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36. ECOLOGICAL ENERGETICS OF THE ROCK OYSTER *SACCOSTREA CUCULLATA* (BORN)

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ABSTRACT

The energy budget partitioning in tlie rock oyster *Saccostrea cucullata* (Born^ has been described and based on this the functional iniportance of these oysters In the astuarins ecosystem has been discussed.

It has been found that a large amount of consumed energy (c *= 100%) Is diverted to the maintenance cost (R = 31.26%). However, at this cost the soma (S) energy Incorporation is only 9.74% while the gonadal (Q) energy output is only 6.51% of the 'C In addition to the gonadal output, 40% of 'C energy is passed to the trophic system back in terms of faeces and urinary excreta (F + U) and 2.49% of the energy !• totally eliminated (E) from the population on account of fishing and predation

INTRODUCTION

The present studies, contextual to modern developments in ecology, emphasizing the importance of energy and energy flow in evaluating the relative importance of species population to the functioning of an ecosystem, concern with the ecological energetics of rock oyster, *Saccostrea cucullata* (Born) in Kalbadevi estuary at Ratnagiri (Maharashtra;.

The energy flow studies in populations of marine and estuarine bivalves have attracted attention of many workers especially where they provide a commercial fishery and contri- . , . . , . , ^ .. u J . X bute significantly to the energy budget of a benthic community. The notable investigations include, studies on oyster, CAa5S0rfrea *virginica* by Dame (1972 a, b, 1976) *Choromytilus meridionaiis* by Griffiths (1981 a, b) *l\Aercenaria mercenaria* by Hibbert (1977 a, b), *Scrobicularia plana* (Da Costa) and *Fissurela barbadensis* (Grnelin) by Hughes (1970, 1971) scallop, *Ch/amys islandica (0. F. MiWet)* by Vahl (1981 a, b) oyster *Ostrea edulis* (L) by Rodhouse (1978, 1979) and *Tellina tenuis* (Da Costa) by Trevallion (1971)

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The intertida popu ations of ndian rock
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oyster SaccosfAea *cucullata* are the typical of tidal estuarine ecosystems common to many coasts of Indian peninsula. In Kalbadevi estuarine ecosystem *Saccostrea cucullata* forms the popular food item in poor class communities. However, inspite of these being the Important members of the estuarine community, the Information concerning their significance to the estuarine ecosystem is nil. While there have been few studies on their biology (Nagbhushanam and Bidarkar 1975, Rajgopal eta! 1976, Mane 1978, D'Silva 1979, Asif 1979, 1980), the present studies report for the first time the quantitative examinations of these oysters' populations in relation to the incident potential energy per unit measure of the ecosystem and the efficiency with which this energy is being utilised by these oysters for various life activities and functions,

MATERIALS AND METHODS

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The oyster community was sampled at low ^.^^^^ ^^ /^^^^ ^ ^^|^^/^^^ ^^^ip ^, ^^^^^ ^^ Kalbadevi estuary. At the beginning of sampling programme, a matrix of 120 (6x20) spots was determined on this shore and 4 spots were chosen monthly at random. A 0.25 m' grid ^gs then placed on the chosen spots and the ^eat contents of all the oysters within these quadrats were dissected out and individually packing in small glass vials containing sea water were transferred to the laboratory for further processing. On bringing to the laboratory the samples were dried to constant weights at 70°C temperature for 96 h. All biomass data ^. * . »u j *• • u» xu- thus refers to the oven dry tissue weights. The data obtained from 4 quadrats was pooled together for various analyses. The samples of 1 square metre were considered sufficient in size to reflect population functioning. For physiological experiments live oysters were required. These were the solitary individuals growing over small shingles.

The determination of energy budget was done by following I. B. P.

notation : $C - P + R + F + U$

where

C = Energy content of the food consumed.

P = Production i. e. energy incorporated by the population in new tissues and garnets and is, therefore, a sum of somatic production 'S' and 'G' which is the energy released into the environment as spawned garnets. Alternatively,

P = S + G + E where,

S = Any net change in energy content ot the standing crop.

G = op. cit.

E «=. The energy content of all individuals eliminated from the population due to various causes, such as predation etc.

R =" Energy dissipated from the population as metobolic heat, represented by respiration and is commonly measured by the oxygen consumption of the animal.

F = The part of 'C which is not absorbed but Is passed out of the gut as faeces.

U = Energy eliminated by secretion of unwanted materials or exudates such as mucus and dissolved organic matter (Rodhouse 1979)

Further, the amount of energy consumed which is utilised (assimilated) by the bivalve can be calculated as below:

$$A = C-(F + U)$$
$$=:P + R$$

and has been called as energy flow by Smalley (1960). This is the energy of assimilation (Trevallion 1971, Hughes 1971, Dame 1972 b 1976 Perkins 1974, Johnson 1976, Hibbert 1977 a, Ansel I et al 1978 Rodhouse 1978, Wu and Leving 1978, Wu 1979, Griffiths 1981 b) It is termed by Engleman (1966) as gross production. The net production according to him is C-(F + R).

The various parameters incorporated in the equation above were determined as follows. *'S'-* the somatic production by Ricker (1968) method, 'G' the reproductive output by the methodology described by Hibbert (1977 a, b) and 'E'the elimination by the method of AnselI etal (1978). The energy dissipation (R) was estimated by measuring the oxygen consumption rates of oysters by standard laboratory experiements with volumetric estimations of dissolved oxygen, and converting the rates of oxygen consumptions into heat productions. For 'C and 'F i U since the independant measurements of feeding and biodeposition rates in the field were lacking, consumption 'C was determined as the amount of food consumption required to produce the energies of assimilation, assuming that food is assimilated at the 60% average efficiency as suggested by Miller et al (1971), i. e.

$$C= A/0.6 \text{ where}$$
$$A=P+R$$

and'F + U'asC-(P+R)

The energy budget was finally completed by converting the weight values (milligrammes) into energy values (kilocalories) by multiplying by 3.39566 (Vijayaraghwan et al 1975, Rajgopal et al 1976) and millilitres oxygen consumption values into energy values (kilocalories) by multiplying by oxycalorific coefficient 0.00482.

RESULTS AND DISCUSSION

The investigations carried out presently were on a representative oyster population sample covering an rock area of one square metre and the time unit was one year. Only the parametres in connection with the energetics of this population are presented here and the results are assumed to represent the characteristic of the whole oyster population system present in the estuary.

The energy utilization or the flow of energy through *Saccostrea cucuUata* is given below represented by the complete energy budget determined with units in Kcal/m7year which serves as a summary of population energetics.

C,	energy consumption	17968.29	Kcal.
A,	energy assimilation	10780.98	„
R,	metabolism energy	5617.79	„

F+ U, faeces & urinary energy loss	7187.31	
S, growth energy	1750.19	„
G, gonadal energy .output	1169.35	,;
E, energy to predators	2243.65	„
P, S + G T E i.e. production	5163.19	„

This complete energy budget can be used to examine the pathways of energy through population and hence to evaluate the role of *Saccostrea cucullata* in the community at the Kalbadevi estuary.

Large amount of consumed energy (C = 100%) is diverted to the maintenance cost (i. e, R = 31.26%). At this cost the soma (S) energy incorporation is 9.74% while the gonadal (G) energy output is 6.51% of the 'C. In addition to the gonadal output, the 40% of 'C' is passed to the trophic system back in terms of faeces and urinary excreta (F+U). The energy that is eliminated (E) from the population on account of fishing, predation and mortality is 12.49% and out of 60% of the energy assimilated (A) by the species 52.1% (R/Ax 100) is required by it for the incorporation of 16.33% of the energy as soma (S/A x 100), into the standing biomass and 10.85% of the energy as the gonadal output (G/A x 100). The 'S +G' together amount to 27.18% of 'A' and the elimination (E) is 20.82% of (A) (E/A x 100).

The ecological energetics budget available in literature may be compared with the energetics budget submitted here. The values reported in literature for C, S, G, P, R and F + U for various bivalves are given in Table. The original values have been converted to percentages of the energy consumed (C) with latter taking as 100% to facilitate comparison.

In bivalves the 'F-|-U' loss may be 14.00% to 94.22% of the consumed energy. It is interesting to note that in majority of bivalves the 'F+U' loss amounts to around 40% of the energy consumed. Tho examination of data in **Table 1 points out that *Saccostrea cucullata* is** an example of feeder with exploitative strategy like all these bivalves listed in this Table, except for the Bivalvia Los Maritas, only in which the energy loss amounts to 34.65% of energy utilization (F-|-U/PxIOO). Bivalvia Los Maritas shows extremely high efficiency ratios and appears to be adopted to conservationalist strategy, reducing energy losses to minimum.

The ratio of growth energy (S t G) to assimilated energy (A) is called the growth efficiency. The growth efficiency value for ***Saccostrea cucullata* may be compared with** the growth efficiency values reported in literature (Table 2) *Saccostrea cucullata* appears to have relatively high growth efficiency compared to ***Mytilus californianus, Scrobicularia plana* and** *Modiolus demtssus,* while it is close to a range **of values for *Donax vittatus, Bivalvia* San Luis' Bivalvia Las Maritas, *Tellina tenuis and Ostrea edulis.* For *Mytilus edulis, Mytilus Chilensis. Perna viridis, Pectinopecien yessoansis* and *Crassostrea virglnica* wide range of growth** efficiency values have been reported.

However, in *Saccostrea cucullata* besides 'F+U'loss of 7187 31 Kcal, fishing predators and mortalities (E) remove an estimated 2243-65 Kcal of energy and further with 'G' as 1169-35 Kcal, this all together amount to 10600.31 Kcal or 59% of the energy consumed (C) by these oysters, and therefore, inspite of the species relatively high growth efficiency, the above channeling of energies may probably be leading to it's inefficient survival and spread in the locality.

However, this may be only speculative, if the ecological efficiency of Sacco^rAfis *cucullata* is compared with the ecological efficiencies of other bivalve species of the same locality. The ecological efficiency is defined by Slobodkin (1962) is:

$$\frac{\text{Ec^Yield } (P=S\text{-}^G\text{-}^E)}{\text{Food intake } (C)}$$

For *Saccostrea cucullata* it comes to 0.2873. Based on the available information on primary productivity of the waters at the locality and on the filtration rate in *Mytilus {Perna) viridis* (Ranade 1977) and *Meretrix* sp (Durve 1963) and length- weight relationship (Kowale' Personal communication) of latter, the consumption of energy in Kilocajories (using calorific coefficient values given by Vijayraghavan et al 1975) required to produce the same amount

TABLE 1. ***Energy partitioning in bivalves from different Localities***

SPECIES	S	G	P	R	F + U
1. *Donax incarnatus*					
Anselletal, 1972	-	-	8.49	51.23	40.28
2. *Donax spiculam*					
Anselletal, 1972	—	-	6.17	53.81	40.02
3. Bivalvia San Luis					
Edwards 1974 a	-	-	19.76	40 22	40.01
4. Bivalvia San Luis					
Edwards 1974 b	—	—	15.55	44.44	40.00
5. Bivalvia Los iVlaritas					
Edwards 1974 a	—	-	4040	45.60	14.00
6. Bivalvia Los IVlaritas					
Edwards 1974 b	—	—	17.52	42.47	40.00
7. *Scrobicularia plana*					
Hughes 1970	-	-	12.40	47.60	40.00
			14.56	45.43	40-00
			12.64	2.37	84.98
			12.60	48.19	39.21
			14.56	45.60	39.83
			12.63	47.40	39.97
8. *Tellina tenuis*					
Travel l ion, 1971	—	-	16.77	43.23	40.00
			14.32	45.67	40.00
			26 50	33.49	40.00
9. *Donax vittatus*					
Anselletal 1972	—	—	18.71	41.29	40.00
10. *Modiolus demissus*					
Kuenzler, 1961	—	—	18.21	42.21	39 67
11. *Choromytilus meridionelis*					
Griffiths, 1981 a, b	1.40	6 87	8.27	12.35	79.36
12. *Chlamys islandica*	0.49	2.58	10.72	34 83	40.01
	to	to	to	to	
Vahl. 1981 a	22.58	10.21	25.16	49.29	
13. *Chlamys islandica*					
Vahl, 1981b	1.76	0.36	2.12	3-58	94.22
14. *Ostrea edulis*					
Rodhouse, 1979	4.45	3 82	8.27	20 18	7153
15. *Mercenaria mercenaria*					
Hibbert 1977 a, b	11.50	9.79	21.29	38.70	40.41
16. *Crassostrea gigas*					
Bernard, 1974	0.59	29.67	30.26	29.73	40.00
17. *Crassostrea virginica*					
Dame, 1976	21.21	4.11	25.32	34.67	40.00
18. *Crassostrea meridionalis*					
Griffiths, 1981	5.98	23.82	29 80	30.20	40.00
19. *Perna viridi's*					
Shafee	-	—	33.78	26.24	39.98
20. *Mytilus Chilensis*					
Navorro, 1982	—	—	33.74	26.99	39 27
21. *Saccostrea cucullata*					
Present studies	9.74	6.51	28.74	31.27	40.00

TABLE 2. ***Growth efficiencies of bivalves from different localities***

	SPECIES	GROWTH EFFICIENCY'	AUTHORITY
1.	***Donax incarnatus***	14.22	Ansell et al 1972
2.	***Donax splculum***	10.29	- d o -
3.	Bivalvia San Luis	32.94	Edwards, 1974 a
4.	- " —	25.92	- d o
5.	Bivalvia Los Maritas	46.98	Edwards, 1974 b
6.	- " —	29.20	— d o -
7.	***Scrobicularia plana***	20.67,2073 21.04,24.20 24.27,94.21	Hughes, 1970
8.	***Donax vittatus***	31.18	Ansell, et. al 1972
9.	***Modiolus demissus***	**30.14**	Kuenzler, 1961
10.	***Chlamys islandica***	17 86 to 41.94	Vahl, 1981 a
11.	-'•—	**37.19**	Vahl, 1981 b
12.	***Choromytilus meridional is***	40.11	Griffiths, 1981, a, b,
13.	***Ostrea edulis***	29.07	Rodhouse 1979
14.	***Mercenaria mercenaria***	35.49	Hibbert, 1977 a, b,
15.	***Crassostrea gigas***	5044	Bernard, 1974
16.	***Crassostrea virginica***	42.21	Dame, 1976
17.	***Crassostrea meridionalis***	**49.67**	Griffiths, 1981 b
18.	***Perna viridis***	56.28	Shafee, 1979
19.	***Mytilus'jchilensis***	55.56	Navorro, 1982
20.	***Saccostrea cucullata***	27.18	Present studies

* calculated values based on various data of respective authority.

of yield as that was for *Saccostrea cucullata* per square metre annually can be calculated and by dividing the yield by consumption the ecological efficiency is obtained. The ecological efficiency values for the three different species come to:

Mytilus {Perna) viridis	8.8999
***t\AeritriY,* sp**	70.6891
Saccostrea cucullata	0.2873

It will be seen, at once it becomes clear that the clams are severalfold efficient utilizers of the available energy at the Kalbadevi estuary, next to which come mussels and the rock oysters are found to be least efficient in using the available energy resources. The very high ecological efficiency of clams is truly reflected in their very high productions in this estuary. It is reported that 227.27 tons of the species are harvested every year (Ranade 1964). Production of mussels per square metre has been calculated as 7050. 45 g (Ranade 1977) which is strongly in contrast to present species production of 818.21g m/'.

In *Saccostrea cucullata* very large amount of Soma energy Is lost in the form of elimination (Table 3) the main cause being the human fishing activities. However, our laboratory studies indicated high tolerance capacities of these oysters to low salinity grades, survival for two weeks in fresh water has been noted. Similarly, the desiccation experiments have also proved that the short term atmospheric exposers had no effect on oysters, causative of any mortality in them. From the data collected on fishing and natural mortality, it is roughly concluded that about 80% elimination maybe due to fishing activities and remaining 20% may be attributed to the other factors (unpublished data).

That the fishing mortality affects the population structure, growth and production has also been observed by Okera (1976) in his studies on *Senilia senilia.* He found that, he could collect cockles only less than 22 mm in the Sierra Leone river estuary. He observed that predators other than man contribute little relative to total mortality of the cockels.

TABLE 3. *Frequency distribution of different groups sfiown as percentage of tfie total number of individuals collected during the study period of one year.*

Sl. No.	Weight (Mgs) Groups	Number of Individuals	Percentage %
1.	101—120	588	11.88
2.	[illegible]	729	11.55
3.	—DO	TOO	11.OH
4	61—80	582	Q 29
5	81 —100	213	3 37
6	101—120	588	931
7.	121 — 140	567	8 98
g	^^.j —160	503	7 97
9.	161—180	363	575
10.	181 - 200	121	1.92
	5ni 990	94H	%Q'i
12	991 240	91R	"i AK
13	241 - 260	223	3 53
14.	261 —280	251	2 39
15	281 — "OO	4R	n 71
16*	301 — 320	96	i'<^9
*-,	321 340	82	'\\c\
18.	341 —350	70	1 11
19.	361 — 380	48	0 76
20.	381 —400	11	1 17
21.	401 —420	48	0 76
22.	421 — 440	37	Q 59
23.	441 — 460	23	0.36
24.	461 — 480	21	0 33
25.	481-500	13	0-21
27	521-540	in	niR
28.	541—560	9	ai4
29.	561-580	13	0^21
30.	B81 - 600	1	0.02
31.	601-820	4	006
32.	621—640	4	0.06
		fiir^	inn on

In Kalbadevi estuary almost any specimen of *Saccostrea cueullata* of 280 mg and above sizes is prone to be harvested (Table 3). Such a situation however, is not in itself a stable and for the population to be maintained over a indefinite period would require a continuous recruitment of the bivalves. The *Saccostrea cucu/tata* seed oysters were present throughout the year. This oyster showed a continuous breeding pattern. However, the new recruits probably get only few chances to breed and their gonadal output (G= 6.51 %) is apparently ineffective in generating the required scale of recruitment of the species for population growth and spread in Kalbadevi estuary.

The heavy harvesting in effect maximises ^^® removal of reproductively the most valuable individuals in population. Consequently, the ^"^ "^ stability of the resource is being endangered by the present harvesting practices. The fishery should leave the age categories of highest reproductive values in an unharvested portion of the population in order to increase the productive potential of the population.

Considering the salient features of the data presented here in terms of energy, it must be '^^'^^ ^^^ the energy partitioning in *Sacco->trea cucuilata* is suggestive of less functional importance of the species in the estuarine ecosystem at Kalbadevi. The energy utilization by this tropical oyster shows that these bivalves ^'^^ ^ minor role in the functioning of this estuarine ecosystem. Although some growth energy is essentially srored for long periods of ^"^^ "' ^^ shells, large amount of energy produced in the form of tissues is utilised by humans as a food resource.

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