

THE DIET OF THE MEDITERRANEAN SHAG *Phalacrocorax aristotelis desmarestii* ROOSTING ALONG THE SLOVENIAN COAST

Prehrana sredozemskega vranjeka *Phalacrocorax aristotelis desmarestii* na počivališčih vzdolž slovenske obale

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Five hundred pellets of the Mediterranean Shag *Phalacrocorax aristotelis desmarestii* were collected at three roost-sites along the Slovenian coast and analysed. The diet was characterized mostly by the dominance of bottom dwelling fish species of the appropriate size. The Black Goby *Gobius niger* was the most dominant prey and represented the Shag's main prey in the studied area (IRI% = 64.0). The results of the study confirm that the Mediterranean Shag preys mainly on fish species which are without commercial value for local fisheries.

Key words: piscivorous birds, roosts, otoliths, northern Adriatic

Ključne besede: ribojede ptice, počivališča, otoliti, severni Jadran

1. Introduction

The Mediterranean Shag *Phalacrocorax aristotelis desmarestii* is one of the three species of the family Phalacrocoracidae occurring in Slovenia. It inhabits the Mediterranean and the Black Seas. In the Gulf of Trieste, it has been a regular inhabitant since 1980 (SPONZA *et al.* 2010), where it can be sighted mainly during summer and autumn. The Mediterranean Shag population in Slovenian part of the Adriatic Sea is estimated at its seasonal peak at approximately 1,500 individuals, which corresponds to 5% of the subspecies' overall population. They gather at three communal roost-sites along the Slovenian coast (BORDJAN *et al.* 2013). Mediterranean Shag is considered to be a fish-preying top-predator which has a certain impact on the coastal fish assemblage (*sensu* COSOLO *et al.* 2011). For maintaining its population in the Slovenian part of the Adriatic Sea, it is important to understand basic biology of this population, especially its diet and prey availability dependence.

The aim of this paper was to gain knowledge about the Mediterranean Shag's diet in a shallow coastal area with a special focus on the qualitative and quantitative information on the impact of its predation on fish populations. This study is a first step in determining prey consumption by the Mediterranean Shag in

Slovenian waters, which is necessary to obtain information to assess the possible impact on local fisheries. This work was done within the framework of the project SIMARINE-NATURA (LIFE10NAT/SI/141) Preparatory inventory and activities for the designation of marine IBAs and SPAs for *Phalacrocorax aristotelis desmarestii* in Slovenia.

2. Material and methods

The studied area is located in the Gulf of Trieste, which is the northernmost part of the Adriatic Sea (Figure 1). The southern part of the Gulf of Trieste constitutes the Slovenian part of the Adriatic Sea, a shallow area with a depth rarely exceeding 25 m. The coastal area is characterised by rocky environment or sedimentary bottom such as sandy and muddy areas, which may be bare or densely populated by the marine phanerogam *Cymodocea nodosa* (LIPEJ *et al.* 2006).

The diet of the Mediterranean Shag was studied by analyzing the content of pellets. Although this method has some limitations (CASAUX 2003), such as the digestion of small otoliths or the underestimation of the real prey size among others, it is still one of the most used standardized techniques for assessing the diet of many raptorial birds, including herons, cormorants and shags. Pellets were collected at three

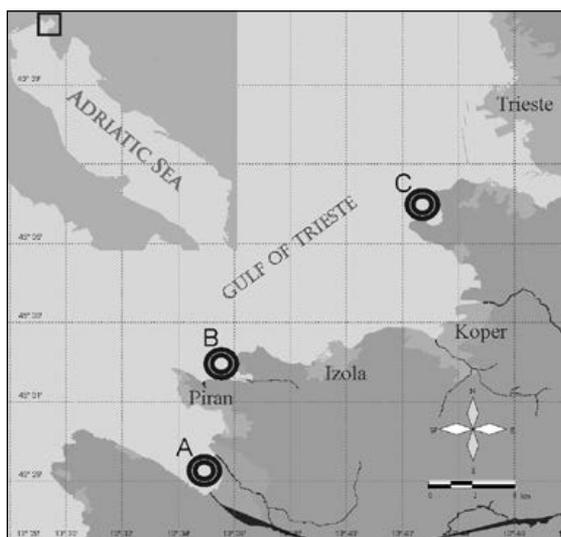


Figure 1: Study area with the three communal roost-sites: (A) Sečovlje, (B) Strunjan, (C) Debeli Rtič.

Slika 1: Območje raziskave s tremi skupinskimi prenočišči: (A) Sečovlje, (B) Strunjan, (C) Debeli Rtič.

communal roost-sites along the Slovenian coast: (1) off the Sečovlje salina (Sečovlje roost-site), (2) in the bay of Strunjan (Strunjan roost-site), and (3) at the Debeli rtič roost-site (Figure 1). Altogether 500 pellets of the Mediterranean Shag were collected from 2011 to 2013, 66% at the Sečovlje roost-site, 29% at the Strunjan roost-site and 5% at the Debeli rtič roost-site (Table 2). Most pellets were taken from buoys of shellfish farms; however, two sets of pellets were collected along the Sečovlje salina outer levee (15%).

Pellets were carefully removed from the roosting ground on buoys or levee and frozen. Before the analysis, they were dried out in the laboratory. After a 24 hours bath in 10% NaOH solution, pellets were washed to sort out skeletal remains such as otoliths and other organic remains like cephalopod beaks and decapod remains. Otoliths were used for identification of fish (Figure 2) to the lowest possible level according to scientific literature such as the key for otolith identification of the western Mediterranean sea and northern Atlantic (TUSET *et al.* 2008) and the available determination key AFORO found on the website (<http://www.cmima.csic.es/aforo/>; LOMBARTE *et al.* 2006). Our own extensive reference collection of otoliths also proved to be helpful in fish determination. For the assessment of the Mediterranean Shag's diet, we used the three commonest indices, dealing with the number of prey items (N%), frequency of occurrence (FO%) and biomass (W%) (PINKAS *et al.* 1971). Additionally, we

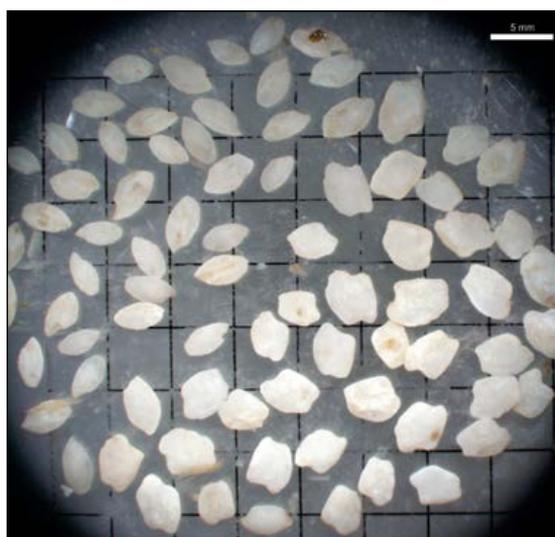


Figure 2: Sample of isolated otoliths prepared to be identified under the stereomicroscope and counted

Slika 2: Vzorec prebranih otolitov, pripravljenih za determinacijo pod mikroskopom in štetje

calculated the universal index of relative importance (IRI%), used in fish biology (CORTES 1997), which was calculated as:

$$IRI = (N\% + W\%) * FO\%$$

$$IRI\% = (IRI_i / \sum IRI_{ij}) * 100$$

For assessing the biomass average weight of each prey species, (W_i) was assessed with measurements of whole specimens of each species *i*, obtained from the study area (*own data*).

3. Results

In total, 20,430 prey items were isolated (Table 1). Four pellets were void of any otoliths or other useful remains for identification. In other pellets the number of prey items varied from 1 to 172 per pellet (Figure 3), on average 41.2 per pellet. In more than half of all pellets the number of prey items varied from 20 to 50 per pellet.

The great majority of all prey items were fish (>99%), while decapods and cephalopods were present in negligible numbers (0.1 and 0.08%, respectively). Otoliths of 30 fish species from 18 families were identified in the pellets. Gobies (Gobiidae) were best represented by 6 species, followed by blennies Blenniidae and sea breams Sparidae, with 3 species each (Table 1).

Table 1: The diet of Mediterranean Shag *Phalacrocorax aristotelis desmarestii* in the 2011–2013 period at three roosting sites in Slovenian waters. The data for mean weight of particular prey items (W_i^*) was obtained by measuring samples of different fish species or from literature data. Legend: N – number of prey items, W – calculated weight, F% – frequency of occurrence, IRI – index of the relative importance.

Tabela 1: Prehranjevalne navade sredozemskega vranjeka *Phalacrocorax aristotelis desmarestii* v obdobju 2011–2013 na treh počivališčih v slovenskem morju. Podatki o povprečni teži plena (W_i^*) so bili pridobljeni z meritvami vzorcev določenih vrst rib ali povzeti po literaturnih podatkih. Legenda: N – število primerkov plena, W – preračunana masa, F% – frekvenca pojavljanja, IRI – indeks relativne pomembnosti plena.

Taxa	N	N%	$W_i^*(g)^*$	W (g)	W%	F%	IRI	IRI%
<i>Atherina boyeri</i>	478	2.34	2.5	1195.00	0.32	9.11	24.24	0.14
Blenniidae indet.	27	0.13	20	540.00	0.14	2.43	0.67	0.00
<i>Cepola macrophthalmal</i>	624	3.05	15.4	9609.60	2.58	47.57	267.99	1.57
<i>Chromis chromis</i>	19	0.09	10.5	199.50	0.05	0.81	0.12	0.00
<i>Diplodus vulgaris</i>	1	0.00	25	25.00	0.01	0.2	0.00	0.00
<i>Engraulis encrasicolus</i>	14	0.07	9.7	135.80	0.04	0.81	0.09	0.00
<i>Eutrigla gurnardus</i>	1	0.00	25.7	25.70	0.01	0.2	0.00	0.00
Gadidae indet.	18	0.09	45	810.00	0.22	2.02	0.62	0.00
<i>Gobius cobitis</i>	58	0.28	35.6	2064.80	0.55	3.85	3.23	0.02
<i>Gobius cruentatus</i>	75	0.37	18.4	1380.00	0.37	9.11	6.72	0.04
<i>Gobius niger</i>	10093	49.40	22.7	229111.10	61.49	98.18	10887.81	63.99
<i>Gobius paganellus</i>	1	0.00	13.4	13.40	0.00	0.2	0.00	0.00
<i>Gobius</i> sp.	5208	25.49	16	83328.00	22.37	91.09	4359.31	25.62
<i>Merlangius merlangus</i>	6	0.03	55.3	331.80	0.09	1.01	0.12	0.00
<i>Monochirus hispidus</i>	36	0.18	15.4	554.40	0.15	3.64	1.18	0.01
<i>Ophidion barbatus</i>	4	0.02	49	196.00	0.05	0.81	0.06	0.00
<i>Pagellus erythrinus</i>	12	0.06	41.3	495.60	0.13	0.61	0.12	0.00
<i>Parablennius gattorugine</i>	13	0.06	43.5	565.50	0.15	0.4	0.09	0.00
<i>Parablennius rouxi</i>	4	0.02	15	60.00	0.02	0.81	0.03	0.00
<i>Parablennius tentacularis</i>	5	0.02	28	140.00	0.04	0.81	0.05	0.00
<i>Phycis blennoides</i>	6	0.03	48.6	291.60	0.08	0.4	0.04	0.00
<i>Pomatoschistus marmoratus</i>	146	0.71	0.25	36.50	0.01	12.15	8.80	0.05
<i>Sardinella aurita</i>	3	0.01	5.8	17.40	0.00	0.61	0.01	0.00
<i>Serranus hepatus</i>	2739	13.41	9.7	26568.30	7.13	62.50	1287.71	7.57
<i>Solea solea</i>	1	0.00	17	17.00	0.00	0.2	0.00	0.00
<i>Spicara flexuosa</i>	4	0.02	26	104.00	0.03	0.2	0.01	0.00
<i>Spondyllosoma cantharus</i>	1	0.00	70	70.00	0.02	0.2	0.00	0.00
<i>Symphodus cinereus</i>	40	0.20	24.5	980.00	0.26	3.85	1.77	0.01
<i>Syngnathus acus</i>	3	0.01	13	39.00	0.01	0.4	0.01	0.00
<i>Trachinus draco</i>	83	0.41	25.6	2124.80	0.57	8.7	8.50	0.05
<i>Trachurus mediterraneus</i>	20	0.10	48.9	978.00	0.26	0.61	0.22	0.00
<i>Trisopterus minutus</i>	95	0.47	45.7	4341.50	1.17	11.94	19.47	0.11
<i>Zosterisessor ophiocephalus</i>	4	0.02	18.9	75.60	0.02	0.61	0.02	0.00
Pisces indet.	550	2.69	10	5500.00	1.48	32.66	136.14	0.80
Decapoda	22	0.11	4.2	92.40	0.02	4.25	0.56	0.00
Cephalopoda	16	0.08	35	560.00	0.15	2.02	0.46	0.00
Total / Skupaj	20430	100.00		372577.30	100.00		17016.17	100.00

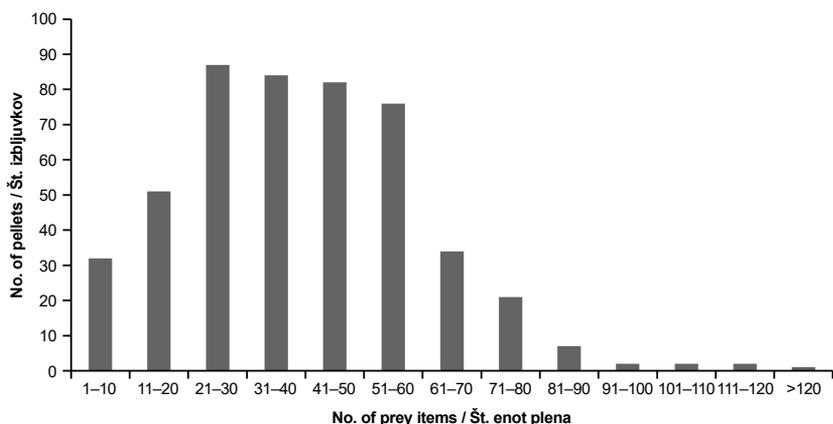


Figure 3: Number of prey items per pellet

Slika 3: Število primerkov plena na posamezni izbijljkov

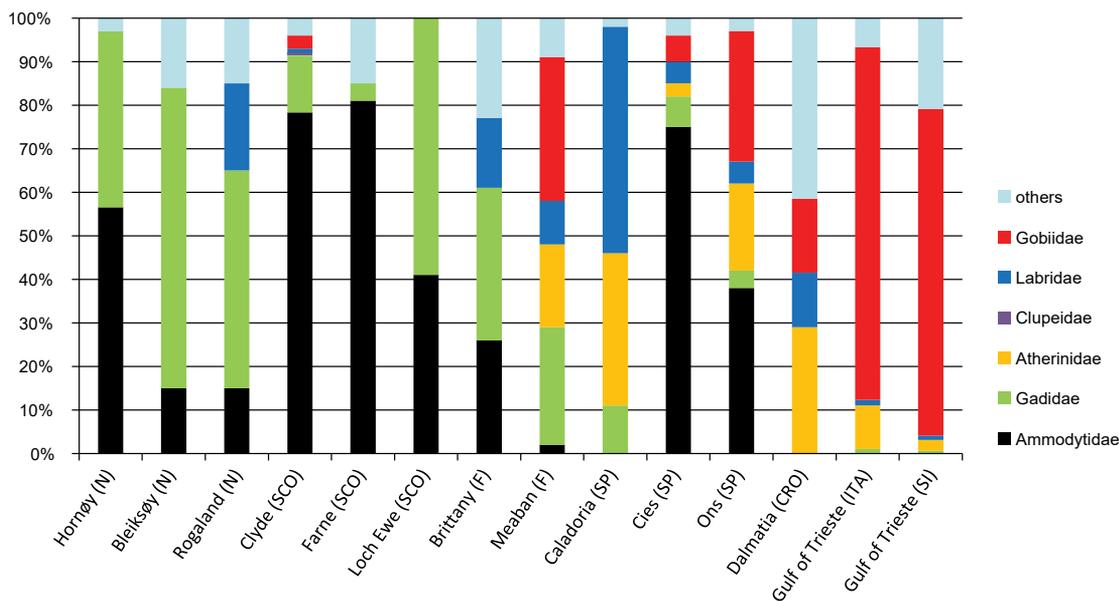


Figure 4: The diet of the European Shag *Phalacrocorax aristotelis* in Europe in comparison with the data of this study. The diet of the subspecies *P. a. desmarestii* is denoted with asterisks. Prey items are grouped in fish families. Sites where the Shag's diet was studied: Norway: Hornøy, Bleiksøy and Rogaland (BARETT *et al.* 1990); Scotland: Clyde, Farne and Loch Ewe (PEARSON 1968, LUMSDEN & HADOW 1946, MILLS 1969; all cited in VELANDO & FREIRE 1999), France: Brittany (PASQUET 1987), Meaban, Bay of Biscay (FORTIN *et al.* 2012); Riou Archipelago (MORAT *et al.* 2014*), Spain: Caladonia, Asturia (ALVAREZ 1998), Cies and Ons, Galicia (VELANDO & FREIRE 1999), Croatia: Oruda, northern Adriatic (COSOLO *et al.* 2011*); Italy: Gulf of Trieste, northern part (COSOLO *et al.* 2011*) and Slovenia: southern part of the Gulf of Trieste (*this work**).

Slika 4: Prehranjevalne navade vranjeka *Phalacrocorax aristotelis* v Evropi in primerjava s podatki pričujočega dela. Dela, ki se nanašajo na prehrano sredozemske podvrste *P. a. desmarestii*, so označena z zvezdico. Plen je združen v večje prehranjevalne kategorije – ribje družine. Lokalizacije, kjer so raziskovali prehrano vranjekov: Norveška: Hornøy, Bleiksøy in Rogaland (BARETT *et al.* 1990); Škotska: Clyde, Farne in Loch Ewe (PEARSON 1968, LUMSDEN & HADOW 1946, MILLS 1969; vsi citirani v delu VELANDO & FREIRE 1999), Francija: Bretanja (PASQUET 1987), Meaban, Biskajski zaliv (FORTIN *et al.* 2012); otočje Riou (MORAT *et al.* 2014*), Španija: Caladonia, Asturija (ALVAREZ 1998), Cies in Ons, Galicija (VELANDO & FREIRE 1999), Hrvaška: Oruda, severni Jadran (COSOLO *et al.* 2011*); Italija: Tržaški zaliv, severni del (COSOLO *et al.* 2011*) in Slovenija: južni del Tržaškega zaliva (*to delo*).

Table 2: Comparison of the diet of Mediterranean Shag *Phalacrocorax aristotelis desmarestii* at different sites in 2011–2013. Legend: P – number of analyzed pellets, N – number of prey items, N/P – number of prey items per pellet, S – number of different species or taxa, *Gnig* – number of Black Gobies *Gobius niger* in the diet, %*Gnig* – percentage of Black Gobies.

Tabela 2: Primerjava prehrane sredozemskega vranjeka na različnih počivališčih v obdobju 2011–2013. Legenda: P – število analiziranih izbljuvkov, N – število primerkov plena, N/P – število primerkov plena na izbljuvek, S – število različnih vrst ali taksonov, *Gnig* – število črnih glavačev *Gobius niger* v prehrani, %*Gnig* – delež črnih glavačev *Gobius niger* v prehrani.

Roost-site / Počivališče	Date / Datum	P	N	N/P	S	<i>Gnig</i>	% <i>Gnig</i>
Sečovlje	2. 9. 2011	6	345	57.50	8	145	42.03
Sečovlje	1. 7. 2012	60	1601	26.68	17	802	50.09
Sečovlje	5. 7. 2012	17	659	38.76	9	248	37.63
Debeli rtič	20. 7. 2012	45	1245	27.67	10	661	53.09
Strunjan	27. 7. 2012	25	607	24.28	11	411	67.71
Sečovlje	1. 8. 2012	21	784	37.33	12	454	57.91
Sečovlje	24. 8. 2012	187	8649	46.25	30	4029	46.58
Sečovlje	25. 7. 2013	37	2239	60.51	15	832	37.16
Strunjan	17. 8. 2013	102	4301	42.17	17	2511	58.38
Total / Skupaj		500	20430				

The Black Goby *Gobius niger* was the dominant species with 49.4% in terms of abundance number and also represented the main prey species (IRI% = 64.0). This number may be even greater since the second most abundant category is represented by Gobies *Gobius* sp. (N% = 25.5% and IRI% = 25.6), which were not identified to the species level due to eroded or damaged otoliths.

The third most preyed fish was the Brown Comber *Serranus hepatus* with 13.4%, while among other prey species only the Red Bandfish *Cepola macrophthalmia* and Mediterranean Big-scale Sand Smelt *Atherina boyeri* were present with more than 1% in diet. Otoliths of the Black Goby were found in almost every pellet (FO% = 98.2%). Two additional species, Brown Comber and Red Bandfish, were present with high frequency of occurrence (FO% = 62.5 and 47.6, respectively), followed by the Marbled Goby *Pomatoschistus marmoratus* (FO% = 12.2) and Poor Cod *Trisopterus capelanus* (FO% = 12.0). In the case of the maximum number of prey items per pellet, all 172 preyed specimens were Big-scale Sand Smelts.

At different localities and in different samples the percentage of the Black Goby varied from 37.6% to 67.7% of all prey items (Table 2). In different samples of pellets it varied from 24.3 to 57.5 prey specimens per pellet. The diet of Mediterranean Shags from the Debeli rtič roost-site differed slightly from those in other areas by preying also a considerable amount of Big-scale Sand Smelts.

4. Discussion

The great majority of all preyed fish species are considered as more or less benthos dwelling species and are always closely related to the sea floor. In that regard all gobies, Red Bandfish, Greater Weever *Trachinus draco* and others are typical epibenthic species, whereas Brown Comber, Grey Wrasse *Symphodus cinereus*, Poor Cod and others are considered nectobenthic species. Only Anchovy *Engraulis encrasicolus*, Gilt Sardine *Sardinella aurita* and Horse Mackerel *Trachurus mediterraneus* are considered as purely nektonic species from the ecological point of view. These results fit well with the study of COSOLO *et al.* (2011) in the northern Gulf of Trieste, but are in contrast to the study of MORAT *et al.* (2014) for the waters off the Riou Archipelago in France where Mediterranean Shag preyed mostly upon pelagic fish and only in low portion on benthic dwelling fish.

From an ecological perspective, the Mediterranean Shag is an important element in piscivorous guild of the northern Adriatic food web. Since it is purely specialized on preying epibenthic fish species on sedimentary bottom of the shallow Gulf of Trieste, it competes with coastal marine fish predators such as rays and skates and benthic sharks (genus *Mustelus*). Black Gobies seem to be the optimal prey species of the Mediterranean Shag due to their availability and easy access in the shallow environment. In fact, they are present in high numbers and easily detected by a

visually searching predator (*pers. observations*). Since Black Gobies can be found more or less motionless in sandy and muddy habitats in few metres of depth, they are easily accessible and the energy expenditure for such hunting is rather low (SPONZA *et al.* 2010).

Although other prey species play a much less important role in the diet of the Mediterranean Shag, they are mostly found in the very same or similar benthic habitats, e.g. sandy or muddy bottoms. This applies especially to Brown Comber, Red Bandfish and Greater Weaver, Common Sole *Solea solea* and, to a lesser extent, to Poor Cod. Among the wrasses, which are typical coastal sea species, only the Grey Wrasse was found in pellets. In comparison with other wrasses the latter is unique in preferring unvegetated areas (LIPEJ *et al.* 2009), which makes it more vulnerable to predation.

The overall percentage of fish species from the more common fish families other than gobies such as wrasses (Labridae), sparids (Sparidae), and blennies (Blenniidae) is surprisingly low, never exceeding 1% of all prey items. It is rather probable that adult sparids and wrasses with deep body do not fit as an optimal prey to be preyed and swallowed by shags. On the other hand, the external anatomy of fish such as Greater Weaver, Red Bandfish and other elongate species are similar to the shape of gobiids, however, they generally bury themselves in the sand (the former) or retreat in their burrows (the latter).

Other goby species are very common in the coastal fish assemblage (e.g. LIPEJ *et al.* 2003), however, they were present in much lower numbers in the diet of the Mediterranean Shag. Since they are dwelling on the rocky bottom, they seem to be less vulnerable to the Shag's predation. Some gobies preferentially inhabit sea grass meadows, e.g. Grass Goby *Zosterisessor ophiocephalus*, which provide a shelter against avian predators.

In certain pellet samples from the protected area of Debeli rtič, one of the dominant elements in the food habits was Big-scale Sand Smelt. In the very shallow area of this site, where sandstone blocks extend far from the coast, Shags were in fact often observed to prey communally on schools of small pelagic fish, especially at the end of summer and in autumn (KOCE 2015). Big-scale Sand Smelt is not a bottom dwelling species, however, it is present in numerous schools in very shallow waters, which makes it an abundant and easily detectable prey item. Nevertheless, smelts are less relevant in terms of relative importance biomass due to the small size of the depredated specimens.

From a commercial point of view, the Mediterranean Shags prey only on a negligible number of target prey, for example Poor Cod (IRI% = 0.11).

Due to the substantial dominance of Black Gobies and other undetermined gobies we could speculate that the optimal prey size was in the size range from 7 to 14 cm, which is the size range of this species in the Adriatic Sea (BOBAN *et al.* 2013). MORAT *et al.* (2014) pointed out the fact that fishermen are generally targeting much larger fish species.

The diet of the species *Phalacrocorax aristotelis* has been studied in several countries such as Norway (e.g. BARRETT *et al.* 1990), United Kingdom (e.g. LUMSDEN & HADOW 1946, PEARSON 1968, MILLS 1969), France (e.g. FORTIN *et al.* 2012, MORAT *et al.* 2014), Spain (e.g. ALVAREZ 1998, VELANDO & FREIRE 1999) and in the Adriatic region (COSOLO *et al.* 2011). In several studies it was demonstrated that the Shag in general, preys opportunistically on various fish species. Although the diet of the European Shag is very variable in different studies and depending on the geographical area as pointed out by VELANDO & FREIRE (1999) in the majority of studies prey of a certain fish family prevails over other prey items. In the Atlantic region prey species from families Ammodytidae and Gadidae are the main prey category, whereas in certain areas fishes from families Atherinidae, Labridae and Gobiidae represent the preferred prey. In the Adriatic sea, gobies represent an important prey category.

The results of our study fit well with the data obtained in the northern (Italian) part of the Gulf of Trieste by COSOLO *et al.* (2011), which reflects the similarity of the two areas in terms of habitat characteristics and prey availability. In their study, the Black Goby was the preferred prey as well and the same was true for alternative prey species, such as the Red Bandfish, Brown Comber, Poor Cod and others. In their study, the mean number of prey items per pellet was also similar (39.26 vs 41.19 in our study). Slight differences are noticeable only in the somewhat different list preyed species and the percentage of smelts Atherinidae in their study. Although the Black Goby is a preferential prey species in the studied area, the Mediterranean Shag should be considered rather as an opportunistic predator. Since gobies are very abundant in the sandy and muddy environments of the southern part of the Gulf of Trieste (and in the northern, too, as demonstrated by COSOLO *et al.* 2011), they are easily accessible for shags. In certain sites, smelts were present in high numbers, which prove that shags are hunting whatever is easily accessible and abundant in the hunting environment. Recently, AL ISMAIL *et al.* (2013) pointed out the fact that in Mallorca the Mediterranean Shags preyed on a substantial number of fish species with hard scales and venomous spines such as members of the families Scorpaenidae and Trachinidae, which

are at the same time also well camouflaged on the sea floor. The authors believed that the Shag predation on such species may be a result of a scarcity of other more palatable prey. In our study few specimens of Greater Weaver, which is otherwise a rather common and abundant fish species in sandy and muddy bottom in the Gulf of Trieste, were found in shag's pellets and no scorpionfish at all.

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5. Povzetek

Na treh počivališčih sredozemskega vranjeka *Phalacrocorax aristotelis desmarestii* vzdolž slovenske obale smo nabrali 500 izbljuvkov in jih analizirali. V prehrani so prevladovalе ribje vrste primerne velikosti, ki bivajo na morskem dnu. Dominantna vrsta v prehrani in glavni plen vranjeka na preučevanem območju je bil črni glavač *Gobius niger* (IRI% = 64.0). Izsledki raziskave potrjuje, da sredozemski vranjek pleni predvsem vrste rib, ki so za ribiče komercialno nezanimive.

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