ENDANGERED SPECIES ACT

STATUS REVIEW REPORT

Undulate Ray, *Raja undulata*

Source: JJMerelo ©

Therese A. Conant

January 2015

National Marine Fisheries Service
National Oceanic and Atmospheric Administration

ACKNOWLEDGEMENTS

I thank Dwayne Meadows for the distribution map. Review by Heather Coll, Lisa Manning, Dwayne Meadows, Margaret Miller, Marta Nammack, Ron Salz, and Kerry Whittaker greatly improved the document. I also thank John Musick and Jim Ellis for serving as peer reviewers and providing helpful and expert insights.

This document should be cited as: Conant, T.A. 2015. Endangered Species Act Status Review Report: Undulate Ray, *Raja undulata*. 41 pages.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

INTRODUCTION

Background

On July 15, 2013, the National Marine Fisheries Service (NMFS) received a petition from WildEarth Guardians to list 81 marine species, including the undulate ray, *Raja undulata*, as endangered or threatened species under the Endangered Species Act (ESA) and to designate critical habitat.

Under the ESA, if a petition is found to present substantial scientific or commercial information that the petitioned action may be warranted, a status review shall be promptly commenced (16 U.S.C. §1533(b)(3)(A)). NMFS decided that the petition presented substantial scientific information that listing may be warranted and that a status review was necessary (79 FR 10104, February 24, 2014). This report is a compilation of the best available scientific and commercial information on this species, threats it is facing, and an assessment of extinction risk to the species.

Approach to the Status Review

For the purposes of this status review, I reviewed the best available information, both through submission during the public comment period. We received one comment from the petitioners reiterating their data and rationale for petitioning the undulate ray for listing under the ESA. I also conducted a literature search including *Google Scholar, Science Direct, Aquatic Sciences and Fisheries Abstracts*, and reports available through websites such as the International Council for the Exploration of the Sea (ICES) and the United Kingdom Centre for Environment, Fisheries, and Aquaculture Science (CEFAS). I conducted the literature search through December 31, 2014. I organized the information based largely on the demographic risk factors described in McElhany *et al.* (2000) (i.e., population size, growth rate and related parameters, spatial structure, diversity) to determine the species' status. I considered the ESA section 4(a)(1) (16 U.S.C. 1533(a)(1); 50 CFR 424.11(c)) threat factors: the present or threatened destruction, modification, or curtailment of habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; inadequacy of existing regulatory mechanisms; and any other natural or manmade factors affecting the species' existence.

In the extinction risk assessment, I used a qualitative 4-level ranking scale modified from reference levels commonly used in other ESA status reviews (e.g., rockfish in the Puget Sound, Washington: http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/rockfish.pdf) to characterize the level of extinction risk. I did not make recommendations as to whether the species should be listed as threatened or endangered. Rather, I drew conclusions about the overall risk of extinction faced by the species based on an evaluation of the species' demographic risks and present and future conditions of threats.

According to the ESA, the determination of whether a species is threatened or endangered should be made solely on the basis of the best scientific information available regarding its current status, after taking into account efforts being made to protect the species. NMFS will consider any conservation measures that have not yet been implemented or shown to be effective in a separate process (NMFS and U.S. Fish and Wildlife Services Policy on Evaluation of Conservation Efforts When Making Listing Decisions, 68 FR 15100; March 28, 2003) prior to proposing listing determination. During the extinction risk assessment, effects of conservation measures are taken into account to the extent they are reflected in the ESA section (4)(a)(1) factor—inadequacy of existing regulatory mechanisms.

STATUS REVIEW

Life History and Ecology

Taxonomy

Kingdom:	Animalia
Phylum:	Chordata
Class:	Chondrichthyes
Order:	Rajiformes
Family:	Rajidae
Genus:	*Raja*
Species	*undulata*
Common:	undulate ray

The undulate ray was described by Lacepède in 1802. It is a member of the Family Rajidae whose origin is from the Late Cretaceous period, about 100 to 66 million years ago. Species diversification within the Family Rajidae occurred 15 to 2 million years ago in the northeast Atlantic and Mediterranean where undulate rays exist today (Valsecchi *et al.* 2004). The undulate ray is part of the Rajini tribe, which is a taxonomic category above the genus and below the family level (Figure 1: *source* Chiquillo *et al.* 2014). The Rajini tribe is defined by two morphological characteristics: (1) disc free of denticles, and (2) crowns of alar thorns (sharp-pointed, recurved thorns located on the outer aspect of pectoral fins of mature males) with barbs (McEachran and Dunn 1998).

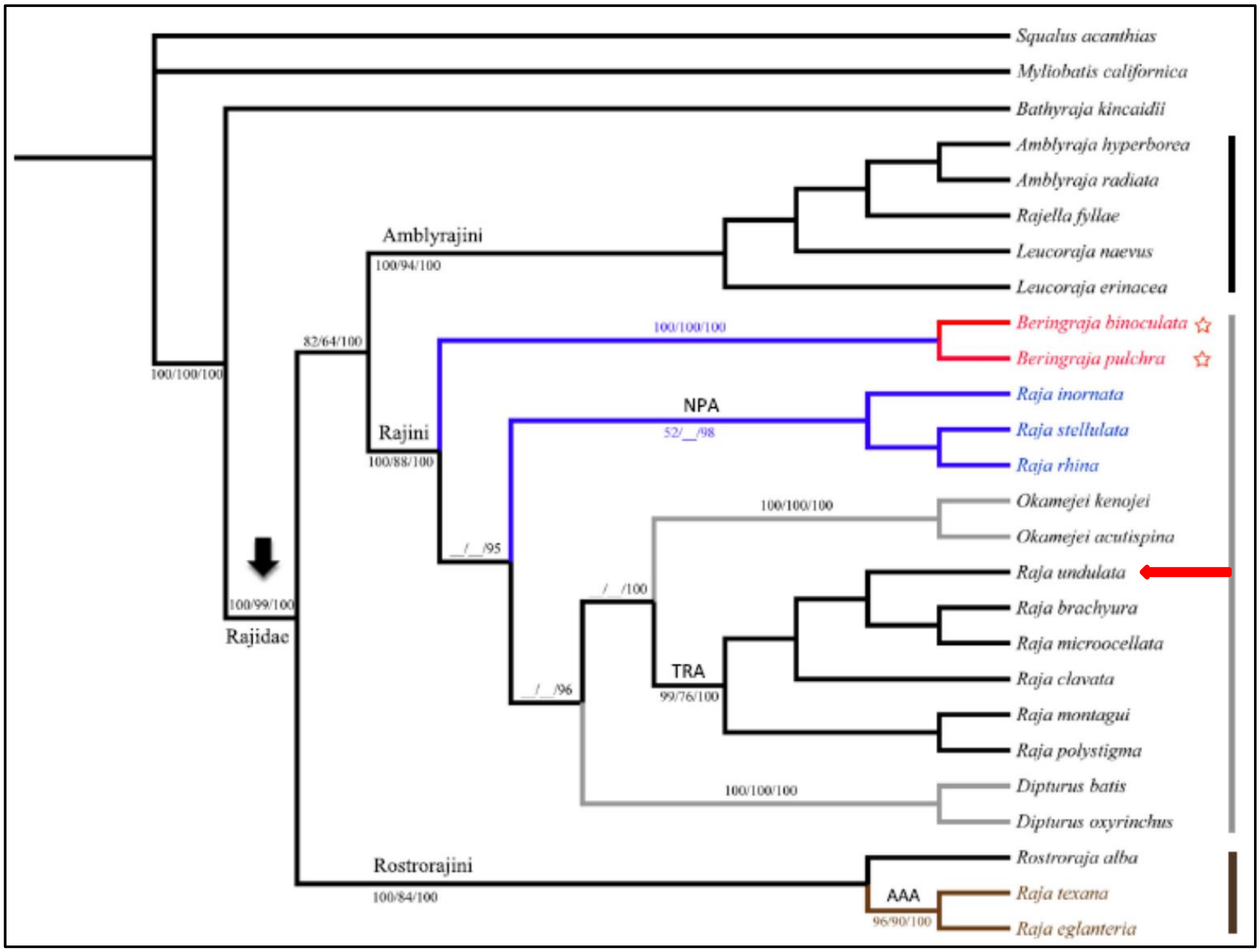

Figure 1. Phylogenetic hypothesis of skates in the family Rajidae based on mitochondrial DNA analysis. Black arrow indicates the family Rajidae. See Chiquillo *et al.* 2014 for description of color codes. (*Source*: Chiquillo *et al.* 2014). Red arrow highlights *Raja undulata* phylogenetic position.

Physical Appearance

The undulate ray gets its name from the leading edge of the disc, which undulates from the snout to the wingtips during movement. Its dorsal color ranges from almost black to light yellow-brown interspersed with dark wavy bands lined by a twin row of white spots, which may camouflage them against the seabed. The underbelly is white with dark margins (Figure 2). The dorsal fins are widely spaced, normally with two dorsal spines between them. The undulate ray is relatively large, reaching 114 cm in total length (TL) as an adult (Ellis *et al.* 2012).

Figure 2. Adult undulate ray (*source:* © Dave Proudfoot www.planetseafishing.com).

Range and Distribution

The undulate ray occurs on the continental shelf of the northeast Atlantic Ocean, ranging in the north from southwest Ireland and the English Channel, south to northwest Africa, west to the Canary Islands, and east into the Mediterranean Sea (Coelho and Erzini 2006; Ellis *et al.* 2012; Serena 2005). The undulate ray exhibits a patchy distribution throughout its range. According to ICES (2008), the patchy distribution of the undulate ray may have existed as far back as the 1800s. It is locally abundant at sites in the central English Channel, Ireland, France, Spain, and Portugal (Ellis *et al.* 2012). Within the Mediterranean Sea, occasional records occur off Israel and Turkey, but they are mainly recorded from the western region off southern France and the Tyrrhenian Sea (Ellis *et al.* 2012; Serena 2005). In 2001, one undulate ray was recorded in a total of 131 bottom trawl hauls (Massutí and Moranta 2003) and two specimens in 88 hauls (Massutí and Reñones 2005) on the continental shelf of the Balearic Islands off the Iberian Peninsula in the western Mediterranean. Specimens have been reported in the southern North Sea and Bristol Channel, but these areas are outside the normal distribution range (Ellis *et al.* 2012). See Figure 3 for overall range and Figure 4 for more detailed distribution, including specific geographic locations mentioned in the text.

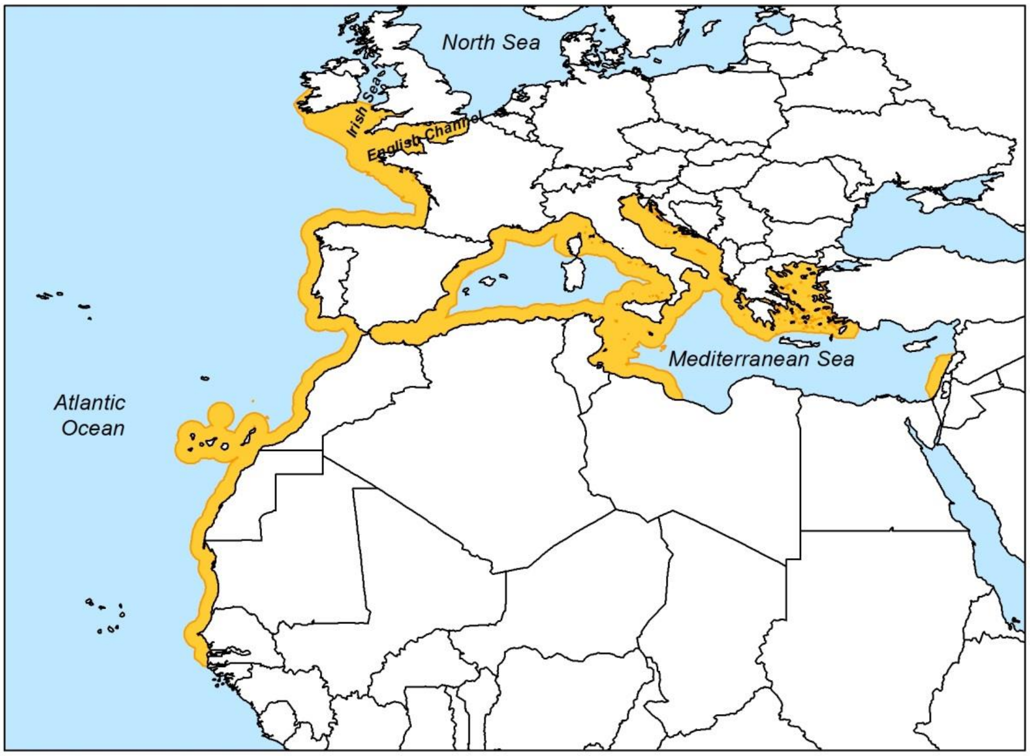

Figure 3. Undulate ray range. *Source*: modified from IUCN Redlist.

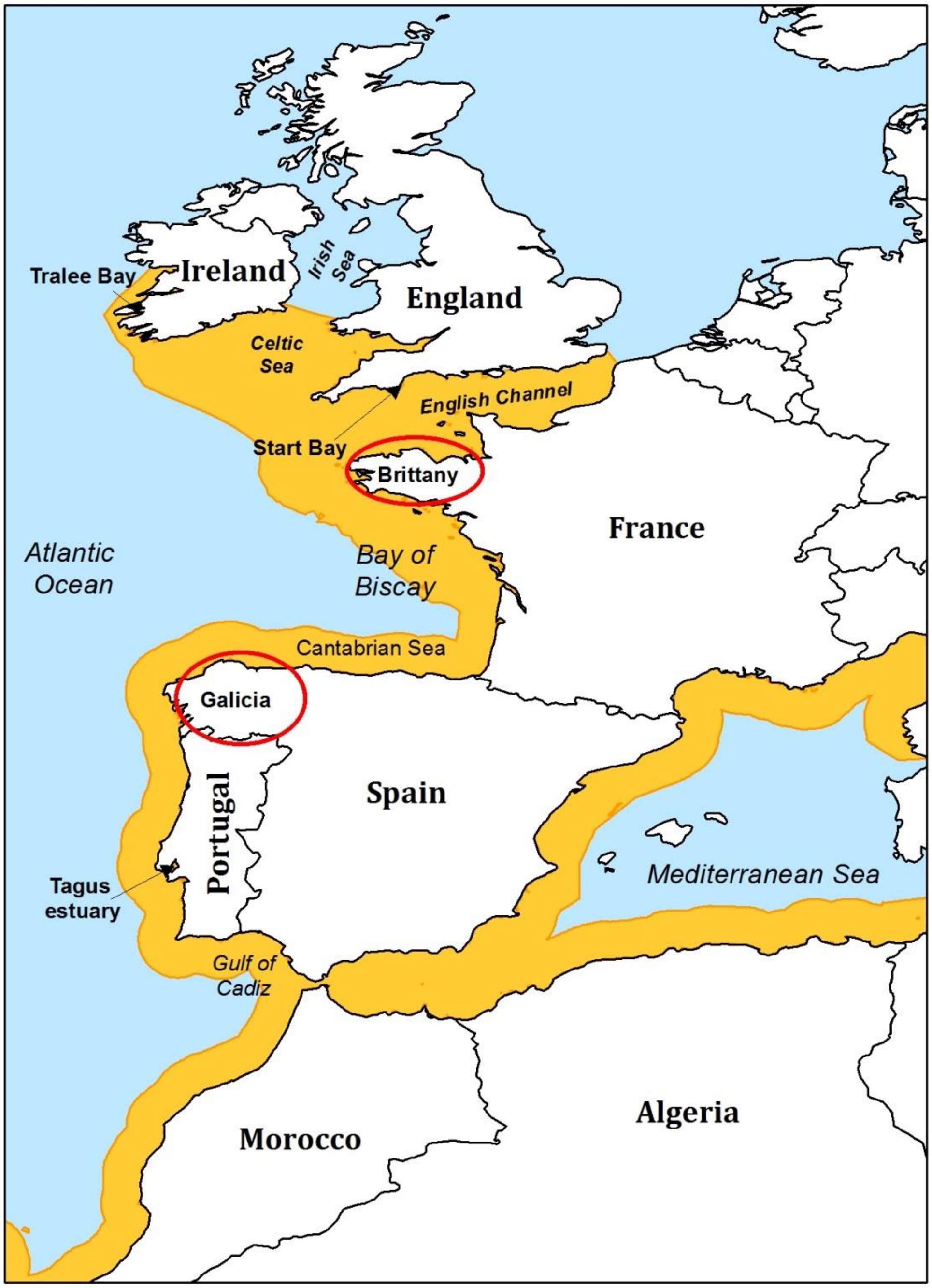

Figure 4. Undulate ray distribution Ireland through Morocco with locations described in the Range and Distribution and Abundance and Trends sections. Several locations are circled in red for ease of location.

Few data exist regarding undulate ray population structure. Small-scale tagging studies of skates, including the undulate ray, in the English Channel were undertaken off the Channel Islands in the Normano-Breton Gulf since 2006 (Ellis *et al*. 2011). More extensive studies were conducted in French waters from 2012 through 2014 to determine population structuring of the undulate ray in the English Channel, central Bay of Biscay, Iroise Sea (defined as part of the Atlantic Ocean off the coast of northwestern France bordering the Celtic Sea to the north and west and the Bay of Biscay to the south), South Brittany, and Morocco, North Africa (Delamare *et al.* 2013). Preliminary data from the Bay of Biscay and western English Channel indicate undulate rays do not migrate great distances. In the central Bay of Biscay, 1,700 undulate rays were tagged from April 2012 through May 2013. Of the rays tagged, 98 were recaptured within 450 days of tagging, mainly within 30 km of the tagging location; about two-thirds were recaptured within 10 km, indicating high site fidelity. The number of days between capture and recapture did not affect the distances between the two points, also supporting high site fidelity (Delamare *et al.* 2013). The central part of the Bay of Biscay may host a closed population exhibiting a small degree of emigration and immigration (Delamare *et al.* 2013). Mark and recapture studies in the western English Channel around the Island of Jersey also indicate high site fidelity (Ellis *et al*. 2011). Results from ongoing genetic studies of the undulate ray population structure in the western English Channel and Bay of Biscay have not yet been published (Stéphan *et al.* 2013). Discrete populations may also occur in the bays of southwest Ireland (ICES 2007, 2013). Tagging data indicate undulate rays move in and out of these bays of southwest Ireland, but dispersion and migration patterns are unknown and other survey methods should be considered to determine population structure (ICES 2007).

The ICES Working Group on Elasmobranch Fishes (2013) recommended the species be managed, under ICES, as five separate stocks: (1) English Channel; (2) southwest Ireland; (3) Bay of Biscay; (4) Cantabrian Sea; and (5) Galicia and Portugal. However, the recommendation was based only on the species' patchy distribution and not direct evidence of population structure. Data are lacking on population structure based on behavioral, morphological, and/or genetic characteristics.

Growth Rate, Reproduction, and Related Parameters

Growth rates, size and age at maturity, and seasonal patterns of reproduction in undulate rays were determined from individuals taken from trammel nets, beach seines, and fish markets in Portugal (Coelho and Erzini 2002, 2006; Moura *et al.* 2007). The undulate ray exhibits rapid growth in the first year, but overall has a slower growth rate (n = 187; Von Bertalanffy growth L_{inf} = 110.22 cm, K = 0.11 per year and t_0 = -1.58 year) compared to most species of *Raja* (Coelho and Erzini 2002). Females appear to become sexually mature later in life and at a larger body size than males (Coelho and Erzini 2006; Moura *et al.* 2007; Serra-Pereira *et al.* 2013). In the Algarve estuary along the south coast of Portugal, the mean age and body size at which half of the females became sexually mature was 8.98 years and 76.2 cm TL. Half of the males became sexually mature at 7.66 years and a body size of 73.6 cm TL (Coelho and Erzini 2006). This means that half of the females in the Algarve estuary became mature at 86.3% of their maximum size and 69.1% at their maximum age and half of the males became mature at 88.5% of maximum size and 63.8% at maximum age, which makes the undulate ray, at least for this study area, a late maturing species (Coelho and Erzini 2006). Moura *et al.* (2007) found slightly larger values for length at maturity for females (83.8 cm TL) and males (78.1 cm TL) in the Peniche region on the central coast of Portugal, which may indicate two different populations of the undulate ray exist on the Portuguese continental shelf (Moura *et al.* 2007). However, low sample sizes and different survey methods may account for the differences found between the study areas (Ellis, CEFAS, 2014 personal communication). Serra-Pereira *et al.* (2013) also found age-at-maturity to be slightly later for females (8.7 to 9 years) than males (7.6 to 8 years) in Portugal. Although minimum length at maturity for females was not reported in their preliminary report (Stéphan *et al.* 2013), minimum length at maturity for males captured in the English Channel and Bay of Biscay was 74 cm TL, with 50% of the sample (n = 191) reaching maturity at 80 cm TL. Preliminary estimates of length at first maturity for undulate rays caught mainly in the English Channel in groundfish surveys conducted between 1992 and 2010 were 80 cm TL for males and 79 cm TL for females. Half of the males reached sexual maturity at 83 cm TL; however, the sample size for females was too small to obtain this value (McCully *et al.* 2012).

Estimated generation length (the age at which half of total reproductive output is achieved by an individual) for this species varies from 14.9 to 15.9 years in females and from 14.3 to 15.3 years in males (Coelho *et al.* 2009). Undulate rays (n = 187) caught in commercial fisheries in Algarve, Portugal, were estimated to be up to 13 years old based on an analysis of vertebral band deposits (a pair of bands are deposited annually) (Coelho and Erzini 2002), but overall longevity has been estimated to be as high as 21-23 years (Coelho *et al.* 2002).

The undulate ray is a seasonal breeder; however, temporal differences in breeding season were found between nursery areas (Moura *et al.* 2007). Individuals from the Algarve region in south Portugal were found to breed only in the winter (Coelho and Erzini 2006), whereas those from Peniche in central Portugal were found to breed from February through May (Moura *et al.* 2007; Serra-Pereira *et al.* 2013) and in Portugal's north central coast breeding occurred from December through June (Serra-Pereira *et al.* 2013). Water temperatures in the Peniche region are colder than the Algarve and may explain the longer breeding season observed there (Moura *et al.* 2007).

The undulate ray is oviparous in that the fertilized egg, which is encased in an egg capsule, hatches outside of the parental body (Moura *et al.* 2008). Egg cases measure 70-90 mm long and 45-60 mm wide (Figure 5). Typical reproductive output is unknown; however; one female was observed to lay 88 egg cases over 52 days and the incubation period was 91 days (Shark Trust 2009). Although data on incubation length exists on one female, general data are lacking for the undulate ray. Rajidae generally exhibit protracted incubation times ranging from four to 15 months (Serra-Pereira *et al.* 2011).

Information on sex ratios in the population is sparse, but appears to indicate a slight female bias in some areas and significant male bias in other areas. In the eastern English Channel, individuals collected in bottom trawl surveys were slightly female-biased at 57% female and 43% male (Martin *et al.* 2010). Undulate rays caught in the Bay of Biscay, France, by fishermen, fishing guides, and scientists were generally 48 to 95 cm in total length and the sex ratio was 54% female and 46% male (Delamare *et al.* 2013). Other studies have found a preponderance of males. During three gillnet fisheries trips in May 2010 and two trips in February-March 2011 off the Isle of Wight in the English Channel, the ratio of females to males was 1:4.5 and 1:6.0, respectively, and all were mature adults (Ellis *et al.* 2012).

I was unable to find information on natural mortality/survival rates for the undulate ray.

Figure 5. Undulate ray egg case (*Source*: Wikimedia Commons).

Habitat and Ecosystem Conditions

Undulate ray habitat in the northeastern Atlantic Ocean includes sandy and coarse bottoms from the shoreline to no deeper than 200 m, but undulate rays are generally found in waters less than 50 m deep (Ellis *et al.* 2012; Saldnaha 1997 as cited in Coelho and Erzini 2006; Martin *et al*. 2010, 2012). Undulate rays, especially juveniles, inhabit inshore waters, including lagoons, bays, rias (defined as a coastal inlet formed by the partial submergence of a river valley that is not covered in glaciers and remains open to the sea), and outer parts of estuaries (Ellis *et al.* 2012). Site-specific data on undulate ray habitat are sparse, and I was unable to find information on habitat use and ecosystem conditions specific to the undulate ray for its range in northwest Africa, west to the Canary Islands, and east into the Mediterranean Sea. The following describes habitat information where known.

The English Channel provides important habitat for the undulate ray (Martin *et al.* 2010, 2012). The English Channel is a shallow sea area, which supports feeding, spawning, and nursery areas for numerous marine species. Mid-channel depths are 60–80 m and tidal strength and currents are strong in the area. These oceanographic features influence the substrate within the Channel with hard (gravel and pebbles) bottom where currents are strong and soft (sand and muddy-sand) bottom in areas more sheltered from strong tidal currents. The main predictors of elasmobranch habitat in the English Channel were depth, bed shear stress (an estimate of the pressure exerted across the seabed by tidal forcing), and stability, followed by seabed sediment type and temperature (Martin *et al.* 2010). The undulate ray was found more frequently in the western area of the English Channel, particularly in the area between the Cherbourg Peninsula and Isle of Wight, where the seabed is hard (pebble) and tidal currents strong. However, the species was also reported in patches of lower density in some shallower coastal waters in the eastern part of the English Channel (Martin *et al*. 2010, 2012). Although data are lacking on partitioning of habitat by size class in the undulate ray, in the eastern English Channel, younger age groups of the thornback ray (*R. clavata*) were found in shallow coastal waters, sheltered from tidal currents. Martin *et al.* (2010) state that younger, smaller fish are likely to be limited in their swimming and competitive abilities and vulnerable to predators in unsuitable habitats. Based on counts of egg cases recorded on beaches along the south coast of England, areas to the west and east of the Isle of Wight may be important nursery areas for the undulate ray (Dorset Wildlife Trust 2010). Shallow coastal waters may offer protection against predators and provide warmer water and ample food resources to encourage growth (Martin *et al.* 2010).

The Gironde estuary of France provides important sand and mud bottom habitat for the undulate ray (Lobry *et al.* 2003). Tides are strong within the estuary with an average flow volume between 800 and 1,000 m^3/s, and the tidal range can reach 5 m at the mouth (Dauvin 2008). The water traps river sediment and results in extreme turbidity, frequently exceeding 400 mg/L. Substrate is muddy, and the organic nutrients provide a rich biota for migratory fish (Dauvin 2008). The Gironde estuary is considered somewhat pristine as it lacks nearby densely populated cities and the surrounding area supports tourism and wine-growing. The estuary has relatively lower phosphate and nitrogen content compared to other estuaries in France, such as the Seine, Loire, and Rhône (Mauvais and Guillaud 1994 cited in Lobry *et al.* 2003). In France, undulate rays are also common outside of these estuaries (Ellis, CEFAS, 2014, personal communication).

The undulate ray is one of the most common species found in the coastal waters of the Tagus estuary in the central and west coast of Portugal (Prista *et al.* 2003). The Tagus estuary is rich in biodiversity and is a wetland site of importance under the Ramsar Convention. As such it has 14,000 hectares specifically created to protect aquatic birds. The estuary and surrounding upstream habitat to the mouth of the River Trancão and southernmost point of the Montijo peninsula were designated as the Tagus Estuary Special Protection Area under the European Community Directive 79/109/CEE. The estuary provides important habitat for the undulate ray as evidenced by their common presence in the estuary. About 60% of the estuary is exposed at low tide, revealing soft bottom habitat. However, specific data are lacking on the undulate ray's distribution and association with specific habitat within the estuary.

The undulate ray diet consists mainly of brachyuran crabs (Moura *et al.* 2008). In waters off Portugal, diet changed as the undulate ray matured. Smaller individuals had a generalized diet, consuming a variety of semi-pelagic and benthic prey, including shrimps and mysids. However, larger undulate rays began to specialize on the brachyuran crab, *Polybius henslowi*, with the largest undulate rays eating *P. henslowi* almost exclusively (Moura *et al.* 2008). The shift in diet from semi-pelagic and benthic species to primarily benthic crabs occurred at 55 cm TL, and the shift from more generalized to specialized diet occurred at 75 cm TL. The first shift may be due to juveniles migrating from nursery to foraging habitat, and the second shift may be related to the onset of maturity (Moura *et al.* 2008).

Abundance and Trends

Determining population size or trends is problematic due to the patchy distribution of the species, variable survey effort and different survey methods over time, inconsistent metrics for reporting abundance, limited (less than 20 years) data sets, and misidentification of species. Also, earlier surveys were originally designed to provide abundance indices for teleost and not for skates and rays, and so the type of gear used and/or the distribution of survey hauls may not be appropriate for some skate and ray species (Ellis *et al.* 2010). Prior to 2009, the undulate ray was often classified at a higher taxonomic level, i.e. miscellaneous rays and skates. (LeBlanc *et al.* 2013); thus, the species was an unknown percentage of a larger sample and were likely underrepresented in the landings data. In addition, historical abundance data are lacking. In the early 1800s, skates and rays had limited market value and were referred to as 'rabble fish' (see Ellis *et al.* 2010). There were no scientific surveys of them. By the early 1900s, skates became increasingly marketable, and the United Kingdom (UK) began to report skate landings, but not by species. Trends data based on fisheries-dependent landings have limited utility in understanding true population trends, as they represent trends in fisheries practices and regulations. Restrictions and catch limits have been implemented for the undulate ray at least since 2009; thus, any reported decline in recent species-specific landings may or may not reflect reduced fishing opportunities and not necessarily changes in abundance (see Ellis *et al.* 2010).

By the early 1900s, the UK reported general skate landings of 25,000–30,000 t per year with several high and low years during the First and Second World Wars (Ellis *et al.* 2010). Since 1958, general skate landings have declined and have been less than 5,000 t per year since 2005 (Ellis *et al.* 2010)—approximately an 80% decline from the early 1900s. Only one study (Rogers and Ellis 2000) compared the undulate ray historical data with more recent data for the most northern part of its distribution. Fish assemblages and abundance were compared from fisheries independent trawl surveys from 1901 to 1907 and 1989 to 1997 in the Irish Sea, Start Bay, and southern North Sea around the British Isles (Rogers and Ellis 2000). Some data were comparable because the survey methods were similar. There was a decline in abundance of large sharks, skates, and rays over that time period. However, undulate rays were not observed in the Irish Sea and Start Bay in either time period and increased slightly from 0/hour/area (1901 to 1907) to 0.4 /hour/area (1989 to 1997) in southern North Sea (Rogers and Ellis 2000). However, it is important to note that the data from this study were from fishing grounds outside of the undulate ray's main range and may have limited utility in understanding population abundance and trends elsewhere.

Although historical abundance data are limited, ICES (2007) provided a presence and absence category and scale of approximate current abundance based on fisheries dependent and independent surveys throughout the undulate ray's distribution in the Atlantic Ocean (Table 1).

Table 1. Undulate ray occurrence by ecoregion and approximate abundance (0 = Absent; 1 = Vagrants occasionally recorded; 2 = Historical known to have occurred, but no recent authenticated records; 3 = Uncommon occasionally take in surveys, but data probably only reliable to confirm presence; 4 = Regular often caught, though in low numbers and sporadically, maybe suitable for presence/absence analyses; 5 = Common caught routinely and in reasonable numbers, maybe worthwhile to examine trends in CPUE; 6 = Common (as 5) and also well known, in terms of life-history and/or stock identity (adopted from ICES 2007 and updated Ellis, CEFAS, 2014 personal communication).

Barents Sea	Norwegian Sea	North Sea	Irish Sea	Bristol Channel	English Channel	Celtic/West Ireland	West Scotland	Rockall	Faroe	Iceland	Greenland	Biscay	Portugal	Azores	Deep Water
0	0	1	1	1	4-5	4	0	0	0	0	0	3	4-5	0	0

In the English Channel (ICES survey area VIId.e), data on the undulate ray are collected from fisheries-independent groundfish bottom trawl surveys and beam trawl surveys. In the eastern English Channel, fisheries-independent bottom trawl surveys were conducted each October from

1988 through 2008 (Martin *et al.* 2010, 2012). Over 1,800 hauls were conducted and density was expressed as the numbers of individuals per km^2. Overall, 16 elasmobranch species were captured, including the undulate ray. The undulate ray was the eighth most abundant elasmobranch in terms of individuals caught and percent total biomass (Martin *et al.* 2010). Mean density fluctuated dramatically from 1988 through 2008, and no trend could be detected (Figure 6). The undulate ray was present in 3.8% of the fisheries-independent bottom trawl survey hauls (n = 550) from 1988 – 1996 and 3.8% of hauls (n = 1,146) from 1997 - 2008 conducted in the eastern English Channel, indicating stability in presence in the area (Martin *et al.* 2010).

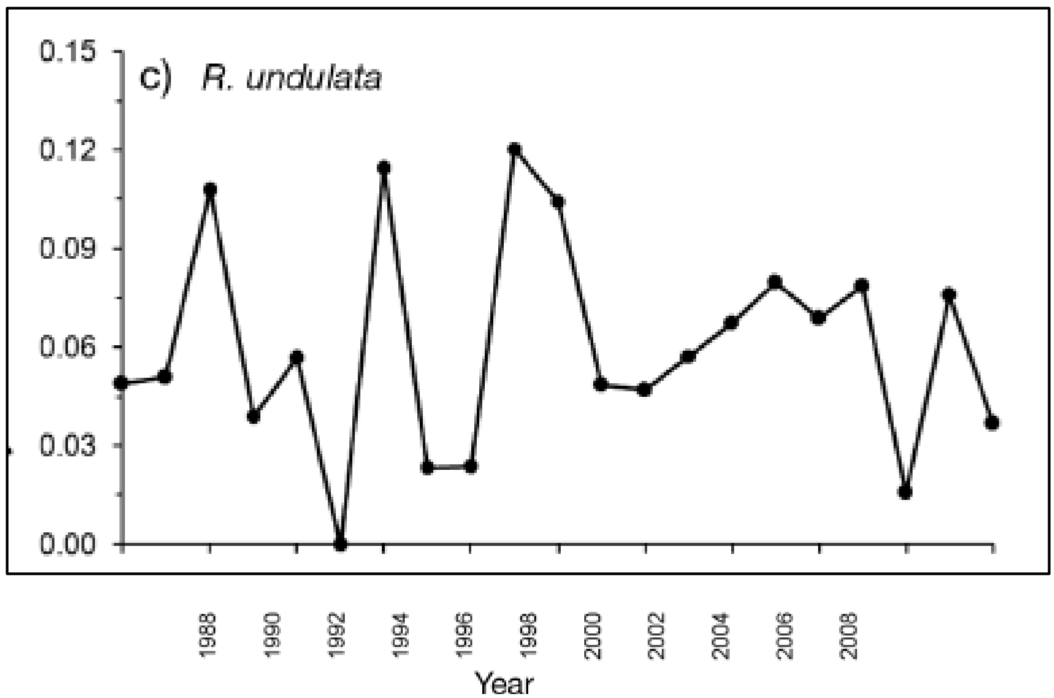

Figure 6. Eastern English Channel undulate ray trends in mean density (individuals/km^2) in fisheries-independent bottom trawl surveys, October each year from 1988 -2008 (*source:* Martin *et al.* 2010—Figure 3.c).

In the English Channel fisheries-independent beam trawl surveys have been conducted each year since 1989. Within the eastern English Channel survey, the undulate ray catch rates were generally low and variable and the species was absent from 2006 and 2007 surveys, partly due to the patchy distribution of this species. More recent data from 2011-2013 for this survey area show a mean annual catch of up to 0.25 individuals per hour survey effort (Figure 7) (ICES 2014a).

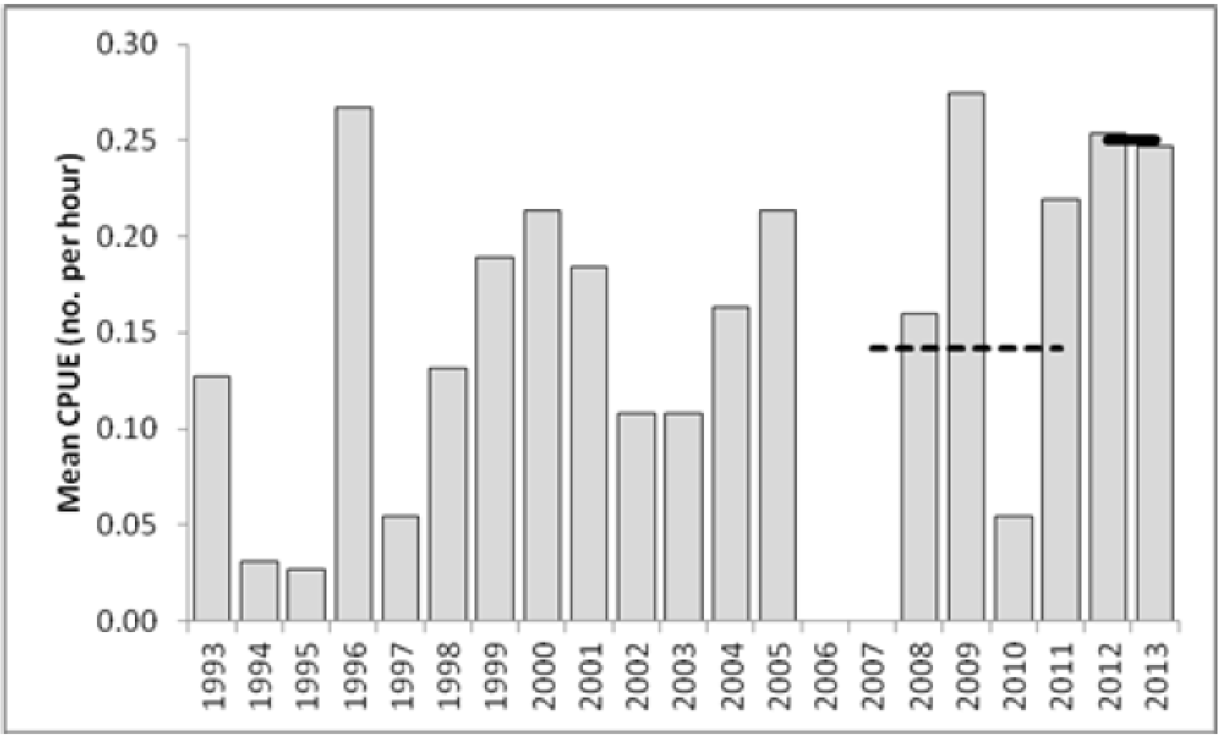

Figure 7. Eastern English Channel undulate ray trends in mean catch per unit hour effort in fisheries-independent beam trawl surveys. Note: dashed and solid line are not described (*source:* ICES 2014a).

In the western English Channel, undulate ray catch in the beam trawl surveys has been low and variable (Figure 8) (Burt *et al.* 2013), and appears to have decreased since 2004. Preliminary results from surveys conducted in 2012-2013 of fishermen operating in the western English Channel indicate that the undulate ray is a main species caught (approximately 75% of ray catch) in trawl, dredge, gillnet, and longline gear (LeBlanc *et al.* 2013). It is unknown why fishermen report the undulate ray being the most common species caught in 2012-2013, but low catch was found in fisheries-independent surveys in recent years in the western English Channel (Figure 8). Given the undulate ray's patchy distribution and the random stratified sampling methods used in the surveys, more intensive sampling is needed in order to determine the undulate ray's stock status (ICES 2013). The English Channel undulate ray stock status was considered uncertain and classified as a 'data-limited stock' with a precautionary margin of 20%[1] applied in any advice to manage the fishery (ICES 2012).

[1] The "precautionary margin" is a 20% buffer reduction to catch advice when reference points for stock size or exploitation (e.g., maximum sustainable yield) is unknown. See ICES (2012) for further details.

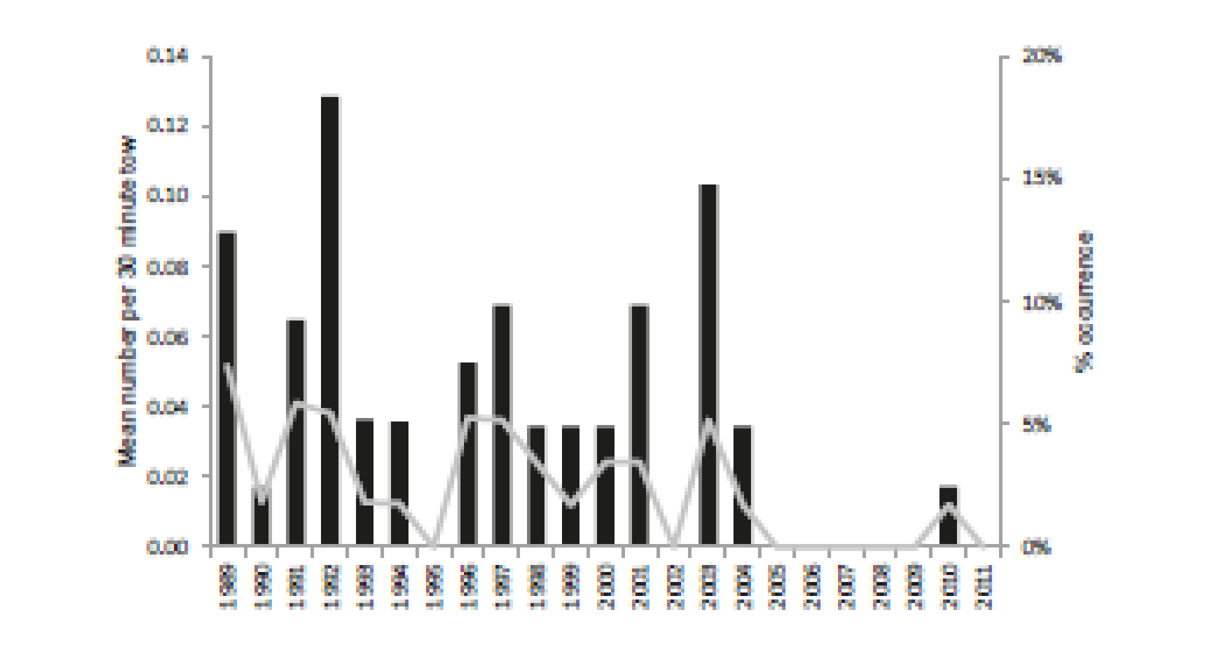

Figure 8. Western English Channel fisheries independent beam trawl surveys of the undulate ray—trends in the mean relative abundance (numbers per 30 minute tow, grey columns) and frequency of occurrence (solid line) from 1989-2011 (*source:* Burt *et al.* 2013).

In the southern region of the North Sea, the undulate ray may be a rare vagrant, but it is absent further north (Ellis *et al.* 2005). From 1990-1995, surveys conducted in coastal waters of the eastern North Sea, English Channel, Bristol Channel and Irish Sea also indicated the undulate ray was the least common (number of individuals per 8-m beam trawl per hour) of 7 species of ray collected in the surveys (Rogers *et al.* 1998a). Overall abundance in the British Isles was low (<8 individuals per hour per ICES survey area) (Ellis *et al.* 2005). The undulate ray was reported in trawl surveys conducted from 1973 to 1997 along the south coasts of England (0.003 individuals per 1000 m^2), but is absent from other parts of the survey grid (Rogers and Millner 1996; Rogers *et al.* 1998b). Juveniles were infrequent catches in the surveys (Rogers *et al.* 1998b). Cooler water temperatures may explain the absence of the undulate ray in sampling stations along the more northern coast of England (Rogers and Millner 1996).

In Tralee Bay, southwestern Ireland, data from anglers suggest declines have occurred. Beginning in 1981, two charter vessels began to report all their catch each year from Tralee Bay (ICES 2007); however, the number of trips per season has not been reported. The data (Figure 9) show that the undulate ray catch was at a high of 80-100 fish per year in the first two years of reporting, then declined to 20-30 fish per year by the mid-1990s and then began to increase to about 40-60 fish per year at the turn of the century and now appears to be declining again, although catches fluctuate each year (ICES 2007). Due to the shallow depth of this bay, existing surveys are unable to quantify the abundance or local distribution of this species (ICES, 2007).

Tag and release data collected in the recreational fishery throughout southwestern Ireland, including Tralee Bay, from 1972-2014 indicate a decline since the 1970s, but potential changes in fishing effort were not provided (Figure 10) (ICES 2014b). Also, total number of undulate rays caught and percentage tagged and released in the Sportfish Tagging Programme were not provided.

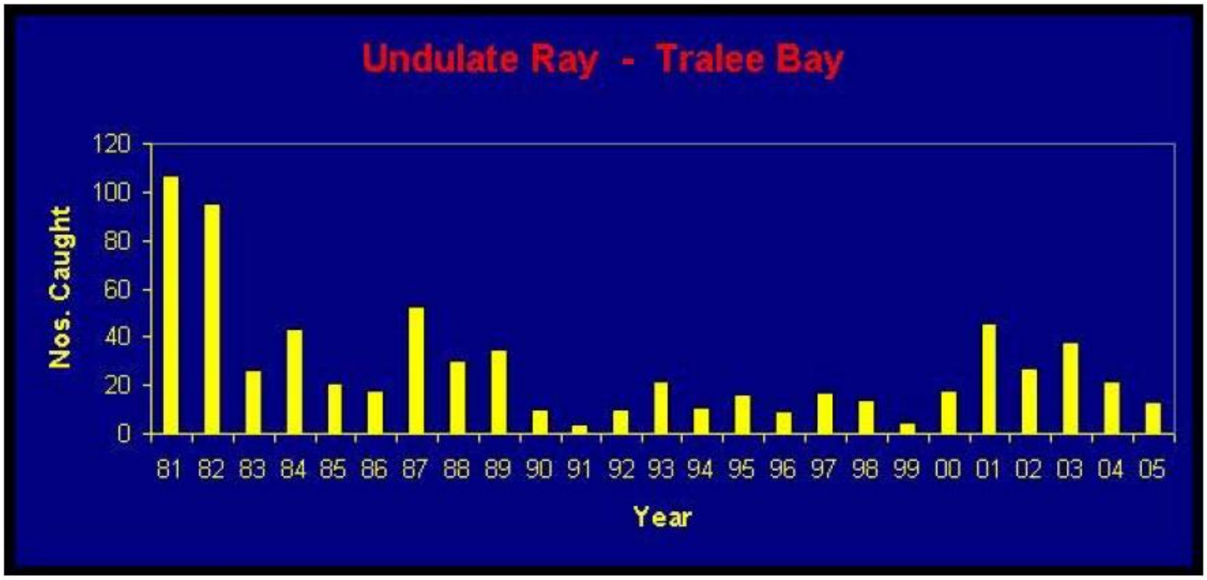

Figure 9. Number of individual undulate rays caught each year 1981-2005 in recreational fisheries in Tralee Bay, Ireland (*source:* ICES 2007).

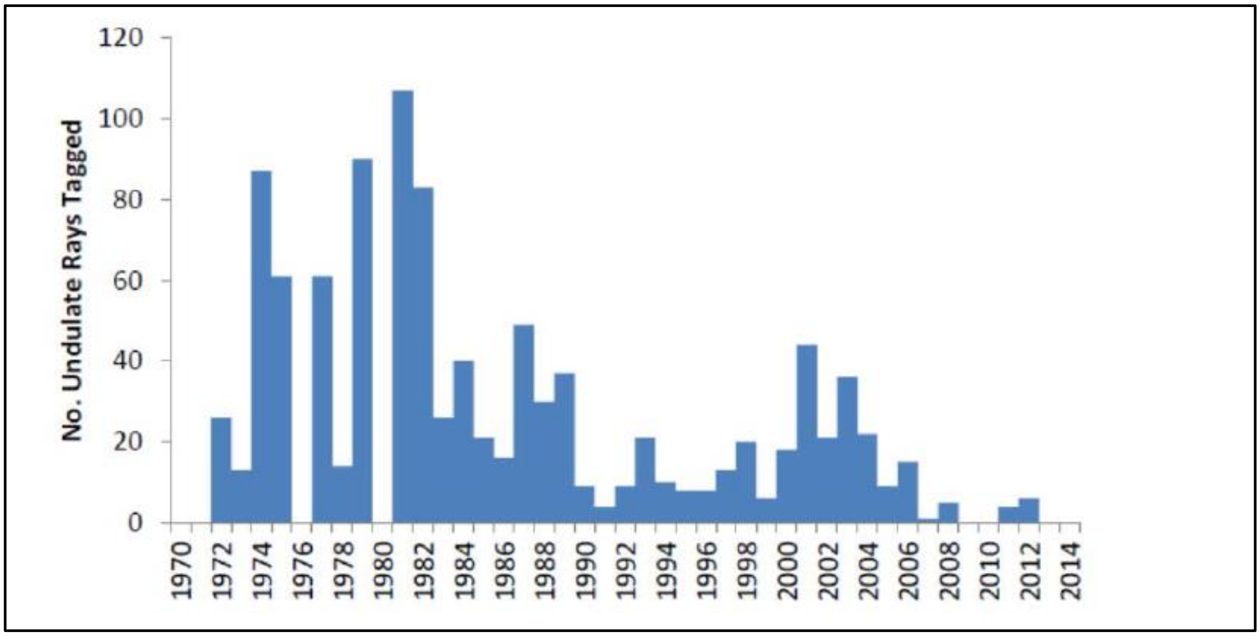

Figure 10. Number of Undulate Rays tagged in southwestern Ireland (ICES survey Division VIIj) under the Irish Marine Sportfish Tagging Programme 1972-2014**.** *Source:* ICES 2014b.

Landings data for the undulate ray are reported from some areas such as the Celtic Sea of France. French landings data on the undulate ray for the Celtic Sea were 12 t in 1995, 6 t in 1996, 10 t in 1997, after which landings fell to 2 t in 1998, 1 t in 1999, to 0 t in 2000-2001 (ICES 2007). However, not all French fisheries reported skate landings to species, and landings data was likely affected by changes in the regulations in 2010.

The undulate ray is one of the most common species found in the coastal waters of the Tagus estuary in the central and west coast of Portugal (Prista *et al.* 2003). The Tagus estuary was surveyed between 1979 and 1981 and from 1995 through 1997 to determine fish abundance and diversity (Cabral *et al.* 2001). The undulate ray was a common species, usually in the top 3 to 5 most common species found in the surveys over time. Mean density was similar or even slightly increased over the sampling period (less than 0.01/1,000 m^2 in 1979 and 1995; 0.01/1,000 m^2 in 1996; 0.03/1,000 m^2 in 1997) (Cabral *et al.* 2001). These data are decades old and may or may not reflect the current status of the undulate ray in the region. In coastal waters off Spain, based on bycatch data from artisanal fisheries, there is no evidence of a decreasing trend in undulate ray abundance (Bañon et al., 2008 as cited in ICES 2010).

I was unable to find data on abundance and trends in the western Mediterranean Sea and northwest coast of Africa.

Analysis of the ESA Section 4(a)(1) Factors

Pursuant to the ESA and its implementing regulations, NMFS determines whether species are threatened or endangered based on any one or a combination of the following five section 4(a)(1) factors: the present or threatened destruction, modification, or curtailment of habitat or range; overutilization for commercial, recreational, scientific, or educational purposes; disease or predation; inadequacy of existing regulatory mechanisms; and any other natural or manmade factors affecting the species' existence. The following provides information on threats from each of the five factors as they relate to the undulate ray.

Present or Threatened Destruction, Modification, or Curtailment of Habitat or Range

The Tagus estuary in Portugal has been subjected to industrial development and urbanization (Cabral *et al.* 2001). Lisbon, which is on the Tagus River and estuary, has experienced dramatic increases in human population growth since the early 1900s. In 2000, the human population living along the coast of the estuary was estimated at 2 million, which has resulted in high pollution loads in the estuary and poor water quality (Cabral *et al.* 2001; Costa and Bruxelas 1989). The Tagus estuary is one of the largest and most contaminated by anthropogenic mercury in Europe. A recent study [http://proflux.weebly.com/the-project.html] found 21 tons of mercury within the first five centimeters of the surface sediments. This mercury pool may be released to the water column and may accumulate in aquatic organisms, causing contamination within the food chain. Accumulation of metals has been documented in other species, such as the European eel (*Anguilla anguilla*), that were collected from the Tagus estuary (Neto *et al.* 2011). However, data are lacking on specific contaminant loads and effects on the undulate ray. In fact, abundance data in the Tagus estuary reported by Cabral *et al.* (2001) indicate that the undulate ray density slightly increased between 1979 and 1997.

As stated earlier, the Gironde estuary is considered somewhat pristine as the surrounding area supports tourism and wine-growing. This estuary has relatively fewer phosphates and nitrogen content compared to other estuaries in France, such as the Seine, Loire, and Rhône (Mauvais and Guillaud 1994 cited in Lobry *et al.* 2003). However, human impacts have been documented for the estuary including contamination, nitrogen loads, and hypoxic conditions from upland activities (Dauvin 2008).

The English Channel, and its local biodiversity, are also subject to numerous anthropogenic impacts, including shipping, aggregate extraction, aquaculture, and eutrophication (Dauvin 2008; Martin *et al.* 2010, 2012). Maritime traffic in the English Channel is intense with up to 600 vessels passing through the Dover Straits each day. Transportation of oil is a major component of the shipping industry in the English Channel.

Major oil spills have occurred in European seas, including the coast of Brittany, France, Cornwall coast of England, and along the Galician coast of Spain (see Dauvin 2008). In 2002, a spill of over 50,000 tons of heavy oil occurred 250 miles from Spain's coast (Serrano *et al.*

2006). The spill occurred during November, and the winter conditions dispersed and sank the oil as tar aggregates along the continental shelf. These tar aggregates were still detected on the continental shelf one month after the spill, and oil was found in zooplankton species. Serrano *et al.* (2006) sampled the area affected by the oil and compared it to pre-spill data to determine if changes in biomass and benthic diversity had occurred due to the oil spill. The undulate ray was one indicator species in the study; however, the data were aggregated across taxa. Although density of several taxa declined significantly in 2003, their density increased to pre-oil spill numbers in 2004—two years after the oil spill (Serrano *et al.* 2006). Also, the dissimilarity in species abundance between 2002 and 2003 was not due to changes in rays. The study found no effect on biomass and benthic diversity due to the tar aggregation. Rather, environmental variables such as depth, season, latitude, and sediment characteristics influenced benthic community structure (Serrano *et al.* 2006).

In conclusion, the geographic areas in which the undulate ray occurs are being impacted by human activities. However, data are lacking on impacts to habitat features related to the undulate ray and/or threats that result in curtailment of the undulate ray's range. Predictions of how these threats may impact the undulate ray in the foreseeable future would be largely speculative.

Overutilization for Commercial, Recreational, Scientific, or Educational Purposes

The undulate ray is mainly bycaught in demersal fisheries using trawls, trammel nets, gillnets, and longlines, but has been recorded as landings in other fisheries operating within its range (Coehlo *et al.* 2009). As discussed earlier, landings data are generally reported as a generic 'skates and rays' category and are not specific to species. Where landings are identified to the undulate ray, recent restrictions on fisheries need to be considered in any interpretation on trends (Ellis *et al.* 2010). Prior to the 2009 European Council Regulations (EC No 43/2009) and the 2010 European Union (EU No 23/2010) ban on retention of the undulate ray, the species was a relatively common commercial fish caught in the northeast Atlantic and Mediterranean bays and estuaries (Costa *et al.* 2002).

French landings data on the undulate ray for the Celtic Seas were 12 t in 1995, 6 t in 1996, 10 t in 1997, after which landings fell to 2 t in 1998, 1 t in 1999, to 0 t in 2000-2006 (ICES 2007), which may indicate overexploitation in this area. However, not all French fisheries reported skate landings to species. It is unknown what percent of French fisheries reported skate landings to species. French landings data of *Rajidae* from 1996 to 2006 were variable with no detectable trend and ranged from 934 t in 2003 to 2,058 t in 1997 (ICES 2007). In the two years preceding the ban on retaining undulate rays in 2009, 60-100 t per year were landed in the Bay of Biscay off the coast of France (Hennache 2012 cited in Delamare *et al.* 2013).

In Portugal, prior to the 2009 ban on retention, over 90% of the undulate rays caught in Portuguese trammel nets were retained for commercial purposes or for personal consumption

(Baeta *et al.* 2010; Batista *et al.* 2009; Coelho *et al.* 2002, 2005). The undulate ray was the most prominent species by weight (8.51kg per 10 km of net), comprising almost 35% of the elasmobranch biomass caught in the Portuguese artisanal fisheries using trammel nets between October 2004 and August 2005 (Baeta *et al.* 2010; Batista *et al.* 2009). Catch per unit effort was highest in shallow waters (0-25m) and slightly increased in cooler months. The undulate ray had the highest commercial value compared to other harvested species in the Tagus Estuary, Portugal (Costa *et al.* 2002). Overall, *Raja* spp. landings in Portugal artisanal fisheries have decreased 29.1% between 1988 and 2004 (Coelho *et al.* 2009). Specific landings data were not reported for the undulate ray, so trends in landings data for this area are unknown. Regardless of known trends in landings data, the undulate ray's large size, which indicates a low intrinsic rate of population increase and high trophic level, may render it more vulnerable to depletion from exploitation than smaller skate species (Dulvy *et al.* 2014).

In the Gulf of Cadiz off Spain, the undulate ray was the 5th most common species discarded (Gonçalves *et al.* 2007). The undulate ray is also bycaught in the Spanish demersal trawl fleet operating in the Cantabrian Sea located in the southern Bay of Biscay (ICES 2007). However, trawling is banned in waters shallower than 100 m, so much of the bycatch in the area occurs in small artisanal gillnet fisheries operating in bays or shallow waters (ICES 2010). The undulate ray is an important species for artisanal fisheries operating in the coastal waters of Galicia, and there is no evidence of a decreasing trend in its abundance in the area (Bañon et al., 2008 as cited in ICES 2010).

Landings data are not available for the northwestern coast of Africa, but the undulate ray's preference for shallow waters may render it vulnerable to intensive artisanal coastal fisheries operating in the area (Coelho *et al.* 2009). In 2001, one undulate ray was recorded in a total of 131 bottom trawl hauls (Massutí and Moranta 2003) and two specimens in 88 hauls (Massutí and Reñones 2005) on the continental shelf of the Balearic Islands off the Iberian Peninsula in the western Mediterranean.

As discussed earlier, recreational landings have declined in Tralee Bay and southwestern Ireland, which may indicate overexploitation in this area, although fishing effort data are not available. The International Game Fish Association (IGFA), which has 15,000 members in over 100 countries, lists the undulate ray as a trophy fish (Shiffman *et al*. 2014). Trophy fishing may result in catching large and fecund fish. For the undulate ray, trophy fishing is a catch and release program and fish may die after being released (Shiffman *et al*. 2014), but data are lacking on post-release mortality of undulate rays. Records on numbers of undulate ray actually caught in the IGFA program are also lacking.

Inclusion of the undulate ray on the EC prohibited species list has increased discarding of this species, especially in areas where it is locally common (ICES 2013). Mortality may be high in skates and rays discarded from fishing gear operating offshore where soak times are relatively long (see Ellis *et al.* 2010); however, skates primarily caught in otter trawls, gillnets, and beam trawls by inshore vessels operating in areas occupied by undulate rays have shown high survival rates (Ellis, CEFAS, personal communication 2014). Data are lacking on mortality in the undulate ray as a result of discarding.

Scientific research on undulate rays could have an impact on the species. Mark recapture studies have begun in the Bay of Biscay, France, in order to understand population abundance. Petersen disk tags were tested for the level of mortality that may result from their use under controlled conditions in holding tanks. Two of 34 tagged rays died, most likely due to the applied tags (Delamare *et al.* 2013). The authors stated that although the mortality is low, it is not negligible and needs to be accounted for in designing and carrying out future studies involving tags. Studies using Petersen disk tags were conducted in 2013 in the western English Channel and Bay of Biscay. During 6 sampling trips in the Atlantic, 2,002 skates were caught, 90% (1,805) of which were the undulate ray. Of these, 1,700 were tagged and released. In the English Channel, during 4 sampling trips, 418 skates were caught, 68% (283) of which were undulate rays, 224 of which were tagged and released (Stéphan *et al.* 2013). These studies will provide useful information on mortality under normal conditions that may result from the use of the Petersen tags as well as provide additional data on the undulate ray biology and movement in the region. Fisheries independent surveys are conducted to collect, in part, data on the undulate ray. These surveys generally result in low mortality of all species of rays caught (Ellis *et al.* 2012). One undulate ray, caught on the first survey day, was tagged and released and subsequently found approximately 0.5 miles from its release position on the fourth day of the survey. Its condition was good (Ellis *et al.* 2012).

In conclusion, overexploitation may occur in some areas (based on recreational catch data in Tralee Bay and southwestern Ireland), but exploitation levels are unknown over the main parts of the range, and the undulate ray is a prohibited species in most areas of the EU. Recent research cruises (Stephán *et al.* 2013) suggest the undulate ray is still common in the English Channel and Bay of Biscay. Some mortality may also occur as a result of tags used in scientific research activities, although the level of research activities using these tags and the impact from the use of these tags are unknown. Regardless, the number of rays tagged is relatively minor and unlikely to represent a large portion of the overall population. Mortality is generally low in fisheries independent surveys. Predictions of how these threats may impact the undulate ray in the foreseeable future would be largely speculative.

Disease or Predation

Parasite loads in undulate rays captured in the Ría of Muros Bay in Spain consisted mainly of cestodes and nematodes, which can adapt to the high urea concentrations in the ray's tissue and body fluids (Sanmartín *et al.* 2000). These parasites occur naturally in the undulate ray and are not considered a result of a contaminated environment (Sanmartín *et al.* 2000), and I did not find any information to suggest that these parasites negatively impact the undulate ray. No other data were found on disease or predation of the undulate ray.

In conclusion, I do not consider disease or predation as posing a threat to the undulate ray. Predictions of whether these threats may impact the undulate ray in the foreseeable future would be largely speculative.

Inadequacy of Existing Regulatory Mechanisms

In 2009, the European Commission through Council Regulation (EC. No 43/2009) and, in 2010, the European Union (EU No 23/2010), designated the undulate ray as a prohibited species that could not be fished, retained, transshipped or landed. Member countries of the EU include France, Spain, Portugal, UK, and Ireland--all countries where the undulate ray occurs. Although ICES did not recommend the undulate ray be a prohibited species, the justification for the ban was based largely on ICES advice (2008), which indicated that the state of conservation of the undulate ray in the Celtic Sea was 'uncertain but with cause for concern' and recommended no targeted fishing for this species (ICES 2014b). ICES classified the undulate ray as a 'data-limited stock' and applied a precautionary margin to its advice of approximately 20% (ICES 2012). For the Bay of Biscay and Iberian waters, no specific advice was provided; however, the general advice for elasmobranchs was: "... a cautious approach to management should be considered, which could imply reducing landings compared to recent averages," and "... since elasmobranch species are caught as a bycatch in demersal fisheries, they would benefit from a reduction in the overall demersal fishing effort" (ICES 2010).

These regulations have been controversial for some countries. Citing poor data, France, Spain, and Portugal have questioned the rationale behind the regulations, but are still bounded by the regulations (ICES 2013, 2014). In 2010, the EC asked ICES to comment on the listing of the undulate ray as a 'prohibited species' under the EC regulations. ICES (2010) stated that the undulate ray would be better managed under local management measures and advised:

> "*There is no basis in the current or previous ICES advice for the listing of undulate ray as a prohibited species. Therefore it should not appear on the prohibited species list in either the Celtic Seas or the Biscay/Iberia ecoregion fisheries legislation… In view of the poor knowledge and patchy distribution of these populations, ICES recommends a precautionary approach to the exploitation of these populations of undulate ray*".

In 2014, the undulate ray was removed from the prohibited species list (but remained as a species that should be returned to the water unharmed to the maximum practicable and cannot be landed) in ICES Sub-Area VII, which includes Ireland and the English Channel (ICES 2014b). Studies are underway to determine biology, stock structure, abundance, and distribution of the undulate ray in the areas of dispute (e.g., Delamare *et al.* 2013; LeBlanc *et al.* 2013; Stéphan *et al.* 2013). Based on updated information, the ban on retention may be revisited.

Other regulations that apply generally to skates and rays are local English and Welsh minimum landing sizes operating in some inshore areas (Ellis *et al.* 2010). In 1999, a total allowable catch

(TAC) set at 6,060 t was established for skates and rays in the North Sea (ICES Division IIa and sub-area IV). The TAC was reduced further by 20% (to 4,848 t) for the period 2001–2002, and has been reduced between 8 – 25% in subsequent years. In 2010, the TAC was at a record low of 1,397 t (Ellis *et al.* 2010). Other measures include bycatch quotas for skates and rays, whereby skates and rays may not exceed 25% live weight of the catch retained on board for larger vessels. In 1998, mesh size restrictions were implemented for fisheries targeting skates and rays (Ellis *et al.* 2010). Other technical measures have been implemented that may benefit skate and ray populations, including height of static nets, delimitation of fishing grounds and depths, and duration of soak time (e.g., European Council Regulation CE No. 3071/95, 894/97, 850/98) (Gonçalves *et al.* 2007).

Portuguese legislation limits trammel net soak times to 24 hours, unless nets are set deeper than 300m for which the soak time can be 72 hours (Baeta *et al.* 2010). In 2011, Portugal adopted a law (Portaria No. 315/2011) that prohibits landing of any skate species belonging to the Rajidae family during May within the nation's exclusive economic zone. In addition, a maximum of 5% bycatch, in weight, of those species is allowed per fishing trip (ICES 2013).

In England and Wales, the undulate ray is designated as a species of principal importance in conserving biodiversity under Section 41 and 42, respectively, of the Natural Environment and Rural Communities Act of 2006. Thus, England and Wales must take into consideration the undulate ray in conserving biodiversity when performing government functions such as providing funds for development.

I found no information on regulatory mechanisms related to the undulate ray for the non-EU Mediterranean Sea and northwest Africa.

In conclusion, several regulatory mechanisms appear to use a precautionary principle in managing fisheries harvest and bycatch of the undulate ray. Information indicates the ban on retention of the undulate ray is being re-examined, but a precautionary approach to fisheries management is advised for the undulate ray and is likely to continue into the foreseeable future. Other fisheries measures for skates and rays in general will reduce the impact to the undulate ray and are likely to continue into the foreseeable future. However, information on regulatory mechanisms is lacking for the non-EU Mediterranean Sea and northwest Africa, which represents a large part of the undulate ray's overall range, although there does not appear to be any studies indicating that undulate ray is or has been locally abundant in the Mediterranean Sea.

Other Natural or Manmade Factors Affecting Its Continued Existence

Climate change has impacted the areas within the range of the undulate ray. In the western English Channel, sea surface temperatures increased over nearly a century by 1 °C from 1905 to 2003, and within the Gironde estuary sea surface temperatures increased by 2 °C between 1978 and 2003, with an accompanying decrease in water flow input (see Dauvin 2008). Changes in zooplankton communities have resulted from the increased temperatures (see Dauvin 2008); however, specific impacts to undulate ray habitat or diet are unknown. In the North Sea, average sea surface temperatures are anticipated to increase 0.77 -1.27 °C by 2050 (Jones *et al.* 2013). This warming, along with several other environmental variables (e.g., salinity, sea ice concentration), was used to predict a shift toward the North Pole of 17 species, including the undulate ray. All species combined showed a 26 – 28 km decade^{-1} northward shift through 2050. However, the undulate ray's predicted distribution shift ranged from 32 km southward to 247 km northward and suitable habitat for the undulate ray within selected Special Areas for Conservation was anticipated to not change by 2050 (Jones *et al.* 2013).

I was unable to locate any additional information on natural or manmade factors related directly to effects on the continued existence of the undulate ray.

In conclusion, data are lacking on specific threats to the undulate ray from other natural and manmade factors. Predictions of how these threats may impact the undulate ray in the foreseeable future would be largely speculative.

ASSESSMENT OF EXTINCTION RISK

According to section 4 of the ESA, the Secretary (of Commerce or the Interior) determines whether a species is threatened or endangered as a result of any (or a combination) of the following five section 4(a)(1) factors: (A) destruction or modification of habitat, (B) overutilization, (C) disease or predation, (D) inadequacy of existing regulatory mechanisms, or (E) other natural or man-made factors. Collectively, the Services simply refer to these factors as "threats" (albeit conservation efforts as an outcome of regulatory mechanisms are inherent when considering factor D). In addition to reviewing the best available data on threats to the undulate ray, I considered demographic risks to the species similar to approaches described by Wainwright and Kope (1999) and McElhany et al. (2000). The approach of considering demographic risk factors to help frame the consideration of extinction risk has been used in many status reviews including Pacific salmonids, Pacific hake, walleye pollock, Pacific cod, Puget Sound rockfishes, Pacific herring, scalloped hammerhead sharks and black abalone (see http://www.nmfs.noaa.gov/pr/species/ for links to these reviews). In this approach, the collective condition of individual populations is considered at the species level according to the four demographic risk factors: abundance, productivity/population growth, spatial structure/connectivity, and diversity/resilience. These demographic risk factors reflect concepts that are well-founded in conservation biology and that individually and collectively provide strong indicators of extinction risk. I then describe the likely extent of extinction risk faced by the undulate ray based on its current status and how it will likely respond to projected threats. Projected threats are considered those that I can reasonably predict. I do not have a definitive time horizon as predictability of threats may vary depending on the threat and sufficiency of data. Because the information is often non-quantitative and sometimes sparse, I use a qualitative

4-level ranking scale modified from reference levels commonly used in status reviews (e.g., rockfish in the Puget Sound, Washington: http://www.nmfs.noaa.gov/pr/pdfs/statusreviews/rockfish.pdf) in the synthesis and finding to rank demographics, the 4a1 threats, and overall extinction risk.

The likelihood that each particular demographic risk factor and threat is contributing to the extinction of the undulate ray is summarized at the end of this section according to a qualitative scale:

(1) Very low – meaning it is very unlikely that the particular demographic factor or threat contributes or will contribute to the extinction of the species;
(2) Low - meaning it is unlikely that the particular demographic factor or threat contributes or will contribute to the extinction of the species;
(3) Moderate - meaning it is likely the particular demographic factor or threat contributes or will contribute to the extinction of the species;
(4) High - meaning it is highly likely that the particular demographic factor or threat contributes or will contribute to the extinction of the species; and
(5) Unknown – data are lacking on assigning a likelihood of risk.

Qualitative Risk Analysis of Demographics

In considering the demographic risks to the species (Table 2), I assigned a likelihood that the demographic characteristic is presently contributing to extinction based on the scale described above from my assessment of the best available information. Future effects of the demographic risks are considered in the overall extinction risk section.

The undulate ray is a large-bodied skate and exhibits life-history characteristics that make it more vulnerable to exploitation than smaller skate species. It has a delayed age to sexual maturity. Females appear to become sexually mature later in life and at a larger body size than males. The undulate ray has a long generation length from 14.9 to 15.9 years in females and from 14.3 to 15.3 in males. Life span has been estimated to be as high as 21-23 years. Typical reproductive output is unknown; however; one female was observed to lay 88 egg cases over 52 days and the incubation period was 91 days, indicating protracted parental investment. Survivorship in life stages is unknown. The demographic characteristics of the undulate ray are intrinsic and similar to other elasmobranchs, which generally render them vulnerable to extinction (Dulvy *et al.* 2014; Musick, 2014, Virginia Institute of Marine Sciences, personal communication). For these reasons, I conclude that the undulate ray's demographic characteristics related to growth rate and productivity have a moderate to high likelihood of contributing to the extinction of the undulate ray. However, my conclusion is tempered by the apparent lack of response to threats (see Qualitative Risk Assessment of Threats below), which may or may not indicate some intrinsic demographic characteristic that allows for resiliency against extinction risk, despite these characteristics.

Historical abundance data are lacking, and only one study compared the undulate ray historical data with more recent data, and only for the most northern part of its distribution. Fish assemblages and abundance were compared from fisheries independent trawl surveys from 1901 to 1907 and 1989 to 1997 in the Irish Sea, Start Bay, and southern North Sea around the British Isles. Although there was a decline in abundance of large sharks, skates, and rays over that time period, the undulate ray increased slightly (0 per hour/area from 1901 to 1907 and 0.4 per hour/area from 1989 to 1997) in southern North Sea and was absent from the other areas over those time periods. Prior to the ban on retention, fisheries landings data indicate that it was a common species caught in the Celtic Seas off west Ireland, Portugal, and the English Channel, but was uncommon elsewhere. In the eastern English Channel, fisheries-independent surveys from 1988 through 2008, indicate the undulate ray was the eighth most abundant elasmobranch species caught and mean density fluctuated dramatically from 1988 through 2008, but no trend could be detected. Undulate ray percent presence (3.8%) remained unchanged from 1988 through 2008, indicating some population stability in the eastern English Channel. In Tralee Bay and southwestern Ireland, data collected from recreational fisheries suggest declines have occurred. Fisheries dependent data from France showed a decline in undulate ray catch over the period of 1995 through 2001. In the Tagus estuary, Portugal, the undulate ray mean density was stable or slightly increasing from 1979 through 1997. In coastal waters off Spain there is no evidence of a decreasing trend in the abundance of the undulate ray in the area. Thus, in some areas population abundance may be declining (and nearshore waters of Ireland are at the north-western limit of its biogeographical range), but in other areas the population appears to be stable or increasing. For these reasons, I conclude population abundance trends reflect a low likelihood of extinction risk to the undulate ray.

The distribution of the undulate ray is patchy, and few data exist on the undulate ray population structure. Preliminary data indicate undulate rays do not migrate great distances and exhibit high site fidelity. Similar to other large skates, these life-history characteristics may increase the undulate ray's vulnerability to exploitation, reduce their rate of recovery, and increase their risk of extinction (ICES 2007; Rogers *et al.* 1999). However, based on the preliminary data on site fidelity and migration, these demographic factors may have contributed to the apparent declines in the undulate ray populations in Tralee Bay. However, those declines apparently are not widespread. Thus, I conclude spatial structure and connectivity characteristics have a low likelihood of contributing to the extinction risk of the undulate ray.

Based largely on insufficient information on genetic diversity, I conclude this characteristic presents an unknown likelihood of contributing to the extinction of the undulate ray.

Table 2. Summary of demographic risks for the undulate ray and relative strength of the evidence indicating these factors are posing an extinction risk for the species. Characterizations of the relative likelihood (very low, low, moderate, high) that a particular factor is contributing to the extinction of the species are explained further in the text above. Where data are absent, it is indicated by (unknown).

Demographic Risk	Likelihood
Growth rate/ productivity	Moderate to high
Abundance (disparate regional trends)	low
Spatial structure and connectivity	low
Diversity (unknown)	unknown

Qualitative Risk Analysis of Threats

In considering the threats to the species (Table 3), I assigned a likelihood of contributing to the extinction to the species throughout its range based on the scale described above from my assessment of the best available information. General threats to chondrichthyans include overexploitation from targeted fisheries, bycatch, habitat loss, and climate change. However, specific studies on the extinction risk due to threats to undulate rays are lacking.

Regarding habitat destruction, modification, or curtailment of habitat or range, several estuaries inhabited by the undulate ray have been degraded. The Tagus estuary in Portugal has been subjected to industrial development and urbanization. The Tagus estuary is one of the largest and most contaminated by anthropogenic mercury in Europe. In 2000, the human population living along the coast of the Tagus estuary was estimated at 2 million, which has contributed to pollution loads in the estuary and poor water quality. However, data are lacking on specific contaminant loads and effects on the undulate ray. In fact, abundance data in the Tagus estuary indicate that the undulate ray density slightly increased between 1979 and 1997. The Gironde estuary is considered somewhat pristine as the surrounding area supports tourism and wine-growing. The estuary has relatively fewer phosphates and nitrogen content compared to other estuaries in France. However, human impacts have been documented for the estuary including contamination, nitrogen loads, and hypoxic conditions from upland activities. In the English Channel, impacts to habitat include shipping, aggregate extraction, aquaculture and fisheries gear, and eutrophication. Major oil spills have occurred throughout the area, including the coast of Brittany, France, Cornwall coast of England, and along the Galician coast of Spain. However, one study on the impact to undulate rays indicates their abundance may rebound over time from major oil spills. Although anthropogenic impacts to several estuaries and coastal areas inhabited by the undulate ray occur and are reasonable likely to continue, the few data on abundance in degraded habitat indicate the undulate ray may be resilient to these impacts. For these reasons, I conclude habitat destruction, modification, and curtailment of habitat or range has a low likelihood of contributing now or in the foreseeable future to the extinction of the undulate ray.

With respect to overutilization, the undulate ray is mainly bycaught in demersal fisheries using trawls, trammel nets, gillnets, longlines, but has been recorded as landed in other fisheries operating within its range. As discussed earlier, recreational landings data for the undulate ray have declined in Tralee Bay and southwestern Ireland, which may indicate overexploitation in this area. The numbers of undulate ray actually caught as a result of recreational fishing is unknown, but probably low. French landings data on the undulate ray for the Celtic Seas may indicate overexploitation in this area but data are incomplete. In Portugal, prior to the 2009 ban on retention, the undulate ray was the most prominent species caught, and over 90% of the fish were retained for commercial purposes. Overall, *Raja* spp. landings in Portugal have decreased 29.1% between 1988 and 2004. Effort data were unavailable and specific landings data were not reported for the undulate ray, so trends in landings data for the species in this area are unknown. The undulate ray is also bycaught in the Spanish demersal trawl fleet. However, there is no evidence of a decreasing trend in abundance of the undulate ray in the coastal waters of northwest Spain. Abundance data are not available for the northwestern coast of Africa, but the undulate ray's preference for shallow waters may render it vulnerable to intensive artisanal coastal fisheries operating in the area. In the Mediterranean Sea, there are only a few records of undulate rays caught in fisheries. Further, mortality is generally high in skates and rays discarded from fishing gear in deeper water where soak times are longer; however, data are limited on mortality in the undulate ray as a result of discarding. Tangle net fisheries targeting large crustaceans in the coastal waters of southwest Ireland may have a bycatch of undulate ray, and the longer soak times in such fisheries likely reduces survival of any undulate ray caught incidentally.

Although tagging methods used in scientific research may impact the undulate ray, mortality is thought to be low, and the overall level of research activities is unknown and likely low.

Overexploitation has occurred in some areas, but does not appear to be widespread. Fisheries independent data indicate the undulate ray populations are either uncommon in some regions over time or stable or possibly increasing in some areas. Mortality may also occur as a result of tags used in scientific research activities, but the level of research activities using these tags is unknown. For these reasons, I conclude that overutilization has a low likelihood that it contributes or will contribute to the extinction risk of the undulate ray.

With respect to disease or predation, there is no evidence of any threat acting on the undulate ray. For this reason, I conclude that there is a very low likelihood that disease or predation contributes or will contribute in the foreseeable future to the extinction of the undulate ray.

With respect to inadequacy of existing regulatory mechanisms, the undulate ray is banned for retention in France, Spain, Portugal, UK, and Ireland--all countries where the undulate ray occurs. The ban on retention has come into question by several member countries, and several studies are underway to better understand biology, stock structure, abundance, and distribution of the undulate ray in the areas of dispute. Based on updated information, the ban on retention may be revisited. However, ICES precautionary advice to fisheries management for the undulate ray remains in place and other fisheries regulations that apply generally to skates and rays (e.g., TACs, seasonal bans on retention) will benefit the undulate ray and are likely to continue in the foreseeable future. In England and Wales, the undulate ray is designated as a species of principal importance in conserving biodiversity under Section 41 and 42, respectively, of the Natural Environment and Rural Communities Act of 2006. Thus, England and Wales must take into consideration the undulate ray in conserving biodiversity when performing government functions.

Other regulations apply generally to skates and rays, which include English and Welsh minimum landing sizes in some areas, bycatch quotas (whereby skates and rays may not exceed 25% live weight of the catch retained on board), seasonal prohibitions on landing any skate species, and mesh size restrictions for fisheries targeting skates and rays. Other technical measures have been implemented that may benefit skate and ray populations, including height of static nets, delimitation of fishing grounds and depths, and duration of soak time.

The existing regulatory mechanisms within northern Europe appear to use a precautionary principle in managing fisheries harvest and bycatch of the undulate ray and recognize the species in conserving biodiversity. Data are lacking on regulatory mechanisms relevant to the undulate ray in the Mediterranean Sea and northwest Africa. Based on insufficient data on the eastern and southern portion of the undulate ray's range and the existing precautionary regulations within a large portion of its range, I conclude that there is a low likelihood that the existing regulatory mechanisms contribute or will contribute in the foreseeable future to the extinction of the undulate ray.

With respect to other natural or manmade factors, increasing water temperatures associated with climate change may affect reproduction in the northern limit of its range. In the western English Channel, sea surface temperatures increased by 1 °C from 1905 to 2003, and within the Gironde estuary sea surface temperatures increased by 2 °C between 1978 and 2003, with an accompanying decrease in water flow input. Changes in zooplankton communities have resulted from the increased temperatures; however, specific impacts to the undulate ray are unknown. I was unable to locate any additional information on natural or manmade factors related directly to effects on the continued existence of the undulate ray. The species is a mid-latitude species and most likely will expand its range north with warming sea temperatures (Musick, 2014, Virginia Institute of Marine Sciences, personal communication). I conclude that there is a low likelihood that natural or manmade factors contribute or will contribute in the foreseeable future to the extinction of the undulate ray.

Table 3. Summary of possible threats to the undulate ray, and the likelihood (very low, low, moderate, high) that each particular threat contributes or will contribute in the foreseeable future to the extinction of the species. Threats are organized by their appropriate ESA section 4(a)(1) factor.

ESA 4(a)(1) Factor	Threat	Likelihood
Present or threatened destruction, modification, or curtailment of its habitat or range	Pollutants, Oil spills	low
Overutilization for commercial, recreational, scientific, or educational purposes	Harvest, Bycatch, research	low
Disease or predation	None	very low
Inadequacy of existing regulatory mechanisms	Harvest, Bycatch	low
Other natural or manmade factors affecting its continued existence	Climate change	low

Overall Extinction Risk—Synthesis and Finding

In determining the overall extinction risk of the undulate ray, I first analyzed the demographic risks to the species. Following this analysis, I assessed the threats to the species to determine if these threats contribute to the extinction of the species.

In terms of growth rate/productivity (large, delayed sexual maturity, protracted incubation) and spatial structure/connectivity (high site fidelity, low migration), the data support that several of these demographic risks are intrinsic to elasmobranchs and may render the undulate ray more vulnerable to extinction. However, the undulate ray does not appear currently to be responding adversely to threats. However, depending on the level of threat, the species may respond in the future. Data are lacking on diversity and how it may or may not contribute to extinction; thus, it is unknown how this characteristic contributes to the risk of extinction. Overall abundance is unknown. Where data exist on trends, some populations appear stable or increasing, while the Tralee Bay and southwestern Ireland population appears to be declining based on recreational fisheries data (albeit fishing effort is unknown). Thus, this characteristic poses a low risk of extinction.

In considering the threat risks, overutilization from directed harvest and bycatch may have occurred in some areas, but does not appear to be widespread. In addition, current regulations ban the retention of the undulate ray for many of the countries that fish within the undulate ray's distribution. Other fisheries regulations (e.g., seasonal restrictions on undulate ray catch) reduce the threat. Although pollution and contaminants have degraded some estuaries inhabited by the undulate ray, long-term effects to the habitat and direct impacts to the undulate ray have not been demonstrated. Evidence is lacking that disease and predation pose a threat to the undulate ray. Although the undulate ray is sensitive to ambient water temperatures for breeding purposes, data are lacking on impacts, if any, from climate change. For these reasons, I conclude that the known threats pose a very low to low likelihood of extinction risk to the undulate ray.

Although one of the demographic characteristics (growth/productivity) of the undulate ray has a moderate to high likelihood of contributing to the extinction risk, the species appears to not be responding to threats when exposed now, and information does not indicate the species' response to threats will change in the future. Data are needed to better understand the population abundance and trends, spatial connectivity, diversity, and the species' response to existing and future threats. For these reasons, I conclude that the species is presently at a low risk of extinction, with no information to indicate that this will change in the foreseeable future.

CONSERVATION EFFORTS

The undulate ray is listed as endangered under the International Union for the Conservation of Nature (IUCN) Red List of Threatened Species (Coelho *et al.* 2009).

As a member Party to the Convention on Biological Diversity, the UK developed the United Kingdom Biodiversity Action Plan (UK BAP) in 1994, and listed the undulate ray as a priority species for conservation action under the plan in 1997 (Joint Nature Conservation Committee 2010). The UK BAP does not provide legal protection; rather, it includes provisions to work towards European conservation legislation. Actions specific to the undulate ray identified in the UK BAP are: (1) implement effective fisheries management, incorporating scientific advice from ICES; (2) initiate study of movements and population structure; (3) examine available survey data so as to better delineate important grounds for various life-history stages; (4) coordinate the collection of biological material so as to better understand its life-history; and (5) examine discard survival from various commercial gears (Joint Nature Conservation Committee 2010).

In 2010, the undulate ray was listed on the Northern Ireland Priority List of threatened species requiring conservation action in Northern Ireland. The list is designed to assist in prioritizing funding and conservation actions (Joint Nature Conservation Committee 2010).

The Convention for the Protection of the Marine Environment of the Northeast Atlantic (OSPAR Convention; www.ospar.org) entered into force in 1998 and guides international cooperation on the assessment of the quality of the marine environment and prevention and elimination of pollution from land-based and offshore sources in the northeast Atlantic Ocean. France, Ireland, Portugal, Spain, and the UK are Parties to the Convention. The OSPAR Convention requires the Parties to report on what they have done to implement their obligations and commitments, and requires the OSPAR Commission to evaluate what has been achieved. Actions to date within the distribution of the undulate ray include controls on mercury pollution, reductions in emissions from refineries, and phasing out of polychlorinated biphenyls (PCBs) and harmful PCB substitutes. Although not directly related to the undulate ray, improvement of water quality in coastal areas would likely result in benefits to the habitat occupied by the species.

The Convention on Wetlands of International Importance, called the Ramsar Convention, was adopted in 1971 as an intergovernmental treaty that provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. The undulate ray occurs in the Tagus estuary, Portugal, which is a wetland site of importance under the Ramsar Convention. As such it has 14,000 hectares specifically created to protect aquatic birds. The estuary and surrounding upstream habitat to the mouth of the River Trancão and southernmost point of the Montijo peninsula were designated as the Tagus Estuary Special Protection Area under the European Community Directive 79/109/CEE. Although not directly related to the undulate ray, these conservation efforts directly protect habitat occupied by the species.

LITERATURE CITATIONS

Baeta, F., M. Batista, A. Maia, M.J. Costa, and H. Cabral. 2010. Elasmobranch bycatch in a trammel net fishery in the Portuguese west coast. Fisheries Research 102:123-129.

Batista, M.I., C.M. Teixeira, and H.N. Cabral. 2009. Catches of target species and bycatches of an artisanal fishery: the case study of a trammel net fishery in the Portuguese coast. Fisheries Research 100:167-177.

Burt, G.J., J.R. Ellis, B.F. Harley, and S. Kupschus. 2013. The *FV Carhelmar* beam trawl survey of the western English Channel (1989–2011): History of the survey, data availability and the distribution and relative abundance of fish and commercial shellfish. Science Series Technical Report, CEFAS Lowestoft, 151: 139 pp.

Cabral, H.N., M.J. Costa, and J.P. Salgado. 2001. Does the Tagus estuary fish community reflect environmental changes? Climate Research 18:119-126.

Chiquillo, K.L., D.A. Ebert, C.J. Slager, and K.D. Crow. 2014. The secret of the mermaid's purse: phylogenetic affinities within the Rajidae and the evolution of a novel reproductive strategy in skates. Molecular Phylogenetics and Evolution 75:245-251.

Coelho, R. and K. Erzini. 2002. Age and growth of the undulate ray, *Raja undulata*, in the Algarve (southern Portugal). Journal of the Marine Biological Association of the United Kingdom 82:987-990.

Coelho, R. and K. Erzini. 2006. Reproductive aspects of the undulate ray, *Raja undulata*, from the south coast of Portugal. Fisheries Research 81:80-85.

Coelho, R., L. Bentes, C. Correia, , J.M.S. Gonçalves, P.G. Lino, P. Monteiro, J. Ribeiro, and K. Erzini. 2002. Fisheries biology of the undulate ray, *Raja undulata*, in the Algarve (southern Portugal). NAFO Scientific Council Research Document.

Coelho, R., K. Erzini, L. Bentes, C. Correia, P.G. Lino, P. Monteiro, J. Ribeiro, and J.M.S. Gonçalves. 2005. Semi-pelagic longline and trammel net elasmobranch catches in southern Portugal: catch composition, catch rates and discards. Journal of Northwest Atlantic Fishery Science 35:531-537.

Coelho, R., M. Bertozzi, N. Ungaro, and J. Ellis. 2009. *Raja undulata*. In: IUCN 2012. IUCN Red List of Threatened Species. Version 2012.2. <www.iucnredlist.org>.

Costa, M.J. and A. Bruxelas. 1989. The structure of fish communities in the Tagus estuary, Portugal, and its role as a nursery for commercial fish species. Scientia Marina 53(2):561-566.

Costa, M.J., H.N. Cabral, P. Drake, A.N. Economou, C. Fernandez-Delgado, L. Gordo, J. Marchand, and R. Thiel. 2002. Recruitment and production of commercial species in estuaries. Pages 54-123 *in* Elliott, M. and K. Hemingway (editors) Fishes in Estuaries. Blackwell Science Ltd. Oxford.

Dauvin, J-C. 2008. The main characteristics, problems, and prospects for western European coastal seas. Marine Pollution Bulletin 57:22-40.

Delamare, A., C. Hennache, E. Stéphan, and G. Biais. 2013. Bay of Biscay undulate ray (*Raja undulata*) abundance estimate by mark-recapture. Working Document for ICES Working Group on Elasmobranch Fishes. 11 pages.

Dorset Wildlife Trust. 2010. Undulate ray nursery areas: Studland and Swanage Bays, Dorset. 2 pages.

Dulvy, N.K., S.L. Fowler, J.A. Musick, R.D. Cavanagh, P.M. Kyne, L.R. Harrison, J.K. Carlson, L.N.K. Davidson, S. V. Fordham, M.P. Francis, C.M. Pollock, C.A. Simpfendorfer, G.H. Burgess, K.E. Carpenter, L.J.V. Compagno, D.A. Ebert, C. Gibson, M.R. Heupel, S.R. Livingstone, J.C. Sanciangco, J.D. Stevens, S. Valenti, and W.T. White. 2014. Extinction risk and conservation of the world's sharks and rays. eLife:3:e00590. Doi:10.7554/eLife.00590. 34 pages.

Ellis, J.R., A. Cruz-Martínez, B.D. Rackham, and S.I. Rogers. 2005. The distribution of chondrichthyan fishes around the British Isles and implications for conservation. Journal of Northwest Atlantic Fisheries Science 35:195-213.

Ellis, J.R., J.F. Silva, S.R. McCully, M. Evans, and T. Catchpole. 2010. UK fisheries for skates (Rajidae): history and development of the fishery, recent management actions and survivorship of discards. ICES CM 2010/E:10. 38 pages.

Ellis, J.R., G. Morel, G. Burt, and S. Bossy. 2011. Preliminary observations on the life history and movements of skates (Rajidae) around the Island of Jersey, western English Channel. Journal of the Marine Biological Association of the United Kingdom. 6:1185-1192.

Ellis, J.R., S.R. McCully, and M.J. Brown. 2012. An overview of the biology and status of undulate ray *Raja undulata* in the northeast Atlantic Ocean. Journal of Fish Biology 80:1057-1074.

Gonçalves, J.M.S., K.I.Stergiou, J.A. Hernando, E. Puente, D.K. Moutopoulos, L. Arregi, M.C. Soriguer, C. Vilas, R. Coelho, and K. Erzini. 2007. Discards from experimental trammel nets in southern European small-scale fisheries. Fisheries Research 88:5-14.

ICES. 2007. Report of the working group on elasmobranch fishes. ICES Advisory Committee on Fishery Management. 332 pages.

ICES. 2010. Report of the working group on elasmobranch fishes. ICES Advisory Committee on Fishery Management. 560 pages.

ICES. 2011a. Report of the ICES Advisory Committee, 2011. Book 6 North Sea. 371 pages.

ICES. 2011b. Report of the ICES Advisory Committee, 2011. Book 5 Celtic Sea and West of Scotland. 330 pages.

ICES. 2011c. Report of the ICES Advisory Committee, 2011. Book 7 Bay of Biscay and Atlantic Iberian waters. 119 pages.

ICES. 2012. ICES implementation of advice for data-limited stocks in 2012 in its 2012 Advice. DLS Guidance Report ICES CM2012/ACOM68. 42 pages.

ICES. 2013. Report of the working group on elasmobranch fishes. ICES Advisory Committee on Fishery Management. 688 pages.

ICES. 2014a. Celtic Sea and west of Scotland for the undulate ray (*Raja undulata*) in VIId.e (English Channel). Advice Book 5.

ICES. 2014b. Report of the working group on elasmobranch fishes. ICES Advisory Committee on Fishery Management. 681 pages.

Joint Nature Conservation Committee. 2010. UK priority species pages – Version 2. 7 pages.

Jones, M.C., S.R. Dye, J.A. Fernandes, T.L. Frölicher, J.K. Pinnegar, R. Warren, and W.W.L. Cheung. 2013. Predicting the impact of climate change on threatened species in UK waters. PlOS One 8(1):e54216.

LeBlanc, N., A. Tetard, and V. Legrand. 2013. RAIMOUEST: the French fishery of rays in the western English Channel (VIIe). Working Document for ICES WGEF. 9 pages.

Lobry, J., L. Mourand, E. Rochard, and P. Elie. 2003. Structure of the Gironde estuarine fish assemblages: a comparison of European estuaries perspective. Aquatic Living Resources 16:47-58.

Martin, C.S., S.Vaz, J.R. Ellis, F. Coppin, D. Le Roy, and A. Carpentier. 2010. Spatio-temporal patterns in demersal elasmobranchs from trawl surveys in the eastern English Channel (1988 – 2008). Marine Ecology Progress Series 417:211-228.

Martin, C.S., S. Vaz, J.R. Ellis, V. Lauria, F. Coppin, and A. Carpentier. 2012. Modelled distributions of ten demersal elasmobranchs of the eastern English Channel in relation to the environment. Journal of Experimental Marine Biology and Ecology 418-419:91-103.

Massutí, E. and J. Moranta. 2003. Demersal assemblages and depth distribution of elasmobranchs from the continental shelf and slope off the Balearic Islands (western Mediterranean). ICES Journal of Marine Science 60:753-766.

Massutí, E. and O. Reñones. 2005. Demersal resource assemblages in the trawl fishing grounds off the Balearic Islands (western Mediterranean). Scientia Marina 69(1):167-181.

McCully, S.R., F. Scott, and J.R. Ellis. 2012. Lengths at maturity and conversion factors for skates (Rajidae) around the British Isles, with an analysis of data in the literature. ICES Journal of Marine Science 6(10):1812-1822.

McEachran, J.D. and K.A. Dunn. 1998. Phylogenetic analysis of skates, a morphologically conservative clade of ealsmobranchs (Chnodrichthyes: Rajidae). American Society of Ichthyologists and Herpetologists 2:271-290.

McElhany, P., M.H. Rucklelshous, M.J. Ford, T.C. Wainwright, and E.P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionarily significant units. NOAA Technical Memorandum NMFS-NWFSC-42. 174 pages.

Moura, T., I. Figueiredo, I. Farias, B. Serra-Pereira, R. Coelho, K. Erzini, A. Neves, and L.S. Gordo. 2007. The use of caudal thorns for ageing *Raja undulata* from the Portuguese continental shelf, with comments on its reproductive cycle. Marine and Freshwater Research 58:983-992.

Moura, T. I. Figueiredo, I. Farias, B. Serra-Pereira, A. Neves, M.D. Borges, and L.S. Gordo. 2008. Ontogenetic dietary shift and feeding strategy of *Raja undulata* Lacepède, 1802 (Chondrichthes: Rajidae) on the Portuguese continental shelf. Scientia Marina 72(2):311-318.

Neto, A.F., J.L. Costa, M.J. Costa, M.E. Pereira, A. Duarte, I. Caçador, and I. Domingos. 2011. Accumunlation of metals in *Anguilla anguilla* from the Tagus estuary and relationship to environmental contamination. Journal of Applied Ichthyology 27:1265-1271.

Prista, N., R.C. Vaconcelos, M.J. Costa, and H. Cabral. 2003. The demersal fish assemblage of the coastal area adjacent to the Tagus estuary (Portugal): relationships with environmental conditions. Oceanologica Acta 26:525-536.

Rogers, S.I. and R.S. Millner. 1996. Factors affecting the annual abundance and regional distribution of English inshore demersal fish populations: 1973 to 1995. ICES Journal of Marine Science 53:1094-1112.

Rogers, S.I. and J.R. Ellis. 2000. Changes in the demersal fish assemblages of British coastal waters during the 20th century. ICES Journal of Marine Science 57:866-881.

Rogers, S.I., A.D. Rijnsdorp, U. Damm, and W. Vanhee. 1998a. Demersal fish populations in the coastal waters of the UK and continental NW Europe from beam trawl survey data collected from 1990-1995. Journal of Sea Research 39:79-102.

Rogers, S.I., R.S. Millner, and T.A. Mead. 1998b. The distribution and abundance of young fish on the east and south coast of England (1981 to 1997). The Centre for Environment, Fisheries and Aquaculture. Science Series Technical Report No. 108. 133 pages.

Rogers, S.I., K.R. Clarke, and J.D. Reynolds. 1999. The taxonomic distinctness of coastal bottom-dwelling fish communities of the North-east Atlantic. Journal of Animal Ecology 68:769-782.

Sanmartín, M.L., M.F. Alvarez, D. Peris, R. Iglesias, and J. Leiro. 2000. Parasite community study of the undulate ray *Raja undulata* in the Ría of Muros (Galicia, northwest Spain). Aquaculture 184:189-201.

Serena, F. 2005. Field identification guide to the sharks and rays of the Mediterranean and Black Sea. FAO Species Identification guide for Fishery Purposes. Rome: FAO.

Serra-Pereira, B., C. Maia, and I. Figueiredo. 2013. Remarks on the reproduction strategy of *Raja undulata* from mainland Portugal. Working document presented to the ICES WGEF. 2 pages.

Serrano, A., F. Sánchez, I. Preciado, S. Parra, and I. Frutos. 2006. Spatial and temporal changes in benthic communities of the Galician continental shelf after the *Prestige* oil spill. Marine Pollution Bulletin 53:315-331.

Shark Trust. 2009. An illustrated compendium of sharks, skates, rays, and chimera. Chapter I: The British Isles. Part I: Skates and Rays.

Shiffman, D.S., A.J. Gallagher, J. Wester, C.C. Macdonald, A.D. Thaler, S.J. Cooke, N. Hammerschlag. 2014. Trophy fishing for species threatened with extinction: a way forward building on a history of conservation. Marine Policy 50:318-322.

Stéphan, E., C. Hennache, A. Delamare, V. Legrand, and N. Leblanc. 2013. The French RECOAM project: study of the biology and ecology of five skate (Rajidae) species present in the coastal waters of the western English Channel and central Bay of Biscay. Working Document for the ICES WGEF. 8 pages.

Valsecchi, E., P. Pasolini, M. Bertozzi, F. Garoia, N. Ungaro, M. Vacchi, B. Sabelli, and F. Tinti. 2004. Rapid Miocene-Pliocene dispersal and evolution of Mediterranean rajid fauna as inferred by mitochondrial gene variation. Journal of Evolutionary Biology 18:436-446.