Stock Annex: Undulate ray (*Raja undulata*) in Division 9.a (Atlantic Iberian waters)

Stock specific documentation of standard assessment procedures used by ICES.

Stock:	Undulate ray
Working Group:	Working Group on Elasmobranch Fishes (WGEF)
Created:	
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A. General

A.1. Distribution

Global distribution: *Raja undulata* (undulate ray) is a coastal benthic species with a wide geographic distribution in the northeast Atlantic and Mediterranean (Stehmann and Bürkel, 1984).

Species distribution in 9.a: The species displays a patchy distribution along the division 9.a area.

In mainland Portugal *Raja undulata* occurs along the continental coast, being more frequently caught in the some areas of north off Matosinhos and Aveiro, in the centre off Peniche (Figure 1), in the southwest coast off Setúbal (Baeta *et al.* 2010) and in the Algarve (Coelho *et al.* 2005). The species, particularly juveniles, is also registered in estuarine and lagoon habitats, like Tagus River (centre of Portugal) and Ria Formosa (south of Portugal). In the first area, data derived from fishing hauls performed during four research surveys onboard Aquário Vasco da Gama research vessel (with a total of 13 hauls), showed that the species occurred in 50% of the trips and in 31% of the fishing hauls. Although the bathymetric distribution of the species ranges from 4 to 128 m deep, it is more abundant between 30 and 40 m deep.

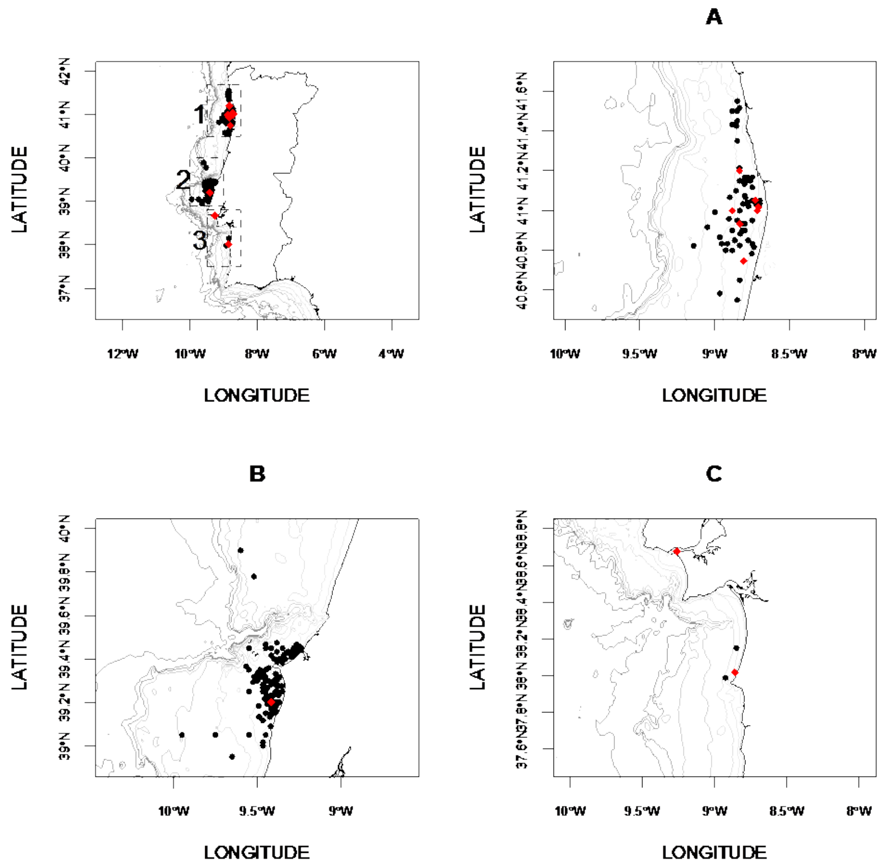


Figure 1 - Portuguese continental coast (ICES Division 9.a). Distribution of *Raja undulata* (black) and egg-laying areas (red), detailed by area: 1) north (n=80), 2) centre (n=247) and 3) southwest (n=4).

A.2. Species dynamics

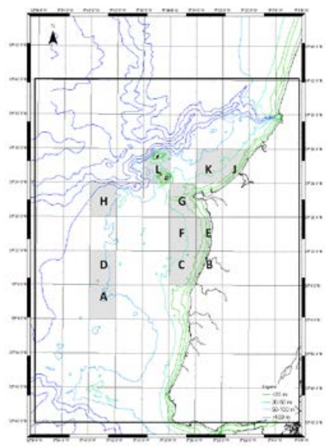
In the Portuguese coast this species mainly occurs associated to sand or coarse sand bottoms, sometimes mixed with shells. Fishery data and fishermen information recorded in interviews give support to the concentration of the species in specific places along the Portuguese continental coast. This spatial pattern is in accordance with the patchy distribution admitted for the species in other areas. In fact such pattern has been also observed in other European areas. In those areas, it is further admitted that there is little exchange between discrete areas, within which the species may be locally abundant (Ellis *et al.*, 2012).

In Portuguese continental areas, egg-laying sites of this species were observed along the coast (north, centre and southwest regions), between 10 and 55 m depth (but mainly at depths shallower than 30 m). Estuaries and coastal lagoons are likely to be important habitats for the species, since both newborn/juveniles and egg-laying females were mainly found to occur in those areas.

At the centre off Portuguese continental coast, Santa Cruz (B), Areia Branca (E) and Foz do Arelho (J) were the fishing grounds where *R. undulata* are more abundant (Table 1).

Those three grounds are located close to shore and shallower than 50 m deep, with a geomorphology dominated by underwater beaches. In those fishing grounds the species is present all year round, but its abundance is higher during the second quarter of the year. Additionally, off Santa Cruz (C) and Berlengas (L), nursery sites were identified (Serra-Pereira *et al.*, 2014).

Table 1. Portuguese continental coast (ICES Division 9.a). Description of the main fishing grounds around the Peniche where *Raja undulata* occurs. Information on: location, depth range, geomorphology, catch percentages of *Raja undulata* in weight in relation to the total catch of skate species, TL range (cm) and identification of nursery areas.



	Name (coordinates)	Depth range (m)	Geomorphology	Catches (%)	TL range (cm)	Nursery area
B	Santa Cruz (39.2ºN, 9.4ºW)	15-55	The skates found in this fishing ground were captured in sand seabed close to rocks.	18.1%	40-95	
C	Off Santa Cruz (39.2ºN, 9.5ºW)	15-110	The skates found in this fishing ground were captured in sand seabed close to rocks.	5.8%	42-90	✓
E	Areia Branca (39.3ºN, 9.4ºW)	13-73	The sand on this fishing ground is mixed with shells.	24.6%	49-93	
F	Off Areia Branca (39.3ºN, 9.5ºW)	24-73	The sand on this fishing ground is mixed with shells	5.3%	44-95	
G	Mar do Cachimbo (39.4ºN, 9.5ºW)	18-110	Isthmus (rocky bottom) that makes the connection between the islands off Peniche and the mainland, at between 30 and 40 m depth [2]	2.3%	41-82	

J	Foz do Arelho (39.5ºN, 9.3ºW)	15-91	Seabed composed of black sand, muddy sand and mud, but to northeast (i.e. closer to this spatial unit) the seabed is composed mostly of black sand [1]	14.5%	49-96	
K	Baleal (39.5ºN, 9.4ºW)	18-128	Situated between the 30 and 50 m isobaths, with seabed composed of a compact sediment with high levels of clay with interstratified levels of sand, overlaid by sandstones or medium orange grains and some disseminated pebbles. Between Óbidos Lagoon (near Foz do Arelho) and Peniche the coastline is sandy, with narrow beaches, and interrupted by rocky outcrops [3,4].	9.6%	48-90	
L	Berlengas (39.5ºN, 9.6ºW)	18-548	Irregular seabed (with many protruding rocks), composed mainly of rock surrounded by sand [1]	9.4%	45-91	✓

[1] Boavida, 1948; [2] Vanney and Mougenot 1981; [3] Diniz, 1988; [4] Ferreira et al. 1989.

A.3. Stock definition

Although in ICES area the stock structure of the species is unknown, short range migrations between different areas of species concentration are admitted (ICES, 2013). For advice purposes, ICES considers a distinct stock unit for Division 9.a (west of Galicia, Portugal, and Gulf of Cadiz).

A.4. Fisheries

In ICES Division 9.a no fisheries targeting *R. undulata* are known to occur.

An important artisanal fleet that frequently catches Rajidae (represents around 8.7 % of Galicia total landings from the different ICES areas) operates inside Galicia estuaries with different types of gillnets, particularly the *miño*. A sampling program carried out between 2004 and 2006 showed that 44% of the skates sampled corresponded to *R. undulata* (Bañón *et al*., 2008).

In Portuguese continental coast the data collected under the Pilot Study on Skates (EU DCF) and EU PNAB/DCF indicates that *R. undulata* is more frequently caught by the polyvalent fleet, particularly by trammel nets, than by the trawl fleet (Figure 2). This may reflect differences on fishing grounds where the two fleets operate: the polyvalent fleet may operate close to the coast while trawl fleet is only allowed to operate at a distance 6 nm apart from the coast, where the species is not so abundant.

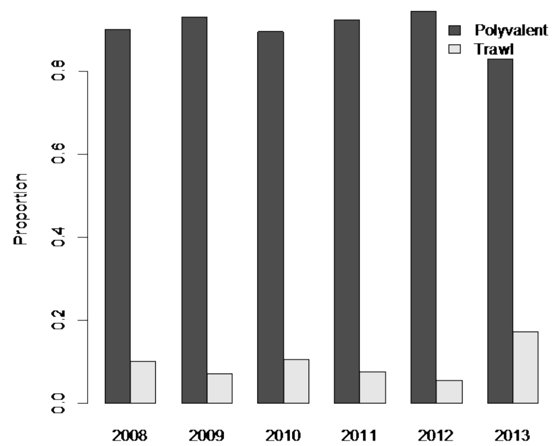


Figure 2 - Portuguese continental coast (ICES Division 9.a). Estimated catches of *Raja undulata*, for the polyvalent and trawl fleet segments.

A.5. Ecosystem aspects

In the west coast of the Iberian Peninsula the most important features enhancing primary production are coastal upwelling, coastal runoff and river plumes, seasonal currents and internal waves and tidal fronts. Maximum values of chlorophyll usually occur in spring and summer (Nogueira *et al*., 1997; Moita, 2001), although high chlorophyll values may be recorded in autumn, particularly in zones with elevated retention characteristics; for example, high chlorophyll concentrations are found in the Rías Baixas, at the time of the seasonal transition from upwelling to downwelling (Nogueira *et al*., 1997; Figueiras *et al.*, 2002). Most of the west Iberian coast, including Galicia and Cantabrian Sea continental shelf, is occupied by cold waters rich in nutrients (Gil, 2008).

The north-south orientation of the coast causes winds from the north to produce offshore transport. During spring and summer, northerly winds along the coast are dominant causing coastal upwelling and producing a southward current at the surface and a northward undercurrent at the slope (Figure 3a) (Fiúza *et al*., 1982; Alvarez-Salgado *et al*., 2003; Peliz *et al*., 2005; Mason *et al.*, 2006). During winter the prevailing winds are mainly south-westerly, and the atmospheric circulation is dominated by eastward displacement of cyclonic perturbations and their associated frontal systems (Figure 3b) (Relvas *et al.*, 2007). However, in some years the presence of episodic atmospheric anti-cyclonic circulation (the Azores High) could give rise to northerly wind events during winter (Santos *et al*., 2001; Borges *et al*., 2003). Indeed, investigations on upwelling along the Galician coast in autumn and winter have been characterized in the Galician rias, indicating that the upwelling process along the Galician coast is not a phenomenon restricted to spring and summer (Alvarez *et al*., 2012).

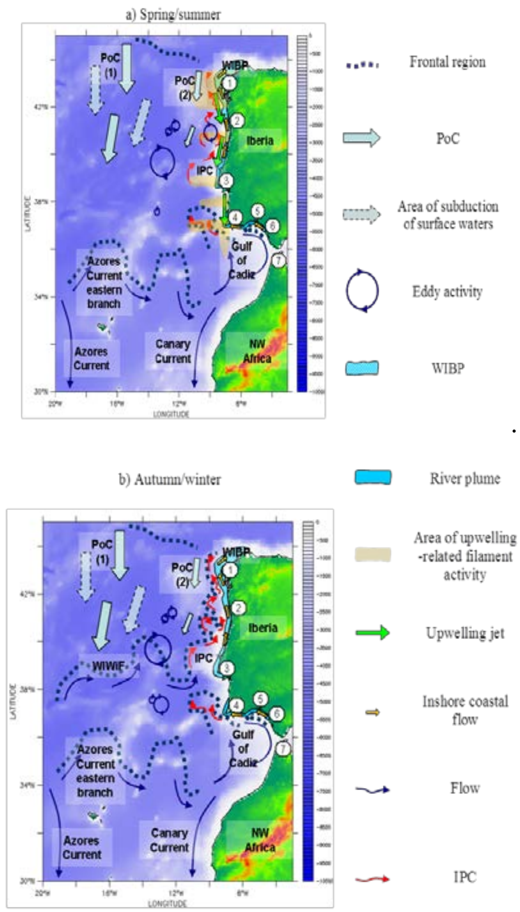


Figure 3 - The western Iberia and Gulf of Cadiz regimes in a) spring and summer, and b) autumn and winter. 1) Cape Finisterre; 2) River Douro; 3) Cabo da Roca; 4) Cape St. Vincent; 5) Guadiana River; 6) Guadalquivir River; 7) Strait of Gibraltar. PoC - southward-flowing Portugal Current, WIBP - Western Iberia Buoyant Plume, IPC - Iberian Poleward Current (Adapted from Peliz *et al*. 2002; Peliz *et al*. 2005).

In winter the Poleward Current (PC) flows northerly. It is a salty surface current (about 200 m deep) of subtropical origin (Eastern North Atlantic Water, also known as the 'Navidad' Current, since because it starts to be evident near Christmas and New Year) and relatively warmer than the surrounding ones (Castro *et al.,* 2011). During winter and spring, the PC results in a convergent front at the boundary between coastal and oceanic water. When saline intrusion is weak, the development of fronts and the formation of a seasonal thermocline are enhanced, leading to phytoplankton blooms. When saline intrusion is intense, strong vertical mixing occurs and prevents phytoplankton growth in spring (Moita, 2001; Santos *et al.,* 2004).

The intermediate deep layers are mainly occupied by a poleward flow of Mediterranean Water (MW), which contours the southwestern slope of the Iberia (Ambar and Howe, 1979), generating the mesoscale features called Meddies. The MW along the west coast of the Iberian Peninsula is characterized by a transport of warm and salty water (typical surface anomalies, 1–1.5ºC and 0.1–0.3‰ in salinity) with velocities up to some 0.2–0.3 m s^{-1} reported by Frouin *et al*. (1990).

The Sea Surface Temperature (SST) registered a generalized warming of a few hundredth of degrees a year since 1960, ranging from 0.015°C/year to 0.037°C/year (Relvas *et al.*, 2009). The SST increase has effect on species populations (e.g. recruitment success, migrations changes) (Brander *et. al.*, 2003).

In the Gulf of Cadiz the most important oceanographic process is the occurrence of a strong interaction between two masses of water, the Atlantic Ocean and the Mediterranean Sea through the Strait of Gibraltar. In general, the exchange of water masses through Strait of Gibraltar is guided by the highly saline and warm Mediterranean Outflow Water near the bottom, and the turbulent, less saline, cool-water mass of the Atlantic Intermediate Water at the surface. The pattern of surface circulation is ruled by a clockwise movement, with a general W to E superficial current, whereas the deep circulation is controlled by the westerly current of the highly saline (salinity>37 PSU) Mediterranean water existing through the Strait.

Bottom temperatures are extremely variable ranging between 3ºC and 20.6ºC whereas values of bottom salinity along the continental shelf range from 35.8 to 36 PSU (Díaz *et al.*, 2006). In the slope there is a wide band with values around 37 PSU, the lower slope showing the minimum values which correspond to the Deep Atlantic Water Mass (Díaz *et al.*, 2006).

The continental slope can be differentiated into four provinces: a) a narrow belt between 130 and 400 m formed by the steep upper slope; b) two gently dipping wide terraces located between 400 and 700 m depth; c) a central sector between the terraces in which several, steep and narrow curvilinear ridges and valleys are located trending NE-SW to E-W; d) the lower slope-upper continental rise at water depths from 900 down to 1500-1800 m. Below 900 m, the lower slope is steeply dipping and generally smooth except for shallow valleys placed in a NE-SW direction (Nelson *et al.*, 1993). The main sedimentary types occurring over the slope are bioclastic sands, silicoclastic sands and muddy sands, sandy muds, sandy and muddy contourites (Díaz *et al.*, 1985).

B. Data

B.1. Commercial landings and discards

Due to the EU legislation adopted for *R. undulata* (Council regulation (EC) No 43/2009), discards of this species are likely to have increased since 2009. *Raja undulata* is mainly captured by small artisanal vessels with little conditions to hold observers and enable data collection on captures and discards. However, information collected until 2010 and onboard data shows that both the frequency of occurrence and the catch rate of the species along the occidental coast off mainland Portugal are higher in areas off Matosinhos and Aveiro. Information collected on landing ports (interviews to fishermen) also indicates a high frequency of occurrence in catches from the polyvalent fleet in Sines and Olhão. In fact, despite the irregular estimates, relatively high abundances in the catches of this species by the polyvalent fleet were registered in 2009 and in 2012 for each landing port, respectively.

The interquartile range of the catch (kg) by fishing trip for Torreira and Espinho (located off Matosinhos and Aveiro), Baleal and off Santa Cruz (located off Peniche) and Cabo Raso (located off Cascais) are presented in Figure 4. The median estimates of the catch weight were similar between Torreira, Espinho, Baleal and off Santa Cruz. In the first two fishing grounds the catches reached a maximum value of 112 kg per trip, which corroborates the higher abundance of the species in that area.

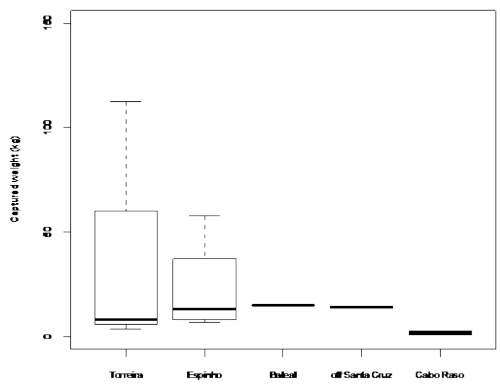


Figure 4 - Portuguese continental coast (ICES Division 9.a). Interquartlie ranges of captured weight (Kg) by trip of *Raja undulata*, recorded onboard fishing vessels using trammel nets, by fishing ground: a) located off Matosinhos and Aveiro - Torreira (n=6 hauls) and Espinho (n=7 hauls); b) located off Peniche - Baleal (n=11 hauls) and off Santa Cruz (n=8 hauls); c) located off Cascais - Cabo Raso (n=4 hauls).

Information on discards of *R. undulata* produced by the Portuguese polyvalent (gillnets and trammel nets) and bottom otter trawl segments operating in the ICES Division 9.a has been collected under the Data Collection Framework (EU DCR). The level of discard is very low (Prista *et al.*, 2014 WD) and the information available is insufficient to reach robust estimates of discards.

In the Gulf of Cadiz, catch and landing data from commercial fisheries are often poor because of a general lack of species-specific recordings. No management program has been established yet in this area. Fisheries research has traditionally been focused on the most commercially important teleosts and poor research has been undertaken on chondrichthyans.

B.2. Length frequency distribution

In Portuguese continental coast, the data collected under the EU Data Collection Framework (DCF, PNAB), since 2008, and under the Pilot Study on Skates (included in DCF) during 2011-2013, show that in recent years the length structure of the population caught shifted to larger individuals. Also, length frequency distribution of the catches is different between fishing gears (Figure 5).

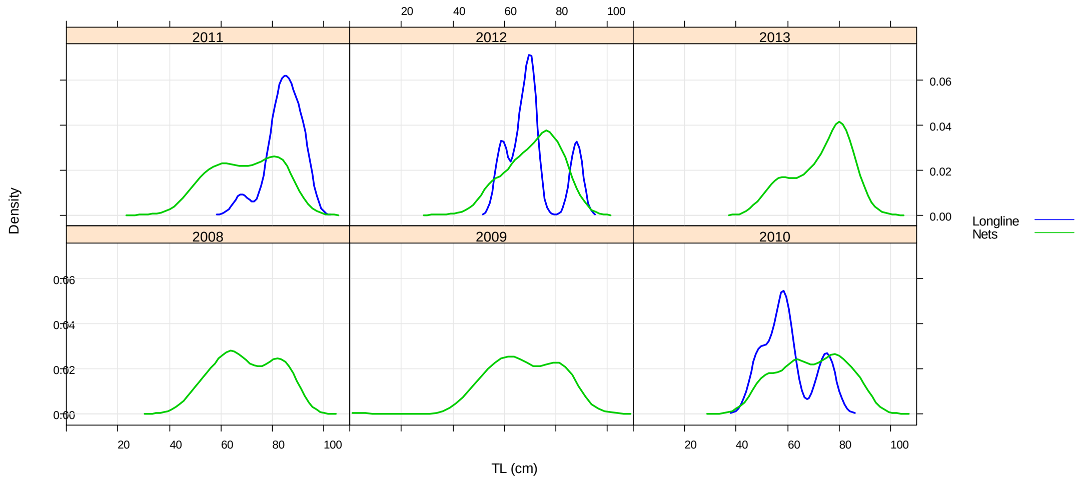


Figure 5. Portuguese continental coast (ICES Division 9.a). Length frequency distribution of *Raja undulata* by fishing gear (longline and nets) for the period 2008-2013.

From data collected onboard fishing vessels operating with trammel nets at different areas off the Portuguese continental coast, caught specimens of *R. undulata* measured between 47 and 88 cm total length. The interquartile range of specimen's total length (Figure 6) and the sex ratio (1:1) was similar between regions. This pattern is in agreement with the patchy distribution admitted for the species, which implies that the species concentrate in specific areas within which it is able to develop the whole life cycle.

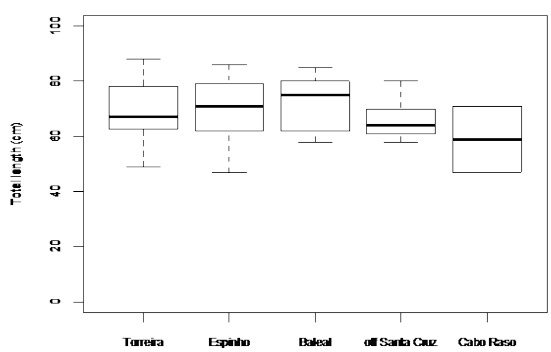


Figure 6. Portuguese continental coast (ICES Division 9.a). Interquartlie range of specimen's total length (cm) of *Raja undulata*, recorded onboard fishing vessels operating with trammel nets, by fishing ground: a) located off Matosinhos and Aveiro - Torreira (n=6 hauls) and Espinho (n=7 hauls); b) located off Peniche - Baleal (n=11 hauls) and off Santa Cruz (n=8 hauls); c) located off Cascais - Cabo Raso (n=4 hauls).

B.3. Survivorship

Under the scope of the EU DCF skate pilot study carried out in mainland Portugal, data on survivorship of *R. undulata* after fishing was collected onboard fishing trips of polyvalent vessels operating with trammel or gillnets. Survivorship was qualitatively evaluated by assuming that the health status of fish after capture is a good indicator of the survivorship index (Enever *et al.*, 2009). The following scale was used to assign health status to each sampled individual (Enever *et al.*, 2009): 1) Good: vigorous wing/body movement and rapid spiracle movement; 2) Moderate: limp wing/body and spiracle movement and; 3) Poor: dead or nearly dead, no body movement, slight spiracle movement.

There are no studies about skates´ survivorship neither in the west of Galicia nor in the Gulf of Cadiz.

B.4. Commercial CPUE

The index of abundance of *Raja undulata* was estimated from the Portuguese polyvalent segment as the landed weight of the species per trip (fishing effort unit), CPUE, and using data collected onboard commercial vessels. CPUE standardisation was constrained to the polyvalent fleet, since the species has no representatively in the trawl segment. Within the polyvalent segment, and since the species is more frequently caught with nets (particularly trammel nets), the latter it was admitted that the standardized CPUE using fishery data derived from nets is representative of the polyvalent segment.

B.5. Biology

The potential rate of population increase was calculated following the proxy proposed by Jennings *et al*. (1999), which assumes a single annual peak of egg-laying. The value of *r'*, when compared to that of other species allows to indirectly evaluate the productivity of a species comparing their vulnerability to fishing.

Natural mortality was calculated using two methods, Pauly's (1980) and Jensen's (1996). And the growth-maturity-longevity relationship calculated as L_{50}/L_∞ vs. k^*L_∞ (Frisk *et al.* 2001), which theoretically indicates where the maximum possible yield is reached if the entire cohort is harvested (Holt 1958).

Table 2 summarizes all the biological data available.

Table 2 - Portuguese continental coast (ICES Division 9.a). Summary of biological information published for *Raja undulata*.

Period		1999–2001	1999–2001	2003–2006	2001–2008	2003–2013
Region		Algarve	Algarve	Centre	North/Centre	North/Centre
Depth range (m)		-	-	-	-	4 to 128 (mostly 30-40)
Egg-laying depth range (m)		-	-	-	-	10 to 55 (mostly < 30)
TL range (cm)		19.4-88.2	32.0-83.2	23.7-90.5	48.0-95.9	23.5-95.9
L50 (cm)	F	76.2	-	83.8	-	86.2±2.6
	M	73.6	-	78.1	-	76.8±2.4
I50 (years)	F	8.98	-	9	-	8.7±0.3
	M	7.66	-	8	-	7.6±0.4

M50 (cm)	-	-	-	-	95.7±15.3
Reproductive period	Dec-Feb	-	Feb-May	-	Dec-Jun
Fecundity (eggs per female)	-	-	-	-	69.8±3.4
Fecundity/batch (eggs per female)	-	-	-	-	15
Number of batches	-	-	-	-	3.6
Size-at-birth (cm)	-	-	-	-	13.5
Lmax (cm)	88.2	83.2	90.5	-	95.9
L∞ (cm)	110.2	119.3	113.7	-	-
k (year-1)	0.11	0.12	0.15	-	-
t0 (years)	-1.58	-0.41	-0.01	-	-
Imax (years)	13	9	12	-	12.6
I∞ (years)	-	28.9	23.6	-	-
TW ~ aTLb a	-	-	-	1.92*10-5	-
b	-	-	-	2.86	-
r′ (Jennings et al. (1999)	-	-	-	-	0.49
M (Jensen 1996)	-	-	-	-	0.24
(Pauly 1980)	-	-	-	-	0.27
References	[1], [2]	[3]	[3]	[4]	[5]

(TL: total length; L50: size-at-maturity; I50: age-at-maturity; M50: size-at-maternity; Fecundity; L∞: asymptotic length; k: growth rate; t0: size ate age-0; Lmax: maximum observed length; Imax: maximum observed age; I∞: maximum theoretical age; TW ~ aTLb: weight-length relationship; r′: potential rate of population increase; M: natural mortality)

[1] Coelho and Erzini 2002; [2] Coelho and Erzini 2006; [3] Moura et al. 2007; [4] Serra-Pereira et al. 2010; [5] Serra-Pereira et al. *submitted*.

B.6. Surveys

The surveys available for this area were not designed primarily to inform on the populations of *R. undulata*, which presents a patchy and shallower distribution. The gears used, timing of the surveys and distribution of sampling stations are considered not optimal for informing on the species and/or life-history stages.

C. Assessment: data and method

Data:

- Fishery dependent data:
  - o Landings estimates by species
  - o Fishing effort (unit: number of fishing trips) by fishing gear
  - o Length frequency distribution by fishing gear
  - o Discards
- Fishery independent data

- Portuguese Autumn Groundfish Surveys (PT-GFS) catch rate ($kg.haul^{-1}$)
- Length distribution

Methods:

1. Standardized CPUE for the polyvalent fleet using nets in Portuguese continental waters

In the standardization process of CPUE, a stepwise generalized linear model (GLM) procedure was applied to find the best GLM model and an estimate CPUE index time series based on the relationship between CPUE vs. available predictive factor variables.

The function bestglm implemented in R software was used to select the best subset of inputs variables (McLeod AI and Xu, 2010). The selection was based on a variety of information criteria and their comparison, following a simple exhaustive search algorithm (Morgan and Tatar, 1972). This algorithm uses a lexicographical method that evaluates the loglikelihoods for all possible glm models. Lognormal error distribution was assumed in the standardization. This distribution is commonly assumed for standardizing catch and effort data, assuming that the expected value of a transformed response variable is related to a linear combination of exploratory variables (Maunder and Punt, 2004).

Different diagnostic plots, e.g. the distribution of residuals and the quantile-quantile (Q-Q) plots, were used to assess the error distribution (assuming lognormal distribution), as well as the model fits for the standardization of the CPUE. Changes in deviance explained by the selected model and the proportions of deviance explained to the total explained deviance was determined and used as indicative of r^2.

The standard errors of the year effects and CPUE for a reference conditions, in the present case: net as fishing gear, 1st quarter of the year; medium vessel size and constant seasonality, were calculated by the delta method. The delta method is commonly applied when functions are too complex for analytically computing their variance. According to this method, a linear approximation of the function, usually with a one-step Taylor approximation, is firstly obtained and then its variance is computed (Oehlert, 1992).

Software used:

All the data analysis was performed in R software (R Development Core Team, 2009).

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