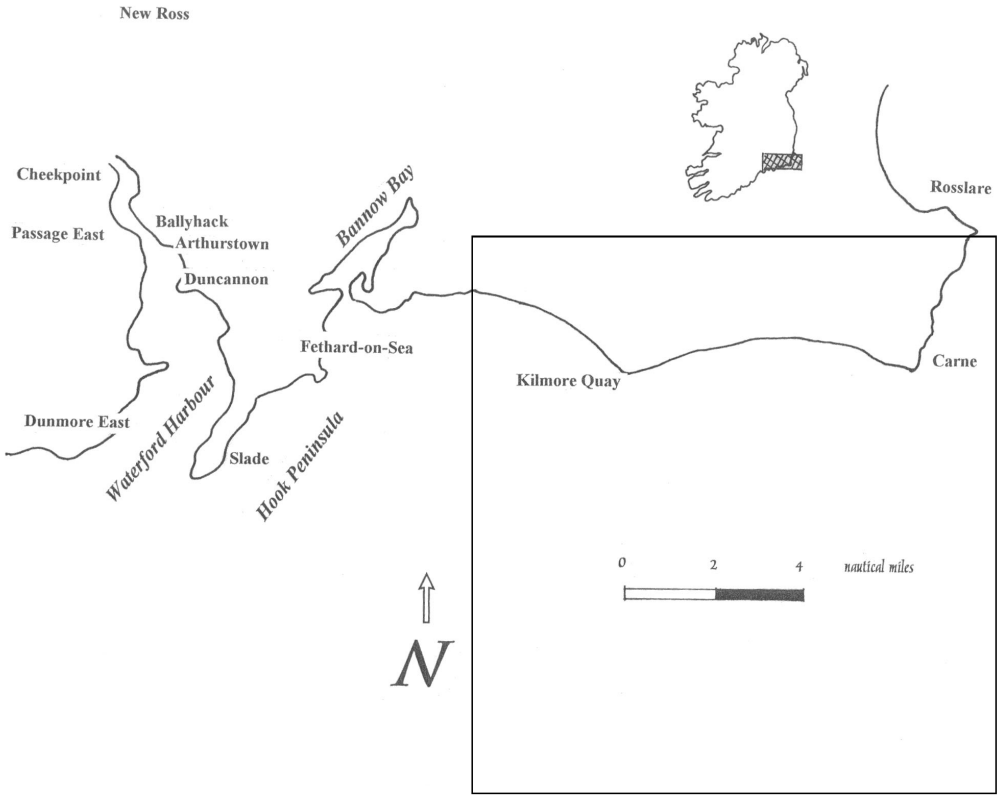

Fig 1. The coastline to which landings were made from the south east inshore crab fishery. The inset map of Ireland shows the location of the area; the rectangle marks the boundaries of the area considered further in Figs 13, 14 and 15.

2. Sources of data

2.1. Fishing effort

In a series of Fishery Leaflets Gibson documented the distribution of fishing effort around the coast in the late 1960s and early 1970s at a time when effort was mainly directed at lobster and crawfish with gear capable of taking brown crab (1969b, 1970, 1972a, 1973a,b). For the period 1968 – 1972 Gibson provided details of the numbers of boats and traps fishing in Co Wexford. These are interpreted as an indication of fishing effort for larger crustaceans. Gibson listed 26 – 31 boats as operating on a coastline of 134 km (Table 1), each one fishing between 95 and 117 traps. The latter figure is a crude estimate because the number of traps operated by a vessel is generally proportional to its dimensions. Fishing effort might also be expressed as 18 - 27 traps per km of coastline which is also an over-simplification because fishing effort would be concentrated on certain areas rather than evenly distributed along the coast of the county. Accepting that pot fishing for larger crustaceans took place along much the same coastline as currently happens [the inshore Celtic Sea is a fishery for crustaceans rather than for whelk, *Buccinum undatum*, for instance (Fahy *et al*, 2000)], the number of traps per km would range between 45 and 66 per km in the period documented by Gibson.

Table 1. Historic estimates of a component of effort in the south east crustacean pot fishery (1) and (2) refer to different estimates (see legend below).

Source	Year	Total no traps	Punts	Vessel type: Boats + outboards	Vessel type: to 30 feet	Vessel type: 31-45 feet	Vessel type: >45 feet
Gibson 1969b	1968	3095	9		21		1
Gibson 1970	1969	3630	9		21		1
Gibson 1971; Gibson 1972b	1970	3480		9	15	7	1
Gibson 1973a; 1973b	1971	2923		5	14	7	1
Gibson 1973a; 1973b	1972	2480		8	11	6	1

Source	Year	Total boats	Km/boat (1)	Km/boat (2)	Traps/boat	Traps/km (1*)	Traps/km (2**)
Gibson 1969b	1968	31	4.3	1.8	100	23	56
Gibson 1970	1969	31	4.3	1.8	117	27	66
Gibson 1971; Gibson 1972b	1970	32	4.2	1.7	109	26	63
Gibson 1973a; 1973b	1971	27	5.0	2.0	108	22	53
Gibson 1973a; 1973b	1972	26	5.2	2.1	95	18	45

(1*) Estimate of total county coastline
(2**) Estimate of south east fishery, 55 km, shoreline

Details of the numbers of pots fished within the study area between 1988 and 1998 were provided by Mr Tom Roche of Kilmore Quay (Table 2). Fishing effort, expressed as the number of pots per km of coastline, approximately doubled between 1972 and 1988 but expansion accelerated in the next decade. Excluding Dunmore East, for which figures were not available, effort increased over the period by 128% (which would include the increase in gear used by an individual vessel and the number of boats) while a single operator increased his effort by 80% in the same period. The number of pots fished per km of coastline increased by approximately 241% in the thirty years between 1968 and 1998.

2.2.The adjoining offshore fishery

The south east inshore fishery is conducted within 10 nautical miles of shore but brown crab is a migratory species (Anon, 2001) and the inshore fishery is likely to have an offshore component. The most likely documented indicator of fishing effort offshore is the Roscoff offshore fleet on which data were supplied by Daniel Latrouite of IFREMER (pers comm). In the period 1986 – 1999 between 11 and 16 vessels whose lengths were between 17 and 25 metres, have fished extensively in the English Channel. Logbook data suggest the fleet is wide-ranging, fishing in 25 – 40 ICES statistical rectangles annually in the course of which 1,500 and 2,500 tonnes of edible crab, 20 – 200 t of spider crab and 15 – 32 t of lobster are landed. Fishing effort (expressed as numbers of pot-hauls) increased slightly from 1986 to 1990 when it stabilised. LPUE remained stable until *c* 1993 when it increased by *c* 16% until 1999.

Table 2. Reports of change in a component of effort (pot numbers) in the south east crustacean fishery.

Year	Landing area: Slade and Duncannon	Fethard	Carne and Rosslare	Kilmore	Totals	Single operator: Kilmore	Pots per km
1988	1,000	600	1,000	2,000	4,600	200	84
1989	1,100	600	1,100	1,800	4,600	200	84
1990	1,100	600	1,100	1,800	4,600	220	84
1991	1,200	700	1,200	2,000	5,100	220	93
1992	1,350	800	1,350	2,000	5,500	240	100
1993	1,350	900	1,400	2,300	5,950	240	108
1994	2,500	1,000	1,700	2,600	7,800	300	142
1995	3,000	1,200	2,000	2,600	8,800	300	160
1996	3,000	1,200	2,100	3,000	9,300	300	169
1997	3,300	1,500	2,300	3,200	10,300	340	187
1998	3,300	1,500	2,500	3,200	10,500	360	191

2.3 The buyers of crab from the inshore fishery

Three buyers of crab were approached and they gave access to their books inwards which provide the data for this analysis. Each currently occupies a different market niche although there is competition among them for product. There are also subsequent sales of crab from one to the other.

Co A is a *vivier* truck operation purchasing live crustaceans for export to Spain which buys according to seasonal activity. Co A deals in lobster, brown crab and velvet swimming crab (*Necora puber*) and also exports a small quantity of spider crab. Data abstracted from the files of Co A span the period 1987 to 1998.

Co B processes brown crab and there are few references to other crab species on its books. Most processing by Co B takes place in the autumn when crabs are in best condition. Various categories of crab are distinguished in the books inwards because they are accorded different monetary values. Rejects have occasionally been quantified but inconsistently so. Males and females have also been identified separately at times; in 1,147 t of brown crab whose sex composition was detailed, males accounted for 10% by weight of the total. Data from Co B are for the period 1990 to 1999 inclusive.

Co C processes a number of shellfish species of which whelk is of most value to the factory. Whelk are captured in pots using a combination of cat shark (*Scyliorhinus* spp) and brown crab as bait. The factory buys in crab carcasses which are sold to the whelk fishermen, the exchange of bait and landings taking place when lorries from the factory make their daily round of landing places. Crab claws are also purchased by the factory. Records from Co C cover the period 1992 to 1999 inclusive.

2.4. Biological investigations

The size composition, weight and sex ratio of catches of brown crab from part of the south east fishery were noted, in order to ascertain the possible influence of location, particularly distance offshore, on these characteristics of the landings. Additional biological observations on catches and landings were made for comparison with similar data recorded in earlier years.

3. Materials and methods

3.1 Treatment of commercial data

This analysis is concerned only with the first sale of brown crab by fishermen within the specified area. Sources of landings were obtained from books inwards in which individual fisherman and landing places were identified. Inter-processor sales were not considered, nor were sales from outside the defined area. The three purchasers obtained most of their crab from the same fishing community.

Crabs are purchased in consignments but the details of a transaction invariably relate to the value of the product which might, in turn, be a consequence of its use. The species of crab was invariably identified, but Co C may have had some spider crab among brown crab destined for use as bait and not separately distinguished. At the other extreme Co B identified some brown crab according to sex, whether a cheliped was missing and whether it was "live" (had the adductor muscle cut to facilitate storage in a keep box) or "cooking" (freshly caught) crab. Co B irregularly quantified reject crab. Co A might grade several crab species by size but not consistently.

As a preliminary all brown crab were raised to live weights. Claws were converted using the multiplier *5. "Cripples" are a category of crab missing one cheliped which are raised to live weight using the multiplier *1.1. Female crab is preferred for processing and it may fetch a higher price than male so the sexes might be distinguished on remittance advices. "Bodies" refers to brown crab used as bait in the whelk fishery; they might originate as rejects from crab processing or be a by-product of the claw fishery or, they might be soft crab which have not yet hardened after moulting. Bodies have been known to include undersized crab and animals which are targeted for use as bait. Examination of bait crab revealed that a large proportion of the animals still had their claws attached (Fahy, 1999). Live weight of crab bodies was not adjusted.

Because claws and crab bodies which are used as whelk bait might come from the same animals, there was a possibility of live weights occasionally being too high when carcass weight and claw weights raised to live weights were added together. The purchases by Co C, which bought crab bodies and claws were examined in this respect. Fig 2 shows the weight of crab claws raised to live weight as a percentage of total brown crab live weight, from local sources over the period 1992-1999. Bodies from the claw fishery accounted for 31 – 51% of live weights.

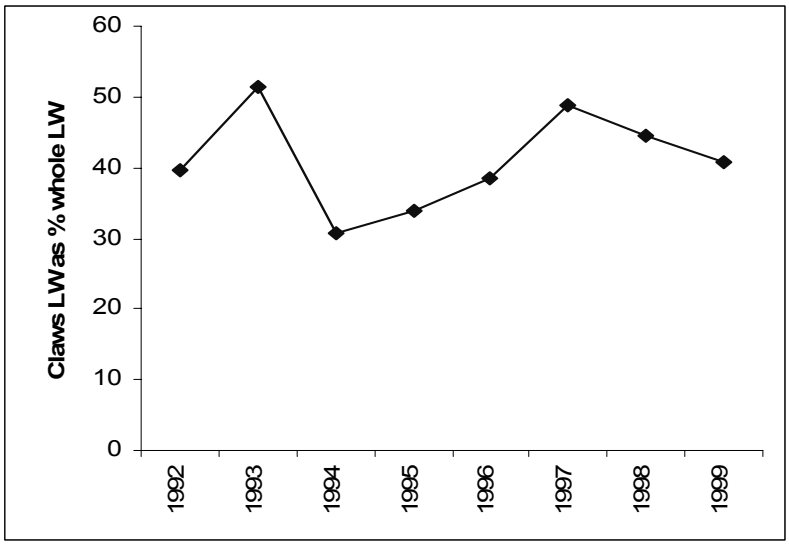

Fig 2. Percentage live weight (LW) of brown crab purchases by Co C, accounted for by crab claws, 1992 – 1999 inclusive.

If all crab purchases to Co C derived from the claw fishery, then claw live weight should approximate 50% of total brown crab purchases. To clarify further, the percentage contribution is set out by month for the duration of the data from Co C in Fig 3.The resulting histogram is taken to indicate that the claw fishery contributes significantly to whelk bait throughout the year but its peak months are August - September, when white (recently moulted crab) are likely to contribute to the landings destined for whelk bait.

In the case of Co C the live weight of crabs based on raised claw weight was calculated separately from the weight of carcasses purchased. The larger of these two figures in any year was reckoned to be the weight of brown crab bought in by the processor.

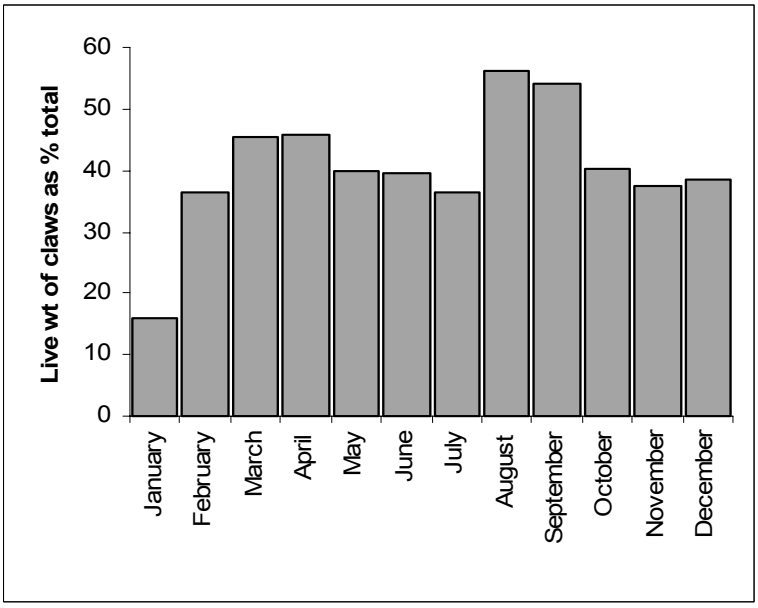

Fig 3.Percentage monthly live weight of brown crab purchases by Co C, accounted for by crab claws, all data pooled.

3.2. Biological samples

Brown crab landings were examined in spring (April and May 1997) and summer (July 1997, 1998 and June 1999) for comparison with the work of Edwards and Meaney (1968) and Edwards and Potts (1968). Crab catches were examined opportunistically in 1997 – 1999 at processors within the area and at sea. The maximum width across the carapace was measured and each sampled animal was sexed in the course of this.

In order to investigate the distribution of yield, sizes and sexes of brown crab on the inshore grounds, the catches from pots fished in four months, October 1999, March, July and September 2000 were examined. On each occasion all brown crab from several trains of pots (each having *c* 30 pots) were examined individually and recorded by sex and whether they were of legal size (130 mm in accordance with E.U. Council Regulation 850/98 and amendments and Council Regulation 3440/84 and amendments) and the numbers landed from each train of pots were counted. A G.P.S. reading was taken at each location.

4. Results

4.1 History of landings

All abstracted crab landings by local fishermen, within the area of interest, sold to the three principal buyers are set out in Table 3. Brown crab accounts for 93.6% and velvet crab for 4.3%. Spider crab makes up most of the balance but is thought to be under-recorded as, to a greater extent, are green crab (*Carcinus maenas*), the latter being a specialised and separate fishery which is not further alluded to here. The total landings of brown crab set out in Table 3, were sourced to the following landing places: Kilmore Quay, 29%; Waterford Harbour 25% (Arthurstown, Ballyhack, Cheekpoint, Duncannon, New Ross, Passage East); Slade, 15%; Fethard-on-Sea, 14%; Carne and Rosslare, 7%, Dunmore East, 8% and Bannow Bay, 2%.

Table 3. Purchase of crab species by three processors in south east Ireland over the period 1987 – 1999.

Species	Tonnes	Percentages
Brown crab	4,325	93.6
Velvet crab	199	4.3
Spider crab	86	1.9
Green crab	10	0.2
Total	**4,620**	

Annual purchases of brown crab by the three principal buyers are set out in Table 4. Only the period 1992 – 1997 (excepting 1995) is comprehensively covered. However the landings attributed to the three processors are not a comprehensive account of all brown crab catches along this coastline. Smaller processors and *vivier* truck operators

are known to have been active in the region but their records were not obtained. Nor is there any account of animals which might have been delivered for sale and then tipped or sold on as bait because their quality was inadequate. Substantial quantities of brown crab were sold-on elsewhere, to be used as whelk bait, for instance, by other processors but these were second rather than first sales and their provenance could not be traced.

4.2. Consignments of brown crab

This appraisal of the south east fishery is based on the analysis of 22,346 consignments of brown crab purchased by the three processors considered here. Exactly what a consignment represents is central to the analysis and it is difficult to determine; in fisheries for shrimp and whelk it is customary to sell a day's catch to a processor and, in such cases, a single consignment represents a day's fishing (although it has not necessarily required the same amount of gear to make every day's landing) (Fahy *et al* , 1996; Fahy *et al*, 2000). Crab fishermen rely to a large extent on keep boxes where landings are accumulated, unless they are of crab claws which are usually disposed of directly, so that it is impossible to say what fraction of a day or how many days' landings a single sales transaction represents. An assumption is made that consignments are transferred to buyer at a rate which is proportional to the amount of fishing activity. A second proposition is that, over the longer term, the landing and sales routines do not change. Thus, there would be more transactions at the busy fishing time than at times of the year when fishing activity is less and it is also assumed that fishermen fill and empty their keep boxes in a similar routine from one year to the next. The weight of a consignment was calculated as the sum of the various categories of brown crab raised to live weight and attributed to a named fisherman on a specific date.

4.3. The crab fishing season

Of the three buyers considered here, only Co A has shown a consistent interest in all three crab species. The season for two of them, spider and velvet crab, begins early in the year, gradually reaching a peak in May, after which it declines (Fig 4). Spider crab has a marked seasonal abundance, the animal moving inshore in response to rising temperatures (Fahy, 2001) and consignments of it increase in weight until June and decline thereafter. Consignments of velvet crab do not show a marked seasonal variation, possibly reflecting a less migratory behaviour pattern.

Brown crab is landed in a similar seasonal cycle, few consignments being purchased in the early months of the year but increasing into the summer and early autumn, then decreasing as winter sets in (Fig 5). This pattern of exploitation resembles that described by Edwards (1979) for the Devon brown crab fishery, rather than, say, the pattern of exploitation he provides for the Yorkshire brown crab fishery, although there is a peak of activity in June in the south east fishery. There are however, two patterns of brown crab purchase: Cos A and C appear to purchase brown crab as it becomes available and between them they share the spring and summer landings while Co B concentrates its purchasing into the period August-October when the animals are in best condition for processing.

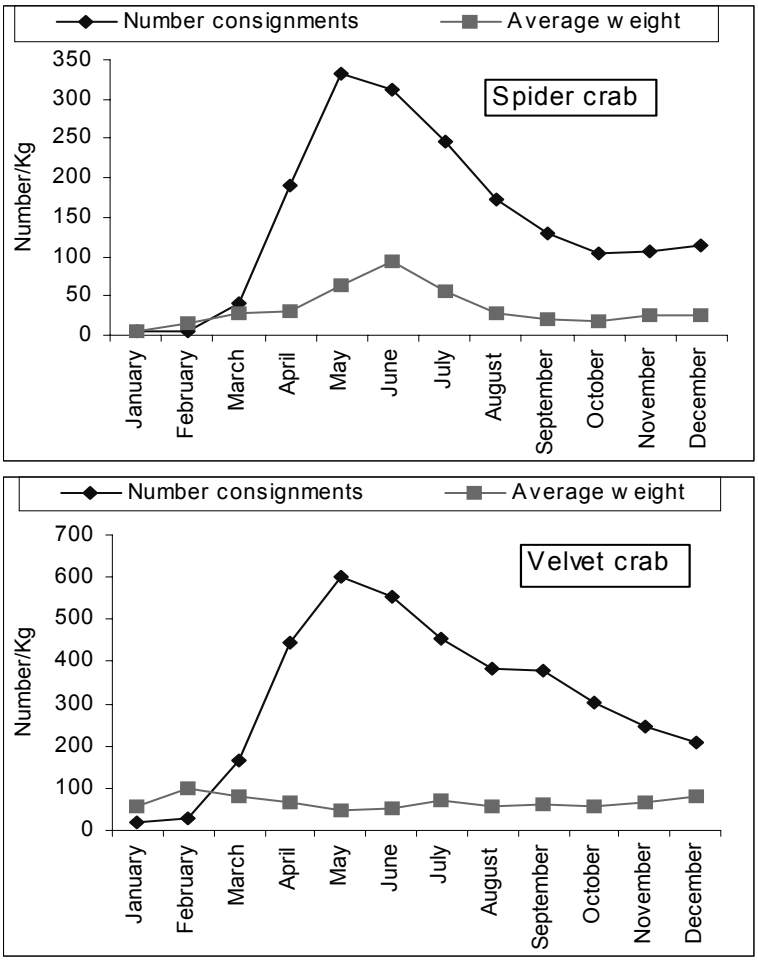

Fig 4.The monthly pattern of purchases of spider and velvet crab by Co A, as indicated by the numbers of transactions and the average weight of a consignment (kg), all data pooled.

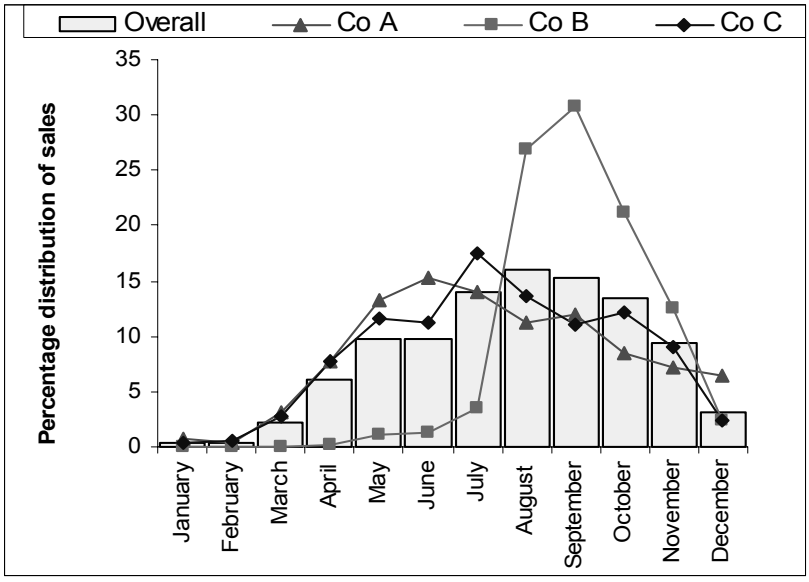

Fig 5. The monthly frequency distribution of sales of brown crab by fishermen to three purchasers, all data pooled.

The weight of an individual consignment also conforms to one or two patterns but these are not associated with the same companies (Fig. 6). The weight of crab sold to Cos A and B have similar frequency distributions. Average weight is highest in crab sold for processing to Co B (mean = 362 kg, s.d. = 308, N= 4,661). Co A, the *vivier* operation, bought over a longer period of the year and slightly smaller consignments (mean = 283 kg, s.d. = 247, N = 3,880). Smallest purchases were made by Co C, the dealer in claws and bodies for bait (mean = 225 kg, s.d. = 828, N=13,805); one third of these purchases consisted of little more than one standard (45 kg) fish box of crab (containing *c* 30 kg of this species). The smallest consignments to this buyer included animals from which the claws had been removed and crabs which had not hardened after moulting, (Fahy, 1999).

4.4. Trends in consignment size and number

Fig 6 shows the weight of a first sale consignment of brown crab in the south east fishery to be variable. In order to reduce variability within the data set for a single processor, the average weights and tonnage landed per month are set out in Fig 7. In each case the period of heaviest landings during which the average weight of a consignment was approximately stable was identified. For Co A, it was June to November inclusive, for Co B August to November and for Co C, two periods of relative stability were identified, April to August, a low season, and October to November, a high season of purchasing activity.

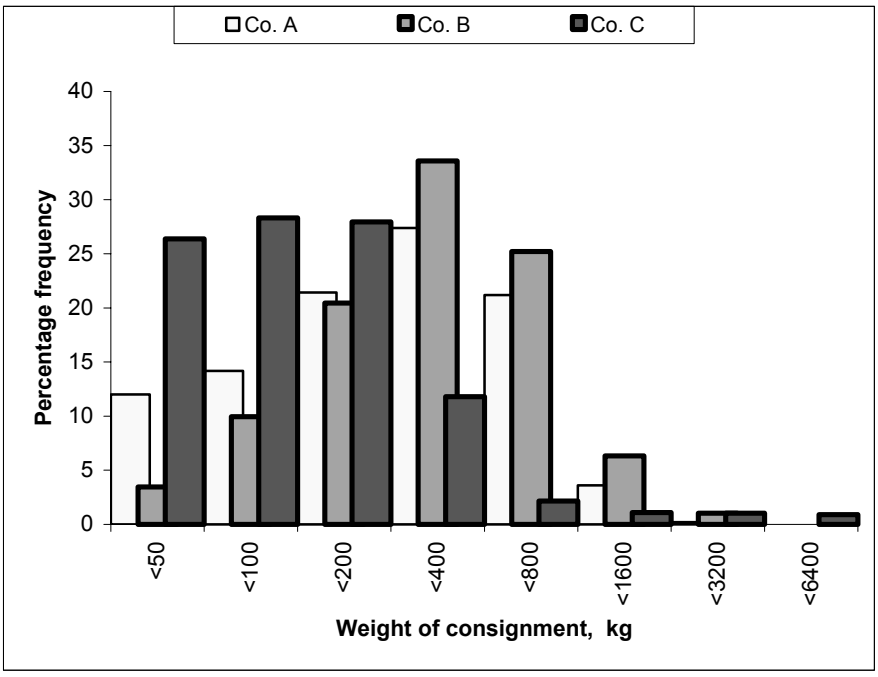

Fig 6. Percentage frequency distribution of consignment weight (kg) of brown crab as purchased by three buyers, all data pooled.

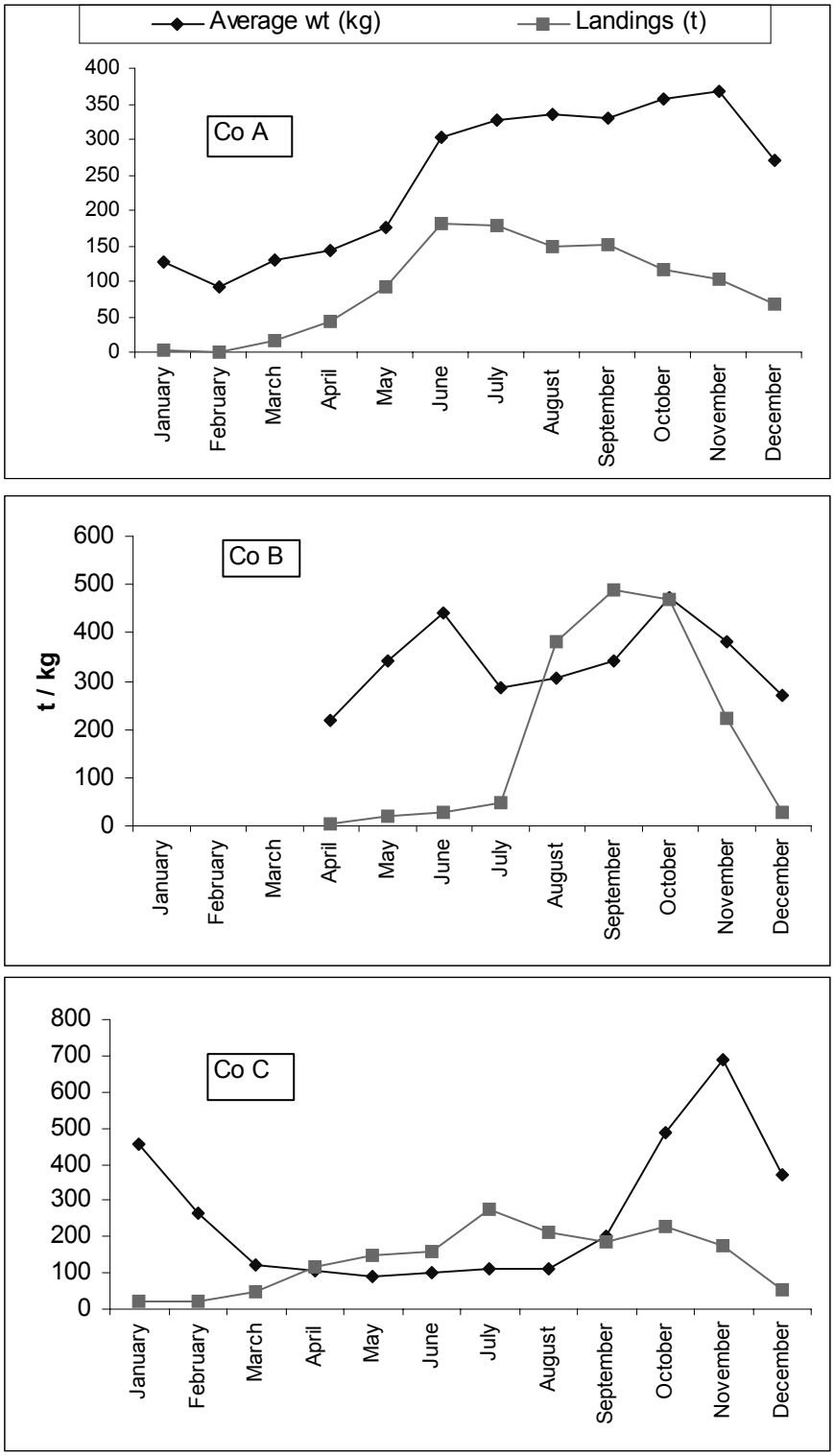

Fig 7.Average weight (kg) of consignments of brown crab purchased and landings per month (t), all data pooled, by three buyers in the south eastern fishery.

Table 4. Annual landings of brown crab to three purchasers, in the period 1987 - 1999. Comprehensive coverage took place in the period 1992 - 1997 inclusive.

Year	Co A	Co B	Co C	Totals (kg)
1987	yes			82,737
1988	yes			218,005
1989	yes			128,948
1990	yes	yes		236,560
1991	yes	yes		234,897
1992	yes	yes	yes	381,272
1993	yes	yes	yes	441,737
1994	yes	yes	yes	315,800
1995	yes	yes	part	228,909
1996	yes	yes	yes	505,017
1997	yes	yes	yes	699,872
1998	part	yes	yes	473,931
1999		part	yes	377,376
2000				
			Total	**4,325,061**

In Fig 8, the average weight of a first sale consignment of brown crab under each of the above headings is standardised to the level of effort in 1990, according to the figures for the number of pots fished by a single operator (from Table 2).

There is a steep decline in LPUE in the late 1980s and early 1990s. Of the five data sets (the fifth being an average of all data), only Co B and the average weight of all consignments recorded annually show a significant downward trend. The trend for Co A, though not significant, is also downwards, while the x-variables for the high and low seasonal values of Co C are both positive (Table 5).

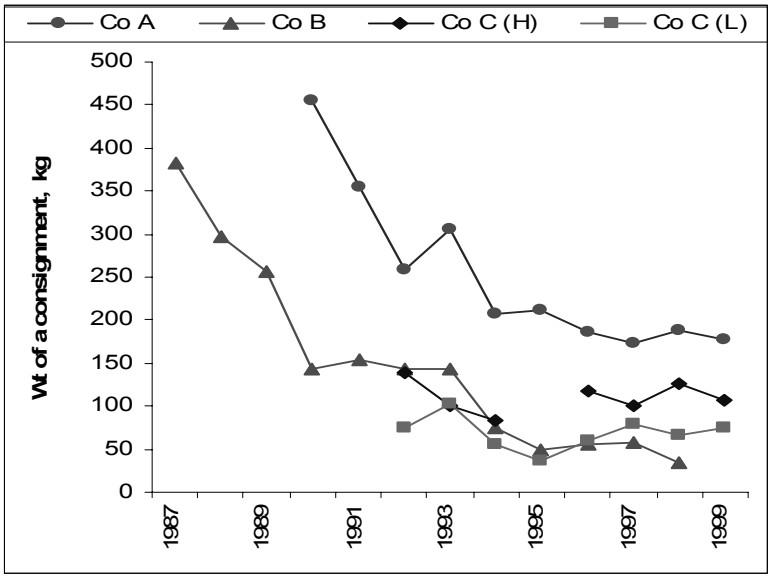

Fig 8.Average consignment weight (kg) of brown crab, standardised at 200 pots, for Cos A, B, C [high season] and C [low season].

Ascertaining the significance of consignment size is crucial to interpreting the performance of the south east brown crab fishery. The use of holding boxes provides a number of options for animals which may be held for a period before sale, or disposed of at once. Progressively smaller consignments could well signify a larger range of sales options and a greater division of landings.

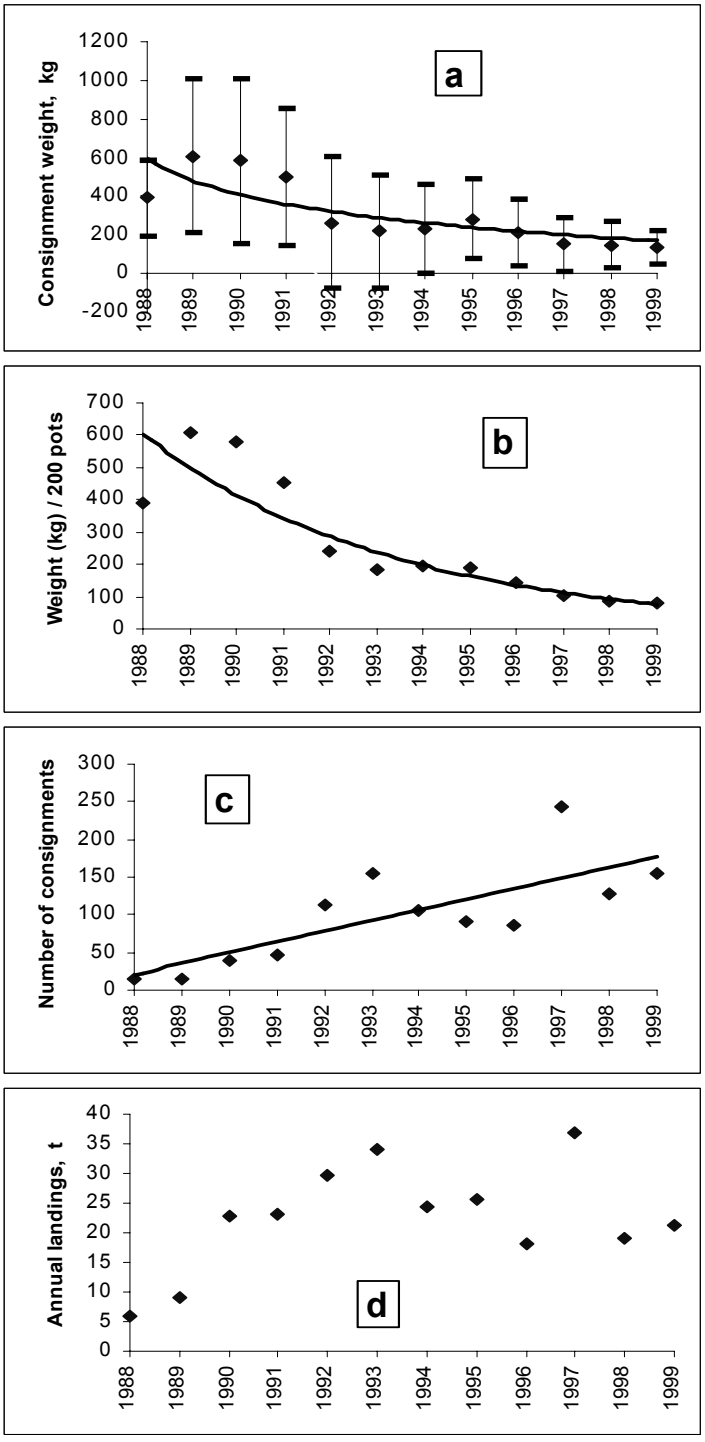

Fig 9. Details of the performance of fisherman No 10:a, average consignment weight per year (shown as the mean +/- 1 s.d.), the trend line is: EXP((year*-0.10803)+221.0695); r2 = 0.7896; N = 12; *P* 0.01>0.001 b, trend line of consignment weight (kg) standardised at 200 pots: EXP((year * -0.16434) + 333.0226); r2 = 0.8833; N = 12; *P* <0.001 c, Number of consignments [records of purchases] annually: y = ((year*13.95105)-27714.4); r2 = 0.5750; N = 12; *P* <0.05; d, annual landings (No consignments * average weight consignment).

Table 5. Log normal plots of consignment size on year for the duration of records.

Criterion	Period	Number points	r2	intercept	x variable	P
Co A	1987 - 1998	10	0.548	90.5	-0.042	N.S.
Co B	1987 - 1998	12	0.905	310.3	-0.153	<0.001
Co C (high)	1992 - 1999	7	0.473	-103.7	0.054	N.S.
Co C (low)	1992 - 1999	8	0.149	-90.5	0.048	N.S.
All consignments	1987 - 1999	12	0.781	245.9	-0.121	<0.01

Another obstacle to clarifying the significance of consignment size and number is the casual nature of inshore fishing which has been alluded to elsewhere (for example, Fahy *et al*, 2000); the majority of participants have a brief and often discontinuous history of targeting a single species. In sales documentation from the three buyers, the 27 most abundantly documented fishermen had details of first sale landings (averaged annually, all sales included) over a period of from four to 13 years: 22 of these had a downward trend in consignment weight and 20 had an upward trend in consignment number. Trends in annual landings were more ambivalent, 16 were positive, 7 negative and 4 were stable over the period covered by the records. Ten fishermen with records spanning 10 – 13 years were selected for closer scrutiny (Table 6). The weight of first sale consignments was averaged annually and correlated against years. Additionally, weight was standardised at landings per 200 pots (effectively the effort of a single operator up to 1990) and that too was correlated against time; both weight correlations were log normal. The number of consignments was correlated against time and a further correlation between total landings (number of consignments*average consignment weight) and time was attempted for the best documented fishermen.

Table 6. Correlations of weight and number of first sale consignments of brown crab.

				Significance < 0.05		
Fishermen	**Location**	**Period**	**Data points**	**a***	**b****	**c*****
Fisherman No 1	Dunmore East	1987-99	195			
Fisherman No 2	Fethard	1988-98	246			
Fisherman No 3	Dunmore East	1987-99	303		yes	
Fisherman No 4	Duncannon	1987-99	367	yes	yes	
Fisherman No 5	Duncannon	1987-98	404		yes	yes
Fisherman No 6	Fethard	1987-99	545	yes	yes	
Fisherman No 7	Duncannon	1988-98	571	yes	yes	
Fisherman No 8	Slade	1989-99	611			
Fisherman No 9	Slade	1987-99	698		yes	yes
Fisherman No 10	Slade	1988-99	1164	yes	yes	yes

* a = weight of a consignment (kg)
** b = weight of a consignment (kg) standardised at 200 pots
*** c = number of consignments

The outcome of these correlations for Fisherman No 10 is set out in Fig 9 which illustrates some of the more prominent features of the data. There is considerable variation in consignment weight but a progressive downward trend is evident (Fig 9a). This is accentuated when landings are standardised at a given effort (Fig 9b). The number of consignments rose throughout the period under review and the consequence, in this case, is no significant trend in annual landings to the fisherman in question (Fig 9d).

Of the four significant correlations between consignment weight and year in Table 6, the average reduction between 1990 and 1999 was by 68% (s.d. = 10, N = 4); standardising landing weight at 200 pots increased that reduction to 76% (s.d. = 10, N = 7). The mean weight of landings in any year was established by averaging a sample of individual readings whereas the number of consignments must be an under-estimate because the data set for the 1990s is incomplete (Table 4). Averaging the increases between 1990 and 1999 in the three correlations between consignment number and time, suggests a rise of at least 231% (range = 136 – 296, s.d. = 84). In order to maintain landings at their level in 1990, the number of consignments should have risen by 310% (420% when LPUE is standardised at pot numbers in 1990).

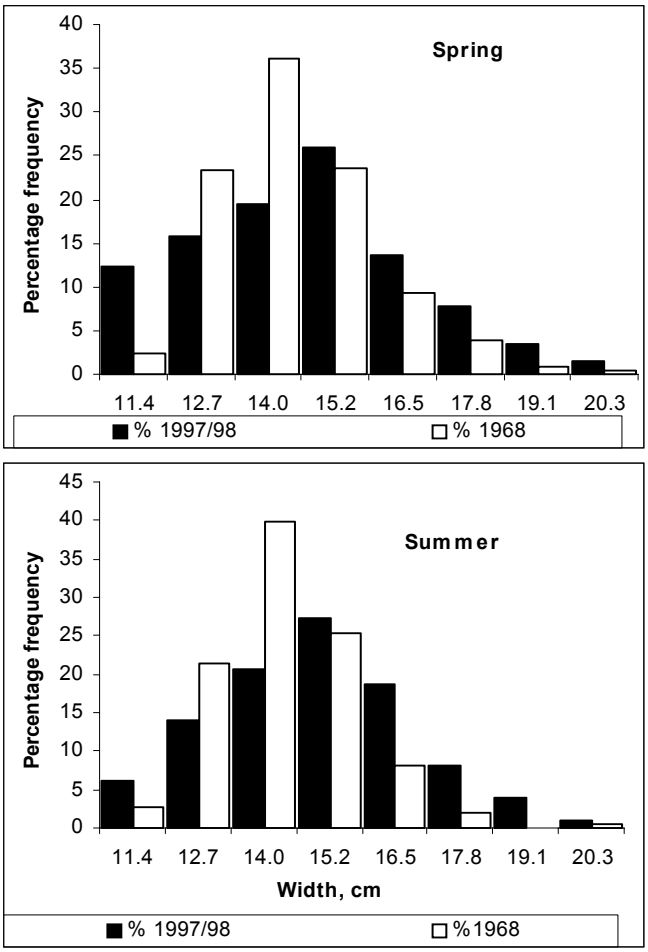

Fig 10. Percentage frequency distributions of brown crab in spring and summer in 1968 compared with the late 1990s.

4.5. Biological investigations

4.5.1. Landings

Brown crab examined in spring, within the width range set out by Edwards & Meaney (1968) and Edwards & Potts (1968), totalled 252 females and 345 males, 42.2 and 57.8% respectively, a ratio which differs markedly from the 1968 estimate when only 21% of the crab examined in spring were males. Brown crab examined in summer, within the width range used by biologists in 1968, totalled 487 females and 448 males, respectively 52.1 and 47.9 %. Males were 26% of the crabs sampled in summer 1968.

Table 7. Details of measurements of brown crab in 1997, 1998 and 1999.

Season	Sex	Average carapace width (cm)	S.d.	Count
Spring	Female	12.8	2.2	252
	Male	12.6	2.4	345
Summer	Female	14.8	2.1	487
	Male	13.8	1.8	448

Table 8. Comparison of width frequencies of male and female brown crab in landings from the south east fishery in 1968 and the late 1990s.

	RAW DATA		PERCENTAGES FOR X^2			
Width intervals	**Males**					
cm	**This survey**	**1968**	**This survey**	**1968**	**X^2**	
11.4	117	22	10	5	4	
12.7	207	108	17	25	2	
14.0	268	148	22	34	4	
15.2	298	94	24	21	0	
16.5	186	45	15	10	2	
17.8	87	16	12	5	10	
19.1	39	2				
20.3	18	3				
Totals	**1220**	**438**	**100**	**100**	**24**	***P<0.001***
Width intervals	**Females**					
cm	**This survey**	**1968**	**This survey**	**1968**	**X^2**	
11.4	62	0				
12.7	78	81	20	20	0	
14.0	115	173	17	43	16	
15.2	208	113	30	28	0	
16.5	120	29	33	10	52	
17.8	66	8				
19.1	31	2				
20.3	6	1				
Totals	**686**	**407**	**100**	**100**	**68**	***P<0.001***

The width frequencies of samples collected in 1968 and in the late 1990s are set out for comparison in Fig 10. They appear similar with, however, better representation of the 14.0 cm width group in the earlier samples, which might be explained by a stronger single year class. In their spring samples Edwards and Meaney reported an average carapace width of 14.4 cm in females and 15.0 cm in males. Their summer results gave similar averages for the males but the females had reduced to 14.2 cm. In the late 1990s the males were on both occasions smaller than the females, but both increased in width from the spring to the summer samples (Figs 11, 12, Table 7).

More detailed comparison, by sex and season, gave a different outcome. Chi-square tests revealed that both male and female brown crab in the landings were significantly larger in the late 1990s than thirty years previously (Table 8).

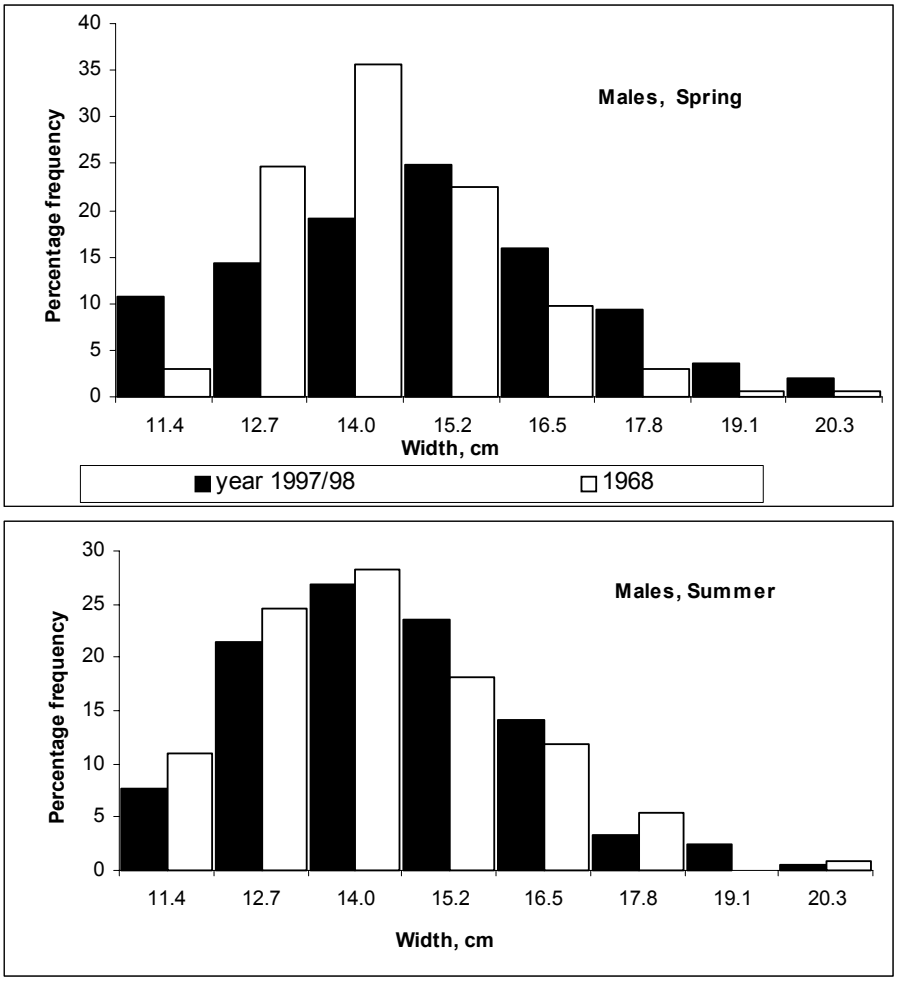

Fig 11. Percentage frequency distribution of male brown crab in spring and summer of 1968 compared with the late 1990s.

4.5.2. Catches

Three characteristics of brown crab catch (percentage male crabs, percentage undersized, both by number, and the landings (numbers of crab above the size limit) per pot were recorded at 55 different potting locations (Figs 13, 14 and 15). The composition of the catches was clearly dependent on where fishing took place. Smaller landings were made close to shore (Fig 13) but the percentage of undersized brown crab

increased in these areas (Fig 14) and the percentage of males also rose moving landwards (Fig 15). Seasonal factors complicated these generalisations but there are clear relationships between the three criteria taking the samples as a whole (Fig 16) Landings and percentage undersized correlate negatively (P 0.01<0.001), landings and percentage males in the catches likewise (P 0.01<0.001) while the percentage males and the percentage undersized in the catches correlate positively (P 0.01<0.001).

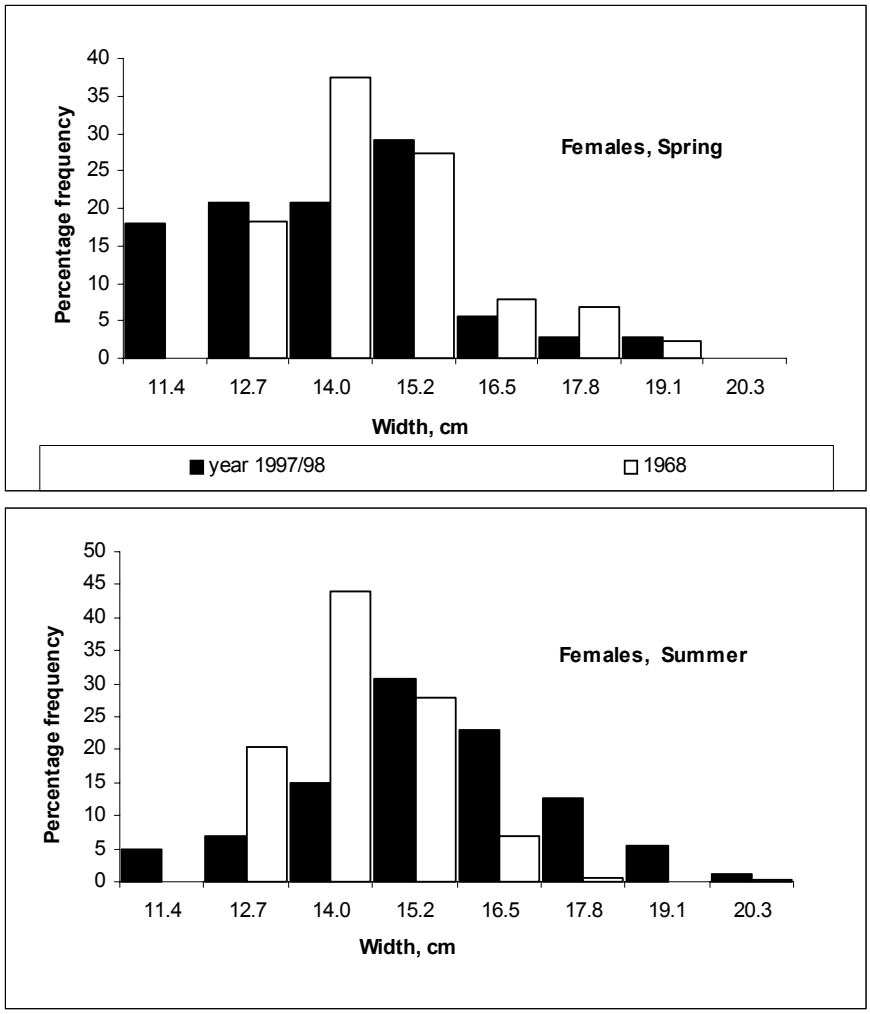

Fig 12. Percentage frequency distribution of female brown crab in spring and summer of 1968 compared with the late 1990s.

DISCUSSION

Although south east Ireland has been regarded as a significant landing place for brown crab for at least thirty years, very little is known about the status of the stock and even fundamental statistics are questionable. In 1996, for example, official statistics reported 283 t of brown crab from the area in question, almost 80% less than the conservative estimate for the area reported here. The periods for which most comprehensive data are assembled, 1992-1994 inclusive and 1996-1997 inclusive, provide landings of 314 and 700 t per year, considerably greater than recorded by the Department responsible for fisheries. These figures are believed to account for 80% of the landings but they almost certainly do not include all reject landed crab which has been damaged in the course of capture and storage. There is a market for this product which can be sold to whelk processors who sell it on to fishermen supplying whelk to their factories, but these second sales are cumbersome because bait has a low value, transport costs are high and one processor does not necessarily wish to supply and thus assist a competitor even when that competitor is exploiting a different shellfish species. In recent years some crab processors have devised a sliding scale of payments to discourage unwanted product which takes into account the cost of disposing of lower grade material. Its consequences for the landings are not known.

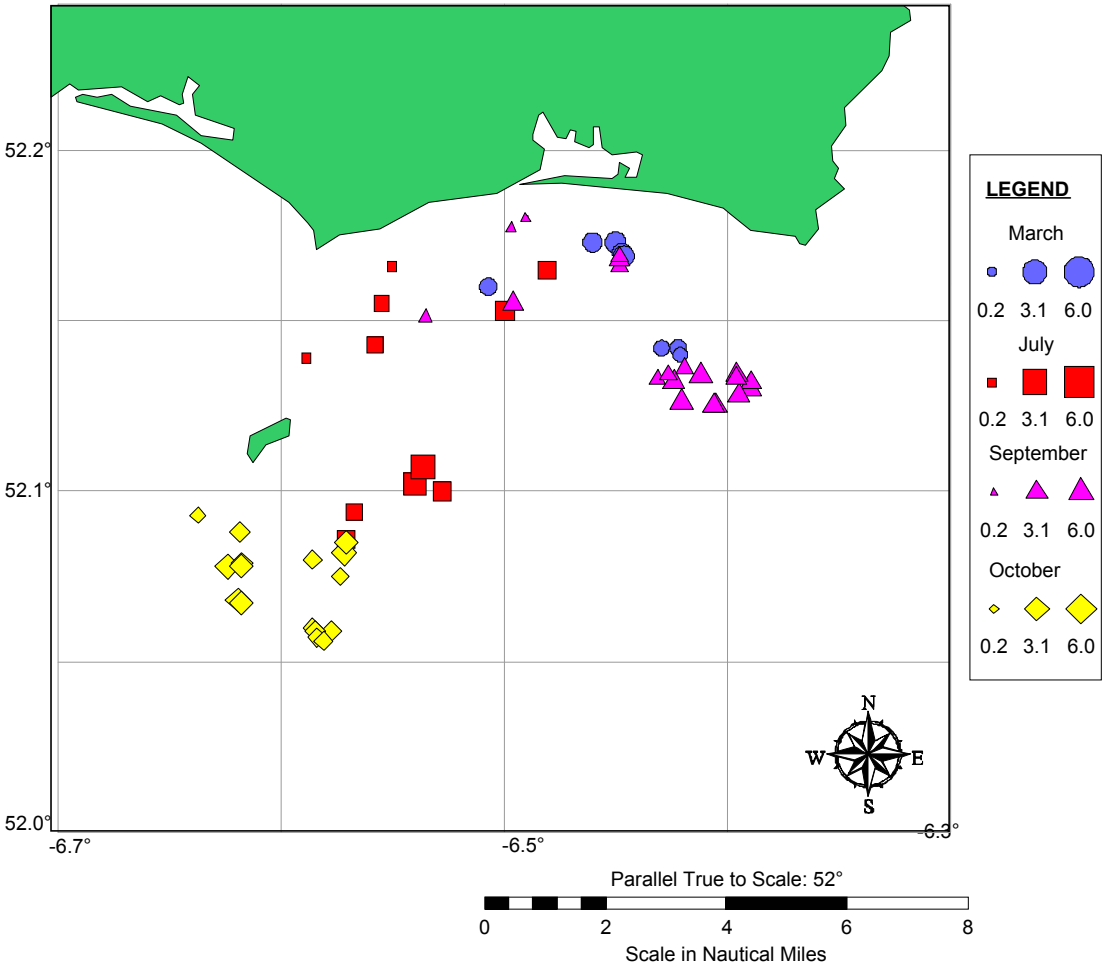

Fig 13.Landings of brown crab (numbers per pot) from the eastern part of the south east fishery in 1999 and 2000.

The landings to the south east are not complete; in fact they concern only a part of the coast, 55 km in length and only to the three processors covered by this investigation. In Table 9, the percentage effort and percentage landings within this area are tabulated for comparison. It is a crude exercise, constrained by the definition of effort provided (Table 2). Slade and Duncannon, a very important sector, might be otherwise variously delimited (Waterford Harbour embraces Duncannon as far as landings are concerned); the importance of Kilmore Quay as expressed in terms of fishing gear, has declined as the 1990s advanced, relative to Slade and Waterford Harbour. Dunmore East is omitted because there is no measure of fishing effort there. Notwithstanding, there is reasonable agreement between the landings and effort in three of the areas, not however in Carne and Rosslare where the effort indicator is three times greater than the landings. This is taken to indicate the purchase of crab from these landing places by buyers other than those from whom data were obtained.

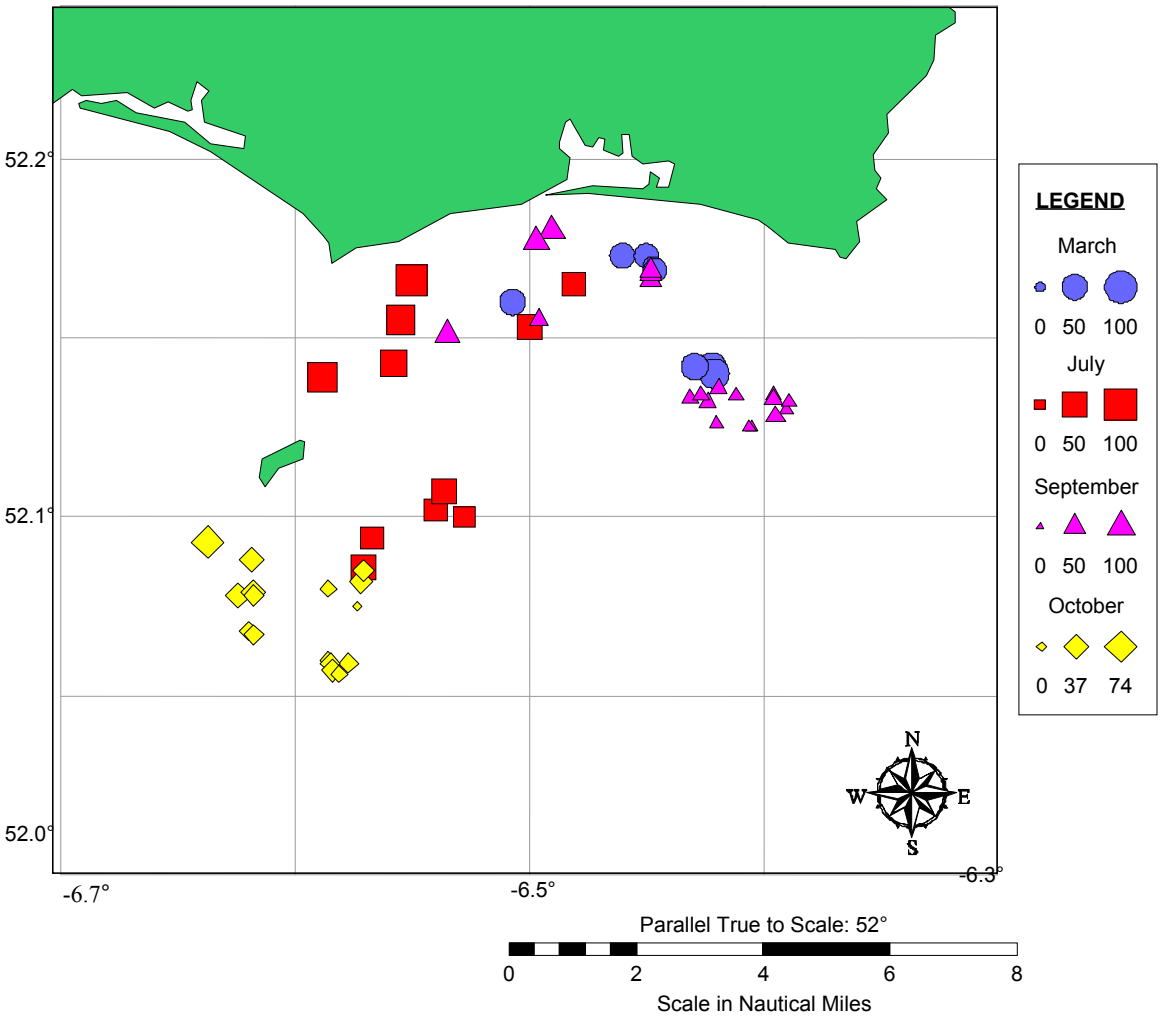

Fig. 14. Percentage undersized brown crab from the eastern part of the south east fishery in 1999 and 2000.

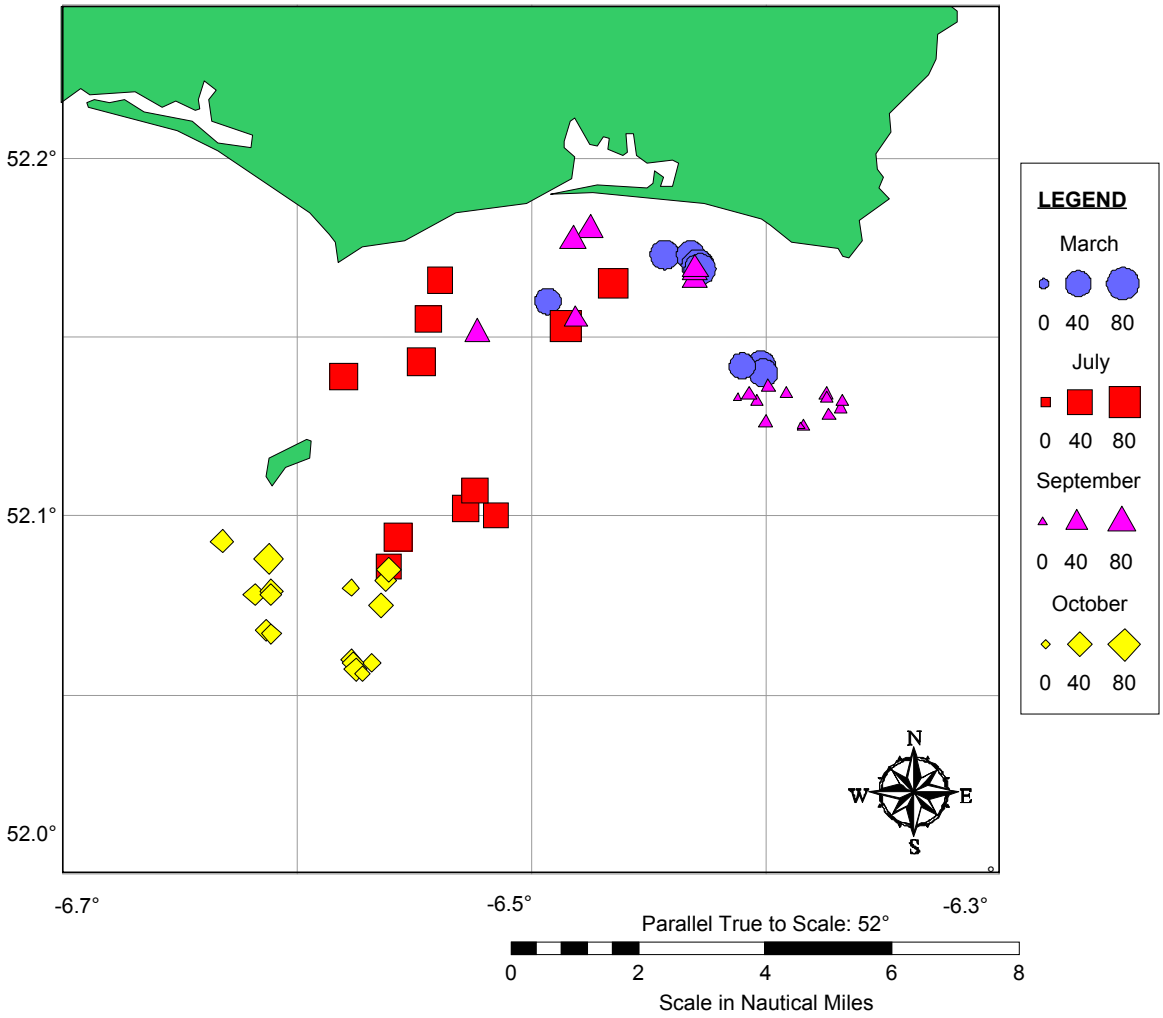

Fig 15. Percentage male crab from the eastern part of the south east fishery in 1999 and 2000.

Over the thirty odd years for which information is available on the south east fishery, fishing effort has considerably expanded. Evidence is provided of growth by 241% but this figure is a rise in pot numbers only. Within the period, the sea worthiness of vessels has improved and boats are now equipped with a range of navigational aids, GPS and hydraulic pot haulers which facilitate more efficient working at sea. The percentage increase in pot numbers should therefore be considered a conservative indicator of the increase in effective fishing power.

Table 9. Percentage distribution of fishing effort and landings among various parts of the south east fishery.

Area	Percentage effort	Percentage landings
Slade and Duncannon	29	40
Fethard-on-Sea	14	14
Kilmore and Bannow	34	31
Carne and Rosslare	23	7
Total	**100**	**92**

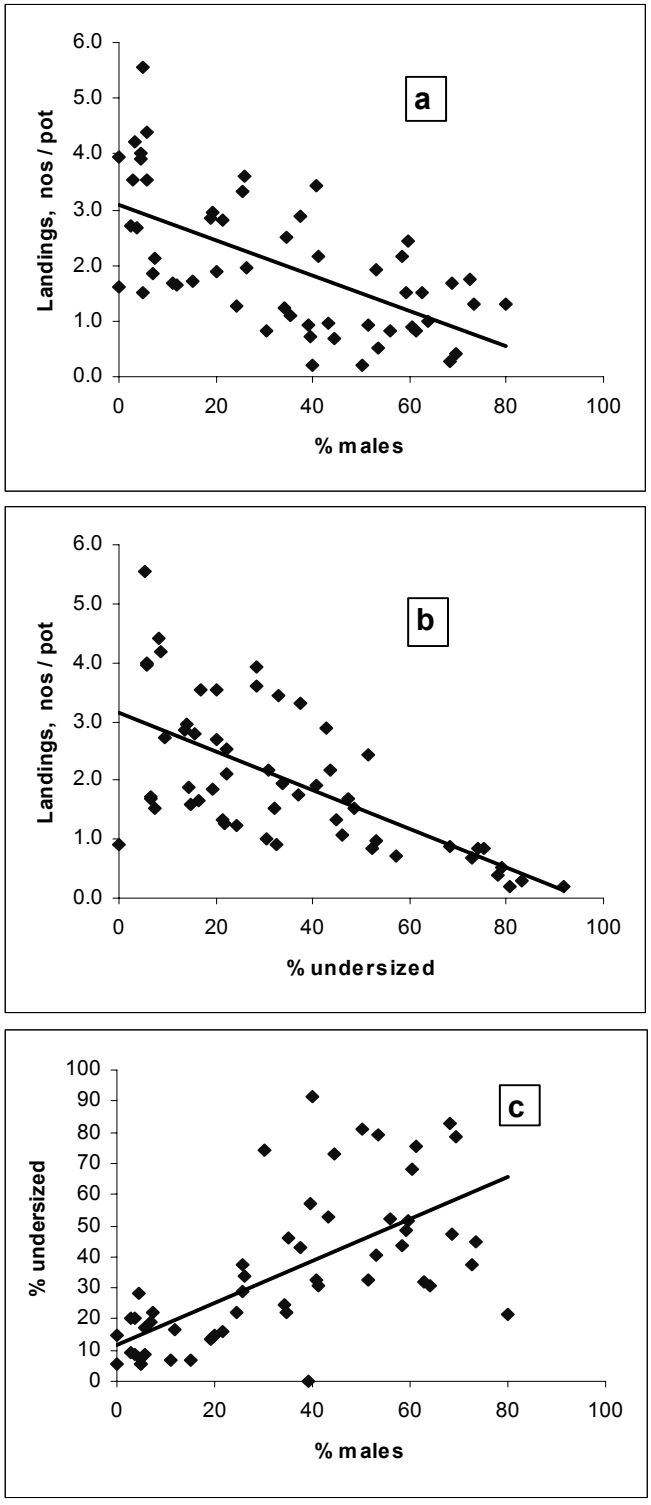

Fig 16. Correlations among characteristics of catches of brown crab in 1999 and 2000: a, numbers landed against percentage males, r2 = 0.3828, *P* 0.01<0.001, intercept 58.00, x-var = -12.06. b, numbers landed against percentage undersized, r2 = 0.4175, P 0.01<0.001, intercept = 60.00, x-var = -12.75. c, percentage undersized against percentage males r2 =0.4368, *P* = 0.01<0.001, intercept = 11.30, x-var = 0.6524. N = 55 in all cases.

Over the period of the records there has been considerable change also in the characteristics of the landings but their interpretation is problematical. Consignment size has decreased but that might represent a change in selling behaviour (the origin of all data purporting to indicate the performance of the fishery is in sales documentation). It is very likely that a seller's choice has widened as the years have progressed, continental markets have expanded and competition for product has intensified. The decline in consignment size has been fairly constant although there is a suggestion (Figs 8, 9a, b) that the decline was steeper up to 1992 after which a period of relative stability ensued. The fall in consignment size has been accompanied by an increase in consignment number.

An increase in pot numbers per vessel has been general throughout the area, assisted by the provision of mechanised pot haulers and motivated by decreasing LPUE. Standardised at the level of effort in 1990 LPUE would be considerably lower than in the late 1990s. Annual landings could however be maintained by increasing consignment number which would have to have risen by more than 300% between 1990 and 1999 even if accompanied by increasing pot numbers.

Precise assessment of the south east fishery is not possible on the basis of available information but the indicators suggest a fishery which is fully or over-exploited. This conclusion might however, be simplistic.

Cancer pagurus is highly mobile undertaking possibly extensive annual migrations on and off shore. The Donegal fishery for example is exploited by inshore boats and by super-crabbers offshore and the LPUE by both are similar (Anon, 2001). There is a large brown crab fishery extending offshore of south east Ireland and such data as are available, suggest that it is under-exploited because the LPUE records from part of it have been rising in recent years. The question of how the inshore and offshore brown crab fisheries inter-relate and to what extent the coastal component is replenished by animals immigrating from the other is obviously crucial. There are other parallels between the south east and the northern fisheries, notably the decline in LPUE which, in the case of the northern fishery, took place in the early 1980s after which it stabilized; a similar phenomenon in the south east fishery appears to have taken place up to a decade later.

Because of the difficulties of assigning ages to brown crab, the assessment of consequences for the stock is largely a matter of speculation. Comparisons of width frequencies from the late 1990s with similar data from some thirty years previously are inconclusive. Indeed, contrary to what might be expected, the later samples appear to contain larger animals than the earlier ones [a finding which might be explained by poor recruitments in recent years]. The sex ratios in the two data sets show the most dramatic disparities but the size and sex composition of inshore brown crab samples can vary considerably within small distances depending on a number of factors, depth of water and the nature of the substratum being two. It is therefore, impossible to make any useful comment on the biological consequences for this stock of increasing fishing effort.

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