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Changes in biochemical and mineral composition during ovarian maturation in the spiny lobster, *Panulirus homarus* (Linnaeus)

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Abstract

Variations in biochemical and mineral composition of muscle, hepatopancreas and ovary were studied during ovarian maturation in the spiny lobster, *Panulirus homarus*. Among the organic reserves in the muscle, lipid alone showed a decline during maturation. In contrast, all the organic reserves in the hepatopancreas declined in the mature and spent lobsters. The decrease in hepatopancreatic reserves amounted to 22.92% (lipid), 0.67% (protein) and 33.33% (carbohydrate) of the total of these organic materials deposited in the mature ovary. The decrease in energy reserves in hepatopancreas and the corresponding increase in the mature ovary indicates that hepatopancreas is the main source of glycolipoproteins contributing to the vitellogenic processes.

In the muscle, concentrations of Ca, Na, P, Mg, Cu, Zn, Mn, Co and Cd increased with attainment of maturity and declined after spawning. However, K was in maximum concentration (17.56 mg/g dry wt.) in immature and Fe (176.96 mg/g dry wt.) and Cr (18.7 mg/g dry wt.) in spent stages. Na, Ca and Mg concentrations in the hepatopancreas increased while K and P decreased in mature and spent lobsters. With the exception of Co, all the trace elements in the hepatopancreas increased with maturation; Cu (3507.33mg/g dry wt.) and Cd (61.34mg/g dry wt.) recording 10 and 17 fold increases. In the ovary, all the minerals and trace elements increased significantly ($p<0.01$) up to the ripe stage and decreased after spawning.

Introduction

Changes in biochemical composition of tissues and organs during ovarian maturation have been studied in many crustaceans. Hepatopancreas or midgut gland, which is the site of protein synthesis, lipid metabolism and the main storage organ, plays a vital role in the supply of energy reserves, especially lipid for maturation process (Allan, 1972; Adiyodi, 1985; Teshima *et al.*, 1989). Mobilization of protein from hepatopancreas during maturation is not certain, while hepatopancreatic sugars are used for maturation process (Adiyodi, 1985). In lobsters, knowledge of biochemical changes during maturation relates only to the presence of female specific proteins in the haemolymph in spiny lobsters and micropinacocytosis within the oocytes of homarid and palinurid lobsters. These studies suggest extraovarian synthesis of lipovitellin or yolk protein in lobsters (Byard and Aiken, 1984; Adiyodi, 1985).

Role of trace elements in maturation of fish and other aquatic animals is not known, but their requirements differ at different stages of maturation (Berman and Vitin, 1968). Very few studies reported in fishes indicate that there is variable accumulation of Na, K, Mg, Mn, Fe, Cu and Zn in different tissues, especially ovary during maturation (Love, 1980). In aquatic animals, minerals required for embryogenesis have to be provided in the egg or are to be absorbed from the medium in which it undergoes development. In the eggs of the spiny lobster, *Panulirus homarus* and the penaeid prawn, *Penaeus indicus*, mineral requirements are met both by parental contribution in the ova as well as selective absorption from the medium (Vijayakumaran, 1990). The paper evaluates biochemical and mineral changes during ovarian maturation in the spiny lobster, *P. homarus*.

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Material and methods

The lobsters were collected from Kovalam, 25 km south of Chennai, from catches of traditional non-mechanized units. Live lobsters were sacrificed immediately after collection and tissues processed for chemical estimation. Mature *P. homarus* with spermatophore deposition were held in aquarium for one or two days and sacrificed soon after deposition of eggs to collect samples of spent lobsters.

Three maturity stages, Immature (Stage 1), Mature (Stage 4) and spent (Stage 5) described for *P. homarus* by Berry (1971) were followed. The size of lobsters varied from 90-120g (immature), 121-545g (mature) and 225-520g (spent).

Tissue samples were dried at 60° C to constant weight and homogenized and dried again for 1-2 hours before storing in airtight glass vials in desiccator. Aliquots from these dried samples were taken for chemical analysis. Whole protein was estimated calorimetrically by modified biuret method (Sumitra and Vijayakumaran, 1979), carbohydrate by phenol-sulfuric acid method (Raymont *et al.*, 1964) and total lipids by methanol-chloroform extraction (Bligh and Dyer, 1969). After initial wet ashing, the samples were dry ashed at 525° C for two hours and mineral analyses were done by the method described for fish and other marine products by Thompson (1969) in a Perkin - Elmer Atomic Absorption Spectrophotometer (Model 2380).

The term concentration in the text means percentage in wet tissues for proximate composition, percentage in dry weight for biochemical and mg or μg/g dry weight for minerals and trace elements. The quantity is expressed as g/100g body weight for proximate composition and mg or mg/100g body weight for minerals and trace elements.

Results

Biochemical changes in muscle

Changes in concentration of water,

protein, lipid, carbohydrate and ash in muscle are given in Table 1. While water and protein concentrations were comparatively stable during maturation, lipid and carbohydrate concentrations decreased with maturity and the minimum values were recorded in spent lobsters. When expressed quantitatively in a unit weight of 100g body weight (Table 2), the quantity of lipids declined significantly ($p < 0.05$) at maturity and also between mature and spent lobsters while other parameters were more or less stable.

Biochemical changes in hepatopancreas

Hepatic index reduced from 3.79 in immature to 3.34 in mature and further to 2.88 in spent lobsters (Table 1). Water and ash concentrations increased marginally at maturity and markedly after spawning. Protein and carbohydrate concentrations showed a significant upward trend in mature lobsters and decreased significantly in the spent ones. A reverse trend, a marked decline at maturity and increase after spawning was noticed in lipid concentration. Quantitative expres-

Table 1. *Biochemical changes in muscle, hepatopancreas and ovary during ovarian maturation in P. homarus (protein, lipid, carbohydrate and ash expressed as percentage in dry weight).*

Maturity stage	Size (g)	% in wet weight	Water (%)	Protein	Lipid	Carbo-hydrate	Ash
			Muscle				
Immature	102.20± 8.77	28.06± 0.36	74.96± 2.25	81.40± 1.30	10.30± 1.70	1.61± 0.71	7.29± 0.66
Ripe	321.61± 173.94	28.83± 1.01	74.49± 2.23	80.90± 2.75	8.86± 1.67	1.48± 0.31	8.41± 0.90
Spent	388.31± 126.59	29.57± 1.42	75.02± 2.23	81.96± 2.36	7.82± 1.32	1.37± 0.07	7.05± 0.02
			Hepatopancreas				
Immature	102.20± 8.77	3.79± 0.05	66.52± 6.67	53.51± 3.21	31.71± 4.50	5.60± 0.61	6.32± 0.36
Ripe	321.61± 173.94	3.34± 0.16	67.51± 6.68	58.76± 1.81	21.19± 0.88	8.88± 0.01	8.41± 0.23
Spent	388.31± 126.59	2.88± 0.51	72.28± 4.12	47.04± 2.24	32.90± 0.13	5.92± 0.41	13.41± 0.11
			Ovary				
Immature	102.20± 8.77	0.20± 0.08	82.11± 1.86	50.99± 1.23	34.88± 0.28	3.17± 0.29	6.37± 0.44
Ripe	321.61± 173.94	5.31± 0.54	52.71± 0.95	62.82± 6.10	29.96± 3.59	3.54± 0.24	4.26± 0.47
Spent	388.31± 126.59	0.83± 0.12	76.92± 6.21	64.97± 4.09	19.11± 3.44	2.73± 0.27	12.91± 0.28

sion (Table 2) revealed a different trend. Quantity of protein declined significantly ($p < 0.005$) at maturity and more so after spawning. Lipid showed a significant reduction ($p < 0.0005$) at maturity and a marginal increase in spent lobsters. Increase at maturity and reduction after spawning were highly significant ($p < 0.005$) in the quantity of carbohydrates of hepatopancreas. Total energy considerably declined at maturity and also after spawning. Quantity of ash showed a significant positive change at maturity and remained so after spawning.

Biochemical changes in ovary

Gonadosomatic index increased sharply from 0.2 to 5.3 at maturity and declined to 0.83 after spawning (Table 1). Maximum concentration of water was recorded in immature ovary and indicated a declining trend in mature ovary and increased after spawning. Concentrations of protein and carbohydrates increased while that of lipid declined at maturity. After spawning, lipid and carbohydrate concentrations declined while protein recorded a marginal and ash 3 times increase in concentration. Quantitatively, all parameters showed high increment and equally significant reduction at maturity and spawning, respectively (Table 2).

Mineral changes in muscle

In general, mineral and trace elemental concentrations increased with maturity in the muscle and declined after spawning (Table 3). K was at maximum concentration in immature stage and so also Fe and Cr. In spent stage Pb was below detectable limit (<0.001mg/g dry wt.) in all stages. Quantitatively, all elements, except Fe, which declined, significantly increased at maturity (Fig.1. a, b & c). Between mature and spent stages all elements except Ca, P, Co, and Cr declined in quantity. The most striking changes were recorded for Co, which was not detectable at maturity and accumulated several fold in the spent stage and for Mn, which increased 8-fold at maturity and declined 15-fold after spawning.

Mineral changes in hepatopancreas

In hepatopancreas, concentration and quantity of all minerals and trace elements, except K, P, Co and Cr, increased significantly in mature stage and recorded sharp reduction after spawning (Table 3 and Fig. 2. a, b & c). As in muscle, Pb was below detectable level in all stages and Co was not detectable in mature stage. 10 and 17 fold increases were recorded for Cu and Cd, respectively at maturity. Maximum rates of change in quantity during maturation and spawning were recorded for Na, Cu, Cd and Co.

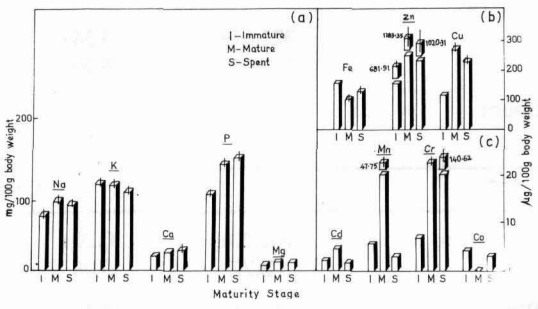

Fig. 1 (a, b & c). *Quantitative changes in minerals and trace elements in muscle during ovarian maturation in P. homarus (values expressed in 100 g body weight)*

Table 2. *Quantitative changes in proximate composition of muscle, hepatopancreas and ovary during ovarian maturation in P. homarus (values expressed in 100 g body weight). Values in parenthesis are "P" values of tests of significance (student's "t") between mature and immature, and mature and spent.*

Maturity stage	Wet weight (g)	Dry Weight (g)	Water (g)	Protein (g)	Lipid (g)	Carbo Hydrate (g)	Ash (g)	Total energy (calculated) (KJ)
Muscle								
Immature	28.06±	7.07±	21.03±	5.72±	0.72±	0.110±	0.51±	164.54±
	0.36	0.01	0.27	0.29	0.04	0.001	0.03	8.39
	(<0.05)	(<0.005)	(<0.05)	(>0.05)	(<0.05)			
Ripe	28.83±	7.35±	21.48±	5.95±	0.65±	0.110±	0.53±	167.18±
	1.01	0.25	0.75	0.20	0.03	0.001	0.08	5.89
Spent	29.57±	7.52±	22.05±	6.15±	0.60±	0.110±	0.53±	169.91±
	1.42	0.33	1.41	0.31	0.03	0.005	0.03	8.54
	(<0.005)	(>0.05)	(>0.05)	(>0.05)	(<0.05)			
Hepatopancreas								
Immature	3.79±	1.27±	2.52±	0.68±	0.40±	0.07±	0.08±	33.01±
	0.05	0.02	0.03	0.01	0.006	0.001	0.001	0.49
	(<0.0005)	(<0.0005)	(<0.0005)	(<0.005)	(<0.0005)	(<0.0005)	(<0.0005)	(<0.005)
Ripe	3.34±	1.09±	2.25±	0.64±	0.23±	0.10±	0.09±	25.94±
	0.16	0.05	0.10	0.03	0.01	0.004	0.004	1.17
Spent	2.88±	0.80±	2.09±	0.38±	0.27±	0.04±	0.09±	20.29±
	0.51	0.14	0.37	0.06	0.04	0.008	0.005	3.13
	(>0.05)	(<0.05)	(>0.05)	(<0.005)	(>0.05)	(<0.0005)	(>0.05)	(<0.05)
Ovary								
Immature	0.20±	0.04±	0.16±	0.020±	0.014±	0.0010±	0.003±	1.04±
	0.08	0.01	0.06	0.005	0.003	0.0003	0.001	0.24
	(<0.0005)	(<0.0005)	(<0.0005)	(<0.0005)	(<0.0005)	(<0.0005)	(<0.0005)	(<0.0005)
Ripe	5.31±	2.51±	2.80±	1.580±	0.750±	0.090±	1.070±	68.27±
	0.54	0.25	0.28	0.160	0.070	0.010	0.100	6.70
Spent	0.83±	0.20±	0.65±	0.130±	0.110±	0.005±	0.010±	7.47±
	0.12	0.05	0.12	0.003	0.002	0.006	0.003	0.16
	(<0.0005)	(<0.0005)	(<0.0005)	(<0.005)	(<0.0005)	(<0.005)	(<0.0005)	(<0.0005)

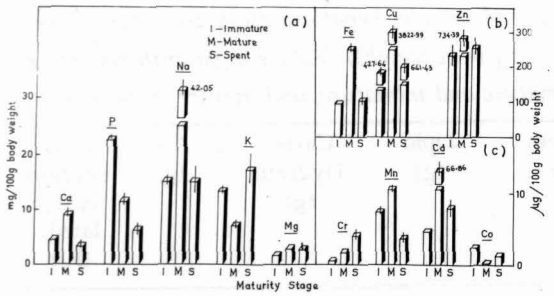

Fig. 2 (a, b & c). *Quantitative changes in minerals and trace elements in hepatopancreas during ovarian maturation in P. homarus (values expressed in 100g body weight)*

Mineral changes in ovary

All elements in immature and spent ovaries could not be detected since extremely low quantities of materials were available for analysis. In contrast to the conditions in muscle and hepatopancreas, concentration of all minerals analyzed declined at maturity and further after spawning (Table 3). With the exception of Co, concentration of all trace elements showed an increasing trend in the mature ovary. In the spent ovary, Zn, Cu and Co were lesser in concentration.

Quantitatively, all minerals and trace elements recorded highly significant ($p < 0.0005$) increase in mature ovary and declined in a similar way after spawning (Fig. 3. a, b & c).

Discussion

Maturation of ovary in *P. homarus* was accompanied by a marked increase in ovary mass, total lipid, protein, carbohydrate and ash. As in many other crustaceans (Pillay and Nair, 1971; Clarke, 1977, Jackel *et al.*, 1989: Teshima *et al.*, 1989), no linear relationship was observed between ovary weight and body weight and the ovary weight increased with maturation irrespective of the size of the lobster.

Concentration of water in the ovary declined significantly from 82.11 to 52.71% at maturity due to progressive addition of organic reserves in developing oocytes. When organic matter so accumulated were finally transferred to the spawned ova, the concentration of water again increased to 72.91% in the spent ovary.

Ovary and hepatopancreas are the main lipid storage organs in crustacea (Guary *et al.*, 1974). The total lipids increase in the ovary during sexual maturation in *P. homarus* (present study), *P. polyphagus* (George and Patel, 1956), in the sand lobster, *Thenus orientalis* (Rahman, 1989) and in many other crustaceans. As the lipid reserves are ultimately transferred to the mature ova, spawning results in heavy depletion of lipids in the ovary.

Main component of crustacean yolk, however, is protein, the lipovitellin

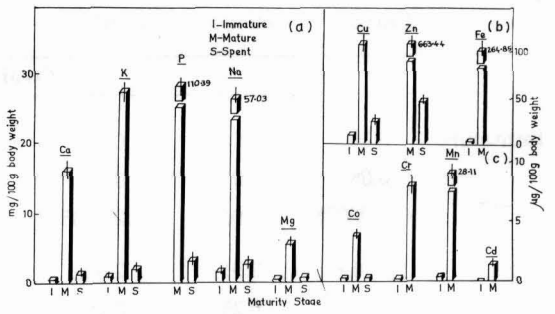

Fig. 3 (a, b & c). *Quantitative changes in minerals and trace elements in ovary during maturation in P. homarus (values expressed in 100g-body weight)*

Table 3. *Changes in minerals and trace elements composition (mg or mg / g dry weight) in muscle, hepatopancreas and ovary during ovarian maturation in P. homarus (N.D. denotes not detectable concentration).*

Minerals/ elements (conc.)	Maturity stage								
	Muscle			Hepatopancreas			Ovary		
	Immature	Ripe	Spent	Immature	Ripe	Spent	Immature	Ripe	Spent
Minerals (mg/g dry weight)									
Na	11.20±0.28	13.46±0.48	12.49±0.56	36.12±1.21	22.72±0.98	22.03±1.62	11.66±0.18	38.58±1.83	21.75±0.91
K	17.56±0.44	16.59±0.39	14.84±0.26	19.48±3.68	10.85±3.44	9.42±2.61	10.29±0.16	6.45±0.31	24.68±0.43
Ca	2.85±0.11	3.56±0.17	3.75±0.62	8.57±0.26	6.40±0.14	6.30±0.17	3.45±0.05	8.35±0.40	4.69±0.12
P	15.47±0.39	21.54±0.69	21.51±0.92	N.E	43.98±3.58	34.70±4.10	17.42±0.31	10.55±0.56	9.03±0.21
Mg	0.97±0.15	1.68±0.19	1.48±0.16	3.10±0.42	2.09±0.59	1.67±0.48	1.19±0.11	2.55±0.19	3.49±0.12
Trace elements (mg/g dry weight)									
Fe	22.66±1.56	141.00±2.98	176.69±3.56	67.72±5.86	105.52±3.81	N.E	72.61±1.41	228.95±10.89	147.61±2.56
Cu	17.17±0.42	38.01±1.02	31.55±1.59	23.20±1.68	42.33±2.53	12.16±2.11	331.92±5.21	3507.33±167.03	929.31±16.24
Zn	97.30±2.52	160.66±4.12	135.68±3.82	N.E	264.32±29.3	222.85±20.61	181.08±2.84	673.71±32.08	369.13±6.46
Cd	0.32±0.09	0.58±0.09	0.20±0.07	0.49±0.11	0.55±0.06	N.E	3.63±0.15	61.34±2.92	11.59±0.26
Co	0.59±0.15	N.D	0.40±0.11	1.57±0.51	1.49±0.73	0.97±0.32	1.89±0.22	N.D	1.87±0.16
Mn	0.81±0.02	6.50±0.86	4.07±0.56	7.21±1.11	11.20±1.06	N.E	5.64±0.16	9.23±0.44	5.34±0.52
Cr	0.97±0.26	3.00±0.56	18.70±1.10	1.70±0.26	3.16±0.57	N.E	0.39±0.12	1.48±0.16	0.59±0.11
Pb	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

(Adiyodi, 1985) and in *P. homarus* also the quantity of protein increases 78 fold (from 0.2 to 1.58g) in the ripe ovary and formed 62.82% of the total dry matter. At the same time, the lipid content increased only 52 fold from 0.014 to 0.75g. The highest concentration of protein in the ovary (64.97%) was recorded in the spent condition, even though the actual quantity was considerably low. Thus, for a better understanding of the accumulation and utilization of organic reserves during maturation, values have to be quantified rather than being expressed in percentage.

Lipid in hepatopancreas of *P. homarus* declined significantly in mature lobsters with concomitant increase in the ovary. This trend has earlier been reported in many crustaceans leading to the conclusion that in crustaceans with well defined hepatopancreas, energy reserves are stored in it and are apparently used during vitellogenesis. Unlike lipid, maximum reductions in quantities of protein and carbohydrate were noticed between mature and spent stages, which might possibly indicate the utilization of these reserves for increased metabolic activity associated with spawning.

In many fishes, both muscle and liver energy are depleted in the process of reproductive spending (Love, 1980), while crustaceans are not generally believed to mobilize energy from muscle for gonad development. In this study, significant decrease was noticed in muscle lipid both at maturity and after spawning which perhaps, would have been utilized for reproductive processes.

Accumulation or depletion of fresh weight dry matter, organic matter, energy and ash in muscle, hepatopancreas and ovary during maturation are summarized in Table 4 indicating the extent of involvement of muscle and hepatopancreas in ovarian maturation. As described earlier, the role of muscle in the reproductive process in *P. homarus* appears to be restricted to supplying small quantity of lipid. In contrast, all organic and inorganic reserves in hepatopancreas declined at maturity and still further after spawning. The most significant reduction (42.50%) at maturity in hepatopancreas was that of lipid, while marked decline (40.62%) in protein quantity was noticed at spawning. Total carbohydrates were also reduced at maturity and at spawning, but energetically its contribution was negligible. Likewise, 7.07KJ (21.42% of total) of hepatopancreatic energy was spent for maturation and another 5.6.KJ (16.96%) of the total during spawning.

These results suggest the important role of hepatopancreas in storage and mobilization of energy during ovarian maturation in *P. homarus*. But to what extent the hepatopancreatic reserves contribute to the total reproductive output have to be evaluated in the right perspective. The decline in quantities of lipid, protein and carbohydrate in hepatopancreas amounts only to 22.92%, 0.67% and 33.33%, respectively, of the total amount of these organic materials deposited in the mature

Table 4. *Summary of quantitative changes in organic and inorganic reserves in muscle, hepatopancreas and ovary during maturation in* Panulirus homarus *(values expressed in 100 g body weight).*

Parameters	Quantitative changes					
	Immature to ripe			Ripe to spent		
	Muscle	Hepato-pancreas	Ovary	Muscle	Hepato-pancreas	Ovary
Wet weight (g)	+0.77	-0.45	+5.11	+0.74	-0.46	-4.48
Dry weight (g)	+0.28	-0.18	+2.47	+0.17	-0.29	-2.31
Water (g)	+0.45	-0.27	+2.64	+0.57	-0.16	-2.15
Protein (g)	+0.23	-0.04	+1.56	+0.20	-0.26	-1.45
Lipid (g)	-0.07	-0.17	+0.74	-0.05	-0.04	-0.64
Carbohydrate(g)	0.00	-0.03	+0.09	0.00	-0.06	-0.09
Ash (g)	+0.02	-0.01	+1.07	0.00	0.00	-1.06
Energy (KJ)	+2.64	-7.07	+67.23	+2.73	-5.65	-61.20
Na (mg)	+20.20	+27.01	+55.59	-5.01	-26.98	-52.62
K (mg)	-1.51	-6.23	+26.45	-10.34	+9.99	-25.35
Ca (mg)	+6.13	+4.65	+15.72	+1.03	-5.86	-14.80
P (mg)	+49.57	-10.97	-	+3.44	-5.27	-105.33
Mg (mg)	+5.53	+1.24	+5.13	-1.12	-0.37	-4.92
Fe (µg)	-58.05	+155.89	+262.14	+29.46	-147.71	-
Cu (µg)	+159.80	+3395.75	+105.32	-42.05	-3181.56	-103.82
Zn (µg)	+501.44	+500.75	-	-163.04	-479.64	-619.87
Cd (µg)	+2.30	+62.18	+1.36	-2.91	-58.86	-
Co (µg)	-4.22	-2.44	+3.68	+3.01	+1.29	-3.55
Mn (µg)	+42.13	+3.48	+27.82	-44.69	-6.98	-
Cr (µg)	+15.76	+1.09	+7.89	+117.83	+2.46	-

ovary. This important point is glaringly omitted in most of the studies, which describes mobilization of hepatopancreatic reserves during maturation in many crustaceans. The bulk of organic reserves deposited in the ovary during maturation should, therefore, come through transformation of ingested food either directly from the gut, through the haemolymph as in the case of echinoderms (Giese, 1959) or through the mediation of tissues like hepatopancrease which is the most important site of protein synthesis in crustaceans (Chang and O' Conner, 1983).

The importance of minerals and trace elements in maturation process has not been studied in detail in crustaceans. Most of the investigations on uptake of elements from water have been intended to know osmotic ion regulation in varying salinities, toxicity to heavy metal concentration, nutritional requirements for growth and bio-accumulation in soft edible tissues.

Trace elements are generally required in minute amounts, with the possible exception of Mg and Fe and are concerned in specific physiological activities (Hoar, 1975). In *P. homarus*, Mg is present in higher concentration in muscle, hepatopancreas and ovary justifying its classification among the major elements or minerals in this study. Concentrations of Cu, Fe and Zn also were high, especially at

mature stage, while all other elements analyzed were present in minute quantities. Pb was not even detectable (< 0.001mg/g dry wt.) which might possibly be due to the exclusion of exoskeleton in this study, as exoskeleton is reported to sequester most of the Pb in crustacea to be expelled at the time of moulting (Eisler, 1981).

The quantity of K is reduced at maturity in muscle and hepatopancreas, and P significantly reduced in hepatopancreas. Other minerals (Na, Ca and Mg) accumulated in muscle, hepatopancreas and ovary during maturation. A similar trend in depletion of K and P during maturation was reported in the penaeid shrimp, *P. indicus* (Vijayakumaran, 1990).

Cu, Zn, Fe, Cd and Mn quantitatively accumulated in muscle, hepatopancreas and ovary at maturity. The accumulation of Cu in hepatopancreas was so high (794.91%) at maturity that the ash was light blue in colour. However, maximum increase (1328.68%) was recorded in the quantity of Cd, which is generally considered as non-essential and toxic (Fleischer *et al.*, 1974). Maximum loss of trace elements (> 80%) after spawning in hepatopancreas was also recorded for Cu and Cd. The loss of trace elements due to spawning was high in hepatopancreas compared to muscle indicating its role in maturation process. Hepatopancreas, in crustaceans, is reported to sequester and accumulate many metals like Cu, Cd and Zn (Eisler, 1981, Bjerregard and Vislie, 1968) in bound and inactive form, possibly to prevent them from being toxic to the animal. Crustaceans expel excess metal through exuvia and to a limited extent through egg production (Davis, 1978). In *P. homarus*, the loss in quantity of trace elements in muscle and hepatopancreas could not be fully accounted for in its deposition in the spawned egg (Vijayakumaran, 1990). Probably, these elements would have been utilized for increased metabolic activity related to spawning.

Notable reduction in Co in muscle and hepatopancreas in *P. homarus* and *P. indicus* at maturity and selective absorption and utilization during embryogenesis in these two species (Vijayakumaran, 1990) point to the importance of Co during maturation and egg development. Fe, Zn and Cu were the most important trace elements, in terms of quantity, in the mature ovary and also just spawned eggs of *P. homarus* and *P. indicus* (Vijayakumaran, 1990). These elements are important components of various enzymes, including cytochrome oxidase and blood pigment and play a major role in the embryonic metabolism of the egg.

In the fish, *Rutilus rutilus*, Ilzinia (1968) noted variable accumulation of Mn, Fe, Cu and Zn in various tissues, especially ovary, with maturation. After spawning, the concentration reduced in the ovary as well as in other tissues like muscle, liver, bones and scales. A similar trend of depletion of inorganic reserves in tissues after spawning, now reported in *P. homarus* indicates the importance of min-

eral accumulation during maturation and calls for further studies to understand the role of individual minerals and trace elements in the maturation process.

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