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Experimental catches and distribution of Queen scallop *Aequipecten opercularis* (LINNAEUS, 1758) (Pectinidae, Mollusca Bivalvia) in the Adriatic Sea

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The paper presents data on the distribution and catch quantities of the species Aequipecten opercularis *(LINNAEUS, 1758) in the Adriatic Sea. The bivalve* A. opercularis *was collected by bottom trawl during 17 cruises of PIPETA Expedition in the Adriatic Sea in the period from 1982 to 1994. A total of 201 bottom trawl hauls were performed in the area of* A. opercularis *distribution in the northern Adriatic (8988 km²).* A. opercularis *has been recorded at 90.55% of hauls. The data do not include the area around islands and inshore part of the northern Adriatic Sea where the species is well represented. Standard "swept area" method was used to estimate the abundance of the species. The catch quantities varied a lot among the cruises. Mean catch values range from 14.51 to 3494.88 kg km⁻². The species is the best distributed at depths of 40 to 49 m on "relict" sand and clayey "relict" sand.*

Key words: bivalve, *Aequipecten opercularis*, distribution, bottom trawl, Adriatic Sea

INTRODUCTION

Data refer to the distribution and catch quantities of the species *Aequipecten opercularis* (L.) collected during the 1982-1994 period within the fishery-biological program (PIPETA) of trawl grounds research on the Adriatic continental shelf carried out jointly by the Institute of Oceanography and Fisheries in Split, Croatia and Laboratory for Marine Biology and Fisheries in Fano, Italy. Earlier data on the species *A. opercularis* were mostly a part of the studies of benthic communities in the Adriatic Sea, describing the species distribution with respect to the depth and sediment type (VATOVA, 1928, 1949; COEN and VATOVA, 1933; PÉRÈS and PICARD, 1958; GAMULIN-BRIDA, 1962; STJEPČEVIĆ, 1967; ZAVODNIK, 1971; PARENZAN, 1974; ALVIZI *et al.*, 1978; COLANTONI and TAVIANI, 1980; STJEPČEVIĆ and PARENZAN, 1980). VATOVA (1928, 1949) noted its commercial importance for markets in Venice, Trieste and the west coast of Istria. PICCINETTI *et al.* (1985) established the area of *A. opercularis* distribution in the northern part of the Adriatic. They stated that this species is mostly spread in relatively shallow waters, on sandy and partly sandy-loamy sediments but not deeper than 62-66 m.

MATERIAL AND METHODS

The biological material was collected by Italian commercial trawler PIPETA during 17 cruises occasionally in the Adriatic Sea from 1982 to 1994. The PIPETA Expedition performed research on nine profiles ("A", "B", "C", "D", "E", "F", "G", "H", "I") at advance planned stations during the first six cruises and on ten profiles from 7th to 17th cruise ("L" profile was introduced) comprehending the surface of approximately 59000 km^2 of the Adriatic continental shelf (Fig. 1).

In this paper we considered only the stations in area of *Aequipecten opercularis* distribution in the northern Adriatic Sea established by PICCINETTI *et al.* (1985). These stations are: A2, A3, A4, A6, A7, B3, B4, C3, C4, C5, C6, D6 on the area of 8988 km^2. The data do not include the area around islands and inshore part of the northern Adriatic where the species is well represented. A total of 201 hauls were done (Table 1).

The standard Italian bottom trawl was used (PICCINETTI, 1972). The station stratification regarding the depth and sediment type was done later, since the station planning for all seventeen cruises was systematic. The stations were situated on the following sediment types: "relict" sand, clayey "relict" sand, sand-silt-clay, clayey silt and silty clay, silty sand and sandy silt. The collected data were elaborated according to the following depth zones: from 10 - 19, 20 - 29, 30 - 39, 40 - 49, 50 - 59, 60 - 69 m.

The weight of the bycatch was measured by filling up a plastic box of 50 x 32 x 10.5 cm by the random sample method with the epifaunal material collected by the trawl. The weight of a plastic box with epifauna was multiplied with the total number of boxes with epifauna collected during a single bottom trawl haul and the value was expressed in kg km^{-2} and N km^{-2}. Leaving apart the problems of species accessibility to bottom trawl at profiles and stations, the widely known "swept area" method (SPARRE and VENEMA, 1992) was used, assuming that

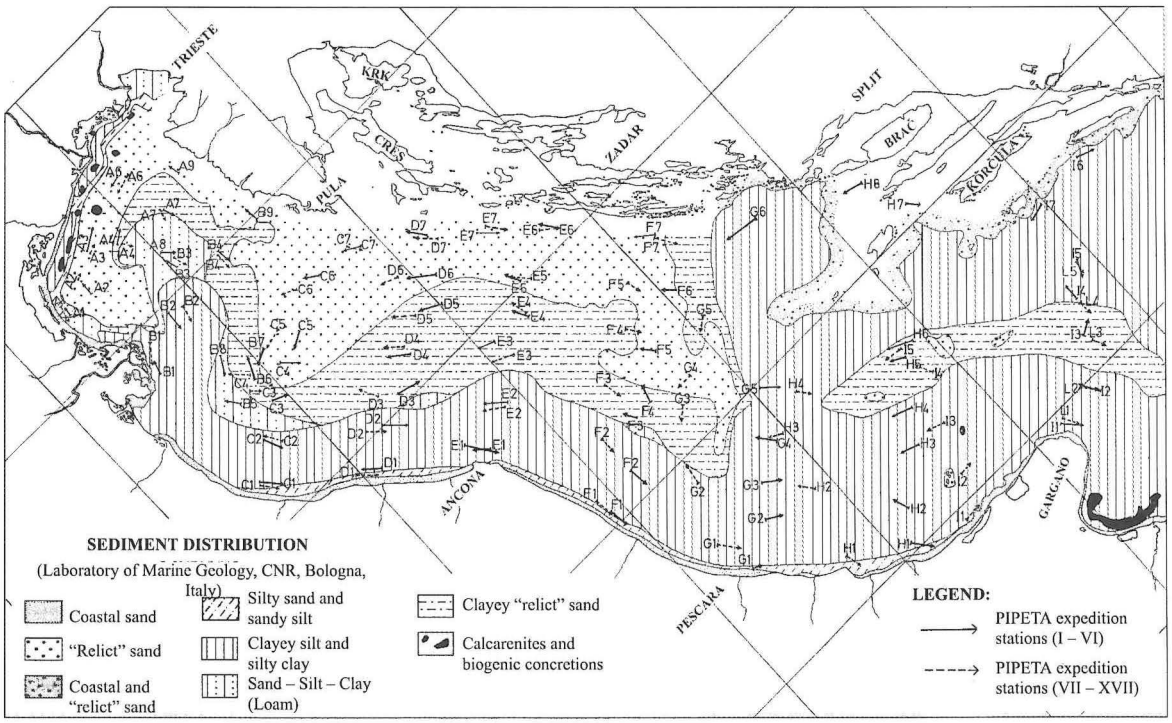

Fig. 1. Stations of PIPETA Expedition (1982 - 1994) plotted on the map of sediment distribution (the map is after the Laboratory of Marine Geology, CNR, Bologna)

Table 1. Investigated stations during the PIPETA Expedition cruises in the Adriatic Sea (1982- 1994)

PIPETA EXPEDITION

CRUISE	DATE	N° OF STATIONS	STATIONS
1st	April - May, 1982	12	A(1,2,3,4,7);B(1,3);C(4,5,6);D(5,6)
2nd	November - December, 1982	18	A(1,2,3,4,6,7,8);B(1,3,4,6,7);C(3,4,5,6);D(5,6)
4th	March - April, June, 1984	16	A(1,2,3,4,6,7,8);B(3,4,6,7);C(3,4,5,6);D(6)
5th	November - December, 1984	13	A(1,2,3,4,6,7);B(3,4);C(3,4,5,6);D(6)
6th	May - June, 1985	15	A(1,2,3,4,6,7);B(1,3,4);C(3,4,5,6);D(5,6)
7th	November - December, 1985	12	A(1,2,3,4,7);B(3,4);C(3,4,5,6);D(6)
8th	June - July, 1986	13	A(1,2,3,4,6,7);B(3,4);C(3,4,5,6);D(6)
9th	May - June, 1987	13	A(1,2,3,4,6,7);B(3,4);C(3,4,5,6);D(6)
10th	December, 1987 - February, 1988	12	A(2,3,4,6,7);B(3,4);C(3,4,5,6);D(6)
11th	October - November, 1988	12	A(2,3,4,6,7);B(3,4);C(3,4,5,6);D(6)
12th	December, 1990 - February, 1991	10	A(2,3,6,7);B(3,4);C(3,5,6);D(6)
13th	February - March, 1992	12	A(2,3,4,6,7);B(3,4);C(3,4,5,6);D(6)
14th	July, 1992	7	A(3,6,7);B(3,4);C(3,4)
15th	September - October, 1992	12	A(2,3,4,6,7);B(3,4);C(3,4,5,6);D(6)
16th	May - June, 1993	12	A(2,3,4,6,7);B(3,4);C(3,4,5,6);D(6)
17th	November, 1993 - January, 1994	12	A(2,3,4,6,7);B(3,4);C(3,4,5,6);D(6)

the catch per unit of effort is proportional to stock density. It was attempted to keep the technological properties of bottom trawl constant at all stations wherefrom the material was collected.

RESULTS AND DISCUSSION

A total of 201 hauls was done in the area of *Aequipecten opercularis* distribution in the North Adriatic Sea and the scallops were present in 182, accounting for 90.55% of total trawl hauls. The catch quantity significantly varied during the PIPETA Expedition cruises (Table 2).

From the 1st to 4th cruise (1982-1984) the mean catch values ranged from 1939.52 to 3079.40 kg km^{-2}. Later from 5th to 12th cruise (1984-1991), the mean catch values were considerably low and ranged from 14.51 to 478.99 kg km^{-2}. During the next three cruises (1992) the mean catch values increased again and ranged from 1843.37 to 3494.88 kg km^{-2}.

The highest mean catch value of *Aequipecten opercularis* was recorded at B4 station area (5544.29 kg km^{-2}; 382006.57 N km^{-2}) and also relatively high mean catch values were noted at C3, C5, C6 and D6 stations (Table 3).

Table 2. The catch quantities ($\bar{x}$=mean catch value, σ=standard deviation) of Aequipecten opercularis *during the PIPETA Expedition cruises (1982 - 1994)*

CRUISE	N° OF HAULS	CATCH (kg km^{-2})		CRUISE	N° OF HAULS	CATCH (kg km^{-2})	
		$\bar{x}$	σ			$\bar{x}$	σ
1st	12	1939.52	3320.84	10th	12	14.51	32.56
2nd	18	3079.40	6128.66	11th	12	201.54	481.81
4th	16	2373.81	4456.14	12th	10	67.19	180.83
5th	13	362.63	435.93	13th	12	1843.37	3986.10
6th	15	261.29	423.61	14th	7	3494.88	8296.16
7th	12	202.96	414.83	15th	12	1720.61	3079.05
8th	13	478.99	952.40	16th	12	980.42	2214.22
9th	13	122.75	163.02	17th	12	353.38	762.77

Table 3.The catch quantities (n=number of hauls, min=minimum, max=maximum, $\bar{x}$ = mean catch value, σ = standard deviation) of Aequipecten opercularis *at stations in the area of its distribution during the PIPETA Expedition cruises*

STATION	N° OF HAULS	CATCH							
		kg km^{-2}				N km^{-2}			
		min	max	$\bar{x}$	σ	min	max	$\bar{x}$	σ
A1	8	0.00	27.00	9.18	8.65	0.00	4756.76	1270.84	1534.61
A2	15	4.76	482.10	152.08	158.98	771.37	54638.49	14517.35	16513.25
A3	16	0.00	2620.20	331.17	650.88	0.00	237042.32	25694.82	58634.77
A4	14	0.00	1671.29	199.33	443.84	0.00	198755.53	20281.10	52450.13
A6	14	5.14	2586.39	640.00	925.71	1101.90	187850.59	37948.27	54042.20
A7	16	1.80	1960.04	399.74	555.27	487.12	418145.12	50249.14	102881.14
A8	2	152.99	276.41	214.70	87.27	8870.72	12958.96	10914.84	2890.83
B1	3	20.57	270.75	113.69	136.80	1864.14	23205.29	10678.89	11144.21
B3	16	0.39	651.80	109.91	190.88	21.47	184266.69	15923.66	45982.94
B4	15	9.38	26949.63	5544.29	7829.65	304.95	2537937.24	382006.57	666809.79
B6	2	132.42	386.71	259.56	179.81	3676.85	15465.91	9571.38	8336.12
B7	2	93.98	583.28	338.63	345.99	2603.36	38658.34	20630.85	25494.72
C3	15	0.39	11582.72	1116.37	3011.70	60.94	360118.15	43548.33	101767.73
C4	15	0.00	940.30	132.35	270.11	0.00	104134.53	10921.17	27313.27
C5	15	0.00	18412.40	2181.73	5007.57	0.00	808006.79	90265.06	214205.64
C6	15	0.00	20100.41	3137.27	5566.13	0.00	1026805.00	169893.77	291214.40
D5	3	2.83	297.36	165.63	149.70	228.84	30173.30	18044.84	15761.62
D6	15	0.00	4707.27	1020.67	1400.27	0.00	386416.23	79782.99	114017.21

All these stations were situated on "relict" sand and clayey "relict" sand. The catch quantities were variable at single stations. At the stations with high mean catch values (B4, C3, C5, C6, D6) from the 5th to 12th cruise the catch quantities were considerably smaller or negligible (Fig. 2). The standard deviation values show

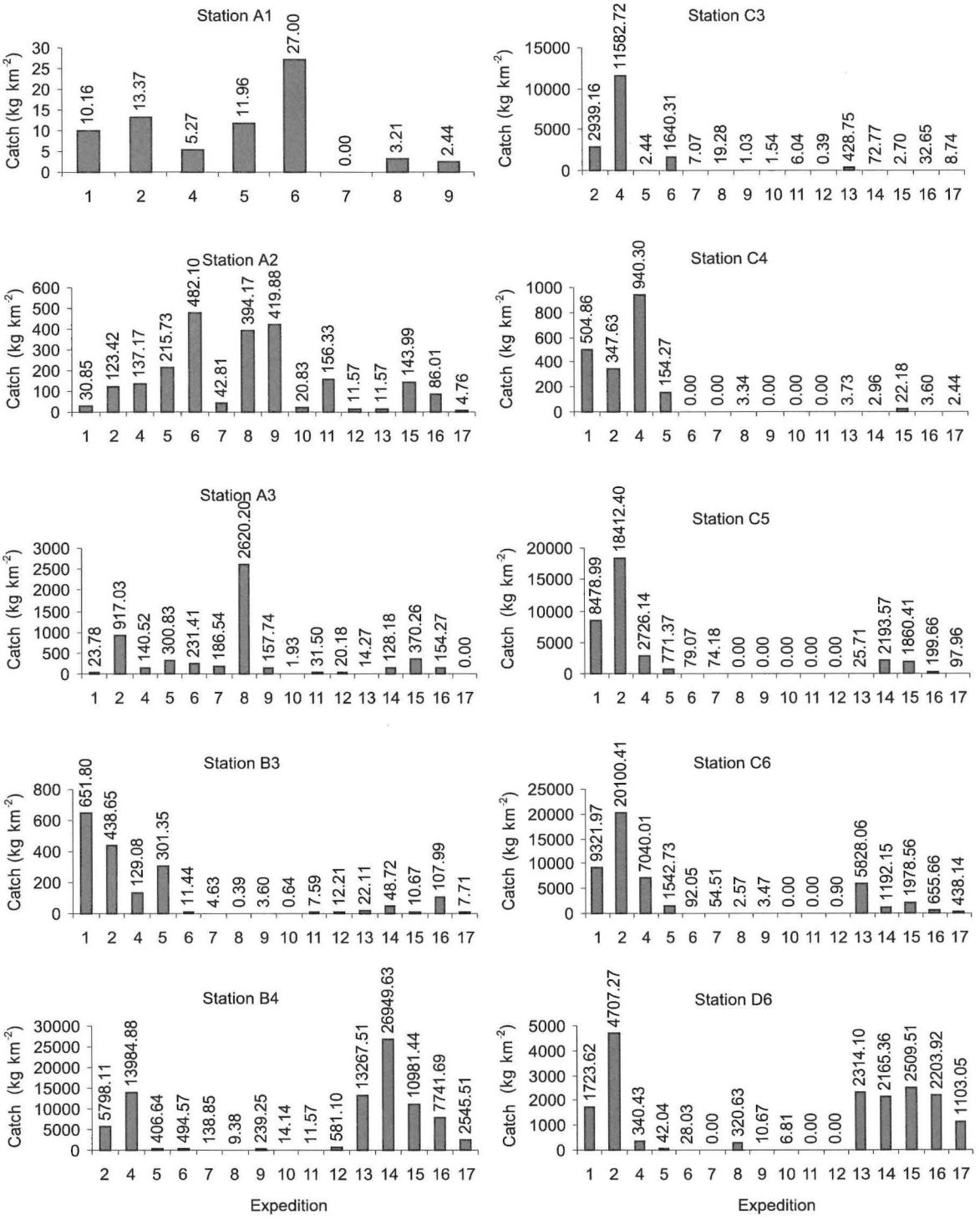

Fig. 2.The catch quantities (kg km^{-2}) of Aequipecten opercularis *at selected stations in the northern Adriatic during the PIPETA Expedition (1st - 17th cruise)*

that the catch quantities varied remarkably among the hauls during each cruise.

On the basis of obtained results we have no explanation what is the reason for the considerable differences in catch quantities during the investigated period. Maybe the reason is the population renewing and its exploitation. The other reason could be the movement of young specimens from the shallow water to fishing area. The third possibility are hypoxic states occurring temporarily in some parts of northern Adriatic (STEFANON and BOLDRIN, 1980; OREL *et al.*, 1986; OREL *et al.*, 1989; HRS-BRENKO *et. al.*, 1992; ŠIMUNOVIĆ *et al.* 1999) that could have a great impact on decreasing of exploitable pectinids stock. Bivalve species

Table 4. The catch quantities (n=number of hauls, min=minimum, max=maximum, $\bar{x}$=mean catch value, σ=standard deviation) of Aequipecten opercularis *in relation to the sediment type and depth during the PIPETA Expedition cruises*

SEDIMENT TYPE	CATCH (kg km^{-2})	DEPTH (m)					
		10-19	20-29	30-39	40-49	50-59	60-70
"RELICT" SAND	n	-	44	1	34	11	6
	min	-	0	504.86	0	0	0
	max	-	2620.20	504.86	20100.41	4707.27	2509.51
	$\bar{x}$	-	375.58	504.86	2404.66	810.98	897.53
	σ	-	673.03	0	4950.05	1525.19	1143.71
CLAYEY "RELICT" SAND	n	-	-	13	37	1	3
	min	-	-	0	0	196.70	2.83
	max	-	-	5798.11	26949.63	196.70	1103.05
	$\bar{x}$	-	-	760.96	2549.09	196.70	467.75
	σ	-	-	1604.57	5751.77	0	569.56
SAND-SILT-CLAY	n	2	2	33	5	-	-
	min	11.96	13.37	0	0.39	-	-
	max	27.00	147.20	1671.29	406.64	-	-
	$\bar{x}$	19.48	80.29	202.62	84.36	-	-
	σ	10.64	94.63	385.83	180.19	-	-
CLAYEY SILT AND SILTY CLAY	n	-	2	2	-	-	-
	min	-	20.57	270.75	-	-	-
	max	-	49.75	438.65	-	-	-
	$\bar{x}$	-	35.16	354.70	-	-	-
	σ	-	20.64	118.72	-	-	-
SILTY SAND AND SANDY SILT	n	5	-	-	-	-	-
	min	0	-	-	-	-	-
	max	10.16	-	-	-	-	-
	$\bar{x}$	4.22	-	-	-	-	-
	σ	3.82	-	-	-	-	-

recruitment and juvenile survival was high in spring and summer 1990 after benthic mortality in previously hypoxic areas (HRS-BRENKO *et al.*, 1994; HRS-BRENKO, 1998). Due to scallops small sizes the catch quantities were low in 1991, but highly increased in 1992 (Tables 1, 2). Earlier, hypoxic conditions were also recorded in the whole northern Adriatic in 1988 (HRS-BRENKO *et al.*, 1992).

Our results agree with PICCINETTI *et al.* (1985) result regarding to *Aequipecten opercularis* catches. The highest mean catch values accounting 2404.66 and 2549.09 kg km^{-2} occurred on "relict" sand and on clayey "relict" sand respectively at depths of 40 to 49 m (Table 4). At the other depths on these types of sediments the mean catch values were considerably smaller. The greatest recorded depth for *A. opercularis* ranged between 66 and 67.5 m and is recorded on the 17th cruise at D6 station. The standard deviation points to the fact that *A. opercularis* distribution varies much in the studied area, which suggests that scallop does not show an uniform distribution, but the tendency of forming larger and smaller enclaves (mosaic-like distribution) which is a general character of shellfish species.

HALL-SPENCER *et al.* (1999) studied impact of rapido trawling on benthic communities in Venice Bay on commercial scallop ground using towed underwater television and they have found a high population density of queen scallops (2.82 N m^{-2} *Aequipecten opercularis*). Their experimental trawling and underwater television surveys indicated that despite of the relative homogeneity of level sandy bottom, pectinids exhibited large-scale patching.

In spite of the fact that rapido gear has a very severe impact on benthic biocoenoses, it is well represented in northern Adriatic in fishing for pectinids (GIOVANARDI *et al.* 1998). It would be interesting to compare catch quantities between bottom trawl and rapido gear in some future paper.

In addition, HRS-BRENKO (1979) reported the species *Aequipecten opercularis* as a frequent one in the central part of the northern Adriatic and along the western Istrian coast. The same author stated that particularly large number of scallop individuals (exceeding 30 N m^{-2}) was caught about 11 Nm off Rovinj in 1968 and 1969.

CONCLUSIONS

During the PIPETA expedition cruises in the period from 1982 to 1994, *Aequipecten opercularis* was sampled at 90.55% bottom trawl hauls in the Northern Adriatic Sea. The catch quantities varied from cruises to cruises so that mean catch values ranged from 14.51 to 3494.88 kg km^{-2}. The species is the best distributed at depths of 40 to 49 m on "relict" sand and clayey "relict" sand. Intensive fishing activity in studied area by bottom and rapido trawls and intensity of frequent hypoxia events play an important role in the population density of *A. opercularis*.

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Eksperimentalni ulovi i rasprostranjenost vrste *Aequipecten opercularis* (LINNAEUS, 1758) (Pectinidae, Mollusca Bivalvia) u Jadranskom moru

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SAŽETAK

U radu se iznose podaci o ulovu i rasprostranjenosti vrste *Aequipecten opercularis* (LINNAEUS, 1758) u Jadranskom moru. Uzorci vrste *A. opercularis* su sakupljani pridnenom koćom tijekom 17 putovanja ekspedicije PIPETA u Jadranu u razdoblju od 1982 do 1994 godine. Obrađen je 201 poteg pridnenom koćom na području rasprostranjenosti vrste u sjevernom Jadranu (8988 km^2). *A. opercularis* je zabilježena na 90.55% potega. Podaci ne uključuju područja oko otoka i obalni dio sjevernog Jadran gdje je vrsta dobro zastupljena. Za procjenu abundacije vrste korištena je metoda "lovna površina potega". Ulovi su se mnogo razlikovali tijekom pojedinih putovanja. Srednja vrijednost ulova je iznosila od 14.51 do 3494.88 kg km^{-2}. Vrsta je najbolje raprostranjena na dubinama od 40 do 49 m na "reliktnom" pijesku i glinovitom "reliktnom" pijesku.

Ključne riječi: školjkaši, *Aequipecten opercularis*, rasprostranjenost, pridnena koća, Jadransko more