Journal of Sea Research 142 (2018) 174–179

Contents lists available at ScienceDirect

Journal of Sea Research

journal homepage: www.elsevier.com/locate/seares

Some biological aspects of juveniles of the rough ray, *Raja radula* Delaroche, 1809 in Eastern Sicily (central Mediterranean Sea)

Francesco Tiralongo[a,b,*], Giuseppina Messina[b], Roberto Cazzolla Gatti[c,d], Daniele Tibullo[a,e], Bianca Maria Lombardo[b]

[a] Ente Fauna Marina Mediterranea, Avola, Italy
[b] Department of Biological, Geological and Environmental Sciences, University of Catania, Italy
[c] Department of Ichthyology and Hydrobiology, Biological Institute, Tomsk State University, Tomsk, Russia
[d] Department of Forestry and Natural Resources, Purdue University, West Lafayette, USA
[e] Department of Biomedical and Biotechnological Sciences, University of Catania, Catania, Italy

ARTICLE INFO

Keywords:
Skates
Feeding habits
Ionian Sea
Elasmobranchii
Rajidae
Fisheries

ABSTRACT

Several biological aspects of juvenile specimens of *Raja radula* were investigated from February to May 2017 in the central Mediterranean Sea. Diet, sex ratio, disc width-weight relationships, and size-frequency distribution were analyzed. Stomach content analysis of 127 collected specimens showed that juveniles of *R. radula* actively feed on small benthic crustaceans, particularly on amphipods and isopods (*Idotea balthica*) (%IRI values of 62.74% and 12.39%, respectively). Although the Levin's index value ($Bi = 0.44$) indicated that juveniles of *R. radula* are a moderately stenophagous feeders, active mostly on crustaceans, the analysis of the prey-specific (*Pi*) biomass of the main preys vs. the frequency of their occurrence (%F) showed no clear dominance. The analysis of the sex ratio showed no significant difference in sex distribution. However, there were significant differences in mean size between sexes: females were, on average, larger than males, and also the b value (slope of the curve) of the disc width-weight relationships was higher in females.

1. Introduction

In Italian seas, skates (Rajidae) are represented by 16 species, distributed in 4 genera: *Dipturus*, *Leucoraja*, *Raja,* and *Rostroraja*. Among these, the genus *Raja* is the most diverse, with 8 species recorded from Italy (Vacchi and Serena, 2010). Although most of these species have low or no commercial value (Silva et al., 2012), some such as *Raja asterias* Delaroche, 1809, *Raja clavata* Linnaeus, 1758 and *Raja miraletus* Linnaeus, 1758 are important for conservation and fishery (Minervini et al., 1985; Zorzi et al., 2001; Ragonese et al., 2003; Enever et al., 2009). However, due to their low fecundity and growth rates, skates, as the other elasmobranch species, are particularly vulnerable to overexploitation (Ragonese et al., 2003).

Raja radula Delaroche, 1809 is an endemic species of the Mediterranean Sea (Serena, 2005), as well as *Leucoraja melitensis* (Clark, 1926), *R. asterias* and *Raja polystigma* Regan, 1923. Furthermore, *R. radula* is listed as "endangered" in the IUCN Red List (Mancusi et al., 2018). In Italian seas, this species, known as "rough ray", seems uncommon in the central (with the exception of Sardinia) and the northern areas, while it is common in the southern areas, especially in Sicilian seas. Here, it is usually caught mostly in trawls and trammel nets and considered as a bycatch or discards (Relini et al., 2000; Tiralongo et al., 2018). This species is a relatively small skate that inhabits sandy (or mixed) and muddy bottoms, from shallow waters of 2–350 m (Mancusi et al., 2018; Tiralongo et al., 2018). Despite its conservation importance, few quantitative studies have been conducted on the feeding habits of this species (Capapé and Azouz, 1975; Abdel-Aziz, 1986; Consalvo et al., 2010; Kadri et al., 2013) and little is known about other aspects of its biology (Kadri et al., 2014), such as the sex ratio, the length-weight relationships, age and growth.

This study provides new additional biological information on *R. radula* juveniles from the central Mediterranean Sea including: (i) diet composition and feeding habits; (ii) disc width-weight relationships; (iii) size-frequency distribution and (iv) sex ratio. These data increase the knowledge on the biology and ecology of this species.

2. Material and methods

A total of 127 specimens of *R. radula* juveniles were collected from fishermen operating trammel nets in the south-east coast of Sicily

* Corresponding author at: Ente Fauna Marina Mediterranea, Via M. Rapisardi trav. VIII, n°2, 96012 Avola, Italy.
E-mail address: fra.tiralongo@hotmail.it (F. Tiralongo).

https://doi.org/10.1016/j.seares.2018.10.001
Received 13 April 2018; Received in revised form 2 October 2018; Accepted 4 October 2018
Available online 06 October 2018

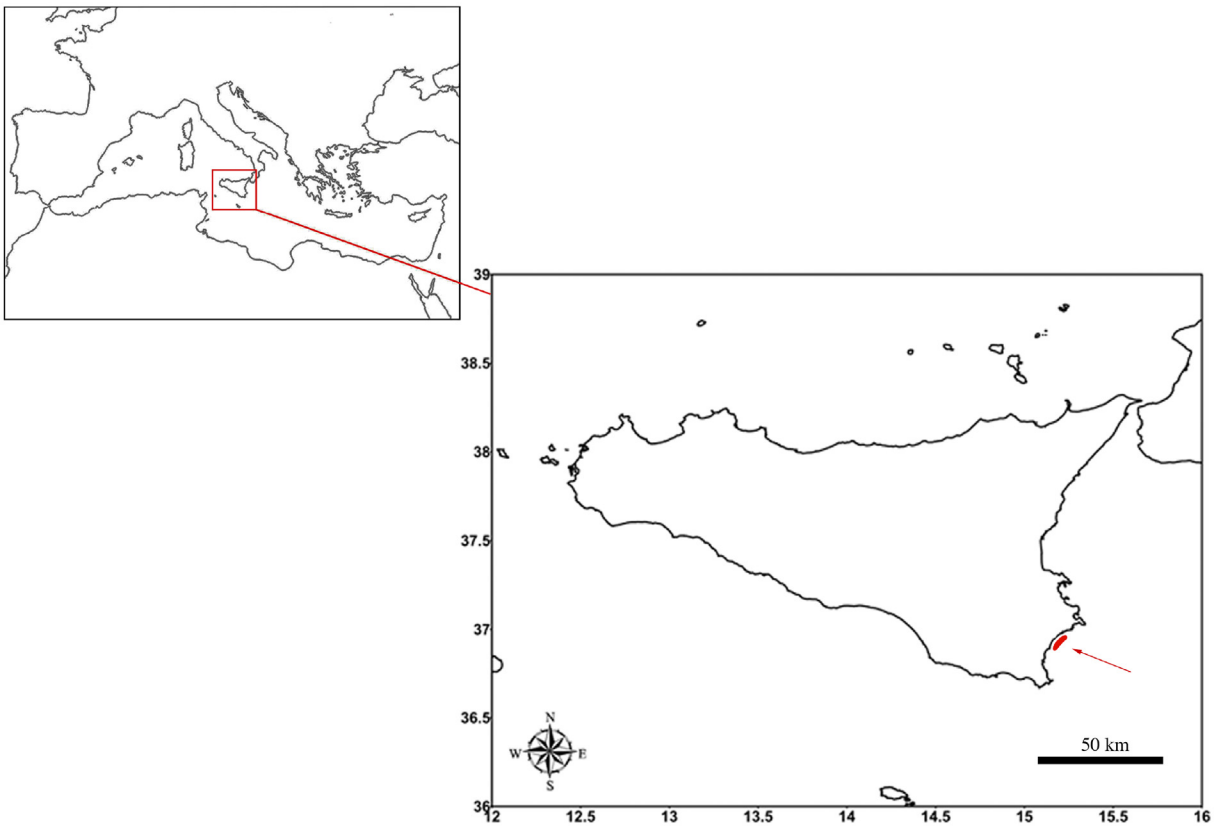

Fig. 1. Study area (in red and indicated by the red arrow) in the Ionian coast of Sicily (central Mediterranean Sea). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

(Avola, Ionian Sea) (Fig. 1). In order to better represent the population, specimens were randomly selected from different fishing vessels. About 32 specimens per month were collected between February and May 2017, at 2–12 m depth, during the fishing season of *Sepia officinalis* Linnaeus, 1758 (Tiralongo et al., 2018). Trammel nets were deployed overnight (from 6 pm to 4 am) for about 10 h, on sandy and mixed bottom (sand and rocks), close to *Posidonia oceanica* meadows.

Each specimen was weighed and measured (straight disc width) and the sex identified. The previous studies conducted in nearby areas, such as Tunisian (Mejri et al., 2004) and Sicilian waters (Consalvo et al., 2010), reported that males and females of *R. radula* become adult (i.e. 100% of the specimens become mature) above 320 and 340 mm disc width, respectively. These reference values were applied to classify specimens as adult or juvenile depending on whether they were above or below such sizes. Weight and disc width measures were used for the length-weight relationships following the formula: $W = aL^b$, where W is the weight in grams (g), L is the disc width (DW) in millimeters (mm), a is the intercept and b is the slope. Disc-width frequency distributions were constructed for both sexes. Chi-square test was used to verify if there was a significant difference ($\alpha = 0.05$) between the observed and the expected sex ratio (M:F) of the whole sample. To test if the regressions of the weight on length were significantly different ($\alpha = 0.01$) for the two sexes, an analysis of covariance (ANCOVA) was employed. We also analyzed the regression between the length and the weight for both sexes on a log-scale to derive the following equation: log(W) = log (alpha) + beta * log(DW) and the related exponential parameters.

The stomach was removed from each freshly caught fish and its content analyzed. All prey items in the stomachs were transferred into a petri dish and counted, weighed (after being washed in clean seawater and dried with blotter paper) to the nearest 0.01 g and identified under a stereomicroscope to the lowest taxonomic level possible.

The frequency of occurrence (%F), percentage weight (%W), percentage abundance (%N) and the Index of Relative Importance (% IRI) were calculated for each prey category (Hureau, 1970; Hyslop, 1980; Carrassòn et al., 1997). The vacuity index (percentage of empty stomachs) was also calculated.

According to the value of their percentage abundance (%N), preys were grouped into three categories (N'Da, 1992): dominant ($N > 50\%$), secondary ($10\% < N < 50\%$) and accidental ($N < 10\%$).

The feeding strategy of *R. radula* was investigated by plotting the prey-specific biomass (P*i*) against their frequency of occurrence (%F) (Amundsen et al., 1996):

$$Pi = \frac{SWi}{SWt_i} \times 100$$

where P*i* is the prey-specific biomass of prey *i*, SW_i the stomach content biomass of prey *i*, and SWt_i the total stomach content biomass in those predators with prey *i* in the stomach.

Standardized Levins' index (B*i*) was used to evaluate the breadth of the diet (Krebs, 1989):

$$B = \frac{1}{\sum p_j^2}$$

$$Bi = \frac{B - 1}{B_{max} - 1}$$

where p_j is the relative frequency specimens in the j^{th} prey item and B_{max} is the total number of prey item categories found (not identified categories were excluded from the analysis). B*i* is comprised between 0 (narrow trophic niche) and 1 (wide trophic niche); if $Bi < 0.40$ the species is considered a specialist, if $0.40 < Bi < 0.60$ is considered an "intermediate", if $Bi > 0.60$ is considered a generalist (Novakowski et al., 2008).

To evaluate whether the number of skate stomachs was sufficient to