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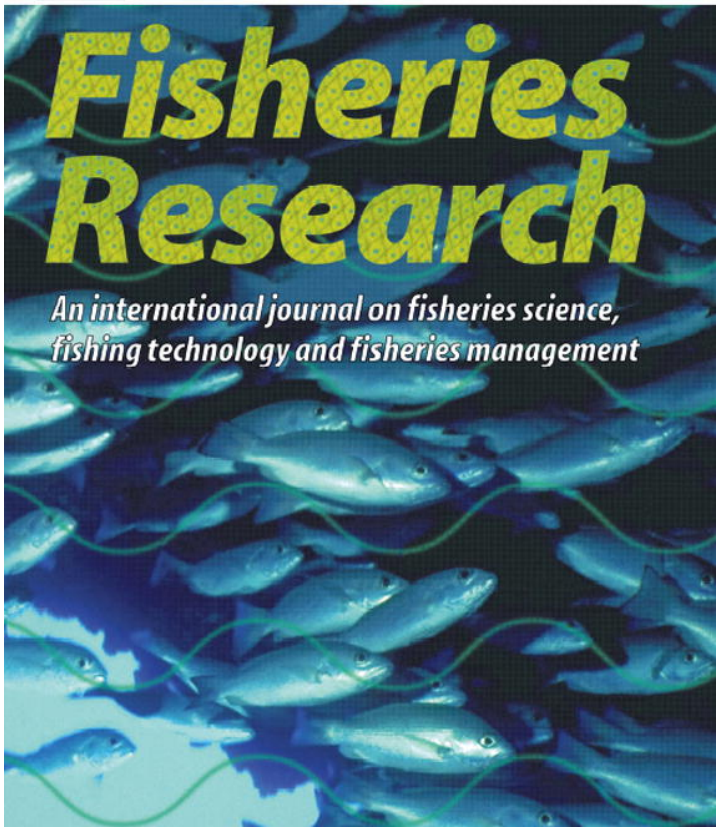

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Discarding in the English Channel, Western approaches, Celtic and Irish seas (ICES subarea VII)

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Abstract

Discarding is a common feature throughout global fisheries and of widespread management concern. The Centre for Environment, Fisheries and Aquaculture Science (CEFAS) catch and discard data collection programme has been conducting sampling operations on English and Welsh registered fishing vessels in the International Council for the Exploration of the Sea (ICES) subarea VII since 2002. Within this subarea, these vessels were found to mainly operate in the English Channel, Western approaches, Celtic and Irish sea. We present the findings of this work and estimate the annual quantities of discards (fish and cephalopods) in terms of numbers and weights between 2002 and 2005. Our analysis was conducted on 3643 hauls from 306 trips aboard commercial fishing vessels (142 different boats). An estimated 186 million (72,000 t) fish and cephalopods were caught every year of which 117 million (24,500 t) were discarded. Beam trawlers and otter trawlers were together responsible for more than 90% of these discards. In all, 182 fish and cephalopod species were caught, yet just 10 species constituted more than 50% (61.5 million) of the annual discards. We estimate that discarding levels in the region are higher (1.5×) than recently reported by the FAO.

Keywords: Discards; By-catch; English Channel; Western approaches; Celtic sea; Irish sea

1. Introduction

Discards (or discarded catch) is defined as that portion of the total organic material of animal origin in the catch, which is thrown away or dumped at sea for whatever reason (Kelleher, 2005). Discarding is a global phenomenon commonly acknowledged by fishers, the scientific community and public as a waste of natural resources. The most recent estimate of annual global discarding was 7.3 million tonnes (Kelleher, 2005). In addition to contributing towards significant unwanted mortalities (Alverson et al., 1994; Alverson, 1998; Kelleher, 2005), studies have shown that discards may cause a range of wider ecological impacts. These include alterations in predator–prey relationships in many seabird communities (Furness, 2003; Votier et al., 2004) and changes in benthic community structure (Brown et al., 2005; van Marlen et al., 1998) and marine mammal feeding habits (van Opzeeland et al., 2005).

The importance of quantifying discarding and integrating the data into sustainable management programmes is becoming more widely recognised. The United States Sustainable Fisheries Act, 1996 (Magnusun-Stevens, 1996), and European legislation EC 1639/2001 (Anon, 2002) both identify the need to collect accurate discard data and lay out guidelines for their subsequent collection. The work presented in this paper is a result of the latter EC legislation.

The majority of European Union (EU) waters lie within the Food and Agriculture Organisation (FAO) major sea-area 27, recently reported by Kelleher (2005) to generate one-fifth of the worlds discards annually. ICES subarea VII (English Channel, Irish sea, Celtic sea and Western approaches) is contained within FAO area 27 (Fig. 1). In total the area covers over 700,000 km^2 (twice the size of Germany), encompassing >9000 km of coastline and borders with the UK, Ireland and France. It supports diverse marine habitats that range from abyssal depths in the North-eastern Atlantic Ocean (the Porcupine Abyssal Plain) to the shallow waters of the Irish sea.

The fisheries in the area are diverse and, in the past 32 years, vessels originating from 27 nations have landed more than 300

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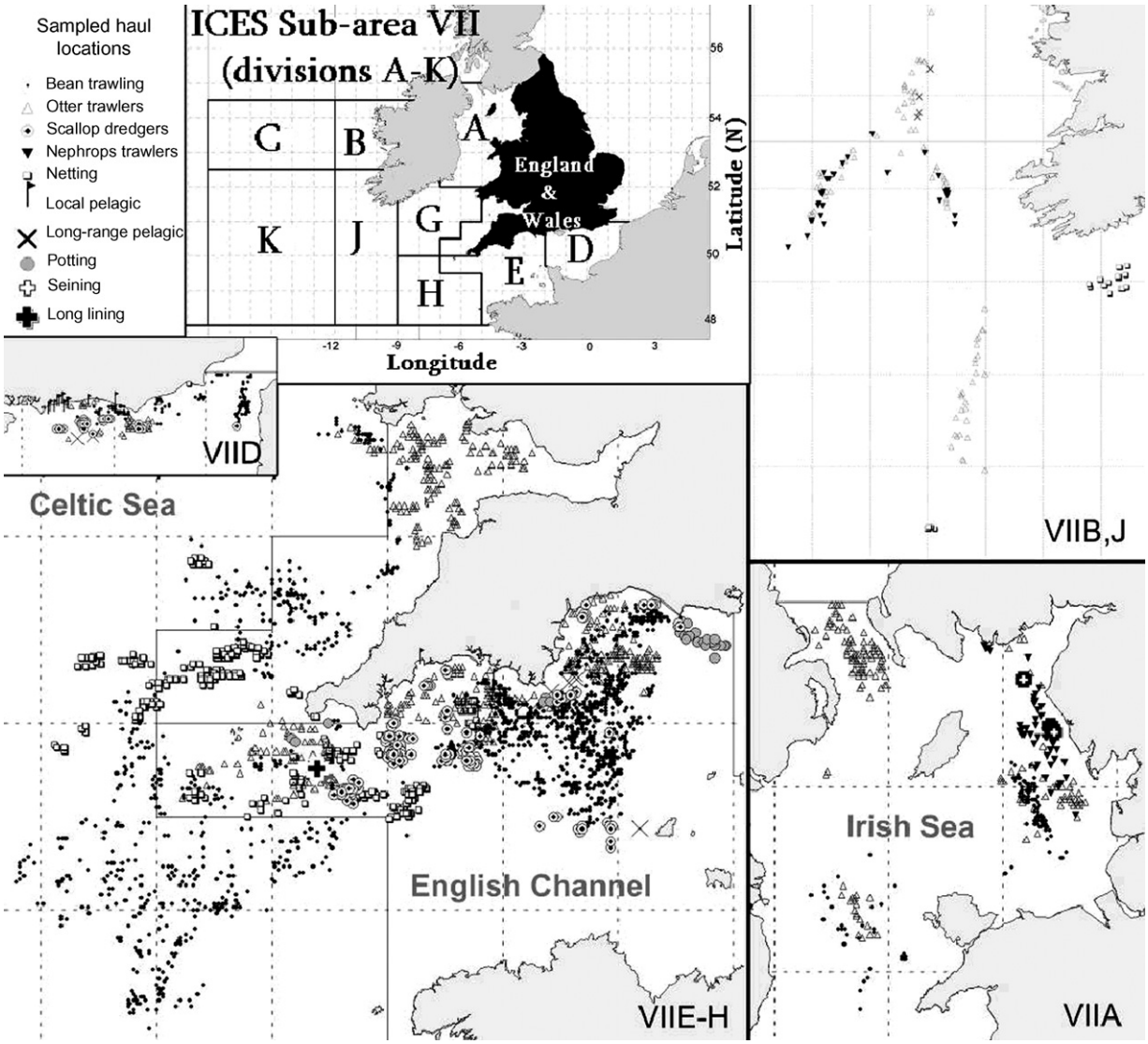

Fig. 1. Map of ICES sub-area VII (divisions A–K) and plots of haul sample locations by gear group.

commercially important species. Species targeted have ranged from primary producers such as marine plants, to top predators, including mako (*Isurus oxyrhinchus*) and porbeagle (*Lamna nasus*) sharks.

From 2002 to 2005, 14% of the total fish and cephalopod landings (by weight) in ICES subarea VII were caught by fishing vessels registered in England and Wales (the study fleet), with an average value of €98 million per year. This work describes catch and discard data collected in subarea VII over a 4-year period (2002–2005) onboard fishing vessels registered in England and Wales and ≥10 m in length overall. We quantify the scale of discarding that has occurred and describe the spatial, temporal and gear relationships to these discards.

When considering discarding, fisheries managers are primarily concerned with the following three issues:

(a) Does it occur?
(b) Does it matter?
(c) What can be done about it?

In this work, we focus on answering the first question. Subsequent papers will directly deal with the remaining issues.

2. Materials and methods

2.1. The CEFAS catch and discard sampling programme

In accordance with EC data collection regulation (1639/2001), the CEFAS catch and discard data collection programme has been monitoring catch components of vessels registered in England and Wales conducting fishing operations in ICES subarea VII since 2002 (Figs. 1 and 2).

Vessel sampling was stratified by gear type proportional to effort corresponding to the same quarter from the previous year. Effort data were taken from the official statistics held by the Department for Environment, Fisheries and Rural Affairs (DEFRA) Fishing Activities Database (FAD). Each quarter, a list of vessels fulfilling the sampling criteria (English/Welsh registered and ≥10 m registered length) was drawn from FAD and a

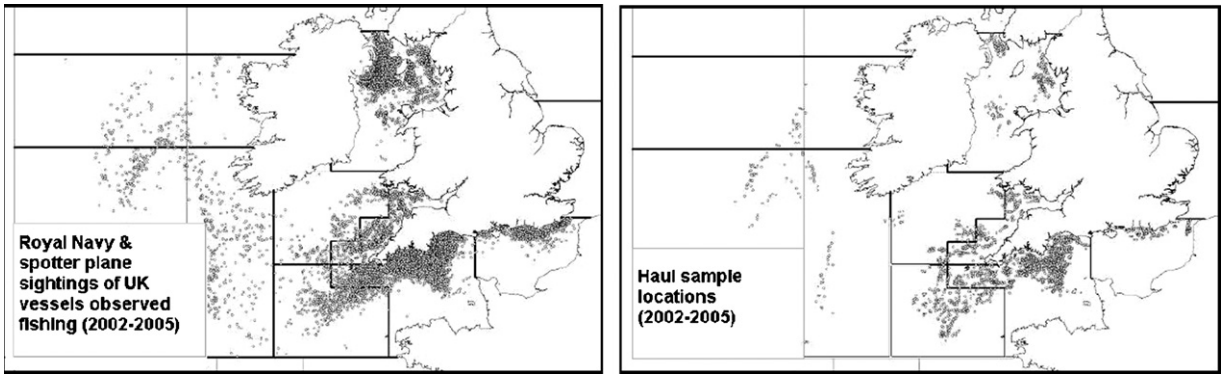

Fig. 2. Map of ICES sub-area VII showing comparisons between sightings data (2002–2005) of UK vessels observed fishing by Royal Navy vessels and DEFRA spotter planes and the CEFAS catch and discard sample locations.

list of vessels for sampling was randomly generated. Vessel participation in the discard programme has been on a voluntary basis and if a vessel was unavailable for sampling, the next vessel on the list was selected. When observers are onboard they do not interfere with fishing operations or influence fisher behaviour and so the data obtained reflects commercial reality. Comparisons between CEFAS catch sampling effort and UK fishing effort (observed between 2002 and 2005 by Royal Navy vessels and DEFRA spotter planes) are given in Fig. 2. These figures give a visual indication that the sampling coverage reflects that of the fleet's activities.

We classified the gear type of the fishing vessel in accordance with the DEFRA classification scheme. Since 2002, 19 gear types have been sampled in ICES subarea VII, which we have aggregated into ten gear groups for the purpose of this study (Table 1).

A minimum of 60% of hauls have been sampled by trained CEFAS observers on every trip and both the discarded and retained components were recorded. Haul sampling was conducted through a rolling period of 24 h to provide day and night coverage. For each haul, environmental conditions (sea state, wind strength/direction), physical conditions (depth, position, haul duration and gear properties) and the biological composition of the retained and discarded catch were recorded. Fish and cephalopods, herein referred to as fish, were measured to the nearest centimetre below (fish were measured to total length and cephalopods to mantle length). Observers aimed to get a representative length–frequency distribution (LFD) for each species on all sampled hauls.

2.2. Length–weight conversion

Fisheries data and studies therein are widely presented in terms of weight. Length data in this study were converted into weights to facilitate broader comparisons with other studies. In this study 182 species were caught and identified, of which length–weight conversion factors for 60 were available. These 60 species represent 98% of the total number of the fleet-raised fish. In total, 28 length–weight relationships were derived from weight-at-length data collected during CEFAS research vessel cruises in ICES sub-area VII between 2002 and 2005 (>40,000 weight-at-length records from 13 cruises). Weights were measured using a POLS marine balance (±2 g) and lengths measured to the nearest centimetre below. Where possible, mean weights for given lengths from the raw cruise data were used. For other lengths, length–weight regression curves were estimated as $W = aL^b$ where W is the estimated mean weight at a given length L using Sigma plot V8.0 software.

A further 32 length–weight relationships were sourced from scientific literature (Coull et al., 1989; Deniel, 1984; Dorel,

Table 1
Annual sampling effort by gear group and gear type

Gear group	Number of trips (number of sampled hauls)					Gear type
	2002	2003	2004	2005	Total	
Beam trawling	11 (306)	19 (569)	29 (776)	17 (448)	76 (2099)	Beam trawl
Otter trawling	18 (130)	33 (192)	55 (294)	40 (140)	146 (756)	Single, twin, triple, light, and heavy rigged demersal otter trawlers
Scallop dredging	–	9 (101)	9 (178)	4 (70)	22 (349)	Unspecified dredge
Nephrops trawling	2 (11)	3 (39)	7 (22)	1 (3)	13 (75)	Single, twin, triple rigged demersal trawls in a *Nephrops* directed fishery
Seining	1 (4)	–	1 (9)	–	2 (13)	Purse, pair fly, Scottish fly and Danish anchor seine
Local pelagic	–	3 (3)	2 (10)	2 (3)	7 (16)	Bottom pair trawl, mid-water trawl, mid-water pair trawl
Factory pelagic	–	1 (5)		1 (11)	2 (16)	Mid-water pair trawl (factory), mid-water trawl (factory)
Netting	3 (42)	8 (97)	12(119)	5 (60)	28 (318)	Trammel, tangle and unspecified gill nets
Potting	2 (N.A.)	3 (N.A.)	4 (N.A.)	–	9 (N.A.)	Top opening, side opening, parlour and mixed pots
Long-lining	–	–	1 (1)	–	1 (1)	Long-lines
Total	37 (493)	79 (1006)	120 (1409)	70 (735)	306 (3643)	

N.A.: data only available by trip for this gear group; –: no data.

Table 2
Mean raising factors for sample to haul, trip and fleet by gear group

Gear group	Sample to haul raising factors		Haul to trip raising factor	Trip to fleet raising factors			
	Discarded	Retained		2002	2003	2004	2005
Beam trawling	8.7 (0.07)	1.6 (0.01)	1.53 (0.02)	257	149	87	141
Otter trawling	4.8 (0.09)	1.7 (0.02)	1.09 (0.01)	538	303	188	225
Scallop dredging	1.6 (0.05)	1.3 (0.03)	1.42 (0.06)	–	308	310	906
Nephrops trawling	9.7 (0.56)	1.4 (0.1)	1.03 (0.02)	72	21	4	119
Seining	4.4 (0.71)	3.1 (0.67)	1.00 (0.00)	24	–	22	–
Local pelagic	1.3 (0.09)	1.1 (0.01)	1.56 (0.17)	–	81	65	45
Factory pelagic	140.2 (62.22)	1390.0 (218.00)	1.30 (0.30)	–	9	–	17
Netting	1.4 (0.46)	1.1 (0.12)	1.09 (0.02)	630	219	146	336
Potting	4.2 (0.20)	5.1 (1.03)	1.27 (0.11)	2370	1540	1246	–
Long-lining	1.0 (N.A.)	1.0 (N.A.)	1.00 (N.A.)	–	–	91	–

Figure in parentheses refer to standard error of estimate. N.A.: insufficient data for estimation of S.E. –: no data.

1986; Froese and Pauly, 2006). Where possible, these were selected to match closely the ICES subarea and period of this study. They do not take into account variations in sex or season.

For the remaining 2% of fleet-raised fish numbers, an estimator for length–weight relationships is calculated by assuming $b = 3$ (Houghton and Flatman, 1978) and taking the mean value for the condition factor a from all the other species, i.e. $W = 0.041L^3$.

2.3. Raising raw catch data to fleet level

Catch and discard data have limited use at the sample level, so multipliers were used to raise the data to fleet level in order to provide more useful management information. Retained and discarded fish numbers for each species were initially raised to haul level as a proportion of the total catch using volume-based raising factors. The haul-raised data were further raised to trip level by multiplying against the haul sampling coverage (i.e. total hauls in trip/sampled hauls in trip). Annual trip numbers were extracted for each gear group from the FAD and divided by the numbers of trips sampled to generate the fleet raising factors (Table 2). The sampling unit (trip) was chosen as advised by Borges et al. (2005a). FAD data relating to pair trawlers were carefully treated to prevent double counting.

2.4. Catch per unit effort

Raw data were raised to haul level (see Section 2.4) and the total fish numbers obtained were divided by the haul duration to determine the numbers of fish caught per hour or catch per unit effort (CPUE). This unit allowed the catch data to be standardised and used for comparative analysis.

3. Results

3.1. Numbers and weights

An estimated annual-average of 186 million fish (72,000 t) was caught by English and Welsh commercial fishing vessels operating in ICES subarea VII. Of this total catch, 117 million fish (63%), equating to 24,500 t (35%), were subsequently discarded (Tables 3 and 4). The inter-annual variation of the estimated total number discarded/retained were most precise for the beam trawl and otter trawl gear groups (<±25%) and

Table 3
Mean annual estimates of fish numbers discarded in ICES sub-area VII by English and Welsh fishing vessels

Rank	Gear group	Number of fish ($\times 10^6$)				% discarded
		Discarded		Retained		
		Range	Mean	Range	Mean	
1	Beam trawling	55.1–81.3	68.5	23.5-37.3	28.2	71(1.6)
2	Otter trawling	31.4–47.7	41.6	19.4-28.0	22.8	64 (1.6)
3	Factory pelagic	0.4–13.6	7.0	8.9-46.5	27.7	14 (9.0)
4	Netting	0.4–2.2	1.2	1.2–3.7	2.1	36 (9.6)
5	*Nephrops* trawling	0.1–2.7	1.2	<0.1–0.3	0.1	*
6	Scallop dredging	0.3–3.1	1.2	1.2–0.3	0.9	*
7	Local pelagic	<0.1–1.4	0.6	0.1–2.0	0.8	34 (21.2)
8	Seining	<0.1–0.1	0.1	0.2–0.3	0.2	24 (6.8)
9	Potting	<0.1–<0.1	<0.1	<0.1–<0.1	<0.1	*
10	Long-lining	<0.1–<0.1	<0.1	<0.1–<0.1	<0.1	33 (N.A.)
Total		109.7–129.2	117.4	54.9–92.7	68.5	63 (3.1)

Ranking according to mean annual discard numbers. Figure in parentheses refer to standard error of annual estimate. N.A.: insufficient data for estimation of S.E.
*Shellfish/crustacean targeted fisheries (shellfish/crustaceans not analysed in this work).

Table 4
Mean annual estimates of fish weights discarded in ICES sub-area VII by English and Welsh fishing vessels

Rank	Gear group	Weight (t)				% discarded
		Discarded		Retained		
		Range	Mean	Range	Mean	
1	Beam trawling	11,152–12,938	12,356	12,888–24,290	17,905	42 (3.5)
2	Otter trawling	6,148–11,135	8,931	7,688–27,332	17,362	36 (5.4)
3	Netting	1,521–2,940	2,013	4,553–10,644	7,624	22 (1.8)
4	Factory pelagic	42–1,634	838	3,034–5,892	4,463	12 (10.2)
5	Scallop dredging	137–2,050	829	695–1,746	1,129	*
6	*Nephrops* trawling	9–411	206	2–230	87	*
7	Local pelagic	2–167	66	59–90	389	17 (14.2)
8	Potting	7–63	32	14–579	254	*
9	Seining	7–15	11	49–69	59	15 (3.2)
10	Long–lining	3-3	3	23–23	23	10 (N.A.)
Total		21,507–27,334	24,628	36,238–55,027	46,572	35 (3.0)

Ranking according to mean annual discard weight. Figure in parentheses refer to standard error of annual estimate. N.A.: insufficient data for estimation of S.E. *Shellfish/crustacean targeted fisheries (shellfish/crustaceans not analysed in this work).

least precise for other gear groups such as factory pelagic, netting and *Nephrops* trawling.

Beam trawlers contributed 58% to the total number of the discards generated (68.5 million fish, 12,500 t) and otter trawlers, 35% (42 million fish, 9000 t (Tables 3 and 4)). Factory pelagic trawlers contributed 3% by number and the remaining gear groups (netters, *Nephrops* trawlers, scallop dredgers, local-pelagic trawlers, seiners, potters and long-liners) together contributed less than 4%.

Beam trawlers and otter trawlers discarded the highest proportion of their catches, which was 71% and 65%, respectively (Table 3). Factory pelagic vessels had the lowest discard rate (14%).

3.2. Species

Since 2002, 182 fish species have been recorded by observers during commercial fishing operations. Of these, 177 were subject to some discarding. Otter trawlers discarded 159 species, beam trawlers 139 species, *Nephrops* trawlers 67, netters 56, scallop dredgers 54 and all other gear groups fewer than 50 species. Otter trawlers discard on average 11 species per haul, beam trawlers and *Nephrops* trawlers 10 species per haul and the remaining gear groups, fewer than 10 species per haul (Table 5).

The 10 most discarded species (by number) and selected commercially important species were estimated for beam trawlers (Table 6), otter trawlers (Table 7) and all other gear groups (Table 8). In all, 53% (61.5 million) of ICES subarea VII total discards caught by beam and otter trawlers from 2002 to 2005 were just 10 species, gurnards [five species] (*Triglidae*), European plaice (*Pleuronectes platessa*), dab (*Limanda limanda*), lesser-spotted-dogfish (*Scyliorhinus canicula*), poor cod (*Trisopterus minutus*) and whiting (*Merlangius merlangus*).

Mackerel (*Scomber scombrus*), caught principally by pelagic fishing methods, is the dominant discard species in the "other" gear groups (Table 8). Other pelagic species, horse mackerel (*Trachurus trachurus*), pilchard (*Sardina* (*clupea*) *pilchardus*)

Table 5
Relative proportion of annual discards in each gear group

Rank	Gear group	Annual discards (%)		CPUE discarded (fish h^{-1})	Species per haul
		Number	Weight		
1	Beam trawling	58 (4.7)	50 (2.6)	313 (7.3)	10 (0.1)
2	Otter trawling	35 (3.4)	36 (3.8)	180 (12.4)	11 (0.2)
3	Factory pelagic	3 (5.6)	2 (3.0)	78,209 (68,027)	6 (0.6)
4	Netting	1 (0.4)	8 (1.2)	3 (0.7)	6 (0.2)
5	*Nephrops* trawling	1 (0.4)	<1 (0.5)	398 (63.5)	10 (0.3)
6	Scallop dredging	1 (0.8)	3 (2.3)	8 (0.5)	3 (0.1)
7	Local pelagic	<1(0.4)	<1(0.2)	194 (95.7)	6 (1.7)
8	Seining	<1 (0.0)	<1(0.0)	246 (57.1)	6 (0.4)
9	Potting	<1(0.0)	<1 (0.1)	0 (0)	1 (N.A.)
10	Long-lining	<1 (N.A.)	<1(N.A.)	0 (N.A.)	1 (N.A.)
Total		100	100		

Ranking according to percentage of fish numbers discarded by gear group. Figure in parentheses refer to standard error of estimate. N.A.: insufficient data for estimation of S.E.

Table 6
Top 10 most discarded species and significant commercial species by English and Welsh registered beam trawlers

Rank	Common name	Latin name	Numbers ($\times 10^6$)		% discarded
			Annual mean	Range	
1	Gurnards	*Trigla* spp.	9.9	6.4–14.9	82 (4.6)
2	Common Cuttlefish	*Sepia officinalis*	7.9	1.4–13.4	58 (5.0)
3	European plaice	*Pleuronectes platessa*	7.2	0.6–23.4	43 (11.4)
4	Dab	*Limanda limanda*	6.8	2.7–15.2	97 (1.1)
5	Lesser-spotted dogfish	*Scyliorhinus canicula*	6.4	5.0–8.5	99 (0.6)
6	Poor cod	*Trisopterus minutus*	5.2	3.8–6.8	100 (0.0)
7	Dragonets	*Callionymidae*	4.9	3.2–6.1	100 (0.1)
8	Whiting-pout (Bib)	*Trisopterus luscus*	4.7	3.4–6.3	75 (5.2)
9	Whiting	*Merlangius merlangus*	2.2	0.6–3.4	83 (2.7)
10	Megrim	*Lepidorhombus whiffiagonis*	1.5	0.4–2.4	30 (3.0)
11	Anglerfish (Monk)	*Lophius piscatorius*	1.1	0.6–1.5	48 (2.9)
14	Lemon sole	*Microstomus kitt*	0.9	0.5–1.2	37 (1.2)
15	Cuckoo ray	*Raja naevus*	0.8	0.2–1.2	82 (2.7)
21	Red mullet	*Mullus surmuletus*	0.4	0.1–0.7	47 (4.1)
22	Spotted ray	*Raja montagui*	0.3	0.1–0.7	80 (4.5)
23	Sole (Dover sole)	*Solea solea* (*s. vulgaris*)	0.3	0.2–0.3	5 (0.6)
Rest (114 species)			8.0	6.4–10.8	80 (1.4)

Ranking according to annual mean discard numbers. Figure in parentheses refer to standard error of annual estimate.

and sprat (*Sprattus* (*clupea*) *sprattus*) are also discarded in large numbers.

3.3. Length–frequency distributions of retained and discarded fish

The length–frequency distributions (of all species combined) were derived from a total of 706,015 measured fish and are presented for beam trawlers, otter trawlers and all other gear groups (Fig. 3). These LFDs demonstrate that both the retained and discarded fish span a broad length range, and are indicative of the multi-species nature of these fisheries. The majority of discarded fish arising from beam and otter trawling are however, less than 30 cm in length.

3.4. Spatial trends using CPUE data

Mean CPUE data indicated that factory pelagic trawlers had the highest discard rate >78,000 fish per hour. However, haul-to-haul variation for this gear type was high (SE 68 027) and was mainly due to one haul, in which the discard CPUE was 1,103,409 fish/h. Variation in CPUE data for the other gear groups was considerably less (Table 5). *Nephrops* trawlers, beam trawlers, seiners, local-pelagic trawlers and otter trawlers on average discarded 398, 313, 245, and 180 fish/h, respectively. Netters, scallop dredgers, potters and long liners all discarded, on average, <10 fish/h (Table 5). Fish and cephalopods were discarded throughout most of area VII, however discarding 'hot-spots' where identified in the English Channel and Irish Sea

Table 7
Top 10 most discarded species, and significant commercial species by English and Welsh registered otter trawlers

Rank	Common name	Latin name	Numbers ($\times 10^6$)		% discarded
			Annual mean	Range	
1	Dab	*Limanda limanda*	6.2	3.0–14.0	96 (1.0)
2	Gurnards	*Trigla* spp.	5.2	1.3–11.1	70 (5.1)
3	European plaice	*Pleuronectes platessa*	3.6	1.8–6.3	60 (3.4)
4	Lesser-spotted dogfish	*Scyliorhinus canicula*	3.5	2.3–5.1	75 (7.3)
5	Whiting	*Merlangius merlangus*	3.1	1.1–4.6	68 (3.1)
6	Boar fish	*Capros aper*	2.4	0.1–6.0	100 (0.0)
7	Gt Silver Smelt	*Argentina silus*	2.8	0.0–8.3	100 (0.0)
8	Poor cod	*Trisopterus minutus*	2.0	0.8–3.3	100 (0.0)
9	Horse-mackerel (Scad)	*Trachurus trachurus*	1.8	0.5–3.5	81 (8.3)
10	Dragonets	*Callionymidae*	1.6	0.2–3.3	100 (0.1)
11	Megrim	*Lepidorhombus whiffiagonis*	1.2	0.0–4.3	33 (16.2)
15	Lemon sole	*Microstomus kitt*	0.6	0.0–1.0	23 (6.8)
17	Haddock	*Melanogrammus aeglefinus*	0.4	0.0–0.8	36 (10.5)
20	Thornback ray	*Raja clavata*	0.3	0.1–0.7	38 (6.2)
21	Greater Forkbeard	*Phycis blennoides*	0.4	0.0–1.1	53 (23.5)
Rest (144 species)			7.2	3.4–14.3	35 (5.5)

Ranking according to annual mean discard numbers. Figure in parentheses refer to standard error of annual estimate.

Table 8
Top 10 most discarded species, and significant commercial species by all other gear groups registered to England and Wales

Rank	Common name	Latin name	Numbers ($\times 10^6$)		% discarded
			Annual mean	Range	
1	(European) Mackerel	*Scomber scombrus*	3.7	0.5–11.3	67 (19.5)
2	Common Cuttlefish	*Sepia officinalis*	0.8	0.0–2.3	82 (16.8)
3	Horse mackerel (Scad)	*Trachurus trachurus*	0.4	0.0–1.5	49 (26.7)
4	Whiting	*Merlangius merlangus*	0.4	0.1–1.1	62 (12.7)
5	Dab	*Limanda limanda*	0.4	0.1–1.1	100 (0.2)
6	European plaice	*Pleuronectes platessa*	0.3	0.1–0.7	58 (13.1)
7	Gurnards	*Trigla* spp	0.2	0.0–0.5	79 (7.8)
8	Lesser spotted dogfish	*Scyliorhinus canicula*	0.2	0.1–0.3	91 (8.6)
9	Sprat	*Sprattus* (*clupea*) *sprattus*	0.1	0.0–0.5	100 (0.0)
10	Pilchard	*Sardina* (*clupea*) *pilchardus*	0.1	0.0–0.4	75 (28.9)
13	Black seabream	*Spondyliosoma cantharus*	0.1	0.0–0.2	11 (4.8)
15	Anglerfish (Monk)	*Lophius piscatorius*	0.1	0.0–0.1	13 (4.1)
16	Cod	*Gadus morhua*	0.0	0.0–0.1	25 (14.2)
23	Pollack	*Pollachius pollachius*	0.0	0.0–0.1	6 (3.1)
26	European Hake	*Merluccius merluccius*	0.0	0.0–0.1	5.1 (0.5)
Rest (97 species)			0.9	0.4–1.9	37 (6.0)

Ranking according to annual mean discard numbers. Figure in parentheses refer to standard error of annual estimate.

(Fig. 4). The CPUE of discarded and retained fish were closely related and, in general, when retention of fish was high so was discarding. However, high discard rates were observed in regions of the Irish Sea, English Channel and Celtic Sea (Fig. 4).

3.5. Temporal trends using CPUE data

Aggregated by month, the discarded and retained CPUE data for beam trawlers and otter trawlers are presented in Fig. 5. Beam trawler monthly discards ranged from 162 to 610 fish per hour (Fig. 5a). Discard levels were highest during winter (November–February) due to large quantities of cuttlefish (*Sepia officinalis*), lesser-spotted dogfish, gurnards, dab and bib-pout (*Trisopterus luscus*) being discarded. Otter trawl monthly discards ranged from 64 to 318 fish/h (Fig. 5b). The rate of discarding was highest in summer (May–July) when high numbers of low-value species (dab, plaice, gurnards, dragonets (*Callionymidae*), horse mackerel, poor cod, lesser-spotted dogfish, whiting bib-pout and boar-fish (*Capros aper*)) were discarded. The discard CPUE for the other gear groups (aggregated together) was much lower (2–58 fish/h).

Seasonality was shown to have little effect on overall discard rates (amongst the 10 studied gear groups) when examining all species together. However, temporal patterns of discarding were observed using individual species CPUE data and gear types. Most notably, mackerel discards were highest for beam trawlers, otter trawlers and factory pelagic vessels during February and November, cuttlefish discards by beam trawlers peaked in December, and lemon sole discards were most prevalent in summer.

4. Discussion

The results of this study show average annual discards (2002–2005) of fish by English and Welsh ≥10 m LOA vessels as 24,500 t (117.4 million fish) and a discard rate of 35% by weight and 63% by number (Tables 3 and 4). Raising discard data to fleet level can be problematic and prone to uncertainty. However, in this work we have been able to gauge the accuracy of our estimates by contrasting them against the official landings statistics. More specifically, we compare our estimates of the total landings of non-quota species (raised from

Table 9
Comparisons between official landings figures for English and Welsh registered vessels (2002–2005) and those estimated by the catch sampling programme for a range of commercial non-quota species

Common name	Latin name	Estimated landings (t) as derived from catch sampling programme	Official reported landings (t)	% difference
Whiting-pout (Bib)	*Trisopterus luscus*	3,114	2,503	19.6
Dab	*Limanda limanda*	320	353	−10.1
John Dory	*Zeus faber*	707	807	−14.3
Lemon sole	*Microstomus kitt*	3,926	3,608	8.1
Ling	*Molva molva*	3,468	3,595	−3.6
Red mullet	*Mullus surmuletus*	660	615	6.8
Turbot	*Scophthalmus maximus*	940	1,189	−26.5
Black sea bream	*Spondyliosoma cantharus*	875	822	6.1
Total		14,010	13,492	3.7

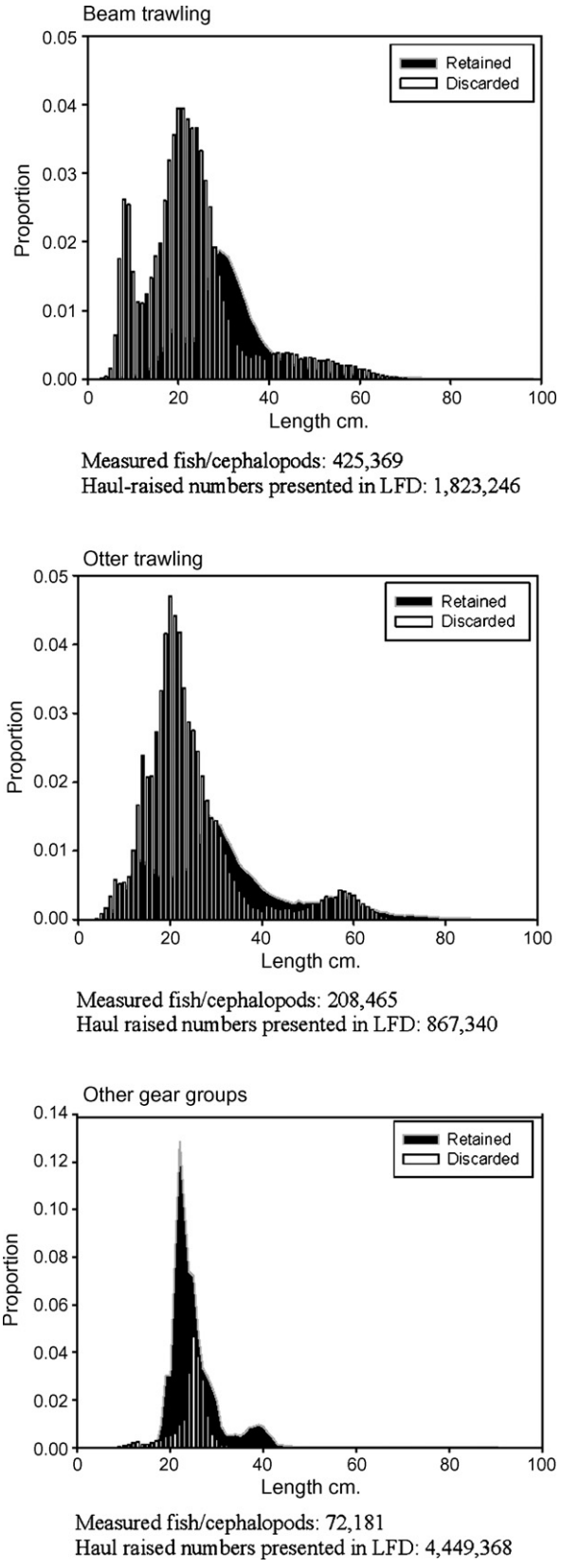

Fig. 3. Haul raised length–frequency distributions (2002–2005) for English and Welsh registered beam trawlers, otter trawlers and all other gear groups combined.

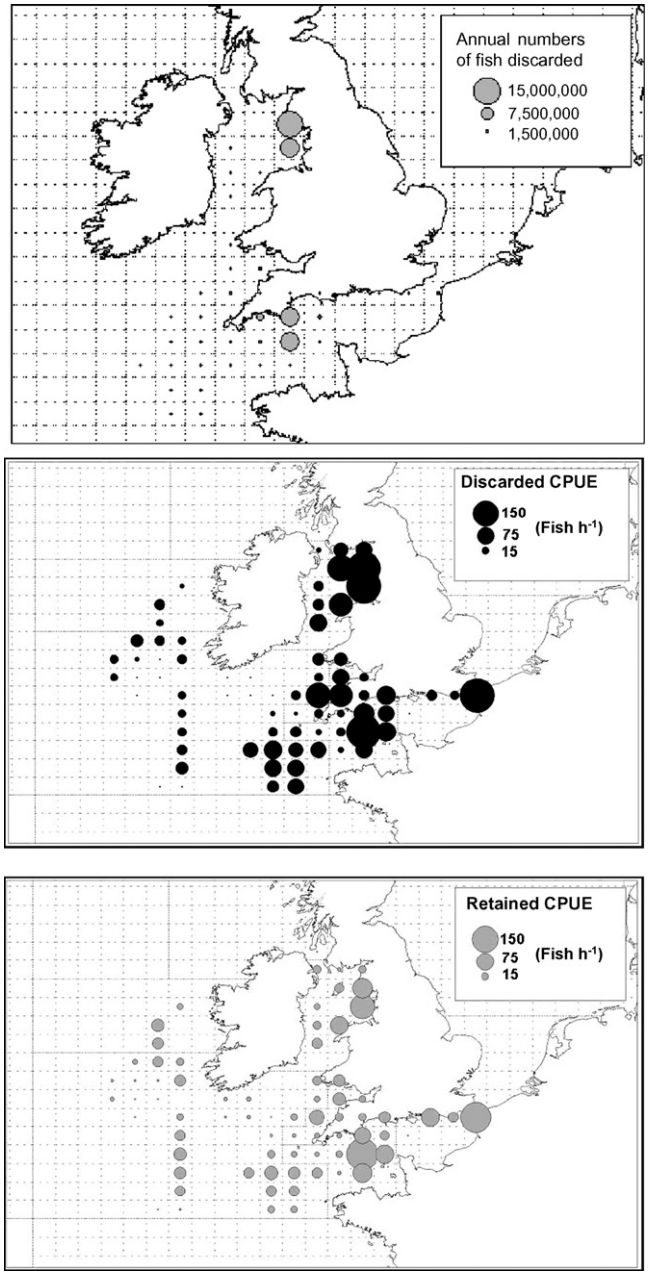

Fig. 4. Spatial distribution (top), discard CPUE (center) and retained CPUE (lower) of discarded fish and cephalopods by English and Welsh registered fishing vessels (2002–2005) in ICES sub-area VII.

the sampling programme) to the equivalent official landings. We use non-quota species for this comparison, as the official landings statistics for these species are likely to be the most accurate and the least prone to mis-reporting. Our comparison of the data from these two sources for the most commonly caught non-quota species ($n = 8$) shows close agreement (<4% difference for all the species pooled), while for individual species the differences range between 4 and 27% (Table 9). Having contrasted our sampling programme in this way against this independent data source (official landings statistics) leads us to conclude that our estimates are acceptably accurate.

Landings data from all countries exploiting stocks in ICES subarea VII show English and Welsh landings in this area to

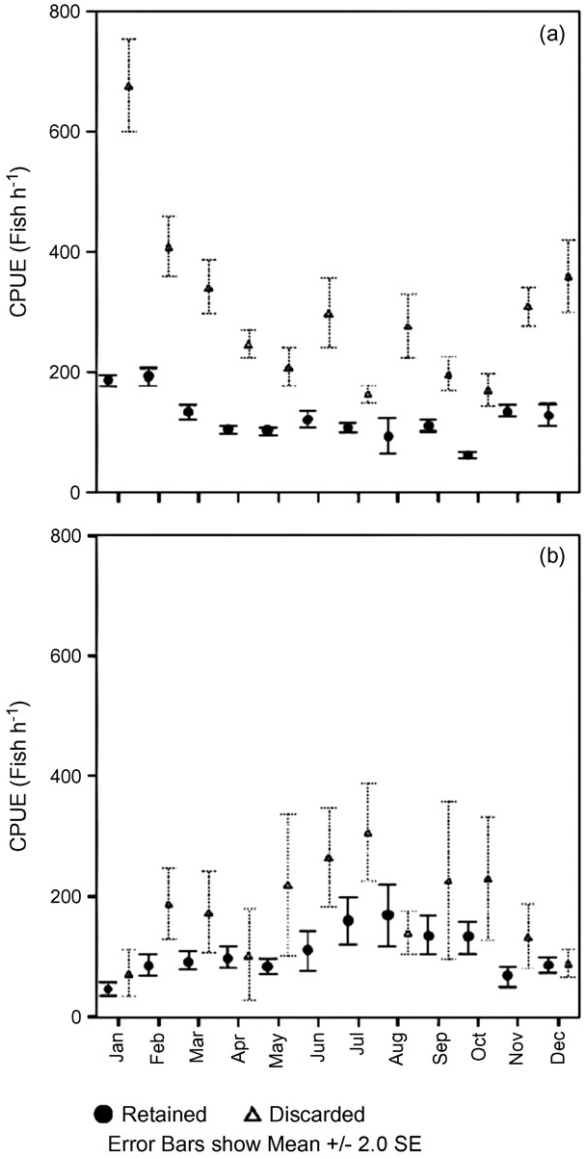

Fig. 5. Aggregated monthly CPUE data for retained and discarded fish and cephalopods caught by English and Welsh registered beam trawlers (a) and otter trawlers (b).

account for 6% of pelagic species and 24% of demersal fish species (11% in total). A figure for discarding for all of ICES subarea VII can be inferred. We use landings as the basis to produce multipliers for raising our discard data to all fleets operating within ICES subarea VII. This raising procedure assumes that the non-English and Welsh vessels operating in ICES subarea VII have comparable discard patterns to those identified in this study. This assumption is somewhat supported by other discard studies in the same regions (Melnychuk et al., 2001; Rochet et al., 2002; Borges et al., 2005a,b). Our estimate for annual fish and cephalopod discards within ICES subarea VII between 2002 and 2005 is 152,000 t. Kelleher (2005) presented data for discards in large marine ecosystem (LME) 24 (Celtic Sea, Bay of Biscay, Irish Sea, Western approaches, English Channel and Hebrides) at 100,893 t. Our estimate (which precludes information on <10 m vessels, shellfish, deepwater fleets and data for discarding in the Bay of Biscay and Hebrides fisheries) suggests that Kelleher (2005) may have under estimated discarding in LME 24 by at least 50%. If we are correct and Kelleher (2005) data for other areas is also correct, LME 24, previously ranked as 15th in the world for generating discards (Kelleher, 2005), would be ranked 7th. With the addition of the <10 m fleets, shellfish, deepwater fleets and data for discarding in the Bay of Biscay and Hebrides fisheries the ranking would be higher still.

Regional discard studies have presented comparable results. For example, Rochet et al. (2002) reported that French fleets fishing the Celtic Sea discard 32% of their catch by weight, compared with 35% by the English and Welsh fleets. Borges et al. (2005b) reported Irish beam trawlers to discard 67% of their catch by weight in ICES division VIIa (Irish Sea) against 42% presented in this study. Unlike most of ICES subarea VII, the Irish Sea is a shallow shelf sea fishery, supporting large numbers of juvenile fish (Dunn and Pawson, 2002; Borges et al., 2005a,b). To this end, the higher discarding levels observed by Borges et al. (2005a,b) may be accounted for by the aggregation of these data into ICES subarea level rather than division. *Nephrops* trawlers in ICES subarea VII predominantly fish in division VIIa (Fig. 1). Although effort by English and Welsh vessels is low (Table 1) *Nephrops* trawlers discard an average of 398 fish per hour, which is the highest rate observed by any of the demersal gear groups in this study (Table 5).

Although this study uses data collected from many trips and numerous fisheries around England and Wales, it has some limitations. Sampling coverage on longliners has been low, but reflects the relatively low effort of this gear group. Sampling aboard potters was discontinued in 2005 because data from the nine trips completed demonstrated a consistently low level of fish discards. The deep-water fleet (operating off the continental slope) has not been sampled owing to logistical restrictions. Although sampling coverage (Table 2) on factory pelagic vessels has been the greatest of all gear groups (as a proportion of fleet effort), the haul-to-haul variation in this gear group has produced the most variable estimates. Catch and discard data from the <10 m sector has not been collected to date. However, in 2006, the CEFAS catch and discard sampling programme started an assessment of this sector to address this issue.

Accurate information on discarding plays an integral role in establishing an ecosystem approach to fisheries, which has become a widely accepted approach to managing sustainable fisheries (FAO, 2003). Discarding has been shown to affect the dynamics of marine food-webs (Anker-Nilssen et al., 1997; Wright, 1996; Mangel and Switzer, 1998), leading to subsequent ramifications on recruitment and productivity of fish stocks (Sparre, 1991; ICES, 1997; Duplisea, 2005). Pascoe and Revill (2004) estimated that discards in the North Sea brown shrimp (*Crangon crangon*) fishery equated to losses of future landings of plaice of around 10–25% of the 1998 total allowable catch for plaice. Kell and Bromley (2004) demonstrated that if plaice discards in the North Sea could be eliminated or the survival of small fish increased, then recovery from low stock levels and/or high yields could be more readily achieved.

Fishers are not always in a position to reduce discarding and are often cautious of the short-term losses and poor

incentives that can be associated with such practices (Jennings and Revill, in press). The LFDs of the catches (Fig. 3) indicate that fish are both retained and discarded across a wide length range and are typical of multi-species fisheries. It also demonstrates the complexity associated with developing discard mitigation measures (such as more selective fishing gears for example).

However, the growing climate of adverse public opinion on discarding may well force that situation to change. In any event, this work in ICES subarea VII has highlighted the fact that discarding may be higher than previously anticipated.

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