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An overview of the biology and status of undulate ray *Raja undulata* in the north-east Atlantic Ocean

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The undulate ray *Raja undulata* is one of the lesser-known skates occurring on the continental shelf of the north-east Atlantic Ocean. It is patchily distributed throughout its range, with sites of local abundance in the central English Channel and off the coasts of Ireland, France, Spain and Portugal. *Raja undulata* is most abundant in coastal waters (<50 m deep) and is often found in proximity to large estuaries, rias and bays. It is a relatively large-bodied species, attaining a maximum total length (L_T) of at least 114 cm, with females maturing at an L_T of *c*. 84 cm in Portuguese waters. Although infrequently taken in existing trawl surveys, it can be locally abundant in certain areas, where it can be the dominant skate species. Given its large size, patchy distribution and concern over the possibilities of localized depletions, the IUCN listed *R. undulata* as an endangered species and, since 2009, the European Union has established regulations to prohibit commercial fisheries landing the species. Given the increased interest in the species, a synopsis of current knowledge is provided, and available data from internationally co-ordinated trawl surveys presented.

Key words: English Channel; fisheries management; Rajidae; skate; stock structure; trawl surveys.

INTRODUCTION

The undulate ray *Raja undulata* Lacépède 1802 is a little known skate from the north-east Atlantic Ocean and Mediterranean Sea (Serena, 2005). It grows to at least 114 cm total length (L_T), and possibly up to 120 cm (Wheeler, 1978; Bañon *et al*., 2008). The IUCN has classified it as endangered (Gibson *et al*., 2008) and, since 2009, *R. undulata* has been listed as a species not to be retained by commercial fishing vessels fishing under European Union fishing regulations. This measure has been unpopular with fishing communities in several localized areas, as the species can be locally abundant. Here, an overview of the species and the data that are currently available are provided.

BATHYMETRIC AND GEOGRAPHICAL DISTRIBUTION

Raja undulata occurs in the north-east Atlantic Ocean from the British Isles southwards to north-west Africa, including the Mediterranean Sea, where it is most

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frequently reported from the western basin (Serena, 2005). Although some general ichthyology books suggest that it can be found as deep as 200 m (Wheeler, 1978; Stehmann & Bürkel, 1984), it tends to occur in inshore waters, is most often reported from waters <100 m and is most abundant in <50 m. Bañon *et al*. (2008) reported *R. undulata* at depths down to 90 m in Galician waters, but most individuals were captured in waters <20 m deep. Earlier analyses of fishery-independent surveys around the U.K. observed *R. undulata* at a maximum depth of 72 m (Ellis *et al*., 2005). In Portuguese waters, Coelho *et al*. (2005) and Baeta *et al*. (2010) both reported that commercial catches of *R. undulata* were from waters <50 m deep.

Within the area covered by the International Council for the Exploration of the Sea (ICES), the northern limits of *R. undulata* is off the coasts of south-west Ireland (ICES Divisions VII b, j; Fig. 1) and in the English Channel (VII d, e), although very occasional specimens may be found in the southern North Sea (IV c) and Bristol Channel (VII f) (Clark, 1926). It is also widely (but patchily) distributed in the Biscay–Iberian ecoregion, including ICES Divisions VIII a, b, c and IX a. The distribution of *R. undulata* within this relatively broad biogeographical range is, however, quite fragmented, as discussed below.

Early accounts on British fishes did not include *R. undulata* (Yarrell, 1836; Day, 1880–1884), although Couch (1864), in discussing small-eyed ray *Raja microocellata* Montagu 1818, described a darker form that corresponds to the normal colouration of *R. undulata*. Hence, there may have been some confusion between these two species, and it worth noting that both species have been commonly referred to as 'painted ray'. Regan (1907, 1913) officially reported on the presence of *R. undulata* off the south coast of England (Cornwall and Sussex) and it has since been recognized as a part of the British ichthyofauna (Jenkins, 1925). Although its presence in the English Channel was not recognized by early British ichthyologists, its occurrence along the French coast of the English Channel was established (Moreau, 1881; Le Danois, 1913). Moreau (1881) noted that it was quite rare at Cherbourg, and less rare at other ports, whilst Le Danois (1913) considered it common off Roscoff. Within the English Channel, recent data (see below) suggest that *R. undulata* is most common around the Channel Islands and elsewhere in the Normano-Breton Gulf, and from Poole to Beachy Head, including around the Isle of Wight, and may be locally abundant in some areas.

Around the coast of Ireland, it is known from a variety of bays on the south-west coast, including off Doonbeg, Tralee Bay, Brandon Bay, off Ballydavid, Dingle Bay and off Mizen Head (de Griffith, 1966, 1968; Minchin & Molloy, 1980; Fahy & O'Reilly, 1990). Although most Irish records have been from bays close to shore, Minchin & Molloy (1980) reported on one instance where a commercial trawler landed 48 specimens from deeper waters (150 m) off Mizen Head.

Elsewhere along the French coasts, Moreau (1881) stated that *R. undulata* was quite common along the Mediterranean Sea coast (including Nice, Marseille and Sète), and was common on the Atlantic Ocean coast, from off Lorient and Brittany, north of the River Loire, and in the southern Bay of Biscay off the coasts of Poitou (north of La Rochelle), and also from the Bassin d'Arcachon (Thimel, 1989).

Around the Iberian Peninsula, *R. undulata* has been taken off Santander (Lozano Rey, 1928), and in Galician waters, including in and outside the Ría de Muros e Noia, Ría de Arousa and Ría de Pontevedra (Rodríguez-Villanueva & Vázquez, 1992; Sanmartín *et al*., 2000; Álvarez *et al*., 2006). *Raja undulata* may be locally

abundant in some of the Galician rias, and is one of the main species taken in artisanal fisheries in these areas (Bañon *et al*., 2008), but it is not typically observed in groundfish surveys further offshore (Fariña *et al*., 1997).

Raja undulata has also been recorded around several parts of Portugal, including from Matosinhos (near Porto), Buarcos (near Figueira da Foz), the Tagus and Sado Estuaries (including off Setúbal), Sines and along the Algarve coast, including at Lagos and Ría Faro-Olhão (Nobre, 1935; Kearn & Beverley-Burton, 1990; Prista *et al*., 2003; Neves *et al*., 2008; Ribeiro *et al*., 2008). Further east, along the southern coast of Spain, *R. undulata* is also taken in the Gulf of Cádiz, including off Mazagon (near Huelva) and in the Bahía de Cádiz (Arias, 1976; Gonçalves *et al*., 2007).

Within the Mediterranean Sea, *R. undulata* has been reported occasionally from the western basin, including from off southern France (including Sète) and the Tyrrhenian Sea, and with very occasional records from the eastern basin, from the Adriatic Sea to Israel (Serena, 2005; Capapé, *et al*., 2006; Psomadakis *et al*., 2006).

In general, *R. undulata* is most often reported from coastal waters and juveniles, in particular, tend to be found in shallow, inshore waters, including coastal lagoons, rias, bays and the outer parts of estuaries, suggesting that *R. undulata* favour such shallow habitats with less saline waters for at least part of their life cycle.

LIFE HISTORY

There have been few biological studies on *R. undulata*, mostly from Portuguese waters, which have provided much of the available data on their diet, growth and reproductive biology.

Raja undulata feed mainly on brachyuran crabs, particularly swimming crabs (Portunidae), with smaller individuals also preying on crangonid and other natantid shrimps, and larger individuals also consuming a variety of fishes, including European hake *Merluccius merluccius* (L. 1758), lesser weever *Echiichthys vipera* (Cuvier 1829), ammodytids, sparids, gobies and flatfishes (Moura *et al*., 2008). The presence of gobies and flatfishes in the stomach contents of *R. undulata* were also observed by de Griffith (1966, 1968).

The growth of *R. undulata* has been examined from both caudal thorns (Moura *et al*., 2007) and vertebrae (Coelho & Erzini, 2002), and the growth parameters

TABLE I. Von Bertalanffy and Gompertz growth-model parameters for *Raja undulata* in Portuguese waters (adapted from Moura *et al*., 2007 and reproduced with permission of CSIRO PUBLISHING)

		Von Bertalanffy			Gompertz		
Location	Sex	L_∞ (mm)	K	T_0	L_∞ (mm)	K	T_0
Algarve	Females	1225	0·112	−0·540	1017	0·225	0·406
	Males	1178	0·124	−0·368	985	0·249	0·471
	Combined	1193	0·120	−0·414	994	0·241	0·448
Peniche	Females	1146	0·146	−0·006	1028	0·259	0·550
	Males	1128	0·149	−0·090	1002	0·272	0·562
	Combined	1137	0·147	−0·010	1015	0·266	0·566

from the former study are summarized in Table I. This study did not detect any significant differences in the growth parameters between the sexes, although there were significant differences between the main study sites (Algarve and Peniche).

In a study off the Algarve, Coelho & Erzini (2006) recorded mature females across an L_T range of 75·5–88·2 cm ($L_{50} = 76{\cdot}16$ cm), and mature males were observed from 70·7 to 83·2 cm L_T ($L_{50} = 73{\cdot}63$ cm). A subsequent study based on samples collected from further north (off Peniche) indicated that females first matured at an L_T of *c*. 83·8 cm (95% maturity at 85·2 cm), whilst the L_T at first and 95% maturity for males were 78·1 and 88·0 cm, respectively (Moura *et al*., 2007). Such latitudinal clines in L_T at maturity have been suggested to occur in other elasmobranchs. It should also be noted that these studies were based on relatively small sample sizes; Coelho & Erzini (2006) examined 93 females (16 of which mature) and 94 males (19 of which were mature) and Moura *et al*. (2007) examined 90 males and 78 females (including both mature and immature fish).

Raja undulata may spawn in the winter, at least in the Algarve, as shown by a high gonado-somatic index and presence of encapsulated eggs (Coelho & Erzini, 2006). Several studies have reported that the juveniles occur in inshore waters, including estuaries and coastal lagoons, such as the Sado Estuary in Portugal (Moura *et al*., 2007).

The relationship between total mass (M) and L_T for *R. undulata* was given as $M = 0{\cdot}00415\ L_T^{3{\cdot}12428}$ ($n = 64$, L_T range = 13–101 cm) for specimens caught in the English Channel (Dorel, 1986).

Parasites can potentially act as useful biological markers to better understand stock structure, and although appropriate data are lacking for most areas of abundance, the parasite fauna of *R. undulata* captured in Iberian coastal waters are relatively well documented (Kearn & Beverley-Burton, 1990; Sanmartín *et al*., 2000; Aragort *et al*., 2005; Álvarez *et al*., 2006). These studies have reported the presence of various monogeneans (*Mycteronastes undulatae* and *Rajonchocotyle emarginata*), cestodes (*Acanthobothrium benedeni*, *Acanthobothrium* sp., *Crossobothrium* sp., *Echeneibothrium beauchampi*, *Echeneibothrium* sp., *Grillotia* sp., *Onchobothrium uncinatum* and *Phyllobothrium lactuca*), nematode worms [*Proleptus* sp., *Schulmanela* (*Piscicapillaria*) sp., *Pseudanisakis rotundata* and Cystidicolidae] and the acanthocephalan *Acanthocephaloides propinquus*.

FISHERY-INDEPENDENT TRAWL SURVEYS

Scientific trawl surveys are conducted across much of the northern European continental shelf, many of which are internationally co-ordinated by ICES through the International Bottom Trawl Survey Working Group (IBTSWG). Those surveys conducted across the southern and western parts of the ICES area, although standardized in terms of catch processing and biological sampling, do not use a standardized gear (as occurs in the North Sea IBTS), and so data cannot be aggregated for analysis (see ICES, 2010*a*, *b* for further details of individual surveys). French surveys used variations of the grand ouverture vertical (GOV) trawl, whereas Spanish surveys used baca trawls, and the Portuguese survey used a Norwegian Campelen trawl (NCT). Furthermore, many of these surveys operate in deeper waters, and so catches of *R. undulata* are generally low and sporadic (Table II).

TABLE II. Summary details of *Raja undulata* captured in trawl surveys co-ordinated by the ICES International Bottom Trawl Survey Working Group (IBTSWG) and Working Group on Beam Trawl Surveys (WGBEAM), summarizing the total length (L_T) ranges sampled, observed depth range and the approximate number of specimens caught each year (years with no records excluded)

							R. undulata		
Co-ordination	Nation	Survey	ICES Area	Month	Gear	Time period analysed	Individuals year^{-1}	L_T range (cm)	Observed depth range (m)
IBTSWG	France	English Channel groundfish survey	VII d	October	grand ouverture vertical (GOV; small)	1988–2010	1–8	27–99	13–82
		EVHOE	VII g–j, VIII a, b	October to December	GOV	1997–2010	1–2	19–75	20–29
	Spain	Cantabrian Sea	VIII c	September to October	Baca trawl	1992–2010	1–6	37–94	36–98
		Gulf of Cadiz	IX a (part)	March and November	Baca trawl	1996–2010	1–5	42–83	19–46
	Portugal	Portuguese shelf	IX a	October	Norwegian Campelen trawl	2001–2010	1–9	49–89	23–70
WGBEAM	U.K. (England)	E. English Channel	VII d, IV c	July	4 m beam trawl	1993–2010	1–14	17–81	10–57
		Start Bay	VII e (part)	September to October		1989–2010	1–7	26–97	16–73
		W. English Channel	VII e	March		2006–2011	4–42	19–95	18–150
	France	Bay of Biscay	VIII a, b	November to December		2007–2010	3–5	14–87	14–51

The French Channel Groundfish Survey is conducted in the eastern English Channel, and specimens of *R. undulata* (27–99 cm L_T, 1–8 individuals year^{-1}) were observed throughout the division (Fig. 1), in waters 13–82 m deep. A recent study on these data has suggested low, but stable catch rates of *R. undulata* (Martin *et al.*, 2010). The French Evaluation des ressources Halieutiques de l'Ouest Europe (EVHOE) survey in the Bay of Biscay (1997–2010) had only six records of *R. undulata*, with single specimens recorded in 1997 and 2007 and two specimens each in 2000 and 2009. These fish were generally small (19–75 cm L_T), and were only recorded at some of the shallowest stations (20–29 m depth).

Surveys conducted along the north coast of Spain in the Cantabrian Sea and off Galicia (1992–2010) also caught comparatively few individuals ($n = 36$, 37–94 cm L_T), with these fish taken at depths of 36–98 m. Most records were off the coastline of Laredo and Santoña (where there is a small network of rias). It should be recognized that this survey has relatively few coastal stations (ICES, 2010*b*) and, although no *R. undulata* were reported from Galician waters, this survey does not include the shallower areas around Galicia where, as stated above, *R. undulata* may be a locally abundant species.

Similarly, only occasional individuals of *R. undulata* were recorded in Portuguese surveys. Specimens reported were 48–88 cm L_T, and captured in waters of 23–70 m deep off south-western Portugal, including off Setúbal, and along the stretch of coastline near Porto and Matosinhos, confirming the locations reported in earlier literature sources. *Raja undulata* were also observed in the Spanish surveys (1996–2010) in the Gulf of Cádiz, with these fish ($n = 15$, 42–83 cm L_T) found in coastal areas just outside the Bahia de Cádiz in waters 19–46 m deep.

There are also several fishery-independent beam-trawl surveys conducted around the coasts of northern Europe, internationally co-ordinated through the ICES Working Group on Beam Trawl Surveys (WGBEAM). Amongst these surveys are those conducted by the U.K. in the (1) southern North Sea and eastern English Channel, (2) Start Bay area and (3) wider parts of the western English Channel, and the French beam-trawl survey that operates in the Bay of Biscay (ICES, 2009).

The annual survey of the southern North Sea and eastern English Channel is conducted in July, and samples were collected at fixed stations (Parker-Humphreys, 2005). The gear is a 4 m beam trawl with chain mat that prevents large rocks entering the net. This allows the gear to be used on the coarser grounds in the survey area (*e.g.* Dover Straits, sites in mid-Channel and off the Isle of Wight). Although beam trawls are considered suitable for sampling smaller batoids, they may not be as efficient for sampling larger batoids in comparison to otter trawls (ICES, 2005), possibly due to the low height of the beam and that the chain mat restricts their capture.

Raja undulata were captured occasionally in this survey, typically in coastal waters, and were found from Poole to Dungeness along the English coastline, and off the Cherbourg Peninsula and Dieppe along the French coast. There were a few records in the southern North Sea (1996 only), but these are questionable and may be due to confusion with small-eyed ray *R. microocellata*. Nearly all of the specimens taken in this survey were immature fish, with only a single occurrence of a specimen >80 cm (Fig. 2). The low incidence of mature fish in this survey may be due to adults inhabiting other areas at this time of the year and a low catchability of the gear for larger specimens, although it should be noted that large, mature *R. undulata* have been taken off the Isle of Wight with commercial gears.

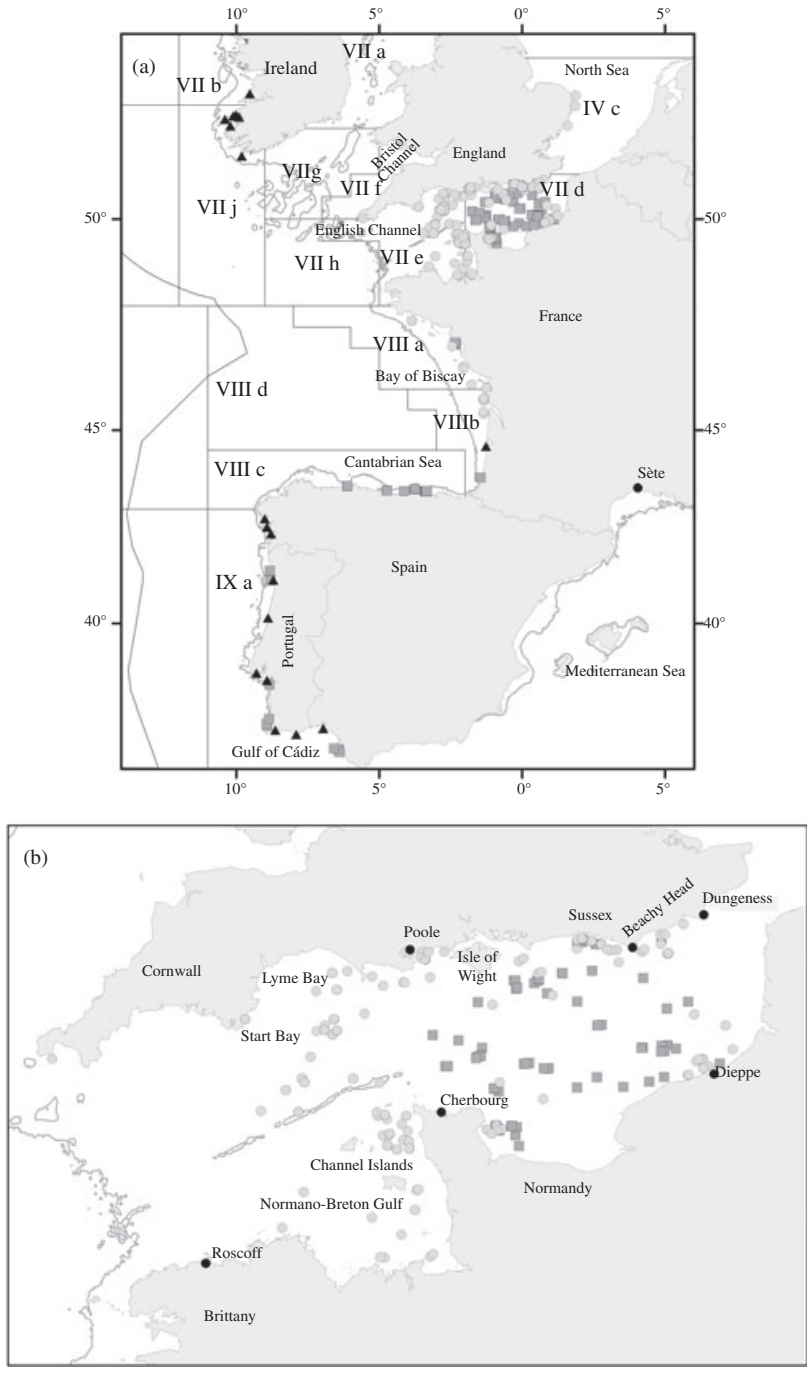

FIG. 1. Distribution of *Raja undulata* in (a) ICES Divisions IVc–IXa, as recorded in recent IBTS (□) and beam-trawl surveys (○), with additional locations from scientific literature (△), showing details for (b) English Channel, (c) south-west Ireland, (d) Bay of Biscay, (e) west coast of Portugal and (f) southern Iberian waters.

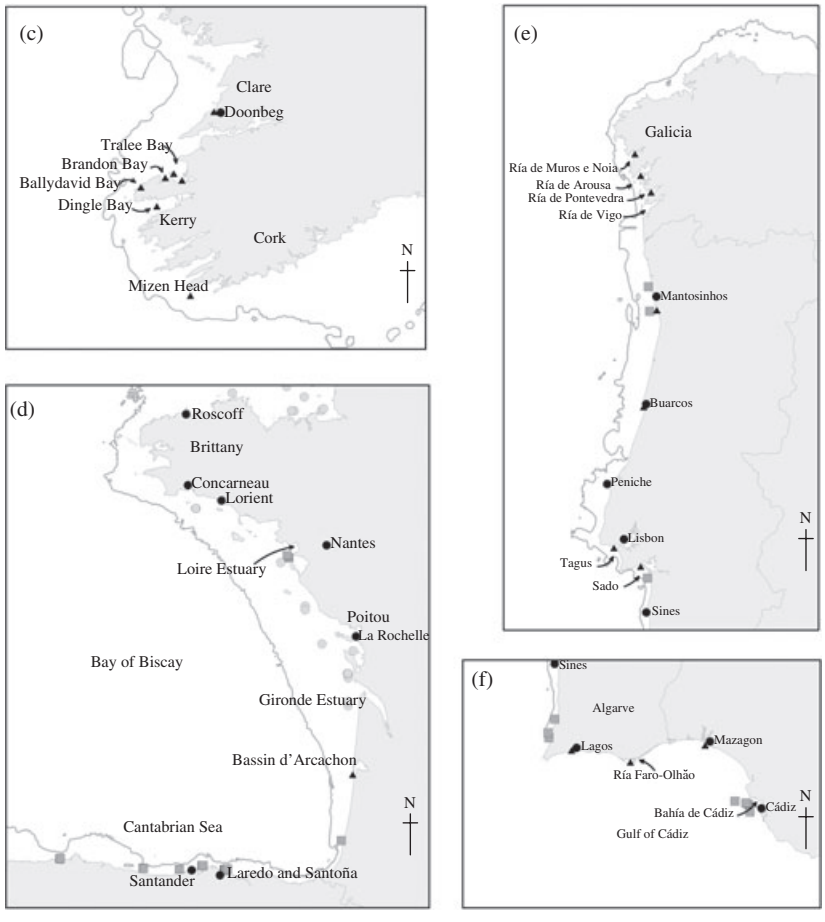

FIG. 1. Continued.

This survey fished most stations on an annual basis, although some stations in mid-English Channel were not fished in recent years, and some tows have been made in other parts of the general area on an *ad hoc* basis when time has allowed. Overall, 70 fixed stations were fished on at least 14 occasions over the 18 year period (1993–2010). During this time, *R. undulata* were typically observed in one to eight hauls each year (frequency of occurrence = 1·5–11·6%), resulting in a low mean catch per unit effort (CPUE) for the area as a whole. No *R. undulata* were reported in the years 2006–2007 (Fig. 3). Given the distinctive appearance of *R. undulata* and that experienced sea-going staff were present during the 2006–2007 surveys, it is not considered likely that they had been misidentified. *Raja undulata* reappeared in the survey series in 2008. Average catch rates are low, and in the years that they have been present, the mean CPUE has ranged from 0·03 to 0·31 individuals h^{-1}.

An annual survey of the area between Start and Lyme Bays has been conducted each October since 1989, and is usually conducted on F.V. *Carhelmar* using twin 4 m beam trawls over a fixed station grid. In 2002–2004, the survey was undertaken on R.V. *Corystes*, from which only one beam trawl was deployed. This survey has

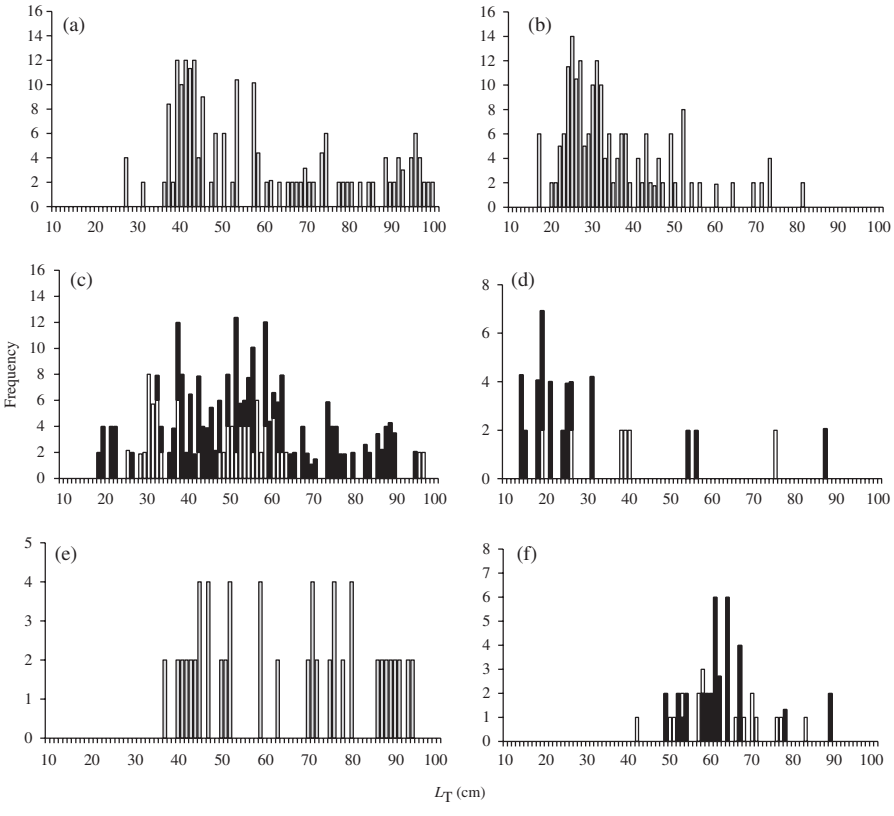

FIG. 2. Total length (L_T)-frequency distribution (sum of individuals h^{-1}) of *Raja undulata* in recent internationally co-ordinated trawl surveys in the (a) eastern English Channel [grand ouverture vertical (GOV) trawl], (b) eastern English channel (4 m beam trawl), (c) western English Channel (□, F.V. *Carhelmar*; ■, South-West Beam-Trawl Survey; 4 m beam trawl), (d) Bay of Biscay (□, GOV; ■, 4 m beam trawl), (e) Cantabrian Sea (baca trawl) and (f) Portuguese waters (■; Norwegian Campelen trawl) and Gulf of Cadiz (□; baca trawl). See Table II for further details of surveys.

caught few individuals (1–7 individuals $year^{-1}$) across an L_T range of 26–97 cm. These fish occurred at depths of 16–73 m.

A more extensive beam-trawl survey (using twin 4 m beam trawls) in the western English Channel has been conducted in March since 2006, and samples a stratified random survey grid. The largest number of individuals recorded was in 2010, but no temporal changes in relative abundance have been presented due to the short time series available. This survey has caught most specimens of *R. undulata* in the Normano-Breton Gulf (especially from the Channel Islands to the Cherbourg Peninsula), and has also caught small numbers of mature fish, up to 95 cm L_T.

Information from the French beam-trawl survey of the Bay of Biscay would suggest that *R. undulata* is caught occasionally outside the Gironde Estuary and northwards to La Rochelle, and also further north, from Concarneau to south of Nantes, including outside the Loire Estuary. Once again, catch rates are low (up to 3–5 individuals $year^{-1}$), with these fish (14–87 cm L_T) all taken in shallow water (14–51 m).

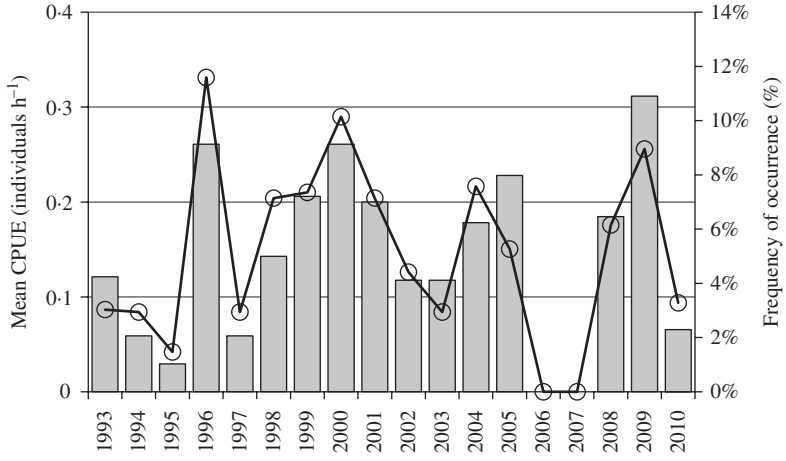

FIG. 3. Mean catch per unit effort CPUE (□) and frequency of occurrence (○ —) of *Raja undulata* in the eastern English Channel beam-trawl survey (1993–2010) for 70 stations that have been fished for at least 14 of the years within the 18 year time series. Number of valid stations each year varied from 57 to 70.

Most survey records of *R. undulata* have been from inshore waters. The overall bathymetric range was 10–150 m (but recognizing that there are few survey stations in waters <20 m deep), and there were only three records of fish caught in waters >90 m. Smaller specimens were generally found in waters <50 m deep, with larger fish also occurring in waters of increasing depth (Fig. 4).

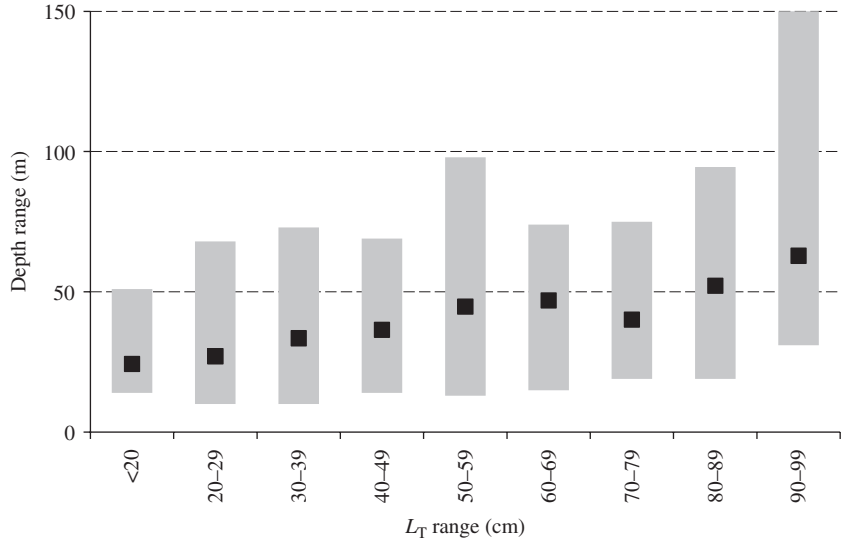

FIG. 4. Bathymetric distribution of records of *Raja undulata* (as recorded in recent International Bottom Trawl Surveys and beam-trawl surveys in the north-east Atlantic Ocean) by total length (L_T) class, giving the mean depth (■) and minimum and maximum depths at which fish in the size category were observed (□).

Given the patchy distribution of *R. undulata*, and that most of the trawl surveys do not have a sufficient density of sampling stations in the main habitat areas (including shallow and inshore sites), existing surveys are not designed to reliably inform on the status of *R. undulata*. Hence, more localized surveys (with an appropriate sampling gear) would be required if the status of *R. undulata* is to be better evaluated.

FISHERY SURVEYS IN AREAS OF LOCAL ABUNDANCE

Although often perceived as uncommon for much of its range, *R. undulata* can be locally abundant in particular areas. For example, it is relatively frequent off Setúbal (Portugal), where it can represent *c*. 22% (by numbers) and 38% (by mass) of the skates taken in commercial trammel net catches (Baeta *et al*., 2010). Similarly, in the inshore waters along the Algarve coast, it can be one the most abundant skates, accounting for 57% (by number) of the skates taken in trammel nets (Coelho *et al*., 2005). There are fewer comparable data for the local importance of *R. undulata* elsewhere in its range.

Recent field studies to better understand *R. undulata* have been conducted on commercial fishing vessels operating in the English Channel, conducted as part of on-going studies to better understand the discard survival of rajids (Enever *et al*., 2009). These studies have included gillnetting off the Isle of Wight and trawling around the Channel Islands, and also sampling on commercial beam trawlers in the English Channel (Table III). During these trips, all batoids were identified to species, L_T and sex recorded and live fish tagged and released to inform on long-term survival.

Field studies were conducted on an inshore fishing vessel on the fishing grounds to the east of the Isle of Wight in May 2010 (19 sets) and February to March 2011 (33 sets). Commercial tangle nets were deployed for 24–48 h. Specimens of *R. undulata* taken in this survey were large (79–100 cm L_T; Fig. 5), although smaller individuals of other rajids were taken (the smallest thornback ray *Raja clavata* L. 1758 and spotted ray *Raja montagui* Fowler 1910 observed were 65 and 54 cm L_T, respectively), which may suggest that smaller *R. undulata* occurred on other grounds. The sex ratio of *R. undulata* (female:male) was significantly skewed towards male fish in both 2010 (1:4·5, $P < 0{\cdot}001$) and 2011 (1:11, $P < 0{\cdot}01$). In total, *R. undulata* accounted for 4·8–27·7% (by number) and 9·3–39·2% (by estimated mass) of the skates caught in the two field seasons. *Raja undulata* could, however, account for up to 50% (by number) and 67·9% (estimated biomass) in any one fleet of net. The main skate taken in this area was *R. clavata.*

Otter trawling was conducted on fishing grounds around the Channel Islands, and tows ($n = 14$) were of 1–4 h duration. Specimens of *R. undulata* taken in this survey covered a broader L_T range (35–94 cm; Fig. 5). The sex ratio of *R. undulata* (F:M) was slightly skewed towards male fish (1:1·31), but not significantly different from the expected 1:1 sex ratio. In total, *R. undulata* accounted for 41·6% (by number) and 42·1% (by estimated mass) of the skates caught, with blonde ray *Raja brachyura* Lafont 1873 being the main species captured. Depending on the nature of the grounds fished, *R. undulata* could account for up to 87·9% (by number) and 91·9% (by biomass) in a single haul.

One trip on a commercial beam trawler was conducted in the main area of *R. undulata* and 34 hauls were processed. In total, *R. undulata* accounted for 57·5%

TABLE III. Summary data for catches of *Raja undulata* and other rajids from studies on commercial fishing vessels in the central English Channel. Significant differences from the expected 1:1 sex ratio were determined by χ^2 tests

				Male		Female		Sex ratio		Overall species composition	
Area	Dates	Gear (hauls)	Species	*n*	L_T range (cm)	*n*	L_T range (cm)	F:M	*P*	%Number	%Mass
Isle of Wight	May 2010	Gillnet (19)	*Raja brachyura*	2	87–97	—	—	—	—	1·7	3·3
			Raja clavata	58	65–85	11	81–90	1:5·27	<0·001	58·0	51·2
			Raja microocellata	2	73–75	1	76	—	—	2·5	2·2
			Raja montagui	10	54–65	2	63–65	1:5·00	<0·05	10·1	4·0
			R. undulata	27	80–97	6	79–91	1:4·50	<0·001	27·7	39·2
	February–March 2011	Gillnet (33)	*R. clavata*	168	60–87	33	55–92	1:5·09	<0·001	80·1	82·6
			R. microocellata	3	67–80	—	—	—	—	1·2	1·2
			R. montagui	16	55–60	19	48–67	1:0·84	>0·05	13·9	6·8
			R. undulata	11	86–93	1	100	1:11·00	<0·01	4·8	9·3
English Channel	December 2010	Beam trawl (34)	*R. brachyura*	19	36–99	41	36–102	1:0·46	<0·01	21·1	31·2
			R. clavata	2	56–60	1	53	—	—	1·1	0·5
			R. microocellata	6	68–76	4	60–80	1:1·50	—	3·5	4·0
			R. montagui	17	44–63	31	33–75	1:0·55	<0·05	16·8	8·7
			R. undulata	71	32–95	92	35–98	1:0·77	>0·05	57·5	55·6
Channel Islands	January 2011	Otter trawl (14)	*R. brachyura*	93	25–103	88	28–91	1:1·06	>0·05	56·5	55·8
			R. microocellata	4	71–78	2	77–80	—	—	1·9	2·1
			R. undulata	76	35–94	58	38–94	1:1·31	>0·05	41·6	42·1

F, female; M, male; L_T, total length; *n*, sample size.

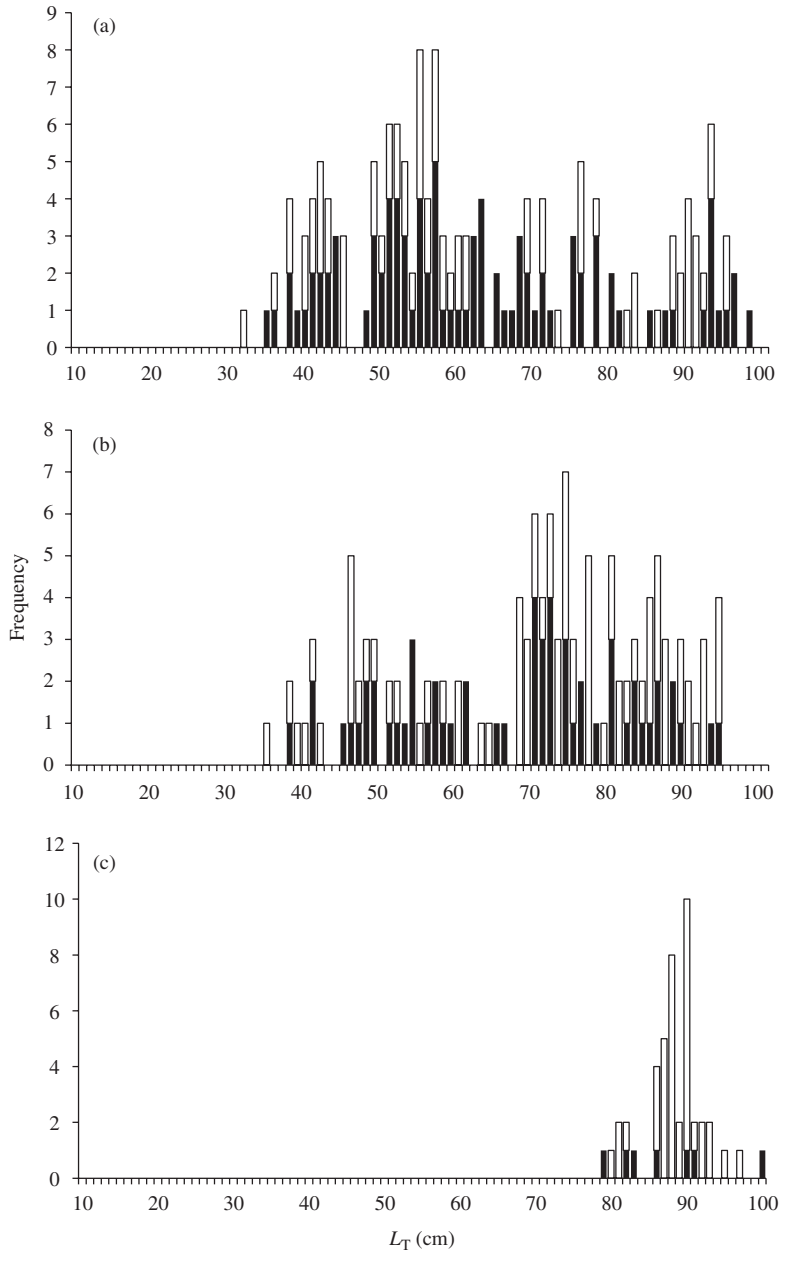

FIG. 5. Length (L_T)-frequency distribution of female (■) and male (□) *Raja undulata* collected in the central English Channel by commercial vessels: (a) beam trawl (b) otter trawl and (c) gillnet.

(by number) and 55·6% (by estimated biomass) of all skates captured. The fish sampled (35–98 cm L_T) were generally smaller than captured by the other gears. The sex ratio (F:M) was slightly, but insignificantly, skewed towards female fish (1:0·77).

CURRENT MANAGEMENT AND CONSERVATION STATUS OF *R. UNDULATA*

The assessment of skates in European waters has been hampered by the lack of species-specific landings data (although this has improved in recent years), paucity of life-history information and unclear stock units. Currently, the management of skates in European waters is undertaken primarily through quotas and prohibited status for selected species, including common or blue skate *Dipturus batis* complex, white skate *Rostroraja alba* (Lacépède 1803) and *R. undulata* (CEC, 2010), mesh size regulations for gillnet fisheries that target skates (CEC, 2008) and, in some inshore waters of the U.K., a minimum landing size.

ICES (2008) only provided advice on *R. undulata* species within the Celtic Seas ecoregion, as no data were available for the Biscay-Iberian ecoregion. For this ecoregion, ICES (2008) noted that, 'Undulate ray has a patchy distribution, with some of these areas showing signs of depletion' and advised, 'As a precautionary measure, target fisheries for this species should not be permitted unless exploitation rates are shown to be sustainable'.

In 2009, the European Community's TACs and quotas regulations stipulated that *R. undulata* in 'EC waters of VI, VII, VIII, IX and X may not be retained on board. Catches of these species shall be promptly released unharmed to the extent practicable' (CEC, 2009). Since 2010, it has been prohibited 'for EU vessels to fish for, to retain on board, to tranship and to land... (*Raja undulata*) ... in EU waters of ICES zones VI, VII, VIII, IX and X' (CEC, 2010). More recently, ICES (2010*c*) advised that 'There is no basis in the current or previous ICES advice for the listing of undulate ray as a prohibited species', but continued to recommend 'a precautionary approach to the exploitation of these populations of undulate ray' and reiterated that there should be 'no target fishing unless information is available to show that such fisheries are sustainable'.

The listing of *R. undulata* as a prohibited species has been a controversial issue for fishing communities in areas such as the Isle of Wight, Normano-Breton Gulf and some coastal areas of Galicia and Portugal, as it can be very abundant on some of the fishing grounds in these areas, and may even be the dominant skate species.

Given the patchy distribution of *R. undulata*, further studies on stock units are clearly required, as it is unclear as to how much interchange there is between what could be a succession of discrete stocks. There are no published studies on population genetics and whilst there is some information on the associated parasites in Galician waters, comparable information is lacking for elsewhere in its range. Limited data from tagging studies are available (Ellis *et al*., 2011), which have indicated a high site fidelity, and such work could usefully be extended to other regions to better understand their movements and potential connectivity between areas of abundance. Similarly, the use of electronic tags could provide more robust information on the home range of *R. undulata*. The differences in life-history parameters observed for *R. undulata* from southern and central Portugal may also be indicative of discrete stocks.

The status of the main skate stocks in northern European waters has generally been evaluated by trends in the distribution and relative abundance, as observed from scientific groundfish surveys. Existing survey data are, however, generally too limited to assess accurately temporal changes in the relative abundance of *R. undulata* for

most parts of the species' distribution. It has been highlighted for species not sampled effectively in scientific trawl surveys, that there are benefits of undertaking dedicated surveys, using commercial vessels with local skipper knowledge and appropriate gears, to better provide the data to understand the spatial and temporal dynamics of the stocks (Ressler *et al*., 2009). The coastal preference of *R. undulata* means that most existing fishery-independent surveys only sample a small part of the habitat, or have a low density of sampling stations in the main habitats. Larger research vessels may not even be able to sample the shallower parts of the habitat safely. Hence, dedicated coastal surveys on inshore fishing vessels would be required for the status of *R. undulata* to be better understood.

Although there are insufficient data to fully understand temporal trends in the population abundance of *R. undulata*, given their large body size and patchy distribution, precautionary management measures to prevent local depletion would seem appropriate as advised by ICES (2008) and commented upon earlier. Further studies to better evaluate regional stock status, sustainable exploitation rates and the most effective management measures are required, however, for areas of high local abundance.

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