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Spat collection, growth and associated problems in mussel (*Mytilus edulis* L.) in two Scottish sea lochs

İskoçyanın iki deniz gölünde midyelerde (*Mytilus edulis* L.) yavru toplama, büyüme ve bunlarla ilişkili problemler

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Abstract
A spat collection experiment was conducted to determine mussel spat settlement, spat growth and the problems of spat collection at depth of 2 m and 6 m in Loch Etive (LE) and Loch Kishorn (LK) on the west coast of Scotland. The results showed that neither depth nor site had a significant effect on temperature, seston, particulate organic matter and chlorophyll-a, while salinity was found to be significantly higher in LE than LK ($P<0.001$). There was a single peak in spat settlement in LE and two peaks in LK. Spat settlement took place in June-July in LE and in June-December in LK. There was a uniform spat settlement and growth in LE, although there were fouling organisms (sea squirt and starfish) which affected spat collection and growth of seed mussels in LK. The results also demonstrated that if polypropylene ropes had been suspended one or two months before than predicted spat settlement time they might be used as efficient spat collector.

Key words: mussel, spat collection, growth

Introduction

Good spat settlement, rapid growth and high survival are essential for successful mussel culture. *Mytilus* species are known to settle on a wide variety of flamentous substrate, including the byssal flaments of nonspecific adults (Eyster and Pechenik, 1987), flamentous algae, fibrous ropes and adult beds (Petersen, 1984). Mussel populations differ in spat abundance, growth and survival performance even between sites a very close proximity and between inlets, bays, fjords, or lochs within the same coastal water (Mallet and Carver, 1989). Most of these differences are induced by environmental variables, namely, salinity, exposure to air, temperature and food availability, particularly in geographically close stocks (Dickie *et al.*, 1984). There is only one published spat collection and transfer experiment on the west coast of Scotland. Batches of differently rigged collector ropes were transferred between Loch Etive and Loch Sunart (Paul, 1987). Loch Etive and Loch Kishorn mussels are well known for their high quality (Karayücel and Karayücel, 1997). Karayücel (1996) described the effect of environmental factors on mussel culture, and Karayücel and Karayücel (1998) investigated the carrying capacity of mussel culture systems in two lochs. The present study was undertaken to determine the effect of depth and environmental factors on a spat collection, seasonal abundance of mussel spat, the possibility of using polypropylene rope as a spat collector and to investigate problems of spat collection until the spat has grown large enough to be used as seed for suspended mussel culture in Loch Etive and Loch Kishorn.

Material and Methods

Study area

The study was carried out in Loch Etive (LE) and Loch Kishorn (LK) on the west coast of Scotland from May 1993 to April 1994. In comparison with the other Scottish sea lochs, LE has an exceptionally high run-off and small tidal range, with a 29.5 km^2 surface area. LE is a fjord, with three basins; the innermost bottom water stagnates for months or years, with slowly changing temperature. LK is one of the smallest (7.1 km^2 surface area) sea lochs in Scotland, showing typical characteristics of coastal seawater (Edwards and Edelsen, 1977).

Experimental design

Spat collections and growth of spat were conducted monthly in Loch Etive and Loch Kishorn on the west coast of Scotland from early May 1993 to April 1994. Polypropylene ropes, 16 mm diameter and 8 m long were prepared at Institute of Aquaculture, University of Stirling. Lengths of 25 cm plastic pegs were inserted into the ropes at 40-50 cm intervals and at the end of each rope a 2-3 kg weight was attached to strengthen spat collector ropes. Six spat collectors were suspended from each raft system at each site. On each sampling date (monthly), water salinity and temperature were measured with a Salinity Temperature Bridge (M.C.5) at 2 m and 6 m depth. At each depth duplicate 1 l water samples were taken using Nansen type sampling bottle and analysed for chlorophyll-a (Ch-a), seston and particulate organic matter (POM). Five hundred ml water samples were also taken to measure the particle concentration. All samples were passed through a 150 µm nylon mesh to remove large particles and zooplankton. Particle number was determined by an electronic particle counter (Counter Multisizer). The amount of seston, POM and chlorophyll-a were determined according to Stirling (1985).

Triplicate spat samples were taken at monthly intervals from depths of 2 m and 6 m spat collectors to investigate the effect of depth on spat settlement and growth. One 5 l capacity tank was filled with seawater before three spat collecting ropes were lifted gently and spat removed from approximately 20 cm of each rope. Spat samples were transferred to 2 l plastic cups (pre-marked and filled with seawater) placed inside a cool box and transferred to the Institute of Aquaculture and maintained in a cold room (9±1°C). Counting of spat was carried out under a stereomicroscope in petri dishes. Spat length and height were measured to nearest 0.01 and 0.1 mm according to spat size. Shell length was determined by measurement of the maximum anterior-posterior axis. Live weight was measured by weighing live animals with their shell closed after blotting them with the tissue paper to the nearest 0.0001 g. The relationship between total length and live weight was determined according to Chatterji et al. (1984). Differences in environmental factors were tested by Students t-test, while growth and density between the depth of 2 m and 6 m, and Loch Etive and Loch Kishorn were tested by ANOVA using Minitab computer software.

Results

The minimum, maximum and mean values of water temperature, salinity, particulate organic matter (POM), and chlorophyll-a are given in Table 1. Neither depth nor site had a significant effect on temperature, seston, POM and chlorophyll-a while salinity was found to be significantly higher in Loch Kishorn (LK) than Loch Etive (LE) ($P<0.001$). Mean particle numbers were measured 36,448±2,385 in LE and 35,886±3,523 in LK ($P>0.05$). There were high fluctuation in salinity, seston and POM values between the months due to snow melting and freshwater run-off from the surrounding mountains. Significant positive relationships were found between temperature and salinity in LE ($P<0.01$) and in LK ($P<0.05$) and between temperature and chlorophyll-a in LE ($P<0.05$) and in LK ($P<0.01$). Seston correlated significantly with POM ($P<0.001$) and with chlorophyll-a ($P<0.05$) at both sites. Primary settlement of mussel spat was noted to be always highest on seaweeds especially, *Laminaria* spp. and *Fucus* spp. followed by dense settlement on the polypropylene collector ropes. Mussel spat settlement occurred in June-July in Loch Etive and in June-December in Loch Kishorn. Spat settlement was first observed from surface moving downward on the rope with time. In terms of spat abundance, there was a single peak (over 35,000 ind.m^{-1} rope) in Loch Etive in July and two peaks (over 48,000 and 16,500 ind.m-1rope) in Loch Kishorn in July and November. There was a uniform settlement of high quality seed after three months spatfall in Loch Etive, while there were fouling organisms on the spat collectors in Loch Kishorn. Observations showed that sea squirts (*Ciona intestinalis*) and starfish (*Asterian rubens*) settle on the spat collector ropes after their planktonic stages with their development continuing on the spat collectors thereafter. Starfish are easily dislodged by handling and environmental factors (such as currents) about 4-5 months after settlement, but sea squirts reach maturation on the collectors; they compete for space with the mussel stock and can eventually occupy 90 to 95 % of the available space. The density of starfish varied between 3 and 10 ind.m^{-1} rope in first four months of mussel spat settlement.

Newly settled spat have a more rounded shape and brighter shell color than older spat. In June, the Height : Length (H:L) ratios were recorded as 85.5 % in Loch Etive and 79.6 % in Loch Kishorn. However, the H:L ratios decreased to 55.3 % and 54.9 % respectively by April. Neither site nor depth had a significant effect on the H:L ratio in the seed mussels. Length on height relationships in seed mussels were; H=0.312+0.536*L (r=0.99) and H=0.171+0.533*L (r=0.99) in LE and LK, respectively. The monthly changes in shell length, weight and specific growth rate (SGR) at 2 m and 6 m depths are given in Table 2 and Table 3. There were clear seasonal patterns of shell growth being highest from June to November, with little growth observed over the winter period until March and April, when growth rates increased once more. Seed growth was strongly influenced by heavy losses from fouling and predation in Loch Kishorn. By April, mussel seed shell length was significantly higher at 2 m compared to 6 m depth ($P<0.001$). Overall, shell growth was significantly higher in Loch Etive compared to Loch Kishorn over the experimental period ($P<0.001$). Length to weight relationships for the Loch Etive (LE) and Loch Kishorn (LK) seed mussels were calculated as follows:

In LE: $Log_{10}LW = -4.0357 + 3.0081 Log_{10}L$, r = 0.99 or

$(LW = 0.000092*L^{3.0081})$

In LK: $Log_{10}LW = -4.0863 + 2.994Log_{10}L$, $r = 0.99$ or ($LW = 0.000082*L^{2.994}$)

There was a clear seasonal cycle in live weight change with a pronounced peak from July to November followed by growth cessation over winter. Live weight did not differ significantly between the depths in Loch Etive. However the differences between the depths were significant in Loch Kishorn ($P<0.001$). Comparing the two sites, the mean live weight of seeds was significantly higher in Loch Etive than Loch Kishorn ($P<0.001$), reflecting the effect of heavy fouling and predation losses at the latter site.

Discussion

The high fluctuation in salinity was attributed to the fresh water run-off in LE. The amount of seston and particulate organic matter were mainly affected by freshwater run-off from surrounding mountains and algal bloom while chlorophyll-a was related to algal bloom. These results showed that freshwater run-off was the main factor determining the hydrography of LE, while hydrography in LK was principally affected by tidal currents. This result shows that when high temperature (over 10°C) and food are available growth rate is high. Seed growth was affected by fouling organisms and predators, and it was observed that larger seed were most affected by fouling organism and predators mainly in LK. The timing of the peak spawning period varied between the geographic regions. Spawning occurs in May-October in Russia, May-September in Norway, May-July in Denmark, April-July in Scotland, January-July on the west coast of England and March-September on the east coast of England (Seed, 1975). In the present study, spat settlement occurred in June-July in LE and in June-December in LK. *Mytilus* larvae attach most readily to filamentous substrates such as byrozoans, hydroids and filiform algae (Eyster and Pechenik, 1987) therefore spat collector ropes were hung from the rafts one month earlier than predicted spat settlement at both sites. It has been considered that a seed density of over 1,200 ind m^{-1}rope is necessary to produce high yields of rope cultured mussel (Okumus, 1993). Recommended densities range from 0.5 kg of seed per meter of stocking (Rontree, 1986) to 1.5 kg per meter (Herriot, 1984). In comparison, a mean spat settlement of over 2,400 ind m^{-1} rope (3.75 kg ind m^{-1}) was obtained in Loch Etive, and over 1,600 ind m^{-1} rope

Table 1. Minimum (min), maximum (max) and mean (±SE) values of environmental factors at 2 m, 6 m and pooled values (2+6 m) in Loch Etive and Loch Kishorn. Same superscript in the same column are notsignificantly different.

		LOCH ETIVE			LOCH KISHORN		
Parameter		2 m	6 m	Pooled	2 m	6 m	Pooled
Temperature	Min.	4.60	5.10	4.85	5.50	6.50	6.05
(°C)	Max.	16.10	15.70	15.75	17.00	16.20	16.60
	Mean	10.33±1.35	10.61±1.3[a]	10.47±1.34	10.74±1.26	10.83±1.13	10.78±1.19[b]
Salinity	Min.	7.50	10.75	9.13	30.00	32.00	31.00
(ppt)	Max.	27.00	28.00	28.50	35.90	36.10	36.00
	Mean	19.86±1.84	21.98±1.6[a]	20.92±1.73	33.12±0.49	33.7±0.32	33.41±0.40[a]
Chlorophyll-a	Min	0.02	0.02 0.02	0.04	0.06	0.05	
(μg/l)	Max	3.10	3.35 2.89	3.85	3.00	3.43	
	Mean	1.11±0.32	0.99±0.36[a]	1.05±0.32	1.17±0.40	0.99±0.33	1.08±0.36[a]
Seston	Min.	1.50	1.30 1.40	1.50	1.20	1.35	
(mg/l)	Max.	4.00	3.40 3.20	5.60	6.00	5.80	
	Mean	2.43±0.25	2.19±0.21[a]	2.31±0.21	3.20±0.45	3.48±0.58	3.34±0.51[a]
POM	Min.	0.90	0.70 0.90	0.80	0.60	0.70	
(mg/l)	Max.	2.80	1.70 2.25	2.20	2.60	2.25	
	Mean	1.42±0.16	1.24±0.1[a]	1.40±0.12	1.40±0.14	1.49±0.21	1.45±0.17[a]

Table 2. Mean (±SE) monthly shell length (mm), weight (g) and monthly specific growth rate (SGR%) of mussel seed in Loch Etive (LE) from June 1993 to April 1994.

	Length(mm)		Weight (g)		SGR (%)	
Mon	2 m	6 m	2 m	6 m	2 m	6m
Jun	0.38±0.01	0.38±0.01	-	-		
Jul	3.61±0.04	3.51±0.05	0.001±1x10^{-4}	0.001±1x10^{-4}	307.00	303.16
Aug.	5.31±0.04	4.03±0.03	0.033±0.007	0.011±0.002	35.08	12.56
Sep	11.98±0.59	13.2±0.50	0.210±0.023	0.270±0.025	78.74	114.82
Oct	18.73±0.77	17.48±0.65	0.843±0.09	0.630±0.360	40.63	25.53
Nov	20.51±0.56	19.87±0.61	0.962±0.07	0.860±0.230	8.78	12.40
Dec	20.58±0.73	20.13±0.67	1.01±0.09	0.91±0.10	0.37	1.39
Jan	20.83±0.63	20.27±0.62	1.03±0.10	0.94±0.08	1.25	0.72
Feb	21.34±0.51	20.96±0.60	1.20±0.14	1.10±0.08	2.13	2.95
Mar	23.59±0.52	22.55±0.39	1.48±0.10	1.18±0.06	10.37	7.56
Apr	25.27±0.51	23.81±0.41	1.72±0.09	1.41±0.07	7.37	5.83

(0.67 kg ind m^{-1}) remained in LK by April before stocking to the socks. These results showed that spat could be collected efficiently by polypropylene ropes (16 mm diameter) on the west coast of Scotland. Growth of spat was mainly affected by temperature, food supply, predators and fouling organisms. Fouling organisms may increase spat fall or they compete for space and food.

Sea squirt and starfish were the two main fouling organisms in Loch Kishorn due to high salinity while none of them caused any problem on spat collection in Loch Etive. Eider duck (*Somateria mollisima*) was also one of the major predator at both sites. It was reported that eider duck feed mostly on mussels of length 10-50 mm which they swallow whole (Galbraith, 1992). Farms should be designed to achieve an output sufficient to maintain at least one full time worker within the cultivation period. In addition to cultivating the mussels, workers would be able to operate other scarring techniques and maintain barriers (such as vertical nets, plastic skirt) to exclude eiders.

Table 3. Mean (±SE) monthly shell length (mm), weight (g) and monthly specific growth rate (SGR%) of mussel seed in Loch Kishorn (LK) from June 1993 to April 1994.

	Length (mm)		Weight (g)		SGR (%)	
Mon	2 m	6 m	2 m	6m	2 m	6 m
Jun	0.49±0.02	0.49±0.02	-	-		
Jul	2.12±0.38	1.49±0.18	0.001±1x10^{-4}	0.001±1x10^{-4}	129.24	98.13
Aug	2.96±0.031	2.99±0.03	0.006±0.002	0.006±0.003	63.32	46.83
Sept	7.64±0.47	6.31±0.23	0.050±0.001	0.023±0.003	74.69	84.75
Oct	14.24±0.49	12.00±0.4	0.300±0.027	0.208±0.019	55.10	54.23
Nov	12.79±0.68	9.52±0.48	0.260±0.043	0.096±0.013	-24.81	-18.16
Dec	11.54±0.37	9.33±0.38	0.170±0.017	0.099±0.015	-1.95	-5.95
Jan	13.31±0.57	10.64±0.46	0.280±0.036	0.153±0.022	13.14	13.70
Feb	14.27±0.59	11.21±0.43	0.330±0.038	0.158±0.017	5.05	5.81
Mar	15.79±0.45	12.20±0.42	0.420±0.037	0.204±0.023	8.46	9.29
Apr	17.97±0.59	12.63±0.43	0.610±0.056	0.226±0.022	3.71	8.7

Özet

İskocyanın batısında Etive ve Kishorn göllerinde midyelerde 2 m ve 6 m derinliklerde yavru toplanması, büyüme ve yavru toplama problemleri üzerine bir araştırma yapılmıstır. Sonuclar göstermiştirki ne alanın nede derinliğin; seston, organic madde ve klorofil-a üzerine etkisi önemsiz bulunmuş iken tuzluluk Kishorn gölünde, Etive gölünden daha yüksek bulunmuştur. Yavru yerleşmesi Etive gölünde bir tepe noktası oluştururken Kishorn gölünde iki tepe noktası oluşturmuştur. Etive gölünde yavru yerleşmesi Haziran-Temmuz aylarında Kishorn gölünde ise Haziran ve Aralık ayları arasında gerceklеşmiştir. Etive gölünde iyi bir yavru yerleşmesi ve büyüme olduğu halde Kishorn gölünde yavru büyümesi ve toplanmasını etkileyen istenmeyen canlilar gözlenmiştir. Sonuçlar göstermiştirki eğer

naylon halatlar tahmini yavru yerleşme zamanından bir veya iki ay önce asılırsa iyi bir yavru toplama materyali olarak kullanılabilir.

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