STUDIES ON ENERGY CONTENT OF FOULING ORGANISMS WITH SPECIAL REFERENCE TO SESSILE BARNACLES

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Mr. K. NANDAKUMAR, *M. Sc.*

RESEARCH GUIDE

Dr. ARUN B. WAGH
HEAD, MARINE CORROSION & MATERIALS RESEARCH DIVISION
NATIONAL INSTITUTE OF OCEANOGRAPHY
DONA PAULA, GOA – 403 004

WORK CARRIED OUT AT

MARINE CORROSION & MATERIALS RESEARCH DIVISION
NATIONAL INSTITUTE OF OCEANOGRAPHY
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S T A T E M E N T

As required under the Ordinance No. O.413, I state that the present thesis entitled "Studies On Energy Content Of Fouling Organisms With Special Reference to Sessile Barnacles", is my original contribution and that the same has not been submitted for any degree of this or any other University on any previous occasion. To the best of my knowledge, the present study is the first of its kind from the Goa Coast.

A.B. WAGH
Research Guide

K. NANDAKUMAR
Candidate

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CHAPTER I

INTRODUCTION

Man is dependent on oceans to meet many of his requirements such as food, energy, transportation etc. This dependence has been increasing with the passing of time because man has realised that the oceans which cover more than 70 % of earth's surface can provide enormous and varied resources. The studies on the marine environments like estuaries and coastal areas are very important since they harbour rich fauna and flora. The fresh water run offs bring various inorganic and organic materials which act as the nutrients and provide food for the marine organisms. Hence, these areas are visited by the fishes for breeding purposes. As a result detailed studies on organisms which contribute considerably to these environments attain high significance.

The fouling organisms with their large number, sedentary nature and gregariousness form a major group of marine invertebrate fauna of estuarine and coastal ecosystems. As any other important group of intertidal organisms such as oysters, mussels etc. sessile barnacles also form a major group of organisms in the intertidal area and in coastal region. The contribution which these organisms make in the maintenance of food chain is expected to be highly significant. The extent of energy contributed by them through their innumerable eggs and larvae to the environment appear to play an important role, directly or indirectly, in the enhancement of productivity potential and the energy flow in the ecosystem.

The sessile barnacles are abundantly observed as intertidal organisms and they also constitute a major group of fouling fauna. Major industries and devices which are affected by fouling are shipping industry, offshore oil industry, ocean thermal energy conversion (OTEC) plants, nuclear power plants, navigational buoys, submarines and other moored oceanographic instruments and systems.

However, the studies carried out so far on the sessile barnacles have been related to their obstructive roles to the various activities of man. But they can also be useful in the marine ecosystem as biological indicators (Anil, 1986), in corrosion prevention at least to some extent (LaQue, 1972) and as the potential source of energy in the maintenance of food chain. However, the review of literature indicates that their role in the food chain of marine environment in Indian waters has not been studied so far.

As stated by Crisp (1984 a), the most comprehensive form of investigation of production is the measurement of the flow of organic matter and energy through each component of ecosystem. The various segments in the ecosystem and their interdependence can be made clear by dividing the flow sheet into different trophic levels. This begins with the primary producers which utilize solar energy to fix inorganic nutrients present in the ecosystem. They inturn pass on this energy to the subsequent trophic levels thereby completing the food chain of the given locality. The major principles involved in the energy flow and its measurement are well described by Odum (1959) and Phillipson (1966).

As pointed out by Odum (1968) in his review entitled "The energy flow in ecosystem", ecology is defined as the study of the relationships between structure and function in nature. He also emphasised the significance of energy flow studies in the ecosystems.

The basic unit of energy (capacity to do work) is very critical in the energy budget studies. Generally, the unit adopted for this energy measurement is 'calorie'. More recently, the energy flow have been measured in 'Joules'. The relationship of Joule and calorie with its conversion factor is explained in detail in the chapter IV, 'Studies on the calorific content'. So in the natural environment, for an animal to survive, the ratio of calorie obtained from the food and the calorie spent for gathering food should always be in surplus or the relation

$$\frac{\text{Food energy absorbed}}{\text{Energy expended during its collection}}$$

must be atleast one or greater than one. The theoretical aspect of this problem has been dealt with in detail by Schoener (1969).

A great deal of work on the bioenergetics of marine organisms including vertebrates and invertebrates has been done so far. According to Odum (1968), the energy oriented thinking in ecology can be traced to the late 19th century. Clarke (1954) in his book regarding the elements of ecology had said that the classical essay of Forbes (1887) entitled "The lake as a microcosm", is the landmark in the development of ecological thought. Because in his essay he has pointed out the concept of the self sufficiency and existence of enclosed ecosystems such as lake, pond etc.

Some of the earlier workers on the aspects relating to energetics of ecosystem and other organisms include Forbes (1887); Dokuchaev (1889); Cowles (1899); Clements (1905); Elton (1927); Manning & Juday (1941); Sverdrup *et al* (1942); Riley (1944); Clarke (1948); Harvey (1950); Rabinowitch (1951); Edmondson (1955); Odum (1960, '62, '63, '68). Those who have worked on the food value of various organisms like copepods, nauplii of artemia etc. include Labour (1918-1922); Gross (1937); Soleim (1942); Dannevig (1947); Morris (1955); Qasim (1959) etc. Among those who have worked on the energetics of various marine organisms are Davis, 1963 (*Carassius aurarus*); Pandian & Schumann, 1967 (in crab *Eupagurus bernbardus*); Pandian 1967 a (*Ophiocephalus striatus*); Pandian 1967 b (*Crangon crangon*); Fluchter & Pandian, 1968 (in eggs of *Solea solea*); Edwards & Steele, 1968 in O-group plaice; Hughes, 1972 (*Nucella lapillus*); Ansell, 1972 (*Donax vittatus*); Plat & Irwin, 1973 (phytoplankton); Perkins (1975) in intertidal organisms; Barnes & Achituv (1976) in *Balanus balanoides*; Wu & Levings (1978) in *B. glandula* etc.

The recent reports regarding the energetics of various marine organisms include the work done by Achituv et al (1980); Barber & Blake (1981); Harms (1984); Boehlert et al (1986); Edmunds & Davies (1986); Willows (1987); Castro & Mattio (1987); Whyte et al (1987); Harms (1987) etc.

In comparison to the work done on energetics and biochemistry of invertebrates in other parts of the world, very little work appears to have been done in Indian waters. Some reports from India regarding the biochemical studies on marine organisms include the work of Hornell (1917); Daniel (1923); Bapat et al (1952); Velankar (1952); Pillai (1953); Pillai (1956); Pillai et al (1956); Velankar (1957); Durve & Bal (1961); Durve (1964); Rahman (1966); Giese (1969); Virabhadra Rao (1969); Pandian (1967 a, b, 1969, 1970 a, b, c, 1972); Qasim (1972); Balasubramanian et al (1972); Qasim et al (1973); Satyanarayana Rao (1974); Rajgopal et al (1976 a, b); Sumitra-Vijayaraghavan et al (1976, 1978, 1980); Wafar et al (1976); Nagabhushanam & Dhamne (1977); Nagabhushanam & Mane (1978); Ramadhas & Sumitra-Vijayaraghavan (1979); Nagabhushanam & Deshpande (1982); Nandakumar et al (1988); Prabhakara Rao et al (1988) etc. As regards the bioenergetics of barnacles and other marine organisms from

Indian waters the review of literature indicated that very little information is available. The works which deserve mention here are those of Pandian (1969); Rajagopal et al (1976 a); Sumitra-Vijayaraghavan et al (1980) and Sumitra-Vijayaraghavan & Ramadhas, 1980.

Regarding the studies on biochemical composition of barnacles and other invertebrates which constitute one of the major fouling organisms in the Indian waters, considerable amount of work seems to have been carried out in different parts of the world in the 1960's and early 1970. Some of the work on barnacles are those of Mitchell (1916); Russell (1923); Masumoto et al (1934); Barnes & Powell (1953); Barnes & Gonor (1958); Patel & Crisp (1960); Barnes (1962, '63, '65); Barnes et al (1963); Cook & Gabbott (1970, 1972); Barnes & Achituv (1976); Barnes et al (1976); Achituv et al (1980); Harms (1984, '86, '87) etc. Greenfield et al (1958); Pearse (1965); Satyanarayana Rao (1966) in starfishes; Giese & Araki (1962); Tucker & Giese (1962) in chiton etc. But reports on either the biochemical composition or energy content of barnacle population from Indian waters are very little (Pillai & Nair, 1972).

Barnacles are sessile organisms found generally on natural substrata like submerged rocks or artificial man made structures. They are gregarious in habit. They belong to the phylum Arthropoda, class Crustacea, family Cirripedeae. Their soft body tissues are ensheathed in a calcareous shell comprised of shell plates. They are filter feeding organisms. The cirri which beat so often to maintain the circulation of water have two functions such as respiration and food collection. Algal cells, diatoms and other particulate matter form the food of barnacles. The beating of cirri was considered as the state of activity (metabolic status) of the organism by many earlier workers.

Barnacles are hermaphrodites and mostly cross fertilization occurs in them. But there are also instances of self fertilization in barnacles. In case of B. amphitrite at least 10 broods of eggs are reported to be produced by a single animal in a single season (Pillai & Nair, 1972). Each brood contain 250 - 300 eggs, which are produced in ovigenous lamellae in the mantle cavity. Eggs after fertilization develop inside the mantle cavity till the first or second stage of nauplii. The sixth stage of nauplii metamorphoses to nonfeeding cyprid larvae. Cyprid on the availability of a suitable substratum attaches and grows as an individual barnacle. The developmental period of eggs may extend from 15 - 20 days (Pillai & Nair, 1972). Total life span of barnacle can vary from 3 - 6 years (WHOI, 1952).

Many workers from India have done extensive studies on different species of barnacles, their distribution, larval recruitment, rearing etc. They include the preliminary reports of Annandale (1905, 1906) who described the list of Indian pedunculate barnacles. Some of the other workers who deserve mention here are Daniel (1955 a, b, 1956); Bhat & Bal (1960); Ganapati & Rao (1960, '62); John (1964); Wagh (1965, '72, '73, '74); Wagh & Bal (1969 a, b, 1970 a, b, 1971 and 1974); Pillai & Nair (1972); Ganti & Kalyanasundaram (1973, '75); Karande 1965, '73, '74 a, b, c, 1979); Balakrishnan (1975, '77); Uday Bhaskar et al (1983); Anil (1986); Venugopal (1987) etc. Nevertheless, detailed and systematic work on energetic aspects and biochemical composition of barnacles seems to be lacking till date from Indian waters. Since, very little effort has only been put into these studies of barnacle production, in the present study, attempts have been made to find out the importance of these organisms in the food chain. Energy flow through these organisms can be studied by employing the computations of energy content which will enable us to estimate the contribution by these organisms to the energy budget. Keeping in view of all the above points, the study on the energy content and biochemical composition of sessile barnacles was carried out from Goa coast for a period of 16 months from April, 1986 to July, 1987.

CHAPTER II

STUDY AREA AND METHODOLOGY

DETAILS OF STUDY AREA:

For the present study, three stations were selected, two along Zuari estuary and one along the exposed seashore at Arambol. The Zuari estuary is located at lat 15° 25'N and long. 73° 45'E - 73° 55'E and the station Arambol is located at lat. 15° 41'N and long. 73° 42'E along the west coast of India. Zuari estuary is one of the largest estuaries along the west coast of India. The Zuari estuary finds its origin from the Western Ghats and after a prolonged flow of 65 km it joins the Arabian Sea. On one side of it is the Dona Paula point and on the other side is Marmagao. The mouth of the estuary is 5.5 km wide with an average depth of 6m. This is classified as a microtidal estuary with average tide level below 2 m (Ahmad, 1972).

The Zuari estuary receives heavy monsoon rain fall and also the discharge from the catchment areas in western ghat. The average rain fall over Goa varies between 2600 - 3000 mm, of which major part of the rain fall occurs during the south west monsoon period (June - September).

The average runoff of Zuari estuary is 9 km^3/annum (NIO tech. Report, 1979). Studies on this estuary revealed that, it is a mixed water column from surface to bottom except during the monsoon season when it becomes clearly stratified. Penetration of seawater during the pre- and postmonsoon season is observed upto about 65km upstream but during the monsoon it gets reduced to about 20 km (NIO, tech. Report No., 02/79).

Two stations in this estuary were selected for the present study. They were Marmagao harbour and Dona Paula jetty. The third station selected for this study was Arambol rocky shore. It was due to two main reasons:

1) It represents an open sea shore, where the seawater is not directly diluted by the freshwater runoff through river drainage, and so represents a different environment than the above two stations.

2) Availability of abundant barnacle settlement on the rocky shore. Two species of barnacles, <u>Balanus tintinnabulum</u> and <u>Chthamalus</u> sp. were available in large numbers through out the year.

Except during the monsoon season, the movement of the water in the Zuari estuary as well as in the Arambol seashore is due to the semidiurnal tides. During the study, the tide along Marmagao (Goa coast) varied between -0.27 m to 2.48 m.

The two stations in the Zuari estuary viz. Marmagao Harbour and Dona Paula point are separated by about 5 km wide water column, but both are located very close to the mouth of the estuary. The distance from the Marmagao Harbour to Arambol is about 30 km (Fig: 1).

MATERIALS AND METHODS

The collection of samples (both animals and organic matter) for the calorific study were made from the above three stations as described below.

Harbour:

To get the fouling barnacles, three to four months before the commencement of the study, aluminium panels admeasuring 15 x 10 X 0.3 cm^3 were suspended in the subsurface water ($\sim$1 m) from the jetty No.7 with the help of polyethylene ropes. Sufficiently large number of panels were suspended so as to get a continuous supply of the live organisms corresponding to various sizes. Monthly collection of these settled barnacles, mainly *Balanus amphitrite* and *Balanus amaryllis* were made by removing the panels. The settled barnacles were removed from the panels with the help of a sharp chisel. Number of barnacles with the percentage of mortality (by counting the shells without soft body) and the dominant size group was noted down at the time of collection. To get the sizes of the barnacles, measurement of Rostro Carinal Apex (RCA), Rostro Carinal Base (RCB), Latero Lateral Apex, (LLA) Latero Lateral Base (LLB) and Height (H) were noted down with the help of a Vernier callipers. Depending on the availability, barnacles belonging to the species *B. amphitrite* were divided into four size groups based on RCB ie. below 5 mm, 5 - 10 mm, 10 - 20 mm and above 20 mm., while *B. amaryllis* were divided into three size groups like 10 - 15 mm, 15 - 20 mm and 20 - 30 mm. The *Chthamalus* sp. collected from Dona Paula and Arambol were divided into two size groups (RCB below 5 mm and 5 - 15 mm) and *B. tintinnabulum* from Arambol into four size groups like below 20 mm, 20 - 30 mm, 30 - 40 mm and above 40 mm. Barnacles were dissected open after washing them in distilled water to remove the soft parts and unwanted materials (Wu & Levings, 1978). They were dried in an oven at 70 ^{o}C for 24 hrs. After this, the tissues were powdered in a mortar and stored in a desiccator till the final analysis. Subsamples of these were taken for the measurement of water content (Wu & Levings, 1978). From each size group 10 to 20 organisms were taken for the observation and pooled together for the subsequent analysis.

The second division of the barnacles were made based on the development of ovary like mature and immature. This division of the barnacles were made according to the specifications given by Karande (1967). The specimens with immature ovary and without ovarian tissue were classified as immature and those bearing mature eggs and first stage of nauplii were classified as mature ones.

Measurement of calorific content of immature egg mass, mature eggs and first stage of nauplii of *B. amphitrite* were carried out as follows: The soft parts of barnacles after washing in distilled water were observed under a stereo microscope. The ovaries were removed and the eggs (both mature and immature) and nauplii were transferred with the help of a spatula and dropper into clean measuring cylinders. They were weighed before they were taken for the calorific content measurements. The methodology of calorific estimation is explained in detail in the latter part of this chapter.

Zooplankton samples from the subsurface water were collected from Harbour station with the help of a Heron Tranter net (Mesh size 300 μ). The samples were dried in an oven at about 70 ^{o}C for 24 hrs., before powdering in a mortar and the subsequent analysis. For measuring the calorific content of suspended matter in the seawater, 3 to 4 liters of seawater was filtered through pre-weighed millipore filters (4.7mm dia., 0.45 μ pore size). The filter papers along with the trapped matter were dried in an oven at 70 ^{o}C/ for 24 hrs. The dry weight of suspended matter was found out by weighing the above filters using a microbalance (Mettler, M - 3). Appropriate blanks were run along with the samples. The determination of calorific content of these samples was made after adding a known amount of standard benzoic acid.

Dona Paula:

Monthly collections of barnacles, *B. amphitrite* and *Chthamalus* sp. were made from the barnacle population on the concrete piles of the jetty. The barnacles were scraped out (approximately 300 Nos.) from the jetty piles with the help of a chisel and hammer. Extreme care was taken not to disturb the specimen during the collection. The groupings according to the size and maturity were made. The soft parts were removed, dried and stored in a desiccator after powdering in a mortar as explained above. Due to the heavy churning up of sediment and less adundance of zooplankton, zooplankton sample collection could not be carried out at this station. Suspended matter samples for the measurement of calorific content were collected at the Harbour station.

Arambol:

The rocky shore of Arambol station inhabited a wide and well established barnacle population belonging to the species B. tintinnabulum and Chthamalus sp. Monthly collections by scraping them with the help of a chisel and hammer were made from a fixed area where the population number was monitored by counting the number of individuals in an area of 1 $ft.^2$. Mortality was assessed in a similar way by counting the number of dead individuals and expressed as percentage of population. In the case of B. tintinnabulum, depending on their availability, they were divided into four size groups as explained earlier and were dissected open to separate the soft parts into body tissue, intestine, cirri and the whole body. These tissues were also dried and powdered and stored in desiccator for the subsequent analyses. Number ranging from 5 - 10 were observed for each size group and pooled together for the sample preparation. The estimation of suspended matter for the calorific content measurement was also collected from this station. Zooplankton samples could not be collected from this station due to the difficulties in the operation of nets at the study area. Collections for June and July, 1986 and June, 1987 could not be made due to the bad weather conditions and heavy wave actions at the time of collection caused by the onset of monsoon.

Calorimetry:

Heat of combustion of a substance is measured in a bomb calorimeter. During the present study the Adiabatic Calorimeter (Model No.1241) was used for this purpose. This bomb calorimeter, employed for the measurement of heat of combustion required $\leq$ 1g of homogeneously powdered and dried biological samples. A weighed quantity of the sample (approximately 1 g) was then compacted into a small pellet by means of a pellet press. The pellet was again weighed and placed on a firing device (a capsule), held by the platinum wire through which an electric discharge was passed to ignite the pellet. The bomb was then filled with oxygen under pressure to the order of 25 to 30 atm. This oxygen filled bomb was then placed inside a steel bucket with water. The temperature of this water was made same as the temperature outside the bucket (the water in the jacket outside the bucket). After putting it on for 2 to 3 minutes so as to get it stabilized, the initial temperature was noted down with the help of a fine thermometer. The sample was ignited by passing electric current. The heat generated during the combustion transmitted to the water outside the bomb (bucket water). The change in temperature of the water in the bucket was noted down after stabilization (final temperature). From the difference in temparature and the fuse wire consumed (platinum), the calorific value was calculated using the formula

$$Hg = \frac{t\ W - e1 - e2 - e3}{m}$$

where

Hg = gross heat of combustion or calorific content in cal.

t = difference in temperature

W = energy equivalent of calorimeter ie., calories required to rise the temperature by $1\,^{o}C$

e1 = correction in calories for heat of formation of nitric acid

e2 = correction in calories for heat of formation of sulphuric acid

e3 = correction in calories for heat of combustion of fuse wire.

The instrument was periodically standardised by using standard thermochemical quality benzoic acid pellets. Correction for the acid production was neglected in the present study, since the correction according to Paine (1964) was negligible and amounts less than 1% of the total calorific content.

The standard benzoic acid was added to those samples which were lesser in quantity at the time of combustion in the calorimeter. As recommended by Crisp (1984 a) millipore filters were used to measure the calorific content of larvae and eggs of the barnacles being lesser in quantity and smaller in size.

Ash content of the samples were estimated by ashing the pre-weighed dried samples in a muffle furnace by charring at 450 °C for 4 hrs. All calorific values were corrected for ash contents and expressed as cal/g. dry wt. (ash free).

Biochemical analysis:

The important biochemical constituents such as protein, lipids, carbohydrates and total organic carbon were estimated for all the animal samples. The methods used for this purpose are described below: the specimens were dried in an oven at 70 °C for 24 hrs. and powdered before taken for the analysis. Protein was estimated following the method suggested by Herbert et al (1971). 0.5g of the dried sample was taken in a dried test tube and homogenized in 0.5 ml of 1N NaOH and 2.5ml of distilled water. This was heated at 80 °C in a water bath for 30 min. to extract the protein. After cooling, 0.5ml of 1N HCl was added to neutralize it and subsamples were taken from this in other test tubes. 2.5ml of mixed reagent (carbonate - tartarate - copper solution) was added followed by 0.5ml of 1N Folins-Ciocalteu reagent. These solutions were mixed well, kept for 30 minutes and centrifuged before measuring the absorbance at 750 nm in a spectrophotometer . Appropriate blanks and standards (bovine serum albumin) was similarly treated to prepare standard curves. All concentrations were expressed in μg/mg.d.wt. of animal tissues.

Carbohydrates were estimated using phenol sulphuric acid method as described by Dubois et al (1956) and modified by Hitchcock (1977). To 1 mg of dried sample, 2 ml of 80% sulphuric acid was added and digested for 20 hrs at room temperature. To this 1 ml of phenol (5%) and 5 ml of concentrated sulphuric acid were added, the mixture was centrifuged before measuring the absorbance at 490 nm. Standard curve was drawn with the help of alar grade D-glucose. Finally concentrations were expressed in μg/mg.d.wt. of dried tissue.

Lipids were estimated following the method given by Parsons et al (1984). From the dried and powdered sample, 5 to 10 mg. was weighed and placed in a glass homogeniser with 8 ml of chloroform-methanol mixture (1:2:0.8 V/v of chloroform, methanol and distilled water respectively). This mixture after filtering through an ignited (450 ^{o}C/4 hrs.) GF/C filter paper, was transferred to a separating funnel. Extraction of lipid was made by the addition of 2 ml of distilled chloroform and 2 ml of distilled water by continuous shaking for 10 minutes. The chloroform layer was separated and evaporated to dryness in vacuum. 2 ml of 0.15% potassium dichromate solution was added and the tubes were kept in boiling water bath for 15 minutes. 4.5 ml of distilled water was added to this, after cooling the absorbance was measured at 440 nm. Blanks and standards (stearic acid) were treated similarly and standard graph was plotted. All concentrations were expressed as µg/mg.d.wt. of dried tissue.

Estimation of total organic carbon in the animal tissue was made by wet oxidation method as suggested by Parsons et al (1984). To a known quantity of the dried and powdered sample, 1 ml of phosphoric acid and distilled water was added in order to prevent the chloride interference and kept in a boiling water bath for 30 minutes. Sulphuric acid dichromate reagent was added (10 ml) to these tubes and were digested in a boiling water bath for a period of 1 hr. This was diluted with distilled water to 50 ml. Subsamples (approximately 10 ml) were centrifuged (4000 rpm) for 20 minutes and absorbance was measured on a spectrophotometer at 440 nm. Blanks and standards (D-glucose) were treated similarly and the standard curve was plotted. Concentrations were expressed as µg C/mg.d.wt. of animal tissues. All the above measurements of absorbance were made using a spectrophotometer.

Collection and Analysis of Hydrographic Data:

Hydrographic parameters such as temperature, salinity, dissolved oxygen, PH, total suspended matter, particulate organic carbon, chlorophyll a, phaeopigments of the surface waters at 3 stations were monitored at monthly intervals. Seawater samples for this purpose were collected from the surface water with the help of clean plastic bucket.

Temperature of the water samples was monitored with the help of a mercury thermometer immediately after the collection. These values were expressed as ^{o}C.

Salinity of the water samples were estimated following the method given by Strickland and Parsons (1968). This involved the determination of chlorinity by the Mohr Knudson titration method with standard silver nitrate solution with potassium chromate as an indicator. Salinity was calculated and expressed as parts per thousand (‰).

Dissolved oxygen concentration of the water sample was monitored using Winkler method. This method involved the fixation of dissolved oxygen using Winkler A and B followed by the titration against standard sodium thiosulphate solution using starch as indicator. The concentration was expressed in ml/lit of the sea water. The pH measurements were made with the help of a pH meter (Philips, PP 9045, digital pH meter).

The total suspended matter was determined by filtering 1 - 4 lts. of seawater through preweighed millipore membrane filter paper. The residue was dried in an oven at 70 ^{o}C and weighed in a balance (Mettler M - 3). The concentrations were expressed as mg/lit (dry weight) of seawater. Particulate organic carbon was estimated following the wet oxidation method using sulphuric acid - dichromate reagent as described by Parsons *et al* (1984).

Chlorophyll *a* estimation was done spectrophotometrically. After filtration of the seawater sample (500 ml to 1 lit.) through GF/C filter papers, they were extracted with 90% acetone in dark bottles below 5 ^{o}C (Yentsch and Menzel, 1963). The values were expressed in mg/lit. of seawater. Phaeopigments were estimated by the acidification of the above sample (acetone extract) with two drops of 50% HCl and measuring the absorbance spectrophotometrically as suggested by Parsons *et al* (1984).

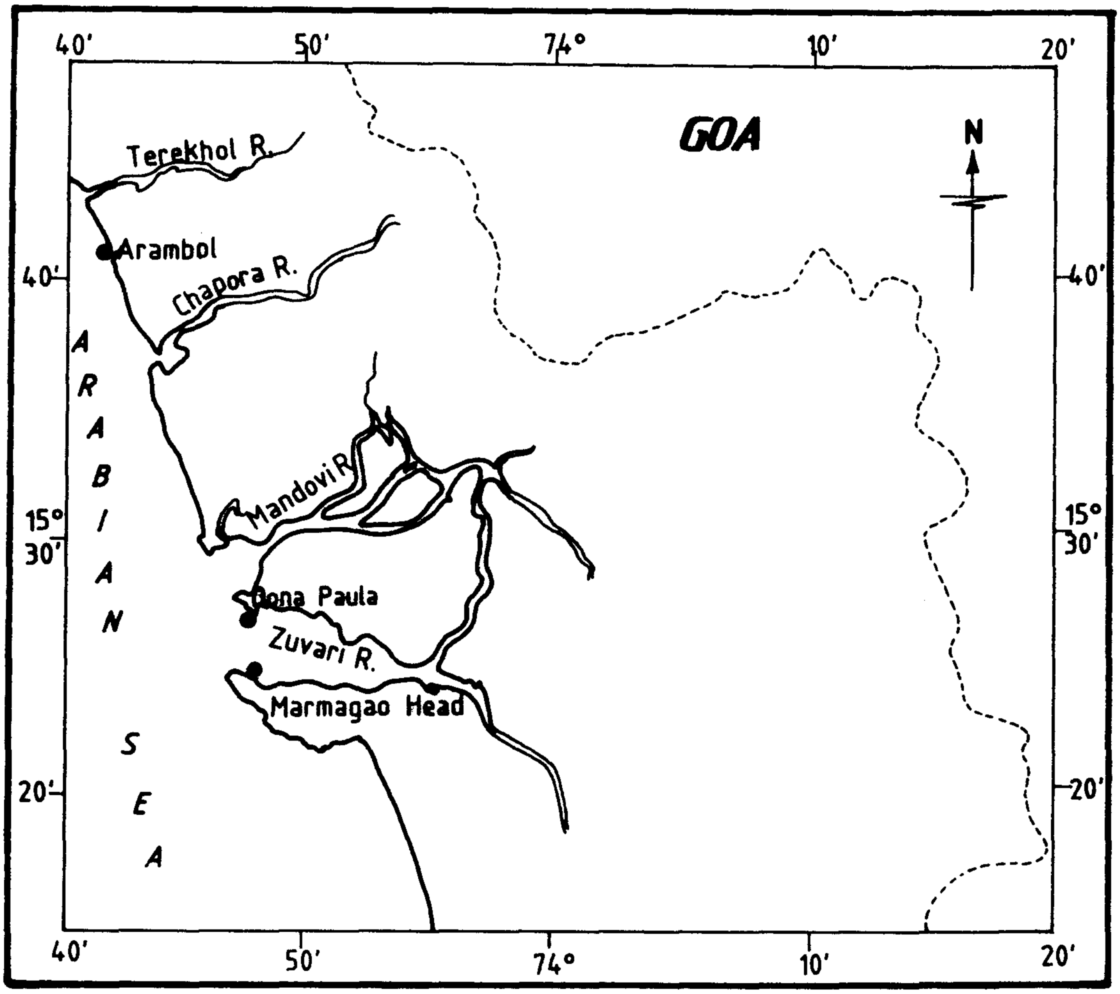

Fig. 1 Location of three study areas (●)

CHAPTER III

ENVIRONMENTAL PARAMETERS

"An estuary is a semienclosed coastal body of water which has a free connection with the open sea and within which seawater is measureably diluted with fresh water derived from the land drainage" (Pritchard, 1967). Naturally, this complex system is prone to seasonal changes, affecting both the biotic and abiotic factors. Because of this nature, any study in an estuary without the background informations of environmental parameters will remain incomplete (Qasim, 1972). On the contrary, an open sea shore which is not apparently affected by the direct river drainage represents a comparatively stable environment. So, it was thought that, a comparative study of these two environments, with sedentary fouling organisms as experimental species will be of much interest.

The literature survey shows only very little information available on the studies of bioenergetics of barnacles with respect to various hydrographic parameters. The physico-chemical features of the environment have a direct impact on the physiological state of marine organisms. Therefore, the important hydrographic parameters such as temperature, salinity, total suspended matter, chlorophyll a, phaeopigments, particulate organic carbon (POC) and pH were monitored during the entire period of study from all the three stations.

In an estuary, the major environmental factor that controls the nature of the community is salinity (Anil, 1986; Meenakumari & Nair, 1984). Many workers from different parts of India have reported the impact of monsoon on the fluctuation of salinity (Panikkar and Aiyar, 1939 from Madras; Ganapati et al, 1958 from Visakhapatnam; Meenakumari & Nair, 1984 from Cochin Harbour; Anil, 1986 from Goa waters).

In the aquatic environment temperature is the other important hydrographic parameter, which controls the growth of marine organisms (Sverdrup, et al, 1942; Kinne, 1970). Slight increase or decrease in temperature can influence the marine life through the alterations in growth, metabolism, distribution, reproduction etc. Indirectly it can alter the chemistry of seawater which in turn affect the marine life. Temperature is an important factor for determining the abundance and distribution of organisms in the higher latitude but may not necessarily act as a controlling factor in tropical environment since the fluctuation of temperature in these waters is marginal (Devassy, 1983). Literature shows large amount of work that has been carried out on the effects of temperature on marine organisms (Southward, 1955, 1958; Patel & Crisp, 1960; Barnes, 1963; Kinne, 1970; Stickle & Bayne, 1982).

The amount of dissolved oxygen in seawater is important as the sole source of oxygen for the marine organisms. The requirement of the same in turn depends on the temperature of the surrounding environment (Sverdrup et al, 1942).

Suspended matter is important as one of the major sources of food for the filter feeding sedentary organisms like foulers. Works on the food value of suspended matter was carried out by many workers throughout the world (Riley, 1970; Qasim & Sankaranarayanan, 1972; Qasim, 1972; Krishnakumari et al, 1978).

POC deserves special mention in this study as it gives the total carbon content of the suspended matter present in the seawater which is available as the source of energy for the filter feeding organisms (Nandakumar et al, 1987). The concentration of POC has been studied by many workers all over the world. Some of them are Menzel

(1974); Wangersky (1976); Qasim (1977); Gordon & Cranford (1985); Nandakumar *et al* (1987).

Measurement of the most important plant pigment, Chl *a* gives an indirect estimation of the primary production at the area studied (Devassy, 1983). This forms the major energy source for the filter feeding organisms especially foulers. Phaeopigments are the degraded products of Chl *a* present in the seawater. Measurement of this parameter is also important in the calculation of the primary production of a certain locality.

The present study period covered monsoon, postmonsoon and premonsoon seasons, as the observations commenced from April, 1986 and extended up to July, 1987. The data so collected are presented with the help of 16 figures and 8 tables.

MARMAGAO HARBOUR

Salinity (Table 1, Fig. 2):

During the period of study at this station, salinity varied from 12‰ to 35.68‰. During the premonsoon months of 1986, salinity did not show much fluctuation. In the early period of monsoon season (June, 1986) the salinity was recorded as 32.57‰. but the value dropped down to 12.00‰. in July, 1986. A rise in salinity values was observed in the latter part of monsoon, 1986. During the post monsoon period 1986 (October, 1986 to January, 1987) and premonsoon period 1987 (February, 1987 to May, 1987) more or less uniform salinity was observed. A similar set of values of salinity could be observed during the monsoon season, of 1987 as that of 1986.

<u>Temperature</u> (Table 2, Fig. 3):

During the study the temperature at this station ranged between 24.5 $^{\circ}$C to 32.0 $^{\circ}$C. During the premonsoon months of 1986, the temperature varied between 30.0 $^{\circ}$C to 31.4 $^{\circ}$C and in the monsoon season, it varied from 24.5 $^{\circ}$C to 28.5 $^{\circ}$C. More or less uniform temperature was recorded in postmonsoon season but the premonsoon period 1987 showed an increase in temperature. A marked variation could not be recorded during the months of June and July, 1987.

<u>Dissolved Oxygen</u> (Table 3, Fig. 4):

During the study period at this station the values for this parameter varied from 1.69 ml/lit. to 5.55

ml/lit. During the premonsoon months 1986, it varied between 4.15 to 5.55 ml/lit and in monsoon, the variation was between 2.99 ml/lit to 4.78 ml/lit. In the postmonsoon period it ranged between 2.37 ml/lit. and 4.10 ml/lit and in premonsoon period 1987, it varied between 2.17 to 4.63 ml/lit. The concentration touched the lowest value of 1.69 ml/lit. in the monsoon period and it could be due to the consumption of oxygen by bacteria degrading the enriched organic matter brought in by the fresh water influx.

pH (Table 4, Fig. 5):

As opined by Sverdrup *et al* (1942) under normal circumstances pH will not act as a controlling factor, as far as the marine life is concerned. During the present study the pH at this station varied between 7.55 to 8.04. The values remained uniform during the entire course of study, except in August, September, November, 1986 and February, 1987 where it crossed 8. Variation of pH with season was not specifically evident.

Total Suspended Matter (Table 5, Fig. 6):

At this station concentration of suspended matter varied from 3.3 to 120.4 mg/lit. there by showing wide fluctuation during the study. However, a seasonal pattern could not be ascertained from the collected data. During April and May, 1986, it varied from 59.87 to 120.4 mg/lit. and during monsoon months from 3.87 to 61.9 mg/lit. Postmonsoon months recorded the values of 3.3 to 71.6 mg/lit. and in premonsoon 1987, 15.3 to 45.2 mg/lit. During the monsoon months of 1987, the variation was negligible ie. from 13.2 to 13.4 mg/lit.

<u>Particulate Organic Carbon (POC)</u> **(Table 6, Fig. 7):**

The POC concentration at this station varied between 386.94 to 6022.86 µgC/lit. It varied from 1310.03 to 1337.48 µgC/lit during the premonsoon months of 1986 and 386.94 to 1744.05 µgC/lit during monsoon 1986. During the postmonsoon, it varied between 1020.64 to 2719.82 µgC/lit and in premonsoon 1987 it varied between 2349.70 to 6022.86 µgC/lit. During the months of June and July, 1987, the concentration varied between 1076.70 to 1693.58 µgC/lit.

<u>Chlorophyll *a*</u> (Chl *a*) (Table 7, Fig. 8):

The concentration of Chl *a* varied between 1.47 to

43.55 µg/lit during the study at this station. During April and May, 1986, the concentration varied between 4.05 to 4.85 µg/lit and during monsoon 1986 it varied between 1.47 to 4.08 µg/lit. An increase in concentration was recorded in postmonsoon period (5.61 to 18.95 µg/lit) and the maximum concentration was recorded in premonsoon 1987 (43.55 µg/lit). During the monsoon months of 1987 the concentration varied between 2.21 to 9.43 µg/lit.

<u>Phaeopigments</u> (Table 8, Fig. 9):

In this study, the concentration of phaeopigments varied between 0.34 to 48.9 µg/lit in July, 1986 and February, 1987 respectively. In the rest of the months, except in August, 1986, it ranged between 2.39 to 5.05 µg/lit., whilst, the concentration in August, 1986 was 0.45 µg/lit.

DONA PAULA

<u>Salinity</u> (Table 1, Fig. 2):

Salinity at this station during the study varied between 12.48‰ to 36.49‰. During the premonsoon months of 1986, it varied between 34.05 to 36.49‰ and during monsoon 1986 it varied between 12.48 to 31.42%. The salinity during postmonsoon varied between 31.31 to 34.73%. Almost a similar range of salinity was observed during the rest of the period with an exception during the monsoon months of 1987 when, the values recorded were 12.60%. and 20.33%. respectively.

<u>Temperature</u> (Table 2, Fig. 3):

Temperature was found to be more or less uniform throughout the period of study at this station. It showed the variation between $24.5^{\circ}C$ to $32.5^{\circ}C$. The minimum temperature observed was in the month of August, 1986. The maximum temperature recorded was in the month of April, 1987, a premonsoon period. Except this, the temperature was found to be more or less stable throughout the study period.

<u>Dissolved Oxygen</u> (Table 3, Fig. 4):

The values of dissolved oxygen varied between 1.74 to 4.25 ml/lit. during the study. The premonsoon months of 1986 recorded a value of 4.01 to 4.10 ml/lit, whereas, during monsoon 1986 it varied between 2.85 to 4.25 ml/lit. More or less uniform values were observed (3.09 to 3.72

ml/lit) during the postmonsoon season and it varied between 1.74 to 3.09 ml/lit during the premonsoon 1987. During the monsoon months of 1987, the values read more or less same as that for premonsoon season of 1987.

pH (Table 4, Fig. 5):

The pH of seawater did not show much variation as expected during the entire study period. The minimum value recorded was 7.58 and the maximum 8.02. The effect of season on pH distribution was negligible.

Total Suspended Matter (Table 5, Fig. 10):

The concentration of suspended matter at this station varied between 10.33 to 60.00 mg/lit (dry weight). A marginal increase in suspended matter concentration was observed during both the monsoon months. Except this the values remained more or less same during the study.

Particulate Organic Carbon (Table 6, Fig. 11):

The concentration of POC varied between 487.89 to

3258.18 µgC/lit. during the period of study. In the premonsoon months of 1986 the values varied between 681.36 to 995.40 µgC/lit. and during monsoon 1986 they varied from 487.89 to 1979.58 µgC/lit. The postmonsoon period showed a variation between 813.14 to 1797.32 µgC/lit and an increase in the POC concentration could be recorded during the premonsoon period 1987 with the values ranging between 1934.72 to 3258.18 µgC/lit. The monsoon months of 1987 showed a concentration of 1357.10 to 2781.52 µgC/lit, which was slightly higher than the values recorded during the months of monsoon 1986.

Chlorophyll a (Table 7, Fig. 12):

As with the Harbour station, at this station too Chl a concentration showed wide fluctuations ranging between 0.70 to 24.5 µg/lit. During the months of April and May, 1986 the values showed a variation of 1.83 to 2.72 µg/lit and the monsoon months recorded the values of 0.7 to 4.06 µg/lit. During the postmonsoon period the Chl a varied between 1.79 and 5.17 µg/lit and in the premonsoon 1987 it ranged between 3.93 to 24.5 µg/lit. The monsoon months of 1987 showed a higher concentration of Chl a than the previous one with the values ranging between 4.09 to 7.82 µg/lit.

Phaeopigments (Table 8, Fig. 13):

The concentration of phaeopigments at this station showed a range of 0.02 to 19.29 µg/lit. With the exception of the high values of phaeopigments for the month of June, 1987 (19.29 µg/lit), they remained below 4.45 µg/lit. (July, 1987). The higher values recorded were only in the monsoon months of 1987.

ARAMBOL

Salinity (Table 1, Fig. 2):

Arambol rocky shore represents an open seashore where the seawater is not directly affected by the river drainage. In contrast to the above two stations, the salinity values were more or less uniform with a little effect of monsoon. Here, during the study period, the salinity ranged between 25.54‰ to 36.97‰. In the months of April and May, 1986 the salinity ranged between 26.80 to 36.97‰ and in 1987 monsoon months it ranged between 25.54 to 26.95‰.

Temperature (Table 2, Fig. 3):

In contrast to the salinity, the seawater temperature at this station showed the effect of monsoon. During the entire study span the temperature ranged between 22.5 ^{o}C and 32.4 ^{o}C. While in the premonsoon months of 1986 temperature ranged between 31.5 ^{o}C to 32.4 ^{o}C, the monsoon period showed a reduced temperature of 22.5 ^{o}C to 28.5 ^{o}C. The postmonsoon period showed the temperature range of 27.0 ^{o}C to 29.6 ^{o}C and the premonsoon 1987 27.8 ^{o}C to 31.7 ^{o}C. Again during the months of monsoon 1987, the temperature dropped down to 24.8 ^{o}C.

<u>Dissolved</u> <u>Oxygen</u> **(Table 3, Fig. 4):**

The values for dissolved oxygen ranged between 1.93 to 4.78 ml/lit during the entire study period. The concentration remained above 3.04 ml/lit till May, 1987 from the beginning of the study and then it dropped down and ranged between 1.93 to 2.22 ml/lit during the rest of the months.

<u>pH</u> **(Table 4, Fig. 5):**

The pH of seawater during the study period at this station varied between 7.44 to 8.23. The pH remained more or less uniform through out the study except on two occasions when it crossed the value of 8 which was recorded in the months of May, 1986 and June, 1987.

Total Suspended Matter (Table 5, Fig. 14):

The suspended load in the seawater at this station varied between 14.2 to 181.5 mg/lit during the study. The maximum value was observed in July, 1986 and the minimum in February, 1987. Generally, the content of suspended matter during the monsoon 1986 and '87 showed a slightly higher value than the rest of the period.

Particulate Organic Carbon (Table 6, Fig. 15):

The abundance of POC during the study at this station ranged between 956.15 to 4133.0 µgC/lit. Comparatively higher concentrations of POC were observed during the monsoon months of 1986 and 1987. During the rest of the period, the concentrations ranged between 956.15 to 2669.34 µgC/lit.

Chlorophyll *a* (Table 7, Fig. 16):

The Chl *a* values varied between 1.45 to 13.42 µg/lit during this study. The higher values of Chl *a* was observed during the earlier half of the study period i.e., from

April, 1986 to November, 1986 than the latter part.

<u>Phaeopigments</u> (Table 8, Fig. 17):

The concentration of phaeopigments ranged between 1.06 to 16.34 µg/lit during the study period. A high content of phaeopigments could be traced during both the monsoon seasons, otherwise the concentration remained more or less the same during the study. The maximum value was observed in the month of August, 1986 and the minimum in April, 1986.

Generally, in tropical area salinity acts as the master factor which may decide the nature of the development of animal and plant communities such as fouling community, intertidal organisms etc. At the same time, the temperature is the master factor deciding the nature of community in the temperate areas. This was reported earlier by many workers (Paul, 1942; WHOI, 1952; Daniel, 1954; Sverdrup <u>et al</u>, 1942; Kinne, 1970).

The major fouling barnacle species of these localities are <u>Balanus amphitrite</u>, <u>B. tintinnabulum</u>, <u>B. amaryllis</u> and <u>Chthamalus</u> sp. The wide salinity flutuations during the south west monsoon may act as major stress on these organisms, which in turn will have to spend more energy to overcome this impact. The wide fluctuation of various hydrographic parameters during the monsoon may even result in the death of these organisms. This was well illustrated by the mass mortality of barnacles that occurred during the monsoon seasons. During the present study at Arambol, mortality of > 50% (in 1986 monsoon) and > 95% (in 1987 monsoon months) of B. tintinnabulum was recorded. At the Harbour station the mortality rate of B. amphitrite during the monsoon period was > 80%. Similar rate of mortality (80 - 85%) in the case of B. amphitrite was reported earlier from the Harbour station by Anil (1986). Effect of salinity on barnalces and their larvae has been worked out for different species of barnacles by Bhatnagar & Crisp (1965); Barnes & Barnes (1974); Cawthrone & Davenport (1980).

The effect of temperature on the development of barnacle larvae has been studied by various workers (Southward, 1964; Crisp & Ritz, 1967; Ritz & Foster, 1968; Cawthrone & Davenport, 1980; Harms, 1984, 1986). The range of temperatures in the present environment is not large enough to act as a controlling factor. Nevertheless, the reason for the high mortality occurred at Arambol station may be the combined effects of low temperature and salinity and high turbidity (high content of suspended matter).

The dissolved oxygen at these stations, except during the monsoon period was uniform. The low values for dissolved oxygen in the water can make the organism anoxic and hence it may undergo heavy stress resulting in the increased expenditure of energy for survival (WHOI, 1952). Indirectly, it is likely to affect the rate of respiration, growth, reproduction, survival etc. In the experiment conducted by Achituv _et al_ (1980), on nauplii stage I and II of _B. balanoides_, it was revealed that under anoxic conditions, the nauplii stage I could only survive 4 hrs. and within that time they became inactive. There was a lot of difference in the biochemical constituents of anoxic and oxic nauplii stage I (Achituv _et al_, 1980).

In the present study, the chlorophyll _a_ content was important so as to assess the rate of primary production which acts as the elementary source of energy available for the marine ecosystem. It can be mainly in the form of unicellular algae, diatoms and bacteria. These organisms constitute the major food for the filter feeding organisms like sedentary fouling barnacles. As reported by Devassy

(1983) the primary production of Goa waters is 0.430 mgC/m^2. The measurements of phaeopigments are also important in the primary production calculation, since they form the degraded product of chlorophyll a. The reason for the unusually high concentrations of Chl a and phaeopigments in the months of February & March, 1987 could be due to the phytoplankton bloom that occurred in the Zuari estuary mouth during that particular period (February & March, 1987).

The quantity of suspended matter was the other important factor in this study, since, it contributes a major share of food for the filter feeding organisms including barnacles. The composition of suspended matter include the detrital organic residues bacteria, parts of diatom cells, algae, larvae of various organisms etc. (Qasim 1972). The particulate organic carbon estimation gives the energy potential of the suspended matter. So, the data on suspended matter supported by the POC content could give a fairly clear picture of the food value of this detrital material in seawater.

In light of these considerations data on physico-chemical parameters have been collected so that the dynamics of energy transfer could be properly understood and explained.

Table 1

Monthly variations in Salinity (ppt) at three stations during the study period.

Month	Harbour	Dona Paula	Arambol
Apr'86	35.68	36.49	35.27
May	35.65	34.05	35.54
Jun	32.57	31.35	30.54
Jul	12.00	12.48	26.80
Aug	15.60	18.96	35.58
Sep	33.72	31.42	36.97
Oct	33.10	31.31	36.27
Nov	34.46	34.73	34.73
Dec	-	34.06	33.91
Jan'87	34.60	33.94	34.72
Feb	33.92	34.86	34.32
Mar	34.05	33.58	35.95
Apr	34.53	28.85	29.32
May	35.00	34.05	36.42
Jun	14.66	20.33	25.54
Jul	14.58	12.60	26.95

Table 2

Monthly variations in temperature (^{o}C) at three stations during the study period.

Month	Harbour	Dona Paula	Arambol
Apr`86	30.0	30.5	31.5
May	31.4	31.4	32.4
Jun	28.2	27.8	28.5
Jul	25.7	28.5	25.6
Aug	24.5	24.5	22.5
Sep	27.5	26.3	22.7
Oct	27.6	28.5	27.0
Nov	27.8	29.6	29.6
Dec	-	27.4	29.0
Jan`87	27.8	26.9	28.1
Feb	29.2	28.9	29.9
Mar	32.0	29.6	29.2
Apr	31.7	32.5	31.7
May	29.4	31.7	27.8
Jun	29.5	31.5	24.8
Jul	29.0	30.5	28.6

Table 3

Monthly variations in Dissolved oxygen (ml/l) at three stations during the study period.

Month	Harbour	Dona Paula	Arambol
Apr'86	4.15	4.01	4.39
May	5.55	4.10	4.49
Jun	2.99	2.85	4.73
Jul	4.39	4.25	4.78
Aug	4.78	3.86	3.76
Sep	3.38	2.90	4.34
Oct	3.81	3.62	3.52
Nov	2.37	3.09	3.04
Dec	-	3.33	3.96
Jan'87	4.10	3.72	3.43
Feb	3.33	1.88	3.52
Mar	3.52	3.09	3.96
Apr	4.63	2.46	4.49
May	2.17	1.74	1.93
Jun	2.22	2.56	2.17
Jul	1.69	2.51	2.22

Table 4

Monthly variations in pH at three stations during the study period

Month	Harbour	Dona Paula	Arambol
Apr'86	7.93	7.84	7.85
May	7.87	8.02	8.12
Jun	7.89	7.77	7.78
Jul	7.81	7.92	7.91
Aug	8.02	7.81	7.92
Sep	8.01	7.85	7.73
Oct	7.91	7.85	7.85
Nov	8.04	7.71	7.69
Dec	-	7.79	7.84
Jan'87	7.90	7.92	7.97
Feb	8.02	7.81	7.96
Mar	7.55	7.58	7.73
Apr	7.56	7.84	7.44
May	7.80	7.85	7.89
Jun	7.73	7.78	8.23
Jul	7.64	7.77	7.56

Table 5

Monthly variations in suspended matter (mg/l) at three stations during the study period

Month	Harbour	Dona Paula	Arambol
Apr'86	59.87±1.2	12.81±0.0	-
May	120.40±00	10.33±2.2	35.80±7.4
Jun	3.87±0.00	46.00±0.0	59.60±0.0
Jul	42.10±0.5	60.00±0.0	181.50±00
Aug	61.9±47.3	16.70±1.3	46.10±5.3
Sep	16.30±3.3	18.37±0.0	18.50±3.3
Oct	71.600±39	17.50±3.5	38.60±1.4
Nov	25.50±1.3	19.30±0.7	37.40±0.0
Dec	-	14.20±0.6	42.6±10.6
Jan'87	3.30±1.30	26.10±6.7	25.70±4.1
Feb	45.20±0.2	27.63±0.0	14.20±0.0
Mar	19.20±3.2	16.50±0.1	20.00±0.8
Apr	15.30±0.5	18.90±0.5	22.70±0.7
May	21.20±0.0	28.32±0.0	24.30±0.5
Jun	13.20±0.4	26.00±1.6	80.1±18.1
Jul	13.40±0.8	13.50±0.5	21.30±0.3

Table 6

Monthly variations in POC (µgC/1) at three stations during the study period. Values in parenthesis represent standard deviation for the duplicate analysis

Month	Harbour	Dona Paula	Arambol
Apr'86	1337.48 (±0)	995.40 (±218.71)	956.15 (±2.81)
May	1310.03 (±89.73)	681.36 (±16.83)	2303.23 (±149.81)
Jun	1149.67 (±280.43)	992.60 (±229.92)	3715.23 (±448.63)
Jul	433.68 (±7.48)	1979.58 (±61.70)	4133.00 (±263.56)
Aug	386.94 (±24.30)	487.89 (±151.41)	1758.08 (±356.10)
Sep	1744.05 (±128.99)	1968.37 (±16.83)	1993.60 (±316.84)
Oct	2719.82 (±179.46)	1390.76 (±11.22)	1668.34 (±58.88)
Nov	1626.29 (±123.37)	1160.83 (±151.41)	1558.74 (±11.46)
Dec	–	813.14 (±56.08)	1623.48 (±126.18)
Jan'87	1020.64 (±185.06)	1797.32 (±14.02)	1766.96 (±236.00)
Feb	6022.86 (±639.30)	2529.14 (±207.50)	2669.34 (±213.10)
Mar	2820.76 (±207.48)	3258.18 (±858.02)	1643.10 (±185.06)
Apr	3073.12 (±919.68)	2125.38 (±151.42)	2456.26 (±67.30)
May	2349.70 (±128.98)	1934.72 (±61.68)	2383.36 (±5.60)
Jun	1693.58 (±157.02)	2781.52 (±201.88)	2063.70 (±179.46)
Jul	1076.70 (±302.82)	1357.10 (±11.22)	2137.14 (±27.50)

Table 7

Monthly variations in Chl.a (μg/l) at three stations during the study period

Month	Harbour	Dona Paula	Arambol
Apr'86	4.05±0.07	1.83±0.16	1.83±0.09
May	4.85±0.54	2.72±0.12	8.35±0.60
Jun	1.66±0.10	1.73±0.17	5.82±0.40
Jul	1.47±0.11	4.06±0.00	8.06±1.13
Aug	1.68±0.23	0.70±0.00	13.42±.33
Sep	4.08±0.16	2.96±0.08	2.07±0.06
Oct	18.95±3.27	5.17±0.07	7.29±0.65
Nov	13.93±2.68	3.45±0.92	6.80±0.00
Dec	-	1.79±0.03	3.23±0.10
Jan'87	5.61±0.23	2.89±0.16	2.03±0.91
Feb	43.55±7.32	24.50±4.60	2.56±0.21
Mar	15.76±1.20	12.91±0.75	2.15±0.01
Apr	11.87±1.30	15.88±0.62	4.50±0.81
May	4.82±0.35	3.93±0.13	1.63±0.28
Jun	9.43±0.00	7.82±0.88	3.32±1.34
Jul	2.21±0.43	4.09±0.00	1.45±0.47

Table 8

Monthly variations in Phaeopigments (µg/l) at three stations during the study period

Month	Harbour	Dona Paula	Arambol
Apr'86	-	1.10±0.26	1.09±0.26
May	2.80±0.11	0.82±0.10	4.15±1.01
Jun	3.12±0.00	1.11±0.12	6.31±0.79
Jul	0.34±0.00	0.02±0.00	6.33±0.36
Aug	0.45±0.00	1.67±0.22	16.34±3.96
Sep	2.81±0.34	0.02±0.00	1.06±0.28
Oct	5.05±2.28	0.13±0.00	7.21±0.74
Nov	2.28±0.04	1.33±0.29	7.28±0.20
Dec	-	2.48±0.00	5.48±1.81
Jan'87	3.02±0.00	2.98±0.38	4.63±1.11
Feb	48.9±2.06	3.69±0.87	2.74±0.18
Mar	2.76±1.09	2.87±2.58	3.32±0.28
Apr	3.01±0.00	3.14±1.09	6.81±1.62
May	3.02±0.26	3.56±0.00	3.51±0.18
Jun	2.41±0.55	19.29±0.46	13.50±6.74
Jul	2.39±0.02	4.45±0.03	4.43±0.42

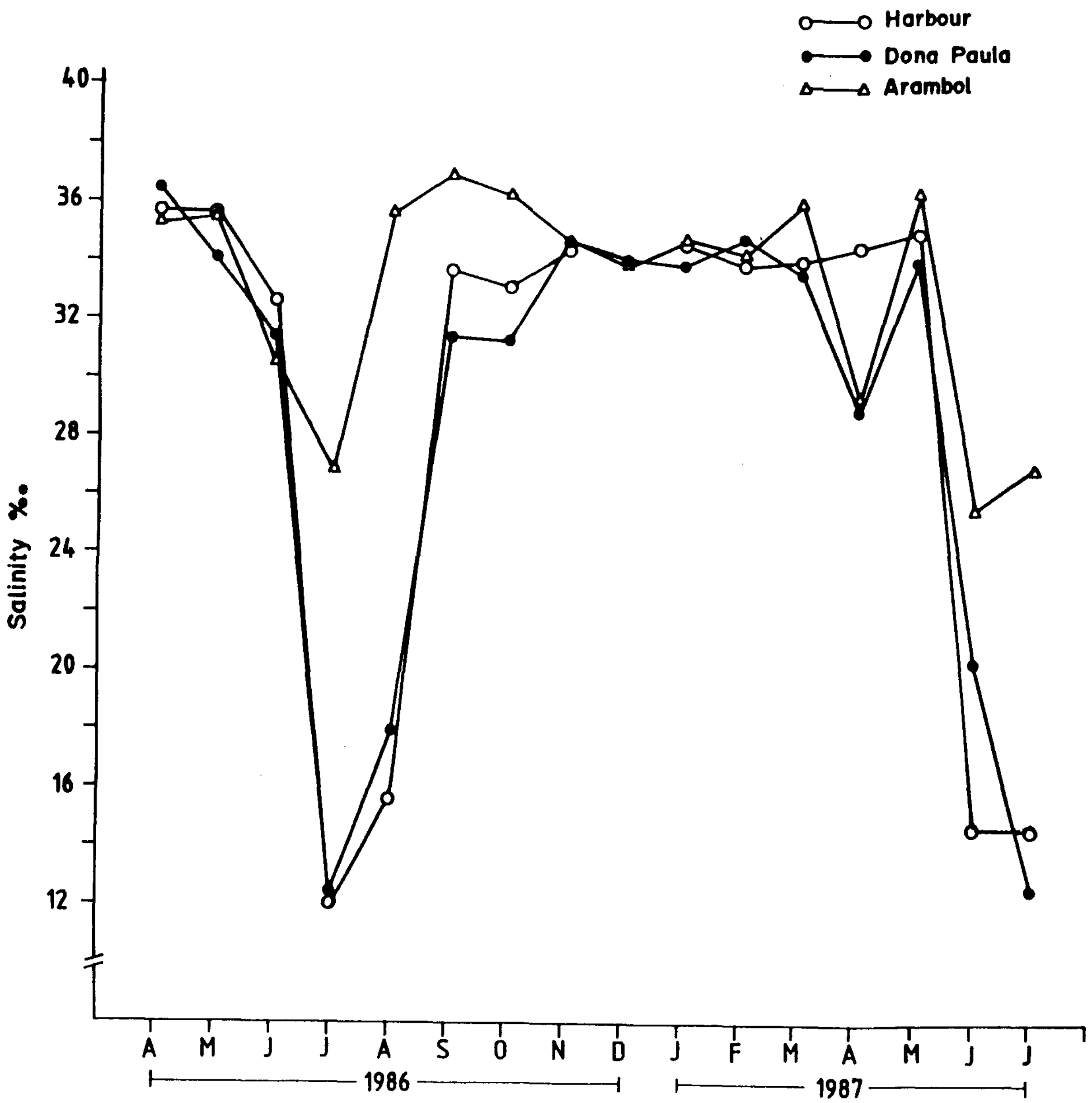

Fig. 2 . Monthly variations of Salinity values at three study stations.

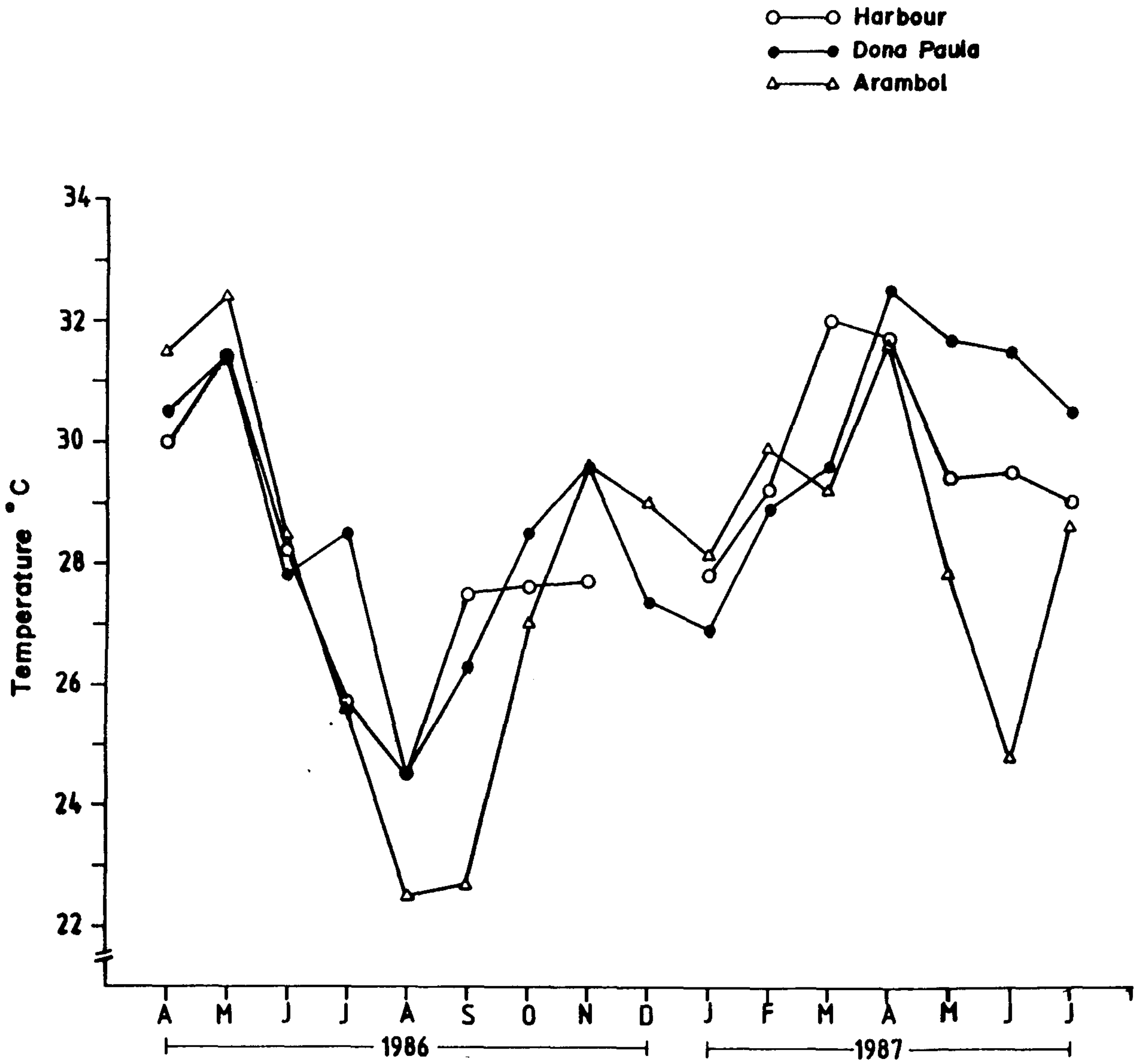

Fig. 3. Monthly variations of Temperature values at three study stations

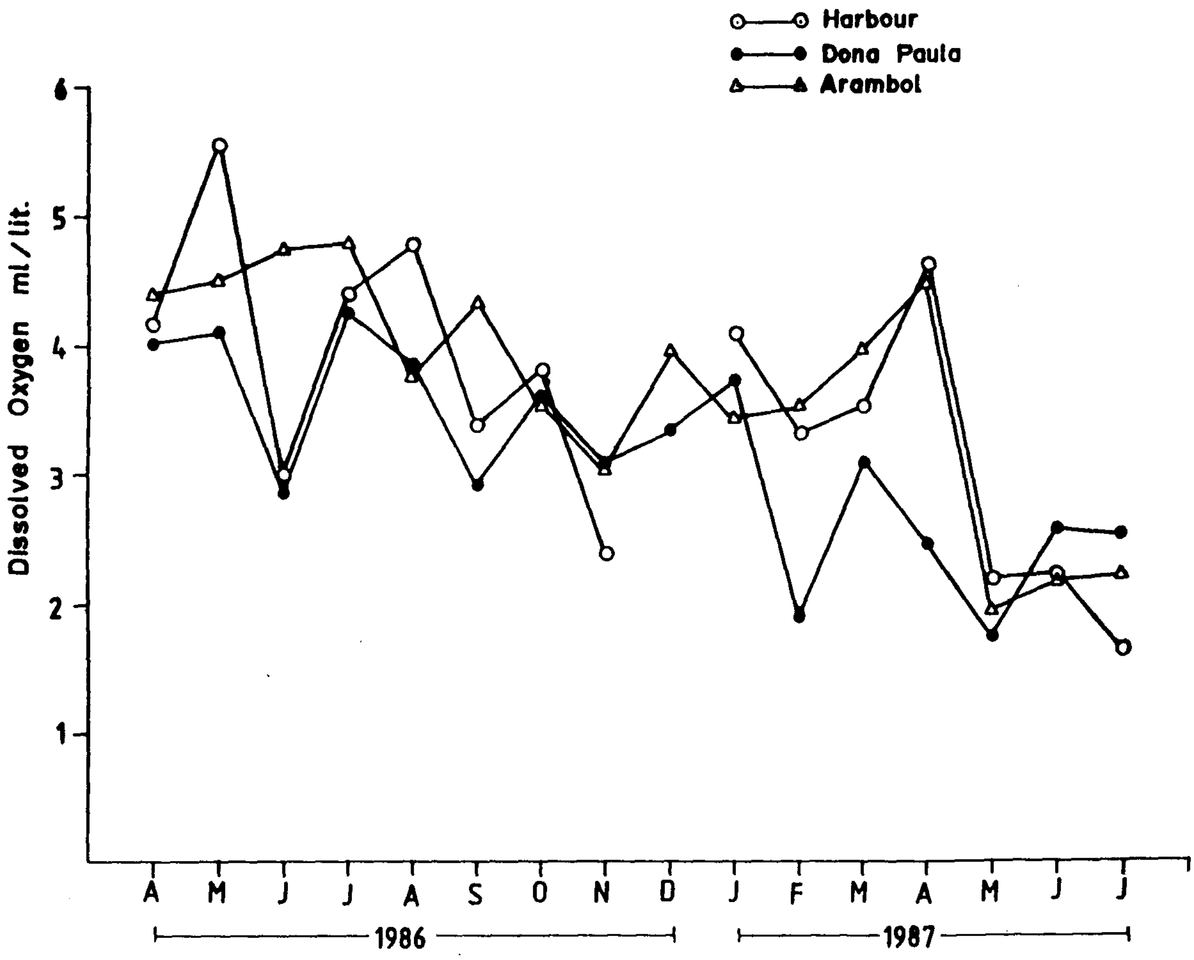

Fig. 4. Monthly variations of Dissolved oxygen concentration at three study stations

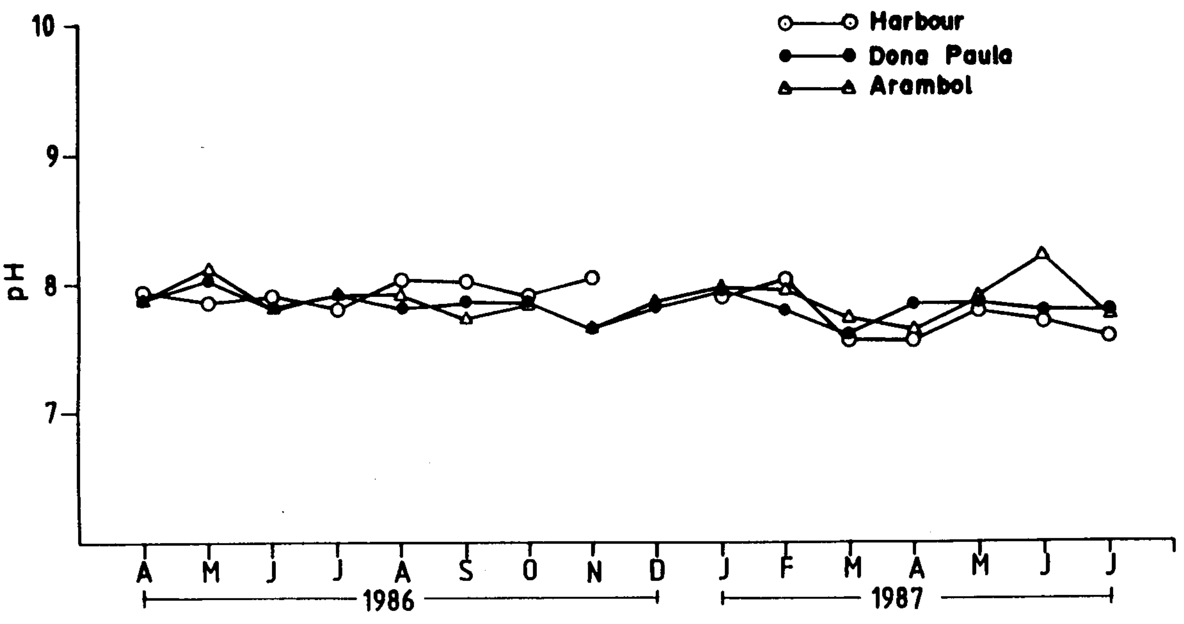

Fig. 5. Monthly variations of pH values at three study stations

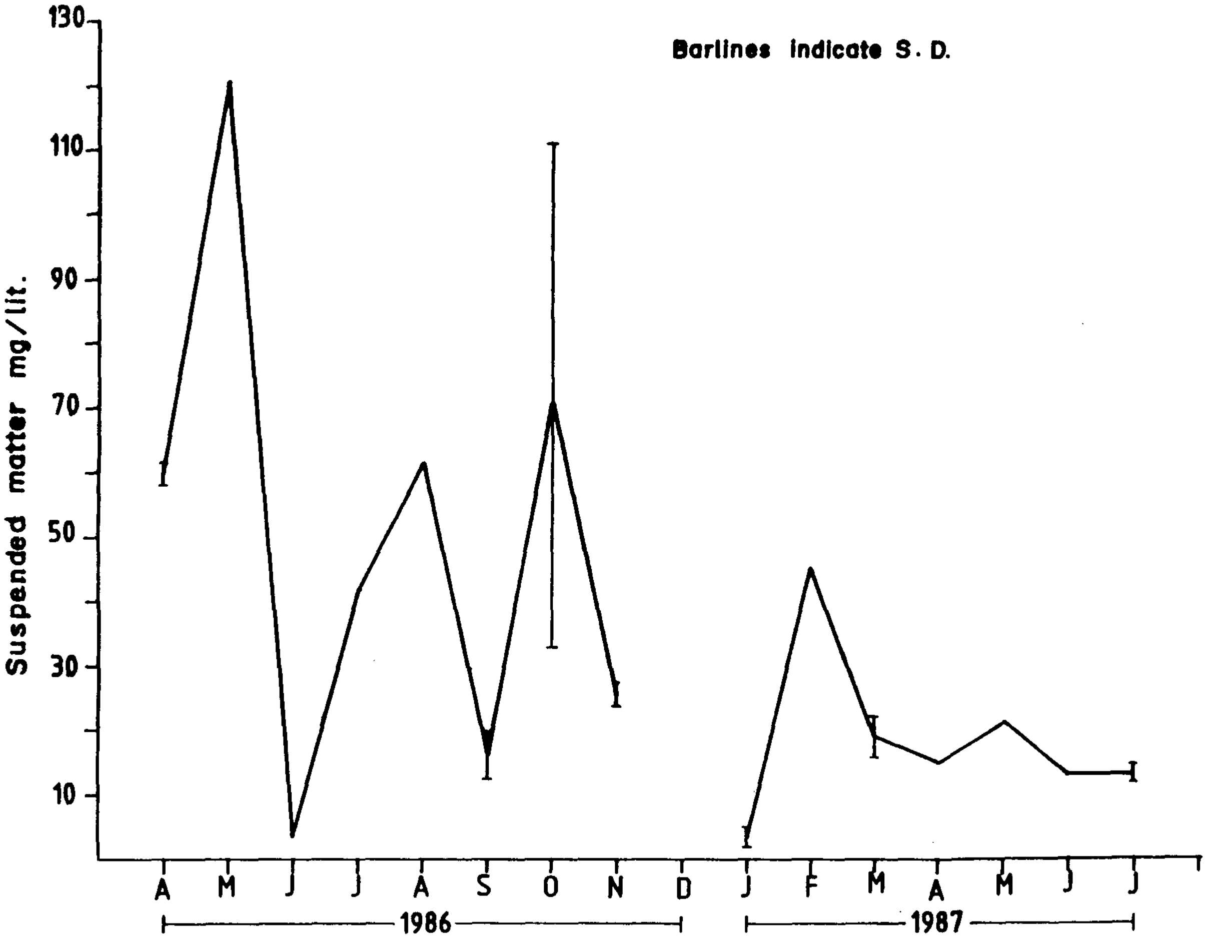

Fig. 6. Monthly variations of suspended matter concentration at Harbour.

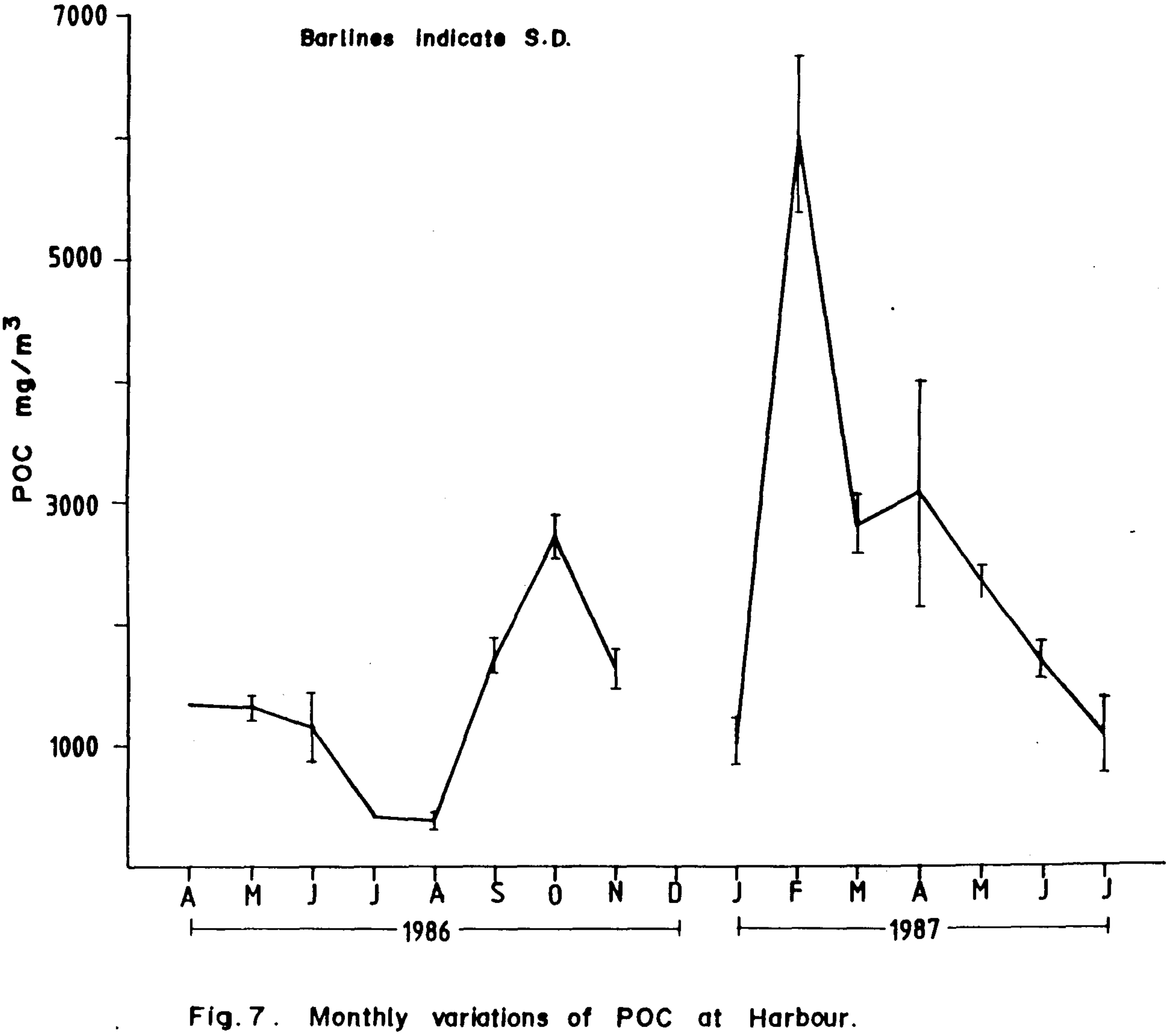

Fig. 7. Monthly variations of POC at Harbour.

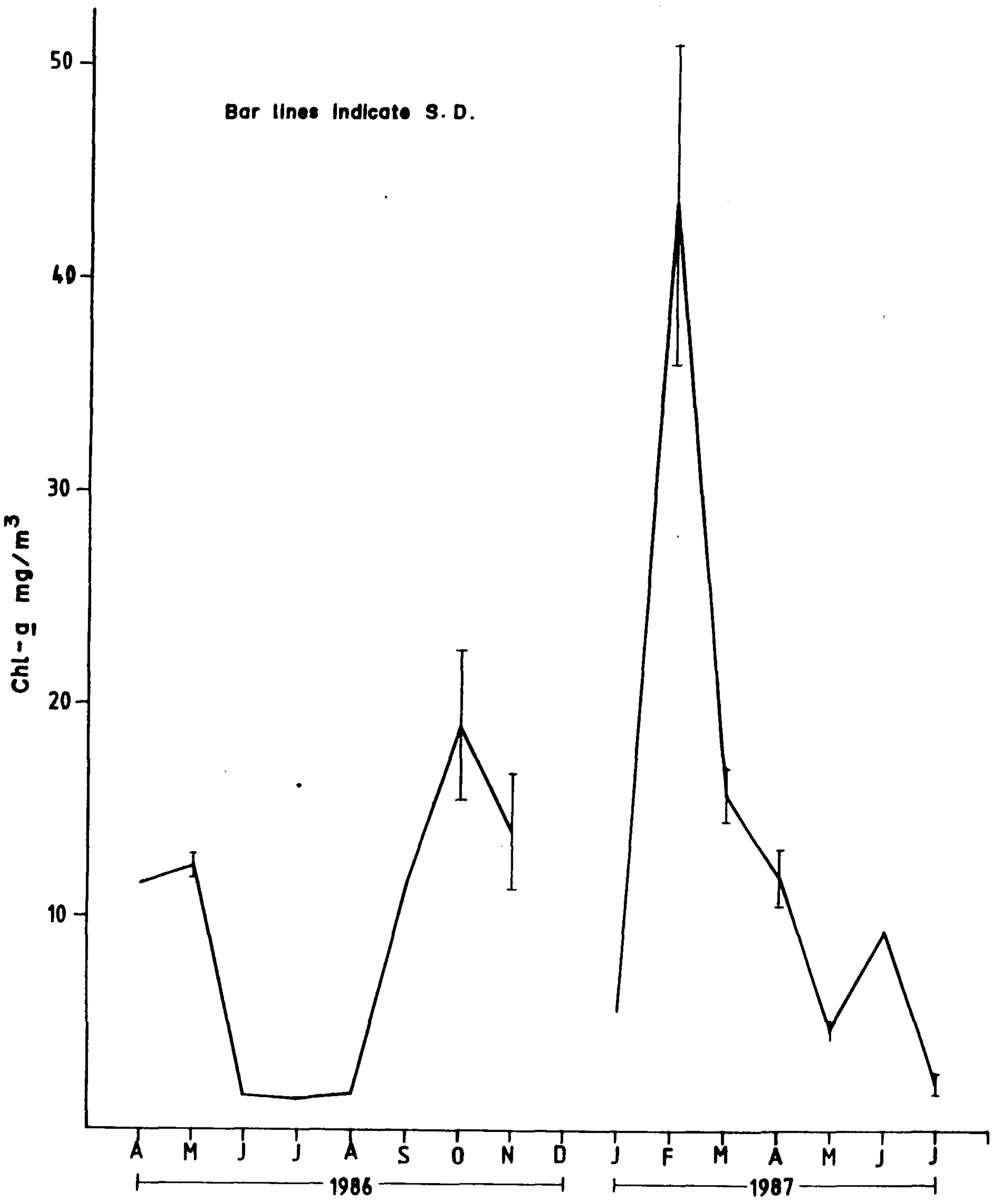

Fig. 8. Monthly variations of Chl-a concentration at Harbour.

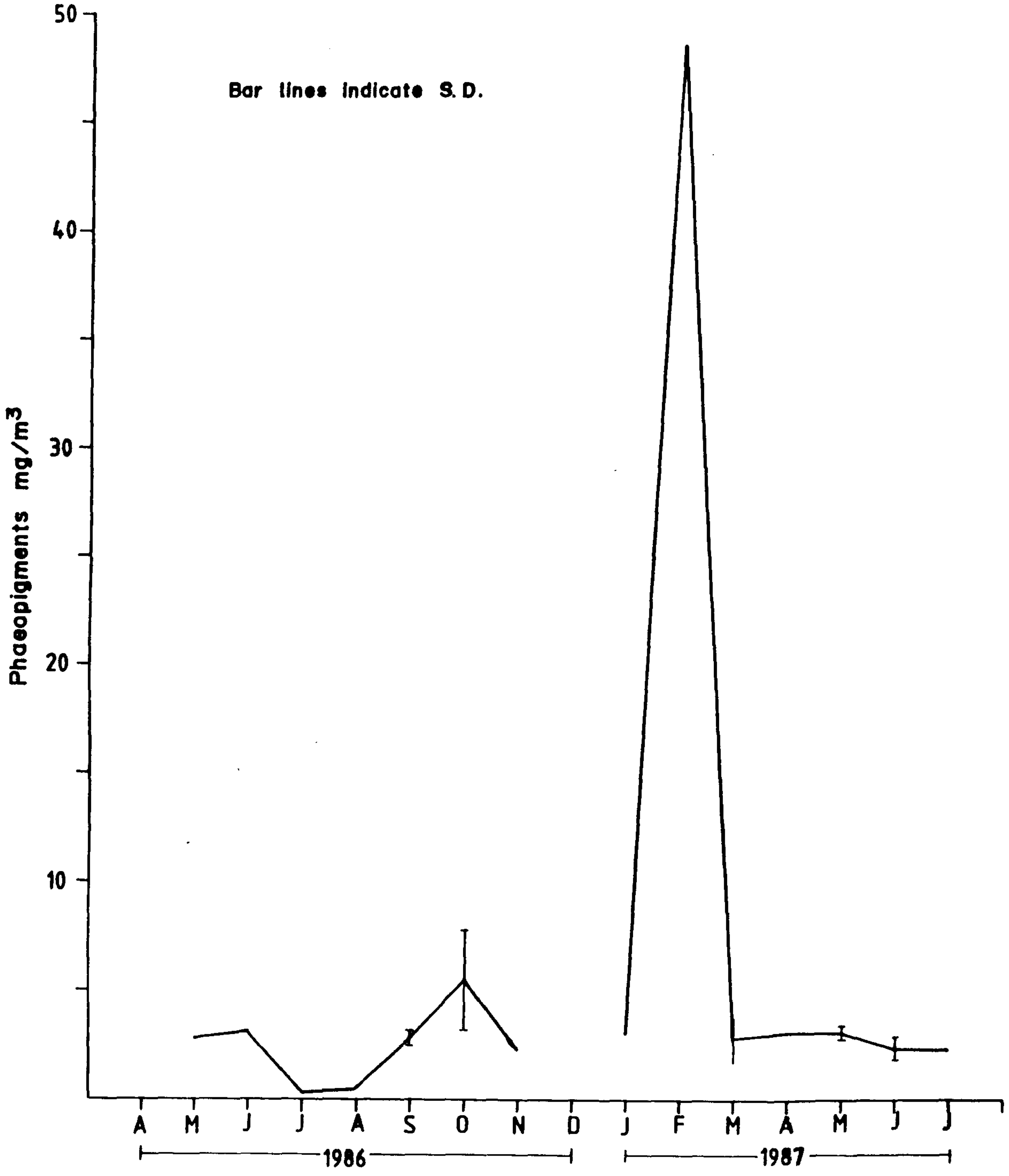

Fig.9. Monthly variations of Phaeopigment concentration at Harbour.

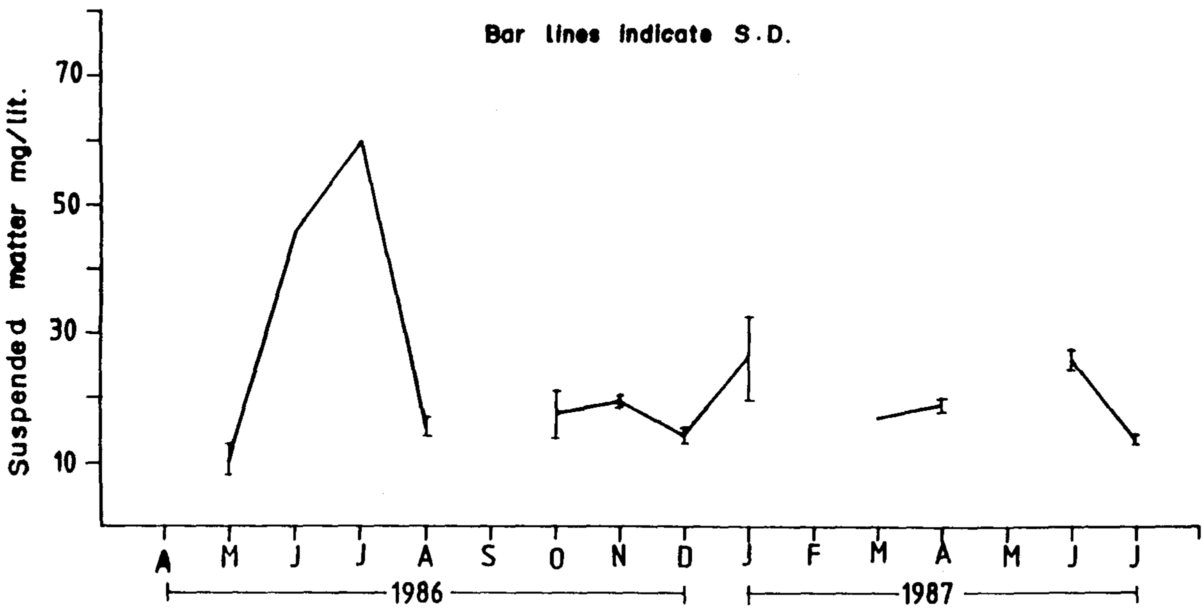

Fig. 10. Monthly variations of suspended matter concentration at Dona Paula.

Bar lines indicate S.D.

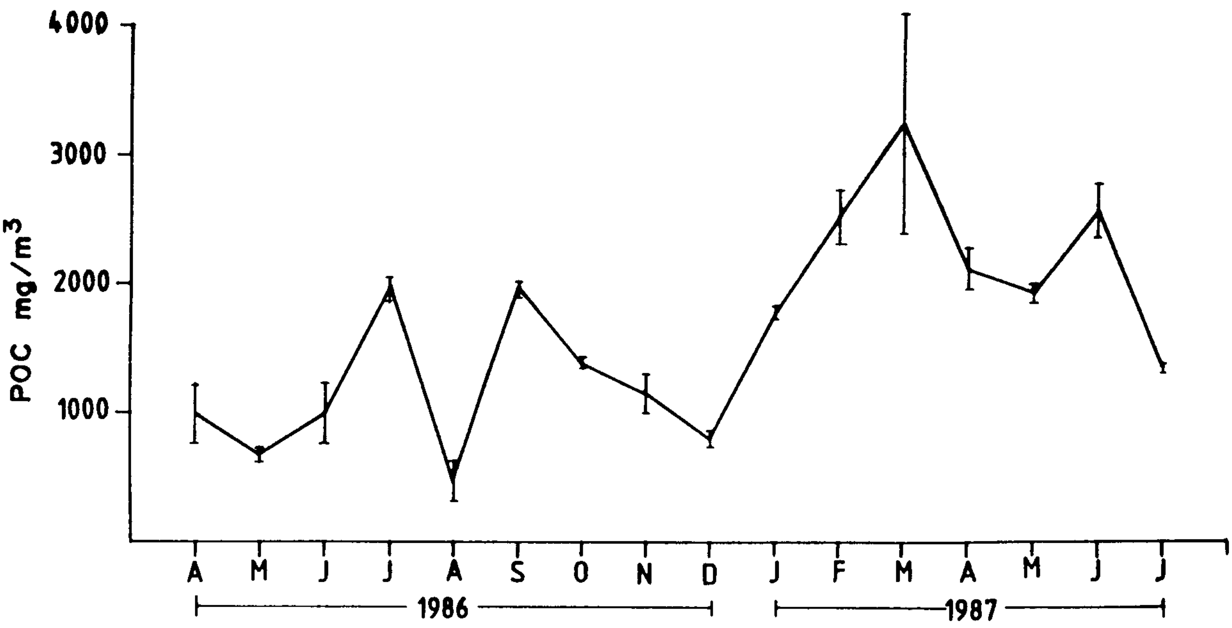

Fig. II. Monthly variations of POC concentration at Dona Paula.

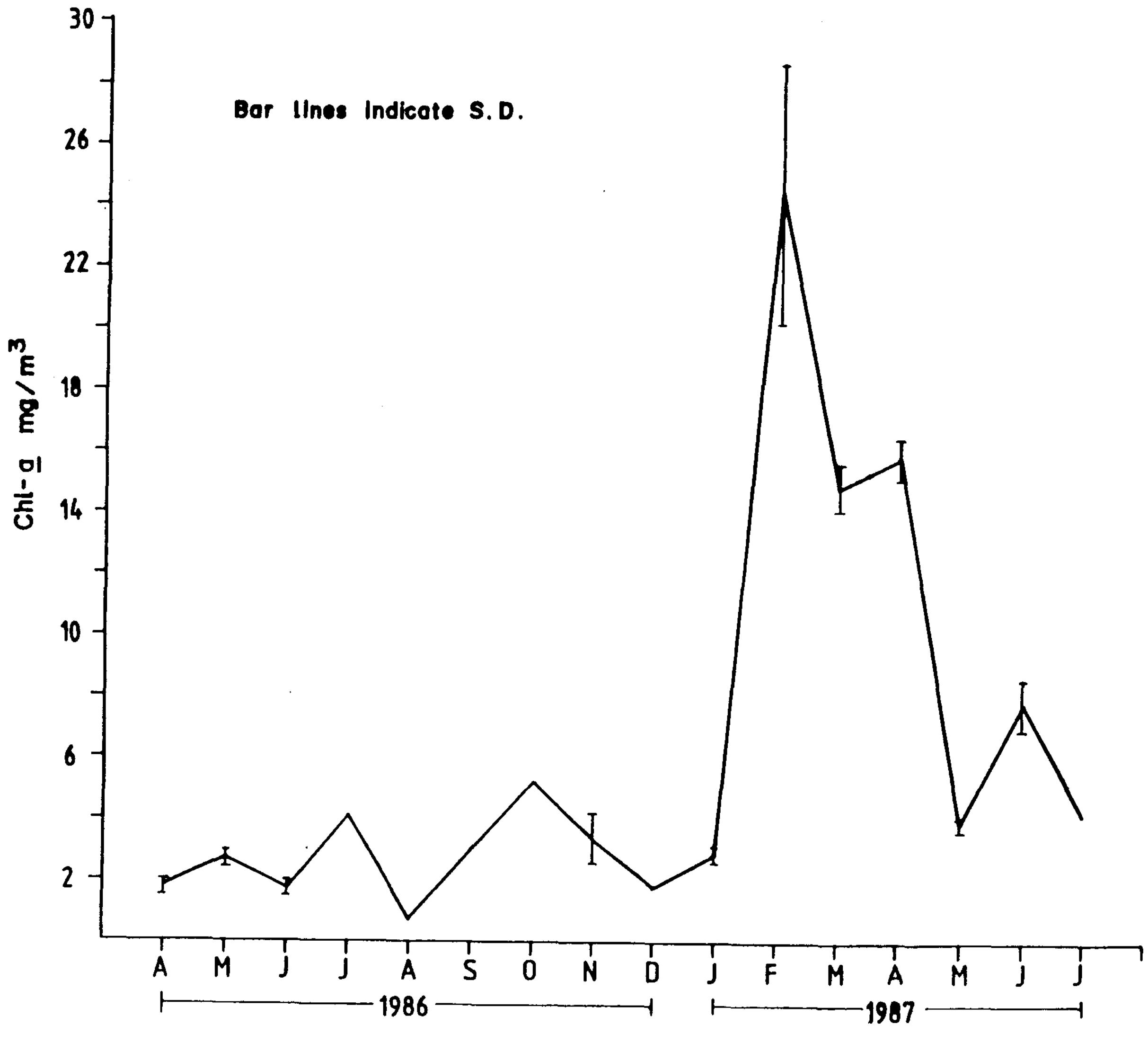

Fig. 12. Monthly variations of Chl-a concentration at Dona Paula.

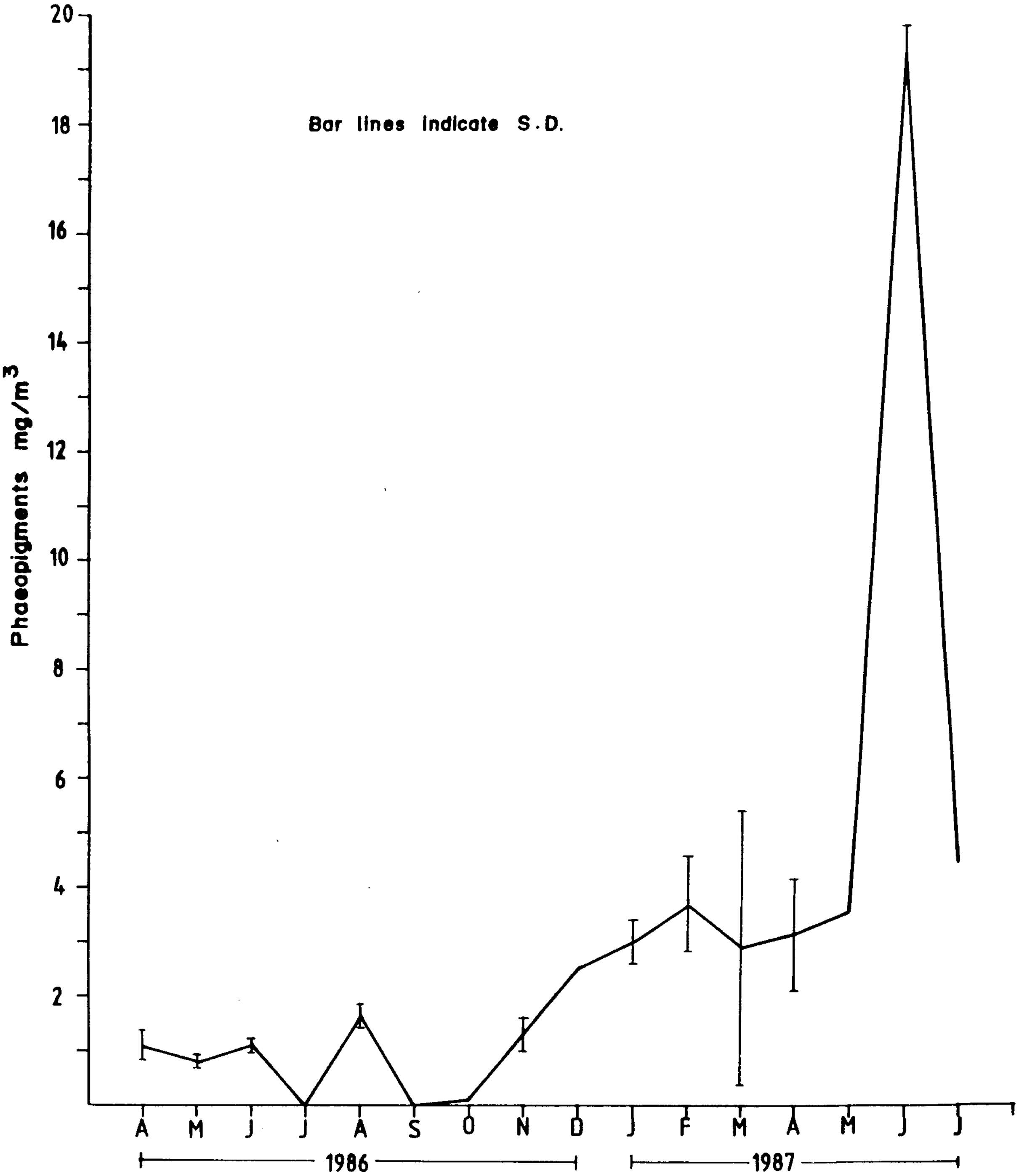

Fig. 13. Monthly variations of Phaeopigment concentration at Dona Paula.

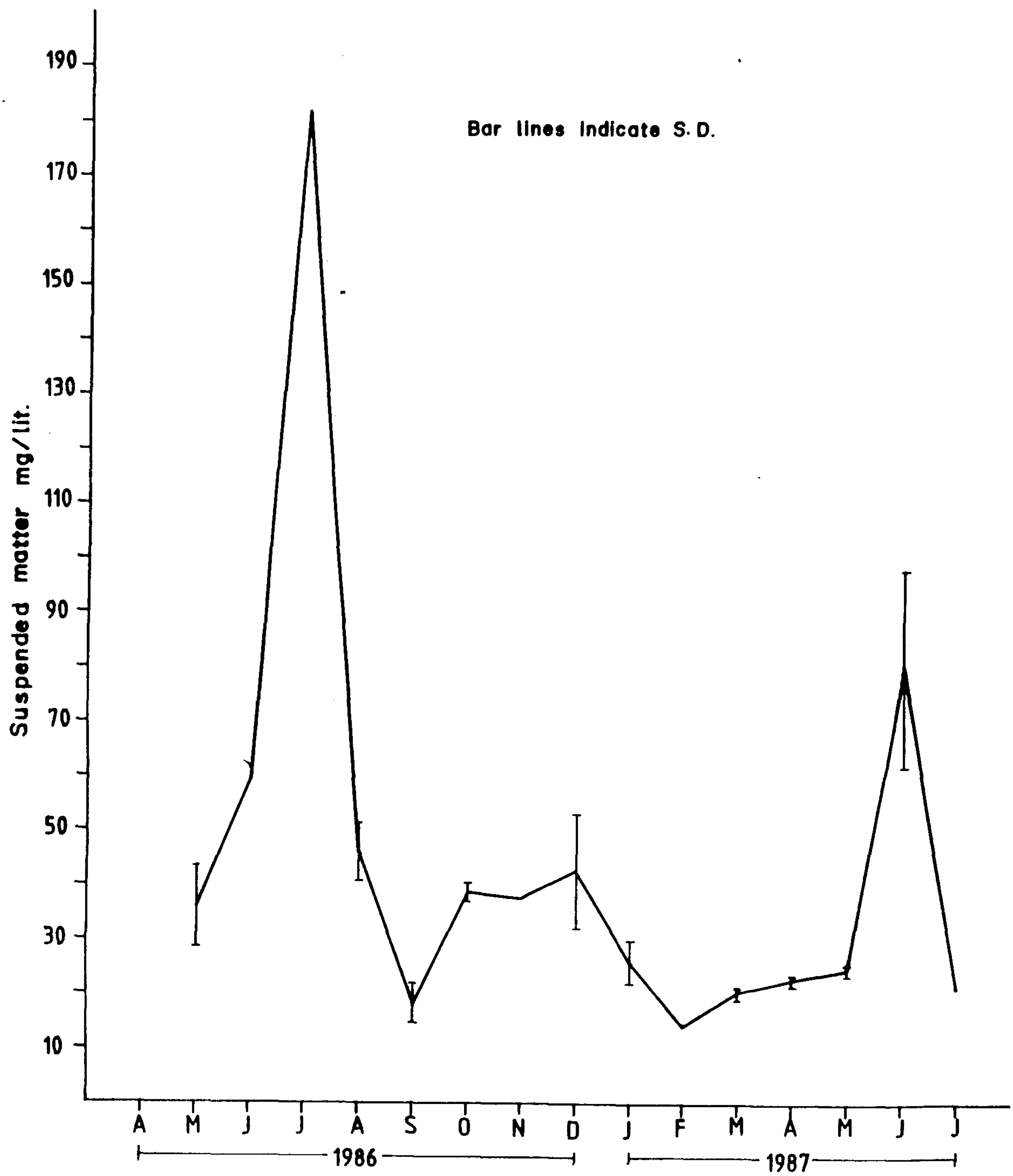

Fig. 14. Monthly variations of suspended matter concentration at Arambol.

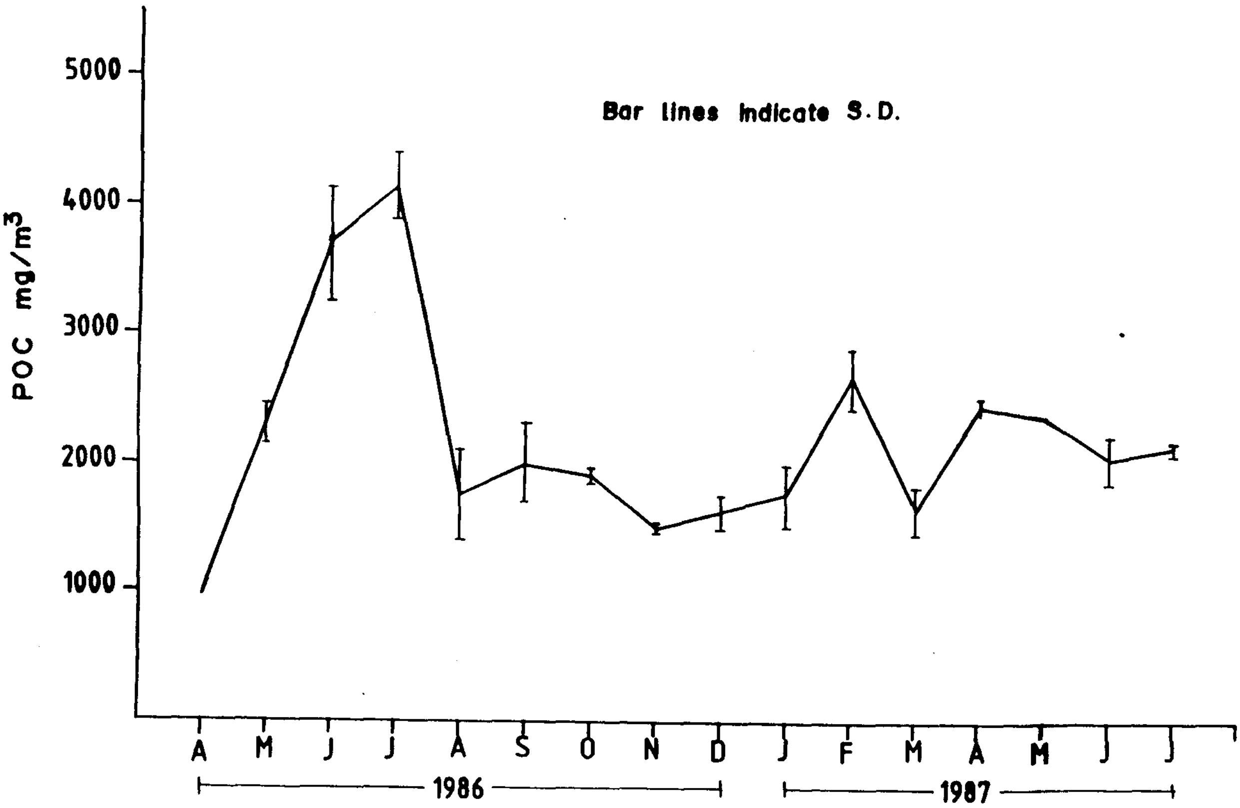

Fig. 15. Monthly variations of POC concentration at Arambol.

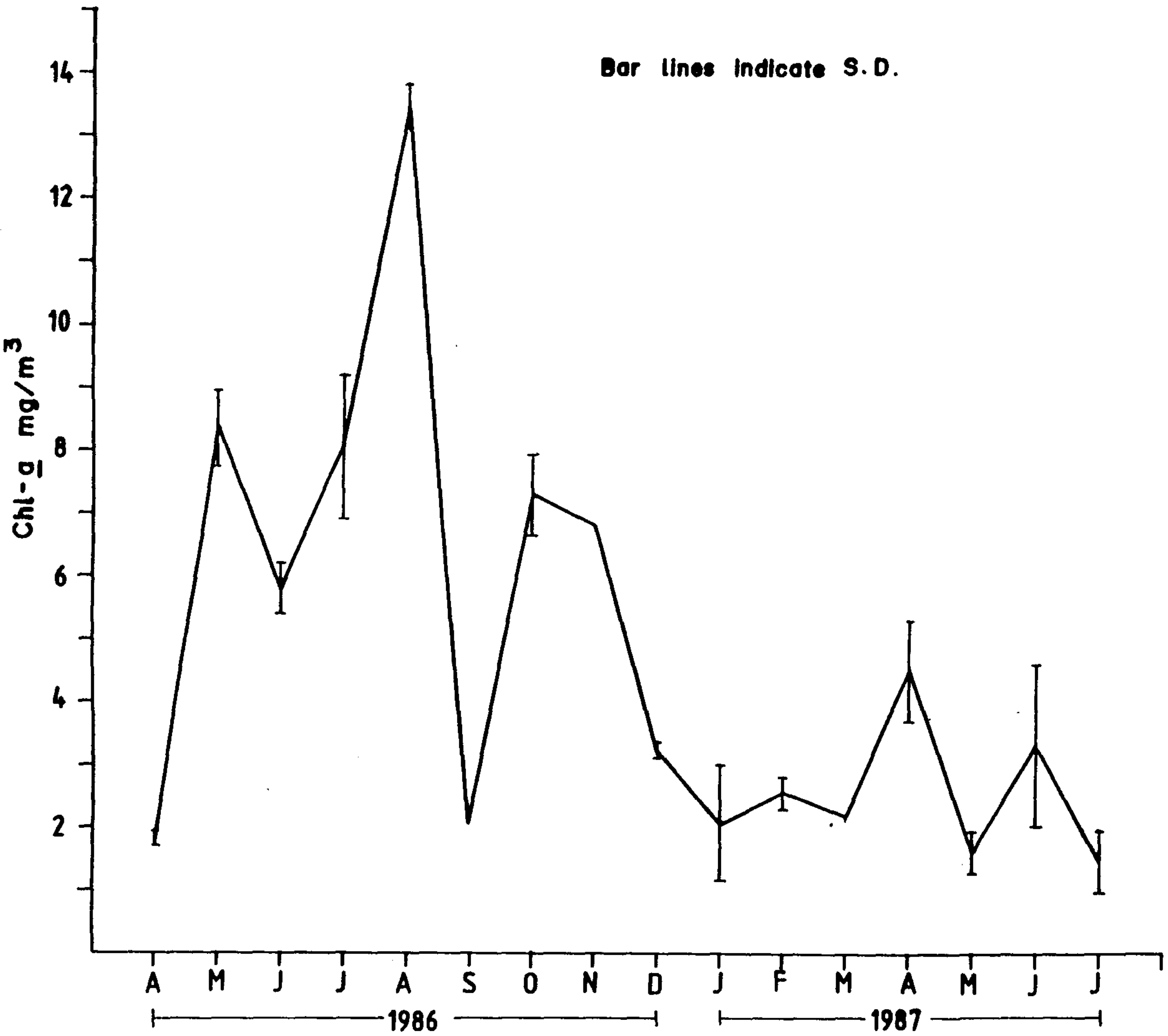

Fig. 16 Monthly variations of Chl-a concentratration at Arambol.

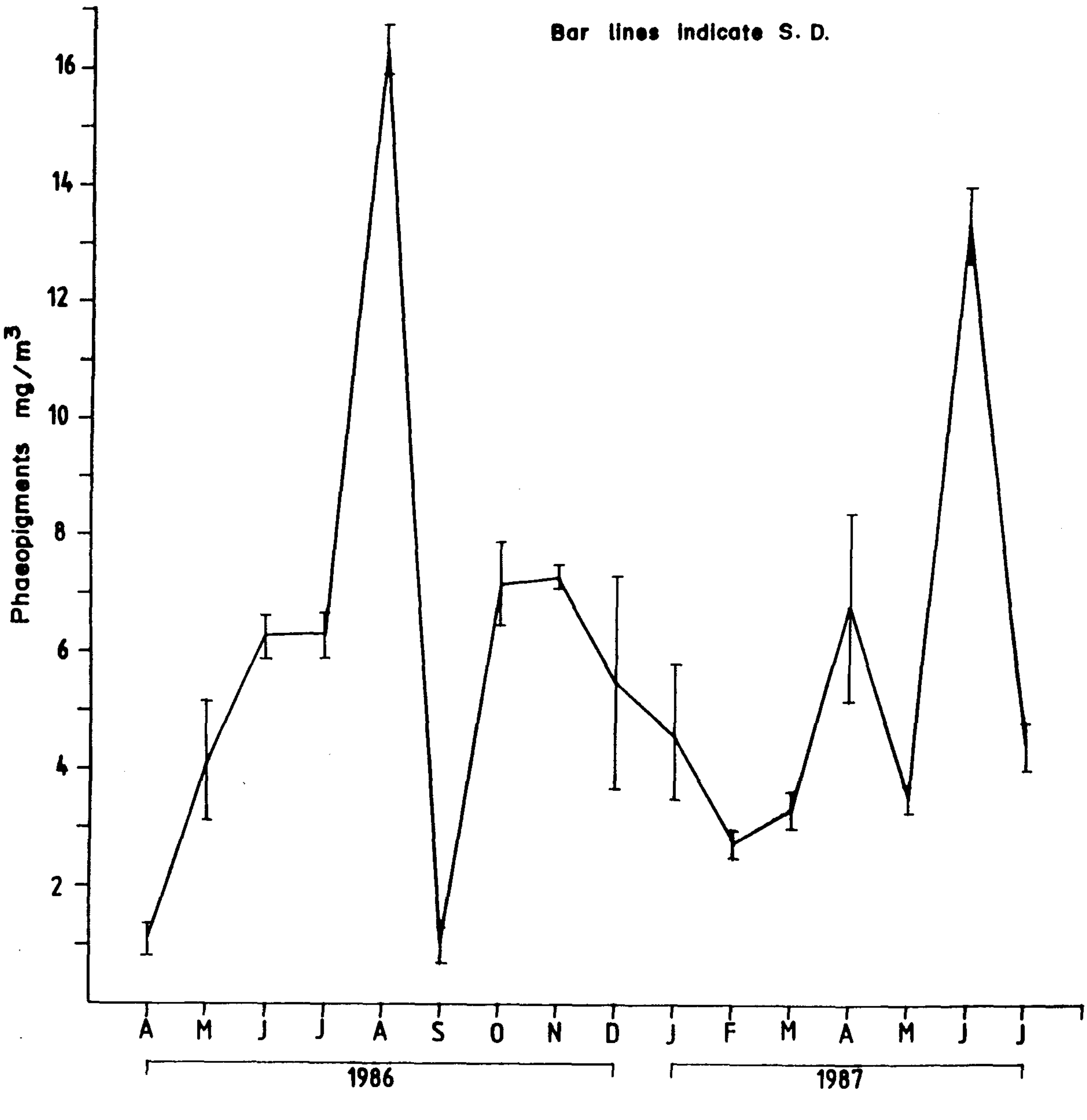

Fig. 17. Monthly variations of Phaeopigment concentration at Arambol.

CHAPTER Ⅳ

STUDIES ON CALORIFIC CONTENT

The calorific content of a substance is defined as the energy released during the complete combustion of 1 g of the dry material. The calorific content of a dry tissue homogenate is an important variable in the energy flow studies. It helps to calculate biomass, usually expressed as dry weight, to be converted into biomass expressed as energy (Crisp, 1984 a).

According to Crisp (1984 a), there are two different ways of estimating energy content. They are:-

1. Direct measurement by calorimetry
2. Chemical methods

In the former method, a known quantity of the dried and powdered sample is burnt and the heat of combustion is measured (See chapter - II). But, in the latter method, again two ways of measurement of calorific content are possible. One by estimating the oxidisable matter in the sample and by applying an oxicalorific coefficient to convert oxygen demand to calorie. Second, by estimating the concentration of biochemical compounds viz.

carbohydrate, protein, and lipid and converting them to calorific content by multiplying with appropriate conversion factors (Prosser & Brown, 1965). The presence of inorganic compounds in the sample may result in the endothermy during the calorimetric combustion resulting in the underestimation of calorific content (Paine, 1966). During the present study the Paar Adiabatic Bomb calorimeter model No. 1241 was used for the energy estimation.

The earlier workers have expressed the energy content and productivity results in calories. During the present study also the energy content was expressed in terms of calories. But, recently some workers expressed the calorific content as joules. The relationship of a calorie and joule is as follows.

$$1 \text{ g. cal. at } 15^{o}\text{C} = 4.185 \text{ joules}$$

However, in the present study the energy content is expressed as calories since it facilitates an easier comparison and discussion with the earlier reports. The presence of the different species of barnacles during the study at monthly interval is given in the Table No.9.

B. AMPHITRITE

The literature survey indicates that, studies on the distribution of calorific content of *B. amphitrite* have not been carried out so far from any part of the world. In the present observation calorific estimations were carried out in triplicate and the values reported are the mean of the triplicate combustion of each of the sample. The standard deviation of the triplicate analyses varied between ± 11.48 to 419.81 cal/g.d.wt.

HARBOUR

Distribution of calorific content:

The data of calorific content in *B. amphitrite* irrespective of size and maturity is given in Table 10 and Fig. 18. It showed the maximum value of 9,567.91 cal/g.d.wt. obtained in the month of August, 1986. The monthly distribution of calorific content showed a decrease in values during monsoon season. The lower values like 6242.66, 5647.35, 4064.78 and 5957.35 cal/g.d.wt. which were obtained during the months June and July of 1986 and 1987, showed the effect of south west monsoon. Unexpected lower values such as 5031.07 and 4777.61 cal/g.d.wt. obtained during the periods of January and

February, 1987 could be due to the overlapping seasonal effect of postmonsoon and premonsoon seasons. In the remaining months, the values were more or less the same 6500 cal/g.d.wt. The average calorific value of *B amphitrite* at this station was found to be 6354.27 cal/g.d.wt.

Calorific content distribution among different size groups:

The calorific values of barnacles belonging to different size groups based on RCB are given in Table 11 and Fig. 19. The maximum energy content was observed in the individuals of the size group RCB 10 - 20 mm. This was evident in 9 out of the 15 months of observation. The maximum value of calorific content (11401.93 cal/g.d.wt) was obtained in organisms belonging to the size group RCB 10-20 mm in the month of August, 1986.

The observations of calorific content of organisms belonging to the size group above 20 mm (RCB) were scanty due to the nonavailability of this size group during the study period. The available data regarding this group showed a maximum value of 7242.23 cal/g.d.wt in April, 1986. In this month the calorific content surpassed the value of barnacles belonging to the size group RCB 10 - 20 mm. The minimum value of 3825.07 cal/g.d.wt was obtained in February, 1987 and the average energy content of this group for the study period was 5743.04 cal/g.d.wt.

In the seasonal studies of the calorific distribution in the size group 10 - 20 mm, a decreasing tendency was observed during some months of the monsoon season. Nevertheless, a definite change in calorific values with season was not observed in the data. The lowest value in this size group was recorded during the month of June, 1987 (4491.38 cal/g.d.wt). On the contrary, a hike in calorific content was recorded in July, 1987. The average energy content of this group during the study period was 6726.56 cal/g.d.wt.

The calorific content in the size group RCB 5 - 10 mm showed the second highest value among the 4 groups studied. In this group the highest value was obtained in the month of August, 1986 (7734.52 cal/g.d.wt) and the minimum in the month of January, 1987 (4142.72 cal/g.d.wt). The seasonal trend of the calorific distribution was not seen in this group. The average energy content of this size group during the study was found to be 6305.23 cal/g.d.wt.

The lowest size group (RCB below 5 mm), which was obtained for 5 months during the entire period of study, showed a lowest value of 1626.91 cal/g.d.wt in June, 1987 and a highest value of 5546.56 cal/g.d.wt. in March, 1987. Due to the nonavailability of organisms belonging to this group in sufficient quantity, monthly trend could not be found out.

The average energy content of different size groups of B. amphitrite have shown an increase in energy content with the size increased upto RCB 10 - 20 mm and thereafter it decreased.

Calorific content based on the maturity of gonad:

The mature and immature barnacles were separated according to the state of gonadial development (Karande, 1967) and the calorific content of the entire mass of the soft tissues was measured as explained in the Chapt. II. The distribution of the energy content in the mature and immature groups of barnacles is shown in the Table 12, Fig. 20. Both mature and immature individuals were present in adequate numbers during 12 months out of the 16 months of observation. During the study period the mature forms were found to have more energy content than the immature forms. The mature forms showed more energy content than the immature forms in majority of the observations. But the immature forms dominated in energy content during the months of April, 1986, January & July, 1987. The maximum value for the mature group was obtained in April, 1987 (8696.90 cal/g.d.wt.) and that of immature group in the month of January, 1987 the value being 8379.54 cal/g.d.wt. In both groups, the seasonal changes were negligible, except a slightly lower value during the monsoon months among immature forms.

<u>Calorific content of Eggs and Larvae</u>:

In order to find out the calorific content of eggs and larvae of barnacles, the organisms were dissected out and the eggs of two different developmental stages (immature egg mass and mature eggs) and nauplii larvae respectively were removed and pooled separately. These samples were estimated for the energy content.

<u>Immature egg mass</u>:

At the Harbour station, the immature egg mass of <u>B. amphitrite</u> could be collected in sufficient quantity only for 6 months during the entire period of study. In the remaining study period, this particular state of development of ovary could be observed rarely. The calorific content of the immature egg mass varied from 5253.30 to 9107.28 cal/g.d.wt. in the months of April, 1986 and June, 1987 respectively (Table 13, Fig. 21). In all the remaining months, the values varied around 5400 cal/g.d.wt. The average value for the immature egg mass during the study at this station was found to be 6595.93 cal/g.d.wt.

Mature eggs:

During the entire period of study the mature eggs of *B. amphitrite* could be collected in sufficient quantity for a period of seven months. The calorific content varied from 4247.08 to 9971.61 cal/g.d.wt. during the months of November, 1986 and April, 1987 respectively. An unusually increasing trend in calorific content was observed towards the end of the study period. Similar pattern was observed in immature egg mass and nauplii also (Table 13, Fig. 21). The average calorific content of the mature eggs during the period of study was found to be 6868.45 cal/g.d.wt. which was 3.97 % greater than that of immature egg mass.

Nauplii:

At the Harbour station, the nauplii of *B. amphitrite* could be collected in the required quantity only for 4 months (Table 13, Fig. 21) during the entire study period. The energy content varied from 7342.16 to 8594.33 cal/g.d.wt. during the months of May & July, 1987 respectively. The average energy content during the study was found to be 8385.39 cal/g.d.wt. This was 21.34% greater than that of immature egg mass and 18.09 % greater than that of mature eggs.

The energy content of individual egg and larvae were also calculated from the above calorific value by counting the number of eggs and larvae analysed at each time. The energy content of an individual egg (mature) varied between 0.003 cal/egg to 0.0053 cal/egg during the months of May, 1987 & March and June, 1987 respectively. In the case of nauplii it varied from 0.0028 cal/nauplius to 0.0068 cal/ nauplius in May & June, 1987 respectively (Table 14, Fig. 23).

Dona Paula:

The energy content of B. amphitrite at this station showed a maximum value of 8480.65 cal/g.d.wt. in August, 1986 and the minimum value of 3405.74 cal/g.d.wt. in February, 1987. The mean value for the entire study period was found to be 5801.80 cal/g.d.wt. The distribution of calorific content had shown the impact of monsoon (Table 10, Fig. 18). As observed at Harbour station, at Dona Paula also the increase in calorific content was evident during the end of monsoon 1986 and the beginning of postmonsoon season 1986. But it could be seen that the values generally were less during the monsoon season, 1987.

Energy content in different size groups:

The data collected on 3 size groups (RCB below 5 mm, 5 - 10 mm and 10 - 20 mm) has shown similarity with the distribution of calorific content at the Harbour station. At this station also, the size group 10 - 20 mm, indicated more calorific content than the lower size groups (Table 15). The average calorific content was found to be 6160.59 cal/g.d.wt., 5895.46 cal/g.d.wt. and 4893.63 cal/g.d.wt. in the size groups 10 - 20 mm, 5 - 10 mm and below 5 mm (RCB) respectively. The distribution of calorific content in these groups has shown a distinct seasonal trend. Both the monsoon seasons recorded a decreased calorific value (Table 15, Fig. 25). However a similar trend could also be seen during the overlapping period of postmonsoon and premonsoon 1987.

Calorific content based on the maturity of gonad:

As observed at Harbour, the mature forms at this station exhibited more calories than the immature individuals. The average energy content of mature forms was 5558.28 cal/g.d.wt. and that of immature was 5447.21 cal/g.d.wt. The monthly distribution pattern showed a decreasing trend in energy contents during the monsoon season of 1986 and 1987. In both immature and mature forms, lowest value of energy content was observed in February, 1987. The values were 3194.43 and 3662.09 cal/g.d.wt. in mature and immature forms respectively (Table 16, Fig. 26).

CALORIFIC CONTENT OF EGGS AND LARVAE (Table 13, Fig. 22)

Immature egg mass:

The calorific content values in the immature egg mass were observed to be maximum in June, 1987 (7096.23 cal/g.d.wt.) and minimum in March, 1987 (4954.28 cal/g.d.wt.). The average energy content of the immature egg mass for the entire period was 5837.23 cal/g.d.wt.

Mature eggs:

The values of calorific content of mature eggs varied from 2364.50 cal/g.d.wt in December, 1986 to 8739.38 cal/g.d.wt. in March, 1987. The observation regarding calorific content in mature eggs is not in agreement with that of the adult organisms where a low energy content was recorded during the monsoon season. The data regarding the calorific content exhibited wide fluctuations during the period of study and the average value for the entire study period was 6861.48 cal/g.d.wt. This was 15.30 % greater than that of the immature egg mass of the same species.

Nauplii:

The data on the calorific content of nauplii could be collected only for few months due to the nonavailability of material in required quantity in all the months during the study period. From the available data, it is evident that the energy content varied from 6344.91 to 8790.00 cal/g.d.wt. in the month of May & July, 1987 respectively. The average energy content of nauplii during the period of study was 7804.20 cal/g.d.wt. This value showed an increase of 25.20 % over the immature egg mass and 11.70 % over the mature eggs.

The calorific content of individual mature egg showed a maximum value of 0.0072 cal/egg and minimum 0.0021 cal/egg in October, 1986 and July 1987 respectively. Calorific content of the nauplius showed a range of 0.0023 to 0.0059 cal/nauplius during the months of May & July, 1987 respectively. (Table 14, Fig. 24).

Some general aspects of energy distribution among *B. amphitrite* at the Harbour and Dona Paula stations:

In order to find out the relationship of the calorific content distribution at these stations, a statistical analysis (Regression alnaysis) has been carried out with the calorific contents. A significant correlation coefficient has been obtained for the above analysis, r = 0.723 (p = > 0.001) suggesting that the distribution pattern is closely related.

HARBOUR

***B. amaryllis*:**

B. amaryllis species was found during 9 months at the Harbour station. They were grouped into three size groups on the basis of rostro-carinal basal diameter. These groups were RCB 20 - 30 mm, 15 - 20 mm and 10 - 15 mm. Grouping based on the gonadial development was not done because of the availability of few number of organisms. Lower values of energy contents were recorded during the monsoon period, 1986. But the same trend was not obtained during the next monsoon, ie. in 1987. The energy content varied between 4970.21 cal/g.d.wt. to 8329.02 cal/g.d.wt. in June 1987 and July 1987 respectively. The second highest value i.e. 7902.88 cal/g.d.wt. was obtained in the month of November, 1986 (Table 17, Fig. 27). The mean calorific content of this species during the entire study period was 6252.46 cal/g.d.wt.

Among the three size groups analysed, the maximum energy content was recorded in the size group 15 - 20 mm (RCB) with an average value of 6612.75 cal/g.d.wt. followed by the size group 10 - 15 mm with 6459.93 cal/g.d.wt. and lowest value was recorded in the size group 20 - 30 mm with 6028.03 cal/g.d.wt. The calorific content varied between 4151.51 to 7336.53 cal/g.d.wt. in the group 20 - 30 mm, 4619.84 to 9287.92 cal/g.d.wt. in size group 15 - 20 mm and it varied between 4970.21 to 8329.02 cal/g.d.wt. in the size group 10 - 15 mm (Table 18, Fig. 28).

CHTHAMALUS SP.

Dona Paula:

The specimens of Chthamalus sp. were also collected along with B. amphitrite from the Dona Paula station during the study. They were also analysed for estimating energy content using adiabatic calorimeter. Samples were pooled irrespective of size or maturity except in January and March, 1987 where they could be separated into two size groups such as 5 - 15 mm and below 5 mm (RCB).

During the entire period of study, the calorific value of Chthamalus sp. ranged between 2828.63 to 7708.74 cal/g.d.wt. These values were recorded in the months of December, 1986 and September 1986 respectively. The average calorific value during the entire period of study was found to be 5215.26 cal/g.d.wt. In the monthly distribution, seasonal trend was observed as in the case of B amphitrite and B amaryllis. During the 1986 monsoon period, reduced values were observed in comparison to premonsoon and postmonsoon seasons (Table 19, Fig. 29). But in the latter period of postmonsoon the values recorded indicated lowest energy content during the study.

Among the two size groups studied (RCB below 5 mm and

5 – 15 mm) lesser energy content was recorded in the smaller size group of organisms the value being 4144.76 cal/g.d.wt. (mean value) while the average energy content of the larger size group was 5215.26 cal/g.d.wt. (Table 20).

<u>Arambol</u>:

<u>Chthamalus</u> sp. collected every month from the Arambol rocky shore were also analysed for the energy content. The organisms were grouped into two groups depending on the size of basal diameter along the Rostro Carinal axis. They were below 5 mm and 5 – 15 mm RCB. This data could be collected for a period of five months when both the groups were present in adequate numbers. During the study the average energy content of <u>Chthamalus</u> sp. varied from 1961.52 cal/g.d.wt. to 6952.57 cal/g.d.wt. in June 1986 and September, 1986 respectively. The mean energy content of this species for the entire study period was found to be 4297.40 cal/g.d.wt (Table 21, Fig. 30).

In the size group analysis, the smaller size group organisms recorded lower energy content (mean 4210.47 cal/g.d.wt.) than the larger size group (4470.06 cal/g.d.wt., Table 22, Fig. 31). In the larger size group the energy content varied from 2178.69 cal/g.d.wt. to 7583.87 cal/g.d.wt. and in smaller size group it varied between 1744.35 cal/g.d.wt. and 5321.27 cal/g.d.wt. (Table 22).

Some observations on the calorific values of *Chthamalus* sp.

Chthamalus sp. from both the stations showed a similar pattern of calorific values. In case of both the stations, the onset of monsoon appeared to have some effect on the energy content. However this effect was more evident at Arambol than at Dona Paula. In other observations, where sizes have been the criterion, the smaller individuals of *Chthamalus* sp. recorded lesser energy content as compared to the larger forms.

***B. TINTINNABULUM*:**

From the rich settlement of *B. tintinnabulum* on the rocky shore of Arambol (approximately one year old), 25 - 30 organisms of varying sizes were removed every month and were analysed after bringing them to laboratory. The organisms were grouped into four according to their sizes (RCB) as, below 20 mm, 20 - 30 mm, 30 - 40 mm and above 40 mm. The results are presented under the following headings such as:

i) Calorific content of *B. tintinnabulum* (whole organism);

ii) Energy distribution with respect to sizes;

iii) Energy distribution in different tissues with respect to different size groups.

Calorific content of *B. tintinnabulum*:

The calorific content of *B. tintinnabulum* showed a variation of calories from 4354.24 cal/g.d.wt. to 7294.24 cal/g.d.wt. during the months of August, 1986 and October, 1986 respectively. Comparatively lower energy content was recorded during the monsoon 1986 (Table 23, Fig. 32). It attained the peak value in the postmonsoon season. The same could not be observed during the next monsoon season (1987). In short, no definite trend in distribution of energy content with seasons could be observed in the monthly data. The average energy content of *B. tintinnabulum* during the whole period of study was 5357.23 cal/g.d.wt.

Energy distribution with respect to sizes (Table 24, Fig. 33):

The maximum energy content was associated with the largest size group i.e. RCB above 40 mm. In this group, the calorific content ranged between 4571.99 cal/g.d.wt. to 7756.72 cal/g.d.wt. in the months of May, 1986 and October, 1986 respectively. The monthly values showed a more or less similar concentration of energy in most of the months except during the monsoon months of 1986. In general, during postmonsoon period more calorific content was observed than the other two seasons. The average energy content in this group was 5606.51 cal/g.d.wt., which is the maximum value among the size groups studied.

The distribution of energy in the second size group i.e. RCB between 30 - 40 mm showed a maximum value of 6611.13 cal/g.d.wt. in October, 1986 and a minimum value of 3681.98 cal/g.d.wt. in January, 1987. Here also during the monsoon, 1986 a lowered value of energy content was registered. The average calorific value for this group was 5211.61 cal/g.d.wt.

In the group RCB 20 - 30 mm, the maximum value recorded was in the month of October, 1986 and the minimum in August 1986 (7514.86 and 3373.11 cal/g.d.wt. respectively). In this group clearer picture of seasonal effect could be seen. The average value (5241.87 cal/g.d.wt.) of this group is slightly higher than that of

30 - 40 mm group and lower than that of 20 mm group.

Observations for the fourth group (RCB < 20 mm) covered a period of four months. The values obtained were less than the average values for other groups except for December, 1986 when the calorific content of this group was found to be 7896.34 cal/g.d.wt. As a result of this single high value the average value of this group amounted to 5453.59 cal/g.d.wt. which was slightly higher than the value of the above size groups (20 - 30 mm and 30 - 40 mm).

Energy content of different tissues with respect to different size groups:

The four groups of barnacles (according to size) were dissected and the tissues such as body tissue, intestine and cirri were separated. They were dried, powdered and calorific contents were measured (Table 25, Fig. 34).

Here, the body tissues include the complex muscle systems of barnacle excluding the cirri and intestine. The gonadial tissue was also included under the category of body tissue.

The calorific content values of body tissue were found to be more or less uniform thus showing hardly any seasonal change. The lowest value of 4863.25 cal/g.d.wt. was obtained in April, 1986 and the highest value of 8204.68 cal/g.d.wt. was recorded in October, 1986. Except for this particular high value, the rest of the period did not show any distinct fluctuation. The average calorific content of body tissue during the entire study amounted to 5959.63 cal/g.d.wt. (Table 25, Fig. 34). The values of calorific contents of these soft parts with respect to different size groups hardly displayed any seasonal pattern as seen from the monthly distribution data (Tables 26 - 29, Figs. 35 - 38). In spite of this least variability the average values of calorific content of different size groups showed an increase with the size. In the lowest size group (RCB below 20 mm), the average calorific content of body tissue was 5243.78, in the next group (RCB 20 - 30 mm) it was 5934.50 cal/g.d.wt., in RCB 30 - 40 mm it was 5988.13 cal/g.d.wt. and in the largest size group i.e. RCB above 40 mm it was 6256.38 cal/g.d.wt.

In the calorific studies of barnacles, so far as the energy rich organs are concerned, one of the important organ is the intestine, because this is the organ primarily responsible for the digestion and absorption of food material for the organisms. The intestine extends right from the buccal cavity to the anal opening. Here, food belonging to different stages of digestion could be seen. So, in order to have a clear idea about the energy content of the intestine excluding the food materials engulfed, intestines were dissected out separately and the calorific content was measured.

The values of calorifc content of the intestinal tissue ranged between 3214.94 cal/g.d.wt. to 6723.23 cal/g.d.wt. These values were recorded in the months of November, 1986 and October, 1986 respectively. The monthly distribution showed a decreased value during the monsoon season 1986 and a more or less uniform value for the rest of the period. The average calorific value of the intestinal tissue during the period of study was observed to be 4783.25 cal/g.d.wt. which was slightly lesser than the average value for the body tissue (Table 25, Fig. 34). The distribution of calorific content of intestinal tissue in the various size groups showed a decreased trend of values during the monsoon season 1986 in all the groups and reduced value in the monsoon months of 1987 in one size group i.e. RCB 20 - 30 mm. The other two size groups showed a more or less similar concentration during this season. The high value of energy content of intestinal tissue during the month of October, 1986 was found in all size groups analysed. Similarly the lowest values were recorded in all the groups during November, 1986.

Cirri are the respiratory and filtering organs of barnacle. They can withdraw cirri completely inside the shell by closing the aperture with the side valves and here the deposition of fats and other biochemical compounds is expected to be minimum. However inorder to have complete picture of the organism as a whole, estimations of calorific values of these parts were also carried out.

The average energy content of cirri of *B. tintinnabulum* was found to be 4541.85 cal/g.d.wt. The data collected showed the maximum value of cirri in the month of October, 1986 (6644.06 cal/g.d.wt.) and minimum in the month of May, 1986 (2688.72 cal/g.d.wt.). The monthly distribution showed effects of the monsoon, 1986 and partially 1987 (Table 25, Fig. 34). Variations in calorific content of cirri in different size groups of barnacle studied have also showed an effect of monsoon. This was well represented in the size group RCB 20 - 30 mm (Tables 26 - 29).

Calorific content of Zooplankton:

The estimations of calorific content of the mixed zooplankton samples have shown the variations of values from 1832.17 cal/g.d.wt. to 10893.05 cal/g.d.wt. These values were observed in the months of June, 1986 and February, 1987 respectively. The monthly distribution showed a clear effect of fresh water influx and turbidity caused by the monsoon (Table 30, Fig. 39). The high value recorded in the postmonsoon, 1986 and premonsoon 1987 was mainly due to the phytoplankton bloom (Noctiluca sp.) which occurred at that time in this locality. The average energy content of mixed zooplnakton sample for the entire period of study was 5480.88cal/g.d.wt.

ENERGY CONTENT OF SUSPENDED MATTER:

This study is important since it helps to assess the energy available in the form of suspended matter for the filter feeding organisms such as barnacles in the environment. Suspended matter include all the objects floating in the water column like, organic and inorganic materials including silt, clay, waste particles, dead parts of phytoplankton and zooplankton, living phytoplankton and zooplankton, faecal materials of all the marine organisms, bacteria etc. These particles constitute a major energy rich material which will be in the process of decay by the bacterial forms. This forms a major part of the energy content of the aquatic environment, which is important in the maintenance of the food chain.

<u>Harbour</u>:

Calorific content of suspended matter at Harbour station showed wide fluctuations ranging from 1514.83 cal/g.d.wt. to 7790.17 cal/g.d.wt. in the month of Jan.1987, May, 1987 respectively. In contrast to the earlier observations of calorific content of soft parts of barnacles, the particulate matter showed an increased energy content during the monsoon season (Table 31, Fig. 40). However, the maximum values recorded were in the months of January and February, 1987. This clearly revealed the influence of phytoplankton bloom which occurred in the estuary during that period. The average calorific content was 4306.43 cal/g.d.wt., which was a lower value than that of the average calorific value of zooplankton and barnacles.

<u>Dona Paula</u>:

Estimation of calorific content in the suspended matter at the Dona Paula waters showed a variation from 1135.89 cal/g.d.wt. to 5099.96 cal/g.d.wt. in the months of October, 1986 and December, 1986 respectively. The distribution of calorific content showed a more or less similar pattern as that of Harbour station with slightly increased values during the monsoon months (Table 31, Fig. 40). The effect of phytoplankton bloom was evident with an increased value of calorific content in the months December, 1986 to February, 1987, though it was not as pronounced as at Harbour station where, the fluctuations with the seasons, bloom etc. were very distinct. The average energy content of suspended matter during the entire period of study was 3409.75 cal/g.d.wt. which is a slightly lower value than that of Harbour.

Arambol:

The study on the energy content of suspended matter at Arambol station showed a lower value as compared to the other two stations. The average value was recorded as 2281.18 cal/g.d.wt. The maximum value was recorded in the month of April, 1987 (9481.46 cal/g.d.wt.) and minimum (345.38 cal/g.d.wt.) in the month of August, 1986. The pattern of distribution showed hardly any trend as far as seasonal changes were concerned. Comparatively some of the months in the monsoon season exhibited high energy content (Table 31, Fig. 41) than the rest of the period. Despite the very high value obtained during the month of April, 1987 the rest of the values were lower than the average value of other stations.

The calorific studies of suspended matter and zooplankton are very important in the studies of energetics of sessile and filter feeding organisms. This may help in ascertaining the linkage between the production of energy and its transformation through the filter feeding organisms to a higher trophic level. The zooplankton as it is called the secondary producers, occupies usually secondary level in the trophic structure of the energy flow. But the suspended matter occupies the last level and also composed of a mixture of all the intermediate layers of trophic structures. This signifies the importance of its study while dealing with the energetic studies of one of the organisms in the food chain.

The average energy content of zooplankton and suspended matter from three different areas showed an increased average energy content in zooplankton samples as compared with the suspended matter and the barnacles.

This shows the high energy reserves in the secondary producers.

In the comparative study of three stations the calorific content of suspended matter, the Arambol station recorded the lowest concentration. The first being Harbour followed by Dona Paula. This could be an expected result as the Arambol is an open sea shore while the other two are estuarine stations where an increased input of energy rich compounds are expected through river runoff.

Table 9

Table showing the presence and absence of four barnacle species during the monthly observations at three stations during the study period

Sl. No.	Month	Balanus amphitrite		Balanus amaryllis	Balanus tintinnabulum	Chthamalus sp.	
		DP	H	H	Arambol	DP	Arambol
1.	Apr`86	+	+	−	+	+	+
2.	May	+	+	+	+	+	+
3.	Jun	+	+	−	NS	+	+
4.	Jul	+	+	+	NS	+	+
5.	Aug	+	+	+	+	+	+
6.	Sep	+	+	+	+	+	+
7.	Oct	+	+	+	+	+	+
8.	Nov	+	+	+	+	+	+
9.	Dec	+	NS	NS	+	+	+
10.	Jan`87	+	+	−	+	+	+
11.	Feb	+	+	−	+	+	+
12.	Mar	+	+	−	+	+	+
13.	Apr	+	+	−	+	+	+
14.	May	+	+	−	+	+	+
15.	Jun	+	+	+	NS	+	+
16.	Jul	+	+	+	+	+	+

DP = Dona Paula; H = Harbour
\+ = Present; − = Absent
NS = Not sampled

Table 10

Monthly distribution of calorific content of *B. amphitrite* at Harbour and Dona Paula

Month	Harbour cal/g.d.wt. (ash free)	Dona Paula cal/g.d.wt. (ash free)
Apr'86	7530.19	7310.71
May	7047.91	6628.79
Jun	6242.66	4161.69
Jul	5647.35	6031.94
Aug	9567.91	8480.65
Sep	7548.62	8143.09
Oct	6276.45	6229.24
Nov	7183.42	6804.32
Dec	–	4424.71
Jan'87	5031.07	4514.86
Feb	4777.61	3405.74
Mar	5198.72	5840.65
Apr	7565.60	5284.32
May	5674.37	6742.40
Jun	4064.78	4864.78
Jul	5957.35	3960.98

Table 11

Monthly distribution of calorific content (cal/g.d.wt. ash free) in different size groups of B. amphitrite at Harbour station during the study period

Month	RCB* Above 20mm	RCB* 10-20mm	RCB* 5-10mm	RCB* below 5mm
Apr'86	7242.23	6720.59	-	-
May	-	7122.30	6973.52	-
Jun	-	5450.73	7456.41	-
Jul	-	6203.20	5091.49	-
Aug	-	11401.93	7734.52	-
Sep	-	7572.20	7256.96	-
Oct	-	6992.82	5560.08	-
Nov	-	7288.94	7077.89	-
Dec	-	-	-	-
Jan'87	5966.49	4984.01	4142.72	-
Feb	3825.07	5793.40	5942.87	2608.78
Mar	-	5816.66	6313.69	5546.56
Apr	-	7158.50	6508.52	-
May	-	6494.42	6525.53	5142.45
Jun	-	4491.38	6076.05	1626.91
Jul	5938.36	7407.39	5612.96	4393.59

* - Rostro Carinal Base diameter of the shell

Table 12

Monthly distribution of calorific content (cal/g.d.wt. ash free) in mature and immature forms of *B. amphitrite* at Harbour station during the study period

Month	Mature forms	Immature forms
Apr'86	7778.38	8379.54
May	-	6973.52
Jun	7456.41	5820.85
Jul	6203.20	5091.49
Aug	-	7734.52
Sep	8137.66	7227.65
Oct	6276.45	-
Nov	7288.94	7077.89
Dec	-	-
Jan'87	4142.72	5966.49
Feb	6497.42	4538.14
Mar	4364.93	3951.78
Apr	8696.90	7898.47
May	6002.91	4206.55
Jun	6076.05	4491.38
Jul	5612.96	6434.47

Table 13

Distribution of calorific content (cal/g.d.wt.) of immature egg mass, mature eggs and nauplii of B. amphitrite at Harbour and Dona Paula stations during the study period

Month	Station	Immature egg mass	Mature eggs	Nauplii
Apr'86	Harbour	5253.30	4858.45	--
	Dona Paula	5411.33	5256.91	--
May	--	--	--	--
Jun	--	--	--	--
Jul	--	--	--	--
Aug	--	--	--	--
Sep	--	--	--	--
Oct	Dona Paula	5843.21	7842.76	7768.00
Nov	Harbour	5654.73	4247.08	--
Dec	Dona Paula	6261.73	2364.50	--
Jan'87	Dona Paula	--	6227.85	--
Feb	Dona Paula	6371.82	8088.35	--
Mar	Harbour	5438.21	6378.38	9436.37
	Dona Paula	4954.28	8739.38	--
Apr	Harbour	5390.64	9971.61	--
	Dona Paula	5386.73	8130.62	8313.90
May	Harbour	--	7736.51	7342.16
	Dona Paula	5372.71	7231.52	6344.91
Jun	Harbour	9107.28	7187.14	8008.71
	Dona Paula	7096.23	--	--
Jul	Harbour	8731.42	7700.00	8594.33
	Dona Paula	--	8141.47	8790.00

Table 14

Distribution of calorific content of egg (cal/mature egg) and nauplius (cal/nauplius) of *B. amphitrite* at Harbour and Dona Paula stations during the study period

Month	Station	Cal/mat.egg	Cal/naup.
Oct'86	Dona Paula	0.0021	0.0038
Nov	Harbour	0.0051	-
Dec	Dona Paula	0.0040	-
Jan'87	Dona Paula	0.0036	-
Mar	Harbour	0.0053	0.0057
	Dona Paula	0.0031	-
Apr	Harbour	0.0034	-
	Dona Paula	0.0042	0.0043
May	Harbour	0.0030	0.0028
	Dona Paula	0.0024	0.0023
Jun	Harbour	0.0053	0.0068
	Dona Paula	0.0072	-
Jul	Harbour	0.0022	0.0031
	Dona Paula	0.0049	0.0059

Table 15

Monthly distribution of calorific content (cal/g.d.wt. ash free) in three different size groups of _B. amphitrite_ at Dona Paula station during the study period

Month	RCB* below 5mm	RCB* 5-10mm	RCB* 10-20mm
Apr'86	-	7743.08	7480.11
May	-	6336.17	6921.40
Jun	-	4390.96	3932.42
Jul	-	5474.65	6589.22
Aug	-	7471.30	9489.99
Sep	-	7771.71	8514.46
Oct	-	6160.92	6298.28
Nov	-	8934.68	6068.78
Dec	-	4378.03	3984.56
Jan'87	4425.43	3801.10	5690.20
Feb	-	3273.47	3492.97
Mar	5587.80	6855.80	6629.49
Apr	-	5293.62	5942.75
May	5586.87	7703.31	7901.40
Jun	4682.58	4943.13	4968.64
Jul	4185.80	3795.41	4664.74

* Rostro Carinal Base diameter of the shell

Table 16

Monthly distribution of calorific content (cal/g.d.wt. ash free) in mature and immature forms of B. amphitrite at Dona Paula station during the study period

Month	Mature forms	Immature forms
Apr`86	6708.94	7743.08
May	6921.40	6336.17
Jun	3932.42	4390.96
Jul	6589.22	5474.65
Aug	-	8480.65
Sep	8143.09	-
Oct	6228.51	-
Nov	6083.56	6129.95
Dec	5004.31	4331.93
Jan`87	3738.06	4919.51
Feb	3194.43	3662.09
Mar	5151.67	4978.51
Apr	5701.43	4199.47
May	6113.39	6407.05
Jun	4968.64	4943.13
Jul	4895.20	4263.77

Table 17

Monthly distribution of calorific content (cal/g.d.wt. ash free) in B. amaryllis at Harbour station during the study period

Month	Cal/g.d.wt.
Apr'86	-
May	6240.43
Jun	5280.85
Jul	5514.70
Aug	5620.86
Sep	6055.36
Oct	6357.92
Nov	7902.88
Dec	-
Jan'87	-
Feb	-
Mar	-
Apr	-
May	-
Jun	4970.21
Jul	8329.02

Table 18

Monthly distribution of calorific content (cal/g.d.wt. ash free) in three different size groups of B. amaryllis at Harbour station during the study period

Month	RCB* 10-15mm	RCB* 15-20mm	RCB* 20-30mm
Apr'86	-	-	-
May	5281.86	9287.92	4151.51
Jun	-	-	5820.85
Jul	5756.20	4619.84	6168.05
Aug	-	5758.07	5483.65
Sep	-	5944.87	6165.84
Oct	-	5379.30	7336.53
Nov	7962.38	8676.51	7069.76
Dec	-	-	-
Jan'87	-	-	-
Feb	-	-	-
Mar	-	-	-
Apr	-	-	-
May	-	-	-
Jun	4970.21	-	-
Jul	8329.02	-	-

* Rostro Carinal Base diameter of the shell

Table 19

Monthly distribution of calorific content (cal/g.d.wt. ash free) in *Chthamalus* sp. at Dona Paula station during the study period

Month	Cal/g.d.wt.
Apr'86	5012.93
May	6724.64
Jun	4873.65
Jul	5115.01
Aug	6847.38
Sep	7708.74
Oct	6226.33
Nov	6185.54
Dec	2828.63
Jan'87	3193.94
Feb	5100.62
Mar	5170.29
Apr	5061.58
May	4139.82
Jun	3676.14
Jul	5504.14

Table 20

Monthly distribution of calorific content (cal/g.d.wt. ash free) in two different size groups of <u>Chthamalus</u> sp. at Dona Paula station during the study period

Month	RCB* below 5mm	RCB* 5-15mm
Apr'86	-	5012.93
May	-	6724.64
Jun	-	4873.65
Jul	-	5115.01
Aug	-	6847.38
Sep	-	7708.74
Oct	-	6226.33
Nov	-	6185.54
Dec	-	2828.63
Jan'87	3003.76	3384.12
Feb	-	5100.62
Mar	5285.76	5054.81
Apr	-	5061.58
May	-	4139.82
Jun	-	3676.14
Jul	-	5504.14

* Rostro Carinal Base diameter of the shell

Table 21

Monthly distribution of calorific content (cal/g.d.wt. ash free) in *Chthamalus* sp. at Arambol station during the study period

Month	Cal/g. d.wt.
Apr'86	4460.99
May	5818.84
Jun	1961.52
Jul	3627.54
Aug	3727.81
Sep	6952.57
Oct	6486.89
Nov	5294.87
Dec	4702.46
Jan'87	3447.04
Feb	4744.35
Mar	3467.45
Apr	3800.36
May	4119.02
Jun	2280.89
Jul	4865.94

Table 22

Monthly distribution of calorific content (cal/g.d.wt. ash free) in two different size groups of <u>Chthamalus</u> sp. at Arambol station during the study period

Month	RCB* below 5mm	RCB* 5-15mm
Apr'86	-	4460.99
May	-	5818.84
Jun	1744.35	2178.69
Jul	-	3627.54
Aug	-	3727.81
Sep	5321.27	7583.87
Oct	5268.84	6704.93
Nov	5168.66	5421.08
Dec	-	4702.46
Jan'87	-	3447.04
Feb	-	4744.35
Mar	-	3467.45
Apr	-	3800.36
May	3549.23	4688.80
Jun	-	2280.89
Jul	-	4865.94

* Rostro Carinal Base diameter of the shell

Table 23

Monthly distribution of calorific content (cal/g.d.wt. ash free) in <u>B. tintinnabulum</u> at Arambol station during the study period

Month	Cal/g. d.wt.
Apr'86	4586.83
May	4401.45
Jun	-
Jul	-
Aug	4354.24
Sep	5627.16
Oct	7294.24
Nov	4874.54
Dec	6304.01
Jan'87	4936.05
Feb	5697.96
Mar	5147.65
Apr	4935.47
May	5163.92
Jun	-
Jul	6320.51

Table 24

Monthly distribution of calorific content (cal/g.d.wt. ash free) in four different size groups of <u>B. tintinnabulum</u> at Arambol station during the study period

Month	RCB* below 20mm	RCB* 20-30mm	RCB* 30-40mm	RCB* above 40mm
Apr 86	-	-	4181.99	4991.66
May	-	4087.14	4545.21	4571.99
Jun	-	-	-	-
Jul	-	-	-	-
Aug	-	3373.11	4727.04	4962.57
Sep	-	6244.13	5420.34	5217.02
Oct	-	7514.86	6611.13	7756.72
Nov	-	4565.97	4828.28	5229.38
Dec	7896.34	5485.41	6184.78	5649.52
Jan 87	4909.81	5168.35	3681.98	5984.04
Feb	4802.32	6860.32	5380.65	5748.55
Mar	4205.88	5122.77	5868.79	5393.17
Apr	-	4651.40	5063.17	5091.84
May	-	4587.13	5391.48	5513.14
Jun	-	-	-	-
Jul	-	-	5866.03	6774.99

* Rostro Carinal Base diameter of the shell

Table 25

Monthly distribution of calorific content (cal/g.d.wt. ash free) in different tissues of *B. tintinnabulum* at Arambol station during the study period

Month	Body tissue	Intestine	Cirri
Apr'86	4863.25	3872.33	3034.45
May	5392.61	4225.36	2688.72
Jun	-	-	-
Jul	-	-	-
Aug	6307.00	4058.53	3689.43
Sep	5614.38	4777.00	4671.76
Oct	8204.68	6723.23	6644.06
Nov	5676.71	3214.94	4991.66
Dec	5494.45	4280.33	6448.57
Jan'87	5746.40	4949.39	4617.04
Feb	6651.09	4723.49	4636.54
Mar	5846.44	5005.75	3984.95
Apr	5480.51	4576.79	4176.51
May	5562.06	5413.32	3845.28
Jun	-	-	-
Jul	6635.66	6361.80	5615.02

Table 26

Monthly distribution of calorific content (cal/g.d.wt. ash free) in different tissues of _B. tintinnabulum_ belonging to the size group RCB below 20 mm at Arambol station during the study period

Month	Body tissue	Intestine	Cirri
Apr'86	-	-	-
May	-	-	-
Jun	-	-	-
Jul	-	-	-
Aug	-	-	-
Sep	-	-	-
Oct	-	-	-
Nov	-	-	-
Dec	-	-	-
Jan'87	-	-	-
Feb	5763.46	3714.28	3790.22
Mar	4724.01	4781.43	3166.61
Apr	-	-	-
May	-	-	-
Jun	-	-	-
Jul	-	-	-

Table 27

Monthly distribution of calorific content (cal/g.d.wt. ash free) in different tissues of _B._ _tintinnabulum_ belonging to the size group RCB 20 - 30 mm at Arambol station during the study period

Month	Body tissue	Intestine	Cirri
Apr'86	-	-	-
May	4295.42	4831.23	2477.62
Jun	-	-	-
Jul	-	-	-
Aug	-	-	-
Sep	-	-	-
Oct	7566.42	7382.03	7855.52
Nov	5593.25	3260.93	4052.49
Dec	5885.53	3758.58	5656.21
Jan'87	5690.00	5640.02	4322.90
Feb	8129.28	5686.17	6306.41
Mar	5552.02	4797.17	4169.94
Apr	5251.57	4542.47	4003.19
May	5447.04	4541.32	3461.51
Jun	-	-	-
Jul	-	-	-

Table 28

Monthly distribution of calorific content (cal/g.d.wt. ash free) in different tissues of B. tintinnabulum belonging to the size group RCB 30 - 40 mm at Arambol station during the study period

Month	Body tissue	Intestine	Cirri
Apr`86	4710.11	3872.33	3034.45
May	6985.79	3970.58	2552.52
Jun	-	-	-
Jul	-	-	-
Aug	5933.73	3889.48	3727.08
Sep	-	4700.36	4973.42
Oct	8471.56	4973.11	4856.07
Nov	5394.23	3192.01	5148.52
Dec	5651.23	4739.56	7120.37
Jan`87	4371.63	4436.19	2483.90
Feb	6073.36	5182.00	4533.28
Mar	7020.45	5101.15	4368.75
Apr	5912.79	4643.81	4168.84
May	4869.81	5731.23	4931.92
Jun	-	-	-
Jul	6462.90	5984.31	4772.13

Table 29

Monthly distribution of calorific content (cal/g.d.wt. ash free) in different tissues of B. tintinnabulum belonging to the size group RCB above 40 mm at Arambol station during the study period

Month	Body tissue	Intestine	Cirri
Apr'86	5016.39	-	-
May	4896.62	3873.88	3036.03
Jun	-	-	-
Jul	-	-	-
Aug	6680.27	4227.58	3651.77
Sep	5614.38	4853.64	4370.10
Oct	8576.07	7814.55	7220.60
Nov	6042.64	3191.88	5773.98
Dec	4946.60	4342.85	6569.13
Jan'87	7177.56	4771.96	7044.33
Feb	7838.24	4111.51	3916.26
Mar	6089.26	5343.26	4234.50
Apr	5277.17	4544.08	4357.51
May	6369.34	5967.42	3142.42
Jun	-	-	-
Jul	6808.42	6739.30	6457.90

Table 30

Monthly distribution of calorific content of zooplankton samples at Harbour station during the study period

Month	Cal/g.d.wt. ash free
Apr'86	4378.12
May	4240.00
Jun	1832.17
Jul	3237.26
Aug	6184.33
Sep	6922.22
Oct	6382.60
Nov	6860.30
Dec	-
Jan'87	4685.60
Feb	10893.05
Mar	9966.79
Apr	6362.65
May	6033.73
Jun	4876.52
Jul	4234.44

Table 31

Monthly distribution of calorific content (cal/g.d.wt.) of suspended matter collected from three stations during the study period

Month	Harbour	Dona Paula	Arambol
Apr'86	3287.60	3842.31	-
May	1514.83	4354.21	900.33
Jun	5318.07	4149.45	2268.43
Jul	4624.74	4707.51	1167.16
Aug	5158.68	2612.44	345.78
Sep	2214.31	4284.36	1464.38
Oct	4144.49	1135.89	1169.42
Nov	1971.17	3364.63	2436.92
Dec	-	5099.96	1270.99
Jan'87	7790.17	4088.92	1540.11
Feb	6262.87	4961.73	4558.14
Mar	3144.55	3064.13	1423.00
Apr	3836.66	2121.77	9481.46
May	4033.65	3134.62	654.96
Jun	5033.77	3407.98	1193.88
Jul	6260.94	3226.09	4342.75

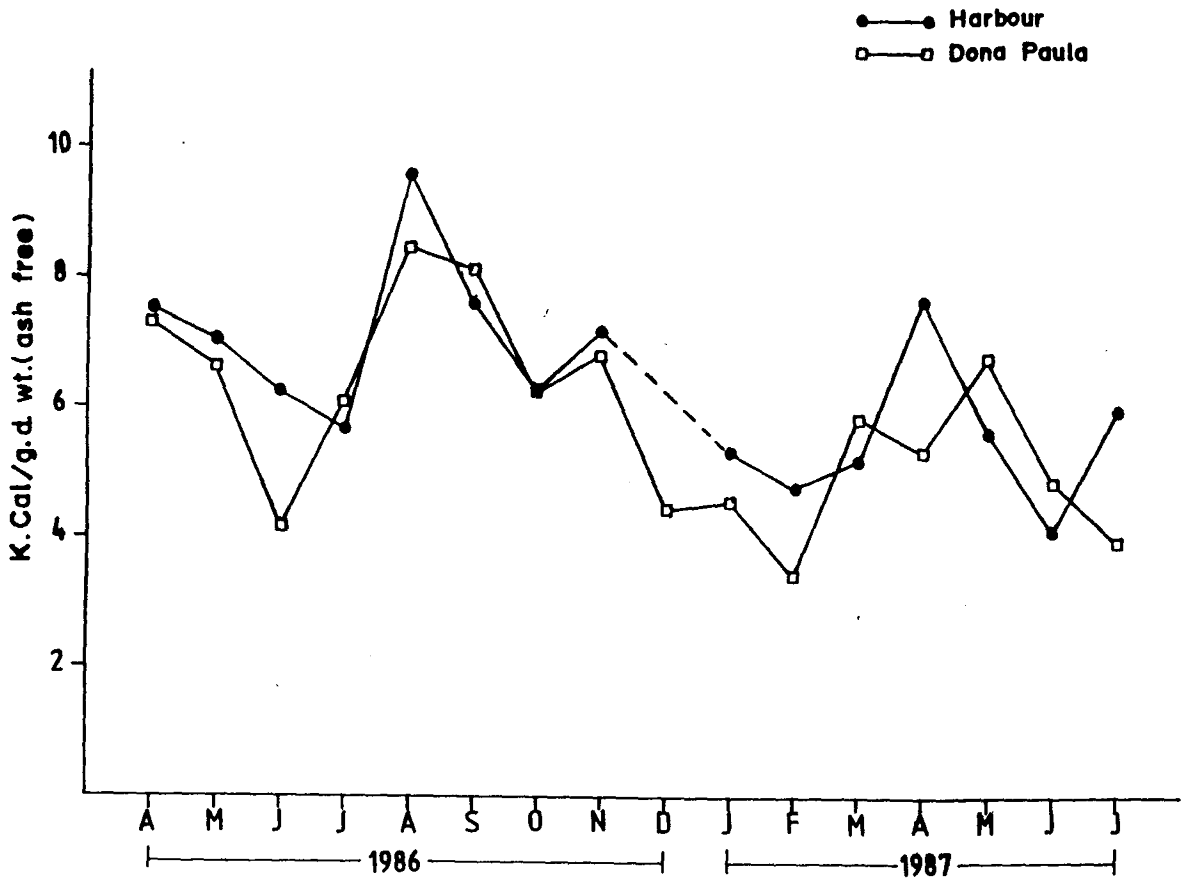

Fig. 18. Monthly distribution of calorific content in **B. amphitrite** at Harbour and Dona Paula.

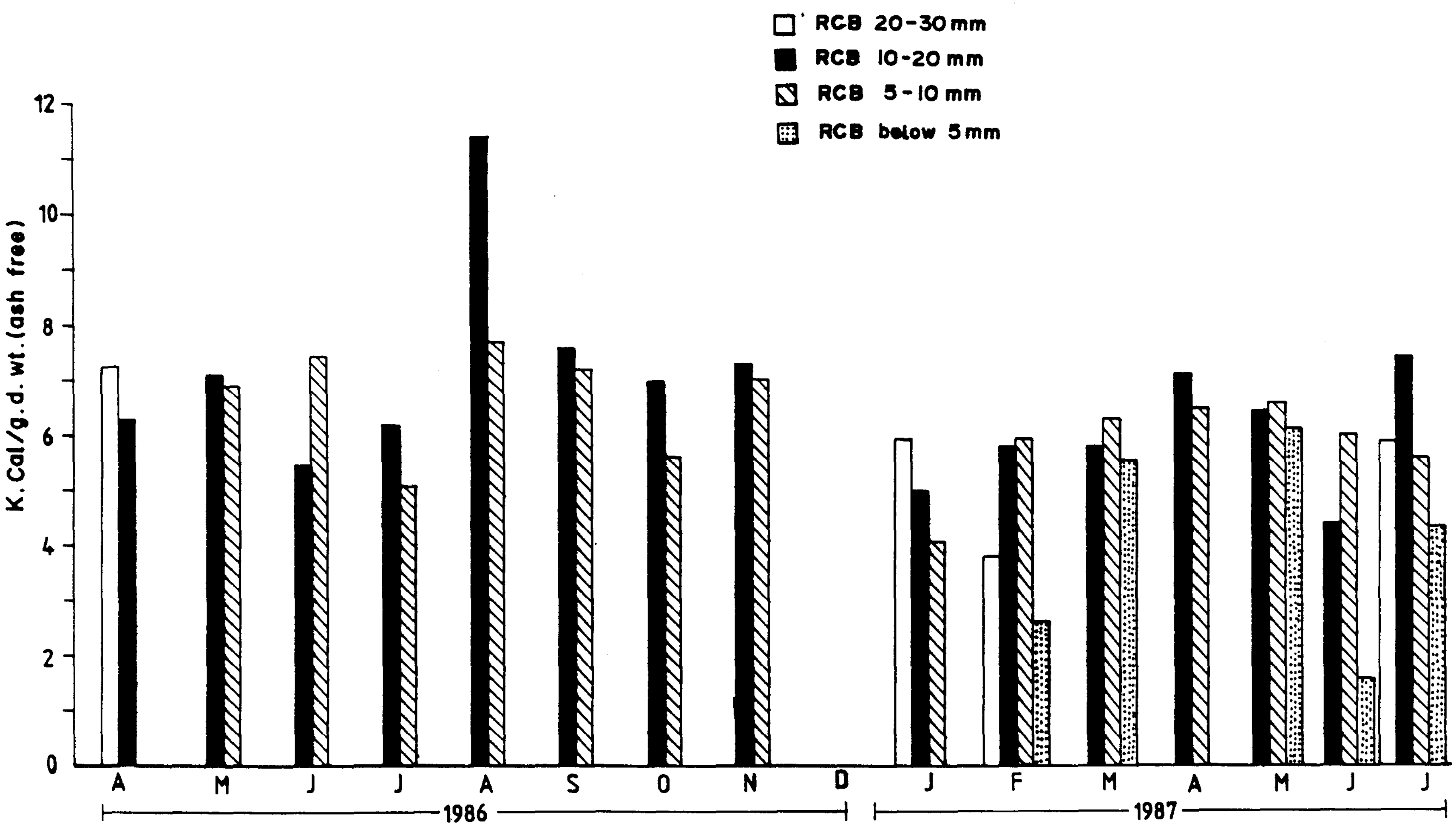

Fig. 19 Monthly distribution of Calorific content in different size groups of B. amphitrite at Harbour.

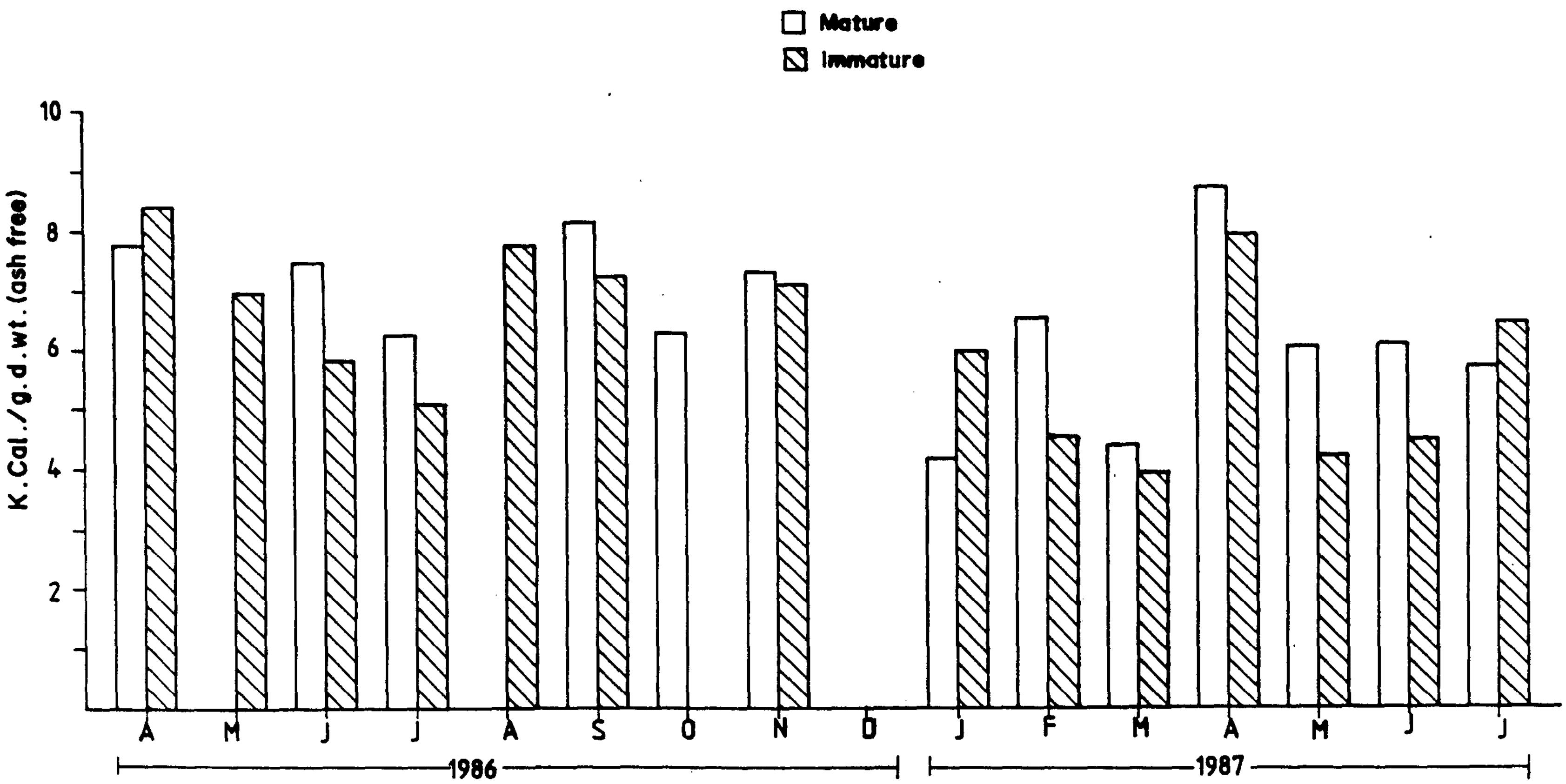

Fig.20. Monthly distribution of Calorific content in mature and immature forms of B.amphitrite at Harbour

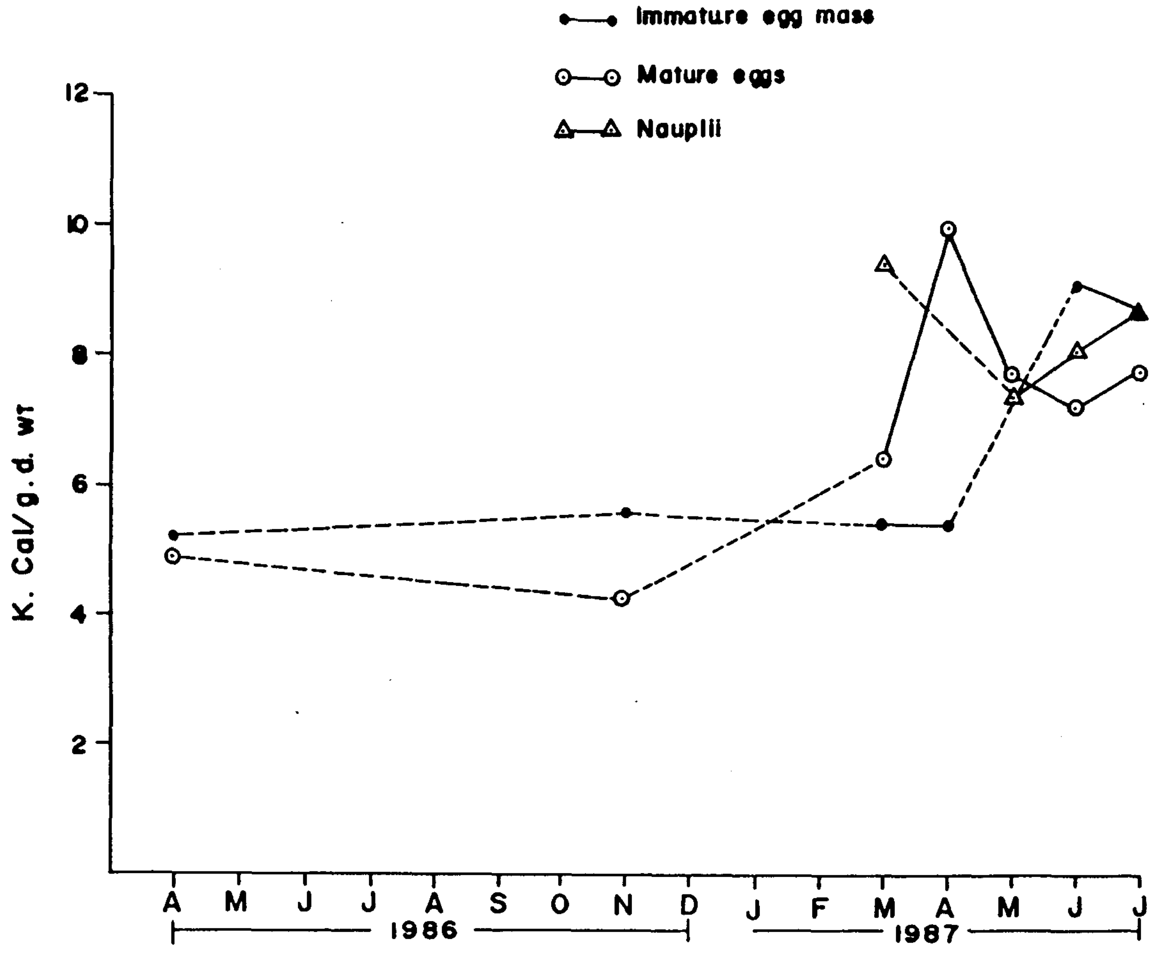

Fig. 21. Monthly distribution of Calorific content in immature egg mass, mature eggs and nauplii of B. amphitrite at Harbour.

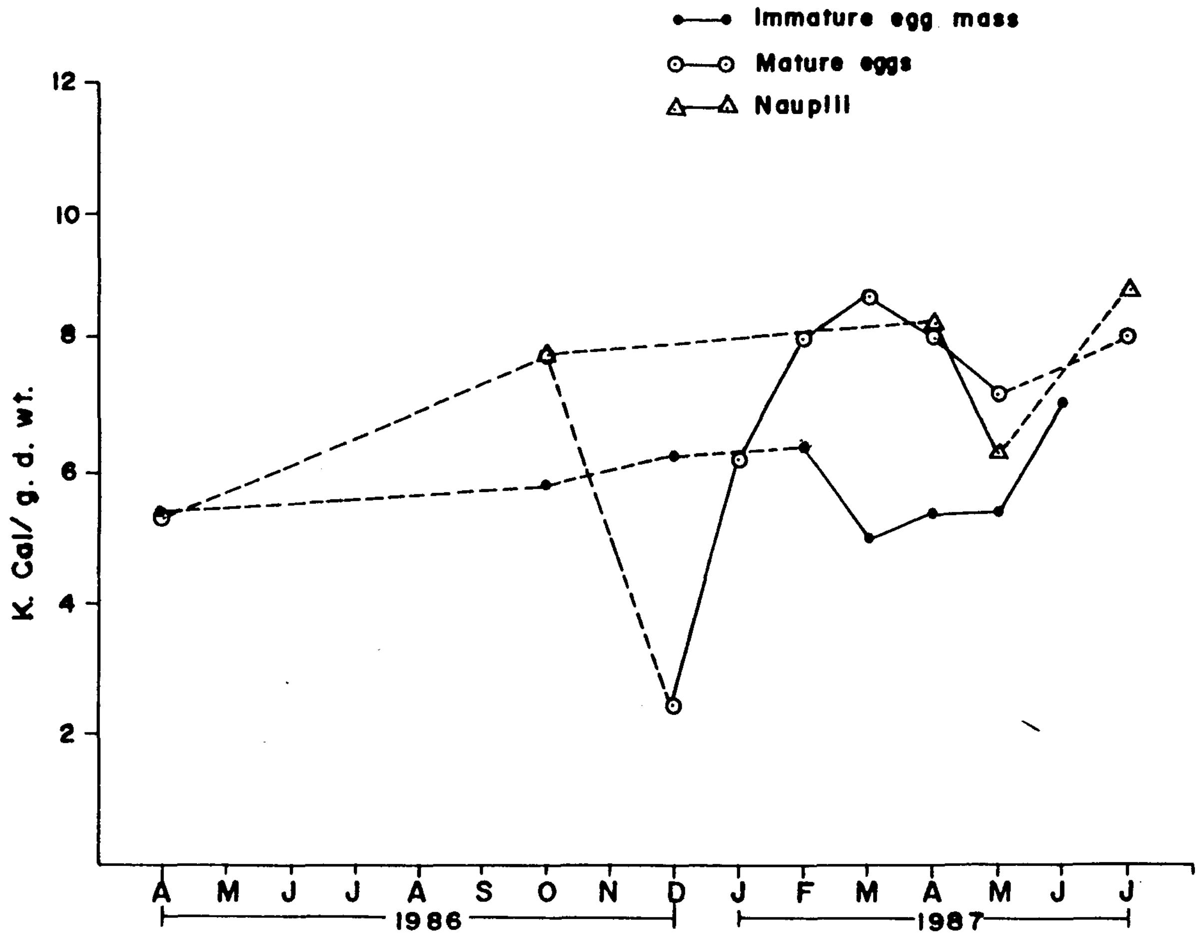

Fig. 22. Monthly distribution of Calorific content in immature egg mass, mature eggs and nauplii of <u>B. amphitrite</u> at Dona Paula.

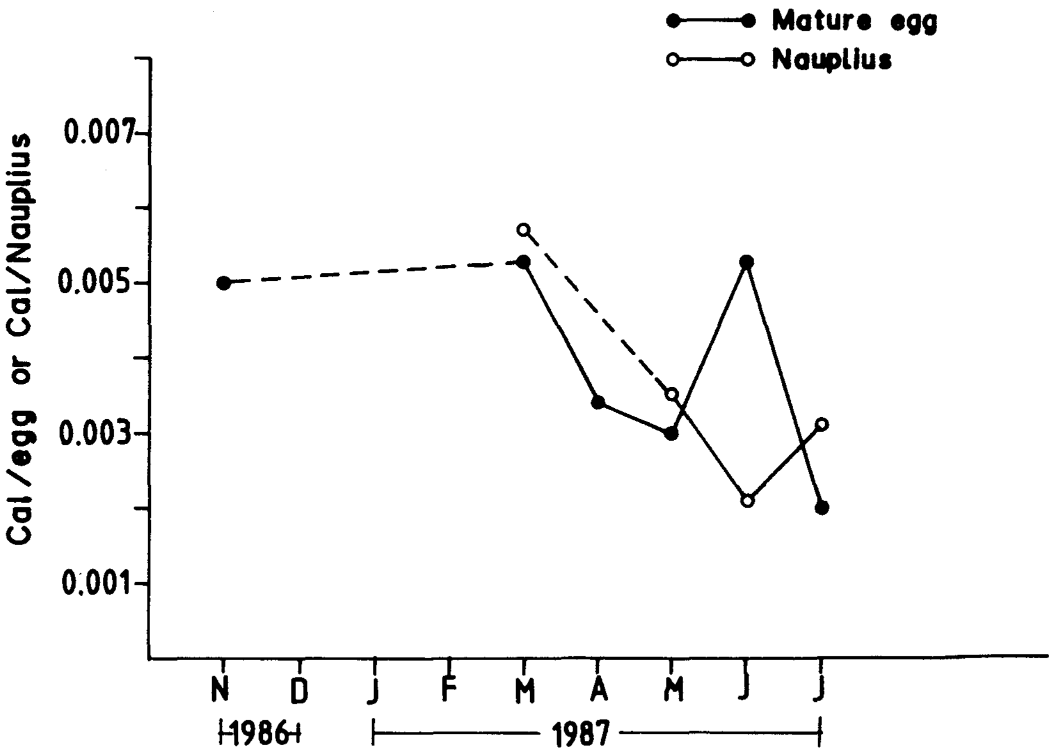

Fig. 23. Distribution of Calorific content in mature egg/nauplius of B. aphitrite at Harbour.

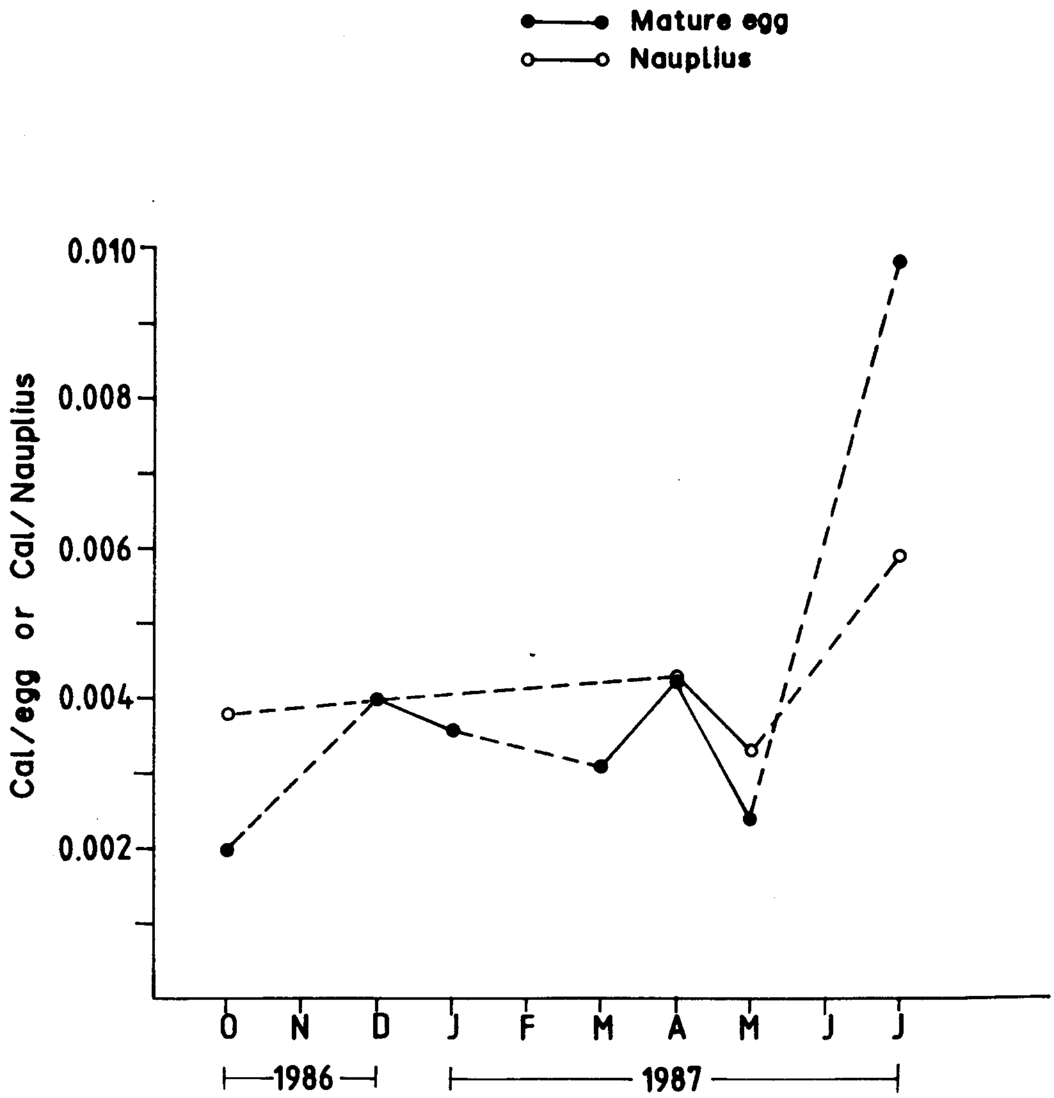

Fig. 24. Distribution of Calorific content in mature egg/nauplius of *B. amphitrite* at Dona Paula.

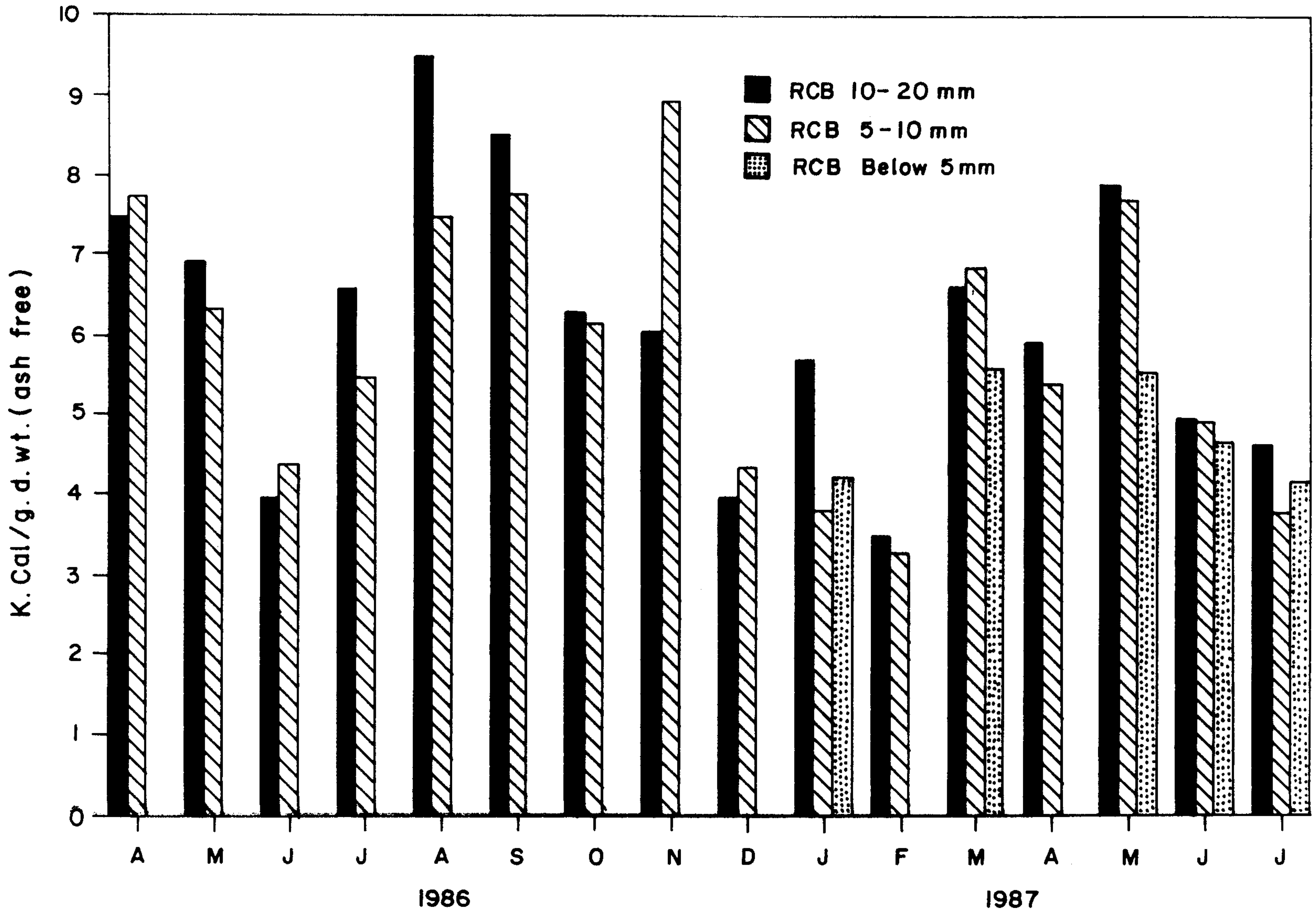

Fig.25. Monthly distribution of Calorific content in different size groups of *B. amphitrite* at Dona Paula.

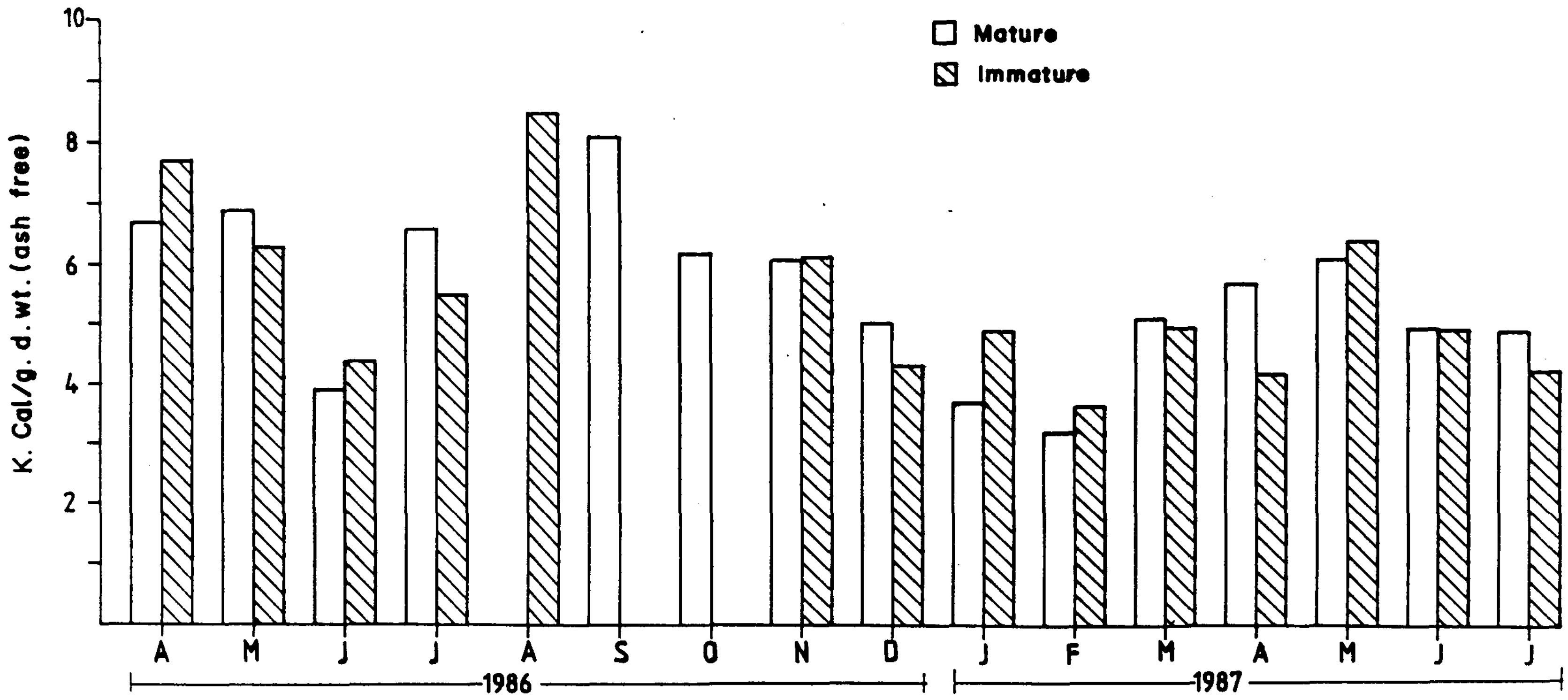

Fig.26. Monthly distribution of Calorific content in mature and immature forms of B. amphitrite at Dona Paula.

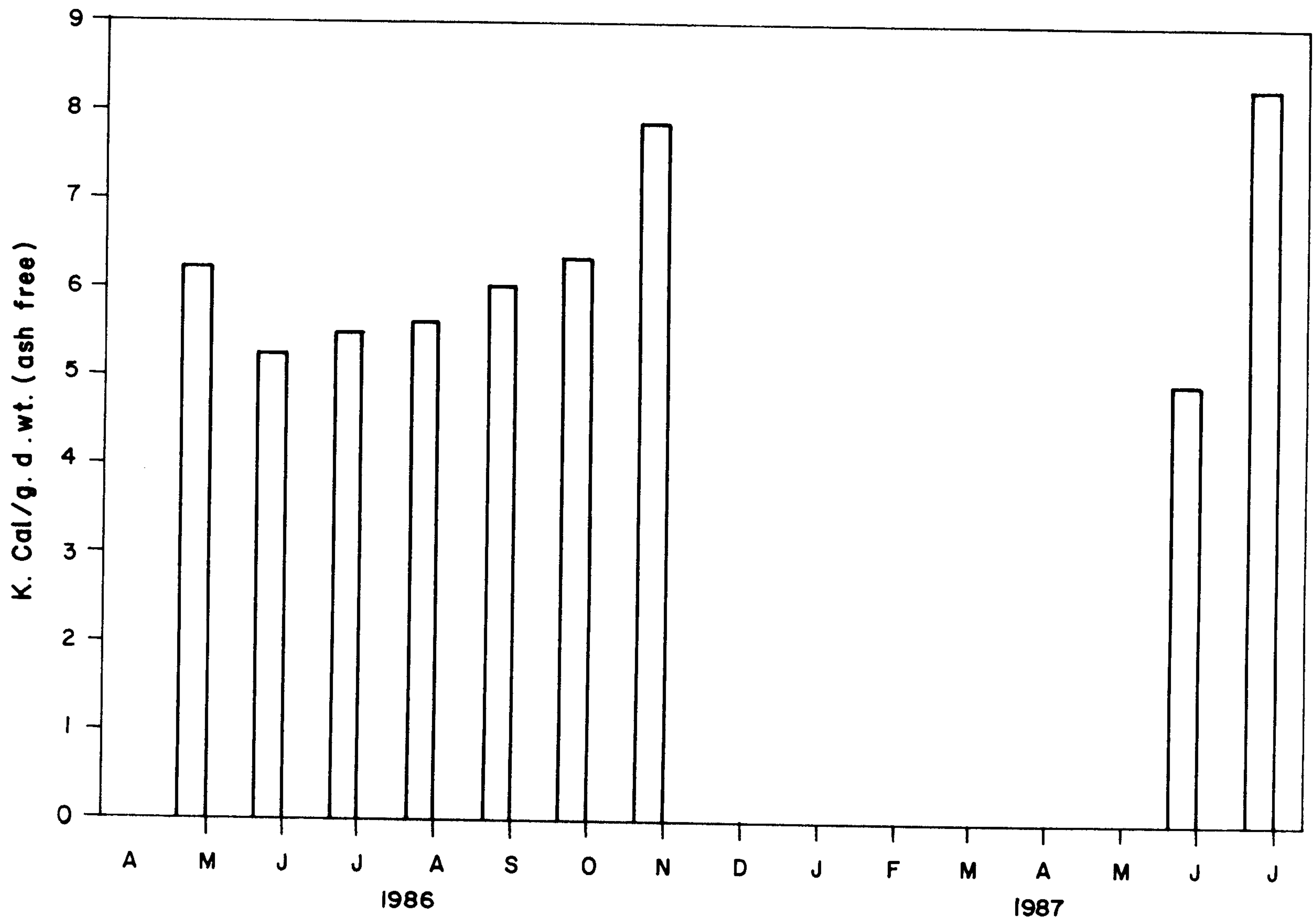

Fig.27. Monthly distribution of Calorific content in B. amaryllis at Harbour.

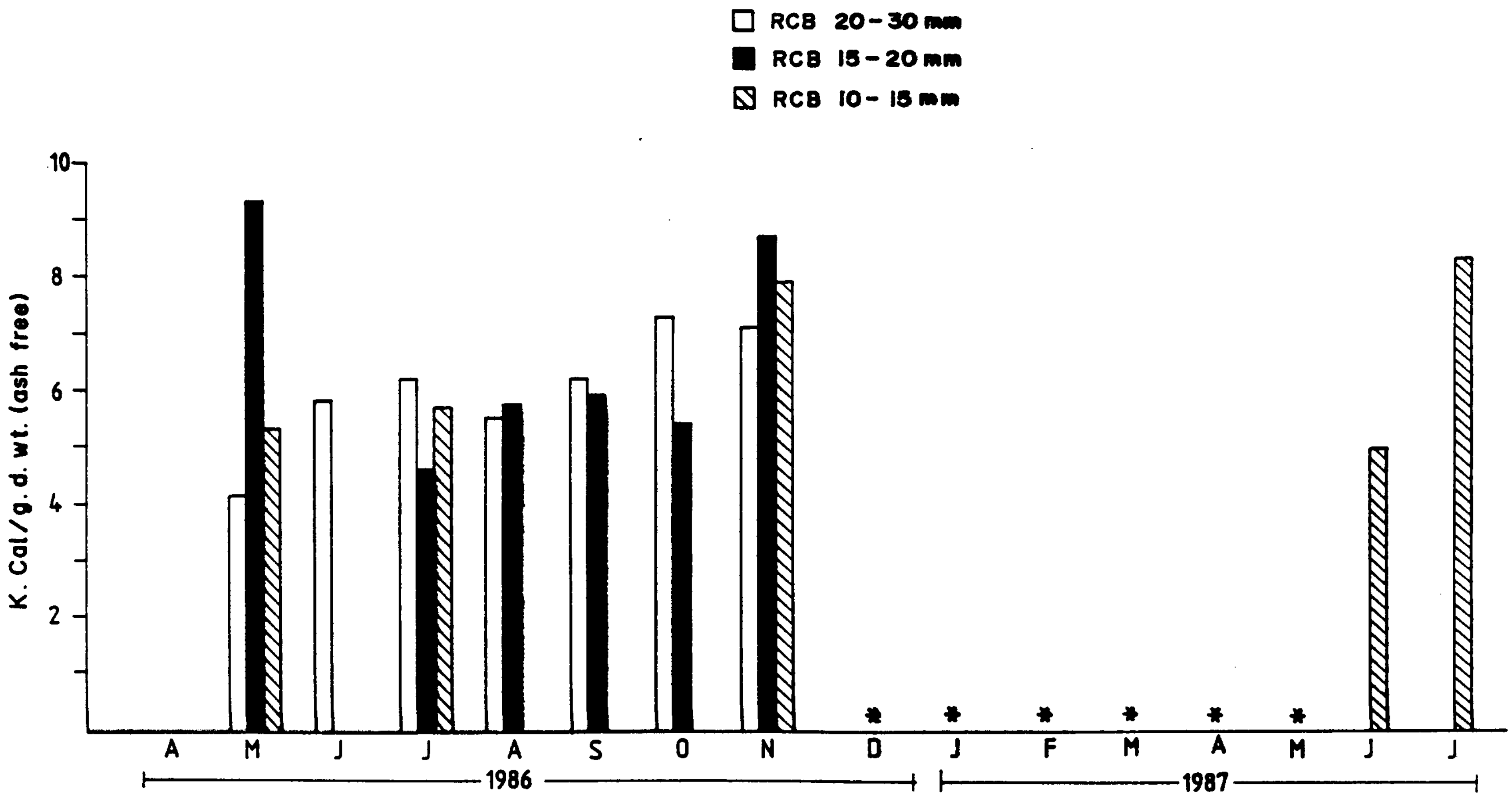

Fig. 28. Monthly distribution of Calorific content in different size groups of *B. amaryllis* at Harbour

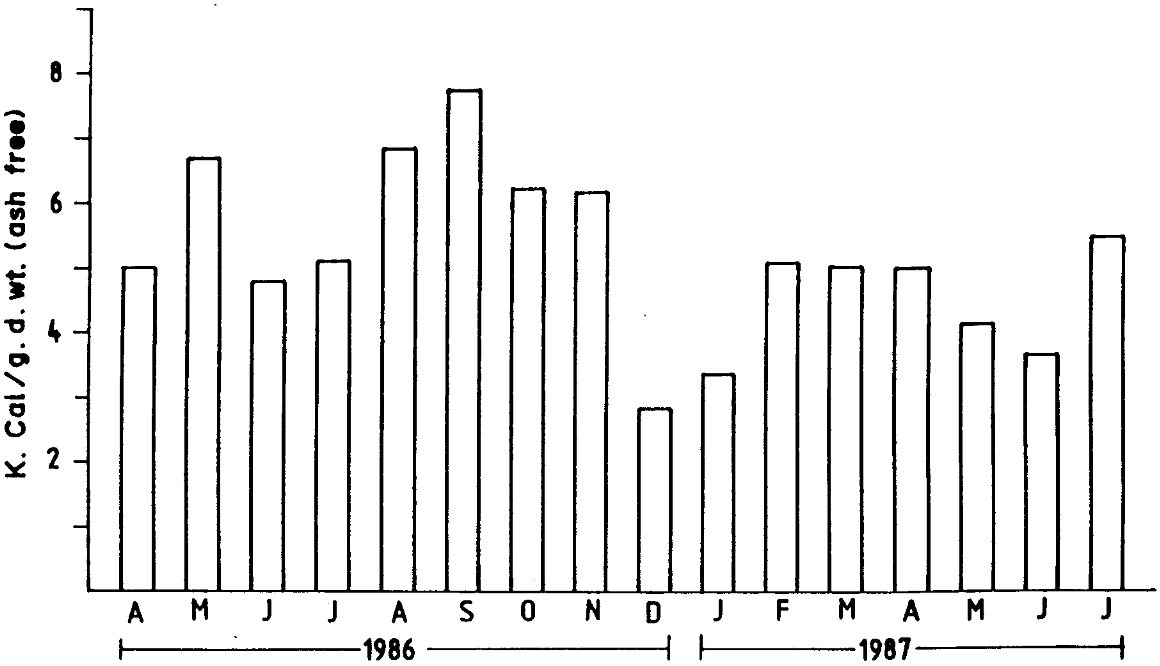

Fig. 29 Monthly distribution of Calorific content in <u>Chthamalus</u> sp. at Dona Paula.

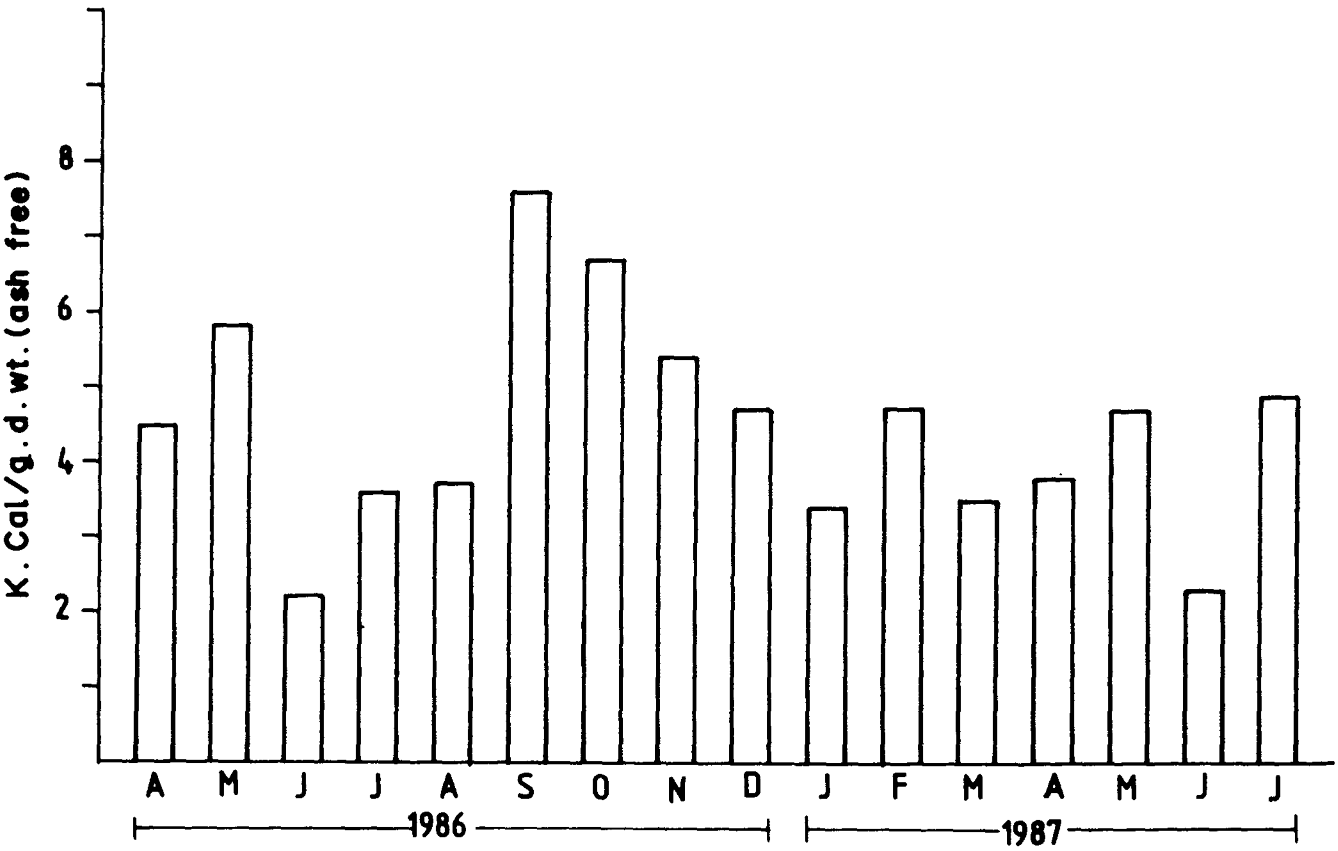

Fig. 30 . Monthly distribution of Calorific content in Chthamalus sp. at Arambol.

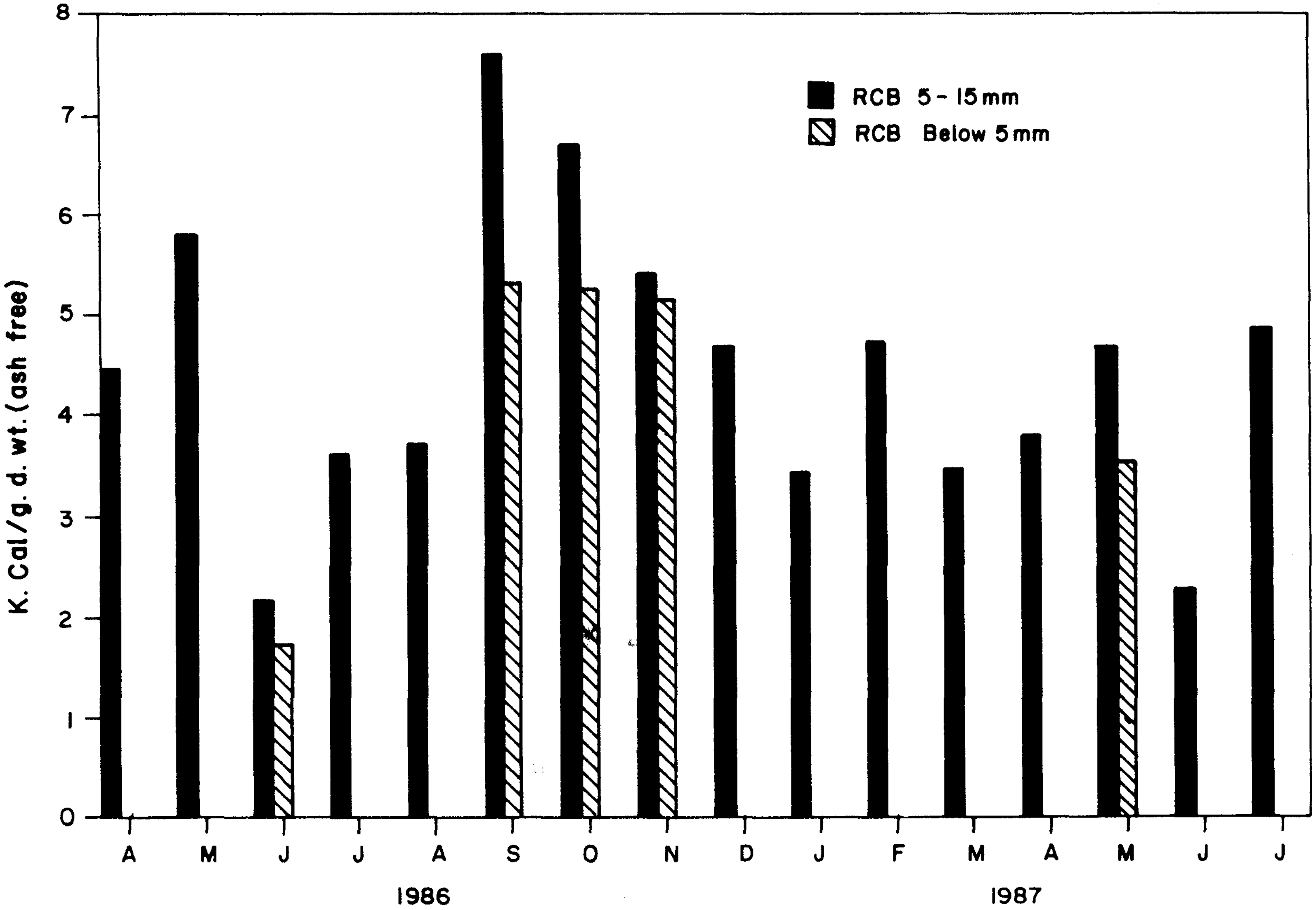

Fig. 31 . Monthly distribution of Calorific content in two size groups of <u>Chthamalus sp</u>. at Arambol.

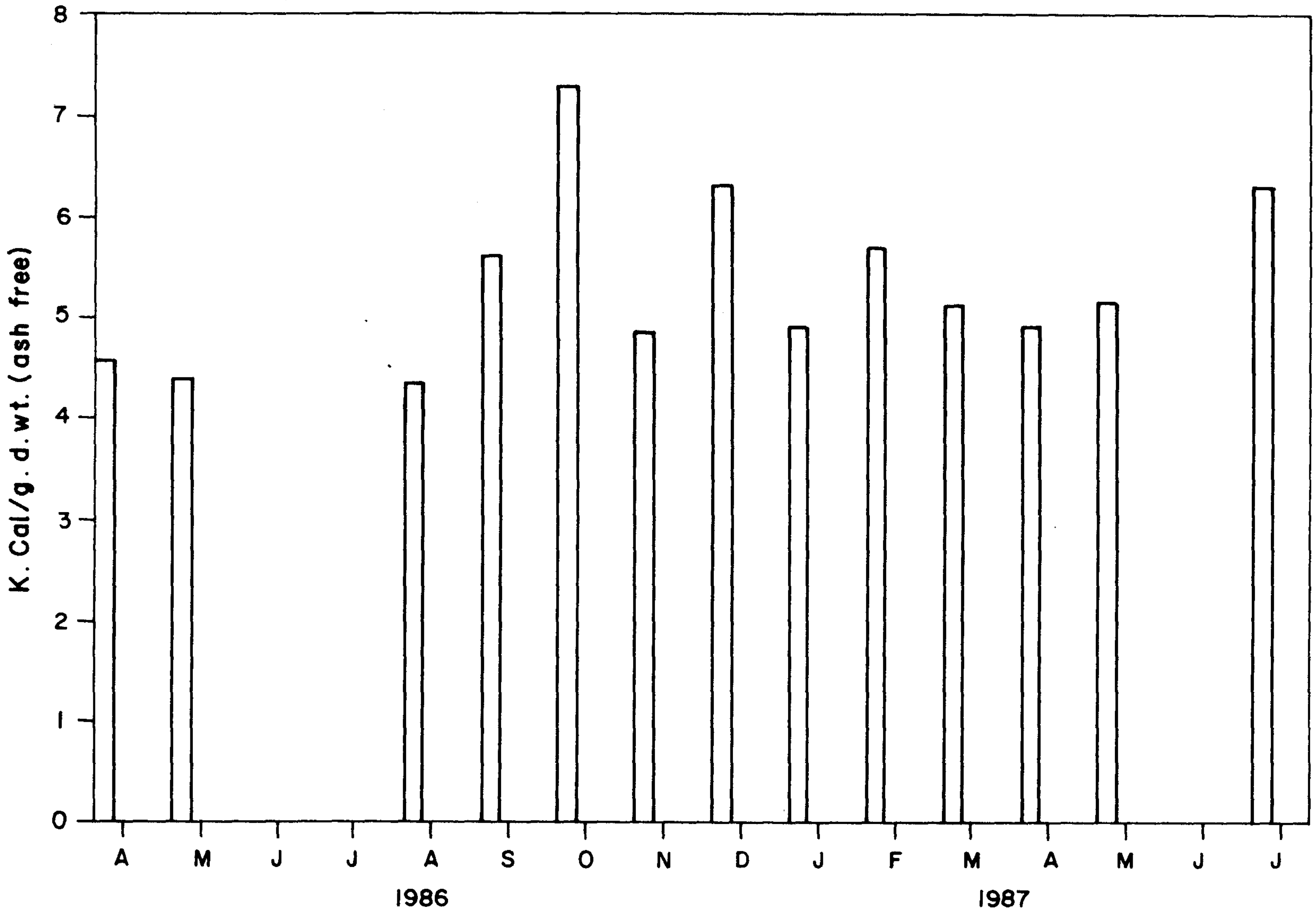

Fig. 32. Monthly distribution of Calorific content in B. tintinnabulum at Arambol.

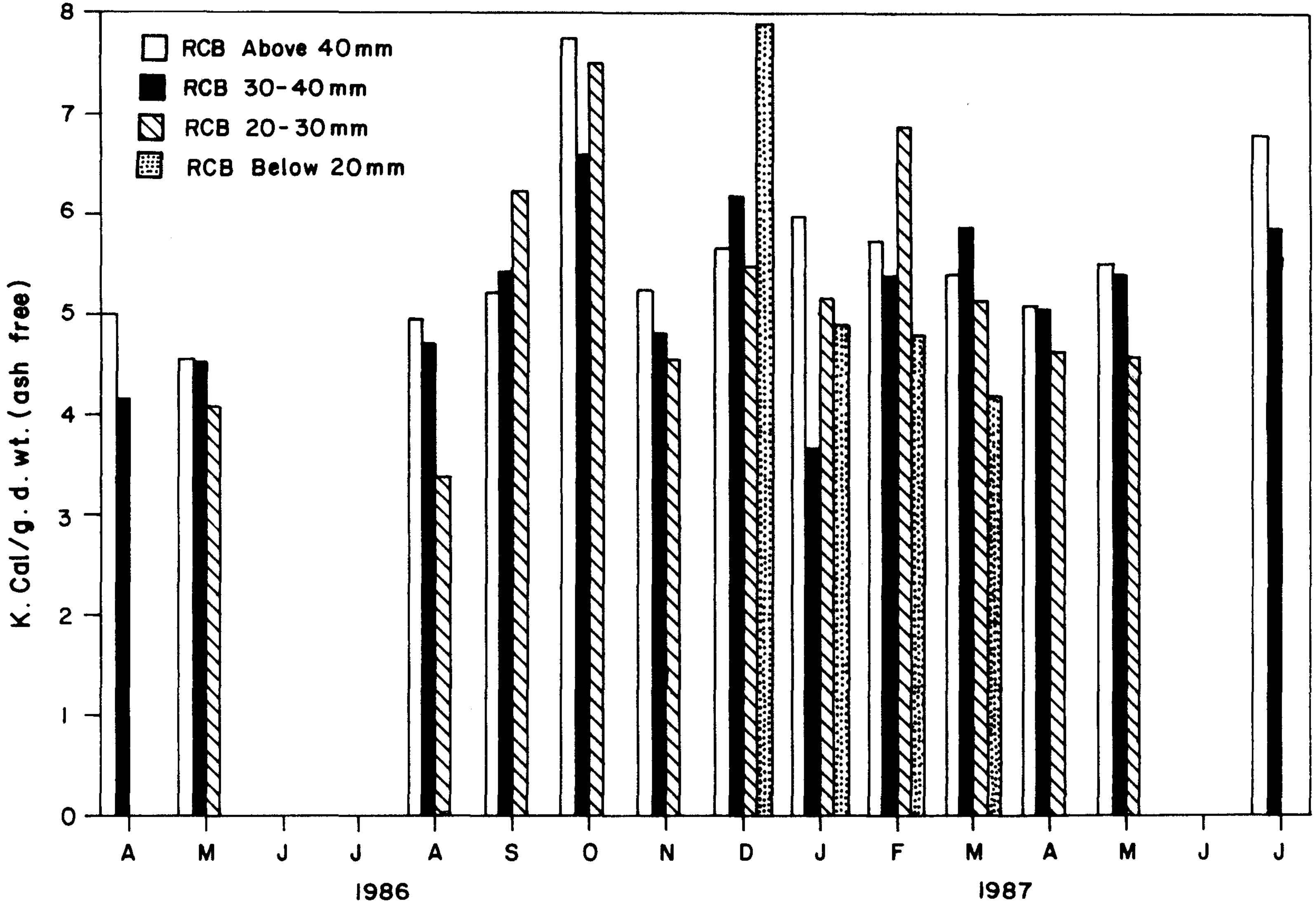

Fig.33 . Monthly distribution of Calorific content in different size groups of <u>B. tintinnabulum</u> at Arambol.

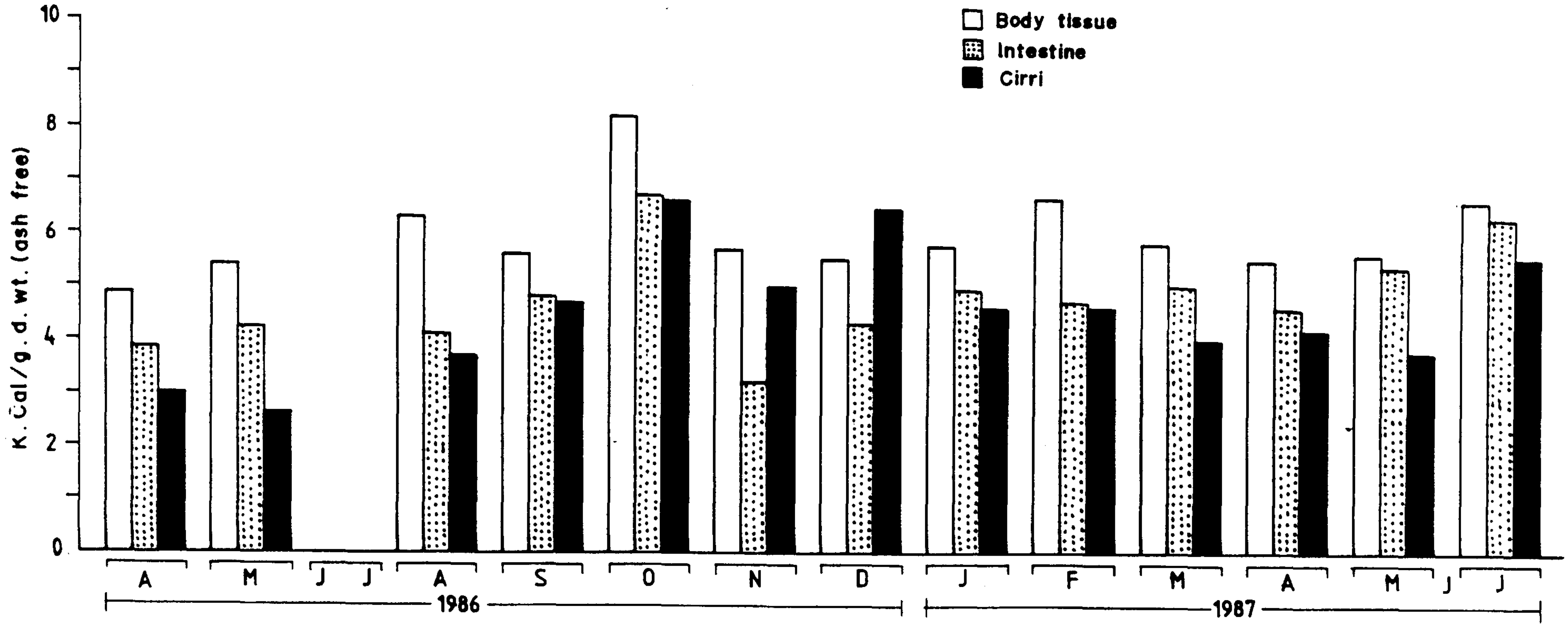

Fig. 34. Monthly distribution of Calorific content in different tissues of B. tintinnabulum at Arambol.

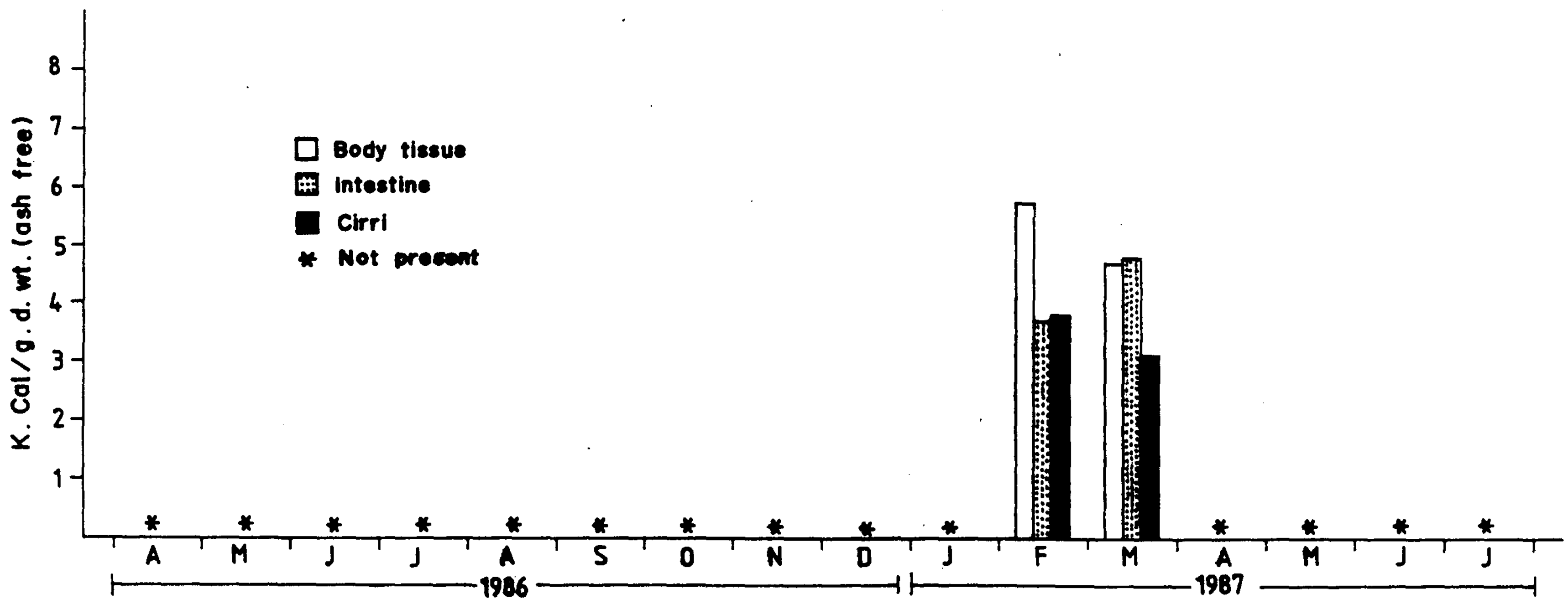

Fig.35. Distribution of Calorific content in different tissues of B. tintinnabulum (RCB below 20 mm)

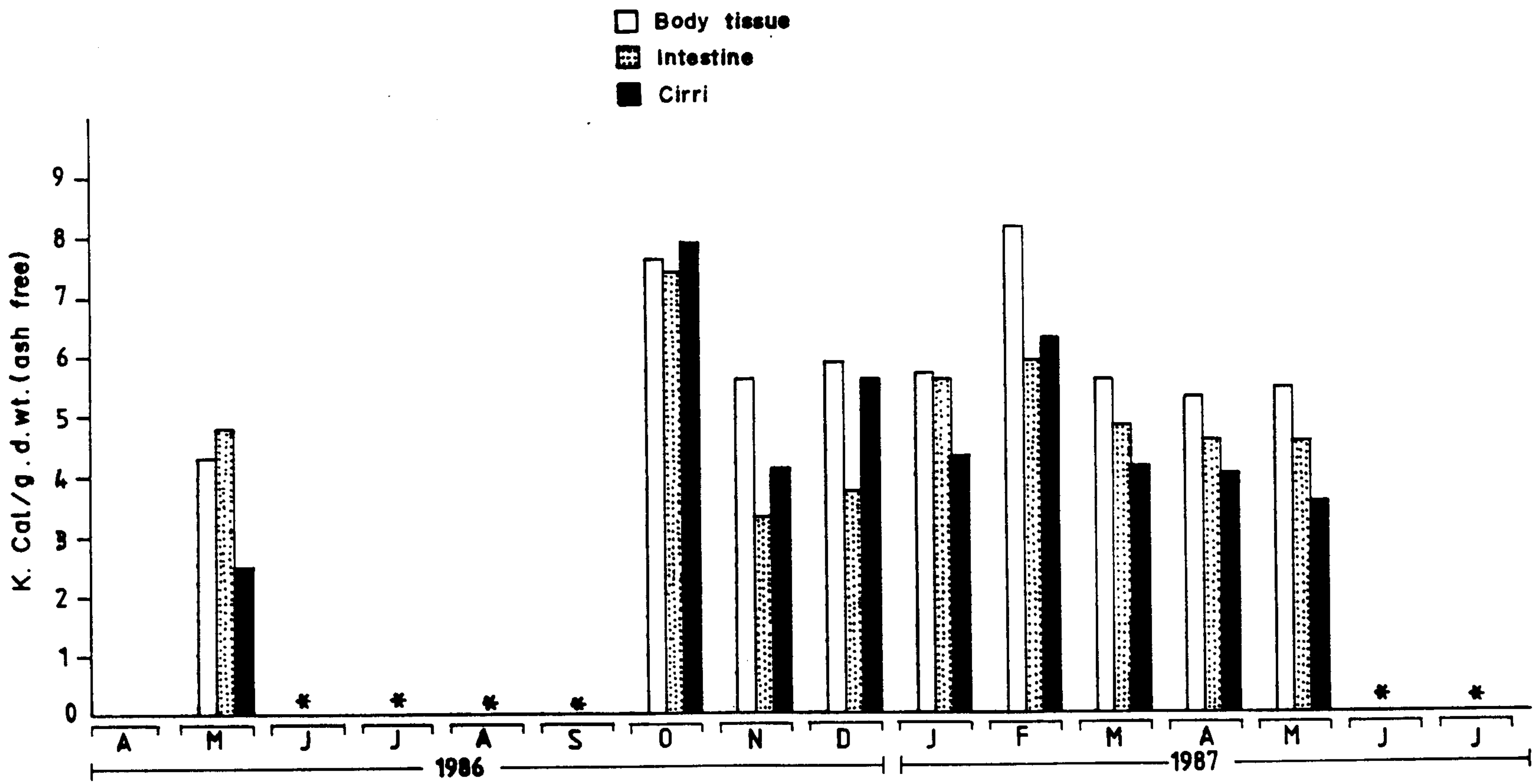

Fig. 36. Monthly distribution of Calorific content in different tissues of B. tintinnabulum (RCB 20-30 mm)

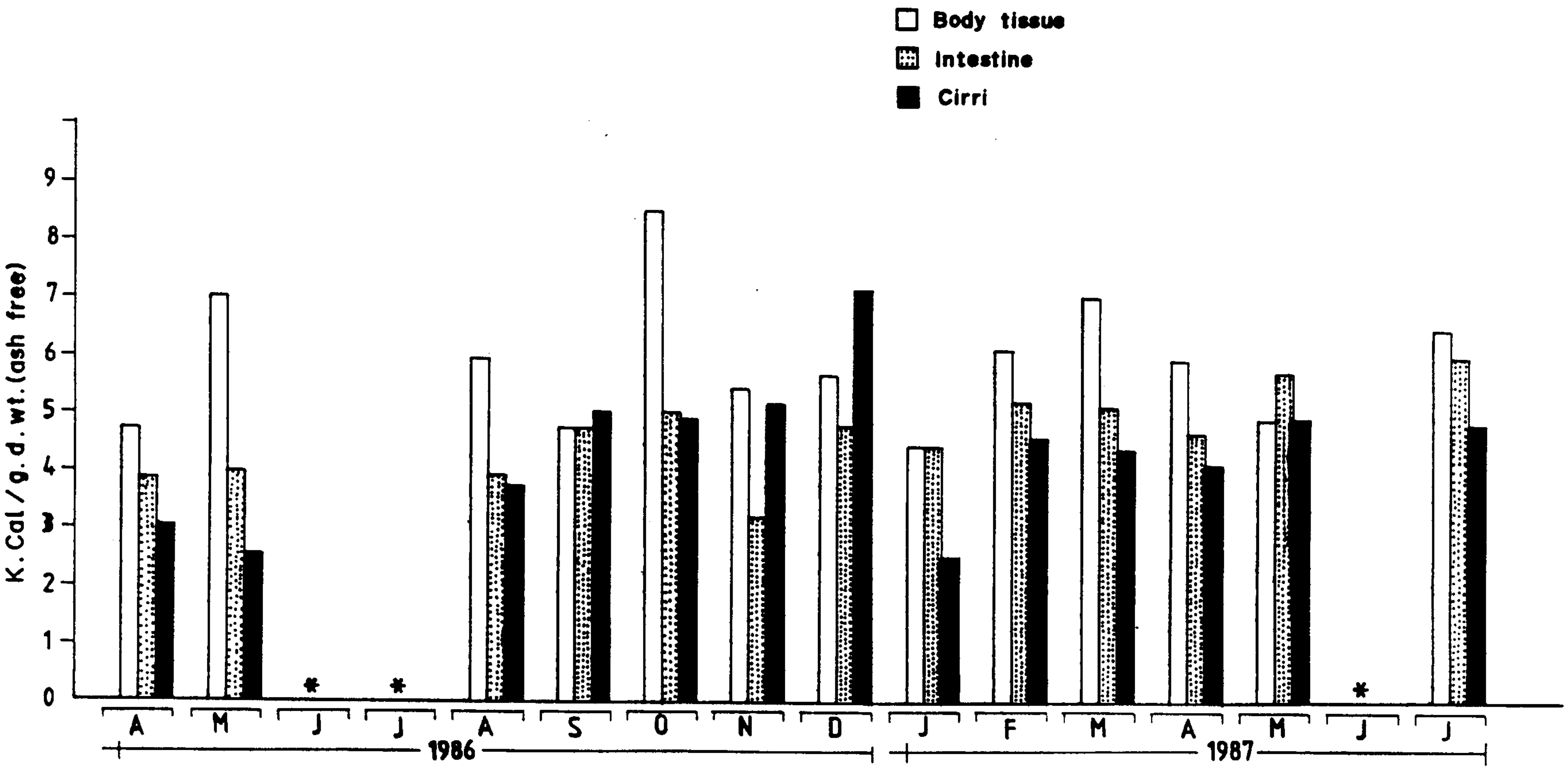

Fig. 37. Monthly distribution of Calorific content in different tissues of B. tintinnabulum (RCB 30-40 mm)

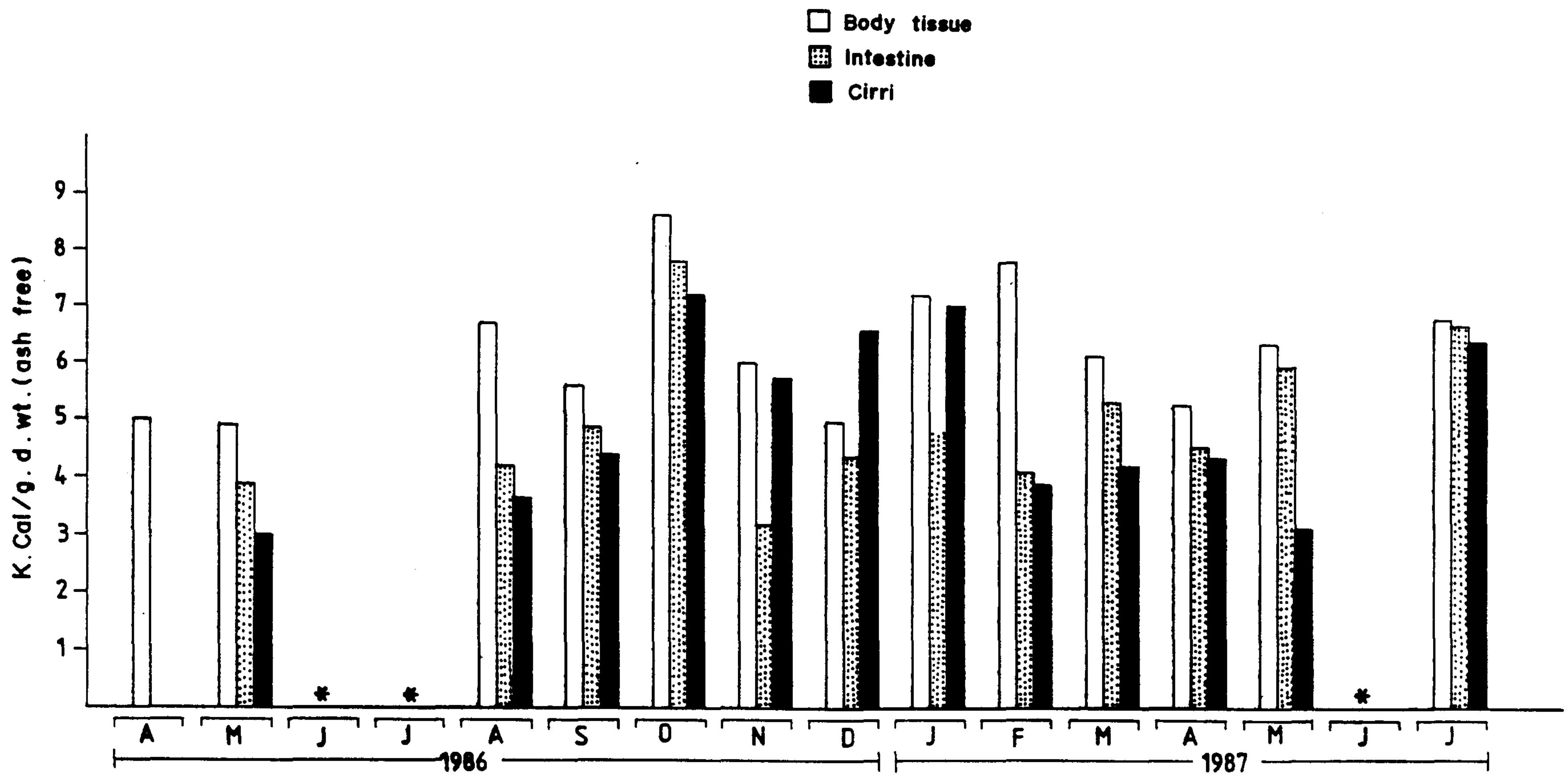

Fig. 38. Monthly distribution of Calorific content in different tissues of B. tintinnabulum (RCB above 40 mm)

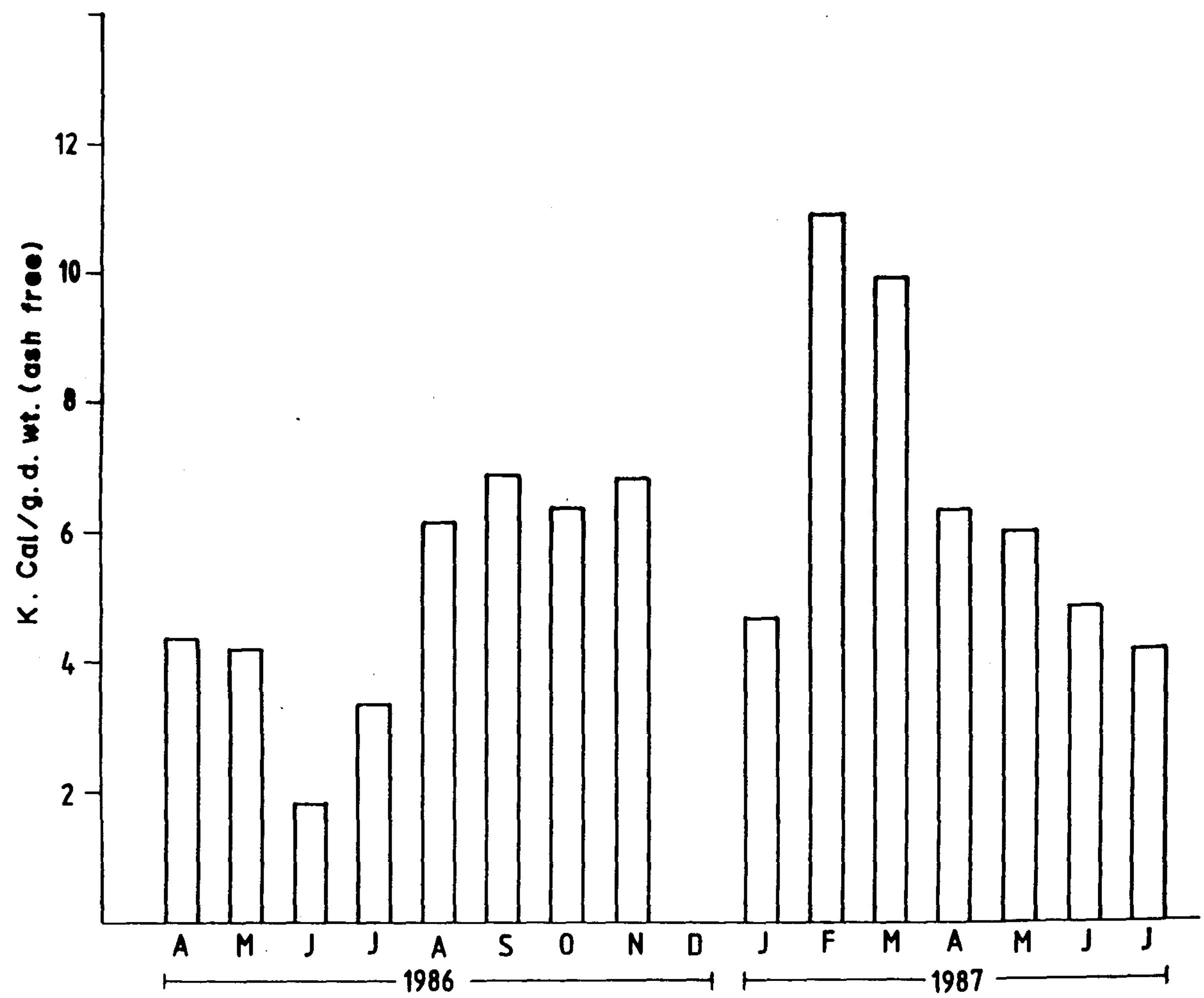

Fig. 39. Monthly distribution of Calorific content in zooplankton sample at Harbour.

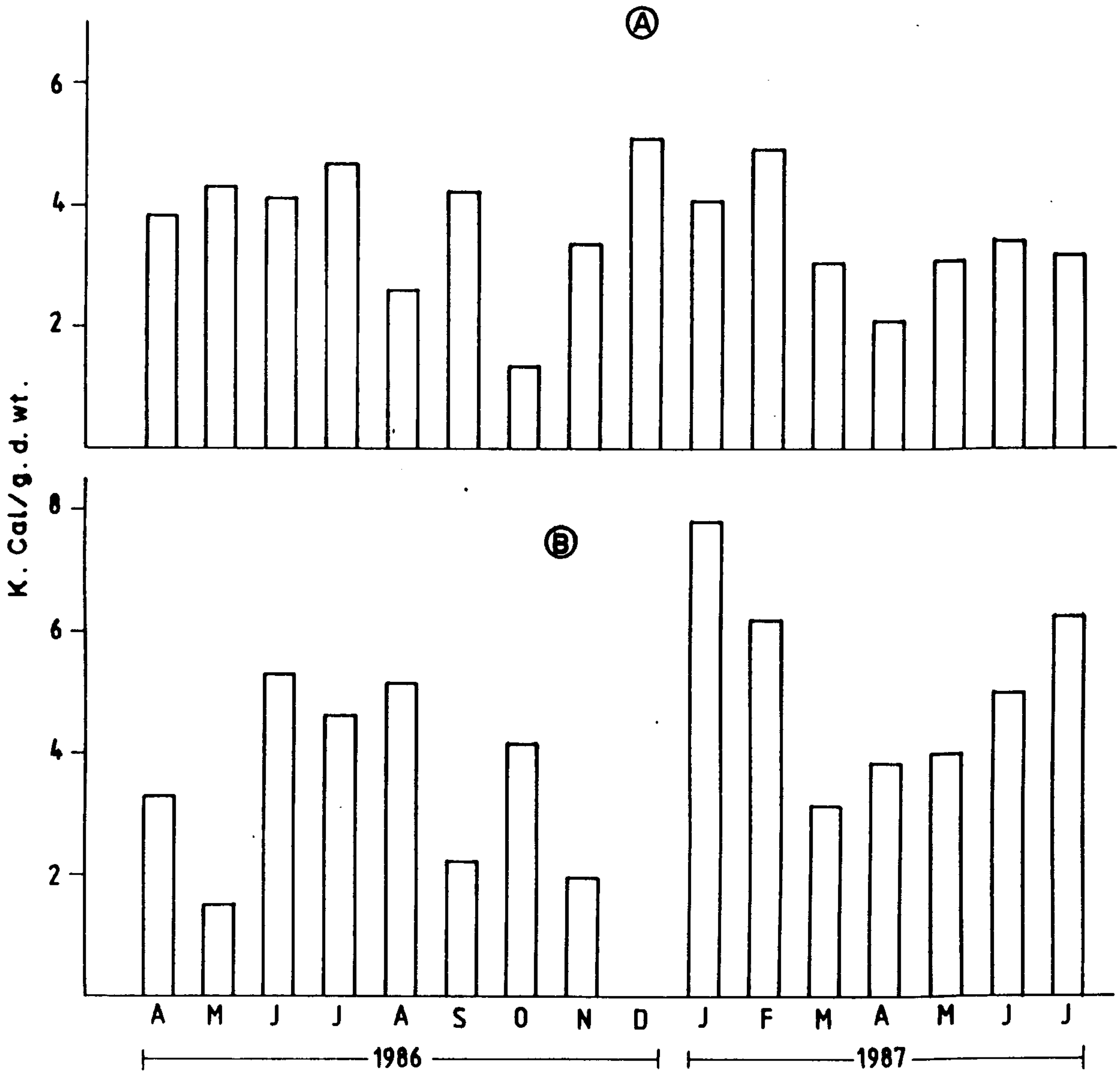

Fig. 40. Monthly distribution of Calorific content in suspended matter at Ⓐ Harbour and Ⓑ Dona Paula.

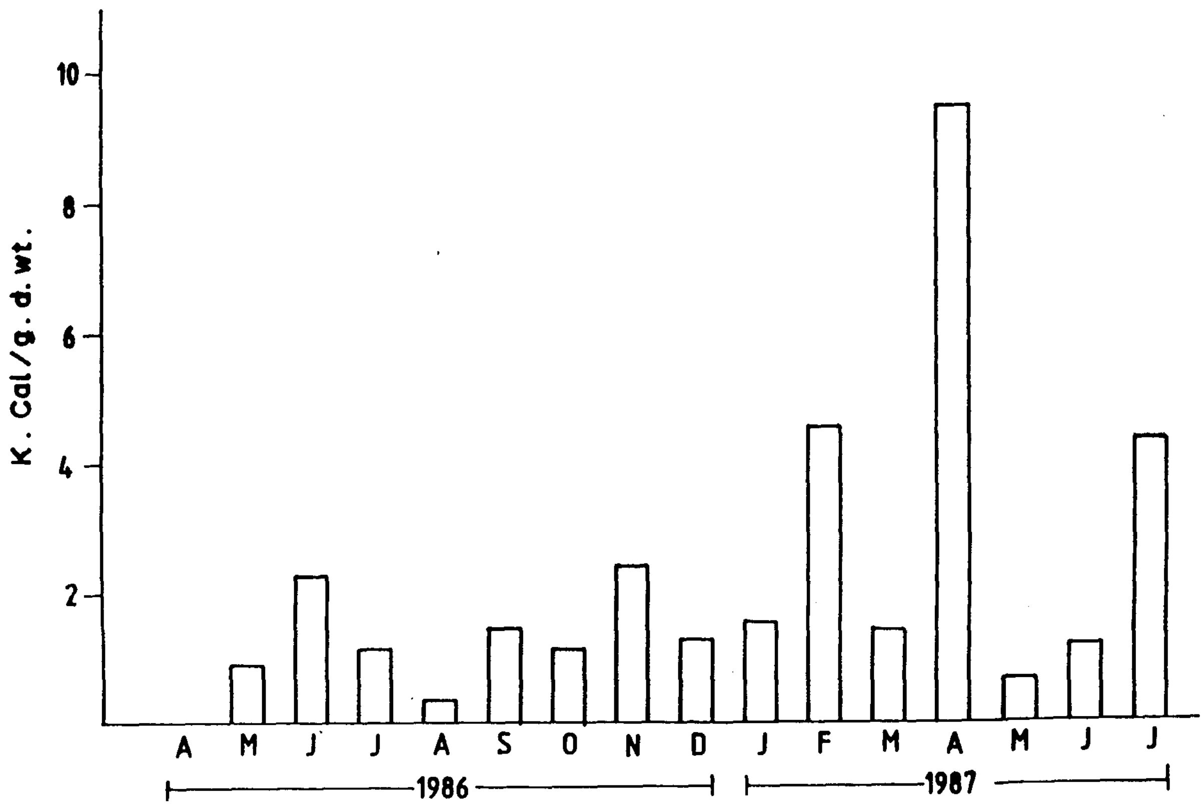

Fig.41. Monthly distribution of Calorific content in suspended matter at Arambol.

CHAPTER V

BIOCHEMICAL COMPOSITION

Studies on the biochemical components such as total carbohydrate, protein and lipid are very important in the calorific distribution studies, since these are the primary biochemical compounds which provide energy for the living organisms (Crisp, 1984 a). Workers from different parts of the world have calculated the calorific content by using specific energy equivalents for carbohydrate, protein and lipid (Brody, 1945). They are:

Component	Calorific content K. cal/g.
Carbohydrate	4.10
Protein	5.65
Lipid	9.45

It is evident that, lipid is laiden with high energy reserve than other two components. In order to get a complete account of total carbon content of the soft tissues, estimation of the total organic carbon of the soft tissue of barnacles was also carried out in all the samples. This data has also been treated along with the biochemical compounds such as carbohydrate, protein and lipid of the barnacles in the following section.

The reports regarding the biochemical composition of barnacles and its seasonal cycle from India as well as from the rest of the world are scanty. Some of the reports on the study of seasonal cycle of biochemical composition of barnacles dates back to 1960 (Barnes *et al*, 1963; Cook & Gabbott, 1970, 1972; Cook *et al*, 1972). The important studies on the biochemical composition of eggs and larvae of barnacles include Holland & Hannant, 1973; Pandian, 1969; Barnes, 1965.

The seasonal changes in the biochemical composition of invertebrates are related to the reproductive cycle (Giese, 1969), gonadial production of the organism (Barnes *et al*, 1963) and the temperature (Cook & Gabbott, 1972). So, in order to have a clear picture of distribution of calorific content and biochemical composition of barnacles monthly observations on different barnacle species such as *B. amphitrite*, *B. amaryllis*, *B. tintinnabulum* and *Chthamalus* sp. collected from three stations were carried out for a period of 16 months from April, 1986 to July, 1987. The organisms were grouped separately according to size (Rostro Carinal Basal diameter, RCB) maturity (mature

& immature) and tissue wise (in *B. tintinnabulum*). The data are presented with the help of 20 graphs and 20 tables. The calorific content through the calorific eqivalents of biochemical compounds was also calculated and presented in each section.

B. AMPHITRITE

Harbour:

In order to get the general concentration of biochemical compounds in *B. amphitrite*, the whole animal irrespective of size and maturity were taken for the analysis.

Carbohydrate (Table 32, Fig. 42):

The concentration of carbohydrate in *B. amphitrite* showed a minimum value of 30.75 µg/mg.d.wt in the month of February, 1987 and a maximum value of 79.66 µg/mg.d.wt. in the month of July, 1987. In general a typical seasonal cycle could not be seen in the carbohydrate distribution. Though a comparatively lower concentration was observed in 1986 monsoon period, the same trend could not be seen in the next monsoon period.

The mean concentration of carbohydrate during the entire period of analysis in _B. amphitrite_ was 53.56 µg/mg.d.wt. i.e. 5.36%.

Protein:

The concentration of protein varied from 189.84 µg/mg.d.wt. to 295.85 µg/mg.d.wt. in the months of July, 1987 and March, 1987 respectively. The distribution of protein showed a marginal effect of monsoon with a decrease in concentration during the monsoon months in both the years, 1986 and 1987. The mean concentration of protein during the study was 233.16 µg/mg.d.wt. (23.31%) which was a slightly lower value as compared to mussels and oysters.

Lipid:

The mean lipid concentration during the analysis showed a lower value 34.13 µg/mg.d.wt (3.41%) as compared with the other invertebrates. The concentration of lipid varied from 18.87 to 63.52 µg/mg.d.wt. during the months of January, 1987 and March, 1987 respectively. A definite trend in distribution with the change in season could not be seen, but the maximum value of lipid coincided with the maximum value of protein, which was observed in the same month, March, 1987.

Organic carbon:

The concentration of organic carbon varied from 341.01 to 499.85 µg/mg.d.wt. during the months of April, 1986 and September, 1986 respectively. A definite seasonal trend could not be seen in the distribution, but, a slightly decreased concentration was noticed during the monsoon months. The mean value of organic carbon during the study (387.78 (38.78%) µg/mg.d.wt.) was a lower value as compared to other marine invertebrate organisms.

Calorific content:

Calorific values as calculated from biochemical equivalents showed comparatively lower concentration as compared to the values measured directly through calorimeter. The maximum value of 2491.82 cal/g.d.wt. was observed during a premonsoon month, March, 1987 and minimum value, 1591.77 cal/g.d.wt. during the month of April, 1986. A seasonal trend could not be seen in the distribution.

DISTRIBUTION OF BIOCHEMICAL COMPOUNDS OF MATURE *B. AMPHITRITE* (Table 33, Fig. 43)

Carbohydrate:

During the period of study, the carbohydrate content of mature *B. amphitrite* varied between 31.57 to 89.52 µg/mg.d.wt. in the months of February, 1987 and November, 1986 respectively. In general, the carbohydrate concentration in mature forms showed a higher value than that of the whole animal at various stages of maturity and size. Seasonal trend was not evident in the monthly distribution data.

Protein:

The concentration of protein varied from 209.04 to 309.81 µg/mg.d.wt. in the months of October, 1986 and March, 1987 respectively. The seasonal studies showed a moderate effect of monsoon on the protein concentrations marked by the decreased values in the monsoon seasons of 1986 and 1987. The mean concentration was higher than that of the general concentration of protein in *B. amphitrite*.

Lipid:

The concentration of lipid during the study varied from 12.70 to 51.43 µg/mg.d.wt. during the months of February, 1987 and May, 1987 respectively. Lipid content did not show much variation with the state of maturity and seasons. The mean concentration of lipid during the study period was 33.24 µg/mg.d.wt. i.e. 3.32%.

Organic Carbon:

Organic carbon concentration during the study varied from 339.48 to 537.98 µg/mg.d.wt. in the months of April, 1986 and November, 1986 respectively. The mean organic carbon concentration showed an increase over the general organic carbon concentration of *B. amphitrite*. The seasonal distribution showed a decreased concentration during the two monsoon seasons of 1986 and 1987.

Calorific values:

The calorific values as calculated from the biochemical equivalents, showed a variation of 1588.20 cal/g.d.wt. to 2400.97 cal/g.d.wt. during the months of April, 1986 and March, 1987 respectively. A seasonal trend in the distribution could not be seen in the data.

DISTRIBUTION OF BIOCHEMICAL COMPOUNDS IN IMMATURE B. AMPHITRITE (Table 34, Fig. 44)

Carbohydrate:

The concentration of carbohydrate in immature forms of *B. amphitrite* during the study varied from 30.73 to 79.01 µg/mg.d.wt. during the months of February, 1987 and July, 1987 respectively. The mean concentration of carbohydrate was lesser than that of the mature forms. Data on monthly distribution did not exhibit a seasonal trend. The average concentration of carbohydrate during the study was 50.41 µg/mg.d.wt. (5.04%).

Protein:

The protein concentration during the study was found to be varying from 190.02 µg/mg.d.wt. in July, 1987 to 288.67 µg/mg.d.wt. in March, 1987. The average concentration of protein (228.19 µg/mg.d.wt.) was lower than the concentration of protein in the mature forms. Regarding the seasonal variations, comparatively lower values were observed during the monsoon seasons of 1986 and 1987 as compared to the rest of the seasons studied.

Lipid:

The average concentration of lipid during the study was 36.26 µg/mg.d.wt. The minimum concentration of 23.38 µg/mg.d.wt. was observed in July, 1986 and maximum value of 73.28 µg/mg.d.wt. was observed in March, 1987. This increased concentration of lipid coincided with the increased concentration of protein in these forms and the trend of increased concentration during the month of March, 1987 was noticed in the mature forms also. A comparatively lower value of lipid could be observed during the monsoon seasons in the years 1986 and 1987.

<u>Organic carbon</u>:

The organic carbon concentration during the study varied between 273.54 µg/mg.d.wt. and 544.28 µg/mg.d.wt. in the months of July, 1986 and September, 1986 respectively. Distinct seasonal trend was not evident in the data. While there was a decrease in concentration during the monsoon in 1986, the same trend was not observed during the monsoon in the year 1987. The average concentration of organic carbon was 377.40 µg/mg.d.wt. which is a lower value than that of mature forms.

<u>Calorific content</u>:

Calorific content showed a range of value of 1387.88

cal/g.d.wt. to 2527.17 cal/g.d.wt. during the months of September, 1986 and March, 1987 respectively. The increased value in the month of March, 1987 corresponded with the increased concentration of protein and lipid in this month. In the distribution pattern a definite seasonal trend could not be noticed.

DISTRIBUTION OF BIOCHEMICAL COMPOUNDS IN B. AMPHITRITE SIZE GROUP RCB ABOVE 10 mm (Table 35, Fig. 45)

Carbohydrate:

Carbohydrate concentration showed a marginally increased concentration during the premonsoon periods in 1986 and 1987. The maximum value of carbohydrate was observed in July, 1987 (81.73 µg/mg.d.wt.) and the minimum value in February, 1987 (32.12 µg/mg.d.wt.). Effect of monsoon on carbohydrate distribution was not evident in the data. The average concentration of carbohydrate during the study was 55.19 µg/mg.d.wt.

Protein:

The distribution of protein content in this size group showed a definite trend with the change in seasons. An increased value in the premonsoon period 1986 was followed by a decreased concentration in the monsoon period 1986 with an exception in the month of September, 1986. This decreasing tendency was continued in the postmonsoon season also. The ending of postmonsoon and the beginning of premonsoon season (January, 1987 & February – May, 1987) registered an increase in concentration. But by the onset of monsoon, 1987 again the concentration decreased. The average value of protein during the study was 241.03 µg/mg.d.wt.

Lipid:

The maximum value of lipid during the observation was found to be 64.31 µg/mg.d.wt. and the minimum 15.69 µg/mg.d.wt. in the months of March, 1987 and January, 1987 respectively. Despite this, a definite trend in the distribution with the change in season was not observed in the data. The average lipid content during the study was 36.47 µg/mg.d.wt.

Organic carbon:

The values of organic carbon varied from 340.98 µg/mg.d.wt. to 440.45 µg/mg.d.wt. in the months April, 1986 and September, 1986 respectively. An increasing tendency in the values of this parameter could be observed in the postmonsoon season 1987. The average value of oganic carbon during the study in this group was 376.30 µg/mg.d.wt.

Calorific value:

Calorific value as calculated from the biochemical equivalents showed a variation from 1694.03 cal/g.d.wt. to 2550.15 cal/g.d.wt. in the months of July, 1986 and March, 1987 respectively. Any definite pattern in the distribution was not evident in the data.

DISTRIBUTION OF BIOCHEMICAL COMPOUNDS IN *B. AMPHITRITE* OF SIZE GROUP RCB BELOW 10 mm (Table 36, Fig. 46)

Carbohydrate:

The distribution of carbohydrate in this group did not show any definite pattern with the change in seasons. The maximum value of 73.54 µg/mg.d.wt. was observed in the month of April, 1987 (a premonsoon month) and the minimum value of 28.58 µg/mg.d.wt. was observed in the month of February, 1987 (also a premonsoon month). The average concentration of carbohydrate during the study was

51.26 µg/mg.d.wt. which was lower as compared to that in the larger size group (RCB above 10 mm).

Protein:

The monthly distribution pattern of protein showed a seasonal trend. A slight decrease in concentration was observed during the monsoon period 1986 as compared to the premonsoon period 1986. With the beginning of premonsoon period 1987, the concentration of protein increased and again during the monsoon period it decreased. The concentrations were found to be between 183.36 µg/mg.d.wt. in the month of November, 1986 and 292.67 in the month of April, 1987. The average value of 218.63 µg/mg.d.wt. was a much lower value as compared to the average concentration of this component in the larger size group (RCB above 10 mm).

Lipid:

The concentration of lipid contents varied from 12.06 to 72.18 µg/mg.d.wt. in the months of January, 1987 and March, 1987 respectively. A definite trend could not be seen in the monthly distribution data. The average concentration of lipid during the study was observed to be

30.56 μg/mg.d.wt., which was lower as compared to the value of lipid contents in larger size group of the same species.

Organic carbon:

Organic carbon distribution did not show any significant pattern with change in seasons. Nevertheless, during the monsoon period 1986 very high organic carbon content were observed. The concentration varied between 348.17 and 589.13 μg/mg.d.wt. which were the values observed in the months of March, 1987 and September, 1986 respectively. The average value during the study was 405.56 μg/mg.d.wt. which was a higher value than that found in the earlier size group studied.

Calorific content:

The calorific content showed a variation of 1341.62 cal/g.d.wt. to 2489.05 cal/g.d.wt. in the months of July, 1987 and March, 1987 respectively. The increased concentration in the month of March, 1987 seems to be a common phenomenon, since all groups of *B. amphitrite* (size wise and maturity wise) harboured a higher value in the month of March, 1987. Despite this, a seasonal trend could not be seen in the data.

DONA PAULA: B. AMPHITRITE (Table 37, Fig. 47)

Carbohydrate:

The monthly distribution of carbohydrate showed a variation of 36.25 µg/mg.d.wt. in June, 1986 to 67.10 µg/mg.d.wt. in the month of March, 1987. In general, the monsoon season 1986 showed a reduced concentration of carbohydrate contents compared to the premonsoon seasons of 1986 and 1987. Inspite of these variations no distinct difference in the data corresponding with seasons could be noticed. The average carbohydrate concentration during the study was 52.81 µg/mg.d.wt.

Protein:

Protein distribution in *B. amphitrite* at Dona Paula showed higher values during the premonsoon seasons of 1986 & 1987. The maximum value was observed in April, 1987 (281.28 µg/mg.d.wt.) and the minimum in July, 1986 (180.22 µg/mg.d.wt.). A reduced concentration in the post monsoon period could be due to the continued effect of the monsoon period of 1986. The average value of protein during the study was 222.22 µg/mg.d.wt.

Lipid:

The concentration of lipid content varied from 25.40 µg/mg.d.wt. to 49.69 µg/mg.d.wt. in the months of July, 1986 and December, 1986 respectively. Despite the lower concentration during 1986 monsoon, it remained more or less same in the remaining months of the study period. The average value of lipid during the study was observed as 33.86 µg/mg.d.wt.

Organic carbon:

The values of organic carbon concentration varied from 317.70 to 438.17 µg/mg.d.wt. during the months of June, 1987 and April, 1987 respectively. The distribution pattern of organic carbon showed an increase in concentration followed by a decrease during the premonsoon and postmonsoon periods of 1986. The latter part of monsoon months indicated a higher concentration. But the premonsoon period 1987 showed the highest concentration of organic carbon. The average value of organic carbon concentration during the study was recorded as 368.26 µg/mg.d.wt.

Calorific value:

The calorific value as calculated from the biochemical equivalents showed a variation from 1410.63 cal/g.d.wt. to 2173.28 cal/g.d.wt. and these values were found during the months of July, 1986 and March, 1987 respectively. Rest of the months recorded more or less stable concentration.

B. AMPHITRITE MATURE (Table 38, Fig. 48)

Carbohydrate:

The distribution pattern of carbohydrate contents showed increased concentration during the premonsoon periods of 1986 and 1987 and a reduced concentration during the monsoon of 1986. The maximum concentration observed was 81.26 µg/mg.d.wt. in April, 1986 and the minimum of 31.77 µg/mg.d.wt. in December, 1986. The average concentration during the study was 49.98 µg/mg.d.wt.

Protein:

The protein concentration during the study period varied between 151.91 µg/mg.d.wt. to 308.81 µg/mg.d.wt. in the months of July, 1986 and April, 1987 respectively. A tendency of increasing concentration during the premonsoon period 1987 could be observed. The monsoon season of 1986 recorded a decreased value and the average concentration during the study was noticed as 219.96 µg/mg.d.wt.

Lipid:

A definite pattern of distribution with change in season could not be recorded in the monthly distribution of lipid contents. The values of lipid concentration during the study varied between 19.25 µg/mg.d.wt. and 48.26 µg/mg.d.w.t which were observed during the months of June, 1986 and July, 1987 respectively. The average concentration of lipid during the study was 30.95 µg/mg.d.wt.

Organic carbon:

The concentration of organic carbon varied from 258.47 to 446.37 µg/mg.d.wt. during the months of June, 1986 and September, 1986 respectively. A decreased concentration of organic carbon during postmonsoon 1986 was followed by an increased concentration of organic carbon during premonsoon 1987. The average concentration during the study was estimated to be 365.70 µg/mg.d.wt.

Calorific value:

The calorific value as calculated from the biochemical equivalents ranged from 1281.90 cal/g.d.wt. in the month of July, 1986 to 2218.60 cal/g.d.wt. in the month of April, 1987. The calorific values showed an increase after the month of March, 1987 till the end of the study.

B. AMPHITRITE IMMATURE (Table 39, Fig. 49)

Carbohydrate:

The carbohydrate concentration in the immature forms of *B. amphitrite* showed a variation of 24.36 µg/mg.d.wt. to 65.50 µg/mg.d.wt. during the months of June, 1986 and June, 1987 respectively. No seasonal trend was observed in the monthly data. The average value for the study period was 50.28 µg/mg.d.wt.

Protein:

The distribution of protein revealed the lowest value of 187.97 µg/mg.d.wt. in the month of November, 1986 and the maximum value of 305.85 µg/mg.d.wt. in the month of July, 1987 respectively. Any specific trend in the distribution pattern could not be observed in the data. The mean value of protein during the entire period of study was observed as 229.61 µg/mg.d.wt.

<u>Lipid</u>:

During the study period the concentration of lipid varied between 25.27 µg/mg.d.wt. (February, 1987) to 54.12 µg/mg.d.wt. (November, 1986) As regards the distribution pattern, monsoon seasons recorded lower concentration of lipid as compared to the rest of the seasons. The average value of lipid for the entire period of study was 38.68 µg/mg.d.wt.

<u>Organic carbon</u>:

The organic carbon concentration varied between 329.88 µg/mg.d.wt. in June, 1986 and 454.10 µg/mg.d.wt. in April, 1987. A lower concentration during the monsoon 1986 was followed by a marginally higher values during the post- and premonsoon seasons culminating into a lowest concetration by the beginning of monsoon 1987. The average concentration for the study was 377.16 µg/mg.d.wt.

<u>Calorific value</u>:

Calorific content as calculated from the biochemical equivalents showed a variation of 1624.84 cal/g.d.wt. to 2263.68 cal/g.d.wt. during the months of June, 1986 and July, 1987 respectively. Any seasonal trend could not be seen in the distribution pattern.

<u>B. AMPHITRITE</u> (RCB ABOVE 10mm) (Table 40, Fig. 50)

<u>Carbohydrate</u>:

The concentration of carbohydrate varied from 35.67 µg/mg.d.wt. recorded in July, 1986 to 84.12 µg/mg.d.wt. found in August, 1986. A reduced concentration of carbohydrate content was observed during monsoon 1986 and a moderately higher concentration was observed during the rest of the study period. The average values of carbohydrate concentration for the entire period of study was 58.47 µg/mg.d.wt.

<u>Protein</u>:

The distribution pattern of protein concentration showed increased values during both the premonsoon periods. The monsoon seasons of 1986 and 1987 showed low protein concentrations. The values ranged from 151.91 µg/mg.d.wt. to 311.73 µg/mg.d.wt.. They were observed in the months of July, 1986 and March, 1987 respectively. The average value of protein during the study was 231.10 µg/mg.d.wt.

<u>Lipid</u>:

A more or less similar pattern of distribution as found in protein was observed in the case of lipid also. The lowest concentration of 19.25 µg/mg.d.wt. was observed in June, 1986 and the highest value of 57.26 µg/mg.d.wt. observed in the month of December, 1986. The average value of lipid during the study was 35.12 µg/mg.d.wt.

<u>Organic Carbon</u>:

The organic carbon concentration during the period of study varied from 310.05 µg/mg.d.wt. to 446.37 µg/mg.d.wt. These values were found in the months of December, 1986 and September, 1986 respectively. A definite trend of distribution of organic carbon with season could not be percieved in the data. The average organic carbon content during the study was 379.75 µg/mg.d.wt.

Calorific content:

The highest and the lowest values of calorific content calculated from the biochemical equivalents were 1281.90 cal/g.d.wt. to 2375.67 cal/g.d.wt. during the months of July, 1986 and March, 1987 respectively. A definite trend with the season was not found in the data.

B. AMPHITRITE (RCB BELOW 10 mm) (Table 41, Fig. 51)

Carbohydrate:

The maximum and minimum concentrations of carbohydrate varied from 38.64 to 78.33 µg/mg.d.wt. during the months of July, 1986 and June, 1987 respectively. The distribution pattern showed a reduced concentration during the monsoon 1986 followed by an increased concentration in postmonsoon 1986 and premonsoon 1987. The average concentration of carbohydrate during the study was 52.27 µg/mg.d.wt.

Protein:

The protein concentration showed more or less similar mode of distribution as that of carbohydrate except for some lower values, which were observed during the months of November and December, 1986 as well as June and July, 1987. The highest value was recorded in the month of March, 1987 (281.06 µg/mg.d.wt.) and the lowest value in the month of June, 1987 (154.66 µg/mg.d.wt.). The average value of protein during the study was 216.31 µg/mg.d.wt.

Lipid:

The lipid concentration during the study varied from 21.44 to 69.33 µg/mg.d.wt. which were the observations made during the months of July, 1986 and June, 1987 respectively. Large variation with change in season was not present in the data. The average concentration during the study was 32.57 µg/mg.d.wt.

Organic carbon:

The organic carbon distribution did not show any definite trend with respect to the seasons. Nevertheless, during monsoon season in 1987 the concentration was low as compared to that of the postmonsoon 1986 and premonsoon 1987. The average value for this group during the study was 350.62 µg/mg.d.wt. The concentration during the study varied between 250.80 and 452.60 µg/mg.d.wt. in the months of June, 1987 and April, 1987 respectively.

Calorific values:

The calorific values varied from 1539.28 cal/g.d.wt. to 2214.36 cal/g.d.wt. during the months July, 1986 and March, 1987 respectively. A definite seasonal trend could not be seen in the data.

HARBOUR *B. AMARYLLIS* (Table 42, Fig. 52)

B. amaryllis samples for biochemical analysis could only be collected for a period of seven months during the study due to its patchy nature of distribution and nonavailability in sufficient number at the Harbour station. Biochemical studies on *B. amaryllis* with respect to size and maturity could not be carried out due to the above reasons.

Carbohydrate:

The concentration of the carbohydrate varied from 35.50 µg/mg.d.wt. to 150.13 µg/mg.d.wt in the months of

July, 1986 and October, 1986 respectively. The average concentration of carbohydrate in this species during the tudy was 82.74 μg/mg.d.wt.

Protein:

The protein concentration varied from 174.24 to 265.71 μg/mg.d.wt. during the months of July, 1987 and July, 1986 respectively. The average concentration during the entire study period was 222.34 μg/mg.d.wt.

Lipid:

The distribution of lipid concentration showed a lowest value of 9.31 μg/mg.d.wt in the month of October, 1986 and highest value of 28.54 μg/mg.d.wt. in the month of June, 1987 respectively. The average concentration of lipid during the study was 21.49 μg/mg.d.wt.

Organic carbon:

A comparatively high organic carbon concentration was recorded in *B. amaryllis* with respect to the other species studied. The concentration varied from 358.02 μg/mg.d.wt in the months of August and September, 1986 to 586.77

µg/mg.d.wt in the month of July, 1987. The average concentration during the study was 440.22 µg/mg.d.wt. This was higher than the average values of organic carbon observed in B. amphitrite from Harbour and Dona Paula.

Calorific values:

The calorific values during the study showed a variation of 1677.46 cal/g.d.wt. to 2049.29 cal/g.d.wt. during the months of June, 1987 and October, 1986 respectively.

DONA PAULA: CHTHAMALUS SP. (Table 43, Fig. 53)

Carbohydrate:

The carbohydrate content showed a maximum concentration of 92.95 µg/mg.d.wt. in July, 1987 and a minimum of 28.42 µg/mg.d.wt. in December, 1986. The pattern of distribution did not show any seasonal trend. The average concentration of carbohydrate during the study was 49.65 µg/mg.d.wt.

Protein:

The distribution of protein showed low values during the monsoon seasons of 1986 and 1987. The premonsoon and postmonsoon seasons recorded comparatively higher values than the rest. The concentration of protein varied from 102.43 µg/mg.d.wt to 190.32 µg/mg.d.wt. during the months of May, 1986 and November, 1986 respectively. The average value of protein during the study was 151.20 µg/mg.d.wt.

<u>Lipid</u>:

The concentration of lipid contents varied from 15.76 µg/mg.d.wt. to 41.29 µg/mg.d.wt. during the months of June, 1986 and June, 1987 respectively. A definite trend could not be seen in the data with the change in seasons. The average value of lipid during the present study was 26.94 µg/mg.d.wt.

<u>Organic carbon</u>:

During the study period, wide fluctuations in the concentration of organic carbon were observed. Eventhough, a definite trend with the change in season could not be inferred from the data, a much reduced value of organic carbon could be observed during the monsoon and the premonsoon seasons. The values ranged between 155.45 µg/mg.d.wt. to 414.89 µg/mg.d.wt. in the months of May, 1986 and April, 1987 respectively. The average concentration during the study period was 294.08 µg/mg.d.wt.

Calorific content:

Calorific content of Chthamalus sp. ranged between 892.96 cal/g.d.wt. to 1867.98 cal/g.d.wt. during the months of May, 1986 and July, 1987 respectively. These values were much smaller than the values of calorific contents for B. amphitrite and B. amaryllis.

ARAMBOL: CHTHAMALUS SP. (Table 44, Fig. 54)

Carbohydrate:

Comparatively lower concentration of carbohydrate was observed in the months of June, July and September, 1986 (monsoon period). Beginning of postmonsoon was marked with rich concentration which was continued to the premonsoon, 1987 also. The months of June and July, 1987 were marked with reduced concentrations. During the study, the values varied from 31.73 µg/mg.d.wt. to 73.68 µg/mg.d.wt. in the months of July, 1986 and May, 1987 respectively. The average concentration during the study was 52.14 µg/mg.d.wt.

Protein:

The distribution pattern of protein during the study followed more or less a similar trend as that of carbohydrate. Here also, the months of June and July, 1986 were marked with lower concentration but it increased thereafter in the post- and premonsoon periods. But with the onset of monsoon 1987, again the concentration showed decrease in values. Postmonsoon season harboured the highest concentration during the entire study period i.e. in September, October & November, 1986 the concentrations were 247.60, 215.17 and 228.74 µg/mg.d.wt. respectively. During the study, the concentrations varied between 154.38 µg/mg.d.wt. and 247.60 µg/mg.d.wt. which were observed in the months of July, 1986 and September, 1986 respectively. The mean value of protein during the study was 201.72 µg/mg.d.wt.

Lipid:

A definite correlation between the values of the lipid concentration with the change in season could not be seen. Lower oncentration of lipid content was recorded during the monsoon months of 1986. But this could not be seen during the monsoon months of 1987. During the study the concentration of lipid content varied between 15.91 to 52.78 µg/mg.d.wt. during the months of September, 1986 & April, 1987 respectively. The average concentration of lipid during the study was 31.71 µg/mg.d.wt.

Organic Carbon:

A typical effect of monsoon and change in seasons were represented in this data. The high concentration was observed in the premonsoon period, 1986 (April and May, 1986) which was followed by a lower concentration in the monsoon months. The lowest concentration of organic carbon was observed in the monsoon month, June, 1986 (245.85 µg/mg.d.wt.). The highest value of 409.35 µg/mg.d.wt. was observed in October, 1986. The concentration was more or less same during the premonsoon 1987 but it dropped down as the monsoon (1987) approached. The average value of organic carbon during the study was 321.41 µg/mg.d.wt.

Calorific content:

The calorific content ranged between 1261.52 cal/g.d.wt. to 2105.39 cal/g.d.wt.. These observations were made during the months of June, 1986 and April, 1987 respectively. The pattern of distribution did not show the effect of change in season as in the case of protein and organic carbon.

B. TINTINNABULUM (GENERAL) (Table, 45 Fig. 55)

During the study, four months of data i.e. June, July & November, 1986 and June 1987 could not be obtained due to the nonavailability in required quantity and/or the collection could not be made due to the rough weather which prevailed at the time of collection.

Carbohydrate:

The data on carbohydrate contents showed a lower concentration during the monsoon months as compared to the rest of the study period. The average carbohydrate content during the study was found to be 65.05 µg/mg.d.wt. This value was higher as compared to that of B. amphitrite and Chthamalus sp. The maximum concentration was observed during postmonsoon period 1987. The values ranged between 34.39 and 85.91 µg/mg.d.wt. which were observed in the months of August, 1986 and February, 1987 respectively.

Protein:

A pattern of low protein values during the monsoon season was observed. The postmonsoon months and the premonsoon months recorded increased concentrations as compared to the monsoon months. The highest concentration was observed during September, 1986 (292.20 µg/mg.d.wt.) and the minimum in the month of July, 1987 (207.72 µg/mg.d.wt.). The average value of the protein concentration during the study was 247.75 µg/.mg.d.wt.

Lipid:

The distribution of lipid did not show any definite trend with the change in seasons. The concentration of lipid varied from 18.27 to 42.61 µg/mg.d.wt.. These values were observed during the months of May, 1986 and January, 1987 respectively. The average concentration of lipid during the study was 28.41 µg/mg.d.wt., which was a lower value as compared to the other species studied.

Organic carbon:

The distribution of organic carbon followed a pattern of lower concentration during the monsoon season and higher concentration during the post-and premonsoon seasons. The higher values of 513.27 and 517.23 µg/mg.d.wt. were observed during the months of September and October, 1986 respectively. The lowest value during the observation was 277.61 µg/mg.d.wt. which was recorded in the month of August, 1986. The average value of organic carbon during the study was 389.94 µg/mg.d.wt.

Calorific value:

The trend in the distribution of protein and organic carbon was evident in the calorific content distribution also. The lower value of 1655.30 cal/g.d.wt. was observed during the month of July, 1987 and the highest value of 2238.02 cal/g.d.wt. was recorded during the month of September, 1986.

B. TINTINNABULUM (RCB ABOVE 40 mm) (Table 46, Fig. 56)

The individuals of *B. tintinnabulum* with RCB above 40 mm were analysed separately for the biochemical compounds. Some months of data were not available due to the nonavailability of this particular size group of organisms in sufficient quantity.

Carbohydrate:

The carbohydrate concentration during the study varied from 56.22 to 88.42 µg/mg.d.wt. during the months of July, 1987 and February, 1987 respectively. The only one observation during the monsoon period 1987 (July 1987) showed a reduced value of 56.22 µg/mg.d.wt. The average concentration during the study period was 74.04 µg/mg.d.wt.

Protein:

The protein concentration during the study varied between 212.59 to 266.71 µg/mg.d.wt. which were recorded during the months of May, 1986 and October, 1986 respectively. More or less a similar concentration was observed during the entire sampling period. The average value of protein during the study was 247.03 µg/mg.d.wt.

Lipid:

The lipid concentration varied between 18.27 to 40.48 µg/mg.d.wt. in the months of May, 1986 and January, 1987 respectively. Hardly any effect of the change in season could be observed in the data. The average value of lipid concentration during the study period was 26.93 µg/mg.d.wt.

<u>Organic carbon</u>:

The organic carbon concentration during the study period varied between 281.93 µg/mg.d.wt. to 500.52 µg/mg.d.wt. These observations were made in the months of April, 1987 and December, 1986 respectively. Except two high values of organic carbon concentrations during the months of October and December, 1986, the concentraions remained more or less same during the rest of the period. The average value of organic carbon during the study was 406.24 µg/mg.d.wt.

<u>Calorific content</u>:

The values of calorific content varied from 1699.57 cal/g.d.wt. to 2098.24 cal/g.d.wt. during the months of May 1986 and December, 1986 respectively.

<u>B. TINTINNABULUM</u> (RCB 30 - 40 mm) (Table, 47 Fig. 57)

<u>B. tintinnabulum</u> belonging to this size group was not

available in required quantity for six months during the study period. So analysis could not be carried out during these months.

Carbohydrate:

Carbohydrate distribution for the period of ten months showed a maximum value of 84.82 µg/mg.d.wt. in December, 1986 and a minimum value of 34.39 µg/mg.d.wt. in August, 1986. A definite trend of distribution with seasons could not be seen in the data. The average concentration of carbohydrate during the study (63.27 µg/mg.d.wt.) was higher than that of other species studied.

Protein:

The protein concentration during the study period varied from 204.76 to 317.25 in the months of May, 1987 and September, 1986 respectively. A high value of concentration of protein was observed in the post and premonsoon periods in 1987 and the concentration was low during the monsoon season. The average protein concentration during the study was 256.33 µg/mg.d.wt.

Lipid:

The lipid concentration varied from 20.14 μg/mg.d.wt. to 40.71 μg/mg.d.wt. during the months of April, 1986 and January, 1987 respectively. No trend in the distribution with change in season could be observed during the study. The average concentration of lipid content during the study period was 30.99 μg/mg.d.wt.

Organic carbon:

The organic carbon concentration during the study period varied between 277.61 μg/mg.d.wt. to 553.13 μg/mg.d.wt. They were recorded in the months of August, 1986 and September, 1986 respectively. Comparatively a higher concentration was observed in the month of October, 1986 and then onwards till the onset of monsoon, a gradual reduction in the concentration could be seen in the data. The average concentration of organic carbon during the study was 404.07 μg/mg.d.wt.

Calorific content:

The concentration of calorific content during the study period varied from 1673.09 cal/g.d.wt. to 2446.82 cal/g.d.wt. during the months of August, 1986 and September, 1986 respectively. The calorific content distribution followed more or less a similar trend as observed in the distribution of organic carbon and protein.

<u>B. TINTINNABULUM</u> (RCB 20 - 30 mm) **(Table 48, Fig. 58)**

Data on the biochemical composition of barnacles belonging to this group could be carried out only for a period of seven months due to its nonavailability or insufficient quantity during collection.

<u>Carbohydrate</u>:

The concentration of carbohydrate varied from 55.38 to 104.70 µg/mg.d.wt. These values, the maximum and the minimum, were observed during the months of May, 1987 and February, 1987 respectively. An increase in concentration was observed from the month of October, 1986 till February, 1987 and thereafter the concentration reduced till May, 1987. The average concentration during the study period was 72.32 µg/mg.d.wt.

Protein:

The concentration of protein was found to be varying between 233.82 and 268.70 µg/mg.d.wt. These values being observed in the months of May, 1987 and March, 1987 respectively. As observed in the case of carbohydrate, an increase in concentration could be seen from the month of October, 1986 till March, 1987 (except in February, 1987) and thereafter it decreased till May, 1987. The average concentration during the study was 252.06 µg/mg.d.wt.

Lipid:

The concentration of lipid contents during the observation period varied from 21.17 to 50.57 µg/mg.d.wt which were the values for the months of April, 1987 and January, 1987 respectively. An increasing trend of concentration was observed from October, 1986 to January, 1987. After that period the concentration was found to decrease till April, 1987. The average value of lipid during the sutdy was 32.96 µg/mg.d.wt.

Organic carbon:

Organic carbon concentration during the study period varied between 349.95 µg/mg.d.wt. to 502.74 µg/mg.d.wt. which were the observations for the months of May, 1987 and October, 1986 respectively. A definite trend of distribution with change in season could not be seen in the data. The average value of organic carbon during the study period wasfound to be 413.14 µg/mg.d.wt.

Calorific value:

The calorific values as calculated from the biochemical equivalents varied from 1794.26 cal/g.d.wt. to 2291.77 cal/g.d.wt. during the period of study.

B. TINTINNABULUM (TISSUE WISE ANALYSIS)

B. tintinnabulum irrespective of sizes were dissected and the major body tissues were removed. This included the intestine (after removing the faecal matter), cirri and the remaining body tissues including the various muscle systems, gonad etc.

INTESTINE (Table 49, Fig. 59)

Carbohydrate:

The carbohydrate contents of the intestinal tissue during the study period varied between 55.16 to 78.85 µg/mg.d.wt. which were the values recorded in the months of July, 1987 and May, 1987 respectively. The distribution pattern did not show any seasonal variations. The average carbohydrate content of intestinal tissue during the observation was 65.72 µg/mg.d.wt.

Protein:

The values of protein contents did not show any fluctuations during the period of study. The minimum value of protein was observed in the month of May, 1987 (225.66 µg/mg.d.wt.) and the maximum value of 264.12 µg/mg.d.wt. was observed in the month of October, 1986. The average concentration of protein during the observation period was 244.26 µg/mg.d.wt.

Lipid:

The lipid concentration of intestinal tissue during the study period varied between 11.94 µg/mg.d.wt. to 54.31 µg/mg.d.wt. which were the values in the months of February, 1987 and September, 1986 respectively. No seasonal trend could be observed in the monthly distribution and the average value of lipid in the study period was 31.79 µg/mg.d.wt.

Organic carbon:

The maximum concentration of organic carbon was observed in the month of October, 1986 (515.82 µg/mg.d.wt.) and minimum in the month of January, 1987 (336.77 µg/mg.d.wt.). Despite the one very high value which was observed in the month of October, 1986 the concentration was varying within the range of 336.77 to 425.69 µg/mg.d.wt. (March, 1987). The average value of organic carbon during the study was 391.23 µg/mg.d.wt.

Calorific content:

The calorific content varied between 1650.30 cal/g.d.wt. to 2184.89 cal/g.d.wt. in the months of April, 1987 and September, 1986 respectively. Any significant variation with respect to season could not be observed from the data.

CIRRI (Table 50, Fig. 60)

Carbohydrate:

The distribution of carbohydrate contents showed an increased concentration from May, 1986 till the end of postmonsoon and early premonsoon, 1987. Thereafter, the values decreased till July, 1987. The maximum value of carbohydrate was observed in the month of February, 1987 (81.91 µg/mg.d.wt.) and minimum in the month of August, 1986 (33.57 µg/mg.d.wt.). Generally, the monsoon season exhibited a decreased concentration as compared to the values observed in the other seasons. The average concentration of carbohydrate during the study was 58.18 µg/mg.d.wt.

Protein:

The protein concentration in cirri varied from 186.06 to 270.54 µg/mg.d.wt. in the months of May, 1986 and August, 1986 respectively. The monthly distribution showed an irregular pattern. The average concentration during the study was 225.07 µg/mg.d.wt.

Lipid:

The premonsoon period of 1987 showed lower values in the monthly distribution of lipid contents. However the concentration of lipid varied from 17.34 to 61.52 µg/mg.d.wt. in the months of February, 1987 and January, 1987 respectively. The average concentration during the study was 36.54 µg/mg.d.wt.

Organic carbon:

In the case of cirri, the premonsoon season exhibited a higher concentration of organic carbon than the rest of the seasons. The pattern of distribution remained more or less same without much seasonal fluctuation. The two high values obtained were in the months of September and October, 1986. The average value of organic carbon during the study was 373.16 µg/mg.d.wt.

Calorific content:

The distribution of calorific content followed more or less a similar pattern of distribution as that of protein. The values ranged between 1515.32 cal/g.d.wt. to 2165.64 cal/g.d.wt. in the months of May, 1986 and December, 1986 respectively.

BODY TISSUE (Table 51, Fig. 61)

Carbohydrate:

The carbohydrate distribution showed a higher concentration in the postmonsoon 1986 and premonsoon 1987 seasons. A gradual decrease in concentration towards the monsoon 1987 was observed in the data. During the monsoon season of 1986, the concentration was low as compared to the other seasons. The maximum concentration was observed in the month of January, 1987 (97.3 µg/mg.d.wt.) and the minimum in the month of August, 1986 (40.06 µg/mg.d.wt.). The average concentration of carbohydrate during the study was 75.03 µg/mg.d.wt. which was one of the highest average values obtained for any sample analysed.

Protein:

The protein concentration varied from 216.82 to 333.57 µg/mg.d.wt. These values were observed in the month of August, 1986 and September, 1986 respectively. The distribution pattern was more or less similar to that of carbohydrate values. The maximum concentration was obtained in the month of September, 1986 and a minimum in the month of August, 1986. The average value during the study was 256.42 µg/mg.d.wt.

Lipid:

The distribution of lipid values did not show any trend with the change in the season. However, the concentration ranged between 11.34 and 35.5 µg/mg.d.wt. which were the values recorded in the months of May, 1986 and May, 1987 respectively. The average concentration during the study was 23.82 µg/mg.d.wt. which was a very low value as compared with the other tissues.

Organic carbon:

The distribution pattern was similar to that of protein and carbohydrate. But the maximum concentration was observed during the month of October, 1986. The concentration after this month showed a gradual reduction till the beginning of monsoon season. The premonsoon 1986 also showed a comparatively higher concentration than that of the monsoon months. During the study the concentration ranged between 353.45 (August, 1986) to 539.51 µg/mg.d.wt. (October, 1986). The average concentration of organic carbon during the study was 439.17 µg/mg.d.wt.

Calorific content:

The calorific content distribution followed the same pattern of distribution as that of protein. It ranged between 1640.55 cal/g.d.wt. to 2404.36 cal/g.d.wt. during the months of August, 1986 and September, 1986 respectively.

Table 32

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in B. amphitrite at Harbour station.

Month	Carbo-hydrate *	Protein *	Lipid *	Organic carbon $	Cal/g.d.wt.
Apr'86	48.27	196.09	30.26	341.01	1591.77
May	49.19	239.25	34.73	363.63	1881.64
Jun	43.68	228.80	26.64	355.01	1723.56
Jul	43.05	231.27	23.18	346.16	1702.23
Aug	45.86	238.31	26.12	408.02	1781.31
Sep	55.68	254.18	29.33	499.85	1941.57
Oct	54.32	201.81	39.00	393.53	1731.49
Nov	61.79	200.25	39.39	436.76	1756.99
Dec	--	--	--	--	--
Jan'87	68.24	210.62	18.87	361.31	1648.11
Feb	30.75	236.07	22.13	405.03	1640.75
Mar	53.66	295.85	63.52	399.99	2491.82
Apr	56.43	275.40	45.88	390.15	2220.94
May	57.69	260.53	45.05	361.14	2134.25
Jun	55.08	239.09	35.54	371.64	1912.54
Jul	79.66	189.84	32.38	383.43	1705.19
Avg.	53.56	233.16	34.13	387.78	1857.61

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 33

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in mature forms of B. amphitrite at Harbour station.

Month	Carbo-hydrate *	Protein *	Lipid *	Organic carbon $	Cal/g.d.wt.
Apr'86	41.26	197.20	32.26	339.48	1588.20
May	56.93	253.72	39.33	363.54	2046.47
Jun	46.87	238.98	27.68	369.35	1803.98
Jul	46.27	279.99	23.73	374.61	1995.90
Aug	48.93	286.38	24.21	411.74	2047.44
Sep	54.13	304.26	26.89	425.45	2195.11
Oct	58.26	209.04	34.49	401.73	1747.00
Nov	89.52	224.90	25.71	537.98	1880.68
Dec	--	--	--	--	--
Jan'87	62.69	204.89	22.06	354.99	1623.12
Feb	31.57	258.92	12.70	365.07	1712.35
Mar	56.54	309.81	44.31	418.22	2400.97
Apr	41.69	231.73	48.51	348.57	1938.62
May	77.18	249.56	51.43	409.77	2212.47
Jun	63.73	209.94	43.47	374.99	1858.25
Jul	84.45	217.24	41.88	382.70	1969.42
Avg.	57.33	245.10	33.24	391.88	1934.66

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 34

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in immature forms of B. amphitrite at Harbour station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr`86	38.94	200.32	29.31	322.31	1568.44
May	42.36	241.23	32.83	349.74	1846.87
Jun	34.31	218.27	24.74	314.99	1607.69
Jul	33.92	221.16	23.38	273.54	1609.57
Aug	35.38	222.84	31.62	312.81	1702.91
Sep	58.88	205.09	34.51	544.28	1387.88
Oct	52.71	200.13	46.52	400.43	1786.46
Nov	65.29	205.98	44.28	465.90	1431.48
Dec	--	--	--	--	--
Jan`87	68.69	228.90	25.68	370.28	1817.59
Feb	30.73	221.75	28.77	423.54	1650.76
Mar	49.68	288.67	73.28	423.32	2527.17
Apr	68.31	274.81	41.74	410.51	2227.19
May	44.51	251.73	40.31	303.15	1985.70
Jun	53.73	251.92	36.71	365.52	1990.55
Jul	79.01	190.02	30.24	380.67	1683.32
Avg.	50.41	228.19	36.26	377.40	1788.24

* – µg/mg. d. wt. of animal tissue

$ – µg C/mg. d. wt. of animal tissue

Table 35

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in <u>B.</u> <u>amphitrite</u> (RCB above 10 mm) at Harbour station.

Month	Carbohy- hydrates *	Protein *	Lipid *	Organic carbon $	Cal/g.d.wt.
Apr'86	81.26	197.10	32.16	340.98	1750.69
May	56.73	243.72	38.33	362.04	1971.83
Jun	49.16	236.64	29.32	358.02	1815.65
Jul	50.81	222.18	24.38	316.91	1694.03
Aug	49.62	231.31	23.81	325.98	1735.35
Sep	51.13	304.26	26.59	440.45	2179.98
Oct	52.71	200.13	46.52	400.43	1786.46
Nov	41.06	187.06	62.85	393.83	1819.17
Dec	--	--	--	--	--
Jan'87	68.87	223.90	15.69	368.03	1695.67
Feb	32.12	249.07	34.19	405.78	1862.03
Mar	58.54	301.31	64.31	410.27	2550.15
Apr	42.19	302.39	41.52	419.37	2273.85
May	58.73	272.59	41.11	352.17	2169.42
Jun	53.18	240.13	30.28	368.60	1860.92
Jul	81.73	203.63	36.06	381.69	1826.37
Avg.	55.19	241.03	36.47	376.30	1932.77

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 36

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in <u>B. amphitrite</u> (RCB below 10 mm) at Harbour station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	31.61	189.73	27.31	362.33	1459.66
May	40.73	218.31	28.43	379.22	1669.11
Jun	44.37	221.31	24.83	377.67	1666.96
Jul	41.21	201.73	21.22	419.54	1509.26
Aug	49.51	212.31	24.83	581.52	1637.19
Sep	58.58	208.08	29.33	589.13	1692.99
Oct	53.61	197.95	28.46	371.52	1607.17
Nov	51.28	183.36	24.71	349.32	1479.74
Dec	--	--	--	--	--
Jan'87	72.69	184.79	12.06	351.90	1456.06
Feb	28.58	214.55	12.86	425.78	1450.91
Mar	49.89	283.61	72.18	348.17	2489.05
Apr	73.54	292.67	51.73	382.19	2443.95
May	50.35	268.23	47.34	379.49	2169.30
Jun	49.63	254.36	31.73	377.46	1940.47
Jul	73.43	148.46	21.35	388.20	1341.62
Avg.	51.26	218.63	30.56	405.56	1734.23

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 37

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in <u>B. amphitrite</u> (general) at Dona Paula station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ Carbon	Cal/g.d.wt.
Apr'86	59.21	223.37	31.85	353.31	1805.78
May	52.56	215.60	29.14	337.97	1709.01
Jun	36.25	217.25	26.89	351.32	1630.20
Jul	37.16	180.22	25.40	371.58	1410.63
Aug	56.57	211.68	32.51	408.00	1735.15
Sep	43.90	200.49	29.12	383.15	1639.89
Oct	52.28	202.78	30.94	362.70	1652.44
Nov	57.71	194.03	39.38	365.55	1705.02
Dec	53.66	193.19	49.69	321.37	1781.10
Jan'87	46.77	241.57	35.91	375.57	1895.98
Feb	41.46	228.76	29.73	373.76	1743.43
Mar	67.10	271.95	38.27	394.88	2173.28
Apr	64.08	281.28	30.10	438.17	2136.41
May	51.83	241.57	29.92	373.95	1860.12
Jun	69.78	197.15	42.81	317.70	1804.55
Jul	54.69	254.56	40.05	363.24	2040.97
Avg.	52.81	222.22	33.86	368.26	1795.25

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 38

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in mature forms of *B. amphitrite* at Dona Paula station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	81.26	197.10	32.16	340.98	1750.69
May	--	--	--	--	--
Jun	43.14	221.72	19.25	258.47	1611.50
Jul	35.67	151.91	29.35	377.97	1281.90
Aug	--	--	--	--	--
Sep	48.26	200.22	26.91	446.37	1583.41
Oct	51.52	186.62	32.27	370.47	1570.59
Nov	55.25	214.26	31.65	310.62	1736.19
Dec	31.77	191.20	47.26	310.20	1657.14
Jan'87	42.44	203.60	21.66	363.53	1529.03
Feb	39.33	210.58	20.98	380.33	1549.29
Mar	68.32	276.67	29.36	395.31	2120.75
Apr	49.84	308.81	28.69	407.98	2218.60
May	50.73	256.51	34.54	409.73	1983.68
Jun	--	--	--	--	--
Jul	52.16	240.34	48.26	382.13	2027.83
Avg.	49.98	219.96	30.95	365.70	1740.05

* – µg/mg. d. wt. of animal tissue

$ – µg C/mg. d. wt. of animal tissue

Table 39

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in immature forms of B. amphitrite at Dona Paula station.

Month	Carbo-hydrate *	Protein *	Lipid *	Organic carbon $	Cal/g.d.wt.
Apr'86	28.56	231.37	41.53	349.17	1795.97
May	--	--	--	--	--
Jun	24.36	208.79	36.54	329.88	1624.84
Jul	--	--	--	--	--
Aug	34.22	207.65	36.29	397.47	1656.47
Sep	--	--	--	--	--
Oct	--	--	--	--	--
Nov	60.97	187.97	54.12	427.10	1823.44
Dec	58.20	213.62	50.83	341.85	1925.92
Jan'87	52.10	274.54	50.16	365.10	2238.77
Feb	40.72	230.89	25.27	364.95	1710.28
Mar	64.73	218.32	51.15	417.77	1982.27
Apr	58.31	243.75	31.68	454.10	1676.56
May	51.73	214.13	28.11	367.77	1687.57
Jun	65.50	218.49	29.55	342.77	1782.27
Jul	63.96	305.85	28.93	367.95	2263.68
Avg.	50.28	229.61	38.68	377.16	1847.34

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 40

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in B. amphitrite (RCB above 10mm) at Dona Paula station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	68.42	233.64	29.43	374.31	1878.70
May	53.37	212.38	31.01	349.22	1711.81
Jun	43.14	221.72	19.25	408.47	1611.38
Jul	35.67	151.91	29.35	377.97	1281.90
Aug	84.12	197.65	39.29	412.47	1832.91
Sep	48.16	190.22	26.91	446.37	1526.50
Oct	61.52	185.52	32.17	370.47	1604.43
Nov	60.69	201.57	35.95	375.38	1727.43
Dec	51.77	191.20	57.26	310.05	1833.64
Jan'87	50.10	274.54	50.16	365.10	2230.57
Feb	45.74	252.81	49.52	377.07	2083.87
Mar	74.69	311.73	32.61	384.92	2375.67
Apr	79.84	308.81	28.39	437.97	2340.40
May	54.73	272.54	32.56	351.65	2071.94
Jun	65.50	218.29	29.55	359.54	1781.14
Jul	58.06	273.10	38.60	375.05	2145.83
Avg.	58.47	231.10	35.12	379.75	1877.38

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 41

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in <u>B. amphitrite</u> (RCB below 10mm) at Dona Paula station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	58.61	231.36	24.27	348.77	1776.84
May	51.74	218.83	29.31	326.72	1725.50
Jun	41.26	221.23	24.89	315.59	1654.33
Jul	38.64	208.54	21.44	347.46	1539.28
Aug	51.36	229.74	27.79	365.18	1771.22
Sep	39.63	210.76	31.33	318.41	1649.35
Oct	43.79	236.21	28.37	347.16	1782.22
Nov	53.92	172.33	35.78	349.10	1532.86
Dec	72.90	176.74	43.39	331.40	1707.51
Jan'87	42.44	213.60	21.66	408.53	1585.53
Feb	40.03	220.74	23.13	372.65	1629.88
Mar	60.67	281.06	39.96	381.03	2214.36
Apr	68.31	263.74	31.63	452.60	2001.25
May	50.12	223.08	24.45	366.66	1696.95
Jun	78.33	154.66	69.33	250.80	1850.15
Jul	44.59	198.96	44.39	327.83	1726.43
Avg.	52.27	216.31	32.57	350.62	1740.23

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 42

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in B. amaryllis at Harbour station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	--	--	--	--	--
May	--	--	--	--	--
Jun	--	--	--	--	--
Jul	35.50	265.71	18.69	409.86	1823.43
Aug	86.06	252.85	26.37	358.02	2030.65
Sep	72.51	215.46	22.89	358.02	1730.95
Oct	150.13	238.19	9.31	451.46	2049.29
Nov	96.37	207.78	23.16	522.62	1787.94
Dec	--	--	--	--	--
Jan'87	--	--	--	--	--
Feb	--	--	--	--	--
Mar	--	--	--	--	--
Apr	--	--	--	--	--
May	--	--	--	--	--
Jun	64.81	202.13	28.54	394.77	1677.46
Jul	73.78	174.24	--	586.77	--
Avg.	82.74	222.34	21.49	440.22	1849.95

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 43

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in <u>Chthamalus</u> sp. at Dona Paula station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr`86	39.11	138.54	21.39	212.36	1145.24
May	37.09	102.43	17.16	155.45	892.960
Jun	38.36	140.02	15.76	204.27	1097.32
Jul	--	--	--	--	--
Aug	35.08	103.27	43.00	251.33	1133.65
Sep	56.18	172.48	25.27	395.37	1443.65
Oct	--	--	--	--	--
Nov	58.16	190.32	27.53	407.45	1573.92
Dec	28.42	103.68	23.11	172.10	920.700
Jan`87	46.60	182.94	24.61	250.61	1457.24
Feb	39.31	182.97	36.55	304.95	1540.35
Mar	58.63	151.79	26.74	383.72	1350.69
Apr	69.42	173.29	32.73	414.89	1573.01
May	42.16	132.19	21.63	362.34	1124.13
Jun	53.69	163.53	41.29	264.80	1534.26
Jul	92.95	179.34	20.69	337.43	1867.98
Avg.	49.65	151.20	26.94	294.08	1332.51

* - μg/mg. d. wt. of animal tissue

$ - μg C/mg. d. wt. of animal tissue

Table 44

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in Chthamalus sp. at Arambol station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	54.32	211.73	36.71	296.84	1765.90
May	--	--	--	--	--
Jun	35.32	164.33	19.92	245.85	1261.52
Jul	31.73	154.38	28.92	254.31	1275.63
Aug	--	--	--	--	--
Sep	32.12	247.60	15.91	392.22	1680.98
Oct	68.69	215.17	36.84	409.35	1845.48
Nov	64.36	228.74	41.61	389.69	1949.47
Dec	--	--	--	--	--
Jan'87	36.34	160.72	32.93	291.50	1368.25
Feb	51.11	185.52	32.35	309.72	1563.45
Mar	57.21	218.31	18.82	283.37	1645.86
Apr	71.31	232.61	52.78	362.64	2105.39
May	73.68	173.34	19.73	394.77	1467.91
Jun	43.48	177.84	36.97	256.70	1532.43
Jul	58.20	218.66	38.75	291.42	1840.24
Avg.	52.14	201.72	31.71	321.41	1638.65

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 45

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in <u>B. tintinnabulum</u> at Arambol station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	44.94	267.34	20.14	290.15	1885.05
May	79.46	212.59	18.27	347.79	1699.57
Jun	--	--	--	--	--
Jul	--	--	--	--	--
Aug	34.39	227.88	25.88	277.61	1673.09
Sep	55.63	292.20	37.99	513.27	2238.02
Oct	66.22	265.80	34.49	517.23	2099.20
Nov	--	--	--	--	--
Dec	81.99	270.24	30.04	431.15	2146.89
Jan'87	76.77	250.22	42.61	378.06	2131.16
Feb	85.91	241.14	22.05	433.26	1923.04
Mar	65.91	263.75	23.39	404.67	1981.45
Apr	63.45	242.50	23.50	371.46	1852.35
May	69.42	231.63	36.01	366.53	1933.63
Jun	--	--	--	--	--
Jul	56.22	207.72	26.58	348.08	1655.30
Avg.	65.05	247.75	28.41	389.94	1934.89

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 46

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in <u>B. tintinnabulum</u> (RCB above 40 mm) at Arambol station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	--	--	--	--	--
May	79.46	212.59	18.27	347.79	1699.57
Jun	--	--	--	--	--
Jul	--	--	--	--	--
Aug	--	--	--	--	--
Sep	--	--	--	--	--
Oct	67.01	266.71	30.87	534.81	2073.37
Nov	--	--	--	--	--
Dec	88.40	262.33	26.84	500.52	2098.24
Jan'87	63.72	232.26	40.48	350.33	1956.06
Feb	88.42	241.62	18.31	427.82	1900.70
Mar	63.80	258.18	21.19	412.16	1920.54
Apr	68.38	255.52	33.57	281.93	2041.28
May	90.95	256.32	26.27	398.69	2069.35
Jun	--	--	--	--	--
Jul	56.22	237.72	26.58	402.08	1824.80
Avg.	74.04	247.03	26.93	406.24	1953.77

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 47

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in <u>B. tintinnabulum</u> (RCB 30 - 40 mm) at Arambol station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	44.94	267.34	20.14	290.15	1885.05
May	--	--	--	--	--
Jun	--	--	--	--	--
Jul	--	--	--	--	--
Aug	34.39	227.88	25.88	277.61	1673.09
Sep	72.29	317.25	37.88	553.13	2446.82
Oct	67.01	266.71	30.88	534.81	2073.47
Nov	--	--	--	--	--
Dec	84.82	281.16	36.37	416.31	2280.01
Jan'87	84.80	257.10	40.71	424.40	2185.00
Feb	51.01	234.52	28.38	402.87	1802.37
Mar	66.02	275.74	32.95	415.88	2139.99
Apr	65.52	230.79	23.10	374.55	1790.89
May	61.94	204.76	33.59	350.96	1728.27
Jun	--	--	--	--	--
Jul	--	--	--	--	--
Avg.	63.27	256.33	30.99	404.07	2000.50

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 48

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in B. tintinnabulum (RCB 20 - 30 mm) at Arambol station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	--	--	--	--	--
May	--	--	--	--	--
Jun	--	--	--	--	--
Jul	--	--	--	--	--
Aug	--	--	--	--	--
Sep	--	--	--	--	--
Oct	69.32	256.92	30.03	502.74	2019.59
Nov	--	--	--	--	--
Dec	74.88	264.60	34.73	401.22	2130.20
Jan'87	75.45	266.29	50.57	392.16	2291.77
Feb	104.70	233.89	23.37	471.66	1965.95
Mar	70.09	268.70	22.72	416.31	2020.23
Apr	56.43	241.21	21.17	357.92	1794.26
May	55.38	233.82	48.16	349.95	2003.25
Jun	--	--	--	--	--
Jul	--	--	--	--	--
Avg.	72.32	252.06	32.96	413.14	2032.18

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 49

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in the intestine of <u>B. tintinnabulum</u> at Arambol station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	--	--	--	--	--
May	78.85	226.92	30.36	354.72	1891.06
Jun	--	--	--	--	--
Jul	--	--	--	--	--
Aug	--	--	--	--	--
Sep	74.36	241.82	54.31	402.78	2184.89
Oct	60.64	264.12	43.42	515.82	2151.22
Nov	--	--	--	--	--
Dec	72.52	244.98	36.47	363.98	2026.11
Jan'87	58.24	244.01	33.63	336.77	1935.24
Feb	64.25	244.62	11.94	360.36	1758.36
Mar	67.46	258.29	24.94	425.69	1971.61
Apr	62.45	246.24	23.06	382.91	1650.30
May	63.25	225.66	37.38	387.71	1865.22
Jun	--	--	--	--	--
Jul	55.16	245.95	22.37	381.60	1827.17
Avg.	65.72	244.26	31.79	391.23	1926.12

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 50

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in the cirri of <u>B. tintinnabulum</u> at Arambol station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	--	--	--	--	--
May	57.60	186.06	24.15	336.20	1515.32
Jun	--	--	--	--	--
Jul	--	--	--	--	--
Aug	33.57	270.54	26.41	266.03	1915.76
Sep	55.44	250.84	45.20	514.88	2071.69
Oct	49.04	237.12	45.81	482.63	1973.70
Nov	--	--	--	--	--
Dec	75.21	259.21	41.56	340.37	2165.64
Jan'87	65.61	232.74	61.52	255.72	2165.35
Feb	81.91	247.67	17.34	368.51	1899.03
Mar	56.80	261.39	25.11	408.35	1947.02
Apr	66.80	226.86	26.28	362.21	1803.99
May	55.99	219.17	35.65	330.77	1804.76
Jun	--	--	--	--	--
Jul	42.05	254.20	52.87	439.10	2108.26
Avg.	58.18	225.07	36.54	373.16	1942.77

* - µg/mg. d. wt. of animal tissue

$ - µg C/mg. d. wt. of animal tissue

Table 51

Distribution of biochemical compounds and calorific content (calculated from the biochemical equivalents) in the body tissue of B. tintinnabulum at Arambol station.

Month	Carbo- * hydrate	Protein *	Lipid *	Organic $ carbon	Cal/g.d.wt.
Apr'86	--	--	--	--	--
May	79.47	230.14	11.34	398.48	2059.11
Jun	--	--	--	--	--
Jul	--	--	--	--	--
Aug	40.06	216.82	26.59	353.45	1640.55
Sep	55.81	333.57	30.78	514.68	2404.36
Oct	86.32	275.10	11.43	539.51	2016.24
Nov	--	--	--	--	--
Dec	94.15	277.80	20.14	509.81	2145.91
Jan	97.30	259.52	30.79	470.49	2156.18
Feb	95.77	237.80	26.50	481.85	1986.65
Mar	71.14	275.24	26.21	412.55	1952.55
Apr	62.26	248.45	27.21	370.38	1916.14
May	79.22	240.85	35.50	373.82	2021.08
Jun	--	--	--	--	--
Jul	63.84	225.37	15.53	405.81	1681.84
Avg.	75.03	256.42	23.82	439.17	1998.24

* - μg/mg. d. wt of animal tissue

$ - μg C/mg. d. wt. of animal tissue

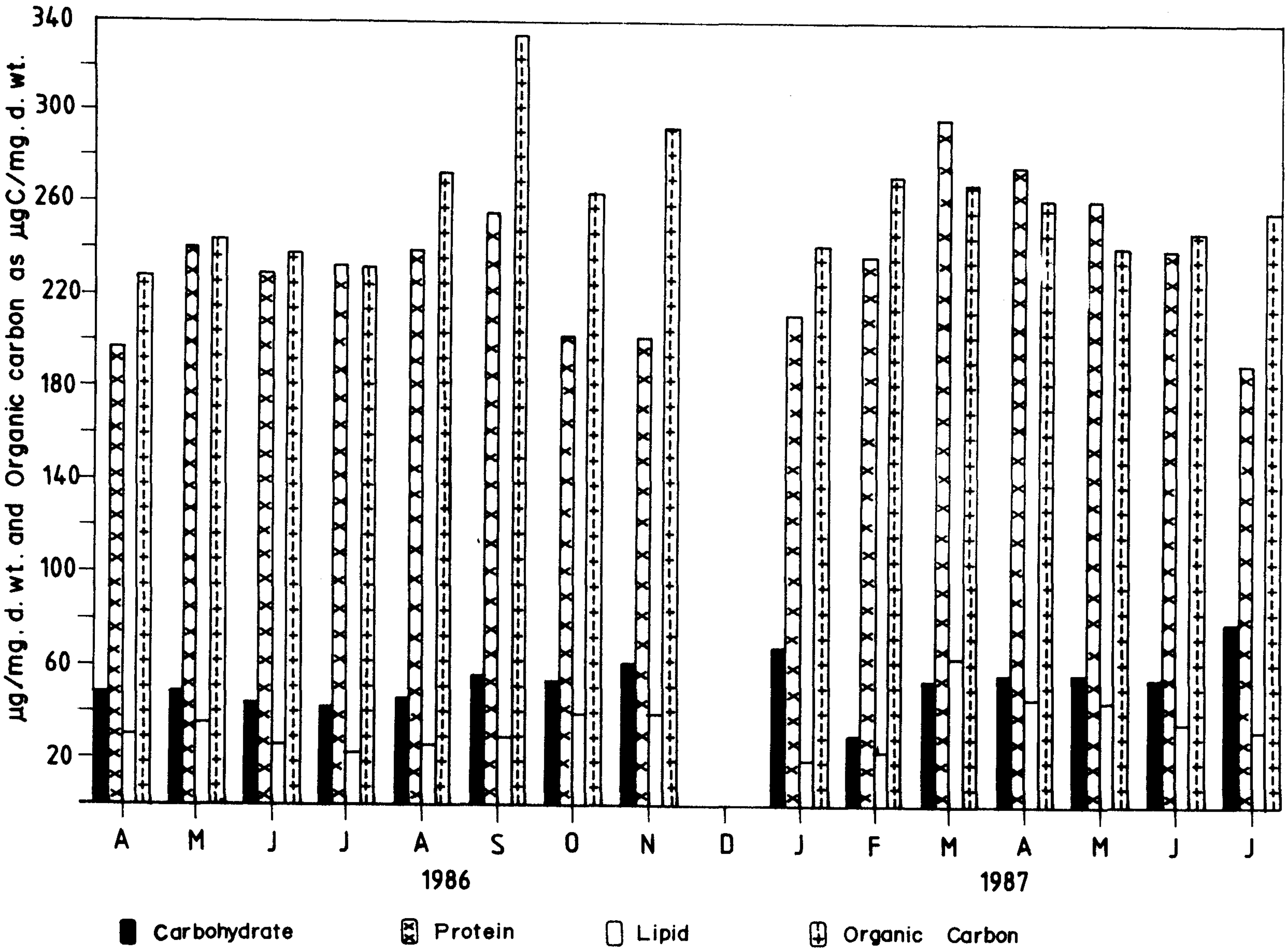

Fig. 42. Monthly distribution of biochemical compounds in B.amphitrite at Harbour.

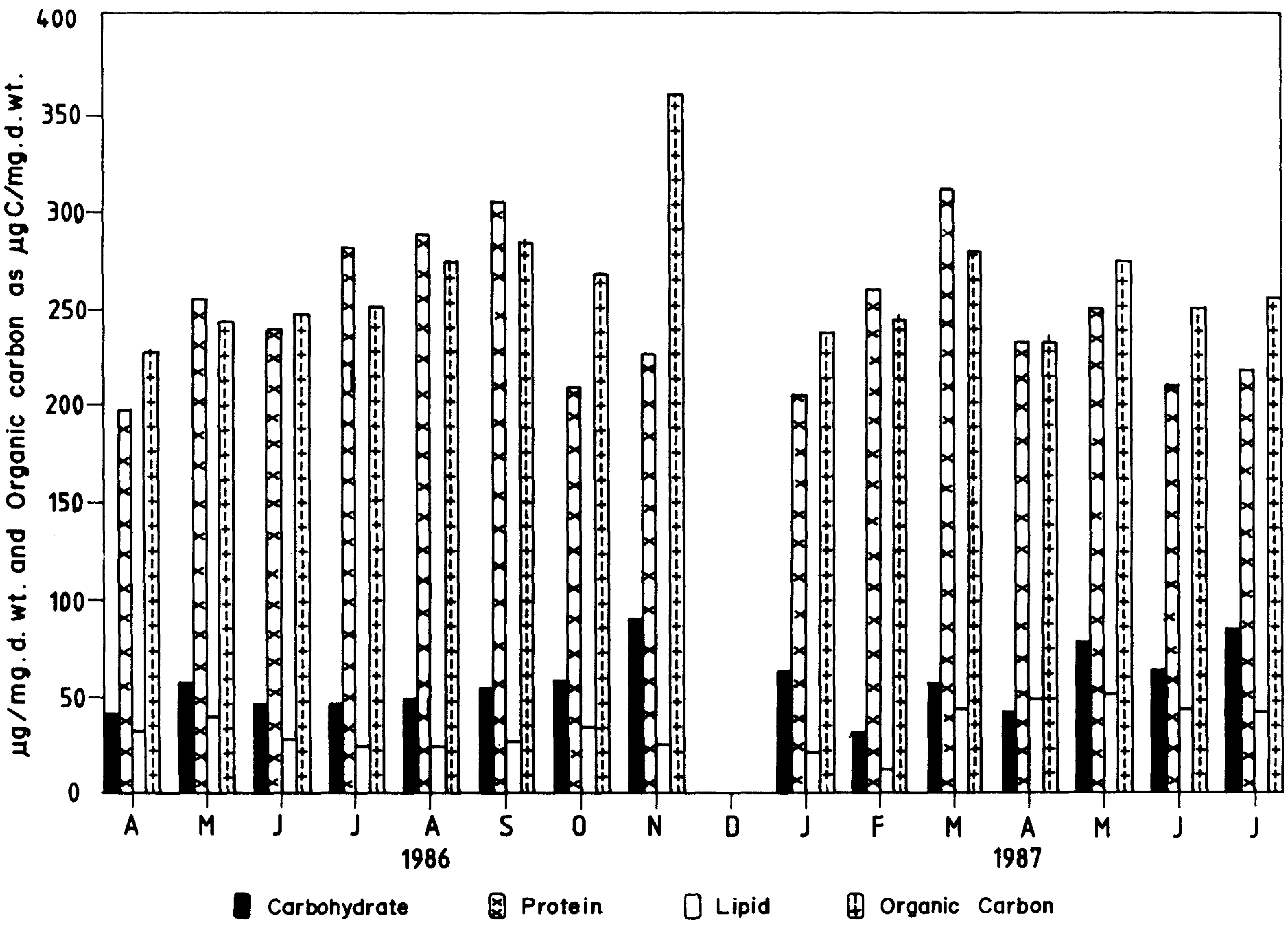

Fig. 43. Monthly distribution of biochemical compounds in mature forms of B. amphitrite at Harbour.

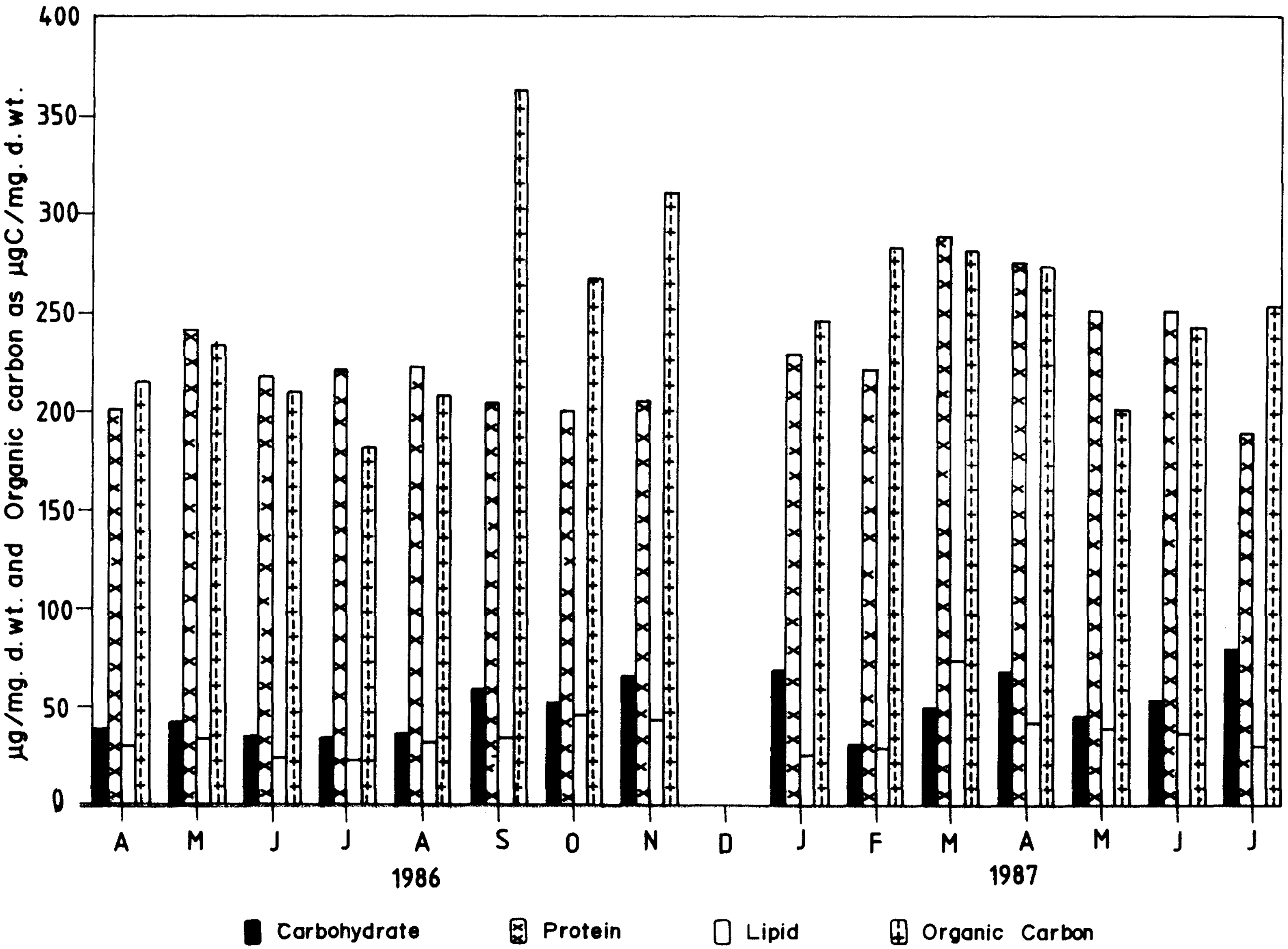

Fig. 44. Monthly distribution of biochemical compounds in immature forms of B. amphitrite at Harbour

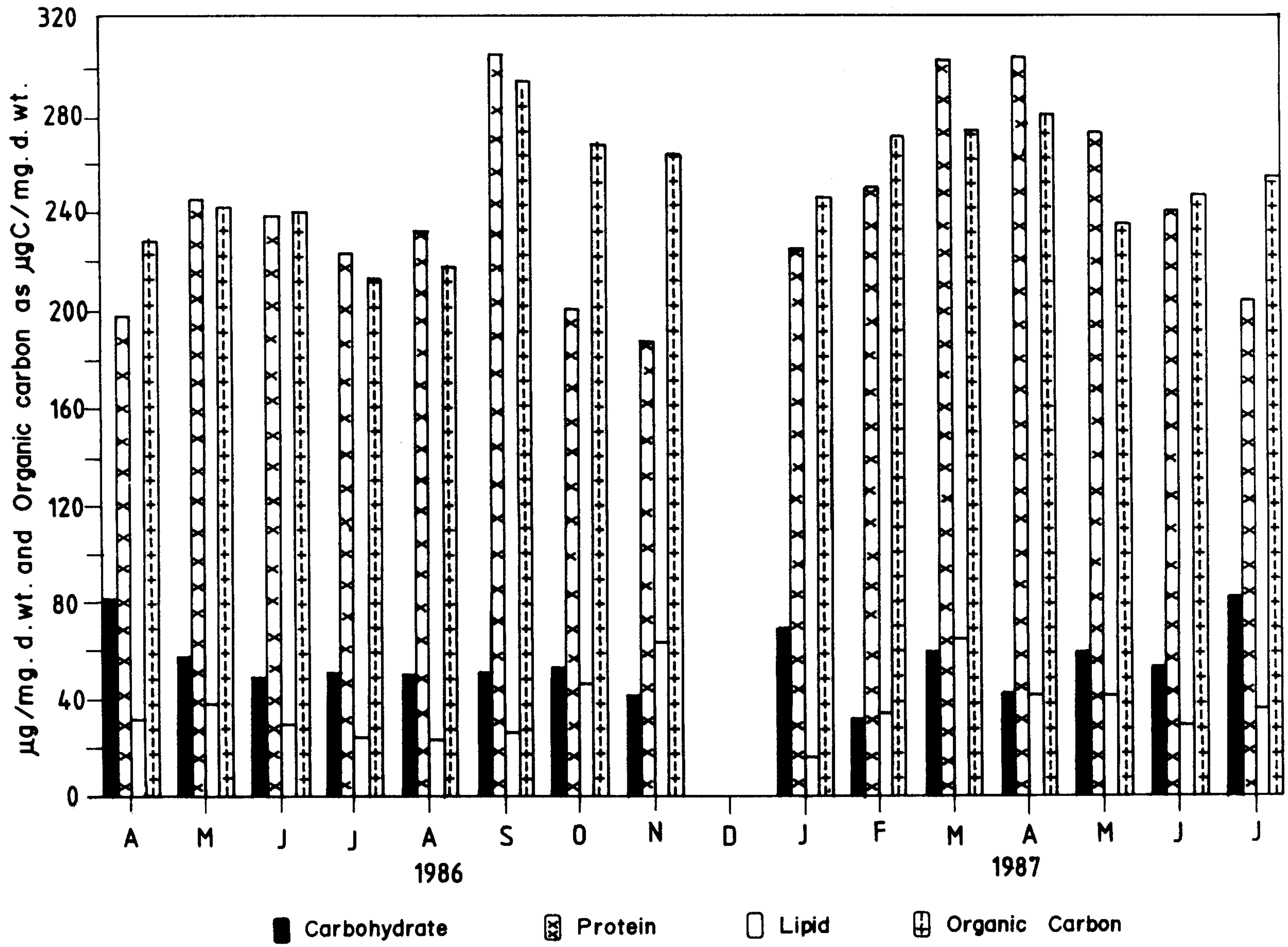

Fig. 45. Monthly distribution of biochemical compounds in B. amphitrite RCB above 10 mm at Harbour.

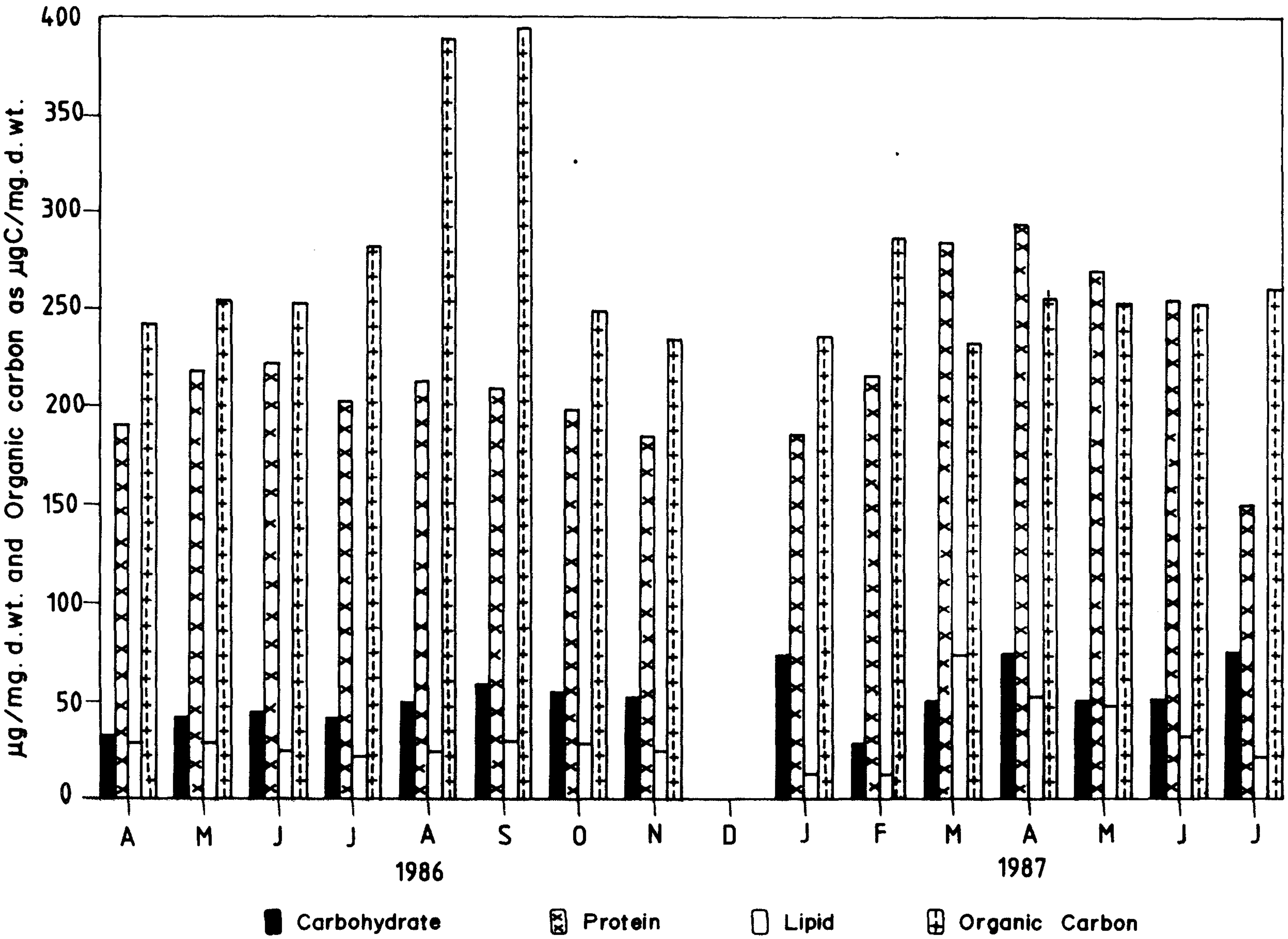

Fig. 46. Monthly distribution of biochemical compounds in B. amphitrite RCB below 10mm at Harbour.

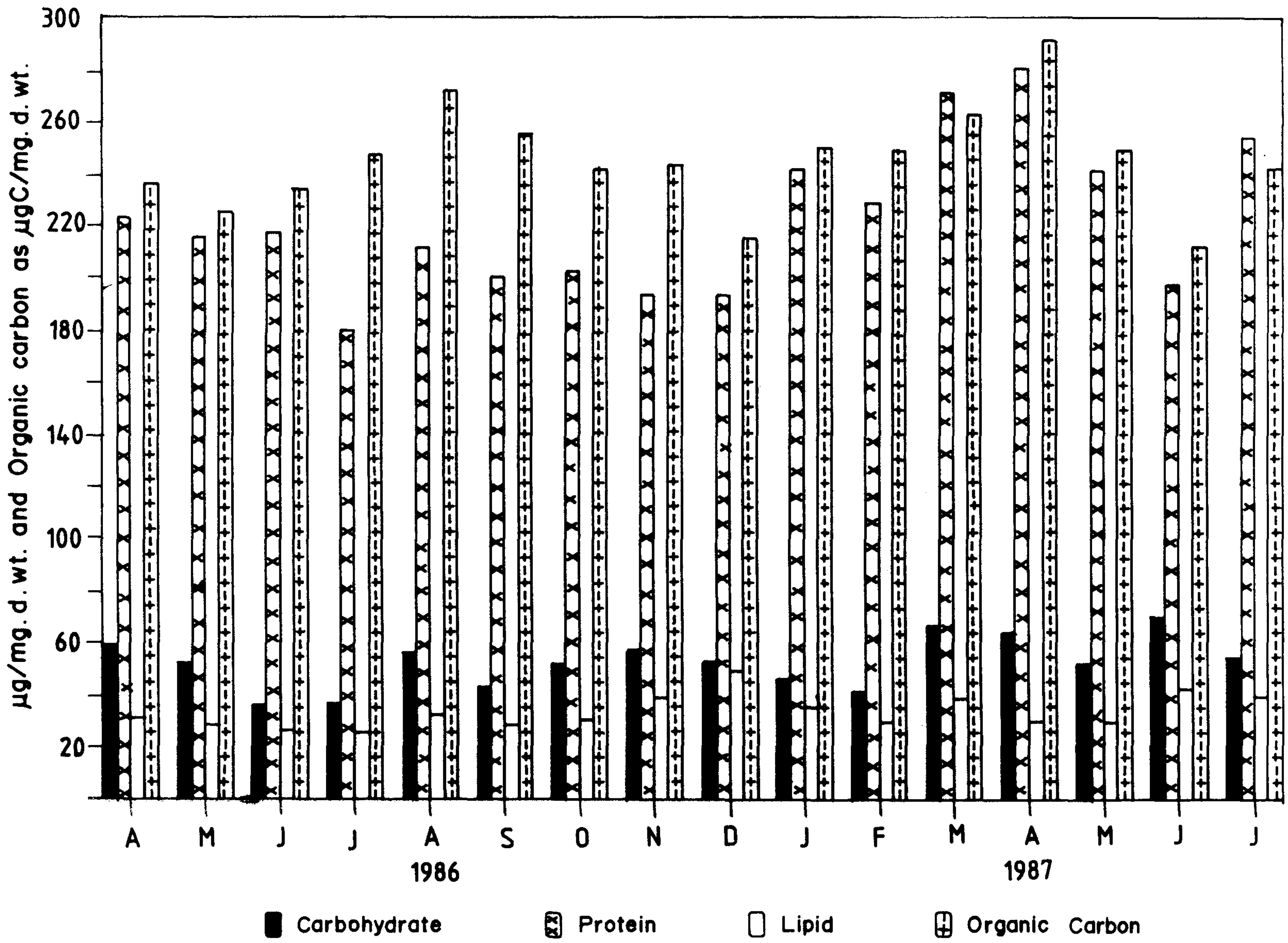

Fig. 47. Monthly distribution of biochemical compounds in B. amphitrite at Dona Paula.

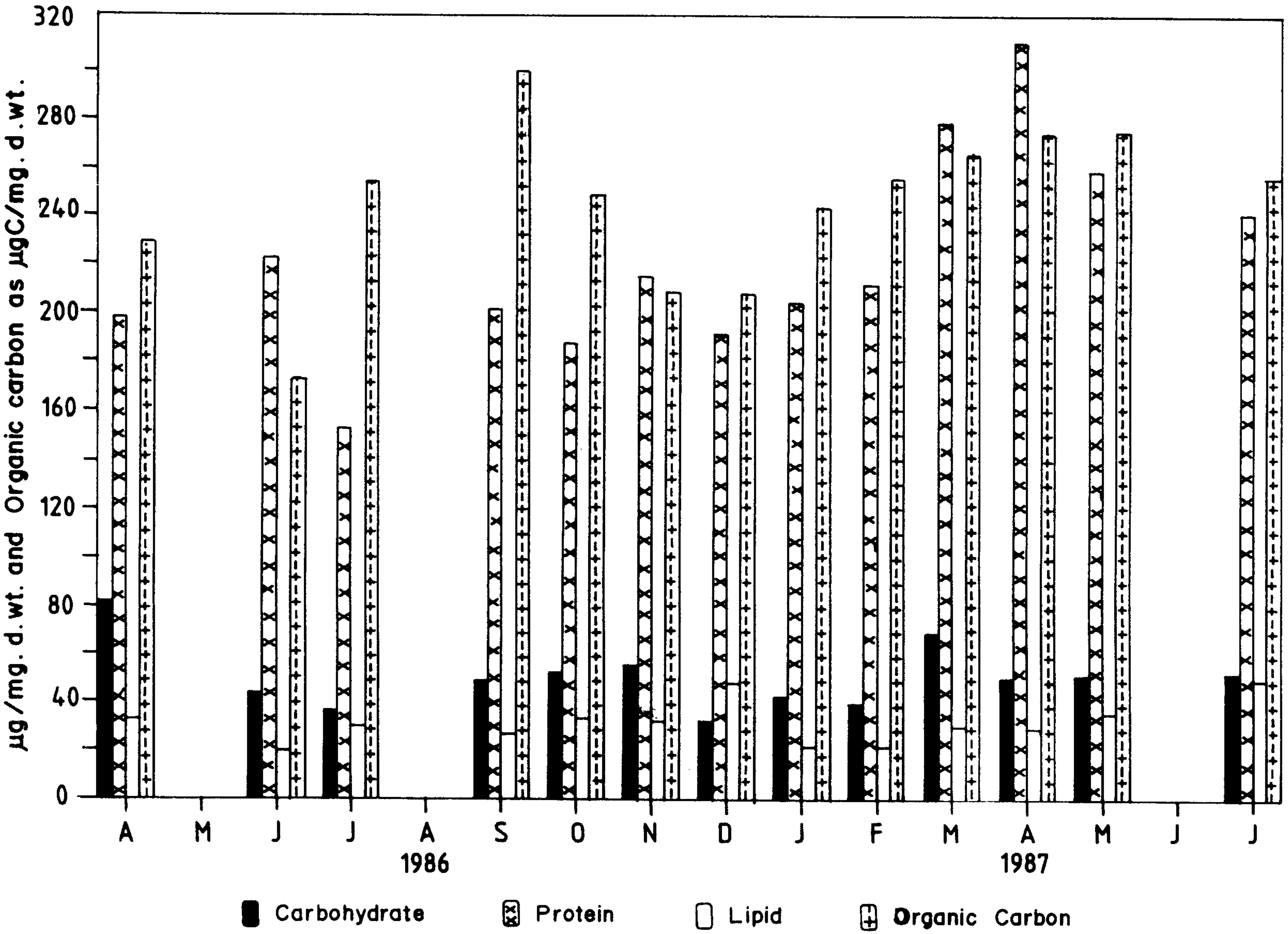

Fig. 48. Monthly distribution of biochemical compounds in mature forms of B. amphitrite at Dona Paula.

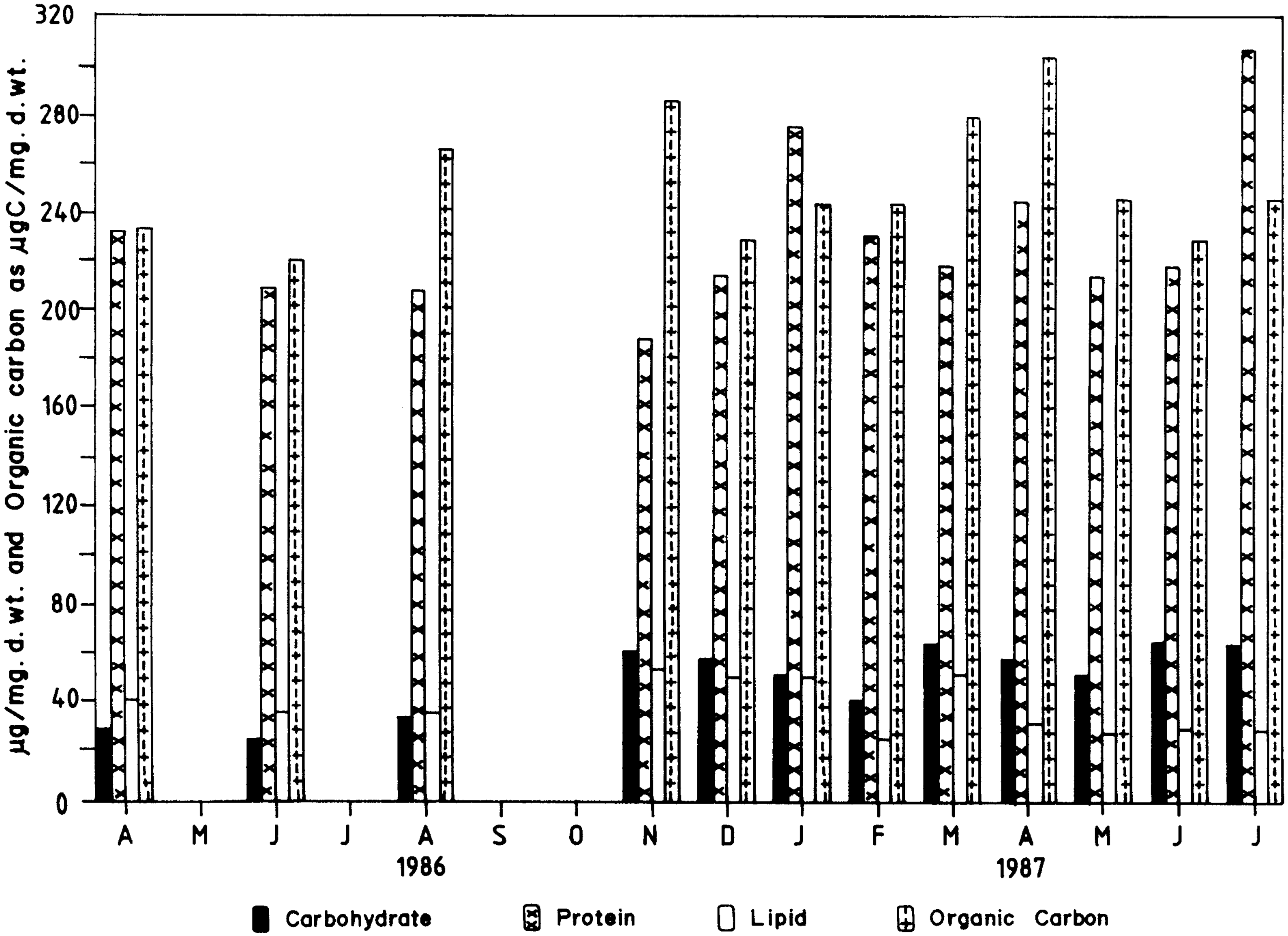

Fig. 49. Monthly distribution of biochemical compounds in immature forms of B. amphitrite at Dona Paula.

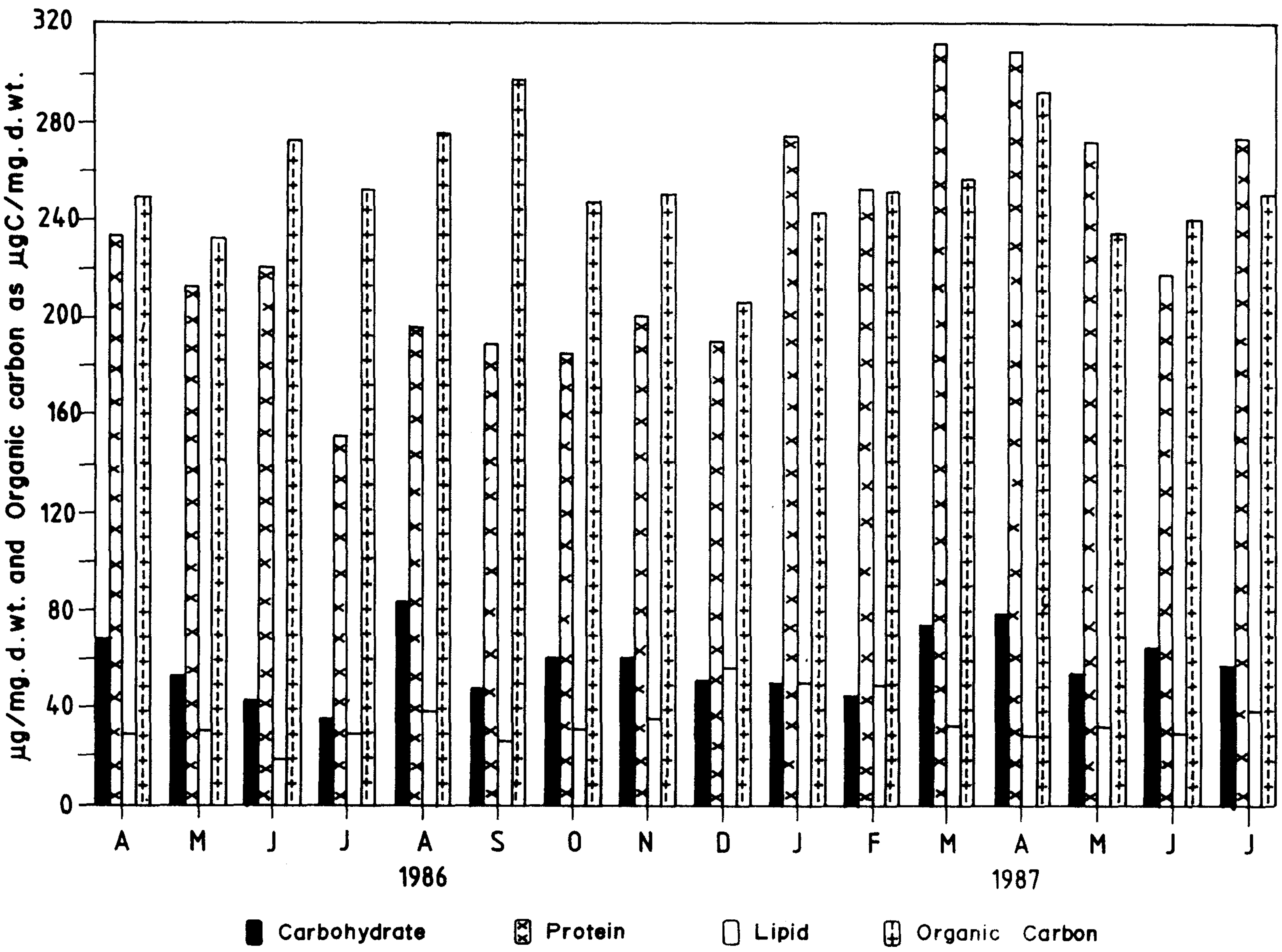

Fig. 50. Monthly distribution of biochemical compounds in *B. amphitrite* RCB above 10 mm at Dona Paula.

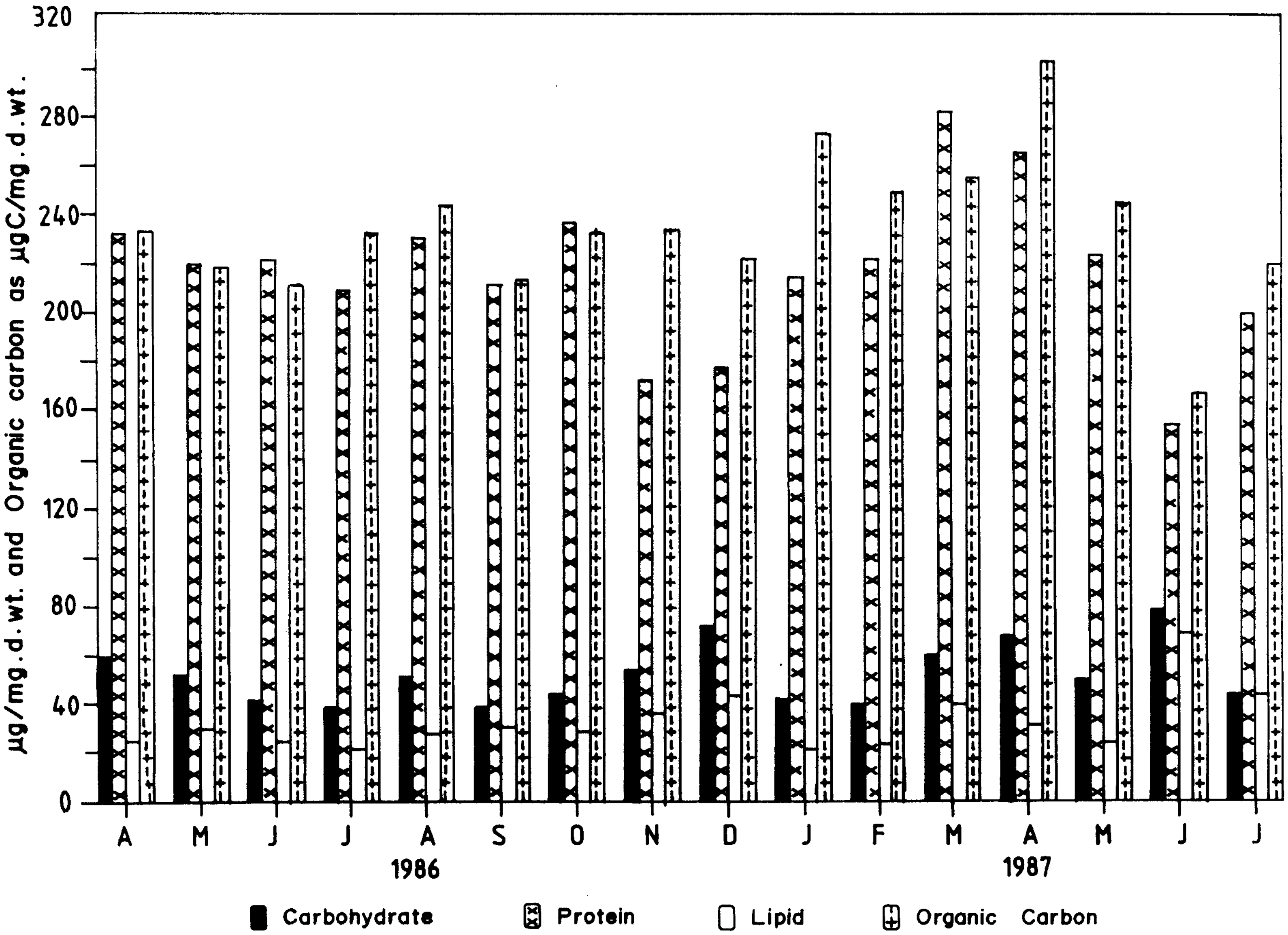

Fig. 51 . Monthly distribution of biochemical compounds in B. amphitrite RCB below 10mm at Dona Paula.

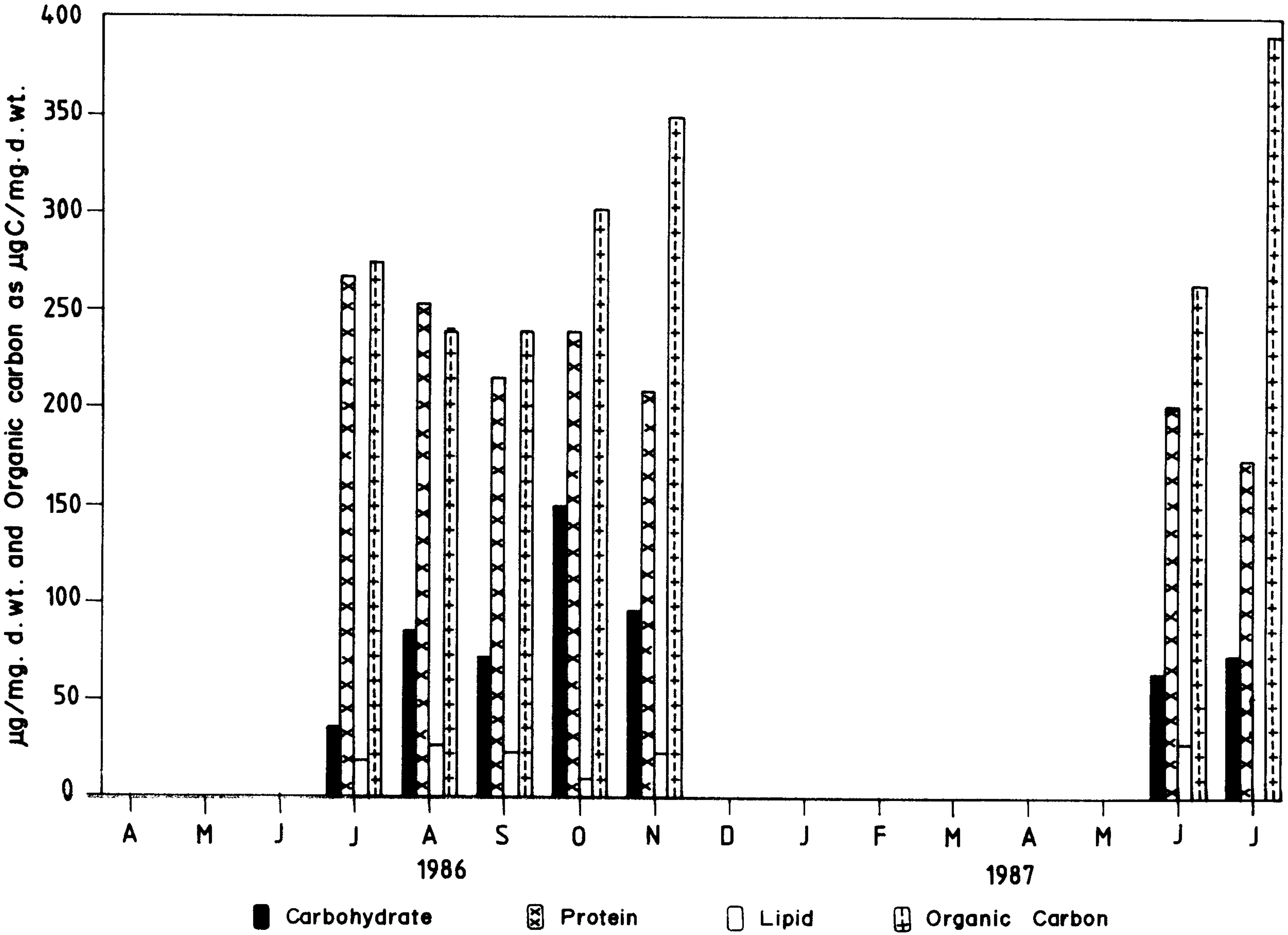

Fig. 52. Monthly distribution of biochemical compounds in *B. amaryllis* at Harbour.

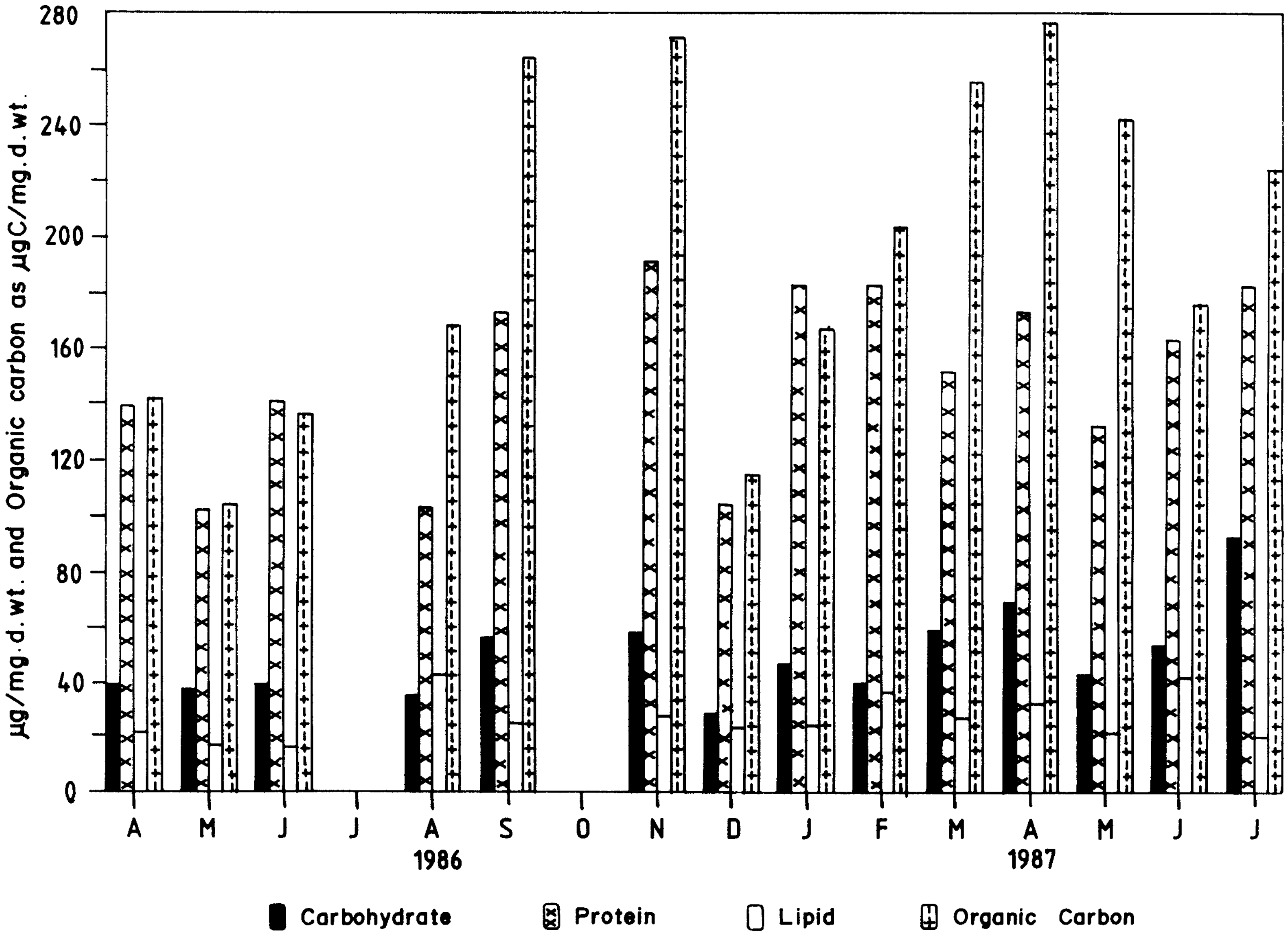

Fig. 53. Monthly distribution of biochemical compounds in Chthamalus sp. at Dona Paula.

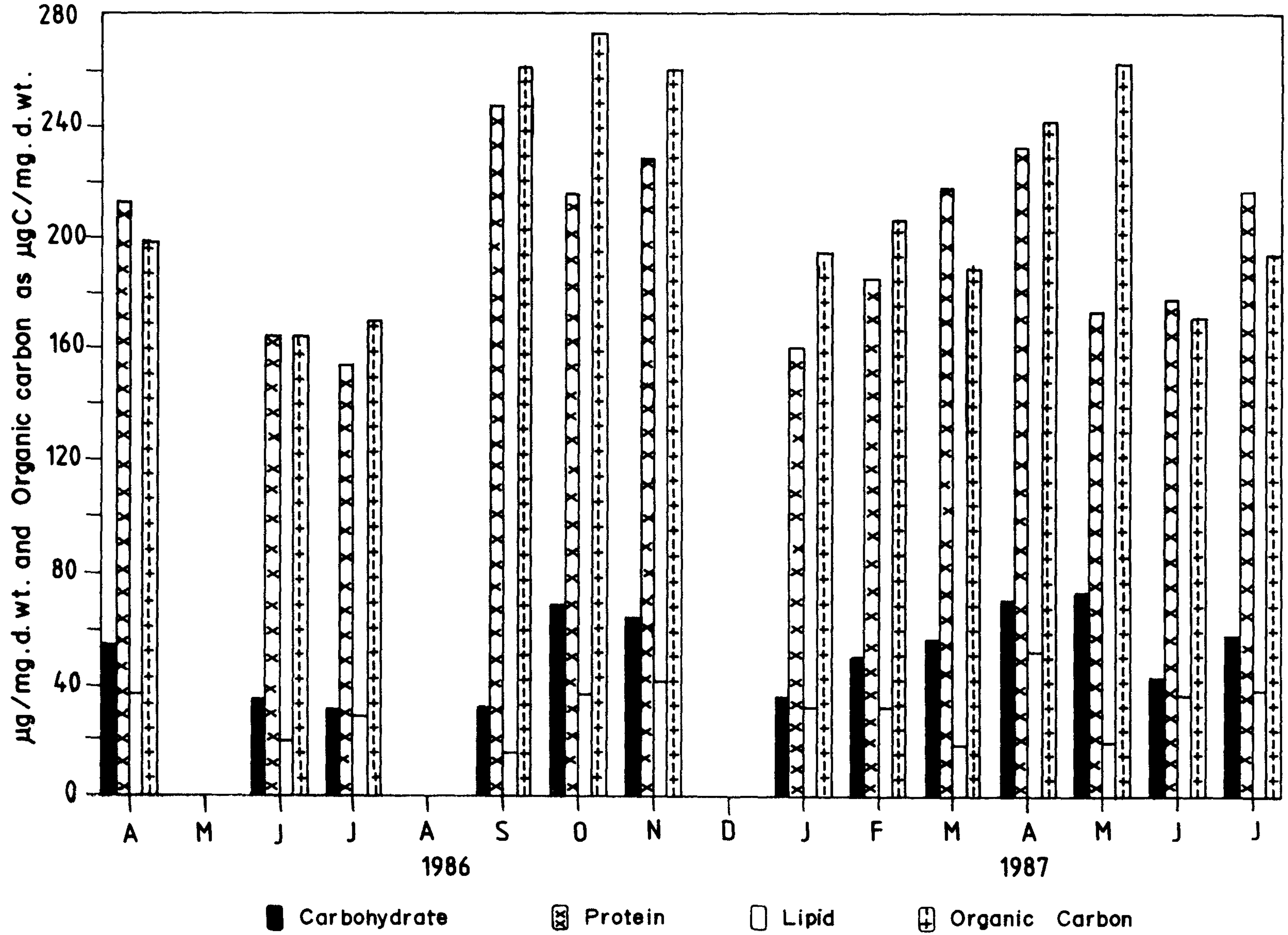

Fig. 54. Monthly distribution of biochemical compounds in Chthamalus sp. at Arambol.

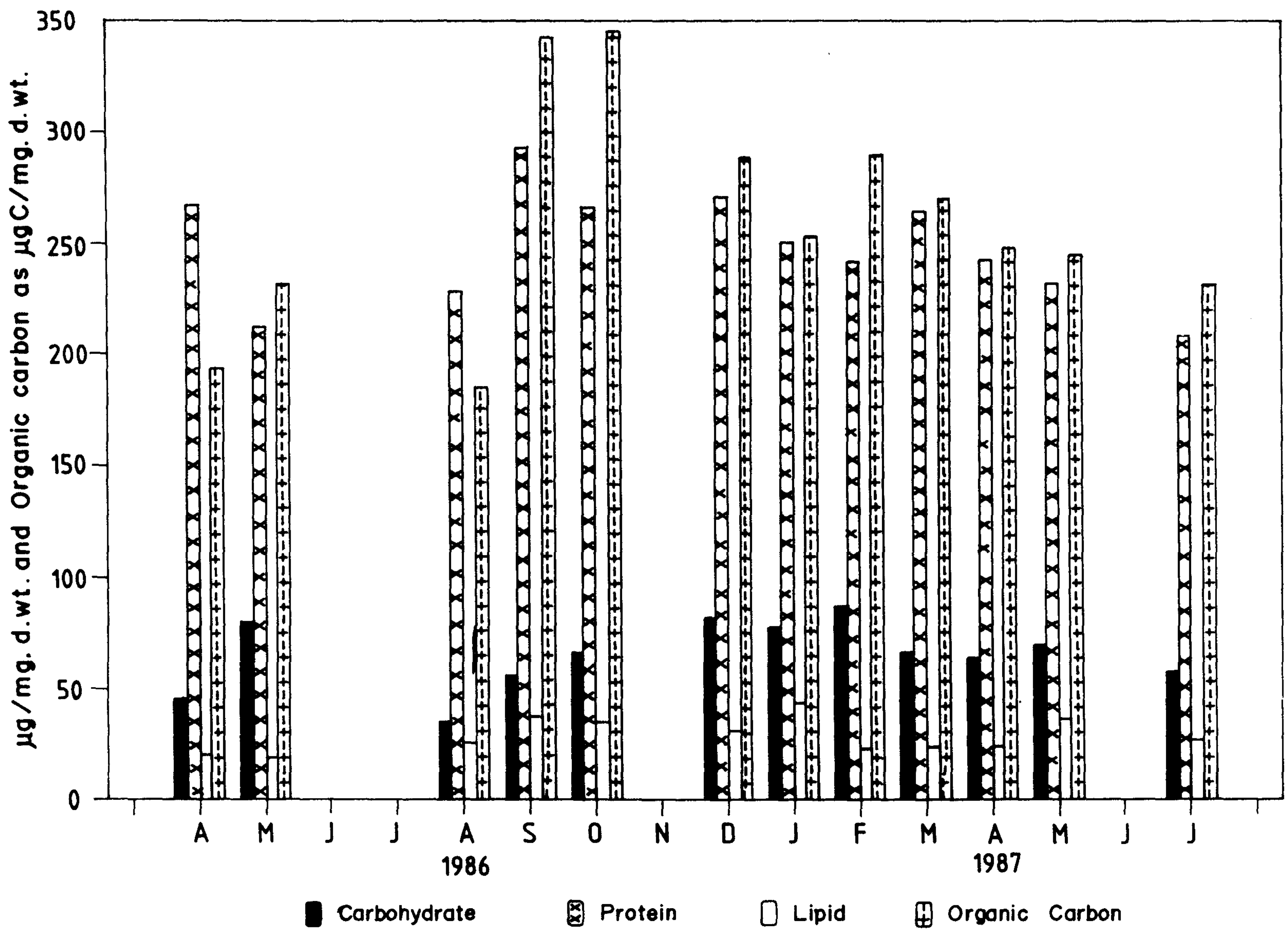

Fig. 55. Monthly distribution of biochemical compounds in B. tintinnabulum at Arambol.

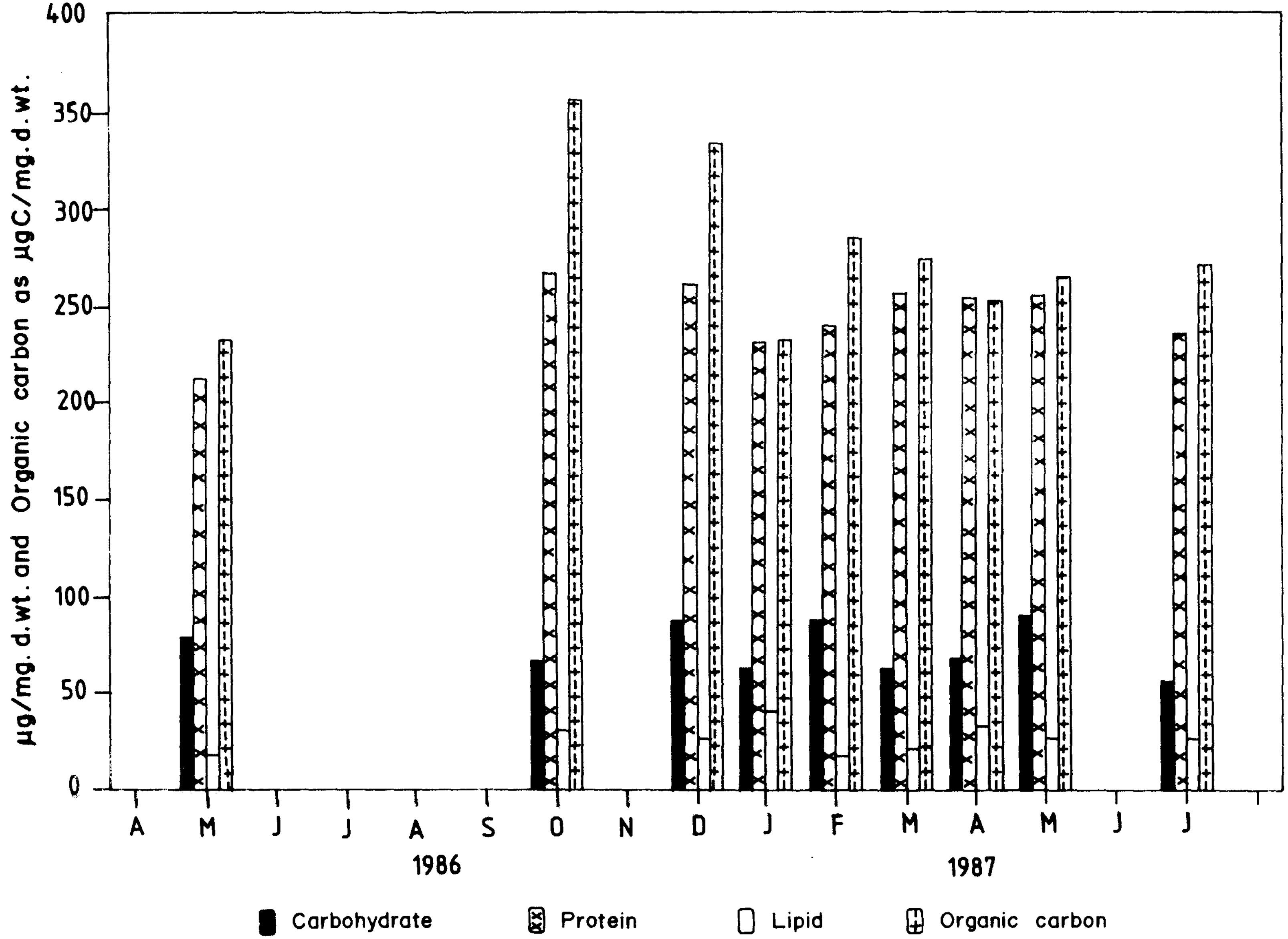

Fig. 56. Monthly distribution of biochemical compounds in B. tintinnabulum RCB above 40 mm at Arambol.

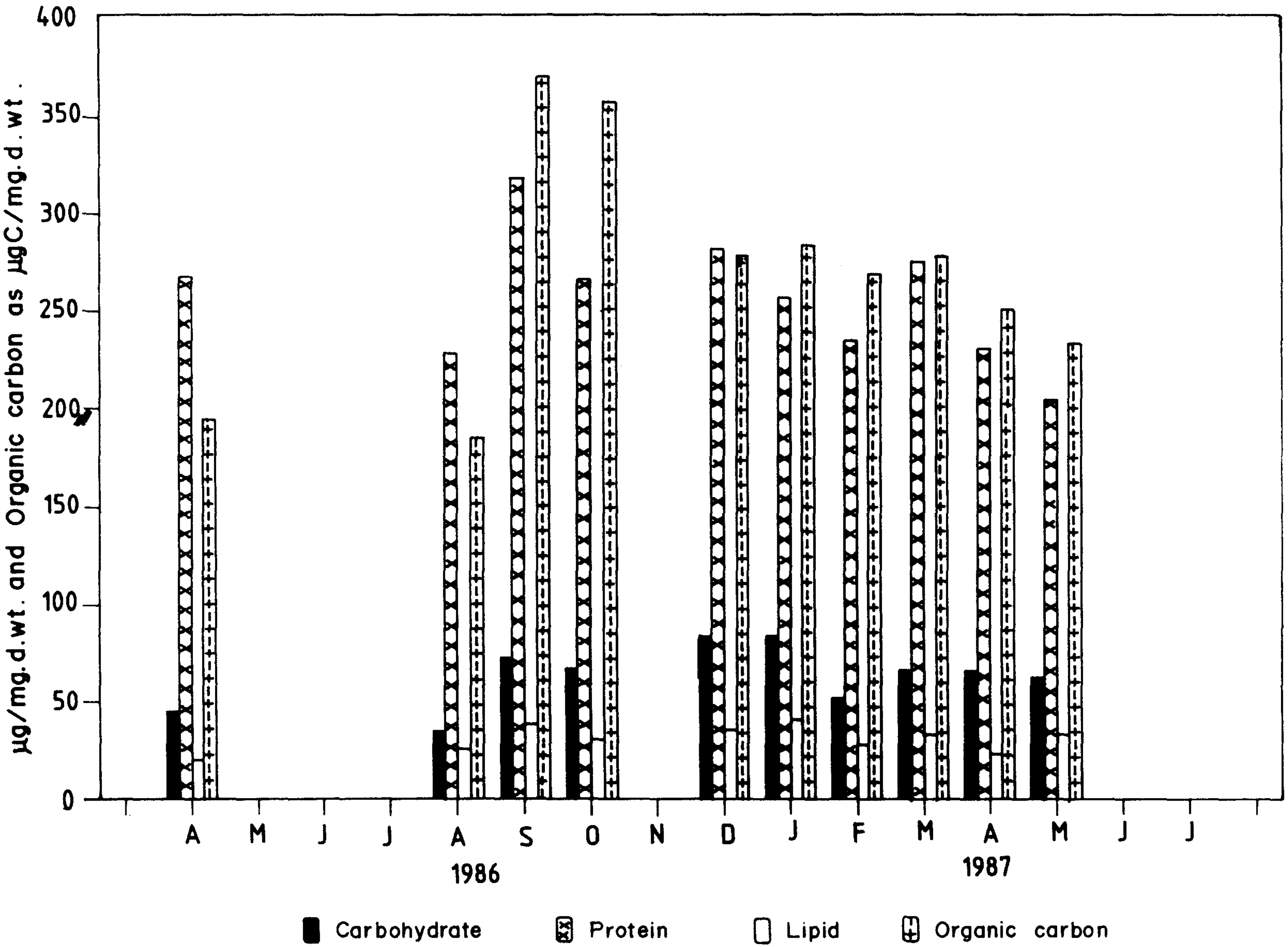

Fig.57. Monthly distribution of biochemical compounds in B. tintinnabulum RCB 30-40 mm at Arambol.

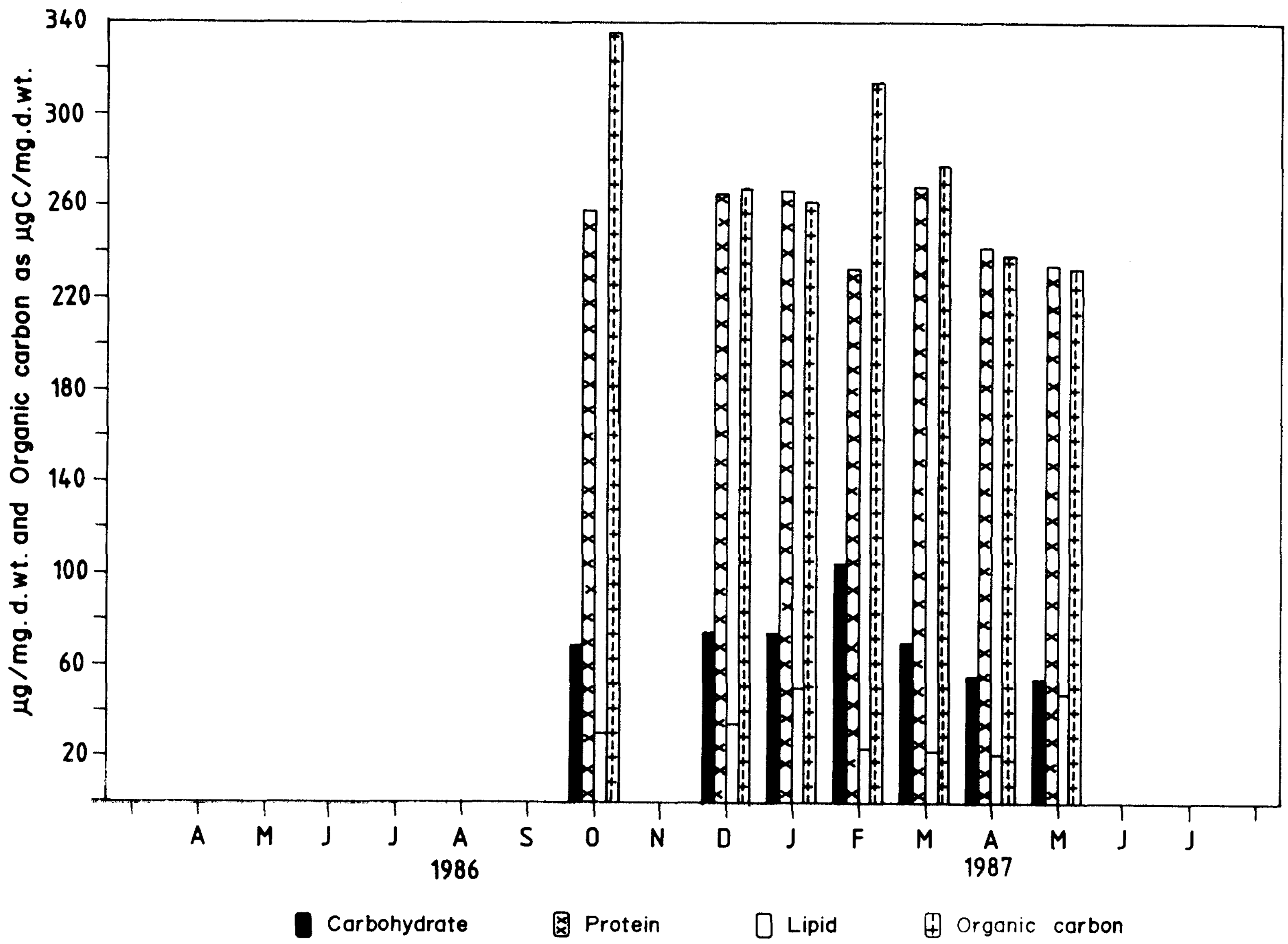

Fig. 58. Monthly distribution of biochemical compounds in B. tintinnabulum RCB 20-30 mm at Arambol.

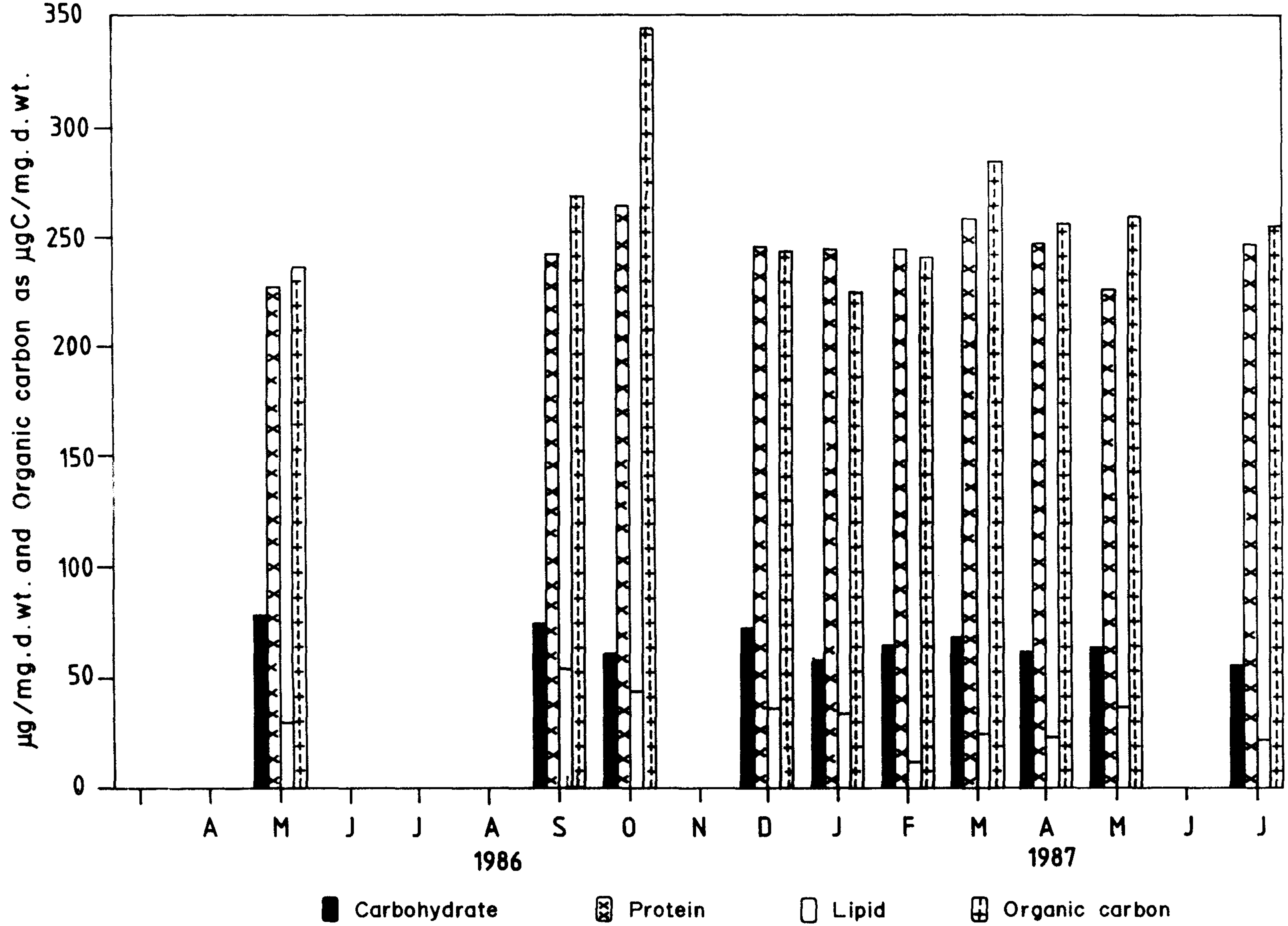

Fig. 59. Monthly distribution of biochemical compounds in intestine of B. tintinnabulum at Arambol.

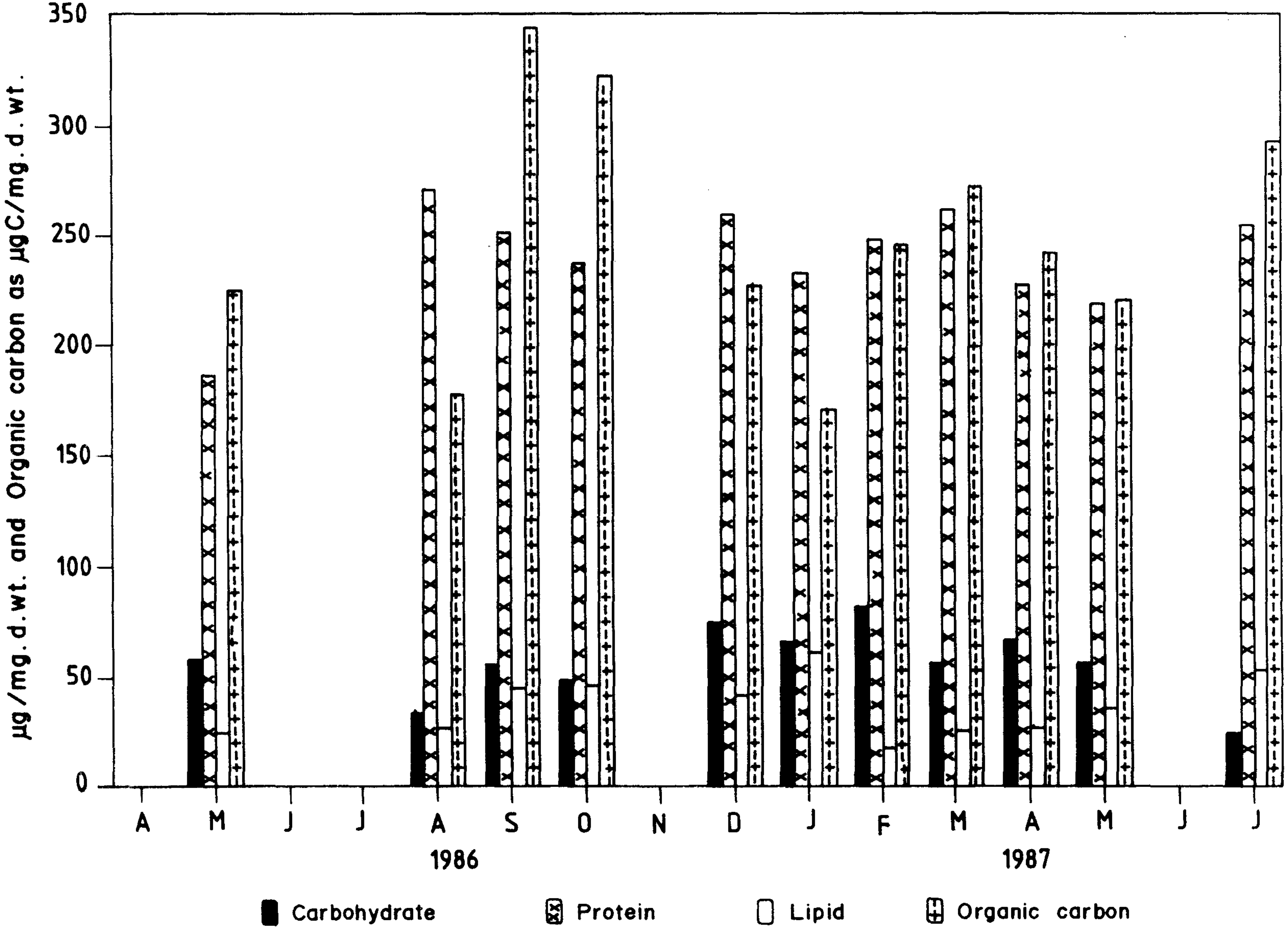

Fig. 60. Monthly distribution of biochemical compounds in cirri of B. tintinnabulum at Arambol.

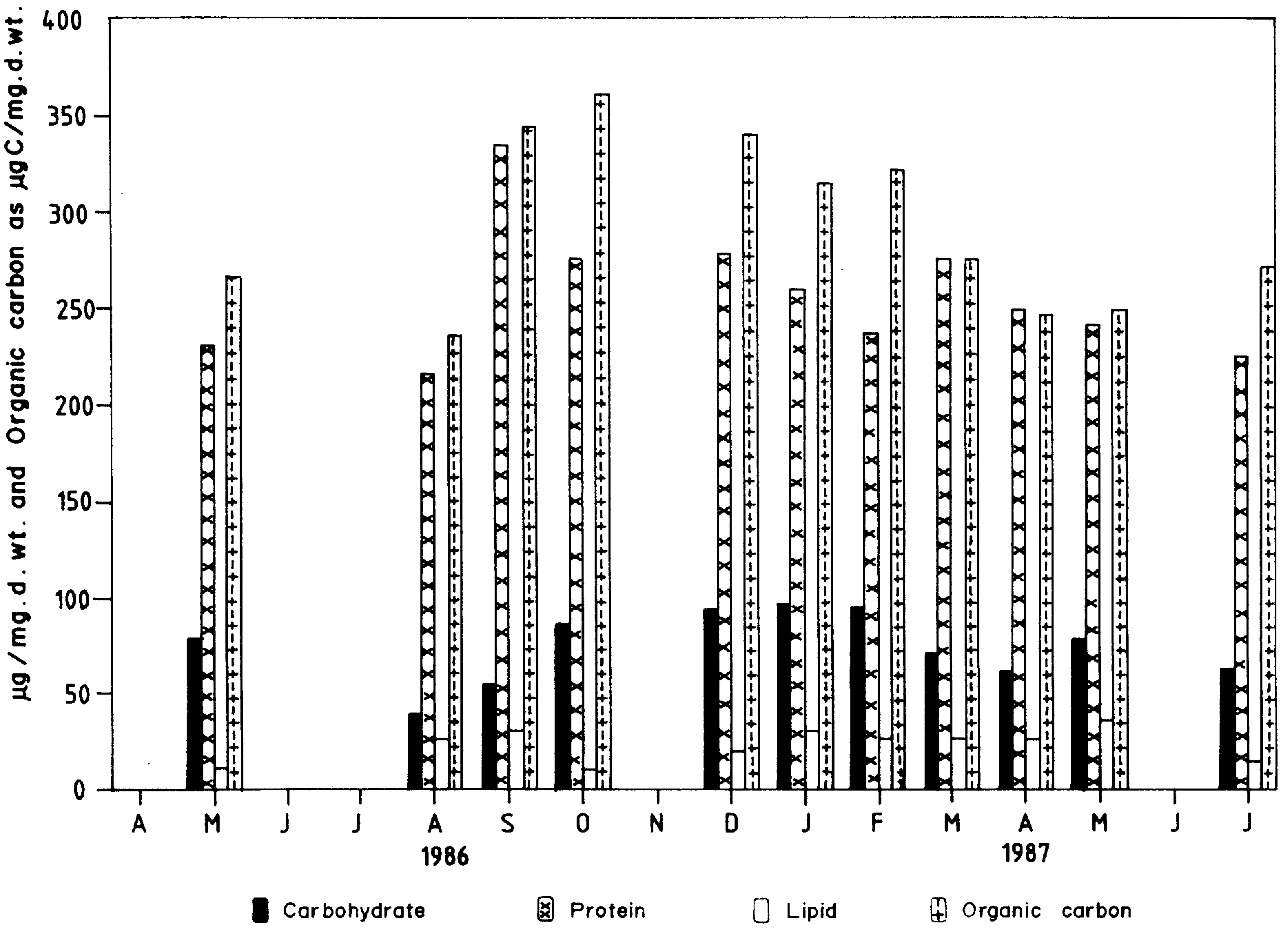

Fig 61. Monthly distribution of biochemical compounds in body tissue of B.tintinnabulum at Arambol.

CHAPTER VI

DISCUSSION

The foregoing account presents the data regarding the monthly variations in the calorofic values as well as biochemical composition of various body tissues of sessile fouling barnacles in relation to various environmental parameters. In this chapter an attempt is being made to interpret the results obtained and to find out the extent of correlation between the calorific values obtained by both the methods viz. bomb calorimetrically and by estimating with the help of biochemical components. The results have also been discussed so as to find out its correlation with the environmental parameters which have been monitored during the period of observations.

Regarding the work done on the studies on energetics of sessile barnacles from different parts of the world, the following works deserve mention. They are Barnes & Barnes (1967); Wu et al (1977); Wu & Levings (1978); Lucas et al (1979); Wu (1979); Achituv et al (1980); Harms (1984, '86, '87) etc. They have worked on various barnacle species and their larvae. As compared to this scanty work, similar studies on other invertebrates is fairly substantial. Mention may be made of the work done by Richman (1958); Golley (1961); Odum et al (1962); Comita & Schindler (1963); Davis (1963); Paine (1964); Paine & Vedas (1969); Hughes (1972); Pandian & Delvi (1973); Humphrey (1978); Griffith (1981); Horn (1986); Garton (1986); Peck et al (1987) Castro & Mattio (1987); Willows (1987).

During the course of present investigation, the highest energy content was observed in *B. amphitrite*. It was followed by the values estimated for *B. amaryllis*, *B. tintinnabulum* and *Chthamalus* sp. The energy content of *B. amphitrite* showed a variation from 3405.74 cal/g.d.wt (ash free) to 9567.71 cal/g.d.wt (ash free). The calorific content of *Chthamalus* sp. ranged from 1961.52 to 7708.74 cal/g.d.wt (ash free). In the other two species viz. *B. amaryllis* and *B. tintinnabulum* it showed a variation from 4970.21 to 8329.02 cal/g.d.wt (ash free) and 4354.24 to 7294.24 cal/g.d.wt (ash free) respectively. In a similar study carried out by Wu & Levings (1978) in case of *B. glandula* the values showed more or less similar range of variations in the calorific content. The variation in the calorific content in different barnacle species during the study period did not show any regular or seasonal pattern. Nonetheless, comparatively lower values were recorded during the monsoon months and higher values during the late monsoon or early postmonsoon season. However, exceptions did exist as in the case of <u>Balanus amaryllis</u> from the Harbour station. This group failed to display any seasonal trend of variations. Among the different species studied, <u>Chthamalus</u> sp. recorded the lowest values during the south-west monsoon seasons.

The highest energy content during these studies was recorded at the begining of postmonsoon season. This could be due to the exponential phase of growth of barnacles settled immediately after the monsoon season and their active reproductive processes. A mortality to the tune of 90 - 100% of the total barnacle population on the study panels during the monsoon season has been reported from the Marmagao Harbour by Anil (1986). In the present study also 80 - 90 % mortality was recorded at the Harbour station during the monsoon which was followed by a boom in the settlement of these sessile cirripedes on the study panels. At this juncture, the process of maturation and spawning is expected in these organisms. It must have been enhancing the storage of biochemical compounds in various tissues. This in turn might have contributed significantly to the increase in the values of calorific content. The increase in the concentration of biochemical compounds and calorific content with maturation has been reported earlier by many workers (Wu & Leving, 1978 in _B. glandula_; Castro & Mattio, 1987 in _Ostrea puelchana_ and in tropical cirithiids by Rao _et al_, 1988). They have also opined that the increase in the calorific content during the maturation time could be due to the increased storage of glycogen, lipid and protein in the gonadial and body tissues.

In regard to the effect and influence of physico-chemical factors on the values of the calorific content of marine organisms in marine environment, salinity and temperature deserve special mention. However, the factors like chlorophyll _a_, dissolved oxygen, particulate matter and particulate organic carbon concentration of the seawater are also important in the above studies since these factors can also influence the physiological conditions of an individual. During the present study, the values of salinity, temperature, chlorophyll _a_ and dissolved oxygen showed large fluctuations. It is therefore likely that the seasonal fluctuations in calorific content in the present study could either be due to the effect of any of these parameters or a combination of the same.

Inorder to find out the relationship between the calorific values and the physico-chemical parameters, the calorific values were subjected to regression analysis with important physico-chemical parameters such as salinity, temperature, dissolved oxygen, chlorphyll a, total suspended matter and particulate organic carbon (POC) (Tables, 52 to 57). The *r* values showed varying significance in different occassions. In the case of *B. amphitrite* from Harbour station, dissolved oxygen (*r* = 0.459, *P* = > 0.05) and chlorophyll a (*r* = 0.539, *P* = > 0.05) were the only two parameters showed moderate significance. Surprisingly, the same two parameters showed similar degrees of significance with *B. amphitrite* calorific content at Dona Paula also (dissolved oxygen, *r* = 0.405, *P* = > 0.1 and with chlorophyll a, *r* = 0.458, *P* = > 0.1). This shows, these two parameters could influence more on the calorific content of *B. amphitrite* than the most expected parameters like temperature and salinity.

Except this, in case of all other species all the above parameters gave insignificant relationship with the calorific content. From the above results, it could be inferred that none of these physico-chemical parameters individually in the natural environment had a significant effect on the calorific content of barnacles. But these factors together might have effected the calorific distribution of these organisms. Southward (1962) who worked on the influence of temperature on the cirrial activity and survival of some species of barnacles such as B. eburneus and B. improvisus concluded that the effect of temperature and tolerance limit depend on the nitch it occupied. He found the species such as B. amphitrite and C. stellatus were less tolerant to the temperature owing to its presence in the temperate waters. The work on the effect of temperature on different species of barnacles have been carried out by different workers like Cole (1929); Southward (1957, '64) and Crisp (1964).

The calorific content distribution of zooplankton at Harbour station showed a definite trend with the change in seasons. The lowest value of calorific content recorded was during the monsoon season. The calorific value during the study ranged between 1832.17 to 10893.05 cal/g.d.wt (ash free) which was well in agreement with the earlier reports (Qasim et al, 1978, Goswami et al, 1981 and Nandakumar et al, 1988). Regression analysis of calorific content of zooplankton with barnacle at Harbour station showed an insignificant relationship. But at the same time, the effect of chlorophyll a concentration and particulate organic carbon on the distribution of calorific content of zooplankton was significant (*r* = 0.787, *P* = > 0.001 with chlorophyll *a* and *r* = 0.781, *P* = > 0.001 with POC).

The importance of suspended matter as food source in an aquatic environment was well studied by many earlier workers (Qasim, 1972, Krishnakumari *et al*, 1978, Mook, 1980 and Nandakumar *et al*, 1988). In a tropical estuarine environment, detritus is a major source of food for marine organisms (Qasim, 1977) which acts as a link between the atrophic and heterotrophic organisms of a food chain (Odum, 1962). According to Thayer (1974 the colonization of particles by microorganisms had been suggested to enhance the nutritive value of detritus and thus indirectly enhance the suspension feeders to derive more energy from these associated organisms (Hansen & Weibe, 1977). During the present investigation, the calorific content of suspended matter ranged from 345.78 cal/g.d.wt. in the month of August, 1986 to 9481.46 cal/g.d.wt. in April, 1987 at Arambol. The values of the calorific content of suspended matter showed a marginal increase during the monsoon season which could be due to the greater influx of organic and inorganic debris brought in by the fresh water run off at the two estuarine stations. More or less a similar observation has been reported by Krishnkumari et al (1978) while studying the dynamics of the calorific content of particulate matter of Zuari estuary. The high calorific contents recorded during the months of January and February, 1987 in the present study could be due to the phytoplankton bloom which occurred during that period at this locality. Nevertheless, a similar observation could not be observed at the open sea-shore station (Arambol), where the bloom was not prevalent and the influx of fresh water carrying the rich suspended load was less.

The regression analysis of suspended matter calorific content with barnacle calorific content (respective species at respective stations) have shown a moderate significance $P = > 0.1$, $r = 0.424$ at Harbour station with B. amphitrite. Except this reading, the correlation of calorific content of suspended matter with that of barnacle was negligible (Tables, 52 to 57).

The calorific content of various size groups of B. amphitrite displayed some interesting features both at Harbour and Dona Paula stations. At Harbour station, among the four groups studied, during most of the months an increasing trend of calorific content was obtained from RCB below 5 mm to the size group RCB 10 - 20 mm. But the largest size group (above 20 mm) showed some what lower value. Almost similar observation was made at Dona Paula also. This could be due to the mature state of these organisms falling under the size group 10 - 20 mm during which the storage of biochemical compounds are expected to be high. Most of the organisms belonging to this group (RCB 10 - 20 mm) at the time of the collection were mature with ripened ovary in their mantle cavity. The calorific content of egg masses and larvae are expected to be more than that of the adult individuals due to their active metabolic state and the presence of reserve food (Wu & Leving, 1978). The gonadial status of the organisms belonging to the size groups other than the mentioned above were a mixture of mature and immature states (Tables, 58 & 59). This could be the reason for the reduced calorific content in these size groups.

More or less, a similar observation has been made about the calorific contents of B. amaryllis. The calorific content according to sizes was RCB 15 - 20 > RCB 10 - 15 > RCB 20 - 30 mm. Since, the presence of B. amaryllis during the investigation was not sufficient a clear picture as in the case of B. amphitrite could not be inferred.

In the case of Chthamalus sp. where two size groups could be studied (RCB between 5 - 15 mm and RCB below 5 mm), more energy content was found in the former size groups than the latter one. This was observed at both the stations (Arambol and Dona Paula). But in the case of B. tintinnabulum, a difference in the pattern was observed. In this case, more energy content was seen in the largest size group (RCB above 40 mm) than the rest (30 - 40 mm, 20 - 30 mm and below 20 mm). The second high value in the energy content was recorded in the size group below 20 mm, followed by 20 - 30 mm and 30 - 40 mm respectively. Here, a notable feature was that the majority of the individuals observed did belong to spent type or with immature ovary. Immature egg mass, mature eggs or nauplii could not be seen in them, except during July, 1987, when immature egg mass was observed in some of the individuals. Hence, the gradation of energy content with size could only be related to the capacity of storage of biochemical compounds in the body tissues and the physiological condition of the individual organisms.

The analysis of calorific content in B. amphitrite with respect to the state of gonadial maturity viz. mature and immature, has shown that the mature individuals had more energy reserve than the immature ones. The maturation of gonads means the presence of full grown eggs and or nauplii in the mantle cavity just prior to spawning. As opined by earlier workers (Pandian, 1969; Holland, 1978; Crisp, 1976; Lucas et al, 1979; Crisp, 1984 b) the developed eggs and larvae of many invertebrates are laiden with the storage of high energy biochemical compounds such as lipid and protein. They have also opined that the storage of lipid is mostly prefered in larvae and eggs as it gives more energy per unit area and concentration for the eggs and larvae to develop and gives more buoyancy to them for floating in the water. This high concentration of biochemical compounds in eggs and larvae explains the increased energy content of mature individuals than in the immature ones. This view is further supported by the observation carried out in two filter feeding bivalves of commercial importance, Mytilus edulis and Ostrea edulis (Helm et al 1973; Bayne et al, 1975). It has been shown that the nutritional status of parent stock may determine the energy reserve present in offspring, thus influencing its viability. This is achieved by a properly balanced and metabolically stable state of parents during the maturation and spawning period.

In this regard, a proper knowledge of calories associated with the eggs (immature and mature) and larvae is important. The estimation of calorific content of immature egg mass showed a lower value than the mature eggs. The average calorific content of eggs and larvae (first stage of nauplii) of B. amphitrite collected from the two stations (Harbour and Dona Paula) were 6216.59 cal/g.d.wt. in immature eggs, 6881.41 cal/g.d.wt. in mature eggs and 8074.79 cal/g.d.wt. in nauplii (Table, 13). The calorific content of mature eggs was greater by 9.66 % than the immature egg mass. But in the case of nauplii of first stage, the energy content increased again by an amount of 14.78 % of that of the mature eggs. Many workers have emphasised the importance of the study of biochemistry and energetics of eggs and larvae of various marine invertebrate and vertebrates. Among them, those that deserve mention here are Barnes (1965); Pandian (1967 b); Pandian & Schumann (1967); Achituv et al (1980); Zandee et al (1980); Crisp (1984 b); Harms (1986); Boehlert et al (1986) and Whyte et al (1987). Especially, the studies on the rate of transfer efficiency of organic matter and energy in developing eggs of crustaceans received considerable attention in the early period of 1960 (Urbani, 1959; Kinne, 1960 - 61; Pandian, 1967 a). As opined by Crisp (1984 b), for a wide range of invertebrates, the eggs have a high lipid content and utilized largely protein and lipid at the time of development. These two biochemical components form the major source of energy in the eggs of bivalves. However, in adult bivalves glycogen is the primary source of energy (Crisp, 1984 b).

As observed by Barnes (1965), the loss of major biochemical compounds during the development of eggs are in the order of carbohydrate (74.6%) nitrogen/protein (25.6%) and lipid (11.5%) in B. balanoides and carbohydrate (79.8%) nitrogen/protein (35.2%) and lipid (17.3%) in B. balanus. Crisp (1984 b) in his review has stated that the above two organisms and fresh water species of Macrobranchium idella are exceptions to the normal invertebrate developmental pattern with respect to the utilization of biochemical compounds.

In the present study, the rate of decrease in calorific content during the development of egg to larvae (nauplii) was 14.78 %. More or less similar observation has been reported earlier by Harms (1987) while studying the development of cyprid larvae of Elminius modestus. But, Pandian and Schumann (1967) reported a reduction of 16.06% in calorific content during the development of marture egg to zoea of the hermit crab Eupagurus bernbardus. Furthermore, the calrorific content of a mature egg during the study was 0.0039 and that of a nauplius was 0.0043. The concentration pattern showed a decrease in calorific content of eggs during the monsoon period of 1986 and more in the monsoon period of 1987.

The distribution of calorific content in different tissues of the barnacle B. tintinnabulum has revealed a definite pattern of calorific distribution. It has shown a decreasing calorific content with the tissues viz. body tissue with gonad > whole animal > intestine > cirri. The body tissue of these specimens including gonadial tissues occupied the primary position. It must be due to the high energy content associated with the gonadial tissues and developing eggs. As reported by Wu and Levings, 1978, the egg masses recorded richest calorific content among the barnacle tissues. This was followed by the the whole body of barnacle treated together followed by intestinal tissue. Cirri occupied last in the order of magnitude of calorific content because they are mainly composed of chitinous exoskeleton. The seasonal distribution pattern of calorific content in different tissues followed more or less a similar pattern of distribution as that of the whole organism. The average concentration of calorific content in different tissues have been shown in Table, 25.

The estimation of the major biochemical compounds in the barnacle tissues revealed some interesting results. It has been reported earlier by Barnes _et al_ (1963) and Cook & Gabbott (1972) in the case of boreo-arctic barnacle _B. balanus_ and _B. balanoides_. These authors emphasized the seasonal mode of distribution of the major biochemical compounds such as lipid, carbohydrate and protein. They have also related the seasonal trend to the breeding cycle and the avilability of food supply. During the present study more or less similar trend of seasonal distribution of biochemical compounds was observed. The concentrations of majority of the biochemical compounds, though not in all the observations did show a more or less decreased value during the monsoon months of 1986 followed by an increase in concentration during the postmonsoon season. Thereafter the concentration decreased in the premonsoon and the monsoon season 1987. As stated by Barnes _et al_ 1963 in temperate waters, the carbohydrate fraction was low during winter due to the preferential utilization by the barnacles. However, in their study, an increase in body weights was observed during the spring season. It might be due to the increased storage of lipid, carbohydrate and protein. But, with the onset of the summer the body weights of these organisms decreased. This increase and decrease have been related to the development and maturation of gonads in those organisms by Barnes _et al_ (1963).

In a more or less similar type of studies carried out by Gabbott & Bayne (1973) on _Mytilus edulis_, carbohydrate in excess was utilized during summer and in autumn lipid was utilized in excess. But during winter, preferentially it utilized protein instead of the above two compounds. But in _M. edulis_ the pattern was different as observed by Zandee _et al_ (1980), who have suggested that during summer lipid was the main source of energy.

During the present study the mode of utilization of biochemical compounds were different from those reported earlier by the above mentioned authors. In the case of _B amphitrite_ a decrease in concentration of all the components was observed during the 1986 monsoon season. This shows the utilization of all the compounds to overcome the monsoon season. However, the rate of utility of protein was higher than the rest of the two compounds. But, as the postmonsoon season approached, the protein utilization seems to have geared up further. But by the end of postmonsoon season (October - January) and the approach of premonsoon season (February - May), the lipid and carbohydrate were utilized rather than the protein which appears to have been accumulated in large quantity.

In Chthamalus sp. the utilization of protein and carbohydrate followed similar pattern except for lipid which did not follow the trend exactly as the other compounds. In this case as well, maximum utilization of all the compounds was observed during the monsoon season and in the pre - and postmonsoon seasons. In case of B. tintinnabulum the mode of utilization of the biochemical compounds followed more or less a similar pattern as above.

In the present study, the seasonal trend of biochemical distribution was related to both the environmental thrust as well as the breeding pattern and food supply. During the monsoon season a tremendous amount of fresh water input to the estuary has been reported (9 km^3 / annum, NIO tech. report, 1979) thereby causing a sudden fluctuation of salinity and temperature (salinity ranged from 12‰ to 35.68‰ and temperature ranged from 24.5 °C to 32.0 °C). This might be causing mass mortality of the barnacle population (80 - 90% during the present study). In order to overcome such a situation during monsoon, these organisms might have utilized more energy. This increased utilization seems to have reflected as the reduced energy content and biochemical concentration in these organisms during monsoon seasons. Cook *et al* (1972) maintained *B. balanoides*, under laboratory conditions at 5 ^{o}C and without food and observed reduced dry weight and lipid and protein content. Ritz and Crisp (1970) also observed the fluctuation of temperature and starvation affected the biochemical composition in these invertebrate organisms.

During the present study the increase in concentration of biochemical compounds during the postmonsoon season could be due to the enhanced feeding rate and maturation process. Similar observation has been reported earlier by Pandian (1968) while studying the biochemical changes during the development of *Crangon crangon*.

In order to find out the degree of influence of the major environmental parameters like temperature salinity and dissolved oxygen on the concentration of biochemical compounds in barnacles, a regression analysis was carried out between them. The results showed varying effects of these parameters on biochemical compounds of different species of barnacles. In the case of *B. amphitrite* temperature was the major parameter that affected the biochemical compsosition. The *r* values showed significant correlation to the level of *P* = > 0.1 to >0.01 with temperature against carbohydrate, lipid and protein (*r* = 0.458 with carbohydrate at Dona Paula, 0.404 with protein at Harbour, 0.412 with protein at Dona Paula and 0.624 with lipid at Harbour, Tables, 52 & 54). But in the case of *B. amaryllis* where only a smaller number of samples could be tested, the temperature was correlated significantly with protein (*r* = 0.854, *P* = > 0.001) whereas carbohydrate was correlated moderately with salinity (*r* = 0.648, *P* = >0.05, Table, 53).

In *Chthamalus* sp. carbohydrate and lipid showed a good correlation with salinity and temperature. The regression analysis of carbohydrate with salinity at Harbour gave an *r* value of 0.557 and *P* = > 0.05 and carbohydrate with temperature at Arambol gave *r* = 0.557 and *P* = > 0.05 and temperature with lipid at Arambol gave *r* = 0.503 and *P* = > 0.1 (Tables, 55 & 57). But the specimens of *B. tintinnabulum* showed moderately significant correlation of *r* = 0.480, *P* > 0.1 with protein and salinity; *r* = 0.482, *P* = > 0.1 with carbohydrate and temperature and *r* = 0.566, *P* = > 0.05 with lipid and temperature respectively (Table 56). From this analysis it could be inferred that during the present study temperature played a major role in the distribution of biochemical composition of barnacles than that of salinity or dissolved oxygen. The effect of different physico-chemical parameters on the distribution of biochemical compounds are varying, i.e. from moderate to good (Tables, 52 to 57). A more or less similar observation was made by earlier workers like Patel & Crisp (1960) and Barnes (1963). They have stated that *Chthamalus stellatus* (Poli), *B. amphitrite* and *B. perforatus* breed only over a limited range of temperature in accordance with the natural breeding season and geographical distribution. In the case of *B. balanoides* there is a critical temperature in the region of 10^{o}C above which the breeding will not take place (Barnes, 1957, '59; Crisp, 1957; Crisp & Clegg, 1960). At the same time Theede and Lassig (1967); Kahler (1970) and Williams (1970) have opined that many intertidal animals can tolerate a wide range of salinity. Hence, in light of these observations, it could be inferred that, temperature could play a major role than salinity or dissolved oxygen in the distribution of biochemical compounds in barnacles of temperate waters.

Food plays an important role in the determination of biochemical composition of any organism. This was also evident in the various barnacle species studied. The algal cells, diatoms and other organic and inorganic suspended matter form the major food components of these sessile filter feeding organisms. During the present study the regression analysis of the Chl a, suspended matter and POC with biochemical compounds gave significant relationships (Tables, 52 to 57). The role played by the food on the biochemical compounds was very well studied in Mytilus edulis by Giese (1969); Williams (1969); Dare (1973); Gabbott & Bayne (1973); Dare & Edwards (1975); Zandee et al (1980). More or less similar type study was carried out in B. balanoides by Cook & Gabbott (1972) and Cook & Lewis (1971).

Gabbott (1976) opined that the annual changes in the storage and utilization of biochemical compounds are very much linked with the reproductive cycle. In this connection the studies on the effect of maturation on the biochemical composition of B. amphitrite collected from the Harbour station have shown that the concentration of biochemical compounds was more in the mature individuals than in the immature ones. As cited earlier the findings of Crisp (1984 b), the enrichment of biochemical compounds in the gonad and reproductive organs occur with maturation so as to ensure a safe viability of eggs and larvae.

Similar observations have also been reported by Pandian (1970 a). The present study at Harbour station revealed that the protein formed the major energy source for the barnacles.

The effect of size on the biochemical composition of barnacles is a very meagerly studied subject. However, the present study on B. amphitrite from two stations (Dona Paula and Harbour) where two groups were examined (RCB above 10 mm and RCB below 10 mm) have shown that the concentration of biochemical compounds were more in the group RCB above 10 mm. This could be due to the increased accumulation of the biochemical compounds coupled with the process of maturation (Dare & Edwards, 1975; Zandee et al, 1980; Crisp, 1984 b). Mostly the barnacles belonged to the group RCB above 10 mm during the present study were mature ones (as revealed in the gonadial index study, Tables, 58 & 59). Whereas, those belonging to the group RCB below 10 mm were a mixture of immature and mature individuals. However, this trend was not true in the case of B. tintinnabulum where three size groups were studied for this purpose. This difference which occured in B. tintinnabulum could be due to the general immature/spent type of individuals present in all size groups.

The tissue wise analysis of the barnacles for the biochemical compounds showed high concentration in the body tissue than the rest of the two tissues i.e. the intestine and cirri. But according to Giese (1969) there are no discreete biochemical compunds storing organs in Molluscs as in vertebrates. Rao et al (1988) while studying the biochemical compounds of cirithiids found that, more concentration of biochemical compounds in gonad and digestive gland complex than the rest of the tissue systems. The body tissue during the present study was a mixture of body muscles and gonadial complex. The increased concentration of biochemical compounds in the body tissue was well in agreement with the calorific content data, where a similar type of increased concentration of calorific content has been observed in the body tissue followed by the intestine and cirri.

As explained in the earlier chapter (Materials and Methods) the measurement of calorific content can be done in two ways which are generally recommended for this purpose. The direct calorimetry and the indirect estimation of calorific content through biochemical equivalents. The latter method was followed by many earlier workers like Winberg (1971); Qasim et al (1978); Beukema & De Bruin (1979); Magniez (1983); Whyte et al

(1987); Castro & Mattio (1987); Nandakumar *et al* (1988) and Bhat (1988). As pointed out by Crisp (1984 a) there is one disadvantage in the direct calorimetric method for assessing the calorific content viz. the trapping of inorganic materials, which will absorb the heat generated during the combustion. This will lead to the under estimation of the calorific content. He has also pointed out that, the underestimation of the biochemical compounds finally will result in the wrong estimation of calorific content. Since both the recommended methods are followed here, an attempt has been made to find out the correlation between both the methods. It could be inferred from the data that the calorific content as calculated by the biochemical equivalents showed much reduced value than the calorimetrically obtained ones (Tables in Chapt. 4 & 5). In order to find out the relationship between the biochemical compounds and the calorific values, regression analysis was carried out with individual biochemical compound and calorific value obtained by both the methods. The results have shown that there was a very significant correlation of calorific values obtained through biochemical equivalents (Tables, 52 to 57). Among the three biochemical components estimated, protein appeared to be significantly correlated in all the four species. Similarly carbohydrate and lipid were equally important in contributing to the total energy content. While studying the calorific values and biochemical composition of zooplankton, Bhat (1988) has also reported similar observation. But the calorific value obtained through direct calorimetric method seems to be significantly correlated with biochemical compounds of barnacles.

As regards to the comparison of calorific content of the barnacles from the two localities during the study viz. stations at Zuari estuary and station at Arambol showed good differences. In the case of *Chthamalus* sp. the average energy content of this species from Dona Paula were greater than those from the Arambol locality. This could be due to the availability of more food at the estuarine stations than of the exposed sea shore. This was evident from the data on calorific contents of suspended matter and Chl *a* (Arambol recorded less values of both the parameters than of the other two stations located along the Zuari estuary except the only one highest value). This tendency was evident in the calorific content of *B. amphitrite* and *B. amaryllis* as compared to that in the *B. tintinnabulum* also. But, this was not distinctly exhibited in the biochemical concentration of barnacles from the above localities. Regarding the effect of seasonal changes, the fluctuations were more distinct at the Zuari estuary in all the species studied except in <u>Chthamalus</u> sp. In these forms the effect was more or less same at both the localities.

The calorific content of various marine organisms including algae show varying concentrations. Some of the earlier reports include Pandian, 1967 a (in eggs of <u>Crangon crangon</u>, from 5.287 to 6.443 K cal/g.d.wt); Paine and Vedas, 1969 (in different species of algae from 0.65 to 5.44 K cal/g.d.wt); Ansell, 1974 (in <u>Lima hians</u>, 3.8 to 4.7 K cal/g.d.wt); Ansell <u>et al</u>, 1973 (in <u>Donax spiculum</u>, 4.62 to 4.79 K cal/g.d.wt.); Sumitra Vijayaraghavan <u>et al</u>, 1975 (in various estuarine and marine organisms, from 1.375 to 5.567 K cal/g.d.wt.); Rajagopal <u>et al</u>, 1976 a (in <u>Crassostrea cucullata</u>, 3.937 K cal/g.d.wt.); Vijayakumaran, 1977 (in <u>Ambasis gymnocephalus</u>, from 2.777 to 4.036 K cal/g.d.wt.); Krishnakumari <u>et al</u>, 1977 (in <u>Meretrix casta</u>, 4.1 K cal/g.d.wt.); Qasim <u>et al</u>, 1978 (in zooplankton from 0.5 to 6.4 K cal/g.d.wt.); Wu and Leving, 1978 (in <u>Balanus glandula</u>, between 5 and 6 K cal/g.d.wt.); Balasubramanian <u>et al</u>, 1979, (in <u>Donax incarnatus</u>, 4.24 K cal/g.d.wt., <u>D. vittatus</u>, 4.85 K cal/g.d.wt., <u>D. spiculum</u>, 4.7 K cal/g.d.wt.); Sumitra Vijayaraghavan <u>et al</u>, 1981, (in <u>Etroplus suratensis</u>, from 4.243 to 4.639 K cal/g.d.wt.); Castro and Mattio, 1987, (in _Ostrea puelchana_, 1.26 K cal/g.d.wt.) etc.

During the present study, it has been observed that the average values of calorific contents of different species of fouling barnacle such as _Balanus amphitrite_ are 6.354 K cal/g.d.wt. and 5.801 K cal/g.d.wt. at Harbour and Dona Paula respectively. In case of _B. amaryllis_ the values were found to be 6.252 K cal/g.d.wt. at Harbour and in _B. tintinnabulum_ they were 5.357 K cal/g.d.wt. at Arambol. _Chthamalus_ sp. recorded 4.68 and 4.34 K cal/g.d.wt. at Dona Paula and Arambol respectively. These values compare well with calorific concentration of the other marine organisms mentioned above. Hence it may be maintained that the role played by these organisms in the food chain could be is equally important as any other economically important intertidal organisms. It is therefore likely that the complete eradication of fouling organisms might cause a serious threat to the balanced state of energy budget in the marine environment.

From the foregoing discussions it could therefore be concluded that the work on the energetics of barnacles from Indian waters has been neglected till date. It is very important to assess the contribution by the intertidal and fouling organisms to the energy budget and food chain. This in turn will indicate the extent of the role played by the various faunastic groups at a particular locality. This could further lead to the investigation enlightning the energy requirements for various physiological process of individual groups of marine organisms, which in turn help in population dynamics studies.

Similarly the studies on energetics of various tissues of economically important marine organisms could help us in the planning of new nutritional strategies.

Table 52

Table showing coefficient of regression (r) and its significance (p, indicated for only those relationships where the significance is on or above 0.1) among various parameters studied on *B. amphitrite* at Harbour station.

	S.M.cal.	Z.cal	B.cal	CHO	Protein	Lipid	Organic carbon
Salinity	0.362	0.321	0.063	0.100	0.173	0.283	0.152
Temp.	0.305	0.245	0.300	0.105	0.404 p=>0.1	0.624 p=>0.01	0.173
D.O	0.200	0.055	0.459 p=>0.05	0.424 p=>0.1	0.200	0.173	0.141
Chl. a	0.141	0.787 p=>0.001	0.539 p=>0.05	0.550 p=>0.05	0.200	0.084	0.223
S.M.	0.425 p=>0.1	0.004	0.363	0.387	0.148	0.071	0.148
POC	0.063	0.781 p=>0.001	0.361	0.387	0.307	0.224	0.224
S.M. cal.	--	0.110	0.424 p=>0.1	0.105	0.261	0.501 p=>0.05	0.351
Z. cal	--	--	0.110	0.224	0.436 p=>0.1	0.400	0.532 p=>0.05
B. cal	--	--	--	0.057	0.055	0.063	0.316
B.cal B.E	--	--	--	0.089	0.884 p=>0.001	0.854 p=>0.001	0.207

S.M. cal - calorific content of suspended matter in the seawater
Z. cal - calorific content of zooplankton
B. cal - calorific content of barnacles
B. cal) - calorific content of barnacles calculated from
B.E.) biochemical equivalents
CHO - carbohydrate; Chl.a - Chlorophyll a; S.M. - suspended matter concentration in the seawater; Temp - temperature of the seawater; POC - particulate organic carbon; D.O - dissolved oxygen concentration in the seawater

Table 53

Table showing coefficient of regression (r) and its significance (p, indicated for only those relationships where the significance is on or above 0.1) among various parameters studied on *B. amaryllis* at Harbour station.

	S.M.cal.	B.cal	CHO	Protein	Lipid	Organic carbon
Salinity	0.728 p=>0.02	0.141	0.648 p=>0.05	0.105	0.387	0.045
Temp	0.316	0.200	0.095	0.854 p=>0.01	0.055	0.500
Chl.a	0.316	0.224	0.800 p=>0.001	0.084	0.510	0.200
D.O	0.377	0.416	0.032	0.954 p=>0.001	0.251	0.686 p=>0.02
S.M.	0.452	0.053	0.560 p=>0.1	0.755 p=>0.01	0.585 p=>0.1	0.283
POC	0.332	0.141	0.735 p=>0.01	0.316	0.500	0.141
S.M. cal	--	0.141	0.200	0.077	0.063	0.184
Z. cal	--	0.316	0.648 p=>0.05	0.071	0.071	0.200
B. cal	--	--	0.265	--	0.200	0.902 p=>0.001
B. cal B.E.	--	--	0.628 p=>0.05	0.633 p=>0.05	0.556 p=>0.1	0.014

S.M. cal - calorific content of suspended matter in the seawater
Z. cal - calorific content of zooplankton
B. cal - calorific content of barnacles
B. cal) - calorific content of barnacles calculated from
B.E.) - biochemical equivalents
CHO - carbohydrate; Chl.a - Chlorophyll a; S.M. - suspended matter concentration in the seawater; Temp - temperature of the seawater; POC - particulate organic carbon; D.O - dissolved oxygen concentration in the seawater

Table 54

Table showing coefficient of regression (_r_) and its significance (_p_, indicated for only those relationships where the significance is on or above 0.1) among various parameters studied on _B. amphitrite_ at Dona Paula station.

	S.M.cal.	B.cal	CHO	Protein	Lipid	Organic carbon
Salinity	0.114	0.055	0.02	0.173	0.001	0.071
Temp	0.200	0.224	0.458 p=>0.1	0.412 p=>0.1	0.014	0.095
D.O.	0.071	0.405 p=>0.1	0.089	0.387	0.089	0.141
Chl.a	0.02	0.458 p=>0.1	0.141	0.440 p=>0.1	0.100	0.361
S.M.	0.305	0.235	0.624 p=>0.01	0.316	0.458 p=>0.1	0.014
POC	0.045	0.283	0.224	0.346	0.022	0.224
S.M. cal	--	0.283	0.510 p=>0.05	0.480 p=>0.05	0.300	0.469 p=>0.1
B. cal	--	--	0.173	0.228	0.285	0.266
B. cal B.E.	--	--	0.667 p=>0.01	0.893 p=>0.001	0.386	0.385

S.M. cal - calorific content of suspended matter in the seawater
B. cal - calorific content of barnacles
B. cal) - calorific content of barnacles calculated from
B.E.) biochemical equivalents
CHO - carbohydrate; Chl.a - Chlorophyll _a_; S.M. - suspended matter concentration in the seawater; Temp - temperature of the seawater; POC - particulate organic carbon; D.O - dissolved oxygen concentration in the seawater

Table 55

Table showing coefficient of regression (r) and its significance (p, indicated for only those relationships where the significance is on or above 0.1) among various parameters studied on Chthamalus sp. at Dona Paula station.

	S.M.cal.	B.cal	CHO	Protein	Lipid	Organic carbon
Salinity	--	0.141	0.557 p=>0.05	0.063	0.379	0.084
Temp	--	0.207	0.370	0.173	0.173	0.207
D.O	--	0.205	0.346	0.458 p=>0.1	0.173	0.567 p=>0.02
Chl.a	--	0.091	0.179	0.448 p=>0.1	0.432 p=>0.1	0.400 p=>0.1
S.M.	--	0.300	0.200	0.205	0.055	0.030
POC	--	0.232	0.346	0.549 p=>0.05	0.336	0.559 p=>0.02
S.M. cal	--	0.182	0.513 p=>0.05	0.122	0.346	0.548 p=>0.02
B. cal	--	--	0.182	0.017	0.045	0.283
B. cal B.E.	--	--	0.841 p=>0.001	0.952 p=>0.001	0.321	--

S.M. cal - calorific content of suspended matter in the seawater
B. cal - calorific content of barnacles
B. cal) - calorific content of barnacles calculated from
B.E.) biochemical equivalents
CHO - carbohydrate; Chl.a - Chlorophyll a; S.M. - suspended matter concentration in the seawater; Temp - temperature of the seawater; POC - particulate organic carbon; D.O - dissolved oxygen concentration in the seawater

Table 56

Table showing coefficient of regression (r) and its significance (p, indicated for only those relationships where the significance is on or above 0.1) among various parameters studied on *B. tintinnabulum* at Arambol station.

	S.M.cal.	B.cal	CHO	Protein	Lipid	Organic carbon
Salinity	0.742 p=>0.01	0.173	0.001	0.480 p=>0.1	0.245	0.265
Temp	0.442	0.148	0.482 p=>0.1	0.283	0.566 p=>0.05	0.247
D.O.	0.141	0.332	0.063	0.447	0.377	0.063
Chl.a	0.228	0.232	0.348	0.307	0.245	0.265
S.M.	0.361	0.200	0.436	0.100	0.245	0.437
POC	0.436	0.032	0.458 p=>0.1	0.500 p=>0.1	0.045	0.161
S.M. cal	--	0.045	0.071	0.173	0.316	0.045
B. cal	--	--	0.283	0.270	0.346	0.728 p=>0.01
B. cal	--	--	0.342	0.804 p=>0.001	0.672 p=>0.01	0.665 p=>0.01

S.M. cal - calorific content of suspended matter in the seawater
B. cal - calorific content of barnacles
B. cal) - calorific content of barnacles calculated from
B.E.) biochemical equivalents
CHO - carbohydrate; Chl.a - Chlorophyll *a*; S.M. - suspended matter concentration in the seawater; Temp - temperature of the seawater; POC - particulate organic carbon; D.O - dissolved oxygen concentration in the seawater

Table 57

Table showing coefficient of regression (r) and its significance (p, indicated for only those relationships where the significance is on or above 0.1) among various parameters studied on Chthamalus sp. at Arambol station.

	S.M.cal.	B.cal	CHO	Protein	Lipid	Organic carbon
Salinity	0.265	0.574 p=>0.05	0.245	0.316	0.387	0.608 p=>0.02
Temp	0.566 p=>0.05	0.224	0.557 p=>0.05	0.114	0.503 p=>0.1	0.032
D.O.	0.141	0.071	0.414	0.071	0.105	0.200
Chl.a	0.077	0.026	0.045	0.141	0.224	0.058
S.M.	0.272	0.277	0.412	0.480 p=>0.1	0.032	0.429
POC	0.010	0.412	0.424	0.578 p=>0.05	0.232	0.412
S.M. cal	--	0.071	0.400	0.412	0.703 p=>0.01	0.141
B. cal	--	--	0.293	0.640 p=>0.02	0.014	0.808 p=>0.001
B. cal	--	--	0.686 p=>0.01	0.849 p=>0.001	0.656 p=>0.01	0.583 p=>0.05

S.M. cal - calorific content of suspended matter in the seawater
B. cal - calorific content of barnacles
B. cal) - calorific content of barnacles calculated from
B.E.) biochemical equivalents
CHO - carbohydrate; Chl.a - Chlorophyll a; S.M. - suspended matter concentration in the seawater; Temp - temperature of the seawater; POC - particulate organic carbon; D.O - dissolved oxygen concentration in the seawater

Table 58

Table showing the state of gonadial maturity and size in <u>B. amphitrite</u> at Harbour station

Month	RCB below 5 mm	RCB 5 - 10 mm	RCB above 10 mm
Apr'86	--	--	4
May	--	2	2
Jun	--	2	2
Jul	--	2	2
Aug	--	2	1
Sep	--	2	3
Oct	--	4	4
Nov	--	2	3
Dec	--	--	--
Jan'87	2	2	2
Feb	2	3	2
Mar	3	3	4
Apr	2	2	2
May	3	3	3
Jun	2	2	4
Jul	4	2	4

1 - Purely immature/spent
2 - Immature egg mass
3 - Mature/fertilized eggs
4 - Nauplii

Table 59

Table showing the state of gonadial maturity and size in <u>B. amphitrite</u> at Dona Paula station

Month	RCB below 5 mm	RCB 5 - 10 mm	RCB above 10 mm
Apr`86	--	--	2
May	--	2	3
Jun	--	2	2
Jul	--	2	3
Aug	--	2	1
Sep	--	3	3
Oct	4	4	4
Nov	2	2	3
Dec	4	4	4
Jan`87	1	3	4
Feb	-	2	3
Mar	2	3	3
Apr	2	3	4
May	2	2	3
Jun	1	2	2
Jul	4	2	4

1 - Purely immature/spent
2 - Immature egg mass
3 - Mature/fertilized eggs
4 - Nauplii

SUMMARY

SUMMARY

The major findings of these studies extending from April, 1986 to July, 1987 on the calorific content and biochemical concentrations of sessile barnacles (B. amphitrite, B. amaryllis, B. tintinnabulum and Chthamalus sp.) with special reference to fouling species can be summarized as follows:

1. The monthly distribution of calorific content in different species of barnacles showed a pattern of low concentration during monsoon season and high values during the beginning of post monsoon seasons.

2. The general calorific content decreased from B. amphitrite to Chthamalus sp. in the order B. amphitrite > B. amaryllis > B. tintinnabulum > Chthamalus sp.

3. The total calorific content of different barnacle species have shown the variation of calories as below

   B. amphitrite - 3405.74 to 9567.71 cal/g.d.wt.

B. amaryllis - 4970.21 to 8329.02 cal/g.d.wt.

B. tintinnabulum - 4354.24 to 7294.24 cal/g.d.wt.

Chthamalus sp. - 1961.52 to 7708.74 cal/g.d.wt.

4. The distribution of individual physico-chemical parameters did not show any significant effect on the distribution of calorific content of barnacles, but it can be attributed to a combined effect of all the physico-chemical parameters.

5. In the size group analysis of *B. amphitrite* more energy content was observed in the size group RCB 10 - 20 mm than the other size groups like RCB above 20 mm, 5 - 10 mm and below 5 mm.

6. In *Chthamalus* sp. more energy content was recorded in the size group 5 - 15 mm (RCB) than in the other size group (below 5 mm) both at Dona Paula and Arambol.

7. In *B. tintinnabulum* more energy content was observed in the size group RCB above 40 mm followed by below 20 mm, 20 - 30 mm and 30 - 40 mm. The irregular gradation in this species is

attributed to the physiological condition of the organisms at the time of sampling.

8. The calorific contents of mature and immature forms of B. amphitrite from the Harbour and Dona Paula have shown a more energy content in the mature forms than the immature ones.

9. The average energy content of immature eggs, mature eggs and nauplii of B. amphitrite have shown that the energy content decreased in the order nauplii > mature eggs > immature eggs. The average rate of increase (mean of both the stations) have shown an increase of 9.66% of calorific content from immature eggs to mature eggs and an increase of 14.78% from mature eggs to nauplii.

10. The calorific content of a single matured egg of B. amphitrite during the study varied from 0.0021 to 0.0072 cal/egg and that of nauplii varied from 0.0023 to 0.0068 cal/nauplii with an average of 0.0039 and 0.0043 of egg and nauplii respectively.

11. The calorific content in the different tissues of <u>B. tintinnabulum</u> have shown an order of decrease like body tissues with gonad > whole animal taken together > intestine > cirri.

12. Distribution of calorific content of zooplankton showed the effect of seasonal changes. The calorific content was found to be varying between 1832.17 to 10893.05 cal/g.d.wt.

13. Distribution of calorific content of particulate matter at three stations have shown a marginally increased concentration during the monsoon seasons. It ranged from 1514.83 to 7790.17, 1135.89 to 5099.96 and 345.78 to 9481.46 cal/g.d.wt. at Harbour, Dona Paula and Arambol respectively.

14. In many of the observations the concentration of biochemical compounds have shown a reduced value during the monsoon months of 1986 followed by an increased concentration during the postmonsoon and next premonsoon seasons.

15. In barnacles the rate of utilization of protein

was more as compared to lipid and carbohydrate during the monsoon seasons.

16. The concentration of biochemical compounds was more in mature forms of B. amphitrite than the immature forms both at Harbour and Dona Paula.

17. The effect of size on the concentration of biochemical compounds have shown more concentration in the individuals belonging to the group RCB 10 - 20 mm.

18. The distribution of biochemical compounds in various tissues of B. tintinnabulum have more concentration of these compounds in body tissues than that of intestine and cirri.

19. An evaluation of both the methods of the calculation of calorific content (direct calorimeter and indirect method using biochemical concentration and its calorific equivalents) have shown that, the direct method is far efficient.

20. The general concentration of calorific content

in the organisms and particulate matter at Zuari estuarine stations were more than that of the open seashore station at Arambol. This was evident in the data relating to particulate matter and chlorophyll a content.

21. The variations in environmental parameters have shown the effect of monsoon in their monthly distribution at all the three stations.

22. The calorific contribution of barnacle population to the food chain is significant as any of the other major invertebrate population with their innumerable eggs and larvae. So it is suggested that, before the complete irradication of the barnacles, a proper thought should be given so as it will not affect the balance of ecosystem.

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