Condition indicators for Antarctic krill, 
*Euphausia superba*

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**Abstract**

Antarctic krill use a variety of strategies to cope with, and thrive in the highly variable Southern Ocean environment. Despite much detailed information on its basic biology produced so far, the linkages between krill populations and the environment are yet to be systematically investigated. There is a practical need to have standardised indicators to assess the ‘condition’ of krill in relation to seasonal cycles and shifts in physical regimes and this study has aimed to develop such indicators.

The level of nucleic acids in abdominal tissue was determined as an estimator of growth rates of individual krill that could otherwise only be obtained by on-board experiments. The dynamics of the major digestive organ, the digestive gland, in its size, protein and lipid content and enzyme activities, were examined in relation to changing food regimes. The potential of using eye diameter as a long-term starvation indicator was also examined.

The amount of RNA and RNA:DNA ratio in krill muscle exhibited a significant relationship with individual growth rates, although the predictability was only modest. This was the case with both field-caught specimens and experimental juveniles. RNA-based indices were clearly different between well-fed, high-growth krill and underfed low-growth krill, and the RNA content levelled off when the growth rates became negative. The moult cycle had no significant effect on nucleic acid content. Overall, the content of nucleic acids varied considerably between individuals. Starved krill also tended to have higher DNA per unit biomass, which implies shrinkage of cells rather than loss of cells. The experimental krill showed a rapid response to the food conditions in their growth rates, either in a positive or negative direction, well within a single moult cycle.
The digestive enzyme activities in the digestive gland of field-caught adults decreased considerably during one week of starvation. The size of the gland decreased substantially both in length and weight, accompanied by a loss of lipid and protein, with the former being more readily utilised. In a laboratory experiment where juvenile krill were alternately fed and starved, the digestive enzyme activities changed in response to the food regime. These changes largely mirrored the mass gain and loss of the digestive glands. The gland size-specific activities of digestive enzymes showed no consistent trends even after a long period of starvation. When the food supply was resumed, the gland regained its mass and enzyme activities. The digestive gland appears to serve as a reserve, which can provide against a few days’ starvation and be rebuilt relatively quickly. Its size showed a prompt and steady response to short-term changes in feeding regime, proving a reliable indicator of recent feeding activities.

By tracking individuals over time and examining specimens sampled as groups, it was demonstrated that fed and starved krill are distinguishable by the relationship between the eye diameter and body length. The eye diameter of starved krill did not decrease even when the animals were shrinking in overall body length. The eye diameter of well-fed krill continued to increase as overall length increased. This created a distinction between fed and starved krill while no simultaneous separation was detected in terms of the body length to weight relationship. It would take approximately 2 moult cycles of shrinkage or more at modest rates for the eye diameter to body length relationship to significantly change. Whether this feature is manifested in the wild would be best seen at the end of winter, after the most likely period of extended food limitation.

Nucleic acid content has only limited predictive power as an estimator of growth rates. Growth rates measured by the ‘instantaneous growth rate’ technique are still the best representation of in situ growth, which is determined by the condition during the period since the last moult. The size of the digestive gland of krill, a crucial short-term storage organ, was more responsive to food condition than enzyme activities. The gland size is a result of feeding activities over the past few weeks and will not be affected by immediate past events such as cod-end feeding. The digestive
gland size should, at least, be a simple measure of whether krill have recently undergone severe, sustained food shortage. Long-term, seasonal starvation and the shrinkage it caused over a few moult cycles can be seen in the body length to eye diameter relationship more obviously than the traditional body length to weight relationship. This suite of measurements will provide a matrix of methods to determine the 'condition' of krill, in time scales from a week to a few months. These techniques are now ready for repeated measurements in the field over wider temporal and spatial extent to examine their applicability and to contribute to unravelling the outstanding questions in krill biology.
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