

Carbon and nitrogen losses through moulting in the Cape rock lobster *Jasus lalandii*

P. Zoutendyk

Division of Earth, Marine and Atmospheric Science and Technology, CSIR, P.O. Box 320, Stellenbosch, 7600 Republic of South Africa* and Zoology Department, University of Cape Town, Rondebosch, 7700

Received 28 November 1987; accepted 15 February 1988

Moulting data were collected from a size range of *J. lalandii* in an aquarium where field conditions of light intensity and temperature were simulated. Elemental analysis was carried out on intermoult exoskeleton, exuviae and whole lobsters. Lobsters lose a mean of 27% of their dry mass per year at ecdysis. Exuviae contained a higher ash content, a 28,1% lower organic carbon content indicating reabsorption, and a similar inorganic carbon content when compared with intermoult exoskeleton. Estimates for a lobster population occupying 100 m² at Robben Island are that 228 g organic carbon and 57,3 g nitrogen are lost annually. However, the annual cost of moulting to *J. lalandii* in terms of exuvial mass, which includes carbon and nitrogen, is considerable when viewed in terms of lost production.

Verdoppingsdata van 'n reeks groottes van *J. lalandii* is versamel in 'n akwarium waar natuurlike lig- en temperatuuroestande nageboots is. Elementanalises is uitgevoer met huidskelet in die tussenverdropstadium, verdopsel en heel krewes. Krewes verloor gemiddeld 27% van hul droë massa per jaar by verdopping. Verdopsel se asinhoud was hoër, sy organiese koolstofinhoud 28,1 persent laer (wat op herabsorpsie dui) en sy anorganiese koolstofinhoud dieselfde as dié van huidskelet in die tussenverdropstadium. Na raming gaan jaarliks 228 g organiese koolstof en 57,3 g stikstof verlore by 'n kreefbevolking versprei oor 'n gebied van 100 m² by Robbeneiland. Die jaarlikse verlies aan verdopselmasse wat koolstof en stikstof insluit, gesien as produksieverlies, is aansienlik.

*Address for correspondence

It is axiomatic that an exoskeleton has survival value to the individual. However, there are distinct disadvantages to this structure when the necessity for growth is considered. In *Homarus* the pre-moult phase may last several months (Aiken 1980). In the spiny lobster, *Jasus lalandii* this phase is similarly long and is associated with a cessation of feeding (Zoutendyk 1988). After ecdysis, feeding can only be resumed when the exoskeleton has hardened sufficiently, which may take several weeks (Zoutendyk 1988). Possibly even more costly to lobsters than the disruption of feeding or being subjected to predation during moulting, is the physical loss of the exoskeleton including the elements carbon and nitrogen. In this investigation these latter losses have been quantified and the results are discussed in relation to carbon and nitrogen budgets at the population level.

Materials and methods

Specimens of *J. lalandii* were collected by SCUBA divers from a depth of 8–15 m in a rock lobster sanctuary at Oudekraal on the west coast of the Cape Peninsula. Details of the research area are given by Velimirov, Field, Griffiths & Zoutendyk (1977).

Nineteen post-moult male rock lobsters in the size range of 80–135 mm carapace length were collected in the early summer of 1983. They were used in feeding and respirometry experiments for a 400-day period (Zoutendyk 1988). A further 18 male rock lobsters in the same size range were collected in August 1984 prior to moulting.

Specimens were kept singly in 100 l seawater tanks at 12°C and a salinity of 35‰ in a recirculating system. Illumination is an important factor in the control of moulting. Lipcius & Herrnkind (1982) and Quackenbush

& Herrnkind (1983), working on *Panulirus argus* discuss the profound effect that light has on the moulting cycle. Similarly, Nelson, Hedgecock & Borgeson (1983) reported that moulting in *Homarus americanus* was controlled by hours of daylight. *J. lalandii* tanks were illuminated by indirect daylight at a level of 35 lx which is close to the level experienced at 15 m water depth at Oudekraal. The animals were thus subjected to both diurnal and seasonal photoperiodicity under intensities as close to natural as possible.

Normal moulting can also be affected by food consumption. Hagerman (1983) observed that moulting decreased in *Homarus gammarus* when the quality of food deteriorated. To prevent this happening, mussels (*Choromytilus meridionalis*) which may form a dominant component in their diet (Pollock 1979) were presented to each lobster in quantities exceeding their daily requirements. Their feeding rate subsequently was monitored regularly 5–7 times per week. When moulting occurred, the exuviae were carefully lifted from the tank and excess moisture removed by gentle tapping on paper towel.

Whole intermoult male lobsters and exuviae were oven dried at 60°C until constant mass was reached (up to 5 days). Small samples of intermoult exoskeletal material were oven dried following Lovegrove (1966). All samples were weighed and subsequently ground using a Wiley mill for large material or a Kinematica hammer-cutter mill fitted with a 0,5 mm screen for small samples. Subsamples were analysed according to the following protocol.

One fraction was heated in a muffle furnace to 450°C for 4 h in order to oxidize the organic carbon while not affecting the calcium carbonate remaining in the ash (Bligh, Bartlett & Eagle 1984). Elemental analyses using a

Carlo Erba 1106 instrument standardized to acetanilide, were carried out on a second fraction of the powder as well as on the ash for total carbon, hydrogen and nitrogen. The difference between the dry mass carbon and ash carbon measurements resulted in an organic carbon value. The factor of 47,70 kJ.gC.⁻¹ after Platt & Irwin (1973) was used to convert carbon values to kilojoules.

In order to interpret results in terms of a natural population, data of Pollock (1978) were used from the lobster sanctuary at Robben Island. Size frequency counts for 14, 20 and 27 m depths were combined. Population figures were expressed per 100 m² by applying the overall mean lobster density of 0,81 m⁻².

Results and discussion

In Table 1 comparative analyses of exuviae, fresh exoskeleton and whole *J. lalandii* are listed. The high wet mass of exuviae in relation to that of fresh exoskeleton is due to water retention in the legs and endophragmal system. A better correlation of exuviae to exoskeleton exists between their respective dry masses and should be used for comparative purposes. Figure 1 shows the power curve regression of exuvial dry mass against carapace length. The regression equation is given below:

$$\text{EDM} = 0,0000334 \times L^{3,045} \quad (1)$$

($r^2 = 0,98$; $n = 26$)

where EDM is the exuvial dry mass and L is carapace length.

The ash content of exuviae constitutes 67% of the dry mass. By comparison, Du Preez & Mclachlan (1983) recorded an exuvial ash content for the swimming crab, *Ovalipes punctatus* of 92,11%. The living exoskeleton of

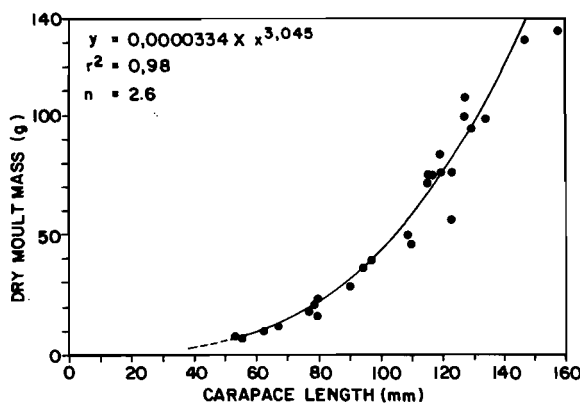


Figure 1 Exuvial dry mass regressed against carapace length.

J. lalandii contains only 54% ash, but has an organic carbon content 28,1% higher than exuviae, suggesting that reabsorption of carbon occurs prior to ecdysis.

Inorganic carbon content was similar in both tissues. If all the inorganic carbon is bound as calcium carbonate it represents 47,6% of the fresh exoskeleton and 51,8% of the exuviae. This small difference between the two tissues suggests that little transfer of calcium carbonate occurs prior to ecdysis. Nitrogen declined by 24 % from exoskeleton to exuviae, a similar percentage to carbon, suggesting that one is not reabsorbed preferentially to the other. The similar C : N ratios corroborate this.

In Figure 2 exuviae dry mass has been plotted against lobster dry mass. The regression is described by the formula

$$\text{EDM} = 0,271 \text{ DM} + 0,6664 \quad (2)$$

($r^2 = 0,94$; $n = 26$)

where EDM is exuvial dry mass and DM is lobster dry mass.

Therefore throughout the observed size range, exuvial mass is linearly related to body mass ($p < 0,001$). From the slope of the regression in (2), the mean annual exuvial loss in *J. lalandii* may be accepted as approximately 27% of animal dry mass.

Figure 3 illustrates by size class the proportion of the total dry mass which is lost annually through moulting in a population of *J. lalandii* from 100 m² at Robben Island. Greatest losses occur in the 70–80 mm carapace lengths where biomass is highest. The overall population loss amounts to 1,83 kg DM or 18,3 g DM m⁻² year⁻¹.

Under aquarium conditions exuviae have been observed to be consumed by other lobsters, even when fed

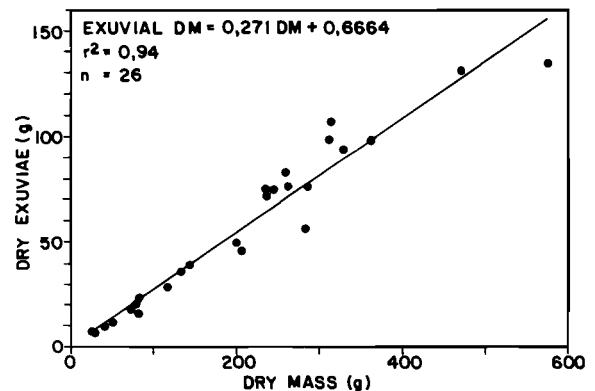


Figure 2 Exuvial dry mass regressed against whole lobster dry mass.

Table 1 Analyses of fresh exoskeleton, dry exuviae and whole *J. lalandii*.

Tissue	WM	DM	AFDM	O.C%	I.C%	N%	H%	n	kJ g ⁻¹	C : N
Exoskeleton	1,49	1	0,46	17,34	5,71	3,88	3,45	7	8,27	4,47
Exuviae	3,6	1	0,33	12,47	6,21	2,95	2,21	3	5,95	4,23
Whole <i>Jasus</i>	3,1	1	0,74	35,51	2,01	9,90	6,35	3	16,94	3,59

Key: WM = Wet Mass; DM = Dry Mass; AFDM = Ash-free Dry Mass; O.C = Organic Carbon; I.C = Inorganic Carbon; N = Nitrogen; H = Hydrogen.

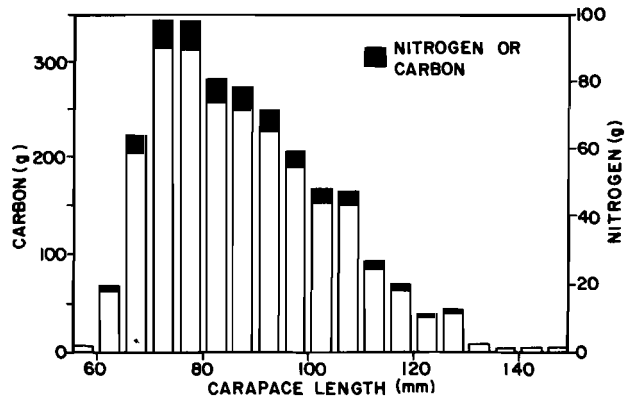


Figure 3 The proportion of the total dry mass lost annually through moulting in a population of *J. landii* from 100 m² off Robben Island.

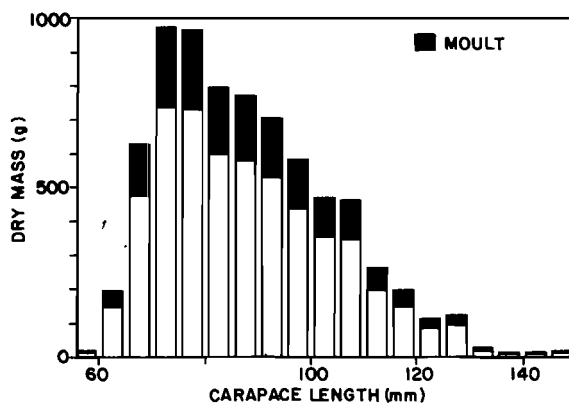


Figure 4 The proportion of the organic carbon and nitrogen lost annually through moulting in a population of *J. landii* from 100 m² off Robben Island.

ad libitum. This may also be expected to happen under field conditions. The remainder of the exuvial material is probably broken down by wave action and remineralized through microheterotroph action.

The cost of moulting to *J. landii* at population level in terms of carbon and nitrogen is summarized in Figure 4. Lobsters lose 8,7% of their total body carbon and 7,4% of their body nitrogen annually. This amounts to 228 g carbon and 53,7 g nitrogen per 100 m². The carbon probably has little environmental impact and the calcium carbonate contained in the exuviae even less where bivalve shells are abundant (Velimirov *et al.* 1977; Pollock 1979). The input of nitrogen to coastal water from exuviae amounts to 0,7% of that required by the inshore primary producers (Zoutendyk 1987 based on Probyn & McQuaid 1985) and the impact is therefore also small. However, the annual cost of moulting to *J. landii* in terms of exuvial mass, which includes carbon and nitrogen, is considerable when viewed in terms of lost production (Zoutendyk 1988).

Acknowledgements

I wish to thank Prof. J.G. Field of the University of Cape Town and Dr R.A. Carter of the Division of Earth, Marine and Atmospheric Science and Technology for their constructive criticism.

References

- AIKEN, D.E. 1980. Moulting and growth. In: The biology and management of lobsters. 1. Physiology and Behavior. (Eds) Cobb, J.S. and Phillips, B.F. pp. 91-147 Academic press, New York.
- BLIGH, D.P., BARTLETT, P.D. & EAGLE, G.A. 1984. Investigation of a method to determine organic carbon concentrations in marine sediments. Report T/SEA. 8450; CSIR, Stellenbosch. 12 pp.
- DU PREEZ, H.H. & MCLACHLAN, A.A. 1983. Seasonal changes in biochemical composition and energy content of the three-spot swimming crab *Ovalipes punctatus* (De Haan) (Crustacea: Brachyura). *J. Exp. Mar. Biol. Ecol.* 72: 189-198.
- HAGERMAN, L. 1983. Haemocyanin concentration of juvenile lobsters (*Homarus gammarus*) in relation to moulting cycle and feeding conditions. *Mar. Biol.* 77: 11-17.
- LIPCIUS, R.N. & HERRNKIND, W.F. 1982. Molt cycle alterations in behavior, feeding and diel rhythms of a decapod crustacean, the spiny lobster *Panulirus argus*. *Mar. Biol.* 68: 241-252.
- LOVEGROVE, T. 1966. The determination of dry weight of plankton and the effects of various factors on the values obtained. In: Contemporary studies in marine science, (ed.) Barnes, H. George Allen and Unwin, London.
- NELSON, K., HEDGECOCK, D. & BORGESON, W. 1983. Photoperiodic and ecdysial control of vitellogenesis in lobsters (*Homarus*) (Decapoda, Nephropidae). *Can. J. Fish. Aquat. Sci.* 40: 940-947.
- PLATT, T. & IRWIN, B. 1973. Caloric content of phytoplankton. *Limn. Oceanogr.* 18: 307-309.
- POLLOCK, D.E. 1978. Growth and production rates of the rock lobster *Jasus landii* (H. Milne Edwards). Ph.D. thesis, University of the Witwatersrand. 226 pp.
- POLLOCK, D.E. 1979. Predator-prey relationships between the rock lobster *Jasus landii* and the mussel *Aulacomya ater* at Robben Island on the Cape West Coast of Africa. *Mar. Biol.* 52: 347-356.
- PROBYN, T.A. & McQUAID, C.D. 1985. *In situ* measurements of nitrogenous nutrient uptake by kelp (*Ecklonia maxima*) and phytoplankton in a nitrate-rich upwelling environment. *Mar. Biol.* 88: 149-154.
- QUACKENBUSH, L.S. & HERRNKIND, W.F. 1983. Regulation of the moult cycle of the spiny lobster, *Panulirus argus*: Effect of photoperiod. *Comp. Biochem. Physiol.* 76A: 259-263.
- VELIMIROV, B., FIELD, J.G., GRIFFITHS, C.L. & ZOUTENDYK, P. 1977. The ecology of kelp bed communities in the Benguela upwelling system: analysis of biomass and spatial distribution. *Helgolander wiss. Meeresunters.* 30: 495-518.
- ZOUTENDYK, P. 1987. Nitrogen excretion by the Cape rock lobster *Jasus landii* and its possible contribution to the inshore Benguela system. In: The Benguela and Comparable Ecosystems. (Eds) Payne, A.I.L., Gulland, J.A. & Brink, K.H. *S. Afr. J. mar. Sci.* 5: 565-574.
- ZOUTENDYK, P. 1988. Consumption rates in captive Cape rock lobsters *Jasus landii*. *S. Afr. J. mar. Sci.* 6: 267-271.