

# Morphometric ratios of six commercially landed species of skate from the Portuguese continental shelf, and their utility for identification

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European skate landings have traditionally been reported under a generic landing category, because of problems with species identification. To address this data deficiency, the ICES Working Group on Elasmobranch Fishes compiled conversion factors, including the relationships between different body measurements, for the main elasmobranch species. Size conversion factors for six common NE Atlantic skate species, *Leucoraja naevus*, *Raja brachyura*, *R. clavata*, *R. miraletus*, *R. montagui*, and *R. undulata* are compiled, and the capability of morphometric data to assist species discrimination is evaluated, highlighting the case of similar species such as *R. brachyura* and *R. montagui*. The estimated size conversion factors displayed some variability between areas and sexes for most species, the allometric relationship between weight and total length did not differ significantly between sexes, and some morphometric ratios proved adequate in discriminating between rajid species (misclassification error 0.12). *Leucoraja naevus* was fully discriminated from the remaining species. Species with a similar dorsal colour, e.g. *R. brachyura* and *R. montagui*, showed good discrimination based on their morphometry, with just 6–11% misclassification between the two.

**Keywords:** biometry, fisheries, Portugal, Rajidae, size conversion factors, skates.

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## Introduction

Skates (order Rajiformes) are one of the most speciose elasmobranch orders and include at least 27 genera and more than 245 species (Ebert and Compagno, 2007). They are found in all oceans, from shallow coastal waters to abyssal regions. Of those inhabiting the shelf and upper slope, some live on soft bottom, others on coarser substrata (Stehmann and Bürkel, 1984; Ebert and Compagno, 2007). Skates are important elements of the marine biodiversity, but they are highly vulnerable to commercial exploitation. In 2006, skate catches amounted for ~59% of the total reported landings (by weight) of elasmobranchs in the NE Atlantic (FAO, 2007).

The external morphology and colour of skates are, in many cases, sufficient to discriminate between species inhabiting the NE Atlantic. Nevertheless, for commercial reasons, the different species are often landed under a generic landing category (Dulvy *et al.*, 2000; ICES, 2007). During a pilot sampling programme conducted at ports in mainland Portugal, eight species of skate were identified: cuckoo ray *Leucoraja naevus*, blonde ray *Raja brachyura*, thornback ray *Raja clavata*, small-eyed ray *Raja microcellata*, brown ray *Raja miraletus*, spotted ray *Raja montagui*, undulate ray *Raja undulata*, and bottlenosed skate *Rostroraja*

*alba* (Bordalo-Machado *et al.*, 2004). In addition, three other species, which are either rare or absent from landings, have been described for this geographic area: longnosed skate *Dipturus oxyrinchus*, sandy ray *Leucoraja circularis* (Figueiredo *et al.*, 2007), and Iberian pigmy skate *Neoraja iberica* (Stehmann *et al.*, 2008). The present work focuses on six of the most common and widely studied species of this assemblage (*L. naevus*, *R. brachyura*, *R. clavata*, *R. montagui*, *R. miraletus*, and *R. undulata*). Identification keys are available for all six (e.g. Stehmann and Bürkel, 1984) to allow for their correct identification. Although the typical specimens of *L. naevus*, *R. miraletus*, and *R. undulata* are difficult to misidentify, because of their unique dorsal colouration, there may be problems distinguishing between the other three, mainly because of the remarkable variability within *R. clavata*, and the similarity between *R. montagui* and *R. brachyura*. *Leucoraja naevus*, *R. miraletus*, and *R. montagui* are small species that reach a maximum length of ~70 cm (Holden, 1972; Du Buit, 1975), maturing at lengths of ~60 cm (Walker, 1999). All three are potentially more resilient to fishing pressure than larger species, such as *R. brachyura*, *R. clavata*, and *R. undulata*, which can reach lengths of >100 cm (Holden, 1972; Moura *et al.*, 2007; Serra-Pereira *et al.*, 2008).

One of the terms of reference for the 2007 ICES Working Group on Elasmobranch Fishes (WGEF) referred to the need to compile conversion factors for elasmobranch species, but little information was made available (ICES, 2007). Conversion factors are commonly used to estimate values from one or more known body measurements. Therefore, morphometric conversions are particularly helpful when, for example, a specimen is damaged, or when dealing with commercially preprocessed specimens (e.g. wings only, tail off, head off, or a combination of these), in which not all morphometric traits can be measured. As conversion factors differ between species, they may also serve as a tool for species identification, especially for persons with limited taxonomic expertise, or for accurate identification of problematic specimens. This is particularly important at landing ports where fish need to be identified on site.

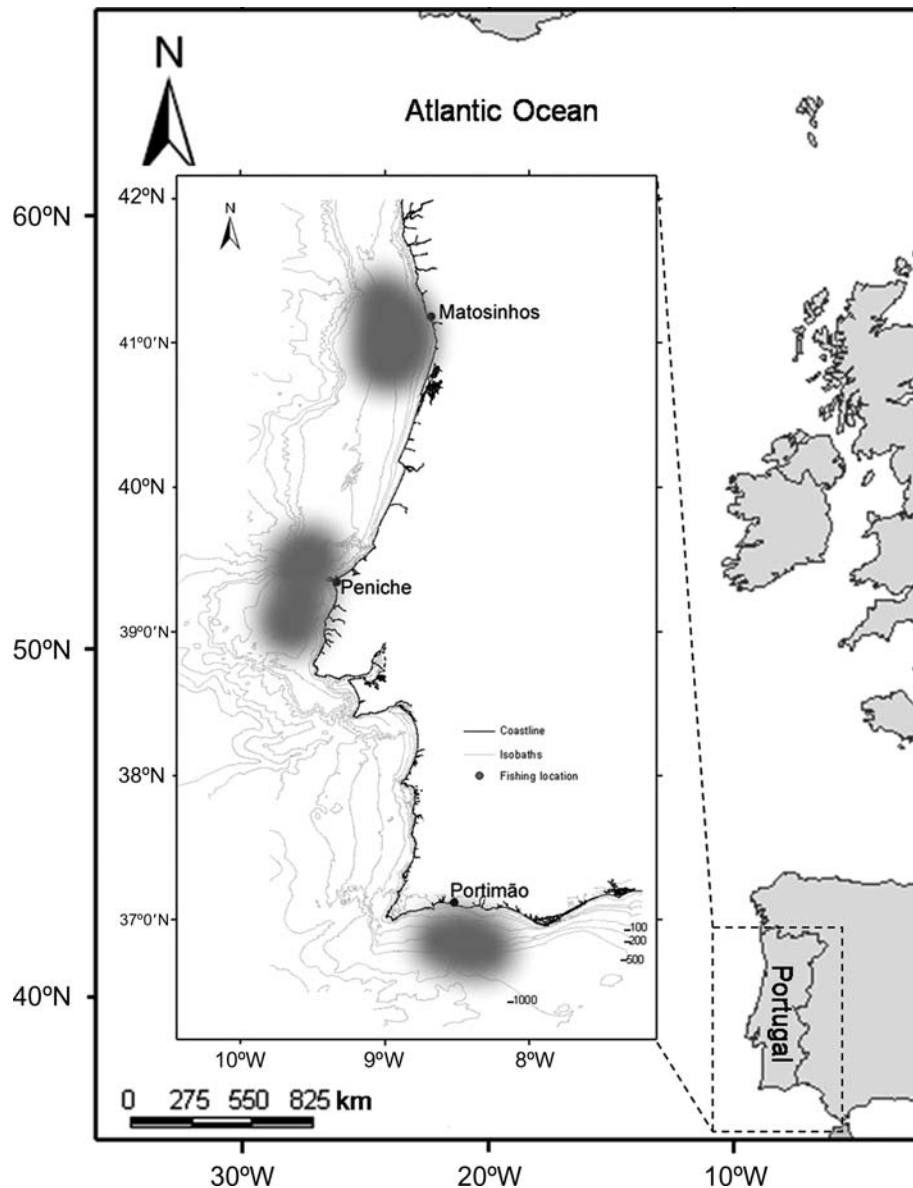
The present study aimed to (i) estimate relationships between different body measurements (i.e. size conversion factors) to

increase the information available for six common NE Atlantic skate species in Portuguese waters, and (ii) investigate the ability of these measurements to discriminate between species to provide additional tools for assisting in the identification of skates on the Portuguese shelf and in other parts of the NE Atlantic.

### Material and methods

Specimens were sampled monthly between February 2001 and June 2008, from commercial landings in three ports along the Portuguese continental coast: Matosinhos in the north, Peniche in the centre, and Portimão in the south (Figure 1). From these ports, skates are caught in a variety of gears, including trammel- and gillnets, longlines, trawls, and traps.

For each boat sampled, a subsample of the total skate landings was selected randomly. For each specimen, the species was identified and the following size measurements were recorded to the nearest millimetre (mm; see Figure 2): total length (TL), disc

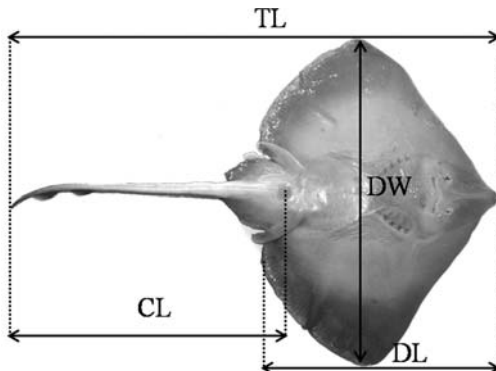


**Figure 1.** Map of the NE Atlantic with details of the study location off Portugal. The landing ports (Matosinhos, Peniche, and Portimão) and the main fishing areas (shaded grey) are identified, and bathymetric contours (isobaths) are provided in metres.

width (DW), disc length (DL), and tail length (CL). Although all the measurements are shown in Figure 2 on the ventral view of a skate, TL, DW, and DL were measured on linear axes under the individual, as viewed from the dorsal side. DL and CL were only available for specimens landed in Peniche. Specimens were also sexed and weighed (total weight, TW, and gutted weight, gW) to an accuracy of 1–10 g.

**Data analysis**

For each species, an exploratory analysis of morphometric ratios (DW:TL, DL:TL, CL:TL, and DL:DW) was performed by sex and



**Figure 2.** Measurements recorded to the nearest 1 mm on linear axes for each fish: total length (distance from the tip of the snout to the end of the tail, TL), disc width (maximum distance between the wing tips, DW), disc length (distance from the tip of the snout to the posterior edge of the disc, DL), and tail length (distance from the cloaca to the end of the tail, CL).

area (landing port), whenever there were sufficient data available for two variables. *Raja miraletus* from the north and centre and *L. naevus* and *R. undulata* from the south were not considered for analysis owing to the small sample sizes by sex ( $n < 10$ ). No *R. brachyura* were available in samples from the south.

To investigate the influence of area and sex on the morphometric ratio DW:TL, TL was grouped into 10 cm size bins (TL classes), and a linear model was adjusted to each species' dataset. The factor TL class is expected to be a major contributor to the variability of this morphometric ratio, so a model that considers the factors area and sex nested on the factor TL class was constructed:

$$\text{Ratio} = \mu + \beta_{\text{Area}} + \alpha_{\text{Sex}} + \gamma_{\text{Area} \times \text{Sex}} + \phi_{\text{Area} \times \text{Sex} \times \text{Lengthclass}} + \varepsilon, \tag{1}$$

assuming that  $\varepsilon \sim N(0, \sigma^2)$ . The other morphometric ratios were only available for central Portugal, so the nested model initially proposed was

$$\text{Ratio} = \mu + \beta_{\text{Sex}} + \alpha_{\text{Sex} \times \text{Lengthclass}} + \varepsilon, \tag{2}$$

under the assumption that  $\varepsilon \sim N(0, \sigma^2)$ . The assumptions of the models, particularly variance homogeneity and normality, were investigated through an analysis of the residuals.

A stepwise algorithm was used to select the factors to be included in the model. Model selection was based on the Akaike Information Criterion (AIC), according to which, competing models may be ranked for a given dataset, and the one with the lowest AIC value is considered to be the most appropriate (Venables and Ripley, 2002).

**Table 1.** Summary of the data available by species, sex, and area, provided as ranges for each morphometric measurement.

Species	Sex	Area	n	TL	TW	gW (g)	DW (mm)	DL (mm)	CL (mm)
JAI	F	South	16	329–488	–	–	228–336	–	–
	M	South	22	313–492	–	–	215–310	–	–
RJC	F	North	150	420–905	200–7 750	–	305–608	–	–
		Centre	155	489–934	623–6 710	585–5 810	345–669	248–489	269–464
		South	22	362–793	900–3 800	–	263–588	–	–
	M	North	133	410–875	450–4 140	–	295–562	–	–
		Centre	80	458–870	540–3 870	480–3 435	321–565	226–428	260–443
		South	30	315–850	1 000–3 200	–	212–547	–	–
RJH	F	North	68	380–975	400–8 520	–	297–715	–	–
		Centre	148	376–1 061	304–10 680	283–9 160	268–771	205–588	230–514
	M	North	67	389–1 005	400–8 700	–	284–723	–	–
		Centre	114	412–1 005	421–7 290	387–6 404	292–692	240–554	260–495
RJM	F	North	33	368–702	270–2 340	–	257–459	–	–
		Centre	185	390–702	388–2 583	360–2 306	285–483	212–373	240–346
		South	18	331–575	–	–	235–412	–	–
	M	North	23	412–651	450–1 980	–	281–430	–	–
		Centre	97	408–612	455–1 575	420–1 450	292–412	209–319	226–336
		South	20	366–522	–	–	253–354	–	–
RJN	F	North	23	497–718	700–2 460	–	270–409	–	–
		Centre	224	448–691	460–2 135	435–1 975	249–399	215–340	250–353
	M	North	23	501–682	720–2 410	–	275–401	–	–
		Centre	130	439–672	317–2 250	298–2 120	259–384	205–329	250–346
RJU	F	North	19	538–860	1 300–6 500	–	407–595	–	–
		Centre	91	517–933	814–7 291	748–6 197	347–655	282–512	286–447
	M	North	24	480–860	650–5 000	–	355–550	–	–
		Centre	94	522–959	640–6 230	570–5 630	348–602	279–507	266–452

TL, total length; TW, total weight; gW, gutted weight; DW, disc width; DL, disc length; CL, tail length; JAI, *R. miraletus*; RJC, *R. clavata*; RJH, *R. brachyura*; RJM, *R. montagui*; RJN, *L. naevus*; RJU, *R. undulata*.

Based on the statistical significance of the adjustments above, two procedures were used to estimate the conversion factors: (i) if the model selected explained  $>50\%$  of the total variance, the size conversion factor was estimated from the combination of the different levels of the factors with a significant effect, using Equations (1) and (2); (ii) if the model captured only a small part of the total variance ( $<50\%$ ), the conversion factors were estimated by adjusting a linear model to the pairs of measurements under analysis, without considering the effect of the previous factors (sex, area, and TL class). The least-squares method was used to estimate the parameters of the expressions  $TL \sim a DW + b$ ,  $TL \sim a CL + b$ ,  $TL \sim a DW + b$ , and  $DW \sim a DL + b$ , where  $a$  is the intercept and  $b$  the slope.

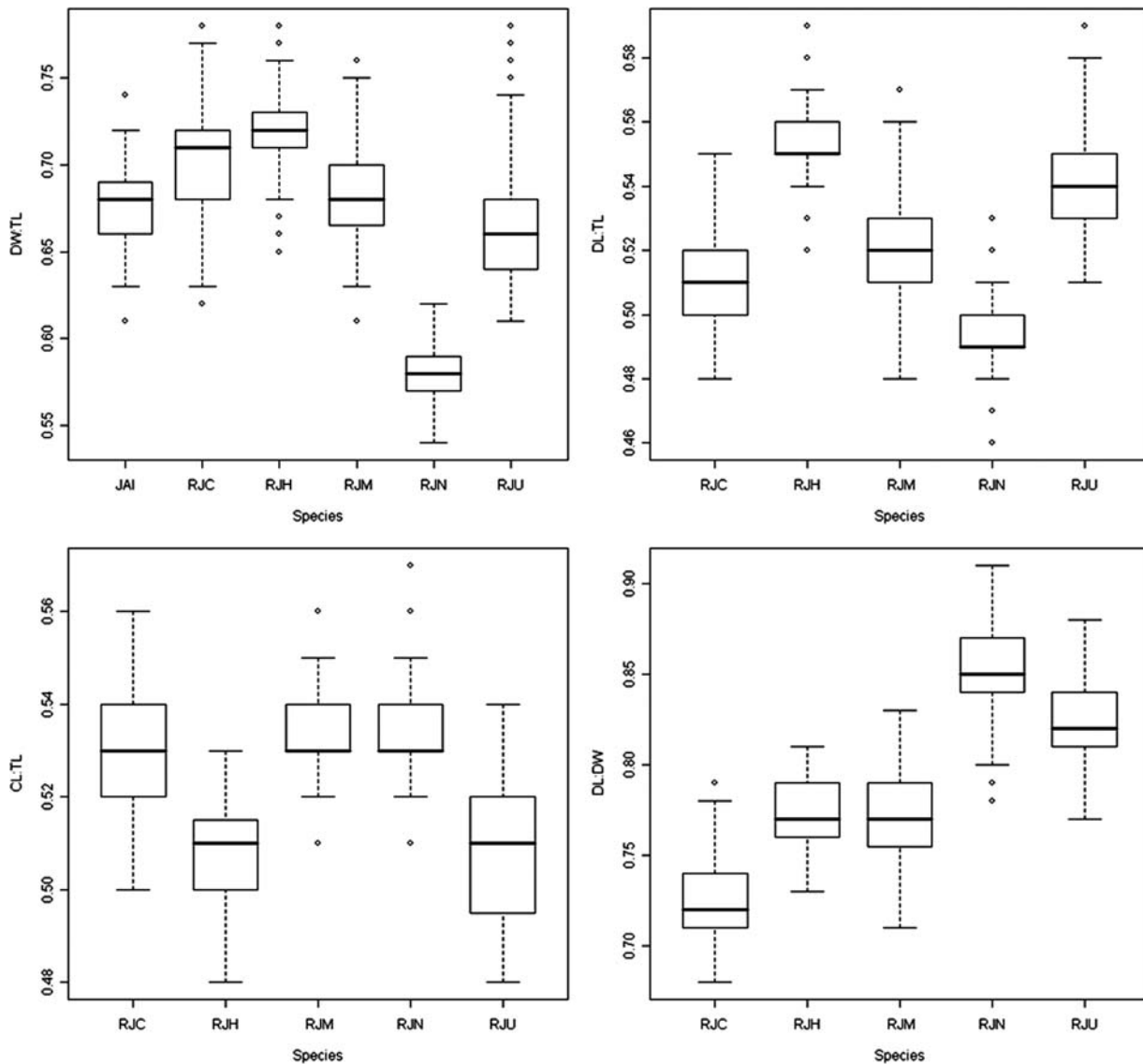
The allometric relationships between TW and TL and between gW and TL were adjusted, and the parameters estimated by a non-linear least-squares method (Venables and Ripley, 2002):  $TW \sim a TL^b$  and  $gW \sim a TL^b$ , where  $a$  is the initial growth coefficient or condition

factor and  $b$  represents the growth rate. Likelihood-ratio tests (Draper and Smith, 1981) were applied to compare the parameter estimates between sexes for the two length–weight relationships.

A flexible discriminant analysis (FDA; Hastie *et al.*, 1994) was applied to investigate whether a simple combination of morphometric ratios was adequate to discriminate between species. All available species were used in these analyses. The FDA is a method for multigroup classification, and rules are built to predict the class membership of an item (species) based on several predictors, in this case the morphometric ratios. The morphometric ratios used as body-shape descriptors were: DW:TL (whole body shape), DL:DW (disc shape), and CL:DL (relative tail size).

## Results

In all, 2009 fish were sampled, and Table 1 summarizes the number sampled by species, sex and geographical area, and their size ranges.



**Figure 3.** Boxplots showing species-specific variation in the morphometric ratios DW:TL, DL:TL, CL:TL, DL:DW. JAI, *R. miraletus*; RJC, *R. clavata*; RJH, *R. brachyura*; RJM, *R. montagu*; RJN, *L. naevus*; RJU, *R. undulata*. Boxplot statistical entries: maximum, third (75%) quartile, median, first (25%) quartile, and minimum, and the open circles represent outliers.

### Morphometric variation within species

Apart from the variability observed between species, differences in the morphometric ratios (DW:TL, DL:TL, CL:TL and DL:DW) were also observed within species (Figure 3). *Leucoraja naevus* was clearly the species showing the most distinctive shape, relative to the other species. It has a narrower disc in relation to body length (lowest DW:TL) and the disc is longer than wide (higher DL:DW). *Raja montagui* showed the following morphometric similarities with the other three species: DL:TL and CL:TL with *R. clavata*; DL:DW with *R. brachyura*; and DW:TL with *R. miraletus*.

Nested models for the DW:TL ratio, considering the interactions of area, sex, and TL classes, were statistically significant for *R. clavata*, *R. montagui*, and *R. undulata* ( $p < 0.001$ ). Nested

models for the CL:TL ratio, considering the interaction between sex and TL classes, were statistically significant for all species except *R. undulata* ( $p < 0.01$ ). The nested model for DL:DW, considering the interaction between sex and TL classes, was only significant for *R. brachyura* ( $p < 0.001$ ). The size conversion factors estimated for the aforementioned nested models are presented in Table 2. Variations between area, sex, and TL class were observed, but there was no general trend.

For the remaining ratios (i.e. TL ~ DW for *R. miraletus*, *R. brachyura*, and *L. naevus*, TL ~ CL for *R. undulata*, TL ~ DL for all species but *R. miraletus*, and DW ~ DL for all species except *R. miraletus* and *R. brachyura*), there were linear relationships (Table 3). The estimates of the parameters for these relationships can be used as conversion factors between the various

**Table 2.** Estimates of the nested models for the morphometric ratios (DW:TL, CL:TL, and DL:DW), by sex, area (N, north; C, centre; S, south), and TL class.

Species	Ratio	R <sup>2</sup>	TL class (mm)	Females			Males		
				N	C	S	N	C	S
RJC	DW:TL	0.56	300	0.715	0.716	0.717	0.642	0.666	0.703
			400	0.722	0.710	0.707	0.717	0.710	0.723
			500	0.711	0.717	0.725	0.704	0.703	0.692
			600	0.721	0.719	0.745	0.682	0.699	0.680
			700	0.715	0.727	0.728	0.663	0.673	0.674
	800	0.709	0.717	–	–	–	0.640		
	CL:TL	0.56	400	–	0.540	–	–	0.557	–
			500	–	0.536	–	–	0.457	–
			600	–	0.527	–	–	0.537	–
			700	–	0.515	–	–	0.540	–
800			–	0.522	–	–	0.540	–	
RJH	CL:TL	0.54	400	–	0.515	–	–	0.510	–
			500	–	0.513	–	–	0.519	–
			600	–	0.523	–	–	0.510	–
			700	–	0.500	–	–	0.513	–
			800	–	0.495	–	–	0.500	–
	900	–	–	–	–	–	–		
	1 000	–	0.480	–	–	–	–		
	DL:DW	0.51	300	–	0.765	–	–	0.81	–
			400	–	0.753	–	–	0.765	–
			500	–	0.752	–	–	0.757	–
600			–	0.76	–	–	0.766	–	
700			–	0.771	–	–	0.776	–	
800	–	0.782	–	–	0.787	–			
900	–	0.78	–	–	0.788	–			
1 000	–	0.772	–	–	–	–			
RJM	DW:TL	0.51	300	0.7	0.74	0.714	0.644	0.662	0.701
			400	0.6933	0.702	0.707	0.682	0.676	0.704
			500	0.702	0.687	0.705	0.66	0.655	0.69
			600	0.684	0.688	–	–	–	–
			700	0.65	0.69	–	–	–	–
	CL:TL	0.52	400	–	0.539	–	–	0.534	–
			500	–	0.533	–	–	0.546	–
			600	–	0.523	–	–	0.551	–
			700	–	0.55	–	–	0.55	–
			800	–	0.532	–	–	0.524	–
RJM	CL:TL	0.51	500	–	0.524	–	–	0.521	–
			600	–	0.524	–	–	0.521	–
			700	–	0.524	–	–	0.521	–
RJN	CL:TL	0.51	400	–	0.55	–	–	0.55	–
			500	–	0.532	–	–	0.524	–
			600	–	0.524	–	–	0.521	–
			700	–	0.524	–	–	0.521	–
			800	–	0.524	–	–	0.521	–
RJU	DW:TL	0.72	400	0.664	0.664	–	0.726	0.726	–
			500	0.74	0.673	–	0.706	0.769	–
			600	0.707	0.678	–	0.69	0.769	–
			700	0.706	0.676	–	0.653	0.759	–
			800	–	0.662	–	0.606	0.738	–

TL, total length; DW, disc width; DL, disc length; CL, tail length; RJC, *R. clavata*; RJH, *R. brachyura*; RJM, *R. montagui*; RJN, *L. naevus*; RJU, *R. undulata*.

**Table 3.** Parameter estimates of the linear models for the pairs of linear distances (DW ~ TL, CL ~ TL, DL ~ TL, and DL ~ DW), and the non-linear models,  $W \sim a TL^b$  and  $gW \sim a TL^b$ , with standard errors around the estimates presented in parenthesis.

Relationship	Parameter	JAI	RJC	RJH	RJM	RJN	RJU
TL ~ DW	a	-33.02 (27.18)	-	-17.78 (5.66)	-	51.89 (7.46)	-
	b	1.60 (0.10)	-	1.43 (0.01)	-	1.57 (0.02)	-
	R <sup>2</sup>	0.88	-	0.98	-	0.93	-
TL ~ CL	a	-	-	-	-	-	-34.66 (17.36)
	b	-	-	-	-	-	2.07 (0.05)
	R <sup>2</sup>	-	-	-	-	-	0.98
TL ~ DL	a	-	45.69 (8.83)	32.62 (5.30)	54.50 (7.86)	66.37 (8.88)	2.23 (12.77)
	b	-	1.83 (0.02)	1.73 (0.01)	1.72 (0.03)	1.78 (0.03)	1.84 (0.03)
	R <sup>2</sup>	-	0.97	0.99	0.94	0.91	0.96
DW ~ DL	a	-	10.12 (6.95)	-	11.75 (5.96)	17.98 (5.04)	37.72 (7.32)
	b	-	1.36 (0.02)	-	1.26 (0.02)	1.11 (0.02)	1.13 (0.02)
	R <sup>2</sup>	-	0.96	-	0.93	0.92	0.96
$W \sim a TL^b$	a	-	$5.20 \times 10^{-6}$ (1.77 $\times 10^{-6}$ )	$1.98 \times 10^{-6}$ (5.07 $\times 10^{-7}$ )	$3.44 \times 10^{-7}$ (1.53 $\times 10^{-7}$ )	$1.55 \times 10^{-7}$ (7.45 $\times 10^{-8}$ )	$1.92 \times 10^{-5}$ (8.61 $\times 10^{-6}$ )
	b	-	3.05 (0.05)	3.20 (0.04)	3.47 (0.07)	3.58 (0.08)	2.86 (0.07)
	R <sup>2</sup>	-	$5.71 \times 10^{-6}$ (2.23 $\times 10^{-6}$ )	$3.22 \times 10^{-6}$ (8.12 $\times 10^{-7}$ )	$8.03 \times 10^{-7}$ (3.79 $\times 10^{-7}$ )	$2.51 \times 10^{-7}$ (1.27 $\times 10^{-7}$ )	$4.91 \times 10^{-6}$ (2.90 $\times 10^{-6}$ )
$gW \sim a TL^b$	a	-	3.02 (0.06)	3.11 (0.04)	3.32 (0.07)	3.49 (0.08)	3.04 (0.09)
	b	-	-	-	-	-	-
	R <sup>2</sup>	-	-	-	-	-	-

TL, total length; DW, disc width; DL, disc length; JAI, R. miraletus; JAI, R. miraletus; RJC, R. clavata; RJH, R. brachyura; RJM, R. montagui; RJN, L. naevus; RJU, R. undulata.

morphometric measurements. The coefficient of determination was high for all adjusted linear models ( $R^2 > 0.85$ ).

According to the results of the likelihood-ratio test, the differences between the estimated parameters of the length ~ weight models (TW ~ TL and gW ~ TL) adjusted by sex were not statistically different at a 95% confidence level, for all species. The parameter estimates of the non-linear models TW ~ TL and gW ~ TL are also presented in Table 3. The estimated allometric coefficients were between 2.86 (*R. undulata*) and 3.58 (*L. naevus*) for TW ~ TL, and between 3.02 (*R. clavata*) and 3.49 (*L. naevus*) for gW ~ TL.

**Species discrimination using morphometric analysis**

In a first FDA procedure, the species and sexes were entered as discriminant classes. The FDA results revealed no sexual dimorphism in the morphometric ratios for most of the species studied (Table 4). The misclassification error was 0.33. The species with the lowest misclassification between sexes was *R. montagui* (10% for females and 0% for males), followed by *R. clavata* (16% for males and 21% for females). Yet, *R. montagui* females were misclassified as *R. clavata* males in 20% and as *R. brachyura* females in 14%. The species with the greatest misclassification between sexes were *R. brachyura* and *L. naevus*, for both of which most males were identified as females, 92 and 77% accordingly.

In the second procedure, only species were entered as discriminant classes. In this case, the morphometric ratios (DW:TL, DL:DW, and CL:DL) proved to be adequate for discriminating rajid species (Table 5). The misclassification error was 0.12. *Leucoraja naevus* was always discriminated from the other case-study species. The greatest proportion of misclassifications was between *R. clavata* (15%) and *R. montagui* (29%). The former was misclassified as *R. montagui*, and the latter as either *R. clavata* or *R. brachyura*.

**Discussion**

Following the call made by the ICES WGEF (ICES, 2007), size conversion factors were estimated for the six skate species studied here. A clear definition of the measurements, including anterior and posterior reference points and how the distance between these two points was measured, allow future application of the results without additional bias (Francis, 2006). As proposed, the longest longitudinal axis (TL) was used in most size conversion factors, because it is considered to be the best index of size (Francis, 2006). In some species (e.g. *R. clavata*, *R. montagui*, and *R. undulata*) differences were recorded between sexes, areas, and size classes. These differences should be taken into consideration when applying the conversion factors to other subsets, and for that reason, the sex, area, sample size, and length range of dependent and independent variables were reported for each species. Only limited morphometric information has been presented by other authors, typically in association with reproduction and growth studies, with the TL ~ W and TL ~ DW relationships the most frequently reported (Du Buit, 1975; Nottage and Perkins, 1983; Ryland and Ajayi, 1984; Coelho and Erzini, 2002). Jardas (1975) was the only author to focus on the morphometry of *R. clavata*, but he did not provide conversion factors. Pallaoro et al. (2005) presented the W ~ TL relationship for *R. clavata* and *R. miraletus*. Comparing the results from different studies, it is evident that, even for the same species, the conversion factors can vary between areas and sexes. The TL ~ W relationship is merely indicative for a species, because weight varies with size

**Table 4.** Results of the FDA between five skate species and sexes (F, female; M, male).

	RJC (F)	RJC (M)	RJH (F)	RJH (M)	RJM (F)	RJM (M)	RJN (F)	RJN (M)	RJU (F)	RJU (M)
RJC (F)	78	21	2	0	0	5	0	0	0	0
RJC (M)	16	54	0	0	20	0	0	0	0	0
RJH (F)	6	4	91	92	14	10	0	0	0	0
RJH (M)	0	0	0	0	0	0	0	0	0	0
RJM (F)	0	21	7	4	66	10	0	0	6	0
RJM (M)	0	0	0	0	0	75	0	0	6	0
RJN (F)	0	0	0	0	0	0	97	77	0	10
RJN (M)	0	0	0	0	0	0	2	23	0	5
RJU (F)	0	0	0	4	0	0	0	0	61	43
RJU (M)	0	0	0	0	0	0	2	0	28	43

Each column corresponds to the identified species and sexes and the rows correspond to the classification made by the FDA model. RJC, *R. clavata*; RJH, *R. brachyura*; RJM, *R. montagui*; RJN, *L. naevus*; RJU, *R. undulata*. The cells of the matrix represent the percentage of the classification. Total misclassification error, 0.33.

**Table 5.** Results of the FDA between five species of skate.

	RJC	RJH	RJM	RJN	RJU
RJC	85	1	18	0	0
RJH	3	91	11	0	5
RJM	12	6	71	0	5
RJN	0	0	0	100	8
RJU	0	1	0	0	82

Each column corresponds to the species and the rows correspond to the classification made by the FDA model. RJC, *R. clavata*; RJH, *R. brachyura*; RJM, *R. montagui*; RJN, *L. naevus*; RJU, *R. undulata*. The cells of the matrix represent the percentage of the classification. Total misclassification error, 0.12.

class, and many external factors may also influence the total weight of an individual, and hence influence the TL ~ W relationship, including maturation, spawning period, and food intake (Bagenal and Tesch, 1978). Moreover, the size range used in an analysis may also account for any differences observed between various studies. For that reason, the TL ~ W relationships are only really applicable for the size range examined (Petrakis and Stergiou, 1995). Data on gW are limited, and such data could be usefully collected in future studies elsewhere in European waters. The gW could be more informative when comparing fish from different sampling areas exposed to different environmental conditions.

The results indicate that morphometric ratios may be considered a useful, simple, and reliable additional tool for helping with species discrimination. They can be applied successfully in cases where recurrent doubts remain on the separation of species, as is often the case between some specimens of *R. montagui* and *R. brachyura*, which can share a similar colour pattern, but do show distinct body morphometry, with a low percentage of misclassification between them. Also, if less specialized workers encounter problematic animals in the field, the collection of more information on the morphometry of such fish could serve as a useful tool for subsequently validating identification, without the need for examining more complex diagnostic characters (e.g. the number of rows of teeth, or clasper structure). Three morphometric ratios (DW:TL, DL:DW, and CL:DL) proved to be adequate for discriminating the six rajid species under study, according to FDA. The measurements proved to be 100% successful in identifying *L. naevus*, a species belonging to a different genus from the remaining five species, and therefore characterized by a defined morphotype, with narrow, long disc, and a long tail.

*Raja montagui* and *R. clavata* provided the most cases of misclassification; both these species have a diamond-shaped disc that could be a reason for the observed misclassification given by FDA.

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