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FISHERIES AND ECOLOGY OF THE SKATES (RAJIFORMES: RAJIDAE) IN THE ENGLISH CHANNEL

S. BITON-PORSMOGUER

Office Français de la Biodiversité (OFB), Délégation Manche Mer du Nord, 4 rue Colonel Fabien, BP 34, 76083 Le Havre, France
sebastien.biton@ofb.gouv.fr

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ABSTRACT. – Skates are the main elasmobranch species exploited in the Northern Atlantic Ocean in France and the United Kingdom, especially in the English Channel. The reported international landings show that the fishery is actually dominated by five species *Raja clavata*, *R. brachyura*, *R. montagui*, *Leucoraja naevus* and *R. undulata*. The stomach contents of *R. clavata* showed that crustaceans and fish dominate the diet. The on-board observations showed that females lay eggs in pairs on sand or mud between February and September, especially in June. The diet of *R. montagui* (mainly juveniles in the sample) is strongly dominated by crustaceans mainly, decapods (crabs and shrimps), mysida (mysids) and amphipoda (amphipods). The spotted ray breeds between April and July. Despite their critical conservation status and the current OSPAR conventions, the different species of skates were subject to intensive fishing in the last 40 years. The Total Allowable Catches (TACs) applied for 2020 concerns all skate species (*Raja* spp.) except *R. undulata*. However, there is no size limit based on the sexual maturity of each species, or any restriction during the laying period. The preservation of protected coastal sites that play a functional role for these species is necessary.

INTRODUCTION

The skates and rays taxonomic group has a large number of species (over 650). The skates are classified in the order Rajiformes while rays belong to three scientific orders (Pristiformes, Myliobatiformes, and Torpediniformes) (Last *et al*. 2016). European waters are home to a dozen species of skates that are commercially exploited. Their reproduction is oviparous: eggs hatch outside of the female's body. The species have different sizes of sexual maturity (between 60 and 75 cm for *Raja clavata* Linnaeus, 1758 and 60 cm for *Raja montagui* Fowler, 1910 (Muus *et al*. 2005).

Rajiformes are the main elasmobranch species exploited in the Northern Atlantic Ocean in France and the United Kingdom (UK) especially in the English Channel (La Manche). *Raja clavata* is the most abundant skate species in the catches in the East Channel and South North Sea (~ 90 % for the East Channel) (ICES 2016). An international fleet formed by France, the United Kingdom, Belgium, the Netherlands and Jersey operates in the English Channel (ICES divisions 7de) (ICES 2020).

Since 2017, according to the EU regulation, catches of *Leucoraja naevus* (Müller & Henle, 1841), *Raja brachyura* (Lafont, 1871), *R. clavata*, *R. montagui* and *Raja undulata* (Lacepède, 1802) should be reported separately for this TAC area. *Amblyraja radiata* (Donovan, 1808) and *Dipturus batis* (Linnaeus, 1758) are both prohibited species in this area, although the former is not expected to occur in the area.

The preferred habitats for rays are bays and estuaries. A study about *R. clavata* in the UK showed that the largest catches were encountered at the more inshore locations, highlighting the importance of these shallow areas as nursery grounds for this species (Ellis *et al*. 2008). *Raja undulata* is most abundant in coastal waters (< 50 m deep) and is often found in proximity to large estuaries, rias and bays (Ellis *et al*. 2012). The coastal area is the marine area the most exploited by the French fishing fleet, using mainly net, pelagic and bottom trawls (IFREMER 2017).

The objective of this work is to define 1) the areas of exploitation in the English Channel (area CIEM 7de) and to determine 2) their biological state (diet and ecology), 3) the ecological function of exploited habitats and 4) to propose some measures of fishery management and conservation. The evolution of landings over 40 years as well as geographic distribution by species based on ICES data (ICES 2011, 2020) and from landings markets (IFREMER 2011, 2012, 2014-2017) will be also analyzed in this study.

MATERIAL AND METHODS

A series of observations on-board fishing vessels (bottom trawler from Le Hourdel, France; Table I; Fig. 1) carried out between 2016 and 2017 will enable to evaluate *in situ* 1) the catch proportion of skates (high presence), 2) the species concerned, 3) their biological state (diet, reproduction) and 4) the ecological function of the habitats confirmed by previous studies (Fabjanczyk *et al*. 2015, DGALN 2017).

Several ecological roles will be particularly studied: 1) food (with a high proportion of individuals with stomach content), 2) reproduction and nursery (females with eggs, and juveniles) and

Table I. – Number of days on-board and individuals sampled by species between February 2016 and October 2017

Year	Month	Number of days on-board/trawl tows	Number of individuals *R. clavata*	Number of individuals *R. montagui*	TOTAL Number of individuals
2016	February	5	6	7	13
	April	9	3	8	11
	July	10	8	7	15
	October	6	4	6	10
2017	February	7	8	7	15
	April	7	5	6	11
	July	11	5	8	13
	October	10	3	6	9
TOTAL		65	42	55	97

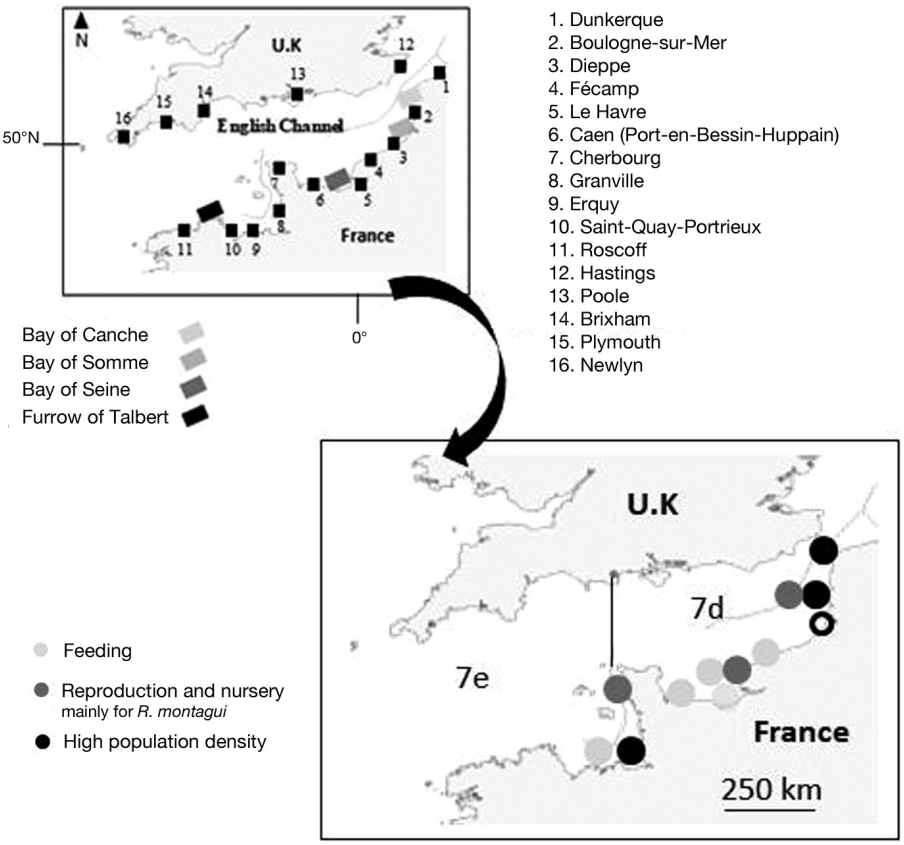

Fig. 1. – Area 7de. Map of the main fishing ports where the skates are landing in the English Channel, location of the home-port of the trawler from Le Hourdel (black circle) and marine area where the observations on-board were realized.

3) population density (high presence). The abundance indices were provided by the annual bottom trawl survey in the eastern English Channel and were standardized to numbers of individuals per km^2. The mean abundance by species is 68 individuals for *Raja brachyura*, 101 for *R. clavata*, 55 for *R. microocellata*, 72 for *R. montagui* and 49 for *R. undulata* (Vaz *et al*. 2007). In the English Channel (7e), the total abundance (numbers) of *R. clavata* and *R. brachyura* decreased in the last four years, following a period of highest catch rates in the time series 2013-2018 (from 1,200,000 in 2015 to 250,000 individuals in 2018 and from 800,000 in 2015 to 100,000 individuals in 2018; respectively) (Silva *et al*. 2018).

The diet of *Raja clavata* and *R. montagui* was studied classifying preys by taxonomical group rather than species, using identification guides. The cumulative prey species curve shows that the analysis of the stomachs must be carried out on approximately 40-50 individuals; beyond that, the number of new prey identified stabilizes (Robinson *et al*. 2007). The specimens, once on-board the trawler, were stored in the ship's cold-storage chamber (after having measured and weighed each individual). The stomachs were extracted after landing the skates in Le Hourdel port's fish market. The samples were immediately frozen. On the basis of the number of empty stomachs, the percentage of vacuity index was estimated. Prey were identified, counted and weighed. Dietary indices of occurrence, number and mass were calculated. Frequency of occurrence (%O) is the

percentage of non-empty stomachs containing a type of prey (Cortés 1997). Percent number (%N) and percent mass (%M) are the percentage of individuals and mass, respectively, of a given prey species (or taxon) versus the overall number of prey within non-empty stomachs. The prey mass is what was actually observed in the stomach, not that of reconstituted prey. The index of relative importance (IRI) is presented in this work and was calculated as follows:

IRI = (% N + % M) × % O (Pinkas *et al*. 1971, Cortés 1997).

RESULTS

On-board observations lasted 65 days spread over different seasons between February 2016 and October 2017. Results are presented hereafter. The size (TL, Total Length in cm)/mass (g) relationships of the sampled individuals shows a strong correlation, $R^2 = 0.904$ for *R. clavata* and $R^2 = 0.899$ for *R. montagui* (Fig. 2).

Raja clavata

The stomach contents of 42 individuals (with preys) over 75 cm in size were analyzed (only adults). The diet of *R. clavata* is strongly dominated by crustaceans (46 % IRI) and fish (36% IRI). Some polychaetes and mollusks are accessory preys (8 % IRI). The vacuity index was 14.23 %.

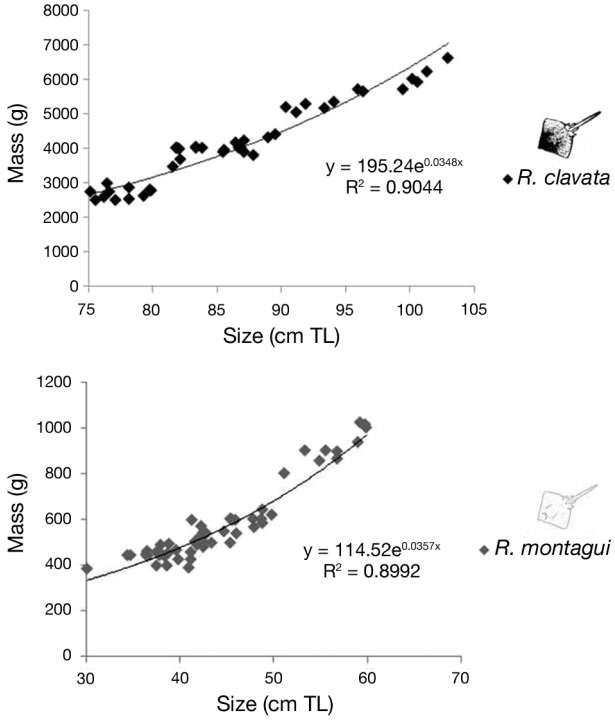

Fig. 2. – Size (Total Length, cm)/Mass (kg) relationship for the *R. clavata* (n = 42) and *R. montagui* (n = 55) sampled in the English Channel.

The on-board observations showed that females lay eggs in pairs on sand or mud between February and September, especially in June. The capsules are oblong with pointed horns. Hatching takes place after 4 to 5 months of incubation (time spent between the observation of the capsules in June and the presence of newborns in October). Moreover, the juveniles appear in August-December in coastal waters and develop quickly during the first years (8 to 14 cm per year) (difference in size observed between juvenile individuals observed in October 2016 and October 2017 in the same fishing areas). The results of this study confirmed that the thornback ray is a demersal species that lives on hard and sandy substrates of the continental shelf and the upper slope between 10 and 200 m deep. Juveniles prefer sandy and shallow areas, protected from strong tidal currents, such as bay and estuaries (Fig. 1).

Raja montagui

The stomach contents of 55 individuals (with preys) under 60 cm in size were analyzed.

The diet of *R. montagui* (mainly juveniles) is strongly dominated by crustaceans (64 % IRI) mainly decapods (crabs and shrimps), mysida (mysids) and amphipoda (amphipods). A few polychaetes and fish are others preys (32 % IRI). The vacuity index was 18.56 %.

The on-board observations showed that the spotted ray breeds between April and July in the English Channel (presence of eggs in female). They spawn oblong capsules about 5-6 cm long and 4-5 cm wide with stiff pointed horns at the corners, preferably deposited in sandy or muddy substrates (presence of capsules in the trawl).

The spotted rays are caught on sandy and hard substrates to a limited depth. The species lives up to 120 m deep but prefers waters between 40 and 80 m according to the bathymetry observed by the ship's sonar. This species observed on-board is present east of the Cherbourg peninsula between July and October (Fig. 1). In October, females are relatively abundant near Le Hourdel and to a lesser extent along the North coasts of Normandy. The males were observed further south.

The results of the observations on-board the trawler specify the functional role in the areas exploited of skates. The species *R. clavata* and *R. montagui* specimens caught in different areas of the English Channel have helped define their ecological function as feeding (Normand-Breton Gulf, Bay of the Seine, Littoral seino-marin, Bay of the Somme), reproduction (eggs laying and nursery) (East of Cherbourg, Littoral seino-marin, Bay of the Somme and Estuaries picards and Opal Sea located between Boulogne-sur-Mer and Dieppe) and high presence especially relevant in the Normand-Breton Gulf, Bay of the Somme and Detroit Pas-de-Calais (East of Dunkerque) (Table II; Fig. 1).

Table II. – IUCN status in Europe of Skates species captured by the French and English fleets in the North Sea and the Channel (Atlantic Ocean) – Ecological functions of different marine areas from the English Channel (feeding, reproduction and high population density). (– no data).

Common name	Scientific name	IUCN status	References	Areas and their ecological function
Blue Skate	*Dipturus batis*	Critically Endangered (CE)	Dulvy *et al*. 2015	–
Small-eyed ray	*Raja microocellata*	Near Threatened (NT)	Ellis *et al*. 2015a	–
Cuckoo ray	*Leucoraja naevus*	Least Concern (LT)	Ellis *et al*. 2015b	–
Undulate ray	*Raja undulata*	Near Threatened (NT)	Ellis *et al*. 2015c	–
White skate	*Rostroraja alba*	Critically Endangered (CE)	Ellis *et al*. 2015d	–
Spotted ray	*Raja montagui*	Least Concern (LT)	Ellis *et al*. 2015e	Feeding (Littoral Seino-marin) Reproduction (eggs laying and nursery) (Littoral seino-marin) High population density (Celtic Sea and Western Channel – Eastern English Channel – Estuaries picards and the Opal Sea – North Sea/Detroit Pas-de-Calais)
Longnosed skate	*Dipturus oxyrinchus*	Near Threatened (NT)	Ellis *et al*. 2015f	–
Thornback ray	*Raja clavata*	Near Threatened (NT)	Ellis *et al*. 2016	Feeding (Celtic Sea and Western Channel – Bay of the Seine - Estuaries picards and the Opal Sea – Normand-Breton Gulf West Cotentin – Littoral seino-marin) Reproduction (eggs laying and nursery) (Littoral seino-marin) High population density (Eastern English Channel – Estuaries picards and the Opal Sea – North Sea/Detroit Pas de Calais)
Starry ray	*Amblyraja radiata*	Least Concern (LT)	Kulka *et al*. 2015	–
Shagreen ray	*Leucoraja fullonica*	Vulnerable (VU)	McCully & Walls 2015	–
Sandy ray	*Leucoraja circularis*	Endangered (EN)	McCully *et al.* 2015a	–
Blonde ray	*Raja brachyura*	Near Threatened (NT)	McCully *et al.* 2015b	–
Common Stingray	*Dasyatis pastinaca*	Vulnerable (VU)	Serena *et al.* 2015	–

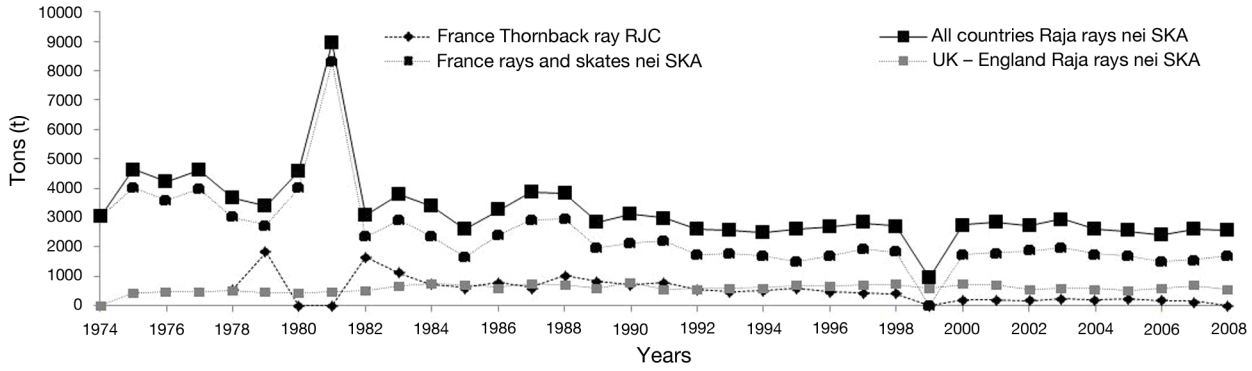

Fig. 3. – Reported landings in Tons of skates (1974-2008) from English Channel Area 7de (ICES 2011). A peak in 1981 is probably due to a statistical error and not corresponding to a strong one-time increase in landings. The level of landings known in 1999 and which contrasts with the general curve is explained by a change in the software for statistical treatment of landings.

DISCUSSION

The fisheries based on landings

French and English landings of *Raja* spp. from the Channel remained broadly stable from 1982 until 2008 (2500-2800 and 400-600 tons per year, respectively) (Fig. 3). They were higher between 1972 and 1984. The quantities landed reach more than 3400 tons in 2018 including all species (see Table III).

The identification of species in the landings really began in 2010 at the international level. During the last years, the reported international landings show that they are dominated by five species *Raja brachyura*, *R. clavata*, *R. montagui*, *L. naevus* and *R. undulata* (see Table II). The small-eyed ray (*Raja microocellata* Montagu, 1818) is not very present in the Channel Canal and is only exploited by the English and Belgian fleets, landing on average 18 tons since 2011, mainly in the eastern English Channel.

Landings considering all species increased during the

Table III. – Reported landing of skates in tons (Ton) in the English Channel (area 7de) per species. (ICES 2020).

Countries	Species	2011	2012	2013	2014	2015	2016	2017	2018	%7d	%7e
Belgium	*R. clavata*	55.7	67.7	92.3	79.7	78	94.5	96.7	98.3	87.8	12.2
	R. brachyura	19.5	28.7	34.5	27.3	35.3	43.6	46.6	71.3	83.8	16.2
	R. montagui	4.2	2.4	3.4	1.0	0.8	1.1	4.0	24.8	42.1	57.9
	L. naevus	1.3	0.9	1.8	1.6	2.0	1.4	1.3	3.7	100	0
	R. undulata	0	0	0	0	0	4.5	23.8	14.8	20.2	79.8
France	*R. clavata*	610.8	802.2	1086.3	1168.8	975.9	1051.1	960.3	1303.5	81.9	18.1
	R. brachyura	227.6	165.7	215.2	311.4	334.7	258.4	283.6	438.7	11.8	88.2
	R. montagui	338.8	309.9	364.2	272.1	265.2	339.5	380	390.7	7.1	92.9
	L. naevus	309.9	223.1	196.9	273.1	193.5	210.1	214.6	204.3	5.3	94.7
	R. undulata	20.1	5.3	2.1	9.9	49.1	57.5	78.8	84.2	20.6	79.4
United Kingdom	*R. clavata*	183.6	246.6	293.5	302.5	279.5	364.7	371.9	459.9	49.5	50.5
	R. brachyura	167.1	190.9	207.7	269.8	299.7	365.7	222.8	264.0	11.6	88.4
	R. montagui	45.1	52.1	64.3	49.5	54.2	67.7	63.7	75.9	9.2	90.8
	L. naevus	89.2	80.5	79.9	86.8	71.3	76.1	74.3	82.2	0.6	99.4
	R. undulata	0	0	0	0	3.4	22.2	35.1	40.8	7.1	92.9
Jersey	*R. brachyura*	23.3	58.9	76.3	83.1	65.2	73.0	34	9.8	0	100
Netherlands	*R. clavata*	9.0	11.0	3.0	5.3	3.2	6.0	7.9	18.8	96.9	3.1

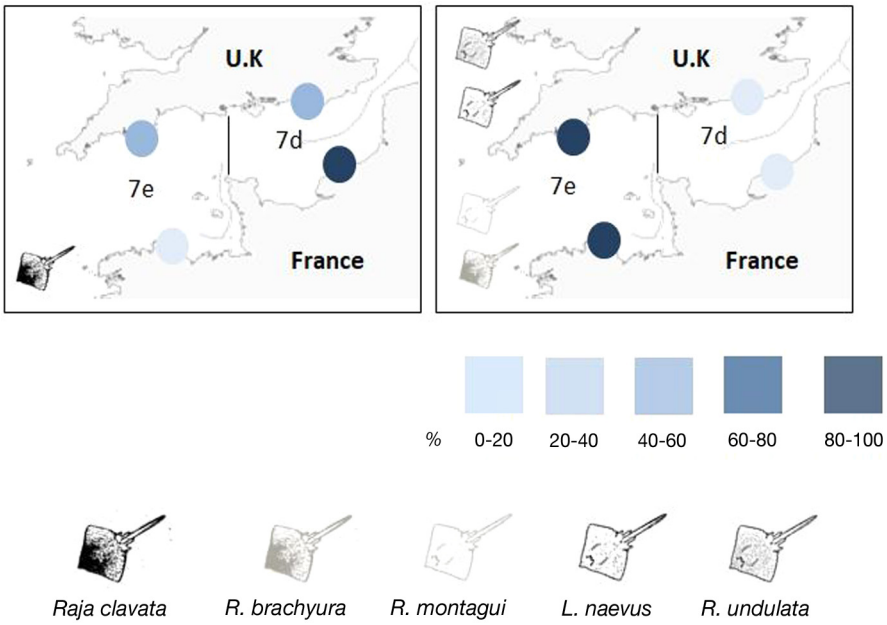

Fig. 4. – Geographic distribution of landings (%) during the period 2011-2018. Eastern (7d) and Western (7e) English Channel.

last 8 years in the English Channel. But a recent drop in landings may be caused by binding TAC. The species most landed by fishing activity is the thornback ray *Raja clavata* (2011-2018). France contributes 80 % to landings of thornback ray from the English Channel. The quantities of *R. brachyura* declared by Jersey are relatively large and the Dutch catches only concern *R. clavata* (see Table III).

Considering that the landings are made close to the fishing areas, *R. clavata* is mainly fished in the Eastern Channel by the French fishermen. English fishermen fish it as much in the east as in the west. The others species (*R. brachyura, R. montagui, L. naevus* and *R. undulata*) are mostly fished and landed in the western English Channel (Fig. 4).

The status of conservation

The status of species conservation is specified by the IUCN (International Union for the Conservation of the Nature). Of the 13 listed species, 1 species is classified as Endangered (EN), 2 species as Vulnerable (VU),

3 species as Least Concern (LC), 2 species as Critically Endangered (CR) and 5 species as Near Threatened (NT) (Table II). Four species of skates recognized as threatened or in decline must be subject to protective measures by the competent authorities in accordance with the OSPAR convention in North-eastern Atlantic (Region II Greater North Sea including English Channel): the common skate *Dipturus batis* (Linnaeus, 1758), the spotted skate *R. montagui,* the thornback ray *R. clavata* and the white skate *R. alba* (Commission OSPAR 2008). The fishery of the *Amblyraja radiata*, *Rostroraja alba* and *Dipturus* sp. is prohibited in the English Channel (zone CIEM 7) (Council Regulation 2018). The biological vulnerability is high for all species, rating 47 % for *L. naevus,* 57 % for *R. montagui,* 63 % for *R. undulata* 65 % for *R. brachyura* and 73 % for *R. clavata* (Cheung *et al*. 2005). The conservation status of exploited skate species is worrying (10 of the 13 skate species exploited have a critical conservation status).

The fishery management of skates

Despite their conservation status and the current OSPAR convention, the different species of skate are not enough regarded (one TAC for all skates and rays species) and subject to intensive fishing, which sharply increased in recent years (see Table III). The thornback ray *R. clavata* and the blonde ray *R. montagui* are near threatened (NT) in the north-eastern Atlantic but the measures of conservation are highly recommended for *R. clavata* by the OSPAR convention.

In France, a limit size for rays has been set at 45 cm (JORF 2017). However, there is no size limit according to the sexual maturity of each species or restriction during the laying period. It is stipulated that catches of cuckoo ray (*Leucoraja naevus*), thornback ray (*Raja clavata*), blonde ray (*Raja brachyura*), spotted ray (*Raja montagui*) and small-eyed ray (*Raja microocellata)* shall be reported separately, although in practice the identification of the specimens captured must be further improved as shown by French statistical data (IFREMER 2011, 2012, 2014-2017). The ICES data (based on fisheries nominal catch statistics reported annually by the national offices) contrast with those of the French fish markets because the landing data by species is not sufficiently precise. We can cite the case of Caen, Dieppe, Fécamp, Le Havre, and Dunkerque where only a few data are specified for *R. clavata*. The identification of species fished by gear and landed is necessary to manage fisheries. In France, in application of European regulation, 105 tons are allowed (234 in total for UE fleet) and a size limit of 78 cm is only applied for *Raja undulata* in Atlantic marine areas (ICES Divisions 7d and e, Manche and Celtic Sea) for 2020 (JORF 2020). The TAC (1474 tons) applied for the UE fleet, and the French quota allocation (1112 tons) for the 2020 in the Eastern English Channel, 7d) concerns all species except undulate ray (skates and rays) (Council Regulation 2020).

Three species of skates and rays are mainly exploited in the English Channel, the thornback ray, the blonde ray and the spotted ray (Table III). The status of stocks for rays is often unknown. However, two stocks are currently distinguished for the thornback ray (*R. clavata*) and the blonde ray (*R. brachyura*), a first one in the North Sea and in the East Channel (3a, 4 and 7d for *R. clavata* and 4c and 7d for *R. brachyura*) and a second one in the western Channel (7e). The stocks of thornback ray and of blonde ray are increasing very strongly in the east of the English Channel with a biomass index up recently by 87 % and 46 %, respectively. But no survey indices are available for these stocks in the western Channel. The areas of exploitation studied on-board the trawler affect indifferently the two stocks of the species in the English Channel (Fig. 1).

The stock of the spotted ray (*R. montagui*) that concerns the North Sea and the East Channel (3a, 4 and 7d) has been increasing since the end of the 2010s with a biomass index up recently by 14 %. But his status is unknown (ICES 2018). Taking into account the ecological data of species is necessary especially in the lack of the stock status.

The ecology of skates and measures in fishery

The relation size-weight of the different species sampled and the fishing landings analyzed in this study coincide with the biological data and the spatial distribution of species in the Channel presented respectively by Leblanc *et al*. (2014) and Fabjanczyk *et al*. (2015). The landings also show a marked seasonality, with more important activities in the west (area 7e) in autumn and winter, and in the east (zone 7d) in summer. The catches are less numerous in spring but evenly distributed over the canal (Guitton *et al*. 2003, Carpentier *et al*. 2009).

No differences were observed in the major prey consumed between the sexes or between size classes for the thornback ray (49-60, 61-70, 71-80, and 81-93 cm TL) (Morato *et al*. 2003). In agreement with other studies on skate diets in the same area (Carpentier *et al*. 2009), the Azores Archipelago (Morato *et al*. 2003) and the Mediterranean Sea (Follesa *et al*. 2010), it was found that juvenile individuals of both species feed on benthic preys (crustaceans and mollusks) and members of the Annelida phylum. The abundance of prey is very dependent on the quality of the sediments and benthic environment. Direct impacts of bottom trawling can result in the removal of organisms, damage to or killing of organisms including benthic invertebrates, modifications to the environment (modifying the sedimentary habitats), and many complex secondary impacts through ecosystem functioning *e.g.*, changes to sedimentary processes, increase or decrease of nutrient flows, loss of habitat heterogeneity, changes

to predator/prey relationships (Nielsen *et al*. 2014, Buhl-Mortensen & Buhl-Mortensen 2018).

The study of diet, spawning periods and habitats showed differences between species, which therefore allows the application of specific measurements. The number of trawls could be limited in a given area (especially in the western English Channel where the fishing pressure is the strongest). A better identification of species on-board, combined with a restriction of catches especially during breeding periods (between April and July, considering the size of the sexual maturity for each species), would significantly improve the sustainability of the fishery. The TAC established for the UE fleet need 1) to be based on information on landings and discards by species (and particularly for *R. clavata*), and not as at present landings only and 2) to be based on only one area (7de) and not separately. In addition, releasing catch alive (discard) in good conditions could facilitate the re-colonization process due to the high survivorship, which can reach 86 % (Enever *et al*. 2009).

The results obtained by this study and the observations on-board provide new data on the ecological states of the species mainly exploited in the English Channel (east and west areas). The functional roles of the exploited areas specified in the study results are essential but not enough studied. However, scientific projects (RAIOUEST, RAIMEST and RECOAM) specified relevant data about fishery and ecology of *R. undulata* in the Gulf Normand-Breton (Leblanc *et al*. 2014), distribution areas and knowledge of the skate stocks in the Eastern English Channel (Fabjanczyk *et al*. 2015), and biological data (size at maturity), movement and structure of the populations in the Gulf Normand-Breton (Stephan *et al*. 2015).

The bays and estuaries located in the English Channel and others protected marine areas are defined as a 'Special Area of Conservation' under the Habitats Directive in France (Natura 2000). As such, the competent authorities must preserve the different habitats in the area as well as their functional roles (European Commission 2012). The characterization of habitats (for each species) and their protection provided by the Natura 2000 network in the British and French zones located in the English Channel are necessary to protect the skates.

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