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RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Gamogenetic cycle, condition index and meat yield of the Noah's Ark shell (*Arca noae* Linnaeus, 1758) from Gerence Bay, Aegean Sea Turkey

Gerence Körfezi'ndeki Nuhun gemisi türünün (*Arca noae* Linnaeus, 1758) gametogenik döngüsü, kondisyon indeksi ve et veriminin belirlenmesi

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Abstract: Gamogenetic cycle, the condition index and meat yield of the *Arca noae* Linnaeus, 1758 (Noah's ark shell) were followed in Gerence Bay (Aegean Sea, Turkey), between August 2009 and July 2010. Temperature, salinity, chlorophyll-a, particulate organic and inorganic matter were monitored during the sampling period. According to histological observation, inactive stage was determined as 100% in September. The spawning period was observed through the year except September, with a peak from April to June. Sex ratios were not equal and females were dominant during the study period (2:1). Meat yield, condition index and gonad index reveal a positive relationship between each other ($P \leq 0.05$). Among environmental parameters, inverse relationship was only found between particulate inorganic matter and reproduction ($P \leq 0.05$).

Keywords: *Arca noae, histology, reproduction, condition index, meat yield*

Öz: Bu çalışmada Gerence Körfezi'nde (Ege Denizi, Türkiye) *Arca noae*Linnaeus, 1758 türünün (Nuhun gemisi) gametogenik döngüsü, kondisyon indeksi ve et verimi Ağustos 2009 ve Temmuz 2010 tarihleri arasında takip edilmiştir. Her örnekleme döneminde sıcaklık, tuzluluk, klorofil-a, partikül organik ve partikül inorganik madde içeriği belirlenmiştir. Yapılan histolojik çalışmalara göre dinlenme safhası Eylül ayında %100 olarak tespit edilmiştir. Eylül ayının dışında, döl atımı tüm yıl boyunca gözlenmiş ve Nisan ile Haziran ayları arasında yüksek değerlerde olduğu belirlenmiştir. Cinsiyet oranı eşit olarak tespit edilmemiştir ve dişiler popülasyonda baskındır (2:1). Et verimi, kondisyon indeksi ve gonadindeksi arasında pozitif ilişki tespit edilmiştir ($P \leq 0.05$). Çevresel parametreler içerisinde sadece partikül inorganik madde ile üreme arasında ters ilişki olduğu tespit edilmiştir ($P \leq 0.05$).

Anahtar kelimeler: *Arca noae, histoloji, üreme, kondisyon indeksi, et verimi*

INTRODUCTION

Noah's Ark or ark shell (*Arca noae* Linnaeus, 1758) is Atlanto-Mediterranean species and distributed in Mediterranean, Black Sea, the eastern Atlantic Ocean,West Africa and the West Indies (Hayward et al., 1996;Öztürk et al., 2014).It is attached by a massive green byssus in dead mollusc shells, among stones, on semi mobile gravies or in rock crevices (Tebble, 1966; Hrs-Brenko and Legac,1996; Morton and Peharda, 2008). It is collected occasionally between tide-marks and offshore to about 119 meters. Ark shell can reach up to 10 cm (Šiletić, 2006) and live approximately for 16years (Peharda et. al., 2002).

The production amount of ark shell in the world was approximately 30250 tons in 2015 (FAO, 2017). This production was carried out by China, Venezuela, Mexico, Korea and Costa Rica. In addition that, it is particularly appreciated in Croatian Adriatic Sea is harvested by local fishermen using modified rakes or divers (Benović, 1997). In Turkey, unfortunately, there is no reported record about ark shell production in fisheries statistics. The most important reason; fishermen and production areas have not been controlled by the government. This species is only produced by fishing from coastal area for mostly bait of Sparidae species and rarely for human consumption. Although there is no scientific data about production, it is thought that natural beds have begun to overexploited and been affected adversely.

Most of the studies on ark shell in Mediterranean Sea, about population structure (growth and age) (Peharda et al., 2002; Peharda et al., 2003; Peharda et al., 2009), reproductive cycle (Peharda et al., 2006), aquaculture (Župan et al., 2012; Župan et al., 2014), biochemical composition (Radić et al., 2014) have been carried out in Adriatic Sea. However, in Turkey, studies on basic biology of the species are lacking still while only faunistic studies have been conducted (Demir, 2003; Öztürk et al., 2005; Öztürk et al., 2014).

In this study, histological examination of the gonads of *A. noae* was carried out to determine the sexual characteristic for Aegean Sea, Turkey. These data will be key element to improve understanding reproductive biology. Therefore, out puts of present study have a great importance to ensure the sustainable fishery, to supply to legal legislations, to provide knowledge for aquaculture activities.

MATERIALS AND METHODS

Study area

This study was conducted in Gerence Bay (38º25' N and 26º30' E) located on the west side of Izmir Bay, Aegean Sea, Turkey; between August 2009 and July 2010 (Figure 1). Ark shells were collected monthly from natural stock by SCUBA diving from 1 m to 5 m water depth at shallow coastal water.

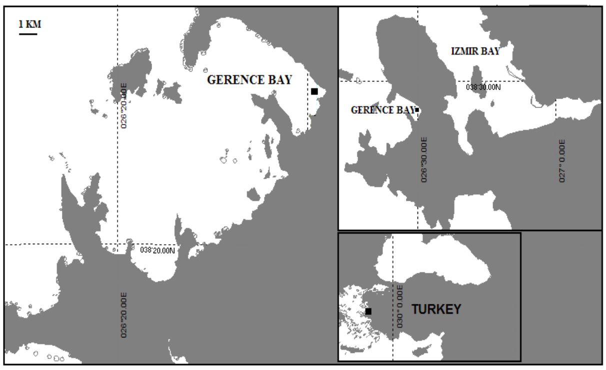


Figure 1. Location of study site in Gerence Bay (Aegean Sea, Turkey)

Environmental parameters

Surface water temperature (ºC) and salinity (psu) were measured by monthly using a thermometer (±1ºC) and light refractometer, respectively. Chlorophyll-a concentration was calculated by spectrofotometric method (Strickland and Parsons, 1972). Particulate inorganic matter (PIM) and particulate organic matter (POM) in suspension were determined by weight differences after heating of filtered papers (Jones and Iwama, 1991).

Meat yield and condition index

Collected samples were transported to laboratory where they were fully removed from biofouling and other adherences. Then, samples were measured for biological parameters such as shell length, total weight and soft tissues except byssus. Whole weight and shell length were measured with an electronic calliper (Mitutoyo CD-15PK) and an electronic scale (0.01 g, Sartorious GE 412), respectively. Shells were dried at 60ºC for 48-72 h to a constant weight while soft tissues were dried by dry freezer (Christ Alfa-1-2 LDplus). Meat yield (MY) and condition index (CI) were calculated according to formulas used in Freeman (1974) and Crosby and Gale (1990), respectively.

$$MY = \frac{wet\ meat\ weight\ (g)}{total\ weight\ (g)} \times 100$$

$$CI = \frac{dry\ meat\ weight\ (g)}{dry\ shell\ weight\ (g)} \times 100$$

Histological treatment

Gonad development stage (S1: early active, S2: developing, S3: mature, S4: partly spawning, S5: spent) and sex ratio were determined using histologically prepared slides. Histological procedures method was used in previous studies (Peherda et al., 2006; Sahin et al., 2006; Yurimoto et al., 2008). The top surface of the stomach for each specimen was dissected to obtain the gonad. The gonad samples were fixed in Davidson solution and dehydrated using alcohol between 70% and 100% series and then embedded in paraffin. Paraffin blocks were sectioned to 4µm thickness and stained with hematoxylin-eosin. Slides were observed under the light microscopy to determine stage of male and female development of gonad.

Gonad index

A gonad index (GI) was calculated for each sample by ranking the different gametogenic stages as follows:

1=inactive (I)+spent (V),

2=early active (II)+late active (III)+partly spent (V),

3= mature (IV)

These values were summed then divided the resulting value by the total number of animals in the sample (Soria et al., 2002).

$$GI = \frac{sum\ of\ specimens \times category}{total\ number\ of\ specimens}$$

Statistically analysis

Percentage data was arcsine transformed before statistical treatment. The chi-square test was used to asses differences from the 1:1 sex ratio. The data distribution to determine normality was tested using the Kolmogorov-Smirnov Test. Pearson's correlation analysis was applied to determine the degree of association between environmental parameters (temperature, salinity, particulate inorganic matter, particulate organic matter and chlorophyll-a) and gonad index (GI), condition index (CI), meat yield (MY). Data were analyzed using SPSS 13.0 for Windows.

RESULTS

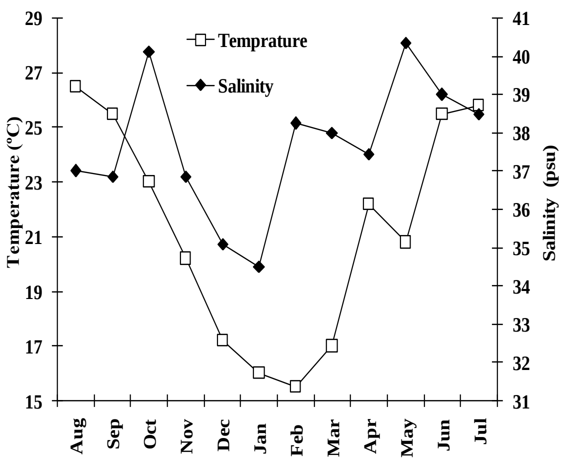
Environmental Parameters

Temperature showed a progressive decrease from 26.5 ºC in August to 15.5 ºC in February and then increased until July except May (Figure 2a). Salinity was recorded between 35psuin January and 40 psu in May and October (Figure 2b).Maximum chlorophyll-a values were observed in December and April (1.32 µg/l) and minimum values were observed in February and June (0.30 µg/l and 0.46µg/l, respectively) (Figure 2c). Monthly variation in particulate organic matter (POM) values associated with particulate inorganic matter value (PIM) (P≤0.05). PIM and POM peaked as 24.5 mg/l and 11.2 mg/l in October, respectively (Figure 2c).

Meat Yield and Condition Index

Length range, weight range, meat yield and condition index were showed in Table 1. Meat yield and condition index reveal a positive relationship between each other (P≤0.01). The highest condition index was recorded as 12.8 in August. The lowest condition index was observed as 8.4 in September. After September, condition index showed fluctuation and it reached to 11.1 at the end of study

a



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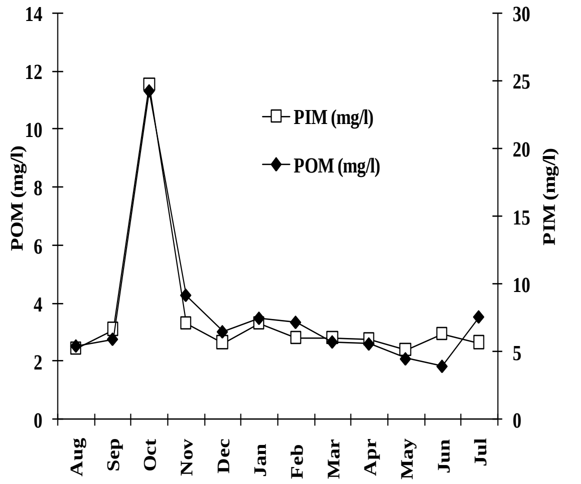

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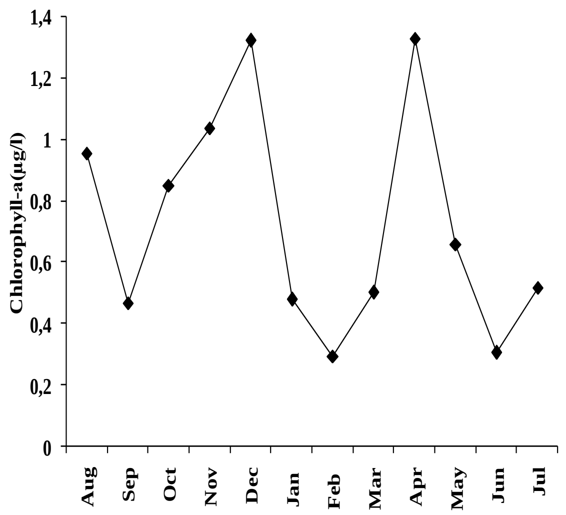

Figure 2. Monthly variations of environmental parameters in the study area(temperature (a), salinity (a), particulate organic matter POM (b), particulate inorganic matter PIM (b), chlorophyll-a (c))

Table 1. Monthly variation of shell length, total weight range, condition index (mean ± SE) and meat yield (mean ± SE) of Noah's ark from Gerence Bay, Aegean Se

	Shell length (mm)	Live weight (g)	Meat Yield (%)	Condition index
August	34.50-71.00	10.60-57.42	27.71±2.23	12.87±0.71
September	36.00-70.00	9.34-50.39	17.48±0.40	8.60±0.27
October	30.96-76.43	4.88-54.61	20.52±1.66	10.37±0.30
November	33.09-55.75	7.58-28.54	22.50±0.61	11.13±0.37
December	38.09-73-46	7.61-47.46	21.14±0.54	11.36±0.45
January 10	42.56-74.39	10.81-53.89	20.47±0.46	10.95±0.30
February	42.67-73.55	11.79-49.79	21.89±0.89	12.03±0.93
March	48.03-78.00	14.11-70.23	22.27±0.65	11.61±0.34
April	50.40-82.00	21.72-78.26	23.47±0.52	12.65±0.37
May	38.03-77.26	13.94-64.42	22.85±0.63	12.38±0.29
June	45.72-70.30	14.21-53.04	20.77±0.49	11.97±0.32
July	43.70-70.50	11.51-48.21	22.72±0.58	11.14±0.29

Sex Ratio

Amongst the total of 360 individuals examined, 84 male (23%), 181 female (50%), 3 hermaphrodite (0.8%) and 92 inactive (25%) were determined (Figure 3, Figure 4, Figure 5). Sex ratio (female: male) during reproductive period was 2.1:1 and female was favorite. The gonad development was not observed in September. Female was dominant through the study period, except in October (6%) and November (20%). Hermaphrodite individuals were observed only one for each December (53.1mm – 32.58g), April (67.2mm – 50.63g) and May (55.24 mm – 32.58g) (Figure 4). At macroscopic observation color of gonad was observed mostly between purple and brown-cream. These colors were observed in female for purple and in male for brown-cream. Hermaphrodite individuals were determined as purple color.

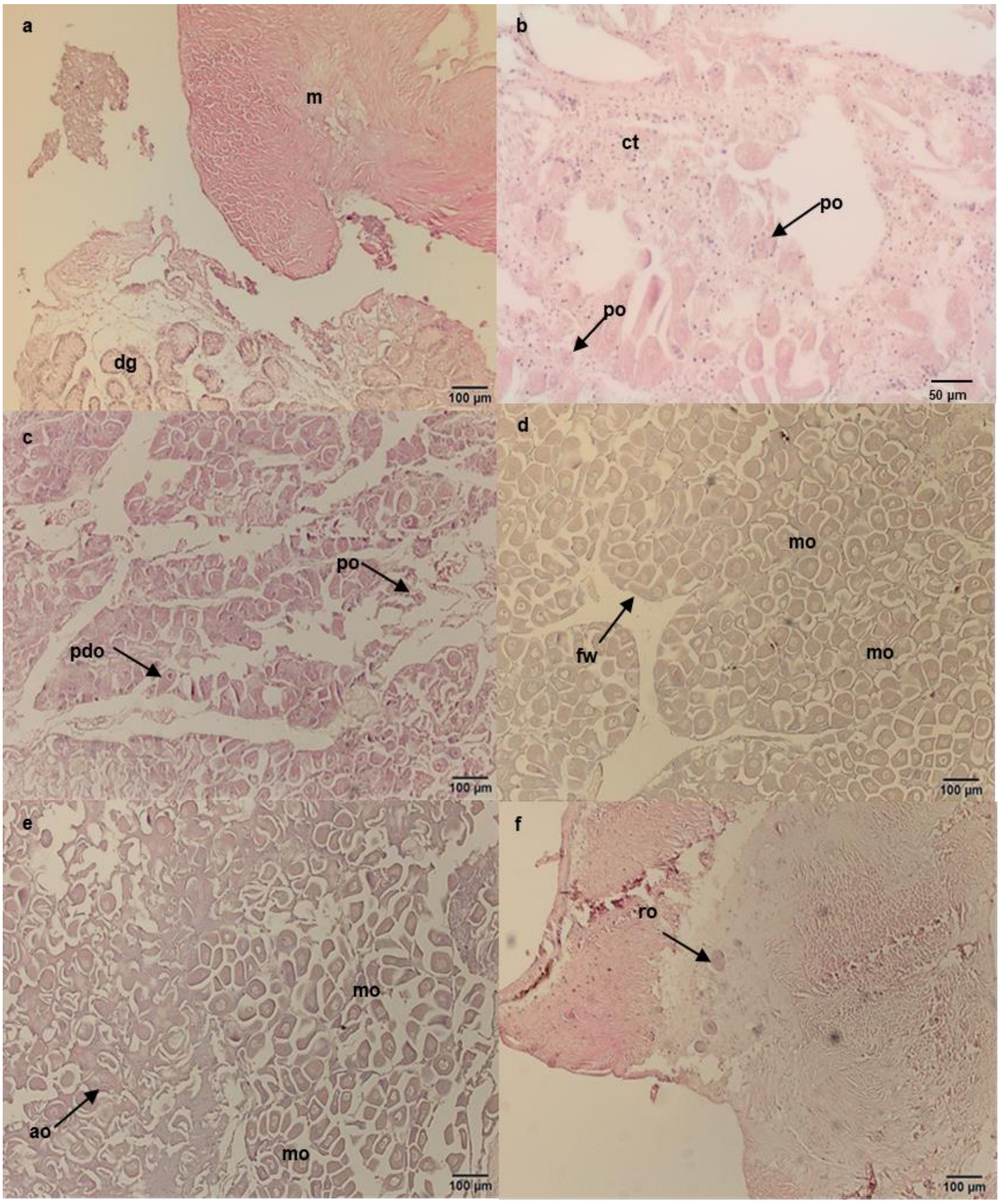

Figure 3. Photomicrographs showing inactive stage (a), reproductive maturity stages of ark shell in female gonad early active (b), late active (c), mature (d), partially spend (e), spent (f). ao: atresia oocyte, cd: connective tissue, digestive gland, fw: follicle wall, mo: mature oocyte, m: muscle, ro: residual oocyte, pdo: pedunculated oocyte, previtollegenic oocyte

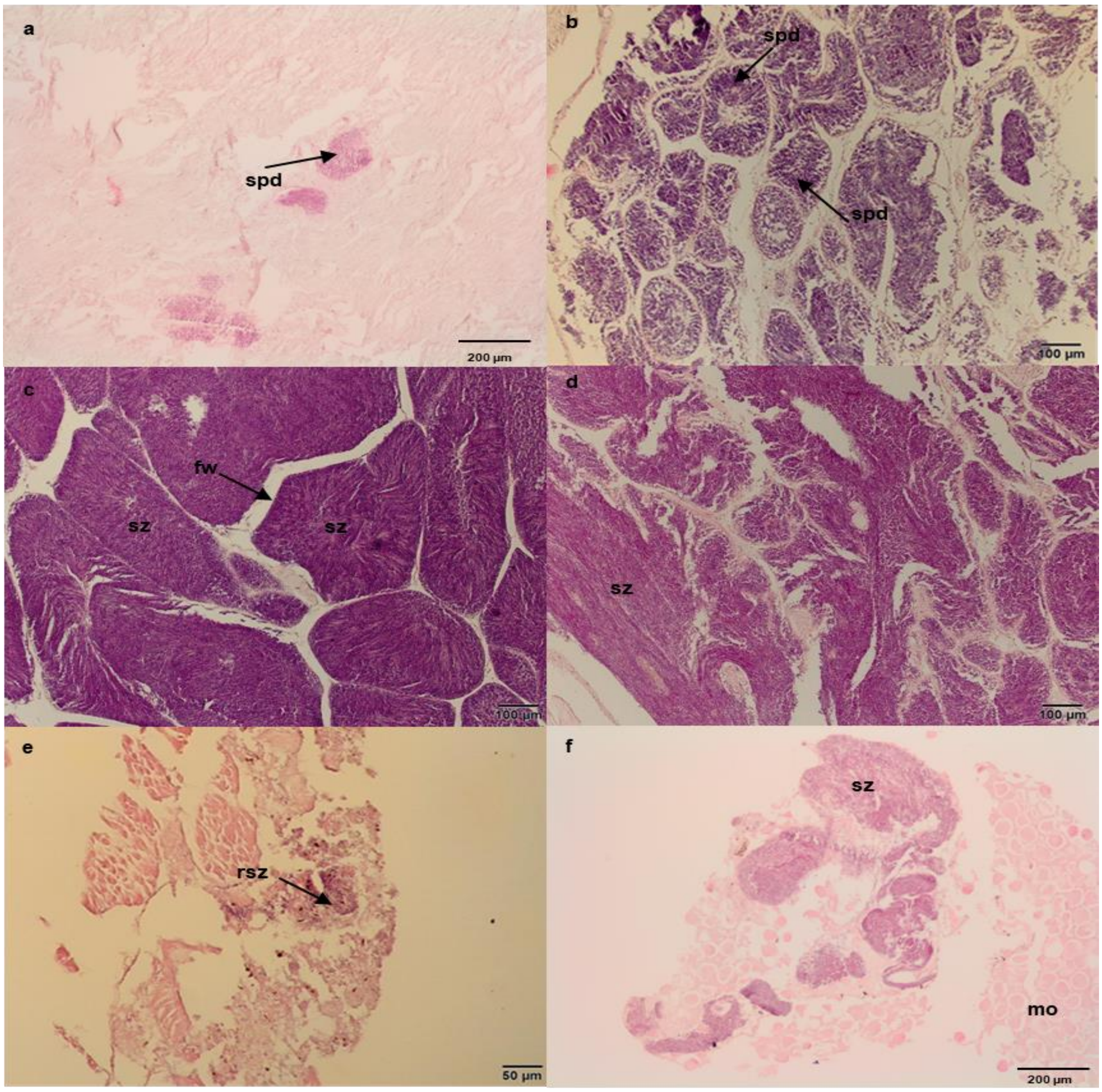

Figure 4. Photomicrographs showing reproductive maturity stages of ark shell in male gonad early active (a), late active (b), mature (c), partially spend (d), spent (e) and hermaphrodite individual (f).fw: follicle wall, mo: mature oocyte, rsp: residual spermatozoa, spd: spermatids, sz: spermatozoa

The reproductive cycle of both sex of *A. noae* from Gerence Bay is presented in Figure 5 and Figure 6. After inactive stage in September no males were in early active stage except in December although early active stage in female occurred from October to March. It appeared that gonad development of females realized longer than male. Late active stage in male individuals was found between October and March. Females in this stage occurred from December to February, and in April. Maturation stage in both sexes was seen at the same time but this stage in female was higher proportion than male. Spawning in female began in January (7%) and increased until June (91%) while spawning in female was observed through the year and more intensive than male. During the study period, spent stage in both sexes was observed firstly in August. After August, spent stage in male and female was observed from October to March and from December to April, respectively.

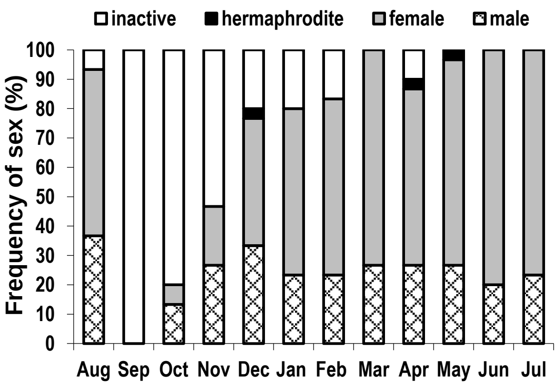

Figure 5. Monthly changes in percentage of inactive, hermaphrodite, female and male individuals in the total population

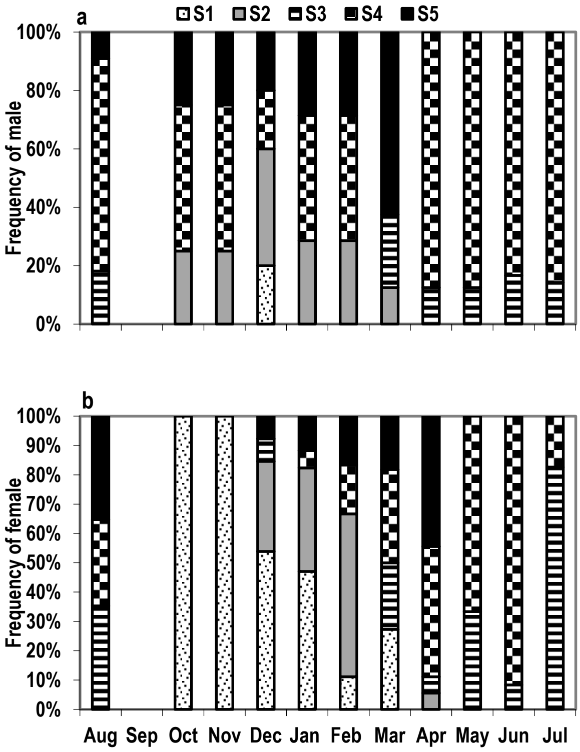

Figure 6. Frequency of gametogenesis in male (a) and female (b)

To sum up the reproduction cycle of the population, beginning of the study inactive stage was determined as 6%, and then it was recorded as %100 in September and gradually decreased to 10% until April. Early and late active stage occurred between October and March. The highest percentage of both stages was found in December and January. Mature stage was seen in August (26%) and December (3%), between March (23%) and July (66%). Spawning stage was observed throughout the study period except in September. Its highest percentage was determined in June (90%) and the lowest in October and December (6%). Spent stage occurred in August, from November to April with maximum activity in March (30%) (Figure 7).

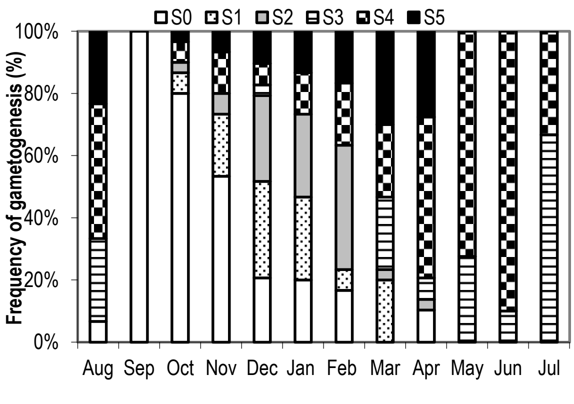

Figure 7. Frequency of different stages of in total population

Gonad Index

GI was sharply dropped from 2.4 (August) to 1 (September), after this month it was gradually increased and reached to 3 (May). It was stable between May and July (Figure 8). GI was significantly related to condition index and meat yield (P≤0.05). Besides, a negative correlation was noted between PIM and GI (P≤0.05). No significant relationships were found between other environmental parameters (Table 2).

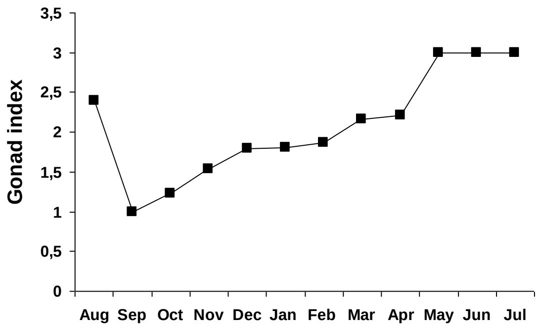

Figure 8. Monthly variation of gonad index (GI) in Noah's ark

Table 2. Pearson correlation of environmental parameters and other parameters (temperature (T), salinity (S), chlorophyll-*a* (CHL), particulate organic matter (POM), particulate inorganic matter (PIM)) gonad index (GI), meat yield (MY) and condition index (CI))

	T	S	Ch	POM	PIM	GI	MY	CI
T	1	.355	.068	.078	-.072	.091	.135	-.170
S		1	-.262	.307	.129	.296	.103	.168
Ch			1	.077	.200	-.132	.378	.221
POM				1	.895**	-.544	-.338	-.375
PIM					1	-.577*	-.201	-.353
GI						1	.595*	.777**
MY							1	.821**
CI								1

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)

DISCUSSION

Previous studies have showed that environmental factors including temperature, salinity, food and energy metabolism influenced on gonad development and maturation in marine bivalves (Resgalla et al., 2007; Acarli et al., 2015; Hasan et al., 2017). This information is not consistent with previous results and same species may vary among geographical areas (Derbali et al., 2009; Kandeel et al., 2013). Comparisons of the spawning period of Arcidae families' species in different localities are shown in Table 3.Peharda et al. (2006) reported that the correlation analyses indicated that an environmental factor was not directly influence the gonadal growth. Findings of the present study show similarities with Peharda et al. (2006). However, only negative association between PIM and gonad index was found in the present study. It is known that increased amount of particulate inorganic particles negatively affect on feeding of bivalves wherefore particulate organic matter and phytoplankton are strongly diluted by inorganic particles (Ward and Macdonald, 1996).As a result of these, food quality in water column and filtration of bivalves rate can decrease (Resgalla et. al., 2007; Çelik et al., 2015). However, Lista et al. (2006) informed that *A. zebra* was well adapted to the high loads inorganic seston in the northeastern Venezuela. It is estimated that *A. noae* could not show same adaptation in this study whereas inorganic matter value was higher than in the northeastern Venezuela.

Table 3. A comparison of spawning period between location and Arcidae species

Locality	Spawning period	Species	References
Turkey	June-September	*Anadara inaequivalvis*	Sahin et al., 2006
Japan	July - September	*Scapharca kagoshmensis*	Yurimoto et al., 2008
Venezuela	June-October	*Anadara notabilis*	Freites et al., 2010
Venezuela	July-late September	*Arca zebra*	Lista et al.,2006
Croatia-Adrriatic Sea	June-September	*Arca noae*	Peherda et al., 2006
North Tunisia	November-April July-September	*Arca noae*	Ghribi et al., 2017
Turkey	Mainly May-August	*Arca noae*	In this study

As it is known, condition index and meat yield values detect commercial quality of bivalves species (Orban et al., 2002), is a parameter of ecophysiological and economic importance, especially with regard to industrial processing (Yıldız et al., 2011). These parameters in bivalves were influenced by environmental parameters (mainly temperature or food availability) (Delgadao and Camacho, 2005; Herrmann et al., 2009) and reproductive activities (Acarli et al., 2015; Christo et al., 2016).It is reported in Peharda et al. (2003) and Şahin et al. (2006) condition index was ranged for *Arca noae* in Mali Ston Bay from 9 (December and January) to 11 (April and June)and for *Anadara inaequialvis* in Southeastern Black Sea Coast from 4.2 (August) to 11.6 (May), respectively. Župan et al. (2014) estimated condition index for *A. noae* in Central Adriatic Sea (Pašman Channel) according to formulas in Davenport and Chen (1987). Condition index was found between 18 (December) and 25 (June) (Župan et al., 2014). In this study, a significant correlation was found between condition index and meat yield. Maximum condition index was determined as 12.8 in August when individuals were in mature and spawning period and minimum condition index was determined as 8.6 in September when individuals were in resting stage. Results of this study show that meat quality of *A. noae* has a good index during the study period, except September when it can be considered as suitable human for consumption.

Sex ratio of marine bivalves for a healthy population is nearest to 1:1 (Morton, 1991). Genetic control (Yusa et al., 2013) or hormones (Thompson, 1996) and changes in environmental conditions such as temperature, salinity and food availability also affect the sex ratio of bivalvia species (Chávez-Villalba et al., 2011;González-Araya et al., 2013; Teaniniuraitemoana et al., 2016). Peharda et al. (2006) notified that *Arca noae* may exhibit functional protandric dioecy with some male individuals changing to female in subsequent. They also determined that rising of female individuals' number is related with increasing shell length or age. Furthermore, Quayle (1969) and Breton et al. (2017) informed that population was in favor of females when food availability conditions were favorable or it was in favor of male in when food availability conditions were poor. A correlation between sex ration and food quality or availability is explained by Diaz-Almela et al. (2004) that females need to heavier energy utilization to development of oocytes. Several authors highlighted that female was in favor in the population for *A. noae* (Valli and Parovel, 1981; Peherda et al., 2006; Ghribi et al., 2017), for *A. zebra* (Villarroel et al., 2016), for *Anadara tranversa* (Walker and Pover, 2004),and for *Anadara antiquate* (Jahangir et al., 2014; Mzighani, 2005).In this study, female individuals dominated at the population with female to male ratio of 2:1. Some authors had expounded that a significant increase in the population of female associated with length or age. In the present study, it is suggested to consider that both food availability and age might be affected on sex ratio.

Hermaphrodite individuals were found as 2.2% for *A. noae* in south Adriatic Sea (Peharde et al., 2006) and 3% for *A. noae* in southwestern Adriatic Sea (Bello et al., 2013), 5.49% for *Anadar aantiquata* in Tanzania (Mzighani, 2005) and 1.1% for *A. noae* in the Aegean Sea (present study). Yolkolu and Lök (2000), and Eversole (1989) stated that the result of environmental trigger such as sudden changes in temperature and salinity or high turbidity maybe lead to hermaphrodite individuals in the population. Furthermore, one gametogenic phase can continue to the next sex phase while reabsorption uncompleted in protandric hermaphroditism (Acarli et al., 2015).

Although there is no relationship between GI and temperature, development seems to be begun during the winter month and reached to maturation and spawning mainly summer months. This information can help for protocol managing of this species for aquaculture activities and strategy of fishery. Also, it has a great importance to ensure the sustainable fishery, to supply to legal legislations.

This paper is the first study to determine reproduction characteristics of *A. noae* in the Turkish coastal waters. Further studies on stock assessment, spawning season, size at first maturity and morphometric characteristics are needed to ensure the sustainability of the stocks. Therefore, decision-makers and Ministry of Food, Agriculture and Livestock of the government should assess and monitor the stock by the relevant investigations, and establish appropriate policy and planning for stock management of this species. It is vital that measures must be taken before the species can be threatened or endangered such as other vulnerable or endangered species. Only then the stock management practices will be fully successful.

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