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Growth and Mortality of Mussels (*Mytilus edulis* L.) Reared in Lantern Nets in Loch Kishorn, Scotland

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Abstract: One-year old rope grown mussels (*Mytilus edulis* L.) were held in experimental lantern nets at 2 m and 6 m depths in Loch Kishorn on the west coast of Scotland. Growth, mortality and shell morphology were monitored from May 1993 to August 1994. Water temperature, salinity, transparency and food availability were also determined. These showed a clear seasonal cycle, in consequence, growth of mussels was relatively rapid from May to November and very slow during the rest of the year. Depth had a insignificant effect on shell length and tissue growth (P>0.05) due to similar environmental factors. Shell length growth and tissue growth exhibited different seasonal patterns and mussels reached marketable size of 50 mm over 2 years old. Shell morphology was similar at both depths (P>0.05) while shell weight was significantly higher at 2 m than 6 m (P<0.05). The natural cumulative mortality rate was found to be 13.6 % at 2 m and 16.7 % at 6 over the 15 months experimental period (P>0.05). Most of the mortalities were occurred just after stocking and attributed to stress due to handling of mussels.

Key Words: Growth, mortality, mussel and Mytilus

İskoçya'nın Kishorn Koy'unda Pinter Ağalarda Yetiştirilen Midyelerin (*Myitulus edilus* L.) Ölüm ve Büyümelerinin Araştırılması

Özet: Halatlarda bir yaşına kadar büyüyen midyeler (*Mytilus edulis* L.) Batı İskocya sahilinde Kishorn koyunda 2 ve 6 m derinliklerde pinter kafeslede denemeye alınmıştır. Büyüme, ölüm ve kabuk morfolojisi Mayıs 1993'den Agustos 1995'e kadar araştırılmıştır. Su sıcaklığı, tuzluluk, ışık geçirgenliği ve yem durumu da tespit edilmiştir. Bunlar açık bir şekilde mevsimsel döngü göstermişler, netice olarak, midyeler Mayıs ayından Kasıma kadar hızlı ve yılın geri kalan kısmında ise çok yavaş bir büyüme göstermişlerdir. Kabuk boyu ve et büyümesi üzerinde benzer çevresel faktörlerden dolayı derinliğin etkisi önemli bulunmamıştır (P>0.05). Kabuk ve etteki artış mevsimsel olarak farklı bir görünüm arzetmiş ve midyeler iki yaşından sonra pazarlanabilir boy olan 50 mm'ye ulaşmıştır. İki mekteredeki midyelerin kabuk ağırlıkları altı metredekilere göre daha fazla iken (P<0.05), kabuk morfolojisi her iki derinlikte de benzer bulunmuştur (P>0.05). Onbeş ayı aşkın bir deneme periyodunda doğal toplam ölüm oranı iki metrede %13.6 ve altı metrede %16.7 olarak bulunmuştur (P>0.05). Ölüm oranlarının çoğu stoklamadan hemen sonra gerçekleşmiş ve bu durum midyelerin ellenmesinden dolayı strese bağlanmıştır.

Anahtar Sözcükler: Büyüme, ölüm, midye ve Mytilus.

Introduction

Mussel production has almost tripled to approximately 1000 tonnes over the last decade in Scotland (1). Loch Kishorn is one of the smallest and simplest sea lochs in Scotland, and affected by freshwater run-off from the surrounding mountains and River Kishorn from the north. It has biggest mussel farm in Scotland with a capacity of 300 tonnes ranged first place in terms of production capacity.

Mussels are filter feeders and mainly herbivorus, eating phytoplankton, but they also eat some zooplankton and much organic detritus (2). Most investigations have been based on environmental factors, because local factors determining nutritional conditions can influence greatly the growth rate and mortality of marine bivalves. The effect of these main environmental variables on growth, physiology and survival of bivalves have been examined, using both alongside in-situ and in-vitro experiments around the world (3, 4, 5). The most important factors are particulate organic matter concentration and quality (6,7), duration of air exposure (8), population density (9), genotypic characteristics (10) and water current velocity (11). In addition, size, age, depth, salinity and temperature effect the growth of *Mytilus edulis* (12).

Mytilus is highly adaptable and especially tolerant of a wide range of environmental conditions. However, extremes in physical factors such as storms, temperature

Table 1. Mean (±SE), minimum and maximum values of environmental parameters measured at 2 m and 6 m depths. POM: particulate organic matter.

Depth		Temperature (°C)	Salinity (‰)	Seston ($mg.l^{-1}$)	POM ($mg.l^{-1}$)	Chlorophyll-a ($mg.l^{-1}$)
2 m	Min.	5.5	30.0	1.5	0.80	0.04
	Max.	16.3	35.9	14.3	4.1	6.32
	Mean	11.07±0.90	33.27±0.36	4.76±0.88	1.86±0.24	1.76±0.44
6 m	Min.	6.6	32.90	1.2	0.60	0.06
	Max.	15.7	36.10	15.2	3.20	8.03
	Mean	11.06±0.81	33.79±0.25	4.91±0.90	1.80±0.21	1.68±0.50

and dessication, and excessive deposition of silt are all known cause to mortality in mussels (13). Predation is undoubtedly the single most important source of natural mortality in *Mytilus*. Unfortunately there is not any available experiment on growth and mortality in Loch Kishorn. Therefore this study is the first experiment to find out the degree of natural mortality and to check differences either in growth parameters or environmental parameters depending on depths.

Materials and Methods

Field studies were carried out on *Mytilus edulis* L. in Kishorn Shellfish Farm in Loch Kishorn on the west coast of Scotland from May 1993 to August 1994. As a result of variable salinity and terrestrial origin of suspended matter (=seston) on water surface, lantern nets were hung 2 m and 6 m below the surface from mussel raft culture system.

Duplicate one litre water samples were collected by a Nansen type sampling bottle from 2 m and 6 m depth to determine seston (total suspended matter), particulate organic matter (POM) and chlorophyll-a and on each sampling date, slinity and temperature were measured with a Salinity Temperature Bridge at the both depths to represent rope length in the raft system at the experimental site. Determination of seston, particulate organic matter and chlorophyll-a were measured according to Stirling (14) methods.

Experimental mussels were one year old rope grown mussels used from spat collectors from raft system and mussels were reared experimentally in lantern nets in Loch Kishorn. Extra large and small mussels were removed to leave a uniform size with a mean of 24.04±0.47 mm (±SE). Mussels were held in four lantern nets hung from raft at 2 different points below 2 m and 6 m. Each lantern net contained three experimental trays (40 cm diameter plastic tray) at a density of 150 mussels per tray or 450 mussels per lantern net. Sampling was carried out monthly, 6-8 mussels from each experimental tray were randomly collected over the 15 months experimental period (samples from 2 lantern nets represented each depth). On each sampling date, empty shells were counted and removed to determine mortality and lantern nets were brushed and cleaned of fouling organisms. All samples were placed in a labelled mesh bag and transported to the Institute of Aquaculture (Universty of Stirling) in a cool box..

The growth parameters measured were change in length, tissue, live weight, dry meat weight and ash-free dry meat weight (AFDMW)(15). The percentage increase in each parameters was calculated as absolute growth estimate divided by its initial value. Monthly specific growth rate (SGR) were calculated from following equation:

$$SGR (\%) = [(\ln L_2 - \ln L_1) / (T_2 - T_1)] * 100$$

where, L_1 and L_2 are mean shell length at the time T_1 and T_2 in days (T_2 - T_1 was an average 30 days) (15).

Mortality calculation of cumulative mortality was determined using the following equation: Cumulative mortality (%) = (Nt / No) * 100

where, Nt is the number of empty shell mussels removed

Table 2. Mean initial (±SE), final growth parameters and increments at 2 m and 6 m in the lantern net experiment. LW: live weight, WMW: wet meat weight, DMW: dry meat weight and AFDMW: ash-free dry meat weight.

Parameters		2 m	6 m
	Initial	24.14±0.40	24.14±0.40
Length (mm)	Final	52.92±0.72	51.03±0.60
	Increment	28.78	26.89
	Initial	1.40±0.08	1.40±0.08
LW (g)	Final	13.89±0.56	12.30±0.39
	Increments	12.49	10.9
	Initial	0.62±0.03	0.62±0.03
WMW (g)	Final	4.91±0.19	5.33±0.19
	Increment	4.29	4.71
	Initial	0.158±0.08	0.158±0.08
DMW (g)	Final	0.974±0.04	1.167±0.41
	Increment	0.816	1.01
	Initial	0.0154±0.001	0.0154±0.001
AFDMW (g)	Final	0.0798±0.003	0.0735±0.003
	Increment	0.0644	0.0581

from the lantern after t time and No is the number of mussels at the begining.

Correlation matrix analysis was performed to evaluate the relationship between growth parameters and environmental factors. One-way ANOVA was applied to test for differences in shell characteristics and growth parameters between the depths and student t test was practiced to find out difference between the depths. Both contingency table (Chi-squared) and ANOVA were used to test signicance of variance in mortality. All statistics were executed using a MINITAB software.

Results

Mean (±SE), minimum and maximum values of environmental factors at 2 m and 6 m are given in Table 1. Transparency (Secchi disk depth) was obtained 7.31±0.5 m with a minimum of 4.5 m and maximum 10.5 m in the loch. Temperature had a positive relationship with salinity ($P<0.05$), while seston and particulate organic matter (POM) had a high positive relationship with chlorophyll-a ($P<0.001$).

Monthly distribution of growth parameters (shell length, live weight, and dry meat are depicted in Figure 1 A,B and C and initial, final and increments values are given in Table 2. Shell growth was occurred higher in the small mussels compared with larger ones. The increaments in shell length was higher at 2 m than 6 m but the difference was not significant ($P>0.05$). At 2 m, 68 % of increase in length occurred from May to September, while at 6m, the length icrease was 63 % over the same period. Shell growth was almost absent during the winter because of low available food and low temperature.

The monthly distribution of specific growth rate (SGR) ranged from 0.04 % to 26.8 % at a depth of 2 m,

Table 3. Mean (±SE) shell characteristics of mussels from two different depths reared in lantern nets. Superscript letters indicate one-way ANOVA test comparison. Values in the same clumn with the same superscrip are not significantly different ($P>0.05$). W: shell width, H: shell height and L: shell length.

	Depth	Length (mm)	Weight (g)	Height (mm)	Width (mm)	W:L	W:H	H:L
Ynitial		24.14±0.40	0.39±0.02	13.04±0.19	8.16±0.15	0.34±0.004	0.63±0.008	0.54±0.005
Final	2 m	52.92±0.72a	4.56±0.18b	25.79±0.32a	19.88±0.34a	0.38±0.004a	0.77±0.009a	0.49±0.004a
	6 m	51.03±0.60a	3.96±0.13a	25.12±0.30a	18.77±0.26a	0.37±0.004a	0.75±0.009a	0.49±0.003a

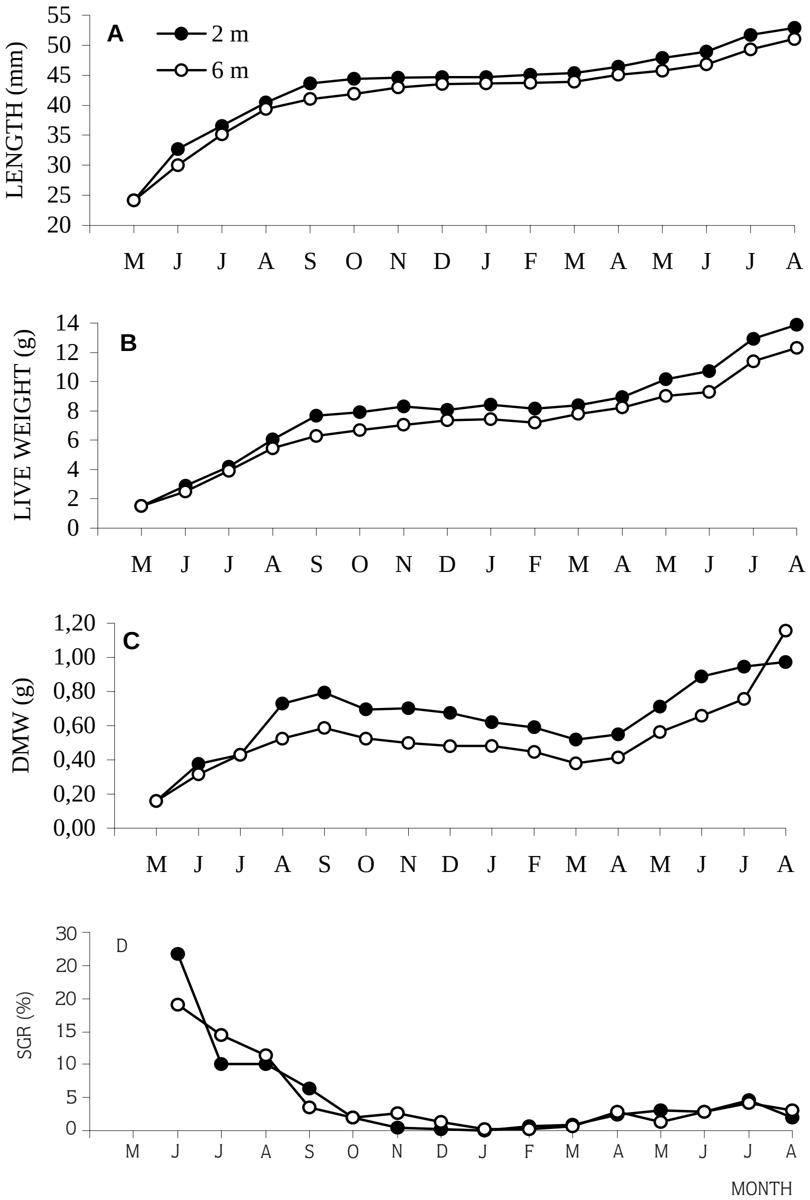

Figure 1. Monthly distribution of shell length (A), live weight (B), dry meat weight (DMW) (C) and specific growth rate (SGR) (D) at 2 m and 6 m depths from May 1993 to August 1994

while it ranged from 0.12 % to 19.2 % at 6 m depth (Figure 1 D). Average SGR values were 4.8 % and 4.7 % at 2 m and 6 m respectively over the 15 months experimental period and maximum values for SGR were obtained in June at both depts. High SGR values reflected available food and temperature conditions, with minimum values coinciding with low temperature and low food supply in winter.

Live weight was affected by gonadal development and gamete release, as well as by growth changes in tissue and shell weight. Some negative increments in wet meat weight were recorded due to spawning or consumption of reserved energy source.

Mortality rate was higher in the younger mussels than the older ones. Cumulative mortality was found to be 16.7 % at 2 m, compared to 13.6 % at 6 m (P>0.05). Mean monthly mortality 1.1 % and 0.9 % at 2 m and 6 m depth, respectively. 37.4 % of the total mortality was recorded in May 1993 at 2 m, while 38.2 % of the total mortality at 6 m occurred in June 1993. The highest mortaliy rate was observed in the young mussels just after stocking them into the lantern nets which can be attributed to the handling stress. The differences in the mortalities with depth were not significant over the 15 months experimental period ($\chi 2=3.841$, $P>0.05$).

The effect of depth on mean values and ratios of shell characteristics analysed by one way ANOVA and results are given in Table 3. Shell length differed insignificantly ($P>0.05$), but shell weight showed significant difference between the two depths over the 15 months experimental period ($P<0.05$). Shell height and shell width were noted to be slightly higher at 2 m than 6 m, but were not significantly higher ($P>0.05$).

Discussion

Seed and Suchanek (13) reported that several environmental factors can modulate growth in *Mytilus*. Growth parameters in mussels are mainly affected by interaction of several environmental parameters, particularly temperature and food availability (16).

The dependence of growth and physiology on water temperature has been extensively investigated, and well documented for mussels (12, 17, 18). High positive correlation ($P<0.01$) between water temperature and spesific growth rate showed that water temperature had a strong effect on shell growth of mussels in Loch Kishorn. Similar results were obtained in White Sea (19) and in west coast of Scotland (20). Several author have identified seasonal and regional variations in both the quantity and quality of utilizable food as important determinants of mussel growth (21,22). Heavy rainfall and run-off bring large quantities of particulate detritus and dissolved humic material into the Loch Kishorn. The positive relationship between chlorophyll-a and seston shows that the amount of seston was clearly affected by phytoplankton blooms over the experimental period. The amount of particulate organic matter (POM) alone does not necessarily provide sufficient information on food availability and growth conditions due to the proportion of non-utilisable POM in seston (23). There was a high correlation between POM and chlorophyll-a in the present study and Riley (24) declerated similar results that phytoplankton might be most important component of POM and the main food for mussels, particularly during spring and summer. Transparency was mainly affected by algal bloom and daily weather conditions.

Growth was very limited from December to March. In April, mussel shell growth faster when chlorophyll-a concentrations exceed 1 $\mu g.l^{-1}$, but temperature is still around 7-8°C which shows that when food is available, growth is occurred without temperature limitation.

Over the experimental period, older mussels had a reduced growth rate that in agreement with Seed (8). The dry weight increased in summer and autumn when new gonad and nutrient reserves were built. These findings are identical to those of reports, both the United Kingdom and Holland (26, 27). During severe food storage, when energy demand from basal metabolism are not met by food uptake, the mussel will have a negative scope for growth and utilize its storage energy reserves, resulting in negative somatic growth (25) as observed.

The natural cumulative mortality was found to be 13.6 % at 2 m and 16.7 % at 6 m over a 15 months experimental period ($P>0.05$). Most of the death in the mussels was occurred just after stocking and attributed to stress due to handling. Okumus (20) reported 4.7 % and 14.4 % in lantern nets over one year experimental period in Loch Etive and Loch Leven on the west coast of Scotland. In general, natural mortality in mussel populations results from an interaction of many biological and physical factors (27).

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