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Seasonal Variation in the Biochemical Constituents, Percentage Edibility and Condition Index of the Estuarine Clam, *Soletellina diphos* (Linnaeus, 1771) (Mollusca: Bivalvia: Veneroida: Psammobiidae)

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ABSTRACT

A variety of biochemical analyses and condition indices have been employed by various authors all over the world to assess the chemical and health index of bivalves. In order to understand the effect of seasonal climate change on the nutritive value and physiological fitness of an estuarine population of the psammobiid *Soletellina diphos* on the West coast of India. The present study was under-taken in order to determine the seasonal fluctuations of the biochemical constituents in different parts of the body and the percentage edibility and condition index. This study has shown that seasonality is related to significant alterations in the biochemical constituents, percentage edibility and condition index ($p<0.001$) of this population of *S. diphos*. These changes could be due to the clam's seasonal activities, particularly those related to its reproductive cycle. Higher values of the protein and lipid contents were recorded during the post-monsoon period, whereas maximum concentrations of glycogen were detected during the winter season. On the other hand, the lowest protein and glycogen contents were recorded during summer, while minimal lipid contents were observed during the winter season. The Percentage Edibility (PE) and Condition Index (CI) significantly fluctuated during the annual cycle, with maximum values occurring during the post-monsoon period (September-October 2008) and the lowest values during winter (November-December 2008). Therefore, it seems that the best nutritive season for *S. diphos* is in the post-monsoon period (September-October), when the highest values of its biochemical composition, percentage edibility and condition index occur. However, during the summer season (April-May), the lowest levels of the organic constituents, the percentage edibility and the condition index were recorded. Hence, that season is not ideal from the nutritive point of view. The study concludes that the physiological activity, the nutritive value and the meat quality of the clam *S. diphos* are seasonally related. Moreover, such baseline information is important from the viewpoint of aquaculture, as it demonstrates the seasonal impact on the nutritive status, reproductive output and physiological fitness of *S. diphos*.

Key words: Biochemical constituents, percentage edibility, condition index, *Soletellina diphos*

INTRODUCTION

Edible marine molluscs, such as clams, mussels, oysters and various gastropods have been a vital resource as seafood and so have become an important socio-economic entity for coastal

communities, with coastal habitats, such as backwaters, estuaries, lagoons, mangals, salt marshes, wetlands and rocky coastlines, supporting a diverse range of molluscan species.

Seasonal studies on the biochemical constituents in different molluscan species have been carried out in many parts of the world, aiming to achieve an understanding of their nutritive value, both quantitatively and qualitatively. Some publications, such as those of Kang *et al*. (2000), Li *et al*. (2000), Ren *et al*. (2003) and Patrick *et al*. (2006) reported seasonal variations in the biochemical content of the Pacific oyster *Crassostrea gigas*. Lodeiros *et al*. (2001) studied seasonal changes in the biochemical content of the scallop *Lyropecten* (*Nodipecten*) *nodosus* and correlated this with energy metabolism, growth and reproduction. Camacho *et al*. (2003) and Anibal *et al*. (2011) reported seasonal biochemical studies in the venerid *Ruditapes decussatus*, while, Yildiz *et al*. (2011) reported their studies on the oyster *Ostrea edulis*. Along the Indian coast, Nagabhushanam and Dhamne (1977) reported seasonal changes in biochemical content in the mussel *Mytilus viridis*. Jayabal (1994) and Suja and Muthiah (2010) reported their works on the venerid *Katelysia opima*.

The biochemical constituents, the percentage edibility (or meat yield) and the condition index vary seasonally among bivalves. According to various publications, both exogenous and endogenous factors - such as water temperature, food availability and the gametogenic cycle are responsible for the variation in the organic content and the physiological fitness of venerid, cardiid, psammobiid bivalves (Orban *et al*., 2002, 2007; Flores-Vergara *et al*., 2004; Delgado *et al*., 2004; Ojea *et al*., 2004). Both the percentage edibility and the condition index are tools widely applied in bivalve aquaculture practices to identify the spawning season and to determine the best harvesting season (Anibal *et al*., 2011; Yildiz *et al*., 2011; Rahim *et al*., 2012). Such information is essential from the standpoint of bivalve cultivation and of harvesting strategy (Okumus and Stirling, 1998). In addition, the condition index characterizes the health index and determines the physiological processes related to reproduction, growth, mortality, parasitic and other infections and secretion (Li *et al*., 2009; Mladineo *et al*., 2007; Celik *et al*., 2012; Li *et al*., 2011).

Recently, Lagade *et al*. (2013) and Taware *et al*. (2012) reported on their oxygen consumption studies on the psammobiid *Soletellina diphos*. However, there is no literature or information available relating to the biochemical composition, percentage edibility and condition index of that species. Studies of this type are necessary to allow an understanding of the seasonal mobility of biochemical and organic constituents (proteins, lipids and glycogen) within the clam's body and to assist in forecasting its nutritional status. In addition, knowledge of the percentage edibility and condition indices is useful in identifying the meat quality and the best harvesting period.

Therefore, in this study, series of investigations were carried out to assess the seasonal changes in the biochemical analysis, percentage edibility and condition index of *S. diphos* from the Bhatye estuary on the Maharashtra coast of India.

MATERIALS AND METHODS

Study area: The Bhatye estuary is situated near Ratnagiri between latitudes73°15'E and 16°51'N. This estuary is noted for the high productivity level of its molluscan resources, particularly of *S. diphos*, when compared to that of other estuaries along the Ratnagiri coast. As in the area of the Bhatye estuary, coastal communities to the North and South have exploited populations of this species for human consumption.

This clam is deeply burrowing (to depths of 300-450 mm), particularly in sandy mud substrates and its thin, elongated shell reaches a length of 125 mm and a depth/height of 55 mm. However, the muscular siphons can extend to 3-4 times the actual body length.

Animal collection and maintenance: Samples of *S. diphos* were collected monthly (from March 2008 to February 2009) from the Bhatye estuary during low tide periods when the intertidal mud flat was exposed. These samples were brought to the laboratory, washed and then placed in filtered seawater for acclimatization. After 72 h, mature clams of about 115-125 mm in shell length were selected for experimentation.

Experimental analysis: As part of the biochemical study, five individuals of *S. diphos* were selected and from each individual, different parts of the body-foot, gill, hepatopancreas, gonad, siphon, mantle and adductor muscle were dissected and their protein, glycogen and lipid contents were analyzed. This biochemical analysis was carried out four times during the study, during the summer (April-May), monsoon (July-August) and post-monsoon (September-October) seasons during 2008 and during the winter (December-January) of 2008-09.

The biochemical analysis of the protein content of these samples was determined by the method described by Lowry *et al*. (1951). Glycogen was analyzed following De Zwaan and Zandee (1972) method, while lipid concentrations were estimated by using Barnes and Blackstock (1973) method. All values of the biochemical constituents were expressed in mg/100 mg of the wet tissue.

The Percentage Edibility (PE) and the Condition Index (CI) were analyzed monthly from March 2008 to February 2009. A total of 30 individuals of *S. diphos* of average size were selected for the analysis of their percentage edibility and condition indices. The flesh of each clam was partially dried on blotting paper, then weighed on a Monopan digital balance. For further drying, the flesh and shells were kept in an oven at 60°C for up to 72 h to determine the constant dry meat and shell weight. The Percentage Edibility (PE) was determined by using the method of Anibal *et al*. (2011), Freeman (1974) and Yildiz *et al*. (2011). The Condition Index (CI) was analyzed as described by Rainer and Mann (1992) and Rahim *et al*. (2012).

The Percentage Edibility (PE) and the Condition Index (CI) were calculated by the following equations:

$$\text{Percentage Edibility (PE)} = \frac{\text{WMW (g)}}{\text{TW (g)}} \times 100$$

Where:
WMW = Wet meat weight (g)
TW = Total wet weight including shell (g)

$$\text{Condition Index (CI)} = \frac{\text{MDW (g)}}{\text{DSW (g)}} \times 100$$

Where:
MDW = Meat dry weight (g)
DSW = Dry shell weight (g)

Statistical analysis: All results of the biochemical constituents are given as the mean of five separate analyses with ±SD (Standard Deviation), while the results of the percentage edibility and the condition index are averages of 30 separate analyses with ±SD. In the statistical analysis, the

one-way analysis of variance (ANOVA) with the Bonferroni post-test to compare replicate means was carried out with the aim of uncovering any significant seasonal variation in the biochemical constituents (protein, glycogen and lipid), the percentage edibility and the condition index.

RESULTS AND DISCUSSION

Biochemical composition: The biochemical constituents- proteins, glycogen and lipids- were analyzed from seven body parts (foot, gill, hepatopancreas, gonad, siphon, mantle and adductor muscles) during four seasons (summer, monsoon, post-monsoon and winter). Details of these biochemical constituents are presented in Table 1.

Protein: The protein content was recorded for the different tissues in each season and was found to vary considerably at all seasons and tissues ($p<0.001$). However, in the hepatopancreas during the winter season and in the adductor muscle between the summer and monsoon seasons, the protein levels were non-significantly obtained ($p>0.05$). The protein content of *S. diphos* during the post-monsoon season was at relatively high levels in all selected tissues excluding the siphon tissue. On the other hand, the samples showed their lowest level of protein in all tissues during the summer season except in the siphon tissue. In that, tissue a high protein level (15.991±0.445) was recorded during the winter season, while a low protein level (10.347±0.246) occurred in the post-monsoon season (Table 1). In all tissues, the highest protein content (19.752±0.296) was recorded in the foot, whereas, the lowest protein content (6.025±0.068) was noted in the gill tissue.

Table 1: Seasonal variations in the protein, lipid and glycogen contents of clam *Soletellina diphos*

	Protein contents in mg/100 mg wet weight tissue			
Body parts	Summer	Monsoon	Post-monsoon	Winter
Foot	8.620±0.763***	9.869±0.471***	19.752±0.296***	11.489±0.573***
Gill	6.025±0.068***	10.407±0.165***	12.034±0.146***	7.736±0.514**
Hepato-pancreas	8.451±0.144***	11.009±0.334***	12.651±0.198***	12.280±0.561^{ns}
Gonad	8.010±0.117***	13.299±0.281***	14.761±0.384*	12.637±0.523***
Siphon	11.025±0.195*	12.649±0.271*	10.347±0.246***	15.991±0.445***
Mantle	8.6507±0.146***	11.4804±0.312***	13.3809±0.283**	11.538±0.363***
Adductor muscle	11.875±0.245^{ns}	12.698±0.197^{ns}	16.229±0.408***	13.850±0.413***
	Lipid contents in mg/100 mg wet weight tissue			
Body parts	Summer	Monsoon	Post-monsoon	Winter
Foot	1.167±0.057***	0.942±0.027***	1.273±0.043***	0.716±0.040***
Gill	1.258±0.058^{ns}	1.349±0.024^{ns}	1.621±0.088***	0.874±0.067***
Hepato-pancreas	2.805±0.048***	3.202±0.080***	4.725±0.122***	2.055±0.096***
Gonad	0.955±0.014^{ns}	1.233±0.018^{ns}	1.928±0.059***	0.762±0.048***
Siphon	1.082±0.028***	1.124±0.024***	1.294±0.036***	1.004±0.047***
Mantle	0.929±0.027***	1.142±0.072***	1.509±0.045***	0.896±0.027***
Adductor muscle	0.958±0.027***	1.541±0.043***	1.731±0.049***	0.918±0.055***
	Glycogen contents in mg/100 mg wet weight tissue			
Body parts	Summer	Monsoon	Post-monsoon	Winter
Foot	48.143±1.912***	65.565±1.250***	57.628±1.943***	67.414±1.836***
Gill	15.438±2.360***	18.012±1.058***	16.882±1.274***	23.294±2.260***
Hepato-pancreas	14.642±1.254***	22.014±2.071***	23.779±1.390***	26.631±1.424***
Gonad	23.426±1.278***	47.319±1.598***	42.790±2.741***	52.925±1.808***
Siphon	14.024±1.340***	20.006±1.166***	16.766±1.257***	22.477±1.948***
Mantle	14.391±1.199***	62.586±1.626***	38.043±2.646***	54.439±2.824***
Adductor muscle	16.436±2.214***	58.230±2.437***	40.048±2.692***	43.289±2.896***

All biochemical results are the mean of n = 5 observations with ±SD, ***$p<0.001$, **$p<0.01$, *$p<0.05$, $^{ns}p>0.05$

Organic elements or substances like proteins, lipids and glycogen are the basic building blocks of living organisms (Yildiz *et al*., 2011) and determine their nutritional value (Orban *et al*., 2007). The percentage edibility or meat yield and the condition index of bivalves determine their chemical nature and physiological fitness (Mohite *et al*., 2009). According to Okumus and Stirling (1998), the condition index tool has been used to measure the fatness and the marketability of clams. It is probably the simplest technique to identify gametogenic activity. A series of investigations have reported that the biochemical composition, percentage edibility and condition index of oysters and clams are significantly affected by both internal as well as by external factors (Zrncic *et al*., 2007; Gullian and Aguirre-Macedo, 2009; Orban *et al*., 2002, 2007; Delgado *et al*., 2004; Ojea *et al*., 2004).

In this study, the maximum protein content was recorded during the post-monsoon season in selected tissues such as those of the foot, gill, hepatopancreas, gonad, mantle and adductor muscle, but not the tissues of the siphon tissue. All of these body parts showed a minimum level of protein during the summer season apart from the siphon. According to the results of this study, the peak value of the protein content in all of the tissues examined occurs during the post-monsoon season, indicating that, at that time, protein is accumulating in the body for the development of gametes. In contrast with these results from the hepatopancreas and gonad tissues, although similar to the results from the siphon tissue, Lomovasky *et al*. (2004) reported the maximum levels of protein in the hepatopancreas, gonad and siphon during the winter season in the venerid *Eurhomalea exalbida*. The current results suggest that during the post-monsoon and winter seasons, all tissues accumulate protein, probably in anticipation of energy requirements for the development of gametes. Rodriguez-Astudillo *et al*. (2005) reported the highest protein content in the hepatopancreas and gonad of oyster *Hyotissa hyotis* during the winter season. Another probable factor in the acquiring of the highest protein content in all tissues may be that the availability of phytoplankton is greater during the post-monsoon and winter seasons. The availability of food is closely related to the accessability of energy needed to enhance the growth and development of reproductive activities in bivalve species (Zandee *et al*., 1980; Lomovasky *et al*., 2001, 2002, 2004). The minimum protein content is, conversely, associated with the decline of food and the increase in the mean summer temperature. Therefore, the lowest protein content was recorded in all tissues-except the siphon-during the summer season. According to the literature, the protein content in different bivalve organism predominantly regulated by exogenous factors (Newell and Bayne, 1980). Lomovasky *et al*. (2002) reported that shell growth in *E. exalbida* decreased due to the energy used for reproductive development instead of for growth. Protein may act as an energy reserve in bivalve species, particularly during gametogenesis (Lucas and Beninger, 1985; Galap *et al*., 1997; Brockington, 2001).

Lipid: The average lipid content in these clams varied considerably in all tissues and seasons. However, in the gill and gonad tissues the non-significant variation ($p<0.001$) was recorded in the summer and monsoon samples (Table 1).

Table 1 shows the lipid variations in different tissues for the four sampling seasons. Significantly higher lipid values in all tissues were detected in the post-monsoon season. Overall, these higher values of lipid ranged between 1.273±0.043 to 4.725±0.122 mg/100 mg wet weight of tissue. On the other hand, the lowest values of lipid among all tissues were observed during the winter season. These values fluctuated from 0.716±0.040 to 2.055±0.096 mg/100 mg wet weight tissue. Among all tissues, the maximum lipid level was noted in the hepatopancreas (4.725±0.122 mg/100 mg wet weight) and the minimum lipid was recorded in the foot (0.716±0.040 mg/100 mg wet weight), followed by that of the gonad tissues (0.762±0.048 mg/100 mg wet weight).

In this study, the lipid content in all tissues of *S. diphos* was high during the post monsoon period, while the lowest lipid content was recorded during the winter season. In this species, the maximum lipid content was noted in the hepatopancreas followed by that in the gonad, adductor muscle and gill tissues. The maximum concentration of lipids in the hepatopancreas indicates that it is the main organ for the storage of lipids in *S. diphos*. Generally, the hepatopancreas is the main storage site of biochemical reserves, particularly of lipids and glycogen. However, these reserves are utilized during periods of food scarcity (Galap *et al*., 1997) and of gamete development (De Zwaan and Zandee, 1972; Lomovasky *et al*., 2004) and their concentration fluctuates during gonadal development (Sokolowicz *et al*., 2006).

Seasonal variations in lipid content in all tissues showed a post-monsoon<monsoon<summer <winter trend of lipid variation except for the foot. However, in foot tissue lipid variation was observed during post-monsoon<summer<monsoon<winter.

The highest lipid concentration during the post-monsoon might have coincided with gamete maturation whereas, during the summer season, the process of gamete emission caused the lipid content to fall. Morriconi *et al*. (2002) and Lomovasky *et al*. (2004) reported the same reasons for the increase and decrease in the lipid content in bivalves. In the same way, Martinez (1991) reported that such a lipid variation is principally related to gamete development. From the result of this survey, it seems clear that the highest level of lipid in *S. diphos* clams occurs when the gonads are mature. Lipids also play a vital role in the energy metabolism, second only to protein (Takashi and Mori, 1971). In mature bivalves, lipids are stored mainly in gonads and constitute the major element of reproduction (Gabbott, 1975). According to Wolowicz *et al*. (2006), the protein and lipid content in the mytilid *Mytilus trossulus* increases during gametogenesis and decreases after spawning. Anibal *et al*. (2011) stated that lipids are more influenced by the seasonal reproductive cycle because of their relationship with gonad maturation.

Glycogen: The glycogen content in these clams varied widely from 14.024±1.340 mg/100 mg wet weight to 67.414±1.836 mg/100 mg wet weight, during the annual cycle. Significantly, the maximum glycogen content was recorded during the winter season in the foot tissues (67.414±1.836 mg/100 mg wet weight), in contrast to the gill (23.294±2.260 mg/100 mg wet weight), hepatopancreas (26.631±1.424 mg/100 mg wet weight), gonad (42.790±1.808 mg/100 mg wet weight) and siphon (22.477±1.948 mg/100 mg wet weight) tissues. In the mantle and adductor muscle tissues, the peak value of glycogen (54.439±2.824 mg/100 mg wet weight) and 43.289±2.896 mg/100 mg wet weight) has been noted in the monsoon season ($p<0.001$) (Table 1).

The lowest glycogen content was recorded during the summer season in all tissues. These low values ranged from 14.024±1.340 to 48.143±1.912 mg/100 mg wet weight tissue. Overall, in all seasons and tissues, the glycogen content varied considerably ($p<0.001$). The peak value of the glycogen content was found in the foot tissue (67.414±1.836 mg/100 mg wet weight), followed by those in the tissues from the mantle, adductor muscle and gonad. A much lower glycogen content (14.024±1.340 mg/100 mg wet weight) was recorded in the siphon tissues, followed by those from the mantle, hepatopancreas and adductor muscle in that order (Table 1).

In this study, the highest glycogen content was recorded in the foot tissue, followed by that of the mantle, adductor muscle, gonad, hepatopancreas, siphon and gill. The glycogen content in clams increased during the winter season and declined in the summer season in all of these tissues. This result confirms that the glycogen content was used for physiological and metabolic processes throughout the year. In *S. diphos*, the foot, mantle and adductor muscle are functional in the

storage of glycogen. Literature reports indicate that glycogen is stored in the mantle and adductor muscle of the mytilid *Mytilus edulis* for use in gonad maturation and reproductive development (Zandee *et al*., 1980). Nagabhushanam and Dhamne (1977) also stated that the glycogen level was at a peak in the immature stages and low in the mature stages of the mussels *Mytilus viridis*; perhaps it may indicate that, in mature bivalves, maximum glycogen is utilized for gonadal development and/or to meet the reproductive success. Similarly, in other bivalves such as scallops (Martinez, 1991; Villalaz, 1994), other mussel species (Bayne *et al*., 1983; Lowe *et al*., 1982) and oysters (Castro and de Vido de Mattio, 1987), the adductor muscle tissue acts as a store for glycogen. However, in contrast, the adductor muscle of *E. exalbida* does not have the same function of storing glycogen for energy reserves (Lomovasky *et al*., 2004). In the venerid *Ruditapes decussatus*, during the winter season the glycogen accumulated prior to gametogenesis, previously it used as an energy source for gonad development, in expectancy of the spawning period taking place in summer (Ojea *et al*., 2004).

Glycogen is the vital constituent stored in marine bivalves (Barber and Blake, 1981; Beukema, 1997), which is used for energy production (Mathieu and Lubet, 1993), including gamete formation (Galap *et al*., 1997). Glycogen is the major element of nutritional value, being the energy source for anaerobic metabolism of many bivalves (Hochachka, 1976). Measurement of its content has been used to interpret the health index in the scallops *Patinopecten yessoensis* (Miyazona and Nakano, 2000; Yamanaka, 2002).

In this study, the glycogen content of all of the organs of *S. diphos* examined was greater than their protein and lipid contents. These results are closely comparable with those observed in the oysters *Crassostrea iridescens* and *Crassostrea corteziensia* (Paez Osuna *et al*., 1993), although the studies of Lomovasky *et al*. (2004) indicated that the glycogen content was moderately lower than the other organic components of *E. exalbida*.

Percentage edibility and condition index: In the present investigation, the percentage edibility and condition index was checked monthly to measure physiological fitness.

Percentage edibility: The percentage edibility was very high ($p<0.001$) from March 2008 to February 2009, except in May and July ($p<0.05$) and in January ($p>0.05$). During the annual cycle, the percentage edibility fluctuated from 45.64-79.96%, with a sharp increase in the percentage edibility during September (79.96±4.420%). From October onwards it decreased considerably, with the lowest percentage edibility (45.64±2.836) being noted in November 2008 (Fig. 1a).

According to the literature, the percent edibility or meat yield among bivalves varies seasonally and geographically, depending on food availability and the timing of the gametogenic cycle (Okumus and Stirling, 1998; Orban *et al*., 2002, 2007; Delgado *et al*., 2004; Ojea *et al*., 2004). In this study, the clam *S. diphos* showed its highest percentage of edibility during September, whereas, its minimum occurred in November. The decreased percentage of edibility of *R. decussatus* and *Paphia malabarica* clam is closely associated with its spawning period (Gozler and Tarkan, 2000; Mohite *et al*., 2009), while the percentage edibility enhances as gametogenesis advances (Anibal *et al*., 2011). Hence, the percentage edibility index or meat yield has an important role concerned with the cultivation and harvesting strategy (Okumus and Stirling, 1998). Bivalves discharge their gonads into their mantle cavities and then out to the surrounding water during their spawning activity, resulting in a considerable loss of meat weight (Okumus and Stirling, 1998; Yildiz *et al*., 2011).

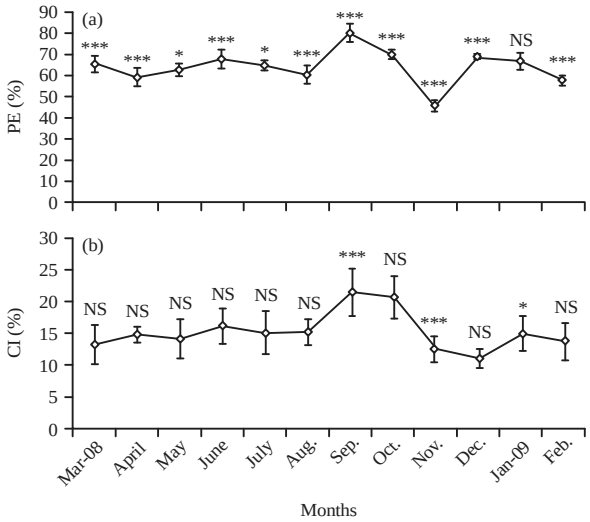

Fig. 1(a-b): Monthly variations in (a) Percentage edibility and (b) Condition index of clam *Soletellina diphos*. All values represented in figures are the mean of n = 30 observations. Bar represents the standard deviations of the mean ***p<0.001, **p<0.01, *p<0.05 and NS: p>0.05

Condition index: During the annual cycle, the condition index showed (p>0.05) significant variation in all months. The condition index of clams was significantly higher in September (21.55±3.92%) and October (20.83±3.39%). However, during November (p<0.001) and December (p>0.05), the condition index (12.57±2.06 and 11.07±1.43%) had decreased, while January 2009 onwards it commenced to elevate gradually (Fig. 1b).

During the monthly observations of the condition indices in *S. diphos*, the peak value of the highest condition index was noted in September-October and the lowest condition index during November-December. The peak value of the condition index in these clams reflects its maturity or physiological fitness (Peharda *et al*., 2006; Ojea *et al*., 2004) while the decline in the value coincided with the onset of the spawning behaviour or the releasing of gametes (Sahin *et al*., 2006; Juric *et al*., 2012). The reproductive behaviour and spawning period of bivalves can be assessed by two methods i.e., direct and indirect. The direct method involves the use of histological sectioning and the microscopic evaluation of the gonads (Adjei-Boateng and Wilson, 2011; Suwanjarat *et al*., 2009; Sahin *et al*., 2006; Hartati *et al*., 2005). The indirect method of analysis involves the condition index technique which is applied to measure the physiological state of the bivalve (Rahim *et al*., 2012). The condition index is a tool widely used all over the world to identify the spawning seasons of bivalves (Celik *et al*., 2012; Yang *et al*., 2011; Park *et al*., 2011).

A seasonal variation in the biochemical composition of marine bivalves reflects the complex interactions between the available food, the environmental conditions and the bivalve's reproduction. Among shellfish, many species of bivalves are considered to be a valuable and nutritional seafood, as they can provide many of the nutritional elements (proteins, vitamins and minerals) which are essential to humans for a completely balanced diet. These elements are distributed unequally in various parts of a bivalve species' body and concentration in the bivalve's tissues can be generally correlated with external climate changes. The periodicity and variability of the nutritional value of such bivalves would be assessed, in a more global approach, by using calculations of the percentage edibility and the condition index.

On the basis of the results of this study, we recommend that the analysis of the organic elements (proteins, glycogen and lipids) and the analyses and calculations of the percentage edibility and the condition index-being effective and important tools in biological science will provide quick and confirmative knowledge about the peak nutritive value and the reproductive output among bivalves and other organisms.

CONCLUSION

These studies on samples from the population of *S. diphos* in the Bhatye estuary indicate that its biochemical components and its physical fitness vary with the seasons. Based on these results, we suggest that the harvesting of *S. diphos* should be concentrated on the post-monsoon season (September-October) when the seafood is at its highest nutritive value. On the other hand, we also recommend that, because the winter (November-January) and summer (April-May) seasons correspond with the periods of low biochemical status of these clams as well as with their low percentage edibility and condition index, these seasons are not ideal for such harvesting.

The information pertaining to the biochemical composition, the percentage edibility and the condition index of *S. diphos* is extremely important from the viewpoint of physiological fitness and nutritive point, since they reflect on the physiological fitness, reproductive output and nutritive value of the clams. A good condition index is a sign of the high accumulation of nutrient, especially of proteins, glycogen and lipids. Accurate and adequate information on the physiology and the eco-physiological aspects of *S. diphos* will eventually promote the development of sustainable management practices in bivalve aquaculture, leading to the enhancement of the population structure of the clam *Soletellina diphos* in the Bhatye and other estuaries.

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