UNIVERZA NA PRIMORSKEM
FAKULTETA ZA MATEMATIKO, NARAVOSLOVJE IN
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MAGISTRSKO DELO (MASTER'S THESIS)

SABAHETA HADŽIAVDIĆ

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(MASTER'S THESIS)

PREHRANJEVALNE NAVADE MALE MORSKE MAČKE (*SCYLIORHINUS CANICULA*) V SEVERNEM JADRANU
(FEEDING HABITS OF THE SMALL SPOTTED CATSHARK (*SCYLIORHINUS CANICULA*) IN THE NORTHERN ADRIATIC

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Prehranjevalne navade male morske mačke (*Scyliorhinus canicula*) v severnem Jadranu

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Izvleček:

V tej raziskavi je bila narejena analiza prehrane male morske mačke iz družine Scyliorhinidae v Severnem Jadranu. Mala morska mačka je ena izmed najpogostejših vrst pridnenih hrustančnic v Sredozemskem morju, tudi v Jadranskem morju. Globalna in evropska populacija sta danes po kriterijih Mednarodne zveze za varstvo narave (IUCN) opredeljeni kot najmnj zaskrbljujoči. Severni Jadran je edini del Jadranskega morja, kjer je mala morska mačka redka vrsta, predvsem zaradi posledic naključnega ulova. Analiza prehranjevalnih navad je nujna, če želimo raziskovati trofično prekrivanje med in znotraj vrst ter ugotoviti stopnjo med- in znotrajspecifične interakcije. Uporaba tradicionalnih metod kot je analiza vsebine želodca lahko zagotovi najbolj podrobne podatke o vzorcih prehrane. Pri tej raziskavi so analizirani osebki male morske mačke, ki so bili ulovljeni na šestih različnih lokacijah hrvaškega dela istrskega polotoka. Zbranih je bilo 205 osebkov, od česar smo analizirali 188 osebkov male morske mačke. Rezultati so pokazali, da predstavljajo glavonožci in kostnice najpomembnejše vrste plena. Od drugih skupin plena so morske mačke plenile rake, črve mnogoščetince, hrustančnice ter razne druge nevretenčarje. Izkazalo se je, da je mala morska mačka oportunistični plenilec, ki se prehranjuje z različnimi skupinami plena. Med spoloma so bile ugotovljene razlike v prehrani male morske mačke. Med velikostjo primerkov in prehranjevalnimi navadami pa razlike niso bile tako očitne. Izračun trofičnega nivoja je pokazal, da gre za mezoplenilca.

Key document information

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Abstract:

The subject of this research were the feeding habits of the small spotted catshark *Scyliorhinus canicula* Linnaeus, 1758 from the Scyliorhinidae family in the Northern Adriatic. This species is one of the most common species of benthic chondrichthyes in the Mediterranean and the Adriatic Sea. The global and European populations are considered to be of Least Concern by the Internacional Union for Conservation of Nature. The Northern Adriatic is the only part of the Adriatic Sea where this species is rare because of by-catch. Analysis of feeding habits is necessary in order to research trophic overlapping between and within species and to determine the level of inter- and intraspecific interaction. Use of traditional methods such as stomach content analysis can guarantee for the most detailed data on feeding patterns. Samples of the small spotted catshark collected from six locations along the Croatian part of the Istrian peninsula were analyzed. A total of 205 individuals were collected and we analyzed 188 of them. The results showed that the most important prey were cephalopods and teleost fishes. Other prey of the small spotted catshark were crabs, polychaet worms, chondrichythean fish and other invertebrates. It was shown that the small spotted catshark is an opportunistic generalist. There were differences in diets of the female and male small spotted catsharks. However, there were no significant differences in the diet of different length categories of the small spotted catsharks. Trophic level calculation showed that this species is a mesopredator.

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TL- total length

1 INTRODUCTION

1.1 Sharks in the Adriatic Sea

The latest and most up to date list of the Adriatic ichthyofauna, which was based on the evidence approach, consists of 444 species with confirmed record (Kovačič *et al.* 2020; Lipej *et al.* 2022). Out of these, latest evidence suggests the number of 55 chondrichtyan species recorded in the Adriatic Sea to date. Over a half of the chondrichthyan species registered in the Adriatic Sea are sharks species (superorder Pleurotremata, 53.57 %); rays (superorder Hypotremata) consist 42,86% of the total number and one species of chimaera is registered (order Chimaeriformes).
The Adriatic Sea presents an independent biogeographical and ecological subunit within the Mediterranean Sea, given to its composition and properties of the biological communities inhabiting the Adriatic (Lipej and Dulčić 2010). Zoogeographical analysis shows almost 60% of the Adriatic chondrichtyans belong to the Atlanto-Mediterranean species group (Dulčić *et al.* 2005).

1.2 Knowledge on feeding ecology of the cartilaginous fishes in the Adriatic sea

Feeding ecology is in a close connection with the population dynamics of a species. Good knowledge on the feeding ecology of a species provides a better insight into resource partitioning, habitat preference, prey selection, predation strategies, evolution, risk effects, competition, trophic ecology and energy transfer within and between ecosystems (Braga *et al.* 2012). Three approaches are necessary in order to study the diet of certain species: the analysis of stomach or gut content, prey availability in the immediate environment and analysis of the preference or rejection of the prey (Saikia 2016).

Fish feeding mode is correlated with their internal and external morphological characteristics, such as body shape, mouth shape, fin and tooth shape and placement, gut length and gill raker size and shape (Cailliet *et al.* 1996; Wootton 1998).

Data on the feeding habits of marine fish species and the mutual predator-prey relationships are very useful for the assessment of a species' role in the ecosystem (Šantić *et al.* 2012).

In relation to that, feeding niches are distinguished in accordance to the food a predator forages on.

There are two different strategies of resource exploitation: it is possible to distinguish generalists, who occupy wide niches and forage on different groups of prey, and specialists, who limit themselves to relatively small niches and feed on prey from only certain groups (Irschick *et al.* 2005). All of the information obtained from studying the feeding ecology of a species are also a valuable tool in the development of conservation strategies and could be referred to as a key element in the protection of species and ecosystems (Braga *et al.* 2012). Although cartilaginous fishes have a relatively simple feeding apparatus, they have evolved a considerable range of prey capture modalities which include ram, suction, filter and bite. These modalities enable for cartilaginous fishes to consume a wide variety of food resources, ranging from zooplankton to whales (Huber *et al.* 2019).

In the past studies, sharks were considered to be mobile generalists with a wide or global feeding range who forage in an opportunistic manner (Munroe *et al.* 2013). Contemporary studies have shown that the feeding habit of sharks can differ depending on the species, within different populations of the same species, different age classes and in between sexes within the same population (Bethea *et al.* 2006; Edwards *et al.* 2011; Sommerville *et al.* 2011). Reasons for such differences are the differences in body shape and size, the ability of capturing the prey and the capacity of prey digestion (Munroe *et al.* 2014).

First studies of the feeding ecology of chondrichthyes in the Adriatic Sea were published by Jardas (1972). In the recent years, feeding ecology of some Adriatic cartilaginous fish species was well studied and described. Most data were obtained on benthic species, as they are most frequently caught during trawling studies or as by-catch during commercial bottom trawling events.

The cartilaginous fish species whose feeding habits were well documented in the Northern Adriatic is the starry skate *Raja asterias* (Delaroche,1809) (Sviben *et al.* 2019). In this study, specimens were collected from three different parts of the Northern Adriatic Sea.

Lipej and associates (2012) conducted a study on the feeding habits of the pelagic stingray *Pteroplatytrygon violacea* (Bonaparte, 1832) in the Northern Adriatic Sea where it was found this species was predominantly preying anchovies and the alternative prey were cuttlefish and the red band fish *Cepola rubescens* Linnaeus,1764. There is also a study conducted on the diet composition of the common smooth-hound *Mustelus mustelus* from the Northern Adriatic, where the main prey of the smooth-hound were portunid crabs from the genus *Liocarcinus* and small pelagic fish (Gračan *et al.* 2014). Another study conducted by Lipej and associates (2011) for the blackspotted smooth-hound *Mustelus punctulatus* Risso, 1826 confirmed that the main represented taxonomic groups in the diet of *M. punctulatus* were crustaceans, cephalopods, polychaetes, bivalves, and teleost fishes. In this study, the preferred prey species in term of frequency of occurrence and abundance was the bivalve *Solecurtus strigillatus* Linnaeus, 1758. A study on the first record of the porbeagle, *Lamna nasus* (Bonnaterre, 1788) in the Gulf of Trieste confirmed cephalopods and medium sized fish in the diet (Lipej *et al.* 2016).

Although there are several studies on the occurence and distribution of chondrichtyes species in the Northern Adriatic, namely the bull ray *Aetomylaeus bovinus* (Geoffroy Saint-Hilaire, 1817), common eagle ray *Myliobatis aquila* Linnaeus, 1758, pelagic stingray *Pteroplatytrygon violacea* (Bonaparte, 1832) (Šlejkovec et al. 2004; Mavrič *et al.* 2004; Lipej *et al.* 2012), the common angelshark *Squatina squatina* Linnaeus, 1758 (Fortibuoni *et al.* 2016), common thresher shark *Alopias vulpinus* (Bonnaterre, 1788), aforementioned *C. plumbeus*, tope shark *Galeorhinus galeus* Linnaeus, 1758, porbeagle shark *Lamna nasus* (Bonnaterre, 1788), common smooth-hound *M. mustelus* Linnaeus, 1758, blue shark *Prionace glauca* Linnaeus, 1758, multiple catshark species *Scyliorhinus spp.* and dogshark species *Squalus spp*. (Barause *et al.* 2014), systematic data on the feeding habits of these species are deficient. It is neccessary to conduct more research on this topic, given that there are studies confirming the occurrence of a fairly large number of cartilaginous fish in this area.

The Central Adriatic is an area where more data is available for the feeding ecology of chondrichtyes. There are available studies on the feeding habits of the brown ray *Raja miraletus* Linnaeus, 1758 (Šantić *et al.* 2013) and the thornback ray *Raja clavata* Linnaeus, 1758 (Šantić *et al.* 2012). A study regarding the feeding habits of the spiny dogfish *Squalus acanthias* Linnaeus, 1758 and the blackspotted smooth-hound *Mustelus punctulatus* (Risso, 1827) confirmed the prefered prey of the spiny dogfish were commercially exploited anchovies and sardines, whereas the main prey of the blackspotted smooth-hound were malacostracan crabs (Gračan *et al.* 2017). A study conducted on the feeding habits of the small-spotted catshark *Scyliorhinus canicula* Linnaeus, 1758 from the eastern Central Adriatic Sea conducted by Šantić and associates (2012) showed the species is a generalistic predator who forages on a large number of prey species, mainly decapod crabs and teleosts, and has a wide range of prey size and morphology (Šantić *et al.* 2012).

For the Southern Adriatic, there has been a study on the feeding ecology of the velvet belly shark *Etmopterus spinax* Linnaeus, 1758 caught off Mola di Bari in the South-western Adriatic. Results of the study indicated this species is a generalistic predator, feeding on nectonic teleosts, cephalopods, decapod and euphasiid crabs (Bello 1998).

1.3 Small spotted catshark *Scyliorhinus canicula*

The family Scyliorhinidae Gill, 1862 is the most diverse family of sharks, which includes around 160 species (Compagno *et al.* 2005). Sharks of this family have a global distribution, from tropical to cold temperate latitudes and are found in depths from the intertidal zone down to 2000 m (Human *et al.* 2006; Soares and de Carvalho 2019). Species of the genus *Scyliorhinus* Blainville, 1816 are distinguished by the presence of a projecting flap at the upper lip margin, the presence of a pelvic apron in males, the presence of an extension of the pelvic apron that is longer than half the length of the pelvic inner margin and varied color patterns, which are used for identification purposes (Soares and de Carvalho 2019). There are 16 benthic shark species in this genus which are distributed in temperate to tropical waters around the world (Ito *et al.* 2022). The small spotted catshark is the type species of the genus (table 1).

Table 1: Systematics of the small spotted catshark (www.worms.org)

Kingdom	Animalia
Phylum	Chordata
Subphylum	Vertebrata
Infraphylum	Gnathostomata
Class	Elasmobranchii
Subclass	Neoselachii
Infraclass	Selachii
Superorder	Galeomorphi
Order	Carchariniformes
Family	Scyliorhinidae
Genus	*Scyliorhinus*

The small spotted catshark is distributed in the northeast and eastern central Atlantic, from the Shetland islands and Norway in the north, to Western Africa in the south, the Mediterranean Sea included (Compagno *et al.* 2005; Ellis *et al.* 2009). It is considered to be the most abundant species of the family Scyliorhinidae in European inshore waters (Ivory *et al.* 2005)(figure 1).

Figure 1: Map of distribution of the small spotted catshark (Ellis *et al.* 2009)

The data available from the Mediterranean International Trawl Survey (MEDITS) programme, conducted from 1994 to 1999, showed this species occurs widely throughout the Northern Mediterranean Sea. During these surverys, *S. canicula* was caught in all parts of the Mediterranean except for Northern and Southwestern Adriatic Sea, northwestern and northern Ionian Sea and off eastern Sicily (Ellis *et al.* 2009). Individuals of this species can be found from the shallow sub-littoral to the edge of the continental shelf, on different kinds of substrates, such as sandy, muddy, coralline algal and gravely bottoms (Ellis *et al.* 2009). It prefers depths from 80 to 100 m, although individuals of the species were found also in depths ranging from 10 to 780 m (Mytilineou *et al.* 2005; Capapé *et al.* 2008).

Individuals of this species are small- sized sharks; the normal size distribution recorded for the Adriatic population falls within the range 9-49 cm in length and the maximum recorded size for a specimen caught in the Adriatic Sea is approximately 70 cm (Jardas 1996; Lipej *et al.* 2004). Females reach maturity at 32-40 cm TL, whereas size at maturity for the males is 27.5-33 cm TL (Županović and Jardas 1989). Compagno and associates (2005) report this species grows to a larger size in the Atlantic than the Mediterranean.

Individuals are known to aggregate in groups by sex and size, although it remains unclear whether this segregation is connected to habitat differences or behaviour paterns (Sims 2003).

Small spotted catsharks have a slender and cylindrical body, the trunk being shorter than the tail. The dorsal part of the body is light-brown in colour, covered in numerous light and dark spots; the abdominal region is pale white. The pectoral fin ventral surface is light gray-brown in colour and covered in small grayish spots, which are changing to white in the basal part. The head is moderately broad and depressed; the head length is 1.7-2.6 times the head width (figure 2). Eyes are positioned dorsolateraly on the head; the nictitating lower eyelid is of rudimentary type, with a shallow subocular pouch and secondary lower eyelid free from the upper eyelid. The first two gill openings are approximately equally wide, with the first one being twice as long as the fifth. All of the gill openings are slightly concave and are not elevated on the dorsolateral surface of the head. The gill filaments are not visible externally. The fifth gill pair is located over the base of the pectoral fin. The small spotted catshark has an arched and moderately short mouth, the length of the mouth is 1.3.-1.4 times the mouth width. The tongue is flat and rounded, usually light-coloured and the oral papillae are hardly detectable (Lipej *et al.* 2004; Lipej *et al.* 2006; Soares and de Carvalho 2019).

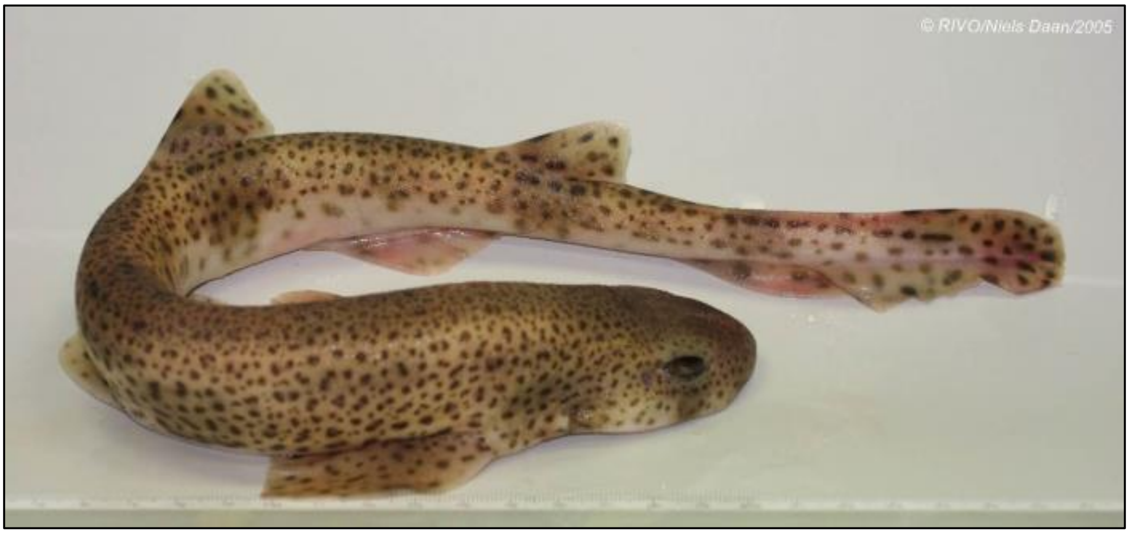


Figure 2: An individual of the small spotted catshark. N. Daan

The teeth of the small spotted catshark exhibit monognathic heterodonty, meaning there is a graded change in shape and size of the teeth present from the front to the back of the jaw (Spath *et al.* 2017; Soares and de Carvalho 2019). Anterior teeth are larger than the parasymphysial ones; the lateral teeth are decreasing towards the distal parts of the jaw (Soares and de Carvalho 2019). Sexual heterodonty is also well distingushed; females present more cusplets in the parasymphysial, anterior and lateral teeth and the principal cusp is shorter in relation to the males (Ellis and Shackley 1995; Soares and de Carvalho 2019). Teeth of the upper and lower jaw are unequally distributed in four to six series. There is a total of 400-450 teeth in the jaws. Mean value of tooth replacement for this species is five weeks/row (Botella *et al.* 2009).

The small spotted catshark, like all of the species in the family Scyliorhinidae, is an oviparous species. The individuals deposit egg-cases that are protected by a horny capsule with long tendrils. The egg-cases are often deposited on macroalgae in shallow coastal waters (Ellis *et al.* 2009). Eggs are 4 cm long, 2 cm wide and 1 cm thick, furnished with long filaments at every angle and because of this the eggs can be fixed to algae and gorgonians living at the sea bottom (Lipej *et al.* 2004). Spawning can take place almost all year round, although in the Mediterranean Sea, individuals breed annually from November to July with gestation lasting approximately 5-11 (usually eight or nine) months; the gestation duration greatly depends on habitat water temperature (Ellis and Shackley 1997; Ellis *et al.* 2009). The sex ratio of recently hatched fish is about 1:1 and the size of individuals at birth is 7-11 cm TL (Ellis and Shackley 1997). The maximum reported age for this species is 12 years (Ivory *et al.* 2005).

The small spotted catshark is assessed as a Least Concern species by the IUCN. Survey catch rates are either stable or increasing throughout the majority of its range both in Northeast Atlantic and Mediterranean Sea. Although commercial landings for the species are reported, with larger individuals being retained for human consuption, individuals of the species are often discarded with a high survival rate afterwards (Ellis *et al.* 2009). As it was already noted, in terms of the Adriatic Sea, this species is rare only in the Northern Adriatic, due to a high rate of by-catch during trawling (Lipej *et al.* 2006).

1.4 Working hypotheses

The purpose of this research is to obtain data on the feeding habits of the small spotted catshark in the Northern Adriatic, an area where the species is rare and susceptible to anthropogenic influence. The obtained data may contribute to developing a more sustainable strategy of the species conservation in the Northern Adriatic.

The first goal is to define which are prey groups the species forages upon most frequently in the coastal area of the Northern Adriatic. Within this, an emphasis will be made on comparing the feeding habits of *S. canicula* and other chondrichtyan species in order to study whether there is competition between sympatric species, which will give an insight into inter-species competition relations. Better knowledge of the preferred prey of this species may also contribute to a better knowledge of its importance in the habitat.

The second goal is to examine whether there are differences in the feeding habits between males and females within the species. This may provide additional data on the potential differences in food preference in relation to sex and intra-species competition. Data may also be used to examine whether these is an ontogenetic shift in the biology of this species. All obtained data will be utilized for the placement of the species in the trophic web of the predators of the Northern Adriatic.

In order to achieve the goals of the research, working hypotheses have been defined:

1. *S. canicula* is a generalistic predator.
2. There are differences in the feeding habits of males and females of the species.
3. There are differences in the feeding habits between juveniles and adults of the species.

2 MATERIAL AND METHODS

2.1 Study area

The Adriatic Sea is a small semi-enclosed sea connected to the Eastern Mediterranean via the Strait of Otranto. It is, apart from the Black Sea, the northernmost part of the Mediterranean Sea. The Adriatic Sea is 783 km long and has a mean width of 243 km, with shelf making up about 74% of the sea bed (Lipej and Dulčić 2004). The western coast is regular, sandy and has a gentle slope, whereas the eastern coast is irregular, with numerous islands and a rocky steeply sloping bathymetry (Zavatarelli *et al*. 1998). The Adriatic Sea is longitudinaly divided into three distinct geographic regions: The Northern, Central and Southern Adriatic. The Northern Adriatic is an area ranging from the north-most point in the Gulf of Trieste to a fictitious diagonal between the towns of Karlobag and Ancona; the Central Adriatic occupies the area south of the Karlobag-Ancona and north of the fictitious Ploče- Monte Gargano mountains diagonal; the South Adriatic is the area south of the aforementioned Ploče- Monte Gargano mountains diagonal (Lipej *et al.* 2006)(figure 3).

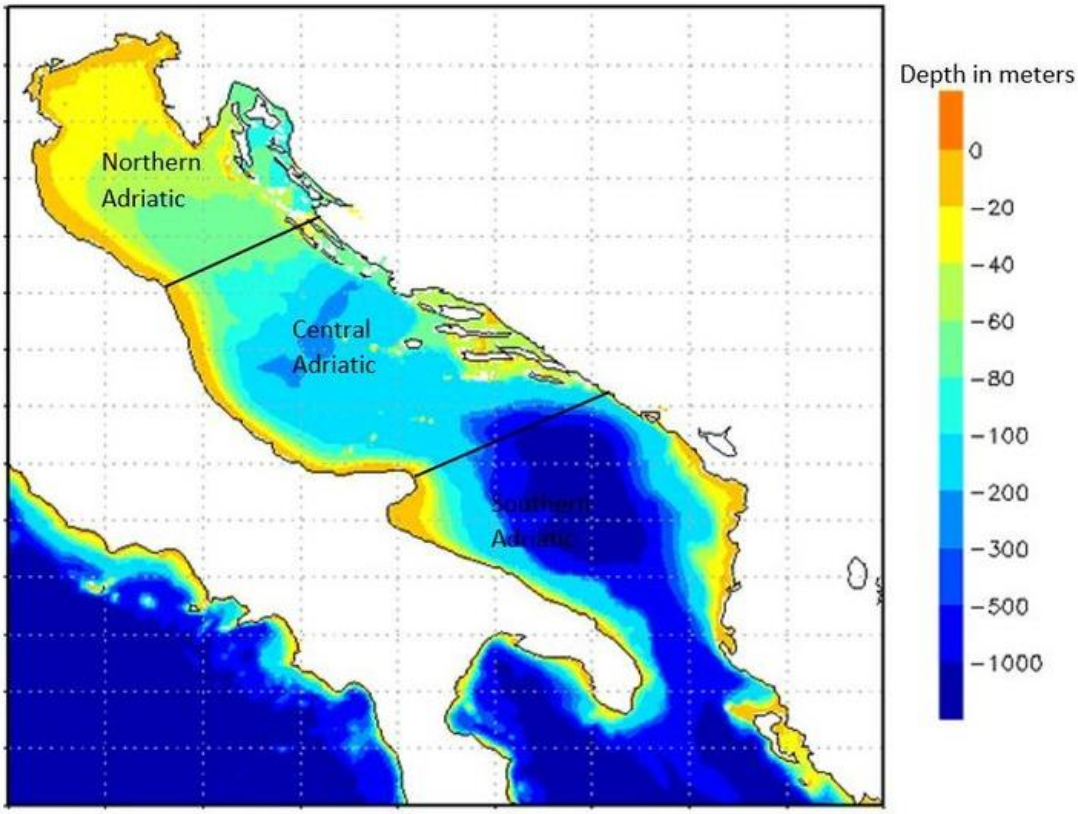


Figure 3: Division of the Adriatic Sea into regions (Akkaya *et al.* 2018)

In general, the Adriatic is a moderately warm sea: the annual surface temperature is 18ºC in the northern part and 25ºC in the southern part, while temperatures of even the deepest layers are generaly above 10ºC, in the southern part above 12ºC away from the shelf. Salinity is relatively high, the largest part of the Adriatic Sea has a salinity of 38.4-38.9, while the northern part close to the Po river mouth has the lowest salinity (Cushman-Roisin *et al.* 2001).

The Northern Adriatic is a shallow and gently sloping region with an average bottom depth of 35 m. It is area area where a strong water stratification can be observed. The water column of the Northern Adriatic is composed of surface water (NadSW) above 20 m depth, which is strongly influenced by river runoff and deep water (NadDW) below 20 of depth. The NadDW has a density greater than 29.2, the average temeprature is around 11ºC and salinity of approximately 38.3 and is observed only in the winter (Zavatarelli *et al.* 1998). The hydrographic properties of the Northern Adriatic are under the influence of surface air-sea flux and the lateral Po river discharge rates (Supić *et al.* 2004). The Po river strongly influences the dynamics of the Northern Adriatic Sea not only with a great input of fresh water (an annual discharge of 1525 m^3) but also has an impact on the character of the seafloor with a massive delivery of sediment (Syvitski and Kettner 2007). The dominant winds are the bora, a northeasterly cold and dry wind, prevailing in winter, and the scirocco, a warm and humid wind that blows from the southeast along the axis of the Adriatic basin. The most important consequence of the bora is a cold air outbreak that cools the northern shallow waters and triggers deep-water formation. The blowing scirocco generally has maximum speeds in the eastern part of the Northern Adriatic, but combined with low atmospheric pressure and high tides, it causes flooding in the shallow lagoons along the Northern Adriatic coast, including the Gulf of Venice (Poulain *et al.* 2001).

The sea bottom in the Northern Adriatic is composed of muddy and sandy sediments. Factors such as active orogenic movements, erosion of the Alpine and Apennine mountain chains and river discharge have been the cause of the accumulation of thick clastic sediments. Along the Istrian coast, where the specimens for this research were collected, main constituents of the sediments are the eroded red soil and calcareous fragments from the northeast coast, biogenic calcareous shell, sand and silt and suspended material from the Po river, consisting of siliceous material (Meischner 1973).

The geographical characteristics of the Northern Adriatic, such as strong winter cooling, low salinity due to river discharge and a great tidal range, make it more similar to the northern Atlantic than to the rest of the Mediterranean (Bianchelli *et al*. 2016).

2.2 Sampling

Samples of the small spotted catshark were collected between March and November 2014 in waters along the Istrian peninsula in Croatia (figure 4).

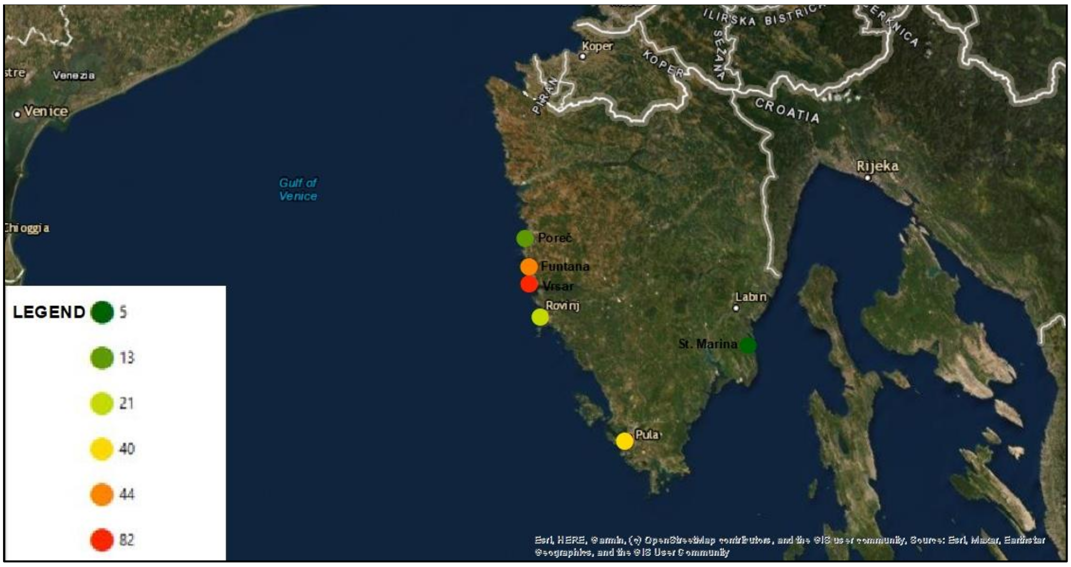


Figure 4: A map of the sampling locations of the small spotted catshark. The colour of the circle corresponds to the number of caught specimens

The specimens were obtained by the researchers of the Marine Biology Station of the National Institute of Biology in Piran, Slovenia from the Slovenian and Croatian fishermen. The individuals were caught as by-catch during trawling activities. A total of 205 specimens were caught. The samples were determined and labeled immediately after the sampling and stored in the collection of Marine Biology Station.

2.3 Laboratory work

2.3.1 Biometric measurements

Biometric analysis had been conducted in the laboratory of the of the Marine Biology Station of the National Institute of Biology in Piran, Slovenia. Biometric measurements were completed according to Compagno *et al.* (1984); out of 205 collected individuals, 188 samples were analyzed for diet composition and biometric analysis was conducted on 155 specimens. The individuals were measured to mm from the tip of the snout to the tip of the upper caudal lobe, sex was determined and the individuals were weighed.

There were 66 to 72 measurements made on every specimen, depending on the sex. There were a total of 100 males and 55 females analyzed (table 2).

Table 2: Number of individuals caught on individual sampling locations. Numbers are presented for the total count, count of females and males for biometric analysis

Location	**Total**	**Females**	**Males**
Funtana	44	17	27
Poreč	12	4	8
Pula	36	13	23
Rovinj	19	4	15
St. Marina	5	2	3
Vrsar	39	15	24

The individuals were also divided into four size categories, according to the total length. Adult specimens were considered those whose total length exceeded 470 mm (table 3).

Table 3: Size categories for the small spotted catshark

Size category	**Lower limit**	**Upper limit**
I	290	370
II	371	420
III	421	470
IV	471	520

2.3.2 Stomach dissection and isolation

Individuals were dissected in order to obtain the stomach. The contents of the stomach were isolated and stored in 70% ethanol for further analysis.

2.3.3 Stomach content analysis

The contents of every stomach was analyzed to the lower possible taxonomic category using the Olympus SZX16 magnifying stereomicroscope and photographed using the Olympus DP-Soft SZX16 program. Prey individuals were identified to the lowest taxonomical category regarding the taxa specific characteristics. We determined cephalopods by identifying their beaks (Francetović 2002), crustaceans by identifying their carapaces and claws using the specimens from comparative collection of the MBS and teleosts on the basis of their otoliths (Lombarte *et al*. 2006; Tuset *et al.* 2008). Other remaining body parts found were arthropod eyes and teleost vertebral columns, which were counted and used for determining the number of individual prey within a specific prey group per stomach content sample.

2.4 Data analysis

2.4.1 Stomach fullness

In order to assess the diet composition of the small spotted catshark, the vacuity index (VI) was calculated. It is defined as an inverse indication of feeding intensity which varies according to variations in the abundance, spawning time and seasonal changes in water temperature and food item (Sakamoto *et al.* 1982). The VI is calculated according to the following formula:

VI= (number of empty stomachs/ total number of stomachs) * 100

2.4.2 Prey numerical abundance, prey frequency and prey biomass

Prey numerical abundance (PN) is calculated using the formula:

PN= (number of *i* prey/total prey number) * 100

Prey frequency (PF) is calculated using the formula:

PF= (number of stomachs containing prey *i*/ full stomach total number) * 100

Prey biomass is assessed through gravimetric composition of the prey (PB), which is calculated by using the following equation:

PB= (prey *i* mass/ total prey mass) * 100

Average mass is calculated using the formula:

Average mass= total prey mass/ total prey number

Average meal is calculated using the formula:

Average meal= total prey mass/ full stomach total number

2.4.3 The index of relative importance

The Index of Relative Importance (IRI) is a composite measure that reduces bias in descriptions of animal dietary data (Hart *et al.* 2002). An accurate quantification of the importance of prey taxa and understanding of the contribution of various prey to predator

well-being is essential for effective management of fisheries resources (Bowen 1996; Liao *et al.* 2001). This index was introduced by Pinkas (1971) and modified by Hacunda (1981).

It incorporates the prey abundance, prey frequency and prey biomass and is calculated as follows:

$$IRI= (PN+PB) * PF$$

The relative IRI (%IRI) was used for easier result comparison:

$$\%IRI= (Prey\ i\ IRI/\ total\ prey\ IRI) * 100$$

The biomasses were calculated according to the data presented in the table 4.

Table 4: The average weight of of the prey biomass of the small spotted catshark

Taxa	**Mass (g)**	**Reference**
Invertebrata- indeterminata	35.7	Estimate
Oestegrenia	0.48	Holme(1953)
Gastropoda	5	Estimate
Sipuncula	0.84	Vargas *et al.*(2016)
Polychaeta	0.5	Ravara (2011)
Anomura	2.6	Ravara(2011)
Nerocila sp.	0.5	Estimate
Cephalopoda - indeterminata	35.3	Ravara (2011)
Sepia officinalis/Sepia sp.	100	Rešek (2010)
Natantia	1	Ravara (2011)
Squilla mantis	35.7	Ravara (2011)
Squilla mantis pseudozoea	0.1	Estimate
Decapoda - indeterminata	4.2	Ravara (2011)
Decapoda - Brachyura	9.9	Ravara (2011)
Ethusa mascarone	21.7	Ravara (2011)
Liocarcinus depurator	7.6	Ravara (2011)
Typton spongicula	4.9	Padilla *et al.*(2022)
Teleostei - indeterminata	15	Estimate
Gobius sp.	20	Estimate

Gobius niger	10	Boban *et al.* (2013)
Chromis chromis	10.5	Dulčić *et al.* (2004)
Mustelus punctulatus	100	Estimate
Egg	0.1	Estimate

In order to identify different prey categories, the prey was sorted according to the %IRI value, from the highest to the lowest and the cummulative %IRI was calculated. The %IRI of the first prey was added to the following until a value of 50% or more has appeared; this prey was marked as the primary prey. The calculation was continued until %IRI of 75% or more was reached; this prey was marked as secondary prey. The rest of the prey was marked as accidental prey.

To calculate the differences in feeding habits in relation to sex, sexual maturity, size classes and sampling location, the Shannon-Wiener diversity index was used (H').

2.4.4 Niche width

A trophic level is a place within the food web, determined by the number of steps in energy transfer up to that level (Šolić 2018). The trophic level for any consumer species *i* is calculated following the formula:

$$TROPH_i = 1 + DC_{ij} \times TROPH_j$$

where TROPH*j* is the fractional trophic level of prey *j*, DCij represents the fraction of *j* in the diet of *i*.

The TROPH and standard errors (SE) of the small spotted catshark in the study area were calculated using TrophLab, which is a stand-alone Microsoft Access routine for estimating trophic levels (www.fishbase.org).

3 RESULTS

3.1 Biometric characteristics of the small spotted catfish

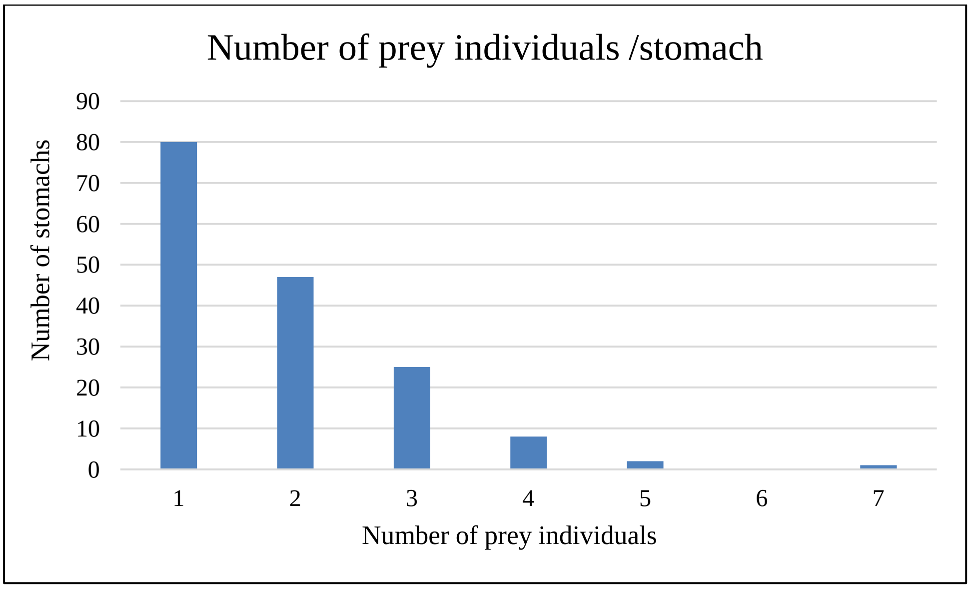
Out of the 205 collected and analyzed samples, biometric data was acquired for 155 individuals (55 females and 100 males). The total length of the individuals varied from 29.0 to 51.4 cm TL; for females, the range was from 29.0 cm to 47.7 cm TL, whereas for the males the range was from 29.0 cm to 51.4 cm TL. The weigth of the individuals varied from 61.0 g to 546.0 g; for the females the range was from 61.0 g to 348 g and for the males, the range was from 61.0 g to 546.0 g. Out of all the analyzed individuals, the average total length of the small spotted catsharks was 42.98 cm TL and the average weight was 2559 g.
For the females, the average length was 40.91 cm TL and the average weight was 229.9 g. For the males, the average length was 44.13 cm TL and the average weight was 270.46 g.

3.2 Diet of the small spotted catshark

3.2.1 Prey abundance, frequency of occurrence and biomass

Out of 188 analyzed stomachs, 25 were found to be empty (VI= 13.3 %). A total of 298 prey individuals were found in the examined stomachs. Almost a half of them contained 1 prey individual (42.6 %) and a third of the examined stomachs contained from two to three prey individuals (38.3 %), whereas the average number was 1.21 prey individuals per stomach. The following presents the number of stomachs containing a certain number of prey individuals (figure 5).

Figure 5: Number of stomachs containing a certain number of prey individuals



In the analyzed stomachs individuals of different taxonomic groups were identified, such as Sipuncula (Annelida), Polychaeta (Annelida), Holothuridea (Echinodermata), Gastropoda (Mollusca), Cephalopoda (Mollusca), Isopoda (Arthropoda), Decapoda (Arthropoda), Elasmobranchii (Chordata) and Actinopterygii (Chordata)(figures 6-8). Due to different stages of prey decomposition as a consequence of the activity of the stomach acid of the small spotted catshark, there was a limited possibility for prey identification to species level.

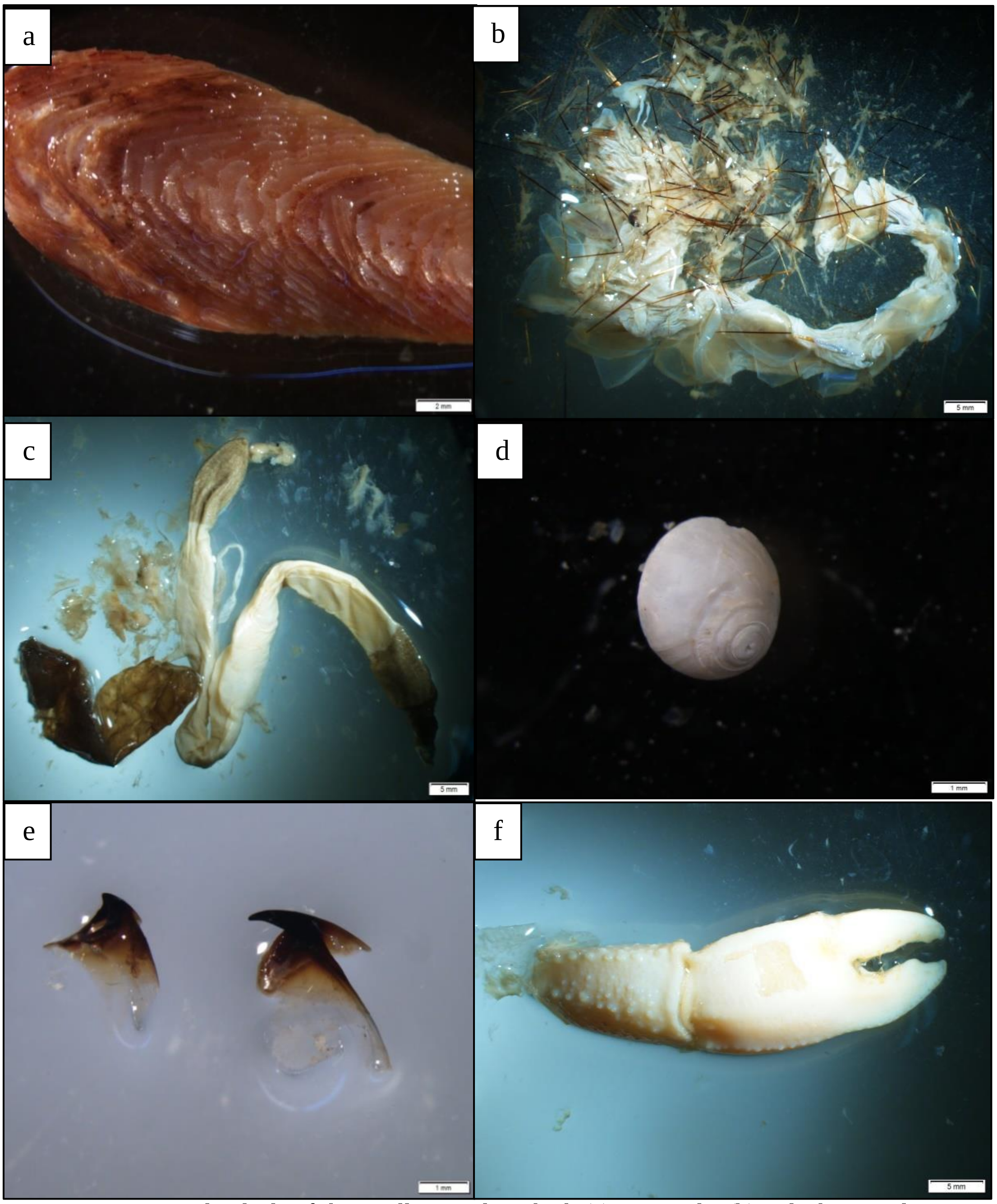


Figure 6: Prey taxa individuals of the small spotted catshark (a) Sipuncula. (b) Polychaeta indeterminata. (c) *Oestergrenia sp*.(d) Gastropoda indeterminata. (e) *Sepia sp*. beaks. (f) Anomura indeterminata. S. Hadžiavdić

Figure 7: Prey taxa individuals of the small spotted catshark (a) *Nerocila sp.* (b) *Ethusa mascarone* (c) *Liocarcinus depurator* (d) *Typton spongicula* (e) Brachyura indeterminata (f) Natantia indeterminata. S. Hadžiavdić

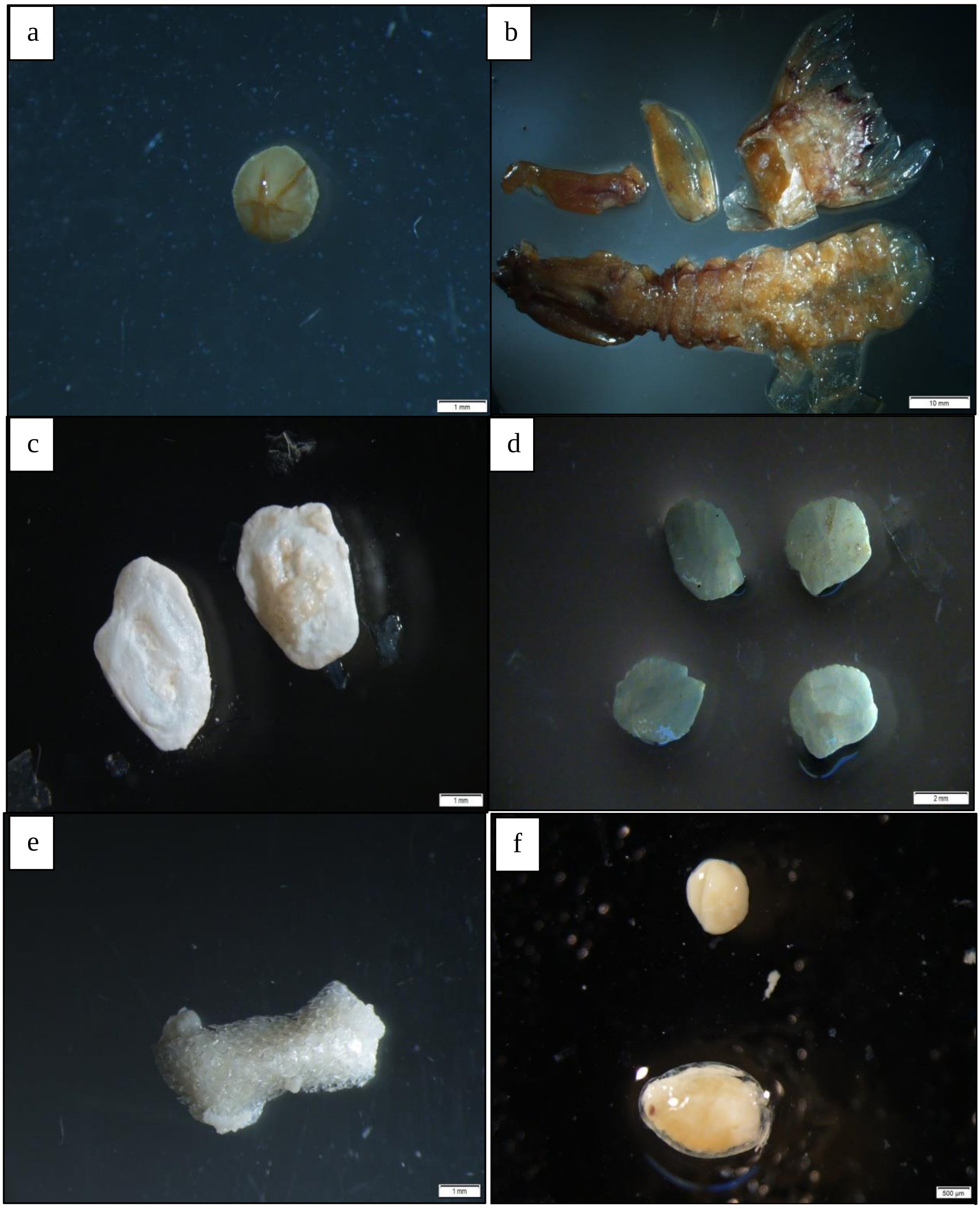


Figure 8: Prey taxa individuals of the small spotted catshark (*Squilla mantis* pseudozoea) (b) *Squilla mantis* (c) *Gobius sp.* (d) *Gobius niger* and *Chromis chromis* (e) Skin remain of *Mustelus punctulatus* (f) Unidentified egg. S. Hadžiavdić

The most abundant group found in the stomachs were crustaceans (39.60 %) out of which the most numerous were decapod crabs (48.30 % of the entire crustacean abundance). The most abundant identified species were *E. mascarone* and the shrimp *T. spongicola* (10.16 % of both the species in terms of total crustacean abundance). The second most abundant group were teleostean fishes (27.12 %) where the most numerous identified species was the black goby *G. niger* (4.93 % of the teleost abundance). The third group according to the abundance were cephalopods (15.77 %) and the most abundant species were specimens from the genus *Sepia*, namely the common cuttlefish *S.officinalis* (93.6 % of the total cephalopod abundance). There was also a significant percentage of polychaet worms found in the stomachs (13.42 %). The relative abundance of other found groups (indetermined invertebrates, sipunculids, gastropods and chondrichtyes) were represented by 5.05 % of the total prey abundance (table 5).

Table 5: Prey groups and prey abundance in the stomachs of the small spotted catshark

Taxa	**Prey number (PN)**	**%PN**
Invertebrata- indeterminata	9	3.02
Oestegrenia sp.	1	0.34
Sipuncula	1	0.34
Polychaeta	40	13.42
Gastropoda	1	0.34
Cephalopoda - indeterminata	3	1.00
Sepia officinalis/Sepia sp.	44	14.77
Crustacea- indeterminata	44	14.76
Anomura	4	1.01
Nerocila sp.	3	0.34
Natantia	4	1.34
Squilla mantis	9	3.02
Squilla mantis pseudozoea	2	0.67
Brachyura- indeterminata	23	7.72
Ethusa mascarone	12	4.03
Liocarcinus depurator	2	0.67
Typton spongicula	12	4.03
Mustelus punctulatus	3	1.01
Teleostei - indeterminata	69	23.15
Gobius niger	4	1.34
Chromis chromis	1	0.34
Egg	1	0.34
TOTAL	**298**	**100**

Table 6 : Prey abundance in the stomachs of the small spotted catshark

Taxa	**%PN**
Polychaeta	13.42
Cephalopoda	15.77
Crustacea	39.60
Elasmobranchii	1.01
Teleostei	27.12
Other invertebrates	4.04
Unidentified egg	0.34
Total	**100.0**

In terms of prey occurrence frequency, it is evident that the crustaceans (65.84 %) were the most common prey of the small spotted catshark, out of which the brachyuran decapod crabs were the most numerous (14.11 %). Teleost fishes were found in nearly half of the examined stomach (44.79 %), polychaet worms were found in 23.31 % and cephalopods were found in 22.09 % of the analyzed stomachs. Two decapod crab species which had the highest frequency of occurrence were the carrier crab *Ethusa mascarone* and *Typton spongicula* (6,13% for each of the species). *Sepia* species were found in more than a fifth of the examined stomachs (20.25 %) and as for the teleost fishes, the most common were the goby *Gobius sp*. species, occurring in 3,68% of small spotted catshark specimens (tables 7,8).

Table 7: Prey occurence frequency in the stomach of the small spotted catshark

Taxa	**Frequency**	**%PF**
Invertebrata- indeterminata	9	5.52
Oestegrenia sp.	1	0.61
Polychaeta	38	23.31
Gastropoda	1	0.61
Cephalopoda - indeterminata	3	1.84
Sepia officinalis/Sepia sp.	33	20.25
Crustacea- indeterminata	40	24.54
Anomura	4	2.45
Nerocila sp.	3	1.84
Natantia	4	2.45
Squilla mantis	9	5.52
Squilla mantis pseudozoea	2	1.23
Brachyura- indeterminata	23	14.11

Ethusa mascarone	10	6.13
Liocarcinus depurator	2	1.23
Typton spongicula	10	6.13
Mustelus punctulatus	3	1.84
Teleostei - indeterminata	64	39.26
Gobius sp.	6	3.68
Gobius niger	2	1.23
Chromis chromis	1	0.61
Egg	1	0.61

Table 8: Prey frequency in the stomachs of the small spotted catshark

Taxa	**%PF**
Polychaeta	23.31
Cephalopoda	22.09
Crustacea	65.64
Elasmobranchii	1.84
Teleostei	44.79
Other invertebrates	7.35
Unidentified egg	0.61

The total biomass in the contents of the 163 full stomachs of the small spotted catshark was 7272.92 g, while the average biomass per stomach was found to be 24.40 g (table 9).

Table 9: Biomass and relative gravimetric composition of the diet of the small spotted catshark

Taxa	**Biomass(g)**	**%PB**
Invertebrata- indeterminata	321.3	4.42
Oestegrenia sp.	0.48	0.01
Sipuncula	0.84	0.06
Polychaeta	20	0.28
Cephalopoda – indeterminata	105.9	1.46
Sepia officinalis/Sepia sp.	4400	60.50
Crustacea- indeterminata	184.8	2.54
Anomura	10.4	0.14
Natantia	4	0.06
Squilla mantis	321.3	4.42
Squilla mantis pseudozoea	0.2	<0.01

Brachyura- indeterminata	227.7	3.13
Ethusa mascarone	260.4	3.58
Liocarcinus depurator	15.2	0.21
Typton spongicula	58.8	0.81
Mustelus punctulatus	300	4.13
Teleostei - indeterminata	1035	14.23
Gobius sp.	120	1.65
Gobius niger	40	0.55
Chromis chromis	10.5	0.14
Egg	0.1	<0.01
TOTAL	**7272.92**	**100.00**

Table 10: Prey biomass in the stomachs of the small spotted catshark

Taxa	%PB
Polychaeta	0.28
Cephalopoda	61.96
Crustacea	14.91
Elasmobranchii	4.13
Teleostei	16.58
Other invertebrates	4.56
Unidentified egg	<0.01
Total	**≈100.0**

The biomass analysis showed that the cephalopod prey contributed the most to the total gravimetric index (61.96 %) (table 10). Out of the cephalopod prey, the *Sepia* species were predominant (60.49 %). The second group to contribute the most to the total gravimetric index were teleost fishes (16.58 %), out of which the goby species contributed the most to the gravimetric index (1.65 %). The third group to contribute with the biomass were crustacean species (14.90 %), with the most dominant biomass contributor being the *Squilla mantis* (4.42 %).

3.2.3 Index of relative importance (IRI)

The relative importance index analysis showed that the most important prey in the diet of the small spotted catshark in the Northern Adriatic were cephalopods (37.40 %)(table 11). The most important cephalopods were the *Sepia sp.* species (37.29 %), namely the common cuttlefish *Sepia officinalis*. The second most important group were teleost fishes, where the total IRI was 36.30 %. Within this group, out of the species that were identified, the goby species were represented with a 0.39 % of relative importance. The crustaceans contributed to IRI with 17.23 % and out of the identified species, the most important were the porter crab *E. mascarone* (1.14 %) and the mantis shrimp *S.mantis* (1 %). The polychaet species contributed to 7.81 % of IRI, whereas the unidentified invertebrates, holothurians, sipunculid and gastropod species did not significantly contribute to the total index of relative importance.

Table 11: The relative importance index of the small spotted catshark prey

	Taxa	%PN	%PF	%PB	%IRI
	Invertebrata-indeterminata	3.02	5.52	4.42	1.005
	Oestegrenia sp.	0.34	0.61	0.01	0.01
	Sipuncula	0.34	0.61	0.60	0.01
	Polychaeta	13.42	23.31	0.27	7.81
	Gastropoda	0.34	0.61	0.07	0.01
Cephalopoda	Cephalopoda - indeterminata	1	1.84	4.52	0.11
	Sepia officinalis/Sepia sp.	14.77	20.25	60.49	37.29
Crustacea	Crustacea-indeterminata	14.76	24.54	2.54	10.39
	Anomura	1.01	2.45	0.14	0.07
	Nerocila sp.	0.34	1.84	0.02	0.016
	Natantia	1.34	2.45	0.06	0.08
	Squilla mantis	3.02	5.52	4.42	1.004
	Squilla mantis pseudozoea	0.67	1.23	<0.01	0.02
	Brachyura-indeterminata	7.72	14.11	3.13	3.75
	Ethusa mascarpone	4.03	6.13	3.58	1.14
	Liocarcinus depurator	0.67	1.23	0.21	0.026
	Typton spongicula	4.03	6.13	0.81	0.73
	Musteluspunctulatus	1.01	1.84	4.12	0.23

Teleostei	Teleostei – indeterminata	23.15	39.26	14.23	35.6
	Gobius sp.	2.01	3.68	1.65	0.33
	Gobius niger	1.34	1.23	0.55	0.06
	Chromis chromis	0.34	0.61	0.14	0.01
	Egg	0.34	0.61	<0.01	<0.01
	TOTAL	**100.0**		**100.0**	**100.0**

Analysis of group prey importance showed the cephalopods and teleosts were primary prey for the small spotted catshark, crustaceans were the secondary prey and the remaining groups (polychaets, sipunculids, gastropods, elasmobranchs and other invertebrates) should be considered as accidental prey (table 12).

Table 12: Cumulative IRI analysis of the diet of small spotted catshark

Taxa	**%IRI**	**Cumulative %IRI**	**Prey importance**
Cephalopoda	37.4	37.4	Primary prey
Teleostei	36.3	73.7	Primary prey
Crustacea	17.23	90.23	Secondary prey
Polychaeta	7.81	98.04	Accidental prey
Other	1.96	100	Accidental prey
TOTAL	**100.00**	**100.00**	

3.2.4 Niche width

The trophic diversity index (ITD) was calculated to be 0.87. Such value indicates a catshark to be feeding on a wide variety of prey and the trophic level was 3.91±0.58. The TROPH value shows the small spotted catshark in the Northern Adriatic is an omnivorous mesopredator species, close to acquiring a TROPH value of 4, where exclusively piscivorous species are categorized.

3.3 Diet comparison according to sex

3.3.1 Diet of females

Feeding habits in female and male specimens of the small spotted catshark were analyzed and compared. Analysis was conducted on 57 stomachs of female specimens of the small spotted catshark (table 13). Out of the 57 examined stomachs, 10 of them were empty (VI=21.28 %). A total of 90 prey individuals were found, distributed in seven taxa: two unidentified invertebrates, 19 Polychaeta, one Sipuncula, one Gastropoda, 15 Cephalopoda, 36 Crustacea and 15 teleost fishes. No holothurians and chondrichthyes were found in the stomachs of female small spotted catshark.

The most abundant prey found in the stomachs of females were crustaceans (39.98 %) and among them the most abundant species was the shrimp *Typton spongicula* (4.44 %). The second most abundant prey group was represented by polychaet worms (21.11 %), followed by cephalopods and teleost fishes (16.67% of abundancy for the both taxa). The most abundant cephalopods were *Sepia sp.* Species (15.56 %) and out of the identified teleost species, goby *Gobius sp.* had an abundance of 1.11 %.
The most frequently occuring prey were crustaceans, who occurred in more than three quarters of the examined stomachs (76.61 %). Out of the identified crustacean species, the most frequent was the shrimp *Typton spongicula* (8.51 %). The second most frequent prey items were polychaet worms (38.30 %). Teleost fishes and cephalopods both showed a frequency of 31.92 %. Considering the frequency of the identified species from the mentioned taxa, the most frequent cephalopod species were *Sepia sp*. (29.79 %) and the identified teleost species was from the genus *Gobius* (2.13 %).

The taxa that contributed most to the biomass index were cephalopods (75.53 %), where cuttlefish (*Sepia sp.)* contributed to 69.44 % of the total biomass. Crustaceans contributed 13.1 % to the biomass, with the species who was contributing the most being *Squilla mantis* (3.54 %). Teleost fishes contributed 13.10 % of the biomass.

The analysis of the relative prey importance showed the most important prey for female small spotted catsharks were cephalopods (50.54 %) and the most important species were *Sepia sp.* (50.42 %). They were followed by polychaets (17.40 %) and crustaceans (15.96 %). The most important identified crustaceans were the crabs (Brachyura) (5.52 %). Teleosts made up for 15.64 % of the prey importance.

Table 13: The diet of the small spotted catshark females in the Northern Adriatic

	Taxa	%PN	%PF	%PB	%IRI
	Invertebrata-indeterminata	2.22	4.26	1.77	0.34
	Oestegrenia sp.	0	0	0	0
	Sipuncula	1.11	2.13	0.04	0.05
	Polychaeta	21.11	40.43	0.47	17.40
	Gastropoda	1.11	2.13	0.25	0.06
Cephalopoda	Cephalopoda – indeterminata	1.11	2.13	6.09	0.12
	Sepia officinalis/Sepia sp.	15.56	29.79	69.44	50.42
Crustacea	Crustacea-indeterminata	13.33	25.53	2.50	8.05
	Anomura	0	0	0	0
	Nerocila sp.	2.22	4.26	0.05	0.19
	Natantia	3.33	6.38	0.15	0.44
	Squilla mantis	2.22	4.26	3.54	0.50
	Squilla mantis pseudozoea	2.22	4.26	0.01	0.19
	Brachyura-indeterminata	10	19.15	4.42	5.52
	Ethusa mascarpone	1.11	2.13	1.08	0.09
	Liocarcinus depurator	1.11	2.13	0.38	0.06
	Typton spongicula	4.44	8.51	0.97	0.92
	Mustelus punctulatus	0	0	0	0
Teleostei	Teleostei – indeterminata	15.56	29.79	10.42	15.55

Gobius sp.	1.11	2.13	0.99	0.09
Gobius niger	0	0	0	0
Chromis chromis	0	0	0	0
Egg	1.11	2.13	<0.01	0.05
TOTAL	**100.0**		**100.0**	**100.0**

An overview of the cumulative IRI showed that cephalopods were the primary prey for the small spotted catshark females in the Northern Adriatic, polychaets and crustaceans were shown to be the secondary prey and teleosts and other remaining taxa were accidental prey (table 14).

Table 14: Cumulative IRI analysis for the small spotted catshark females

Taxa	**%IRI**	**Cumulative %IRI**	**Prey importance**
Cephalopoda	50.54	50.54	Primary prey
Polychaeta	17.40	67.94	Secondary prey
Crustacea	15.96	83.90	Secondary prey
Teleostei	15.64	99.54	Accidental prey
Other	0.46	100	Accidental prey
TOTAL	**100.00**	**100.00**	

3.3.2 Diet of males

A total of 98 male stomachs were examined and 12 of them were empty (VI=13.95 %). A total of 153 prey individuals were isolated from the examined stomachs, distributed in seven taxa: five undetermined invertebrates, one holothurian, 19 polychaets, 26 cephalopods, 49 crustaceans, three chondrichtyes and 50 teleost individuals. Neither sipuncules nor gastropods were found in the examined stomachs of the male small spotted catshark specimens (table 15).

The most abundant and frequent taxa found in the stomachs of the specimens were teleosts, which occurred in 32.67 % of the examined stomachs with a frequency of 53.84 %. The most abundant and frequent teleost species was the black goby *Gobius niger* (2.61 % of both abundance and frequency). The second most abundant and frequent taxa were crustaceans (32.01 % of abundance and 44. 82 %) represented mainly by the decapod Ethusa *mascarone* and the mantis shrimp *Squilla mantis*. Cephalopods accounted for 17 % of prey number, with a 26.75 % frequency, out of which the cuttlefish represented 15.69 % of prey number and 24.42 % frequency. Polychaets showed a total abundance of 12.42 %.

Cephalopods (57.65 %) were the most important group in term of biomass. They were followed by teleosts (17.05 %). The crustaceans contributed 13.10 % to the biomass. Among them mantis shrimp represented the highest share (4.50 %). The identified chondrichtyan smooth-hound shark *Mustelus punctulatus* contributed 7% of the total biomass.

The most important prey for the males of the small spotted catshark were teleost fishes, with a relative importance index of 44.96 %. The second prey group in importance were cephalopods (38.12 %) and the most important cephalopod species were specimens of the genus *Sepia sp.* (37.97 %). Crustaceans were not an important prey for the male small spotted catsharks, as the relative index of importance for crustaceans was found to be 9.1%.

Table 15: Diet composition of the male small spotted catsharks in the Northern Adriatic

	Taxa	**%PN**	**%PF**	**%PB**	**%IRI**
	Invertebrata-indeterminata	3.27	8.62	4.17	1.39
	Oestegrenia sp.	0.65	1.16	0.01	0.02
	Sipuncula	0	0	0	0
	Polychaeta	12.42	20.93	0.22	5.74
	Gastropoda	0	0	0	0
Cephalopoda	Cephalopoda – indeterminata	1.31	2.33	1.65	0.15
	Sepia officinalis/Sepia sp.	15.69	24.42	56	37.97
Crustacea	Crustacea-indeterminata	11.76	11.11	1.76	3.26
	Anomura	1.96	3.49	0.18	0.16

	Nerocila sp.	0	0	0	0
	Natantia	0	0	0	0
	Squilla mantis	3.92	6.98	4.50	1.35
	Squilla mantis pseudozoea	0	0	0	0
	Brachyura-indeterminata	7.84	13.95	2.77	3.21
	Ethusa mascarone	4.58	5.81	3.54	1.02
	Liocarcinus depurator	0.65	1.16	0.18	0.02
	Typton spongicula	1.30	2.32	0.23	0.08
	Mustelus punctulatus	1.96	3.49	7	0.68
Teleostei	Teleostei – indeterminata	28.76	46.51	15.40	44.55
	Gobius sp.	0.65	1.16	0.47	0.03
	Gobius niger	2.61	4.65	0.93	0.36
	Chromis chromis	0.65	1.16	0.25	0.02
	Egg	0	0	0	0
	TOTAL	**100.0**		**100.0**	**100.0**

Cumulative IRI overview showed that the primary prey of the male small spotted catsharks were teleost fishes; the secondary prey were cephalopods and crustaceans, whereas polychaets, other invertebrates and chondrichytes were accidental prey (table 16).

Table 16: Cumulative IRI analysis for small spotted catshark males

Taxa	**%IRI**	**Cumulative %IRI**	**Prey importance**
Teleostei	44.96	44.96	Primary prey
Cephalopoda	38.12	83.08	Secondary prey
Polychaeta	5.75	97.93	Accidental prey
Other	2.07	100	Accidental prey
TOTAL	**100.00**	**100.00**	

The vacuity indices for females and males were 21.28 % and 13.95 %, respectively. Average prey mass was calculated to be smaller for females (22.40 g) than for the males (28.01 g). The same is true for average meal, which were 42.90 g for females and 49.82 g for males.
In regards to prey abundance, the most abundant taxa in small spotted catshark females were crustaceans (39.98 %) and the most abundant identified species was the *Typton spongicula shrimp* (4.44 %). For the males, the most abundant taxa were teleost fishes (32.67 %), out of which the black goby *Gobius niger* accounted for 2.61% of the total abundance.

The most frequent prey for the females were crustaceans, occurring in more than three quarters of the analyzed stomachs (76.61 %). The most frequent identified species was the shrimp *Typton spongicula* (8.51 %). In the case of the males, the most frequent prey were teleost fishes, occurring in 53.48% of the analyzed stomachs. The most frequent identified species was the black goby *Gobius niger* (4.65 %). It is worth noting that polychaet worms showed almost double the frequency in the stomachs of females (40.43 %) in comparison to the stomachs of males (20.93 %).

The biggest contribution to the total biomass for both the females and males was by cephalopods (75.53 % and 57.65 %, respectively).
The most important prey for the females of the small spotted catshark were cephalopods (50.54 %) and the most important species were *Sepia sp* (50.42 %). For the males, the most important prey were teleost fishes (44.96 %) and the most important identified fish species was the black goby *Gobius niger* (0.36 %).

The primary prey for females were cephalopods (50.54 %) and teleost fishes for males (44.96 %). In the small spotted catshark females, prey importance analysis revealed the teleost fishes were accidental prey, although they contributed to the total prey importance by 15.64%. Crustaceans were secondary prey for both the females and males of the small spotted catsharks (15.96% and 9.10%, respectively) (table 17, figure 9).

Table 17: Comparison of %IRI for females and males of the small spotted catshark

Taxa	**%IRI F**	**%IRI M**
Polychaeta	17.40	5.75
Cephalopoda	50.54	38.12
Crustacea	15.96	9.10
Elasmobranchii	0	0.68
Other	0.46	1.39
Total	**100.0**	**100.0**

The trophic diversity index for the females was calculated to be 0.87 for the females and 0.85 for the males.

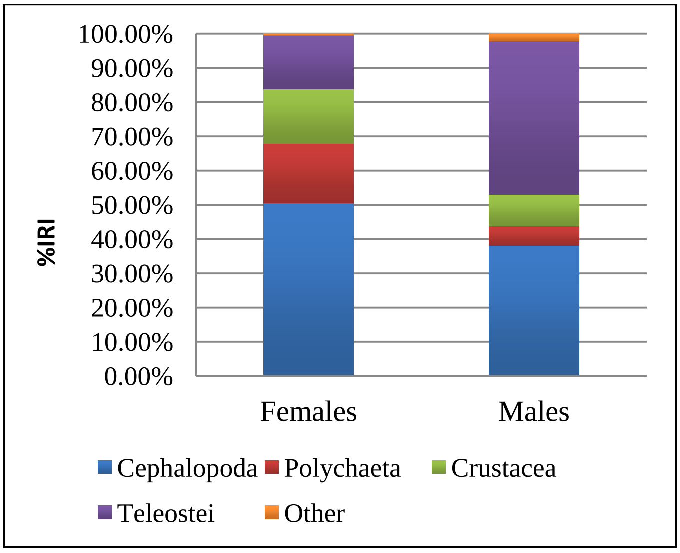


Figure 9: Comparative overview of diet in females and males of the S. Canicula, according to %IRI

3.4 Diet comparison according to body length

Small spotted catsharks were divided into four categories in regards to total body length (TL)(table 18).

Table 18: Total body length categories of the small spotted catshark

Category	**I**	**II**	**III**	**IV**
Individuals	11	44	59	17

The vacuity indices for the categories were 10 %, 11.36 %, 12.65 % and 5.88 % respectively. Several other data points were used for comparison of the diet in-between the categories, all of which are presented in table 19.

Table 19: Comparison of different diet data points for the TL categories of the small spotted catshark

Category	**I**	**II**	**III**	**IV**
Females	6	28	2	1
Males	5	16	56	16
Total of individuals	11	44	59	17
Number of full stomachs	10	39	69	16
Vacuity index (VI)(%)	10	11.36	12.65	5.88

Total of prey individuals	21	68	117	25
Average prey number per stomach	1.91	1.74	1.7	1.56
Total prey biomass (g)	538.6	1222.02	3519.3	570.2
Average prey mass (g)	25.65	17.97	30.08	22.81
Average meal (g)	54.38	31.33	51	35.64

The crustaceans, teleost fishes and polychaets were the taxa who appeared in all four examined categories. Crustaceans had an abundance of 28.57 %, 43.80%, 29.91% and 29.91% respectively for each category. The most abundant decapod crab was the *Ethusa mascarone*, appearing in the last three categories with and abundance of 1.47 %, 3.42 % and 12 %. Teleost fishes were shown to have an abundance of 33.33 %, 23.52 %, 23.9 3 % and 36 % for each respective category. Polychaets appeared in an abundance of 19.05 %, 17.65 %, 12.82 % and 16 %, respectively. The most abundant species were the cuttlefish *Sepia sp.*(19.05 %, 7.35%, 22.22% and 12% for each group respectively)(table 20).

Table 20: Abundance index for total length categories of the small spotted catshark

	%PN			
Taxa	**I**	**II**	**III**	**IV**
Invertebrata indeterminata	0	1.47	5.13	4
Oestegrenia sp.	0	1.47	0	0
Sipuncula	0	1.47	0	0
Polychaeta	19.05	17.65	12.82	16
Cephalopoda indeterminata	0	1.47	1.71	0
Sepia sp./Sepia officinalis	19.05	7.35	22.22	12
Crustacea indeterminata	19.05	14.70	8.55	12
Anomura	0	1.47	1.71	0
Nerocila sp.	0	1.47	0.85	0
Natantia	0	2.94	0	0

Squilla mantis	0	5.87	3.42	0
Squilla mantis pseudozoea	0	1.47	0.85	0
Brachyura	4.76	11.74	7.69	4
Ethusa mascarpone	0	1.47	3.42	12
Liocarcinus depurator	0	0	1.71	0
Typton spongicula	4.76	2.94	1.71	1
Mustelus punctulatus	0	1.47	1.71	0
Teleostei indeterminate	33.33	22.05	21.37	32
Gobius sp.	0	1.47	0	4
Gobius niger	0	0	1.71	0
Chromis chromis	0	0	0.85	0
Egg	0	0	0	0
Total	**100**	**100**	**100**	**100**

The most frequent taxa in the first and fourth category were teleosts (60 % and 56.25 % respectively).
For the second category, the most frequent prey taxa were crustaceans (49.27 %) and the most frequent identified species was the mantis shrimp *Squilla mantis* (5.79 %).

The most frequent prey taxa in the third and second most frequent in the fourth category were crustaceans (49.27 % and 19. 21 %) with the most frequent identified species being the shrimps *Squilla mantis* (10.26 % and 5.79) and *Typton spongicula* (5.13 %) (table 21).

Table 21: Prey frequency in total length categories of the small spotted catshark

	%PF			
Taxa	**I**	**II**	**III**	**IV**
Invertebrata indeterminata	0	2.56	7.25	6.25
Oestegrenia sp.	0	2.56	0	0
Sipuncula	0	2.56	0	0
Polychaeta	40	28.21	21.74	25

Gastropoda	0	0	1.45	0
Cephalopoda indeterminata	0	2.56	2.90	0
Sepia sp./Sepia officinalis	30	12.82	33.33	12.50
Crustacea indeterminata	30	8.10	1.19	2.21
Anomura	0	0.21	0.15	0
Nerocila sp.	0	0.04	0.01	0
Natantia	0	5.12	0	0
Squilla mantis	0	10.26	5.79	0
Squilla mantis pseudozoea	0	2.56	1.45	0
Brachyura	10	20.51	13.04	6.25
Ethusa mascarpone	0	2.56	4.35	12.50
Liocarcinus depurator	0	0	2.90	0
Typton spongicula	10	5.13	2.90	6.25
Mustelus punctulatus	0	2.56	2.90	0
Teleostei indeterminate	60	38.46	36.23	50
Gobius sp.	0	2.56	0	6.25
Gobius niger	0	0	2.90	0
Chromis chromis	0	0	1.45	0
Egg	0	0	0	0

Gravimetric index analysis for the total length categories revealed the taxa that contributed the most to the gravimetric index were cephalopods for all categories (74.27 %). 43.84 %, 75.89 % and 52.61 % respectively), namely the cuttlefish *Sepia sp.* (74.27 %, 40.92 %, 73.88 % and 52.61 % respectively). For the crustaceans, the identified species that contributed the most to the total gravimetric index were the decapod crab *Ethusa mascarone* (1.78 %, 2.47 % and 11.42 % in the second, third and fourth category respectively) and shrimp *Typton spongicula* (0.91 %, 0.80 %, 0.28 % and 0.86 % in all categories, respectively). The chondrichtyes species *Mustelus punctulatus* contributed to the gravimetric index with a 8.18 % in the second and 5.68 % in the third category (table 22).

Table 22: Gravimetric indices in total length categories of the small spotted catshark

	%PB			
Taxa	**I**	**II**	**III**	**IV**
Invertebrata indeterminata	0	2.92	6.09	6.26
Oestegrenia sp.	0	0.04	0	0
Sipuncula	0	0.07	0	0
Polychaeta	0.37	0.49	0.21	0.35
Gastropoda	0	0	0.14	0
Cephalopoda indeterminata	0	2.92	2.01	0
Sepia sp./Sepia officinalis	74.27	40.92	73.88	52.61
Crustacea indeterminate	3.12	8.10	1.19	2.21
Anomura	0	2.56	2.90	0
Nerocila sp.	0	2.56	1.45	0
Natantia	0	5.13	0	0
Squilla mantis	0	11.69	0.15	0
Squilla mantis pseudozoea	0	0.008	0.003	0
Brachyura	1.84	6.48	2.53	1.73
Ethusa mascarpone	0	1.78	2.47	11.42
Liocarcinus depurator	0	0	0.43	0
Typton spongicula	0.91	0.80	0.28	0.86
Mustelus punctulatus	0	8.18	5.68	0
Teleostei indeterminate	19.50	18.41	20.71	21.05
Gobius sp.	0	1.64	0	3.51
Gobius niger	0	0	0.57	0
Chromis chromis	0	0	0.30	0
Egg	0	0	0	0
Total	100.0	100.0	100.0	100.0

The most important prey in the first, second and fourth category were teleosts (42. 07 %, 43.91 % and 62.04 % respectively). For the third category, the most important prey were cephalopods (60.19 % IRI), namely the cuttlefish *Sepia sp*. (59.99 %). Goby species were the most important identified teleost prey in the second and third category (0.22 % and 1.08 % respectively)(table 23).

Table 23: Relative importance indices in total length categories of the small spotted catshark

		%IRI			
	Taxa	**I**	**II**	**III**	**IV**
	Invertebrata indeterminata	0	0.32	1.52	1.47
	Oestegrenia sp.	0	0.11	0	0
	Sipuncula	0	0.11	0	0
	Polychaeta	10.31	14.37	5.31	9.39
	Gastropoda	0	0	0.027	0
Cephalopoda	Cephalopoda indeterminate	0	0.32	0.20	0
	Sepia sp./Sepia officinalis	37.15	17.37	59.99	18.56
Crustacea	Crustacea indeterminata	8.83	5.19	0.22	0.72
	Anomura	0	0.024	0.013	0
	Nerocila sp.	0	0.005	0.0004	0
	Natantia	0	1.16	0	0
	Squilla mantis	0	5.06	0.39	0
	Squilla mantis pseudozoea	0	0.11	0.023	0
	Brachyura	0.88	10.49	2.50	0.82
	Ethusa mascarone	0	0.23	0.48	6.73
	Liocarcinus depurator	0	0	0.12	0
	Typton spongicula	0.75	0.54	0.11	0.27
	Mustelus punctulatus	0	0.69	0.40	0
Teleostei	Teleostei indeterminata	42.07	43.69	28.55	60.96
	Gobius sp.	0	0.22	0	1.08
	Gobius niger	0	0	0.12	0
	Chromis chromis	0	0	0.03	0
	Egg	0	0	0	0
	Total	100.0	100.0	100.0	100.0

Comparison of the relative importance index in all four categories showed a significant teleost prey importance, although it is evident that the relative importance of teleost prey in the fourth category, which represents the individuals of the total length of 470> mm, exceeds the relative importance of teleost prey in the remaining three categories.
The comparison also shows the importance of cephalopod prey in the third group category where they were the primary prey, in contrast to the remaining observed categories (figure 10).

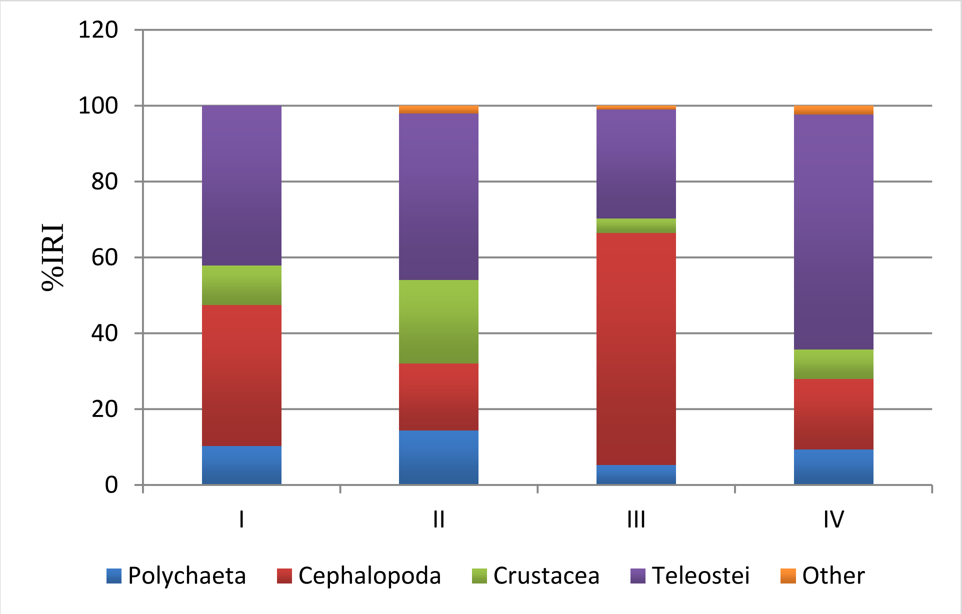


Figure 10: Comparison of prey importance in the four length categories of the small spotted catshark, according to %IRI

Analysis of cumulative %IRI revealed the primary prey for the first, second and fourth length category of the small spotted catshark were teleosts. Crustaceans were also calculated to be the primary prey in the second category, along with teleosts. In the remaining categories however, crustaceans appear as accidental prey. The primary prey in the third category were cephalopods, whereas teleosts were secondary prey. Polychaets were accidental prey in all of the four length categories, although in every category they were represented with a fairly significant %IRI (table 24).

Table 24: Prey importance overview for the four length categories of the small spotted catshark

Length category	**Taxa**	**%IRI**	**Cumulative %IRI**	**Prey importance**
I	Teleostei	42.07	42.07	Primary prey
	Cephalopoda	37.16	79.23	Secondary prey
	Crustacea	10.46	89.69	Accidental prey
	Polychaeta	10.31	100.00	Accidental prey
II	Teleostei	43.91	43.91	Primary prey
	Crustacea	22.08	65.99	Primary prey
	Cephalopoda	17.69	83.68	Secondary prey
	Polychaeta	14.37	98.05	Accidental prey
	Other	1.95	100.0	Accidental prey
III	Cephalopoda	61.19	61.19	Primary prey
	Teleostei	28.70	89.89	Secondary prey
	Polychaeta	5.31	95.2	Accidental prey
	Crustacea	3.86	99.06	Accidental prey
	Other	0.94	100.0	Accidental prey
IV	Teleostei	62.04	62.04	Primary prey
	Cephalopoda	18.56	80.6	Secondary prey
	Polychaeta	9.39	89.99	Accidental prey
	Crustacea	7.82	97.81	Accidental prey
	Other	2.19	100.0	Accidental prey

3.5 Diet comparison according to sampling location

Sampling of the small spotted catshark was done around six different locations in the Croatian part of the Istrian peninsula: Funtana (42), Poreč (12), Pula (37), Rovinj (19), St. Marina (5) and Vrsar (73). A total of 188 samples was collected for analysis (table 25).

Table 25: Samples of the small spotted catshark throughout the six sampling locations

	Sex				**Length category**						
Location	**F**	**M**	**Unknown**	**Total**	**I**	**II**	**III**	**IV**	**V**	**Unknown**	**Total**
Funtana	17	25	0	42	0	0	4	1	0	0	5
Poreč	4	8	0	12	0	0	4	8	0	0	12
Pula	14	23	0	37	0	3	10	21	3	0	37
Rovinj	4	15	0	19	0	1	8	9	1	0	19
St.Marina	2	3	0	5	0	0	12	28	2	0	42
Vrsar	15	24	34	73	3	4	8	15	11	32	73
Total	56	98	34	188	3	4	46	82	6	32	188

A total of 298 prey individuals was caught in the six sampling locations, belonging to seven highter taxa. The most prey individuals were found in the stomachs of specimens caught in Vrsar (125) and the least in St. Marina (8). All the stomachs in the samples from St. Marina were full, for the other locations the vacuity indices were as follows: 9.52 % for Funtana, 8.33 % for Poreč, 16.21 % for Pula, 21.05 % for Rovinj and 13.70 % for Vrsar. Average prey number per stomach varied between 1.5 and 2. Average prey mass had a highest value in Vrsar (29.92 g) and the lowest in St. Marina (14.39 g). The same was observed for the average meal value: it was highest in Vrsar (53.41 g) and lowest in St. Marina (23.02 g) (table 26).

Table 26: Comparison of different data points for sampling locations of the small spotted catshark

Category	**Funtana**	**Poreč**	**Pula**	**Rovinj**	**St.Marina**	**Vrsar**
Females	17	4	14	4	2	15
Males	25	8	23	15	3	24
Total of individuals	42	12	37	19	5	73
Number of full stomachs	38	11	31	15	5	63
Vacuity index (VI)(%)	9.52	8.33	16.21	21.05	0	13.70
Total of prey individuals	62	22	60	26	8	120
Average prey number per stomach	1.5	2	1.94	1.73	1.6	1.98
Total prey biomass (g)	1,344.94	403.20	1,392.90	621.48	115.10	3, 365
Average prey mass (g)	23.60	18.33	23.20	23.90	14.39	26.92
Average meal (g)	35.39	36.65	44.93	41.43	23.02	53.41

Analysis of the relative importance index showed the most important prey for the individuals sampled in Funtana, Poreč and Rovinj were teleost fishes (44.63 %,77.91 % and 47.10 % respectively). Funtana is the only location where prey remains of the shark *Mustelus punctulatus* were sampled and they contributed to the relative importance index by 5.18 %. The most important identified teleost species for Poreč were the black goby *Gobius niger* (9.53 %) and the damselfish *Chromis chromis* (1.47 %). Cephalopods, namely cuttlefish *Sepia sp.* were the most important prey for the individuals sampled in Vrsar (41.82 %). Crustaceans were the most important prey for the location of St. Maria (69.03 %) and the most important prey species was the mantis shrimp *Squilla mantis* (14.31 %). It was shown the most important prey for the individuals sampled in Pula were polychaet worms (38.27 %). The most important identified decapod crab was *Ethusa mascarone* (0.21 % for Funtana, 2.04 % for Poreč, 2.68 % for Pula and 1.01 % for Vrsar; not found in Rovinj and St. Maria) (table 27, figure 11).

Table 27: Comparative %IRI overview in the six sampling locations

	%IRI					
Taxa	**Funtana**	**Poreč**	**Pula**	**Rovinj**	**St. Maria**	**Vrsar**
Invertebrata indeterminate	1.09	2.76	0.24	1.47	0	1.03
Oestegrenia sp.	0	0	0	0.60	0	0
Sipuncula	0.11	0	0	0	0	0
Polychaeta	8.50	3.85	38.27	5.32	0	0.72
Gastropoda	0.13	0	0	0	0	0
Cephalopoda indeterminate	0.27	1.81	0	0	14.19	0
Sepia sp./Sepia officinalis	28.20	5.11	33.15	27.56	0	41.82
Crustacea indeterminate	0.12	2.30	6.90	6.25	47.78	21.19
Anomura	0.46	0	0	0.65	0	0.03
Nerocila sp.	0.11	0	0	0	0	0.12
Natantia	0.11	0	0	0.62	0	0.12
Squilla mantis	0.27	2.76	0	7.09	14.31	0.26
Squilla mantis pseudozoea	0.41	0	0	0	0	0
Brachyura	9.56	1.44	2.09	3.34	6.94	1.89
Ethusa mascarone	0.21	2.04	2.68	0	0	1.01
Liocarcinus depurator	0.43	0	0	0	0	0
Typton spongicula	0.13	0	0	0	0	3.31
Mustelus punctulatus	5.18	0	0	0	0	0
Teleostei indeterminata	44.43	66.91	16.67	47.10	16.78	27.24
Gobius sp.	0.20	0	0	0	0	1.22
Gobius niger	0	9.53	0	0	0	0
Chromis chromis	0	1.47	0	0	0	0
Egg	0.10	0	0	0	0	0
Total	100.0	100.0	100.0	100.0	100.0	100.0

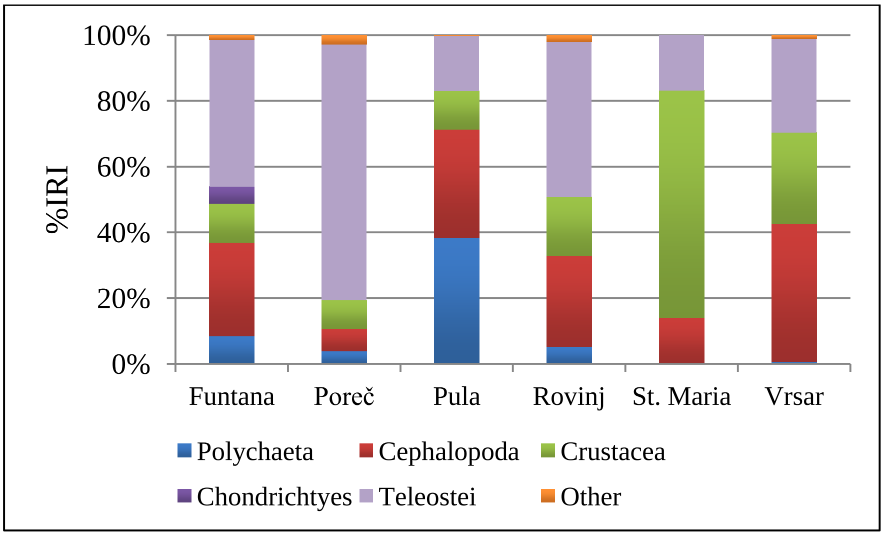


Figure 11: Comparison of prey importance in the sampling locations of the small spotted catshark, according to %IRI

Cumulative %IRI analysis revealed teleost fishes were the primary prey for half of the sampled locations (Funtana, Poreč and Rovinj), cephalopods were the primary prey for the individuals sampled in Vrsar and partially in Funtana and Pula, polychaets were the primary prey for the individuals sampled in Pula and crustaceans were the primary prey for the small spotted catsharks sampled in St. Maria (table 28).

Table 28: Prey importance overview for the sampling locations of the small spotted catshark

Location	**Taxa**	**%IRI**	**Cumulative %IRI**	**Prey importance**
Funtana	Teleostei	44.63	44.63	Primary prey
	Cephalopoda	28.47	73.10	Primary prey
	Crustacea	11.81	84.91	Secondary prey
	Polychaeta	8.50	93.41	Accidental prey
	Chondrichyes	5.18	98.59	Accidental prey
	Other	1.41	100.0	Accidental prey
Poreč	Teleostei	77.91	77.91	Primary prey
	Crustacea	8.54	86.45	Secondary prey
	Cephalopoda	6.92	93.37	Accidental prey
	Polychaeta	3.85	97.22	Accidental prey
	Other	2.78	100.0	Accidental prey

Pula	Polychaeta	38.27	38.27	Primary prey
	Cephalopoda	33.15	72.42	Primary prey
	Teleostei	16.67	88.09	Secondary prey
	Crustacea	11.67	99.76	Accidental prey
	Other	0.24	100.0	Accidental prey
Rovinj	Teleostei	47.10	47.10	Primary prey
	Cephalopoda	27.56	74.66	Secondary prey
	Crustacea	17.95	92.61	Accidental prey
	Polychaeta	5.32	97.93	Accidental prey
	Other	2.07	100.0	Accidental prey
St. Maria	Crustacea	69.03	69.03	Primary prey
	Teleostei	16.78	85.81	Secondary prey
	Cephalopoda	14.19	100.0	Accidental prey
Vrsar	Cephalopoda	41.82	41.82	Primary prey
	Teleostei	28.5	70.32	Primary prey
	Crustacea	27.93	98.25	Accidental prey
	Polychaeta	0.72	98.97	Accidental prey
	Other	1.03	100.0	Accidental prey

4 DISCUSSION

4.1 Suitability of the used methods

The most important deficiency in the conducted research was the number of samples that were analyzed (188) and biometric data lacking for 32 sampled individuals of the small spotted catshark. This occurred due to damages on the sampled individuals and precise measurement to a total length and weighing of the sampled individuals were not possible. Data on sex was lacking for 34 sampled individuals, where it was not possible to determine the sex due to the aforementioned damage on the samples. The damages on the bodies of sampled catsharks happened as a result of improper management and transport of the individuals by the fishermen who collected the samples. It is, anyhow, important to emphasize this species was not a target species for the fishering activities; all analyzed samples were collected as by-catch, therefore proper management was not a priority for fishermen.

Another deficiency in regards to sampling was the fact the samples were not collected during systematic research but as a result of unrelated fishing events. A big contributing factor to the lack of systematic research is also the fact that this species is rare in the Northern Adriatic and conducting systematic research would be demanding.

In regards to identification to a species level, the greatest deficiency is that the stomach acid decomposed many of the prey individuals, having left only small fragments of remains which were difficult to identify to a species level. This resulted in a majority of the prey individuals to be determined only to a higher taxa level. Additionaly, fragments of cephalopod beaks, crustacean carapaces and pincers and teleost otoliths were not whole or were damaged in a majority of the analyzed samples, therefore reliable identification to a species level was not possible. Had it been different, the results presented in this study would have been much more detailed and precise.

4.2 Feeding habits of the small spotted catshark

A total of 298 prey individuals were found in the 188 examined stomachs of the small spotted catshark. Out of the total of prey individuals, it was possible to identify 45 prey individuals to a species level and 54 prey individuals to a genus level, whereas for the remaining prey individuals, identification only to an infraorder level or higher was possible.

The vacuity index for the total of examined stomachs was 13.3 % and an average number of prey per stomach was 1.21, suggesting the small spotted catshark is an active predator in the Northern Adriatic. Comparison of the vacuity index in females and males of the small spotted catshark showed a difference in vacuity indices (21.28 % for females and 13.95 % for males). In addition, the total number of the sampled males was higher than the total of sampled females in the research (98 males and 57 females).

The differences in vacuity index appear more significant when analyzing the different length categories, where VI varied from 5.88 % to 12.65 %. However, these differences depended in great measure of the number of sampled specimens for each total length category. For the fourth category, where the longest individuals were recorded, the VI was fairly low (5.88 %), suggesting the adult individuals of this species are more active foragers. The differences in VI according to different sampling locations were more prominent: in the location of St. Maria where all stomachs were full, only five individuals were recorded for analysis, in contrast to Vrsar, where 73 individuals were sampled and the VI was 13.70%.

Although prey individuals from seven different higher taxa were observed, it was evident that cephalopods, teleosts, crustaceans and polychaets contributed significantly to the total prey importance, whereas all other higher taxa did not contribute in a significant amount. A high number and diverse composition of the prey taxa indicated the species is a generalist predator. The most important and primary prey were cephalopods and teleosts, namely the cuttlefish *Sepia sp* for cephalopods and goby species for teleosts. Species of the cuttlefish genus have a wide depth distribution and mature males and females occur all throughout the year (Ciavaglia and Manfredi 2009), which indicates they are an easily accesible prey for the small spotted catshark. Cephalopod species are on average also larger than crustaceans (Bello 1997), which can make them a more nutritious prey for the small spotted catshark.

It is noticeable that cephalopods were secondary prey in the fourth total length category, where the most important and primary prey in this category were teleost fishes. The visual acuity and olfactory sense of the small spotted catshark increases with age and this allows the individuals to detect prey at greater distances (Bozzano 2001), which could explain why the larger individuals foraged on teleosts the most. The number of olfactory lamellae in the rosette of the small spotted catsharks increases with the increase in length accordingly (El-Attar 1998). The presented data indicate this species is a teuthiphagous and piscivorous predator in the Northern Adriatic. Crustaceans were the secondary prey and the most notable species was the decapod crab *Ethusa mascarone*. This is a species inhabiting sandy and muddy bottoms up to 30 m of depth (Gusso *et al.* 2001). It is a convenient species for the small spotted catshark to feed on, considering the two species inhabit the same type of habitat.

The polychaets worms were the most important accidental prey categories for all individuals, but secondary prey for the female small spotted catsharks and primary prey for the individuals sampled in Pula. This can be explained by either the potential great abundance of polychaets in the sampling location or a small foraging effort required to feed on these individuals.

A peculiar discovery in this study was that the remains of the skin of the black-spotted smoothound *Mustelus punctulatus* were found in the stomachs from the sampling location of Funtana in the second and third total length category (subadults). Although the remains of this prey category did not significantly contribute to prey importance (0.23 of the total %IRI and 5.18 of the %IRI for Funtana), this discovery indicates the small spotted catshark in the Northern Adriatic exhibited scavenger behaviour. This species has been considered an opportunistic scavenger that may feed on inputs by fishing operations, such as discards and dead benthic organisms in the previous studies as well (Lyle 1983; Olaso *et al.* 1998, 2005).

4.3 Diet comparison to other areas

This study of the diet of the small spotted catshark was cpmpared to other studies of the same species elsewhere in the Adriatic sea and other parts of the Mediterranean (table 29).

Table 29: Comparison of the diet of the small spotted catshark in different areas, according to %VI and %IRI

Study area	**Central Mediterranean**	**Central Adriatic**	**Aegean Sea**	**Northern Adriatic**
Author(s)	**Mnasri *et al.***	**Šantić *et al.***	**Kousteni *et al.***	**This study**
Year of publication	**2012**	**2012**	**2017**	
Number of stomachs examined	1125	1200	423	188
VI (%)	13.33	29.00	27.30	13.30
%IRI				
Polychaeta	0.18	0.50	2.15	7.81
Cephalopoda	0.16	3.0	30.80	37.40
Crustacea	1.64	80.00	22.1	17.23
Teleostei	2.50	15.30	42.50	36.30
Other	95.51	1.20	2.45	1.96

A study of the feeding habits of the small spotted catshark in the eastern central Adriatic was conducted by Šantić and associates (2012), where this species is one of the most numerous elasmobranchs in Adriatic bottom-trawl catches (Vrgoč 2009). In this study, a total of 1200 stomachs were analyzed, with a total vacuity index of 29%. The most important prey for the small spotted catshark in eastern central Adriatic were shrimps (%IRI=76.6) and the most important species were *Alpheus glaber, Solenocera membranacea* and *Macropipus tuberculatus* (with a %IRI of 5.1, 3.0 and 1.4, respectively). The only decapod crab species which coincided with the decapod crabs identified in this research was *Liocarcinus sp.* (%IRI= 0.3). In this research, the mentioned species contributed to the total relative index with less than one percent. The teleosts were the second most important prey, although they were the most important prey for the larger individuals. The latter is consistent with the results obtained in our research, where the teleost fishes were also the most important prey for the larger individuals of the small spotted catshark. Differences in diet between sexes were not analyzed in their study.

There are also other available studies where the diet of the small spotted catshark is examined in the purpose of the comparison of diet overlapping with other elasmobranchian species. Valls and associates (2011) conducted such research for the Balearic Sea in the western Meditteranean, Martinho and associates (2011) for the coast off Portugal in the West Atlantic and Olaso and associates (2005) for the Cantabrian Sea as a coastal sea of the Atlantic.

In the study conducted by Kousteni and associates (2017), the three most consumed prey groups were teleosts, cephalopods and crustaceans, which is in accordance with this research. The teleosts were the dominant prey in females for both the immature and mature individuals and mature males, whereas crustaceans were the dominant prey for the immature males. In this research, cephalopods were the dominant prey for females and the teleosts were the most important prey for males.

The study conducted by Mnasri and accociates (2012) showed the dominant prey were teleosts and cephalopods were the second most important prey in this research. The females in this research foraged mostly on crustaceans, whereas the males foraged on teleost fishes. The importance of the teleosts in male small spotted catsharks from this area coincides with the one described in this research.

The research conducted by Olaso and associates (2005) for the Cantabrian Sea as a coastal sea of the Atlantic examined trophic relations of the small spotted catshark and the blackmouth catshark *Galeus melanostomus* Rafinesque, 1810 analyzed 5076 individuals of the small spotted catshark. Teleost fishes and crustaceans were the main prey of the individuals examined in this research.

This study also pointed out the frequency of capture of crustaceans decreases and the capture of fishes increases as the individuals of the species grow, as was also shown in this research.

Valls and associates (2011) also conducted a study on the diet of the small spotted catshark in the Western Mediterranean, in addition to seven other demersal elasmobranchs. Their research locations were the shelf and slopes off the Balearic Sea. Around 900 stomachs of the small spotted catshark were analyzed and the most important prey for the individuals inhabiting the continetal shelf were reptantians (a clade of decapod crabs), polychaetes and teleosts.

Although %IRI values differed from the ones recorded in this research, both of the studies acknowledge the importance of polychaets in the diet of the small spotted catshark, whereas in the previous presented studies polychaets were not at all significant.

Martinho and associates (2011) examined the diet of the small spotted catshark on the coast off Portugal in the West Atlantic in comparison to the longnose spurdog *Squalus blainville* Risso, 1827. A total of 991 small spotted catshark stomachs were analyzed. Crustaceans were found to be the dominant and primary prey and annelids were found to be the secondary prey. Crustaceans were also the most important prey for both the females and males in this part of the western Atlantic.

4.4 Diet comparison to other species

Research of the feeding habits of the chondrichthyes in the Adriatic has become a more examined topic in the recent years, although it cannot be claimed enough studies have been published so far to completely examine the feeding habits of the most common and abundant chondrichthyes species in the Adriatic (table 30).

Table 30: Comparison of the diet of the small spotted catshark and other species, according to %VI and %IRI

Species	***Mustelus mustelus***	***Mustelus punctulatus***	**Pteroplatytrigon violacea**	***Raja asterias***	***Scyliorhinus canicula***
Study area	**Eastern Adriatic**	**Northern Adriatic**	**Northern Adriatic**	**Northern Adriatic**	**Northern Adriatic**
Author(s)	**Jardas *et al.***	**Lipej *et al.***	**Lipej *et al.***	**Sviben *et al.***	**This research**
Year of publication	**2007**	**2011**	**2012**	**2019**	
Number of stomachs examines	139	151	84	88	188
%VI	17.20	13.40	4.76	1.15	13.30
%IRI					
Polychaeta	0.80	4.90	/	0	7.81
Bivalvia	/	12.0	/	0.08	/
Cephalopoda	3.50	19.50	4.42	3.37	37.40
Crustacea	64.00	55.60	0.03	57.54	17.23
Teleostei	31.20	9.20	95.29	38.41	36.30

A study conducted for the feeding habits of the blackspotted smooth-hound *Mustelus punctulatus* in the Gulf of Trieste in the Northern Adriatic (Lipej *et al.* 2011) showed that the main represented taxonomic groups in the diet of this species were crustaceans, cephalopods, polychaetes, bivalves, and teleost fishes. With the exception of bivalves, all of these taxonomic groups also appeared as the most represented prey of the small spotted catshark in this study. It is possible that interspecific competition occurs. The blackspotted smooth-hound is described as a benthic dweller who seeks prey on sandy and muddy bottoms (Lipej *et al.* 2011). However, the competition between the two species could decrease as the individuals of both species grow: while the adults of the smooth-hound feed mainly on cephalopods and bivalves and are, due to morphological adaptations also capable of feeding on pelagic prey, the adults of the catshark feed on teleost fishes and are accustomed to benthic feeding for their entire life.

A similar study conducted on the feeding habits of the smooth-hound *Mustelus mustelus* in the eastern Adriatic (Jardas *et al.* 2007) where it was found decapod crustaceans were the most important prey followed by teleosts. Smaller specimens in this research mainly fed on crustaceans, while the size increase in individuals pointed to an increase of the proportions of teleost fishes and cephalopods in the diet. This study also shows how the smooth-hound species and the small spotted catshark could have interspecific competition.

Sviben and associates (2019) examined the feeding habits of the starry skate *Raja asterias* in the Northern Adriatic, in Slovenian, Croatian and Italian territorial waters. The most important taxonomic group in the diet were decapods, followed by teleosts and cephalopods. The highest %IRI values were found for the decapod crab species the carrier crab *Ethusa mascarone* (13.4) and *Liocarcinus depurator* (2.09) and the teleost species *Gobius niger* (0.87). These were, following the cuttlefish *Squilla mantis* (1 % IRI), also the most important species in this research in their respective groups.
It is possible that interspecific competition occurs, due to similar lifestyles and utilisation of the same area as a feeding niche.

Feeding habits of the pelagic stingray *Pteroplatytrigon violacea* in the Northern Adriatic were examined by Lipej and associates (2012). The results of the study showed the most important prey of the pelagic stingray were teleosts. The most important teleost species were anchovy *Engraulis encrasicolus* (86.95 % IRI), pilchard *Sardina pilchardus*, gilt sardine *Sardinella aurita*, whiting *Merluccius merluccius*, Atlantic horse mackerel *Trachurus trachurus* and red band fish *Cepola macrophthalma*. The diet analysis in the study showed this species is a benthopelagic species, which feeds both in benthic and pelagic habitats, therefore a certain overlap with the feeding niche of the small spotted catshark is possible.

A review on the diet of the deep-water blackmouth catshark *Galeus melanostomus* in the Mediterranean (D'Iglio *et al.* 2021) showed the most important prey for the blackmouth catshark were cephalopods (namely the species *Heteroteutis dispar*), although the authors emphasize the data on the diet of the species were scarce, outdated and the data on the species' diet was acquired along with other teuthivorous predators in the purpose of studies reconstructing the Adriatic cephalopod assemblage (Bello 1995, 1996, 1997). Nevertheless, the mentioned studies are important, as both the blackmouth catshark and small spotted catshark are considered indicator species for the evaluation of fishing efforts, ecosystem stability and broad scale changes caused by exploitation in their ecosystem (Heithaus *et al.* 2008). The similarities in the feeding habits of the two species indicate not only a possibility of interspecific competition, but also the connection of the two species in assessing the state of an ecosystem.

4.5 Role of the small spotted catshark in the food web

The results of this research show that the small spotted catshark is a generalistic predator. Although not all of the higher taxa contributed significantly to the diet, their presence in the analyzed stomachs shows an opportunistic feeding behaviour. The calculated ITD of 0.87 for all the sampled individuals and ITD of 0.87 and 0.85 for females and males respectively confirms the diet of the small spotted catshark contained a variety of prey items.

The calculated TROPH index of 3.91±0.58 for all the sampled individuals and 3.77±0.53 and 3.99±0.6 for the females and males respectively classifies this species as a mesopredator.

4.6 Conservation implications

Elasmobranchs are considered as key stone species in the marine ecosystems, as they maintain the structure and function of the food webs (Libralato *et al.* 2006; Baum and Worm 2009; Barria *et al.* 2015). They are also highly sensitive to ecosystem changes and human impacts such as fishing activity, pollution and habitat degradation (Stevens *et al.* 2000, Myers and Worm 2003; Dulvy *et al.* 2014). Most elasmobranch species are very sensitive to fishing effort and their abundance in the Mediterran is in decline. The small spotted catshark, however, along with the deep-water blackmouth catshark *Galeus melanostomus* is considered to be an indicator species for fishing efforts as it displays high resilience to high fishing effort (Massuti and Moranta 2003; Ferretti *et al*. 2010). Even though the smaller individuals are mostly affected by trawling activity, these are usually discarded or returned to the sea (Carbonell *et al.* 2003).

Therefore, the fact that this species is abundant throughout the rest of the Adriatic sea and classified as a species of Least Concern by the IUCN, but rare in the Northern Adriatic, is especially concerning and indicative of the high fishing and by-catch pressure on the populations of this species in the area. The Adriatic Sea is a heavily exploited part of the Mediterranean basin with a decline of large apex predators over the past two centuries (Ferretti *et al.* 2013).

This research of the feeding habits of this species ought to be the first step to systematic research of the abundance of this species, as it not only sheds light on the feeding habits of the species, but also presents additional data on the abundance of the species from lower trophic levels, which were the prey for this species. Additional research would provide a foundation for a more complete overview of the most endangered species and most vulnerable habitats in the Northern Adriatic.

5 CONCLUSION

Two out of three hypotheses presented at the beginning of this research were confirmed: the small spotted catshark is a generalistic predator feeding on a wide variety of prey categories. There were also differences observed in the female and male specimens of the species, as females prey more cephalopods and crustaceans, while the males prefer to forage on teleost fishes. However, there were not significant differences observed in the feeding habits between different length groups. The main prey of the individuals of the largest length category, considered adult individuals, were teleost fishes, in contrast to subadult and juvenile individuals who were feeding on cephalopods and crustaceans in a larger amount. The role of the small spotted catshark as a mesopredator is especially important in the Northern Adriatic, as the number of apex predators is in decline in the entire Adriatic Sea.

6 POVZETEK V SLOVENSKEM JEZIKU

Mala morska mačka (Scyliorhinus canicula Linnaeus, 1758) je vrsta morskega psa iz družine Scyliorhinidae Gill, 1862, najbolj raznolike družine morskih psov. Je razširjena v severovzhodnem in osrednjem vzhodnem Atlantiku, od Šetlanskih otokov in Norveškega na severu, do zahodne Afrike na jugu, vključno z Sredozemskim morjem. Osebke te vrste lahko najdemo od plitkega sublitoralnega pasu do roba kontinentalnega šelfa, na peščenem, muljastem, koralnem in prodnatem dnu (Compagno in sod. 2005; Ellis in sod. 2009).

Gre za vrsto manjše velikosti; za jadransko populacijo je povprečna velikost 9-49 cm dolžine (Jardas 1996; Lipej in sod. 2004). Telo ji je vitko in cilindrično, hrbtni del je svetlorjave barve, s številnimi svetlimi in temnimi pikami, medtem ko je trebušni del bledo-bele barve (Lipej *et al.* 2006). Zobje te vrste so mononogno heterodontni, kar pomeni da se v čeljustih stopnjujejo zobje, ki so različni po velikosti in obliki, od spredaj proti zadnjem delu čeljusti. Je skupaj 400-450 zob v čeljustih (Spath in sod. 2017; Soares in Carvalho 2019; Botella in sod. 2009). Gre za oviparno vrsto; samice odlagajo jajčeca, ki so zaščitena z roževinasto ovojnico z dolgimi viticami (Ellis in sod. 2009). Najvišja prijavljena starost je 12 let (Ivory in sod. 2005).

Mala morska mačka je po ocenah Mednarodne zveze za varstvo narave (IUCN) opredeljena kot najmanj zaskrbljujoča vrsta. Čeprav poročajo o komercialnem iztovarjanju te vrste, pri čemer se večji primerki obdržijo za prehrano ljudi, se posamezniki vrste pogosto zavržejo z visoko stopnjo preživetja (Ellis in sod. 2009). Podatkov za severni Jadran sploh ni, glede na to, da je le v tem delu Jadrana ta vrsta redka, zaradi visoke stopnje naključnega ulova med ribolovom z vlečno mrežo (Lipej in sod. 2006).

Podatki o prehranjevalnih navadah vseh vrst morskih rib in o medsebojnih plenilec- plen odnosih so zelo uporabni za oceno vloge vrste v ekosistemu (Šantić in sod. 2012). V skladu s tem se določajo prehranjevalne niše glede na hrano, ki jo plenilec zaužije.
Namen te magistrske naloge je bil prispevati k podatkom, ki bi v končnici vplivali na bolj vzdržljive strategije ohranjanja in varstva obravnavane vrste v severnem Jadranskem morju. Prvi cilj magistrske naloge je bil razkriti poznavanje prehranjevalnih navad male morske mačke v priobalnem okolju severnega Jadranskega morja. Drugi cilj magistrske naloge je bil ugotoviti, ali obstajajo razlike v prehranjevalnih navadah tudi med samci in samicami (znotrajvrstna kompeticija). Zbranih je bilo 205 osebkov morske mačke, ki so jih od slovenskih in hrvaških ribičev pridobili raziskovalci Morske biološke postaje Piran. Osebki so bili zbrani na šestih lokacijah hrvaškega dela Istrskega polotoka. Od tega smo analizirali 188 osebkov. Uporabljena je bila standardna metodologija analize prehranjevalnih navad na podlagi preiskave vsebine želodcev.

Po analizi vsebine želodcev in določevanju skupin plena, izračunani so bili parametri: indeks praznine, relativna abundanca plena, relativna frekvenca pojavljanja plena, relativna gravimetrična sestava plena in indeks relativne pomembnosti plena. Plen je bil razdeljen z različnih vidikov, in sicer glede na spol, velikost in glede na lokalitete, kjer so bili posamezni osebki ulovljeni. Statistična analizo podatkov je bila opravljena s programom Microsoft Excel.

Rezultati so pokazali, da predstavljajo glavonožci in kostnice najpomembnejše vrste plena. Od drugih skupin plena so morske mačke plenile rake, črve mnogoščetince, hrustančnice ter razne druge nevretenčarje. Glavonožci so bili v prehrani male morske mačke zastopani z 37.4 % IRI, kostnice z 36.3 % IRI, raki z 17.23 % IRI in črvi mnogoščetinci z 7.81 % IRI.

Indeks trofične raznolikosti (ITD) je bil 0.87, kar kaže da se mala morska mačka prehranjuje z raznolikimi skupinami plena. Trofični nivo je bil 3.91±0.58, kar kaže da je mala morska mačka v severnem Jadranu omnivorna mezoplenilska vrsta.

Analiza relativne pomembnosti plena za samice male morske mačke je pokazala, da so glavonožci (50.42 % IRI) najbolj pomembna skupina, s katero so se hranile samice. Za samce so najbolj pomemben plen bile kostnice (44.96 % IRI). Indeks trofične raznolikosti je bil 0.87 za samice in 0.85 za samce. Raziskava je pokazala, da obstajajo razlike med prehrano med spoloma male morske mačke v severnem Jadranu. Za prehrano med različnimi velikostnimi skupinami male morske mačke niso bile ugotovljene pomembne razlike. Enako je šlo za razlike med lokacijah na katerih so bile morske mačke ulovljene.

Pomanjkljivost te raziskave je predvsem majhno število vzorcev, kar je posledica tega da so vzorci zbrani kot prilov, ne pa v sistematični raziskavi. Tudi je treba poudariti, da so vzorci bili poškodovani in da ni bilo možno narediti biometrijsko analizo na vseh vzorcih, prav zaradi poškodb na telesih. Poškodbe so rezultat obdelave vzorcev od strane ribičev. Druga pomanjkljivost raziskave je, da ni bilo možno določiti vseh osebkov plena do vrste, saj so številni osebki plena bili razgrajeni ali fragmentirani. Zaradi tega je bilo možno določanje le do višjih taksonomskih nivojih.

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