The Open Access Israeli Journal of Aquaculture – Bamidgeh

As from **January 2010** The Israeli Journal of Aquaculture - Bamidgeh (IJA) will be published exclusively as **an on-line Open Access (OA)** quarterly accessible by all AquacultureHub (http://www.aquaculturehub.org) members and registered individuals and institutions. Please visit our website (http://siamb.org.il) for free registration form, further information and instructions.

This transformation from a subscription printed version to an on-line OA journal, aims at supporting the concept that scientific peer-reviewed publications should be made available to all, including those with limited resources. The OA IJA does not enforce author or subscription fees and will endeavor to obtain alternative sources of income to support this policy for as long as possible.

Editor-in-Chief
Dan Mires

Editorial Board

Sheenan Harpaz	**Agricultural Research Organization** **Beit Dagan, Israel**
Zvi Yaron	**Dept. of Zoology** **Tel Aviv University** **Tel Aviv, Israel**
Angelo Colorni	**National Center for Mariculture, IOLR** **Eilat, Israel**
Rina Chakrabarti	**Aqua Research Lab** **Dept. of Zoology** **University of Delhi**
Ingrid Lupatsch	**Swansea University** **Singleton Park, Swansea, UK**
Jaap van Rijn	**The Hebrew University** **Faculty of Agriculture** **Israel**
Spencer Malecha	**Dept. of Human Nutrition, Food and Animal Sciences** **University of Hawaii**
Daniel Golani	**The Hebrew University of Jerusalem** **Jerusalem, Israel**
Emilio Tibaldi	**Udine University** **Udine, Italy**

Copy Editor
Ellen Rosenberg

Published under auspices of
The Society of Israeli Aquaculture and Marine Biotechnology (SIAMB),
University of Hawaii at Manoa Library
and
University of Hawaii Aquaculture Program in association with
AquacultureHub
http://www.aquaculturehub.org

ISSN 0792 - 156X

© Israeli Journal of Aquaculture - BAMIGDEH.

PUBLISHER:
Israeli Journal of Aquaculture - BAMIGDEH -
Kibbutz Ein Hamifratz, Mobile Post 25210,
ISRAEL
Phone: + 972 52 3965809
http://siamb.org.il

The Israeli Journal of Aquaculture – Bamidgeh 55(3), 2003, 169-178.

GROWTH AND PRODUCTION IN LONG-LINE CULTIVATED MEDITERRANEAN MUSSEL *(MYTILUS GALLOPROVINCIALIS)* IN SINOP, BLACK SEA

Sedat Karayücel*, Ismihan Karayücel, Muammer Erdem, Serkan Saygun and Orhan Uyan

Faculty of Fisheries, University of Ondokuz Mayis, Sinop 57000, Turkey

(Received 11.12.02, Accepted 31.3.03)

Key words: Black Sea, culture, growth, mussel

Abstract

One-year rope-grown mussels (*Mytilus galloprovincialis* Lam.) with a mean length of 37.6±0.52 mm and live weight of 5.02±0.28 g were collected from fish farm mooring ropes and cultured in cotton or nylon socks in a long-line system in Sinop, Black Sea. The growth of the mussels, water temperature, salinity, chlorophyll *a*, seston and particulate organic matter were monitored from July 1997 for eleven months. Shell length and live weight were high from May to October when the temperature was 13ºC-25ºC. Growth decreased during late autumn and winter due to the low temperature and food availability. A significant and positive relationship was found between particulate organic matter, shell growth and live weight. At the end of the experiment, shell length reached 59.89±0.93 mm in the cotton socks and 57.81±0.88 mm in the nylon socks, while live weight reached 19.42±0.91 g in the cotton socks and 16.89±0.76 g in the nylon. Harvestable production was lower in the cotton (4.1 kg/m) than in the nylon socks (8.7 kg/m). Meat yield was high during spring and early summer and significantly and positively correlated with chlorophyll *a*, particulate organic matter and seston. In the light of these results, recommendations for mussel culture in the long-line system are given.

Introduction

Marine aquaculture in the Black Sea region is a relatively recent development and not yet widespread. Farming of the mussel (*Mytilus galloprovincialis)* is probably the most important activity in the region, although in Turkey mussels are farmed in the Sea of Marmara but not in the Black Sea. Prospects for mussel culture are quite high due to the favorable salinity, temperature, topography, food availability, reproductive potential and socio-economic conditions in the Black Sea area.

In the Black Sea, mussels are distributed

---

* Corresponding author. E-mail: karayucels@hotmail.com

from the interface to a depth of 80 m, forming the most numerous settlements on hard coastal substrates, rocks, stones, artificial constructions as well as deep-watered silts (Ivanov and Bulatov, 1990). *M. galloprovincialis* is a filter-feeding animal, which depends upon phytoplankton, organic detritus, bacteria and probably dissolved organic matter in the water as sources of food. Both general and local environmental parameters influence the growth rate. General factors include water temperature and salinity, which may affect the rates of biochemical reactions in organisms in temperate latitudes. Local factors that determine nutritional conditions can greatly influence the growth rate of marine bivalves. The most important factors are particulate organic matter (Thompson and Nickols, 1988), duration of air exposure (Seed, 1969), population density (Peterson and Beal, 1989), genotypic characteristics (Dickie et al., 1984; Skidmore and Chew, 1985) and water current velocity (Grizzle and Morin, 1989). Quality and quantity of available food may be the most important factors regulating growth (Rodhouse et al., 1984; Mallet et al., 1987). Growth is generally fast in young mussels and becomes slower as the mussels age and grow (Karayücel and Karayücel, 2000a,b). The slower growth rate in larger mussels is associated with reduced metabolic activity and decreased feeding efficiency.

In the first suspended mussel culture techniques, rafts were used as floating platforms in Galicia, Spain. This technique rapidly expanded to other countries (Figueras, 1990) where different installations such as long lines or racks were used, depending on local geomorphological and environmental factors.

The most recent development is the long line system from which culture ropes are suspended. Site characteristics such as spat fall, water exchange, availability of food, temperature, salinity and position (sheltered or exposed), depth of water, suitability of the sea bottom for anchorage, shore access and infrastructure affect operation and production.

Culture of mussels on ropes suspended from rafts or long lines is well established in several countries (Dare and Davies, 1975; Lutz, 1980; Figueras, 1990; Muise, 1990; Karayücel, 1997). However there is a lack of information on mussel culture in the Black Sea. The present study was undertaken to determine which environmental factors influence growth and production in nylon and cotton socks in long line systems.

This experiment is the only known experiment on suspended mussel culture in the Black Sea, Turkey. Information gathered in this experiment can be used for future experiments on mussel culture and by commercial mussel farmers in the region.

Materials and Methods

The experiment was carried out at a depth of 13 m from July 1997 to June 1998 on the coast of Sinop, Black Sea. The length of the long line was 30 m (Fig. 1). A head rope was suspended from the long line, 1.5 m below the water surface and polypropylene culture ropes (16 mm diameter, 5 m long) were suspended from the head rope at 50 cm intervals. Wooden pegs were placed crosswise on the culture ropes at 40 cm intervals to help support the weight of the mussels and distribute it along the entire length of the rope. The culture ropes were inserted into fine nylon or cotton socks (5 mm mesh), filled with mussels, wrapped with polypropylene line and suspended from the head rope (Karayücel, 1997).

One-year-old mussels, *M. galloprovincialis* Lam., with a mean length of 37.6±0.52 mm and mean weight of 5.02±0.2 g were collected by hand from the mooring rope of a fish farm at a depth of 2-5 m and stocked in 15 nylon and 15 cotton socks (sausage) at a density of 1120±53.5 individuals per meter rope.

At each monthly sampling, three ropes were selected from each sock group (nylon and cotton) and a 30 cm section of the rope was harvested. The mussels from the three ropes were counted and pooled. The shells were scrubbed clean of encrusting organisms (e.g., barnacles, epifauna and seaweeds) and sub-samples were measured to determine mussel growth. Growth was estimated from changes in shell length, live weight and wet meat weight (tissue weight). Live weight (total weight of mussel) was measured by weighing

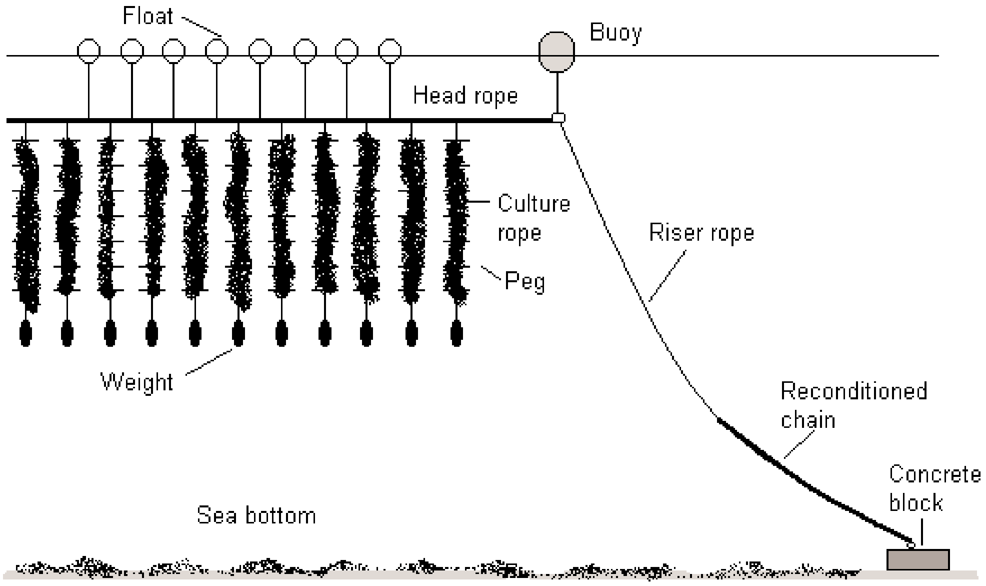

Fig. 1. The long-line system for mussel culture.

live animals and wet meat weight by weighing the meat after dissecting the mussels. Shell length (maximum anterior-posterior axis) was measured to the nearest 0.1 mm with a calliper (Seed, 1968). At the end of the experiment, mussels from eight ropes were counted and the number of mussels per meter of rope was calculated. Production was estimated according to Rivonker et al. (1993). Meat yield was calculated by dividing the wet meat weight by the live weight of the mussels. Specific growth rate (SGR%) was calculated as: SGR (%) = $[(\ln L_2 - L_1)/(T_2 - T_1)] \times 100$, where L_1 and L_2 are the mean shell lengths at times T_1 and T_2 (Chatterji et al., 1984).

On each sampling date, water salinity and temperature were measured with a Salinity Temperature Bridge (U-10 Horriba) at 3 m depth. Using a Nansen-type bottle (Hydro-Blos KIEL), duplicate 1-liter water samples were taken from a depth of 3 m to determine chlorophyll *a*, seston and particulate organic matter (POM) according to Stirling (1985). All samples were passed through a 150-µm nylon mesh to remove large particles and zooplankton. A correlation matrix was used to examine the relationships between the measured parameters and one-way ANOVA was used to test differences between the growth parameters of the two kinds of sock. All statistical analyses were carried out using MINITAB software.

Results

Monthly environmental factors are shown in Fig. 2. The temperature ranged from 7.1ºC in March to 25ºC in July, averaging 15.5±1.9ºC. Salinity ranged 13.9-16.1‰ with a mean of 14.9±0.26‰ and no clear seasonal pattern. Chlorophyll *a* peaked in March as a result of spring algal bloom and reached its lowest in November, with a mean of 3.52±1.75 µg/l. Chlorophyll *a* concentration was significantly different ($p<0.05$) and higher in spring and summer than autumn and winter. POM ranged 0.9-6.1 mg/l with a mean of 2.67±0.48 mg/l. Seston ranged 2.1-13.6 mg/l, averaging 5.9±1.05 mg/l. The percent of organic matter in the seston was 46.5%. There was a positive correlation between chlorophyll *a*, POM and seston ($p<0.05$). Salinity and temperature did not significantly correlate with chlorophyll *a*, POM or seston ($p>0.05$); when chlorophyll *a*, POM and seston peaked in March, the temperature was at its minimum. There was a clear seasonal pattern to the temperature but not to the other environmental parameters.

Monthly changes in shell length, live weight and meat yield are plotted in Fig. 3. At the end of eleven months, the average shell

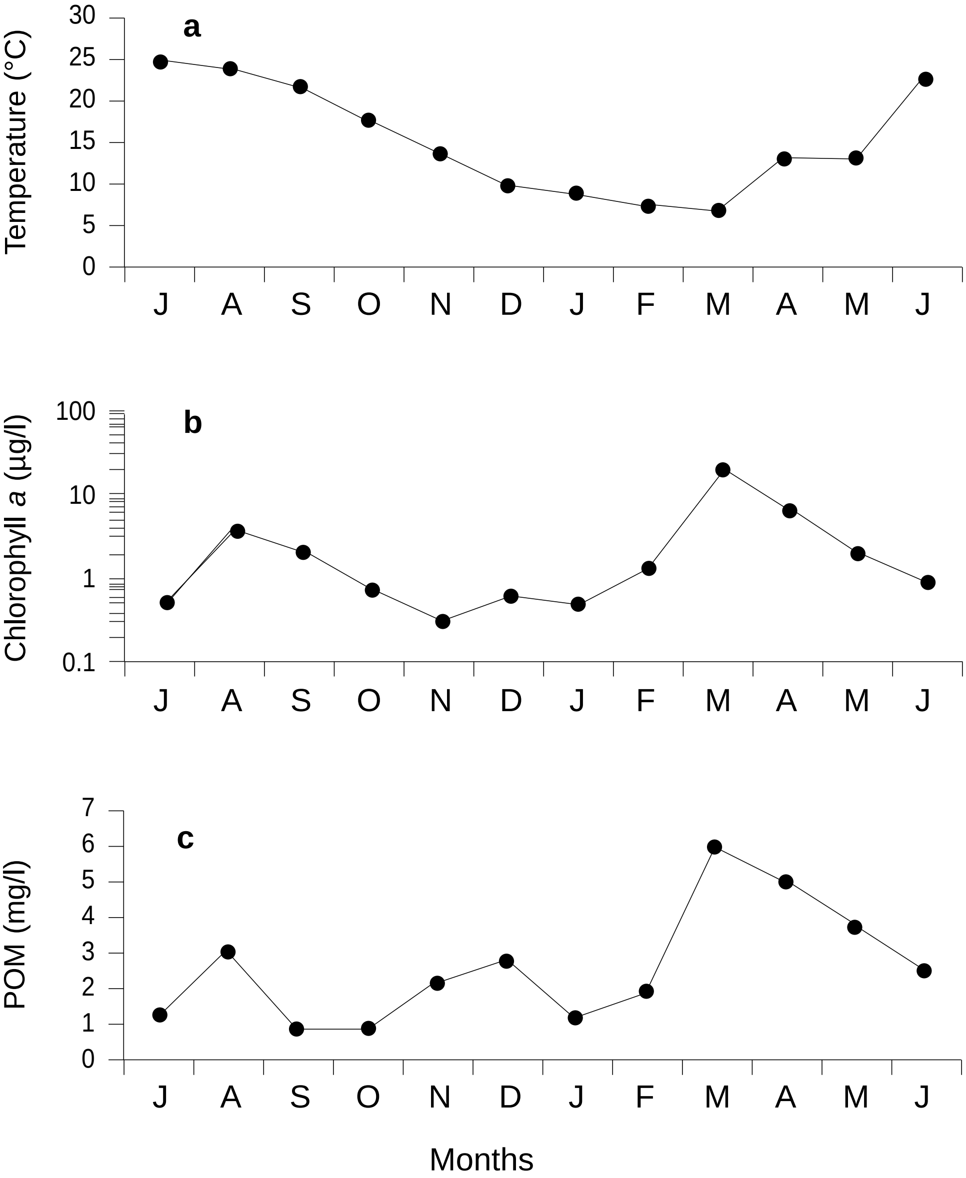

Fig. 2. Monthly temperature (a), chlorophyll *a* (b) and particulate organic matter (c).

length in the cotton socks increased 22.29 mm, reaching 59.89±0.93 mm (range 48.7-73.3 mm). This was greater but not significantly different than the shell growth in the nylon socks, where it increased 20.21 mm, reaching 57.81±0.88 mm (range 47.3-68.8 mm). In the first four months, 47.3% of the total shell growth in the nylon socks and 49.2% of the total shell growth in the cotton socks occurred. The growth rate was very low during the winter and resumed in March. The average live weight in the cotton socks increased 14.4 g, reaching 19.42±0.91 g (range 8.2-27.14 g). In the nylon socks, the weight increased 11.87 g, reaching 16.89±0.76 g (range 10.27-36.83 g). The wet meat weight (tissue weight) was 4.98±0.24 g and 4.48±0.17 g and the shell weight was 6.97±0.27 g and 6.41±0.29 g in the cotton and nylon socks, respectively. Meat yield ranged 15.88-26.52% (mean 21.99±0.04) in the nylon socks and 17.13-34.52% (mean 23.31±0.05) in the cotton and significantly correlated with chlorophyll *a*, POM and seston ($p<0.05$). Shell length frequencies are shown in Fig. 4. The increases in shell length and live weight positively correlated with POM ($p<0.05$) while the wet meat weight positively correlated with POM and chlorophyll *a* ($p<0.05$).

The monthly specific growth rate (SGR%) ranged 0.3-12.3% (mean 3.74%) in the nylon socks and 0.45-11.2% (mean 3.98%) in the cotton socks. The highest SGR was in the first two months when the mussels were younger and the temperature and availability of food were higher. The SGR was lower during the winter due to the low temperature and low availability of food but it resumed in March and continued throughout the spring and summer.

Monthly density of the mussels is given in Fig. 5. The final mean density was 211±7.5 per meter rope for the cotton socks and 532±13.2 for the nylon socks. Final production was 8.7 kg per meter rope for the nylon socks and 4.1 kg for the cotton. Production in nylon socks was higher than in cotton socks in rough environmental conditions due to fewer losses of mussels from the socks.

Discussion

Bivalve growth consists of increases in both the shell and the soft body parts. The measurement of shell length is the most widely used indicator of growth because it is the easiest to measure (Quayle and Newkirk, 1989).

Older mussels have a reduced growth rate (Seed, 1969). The combined effects of reduced feeding rate and increased gamete production in older mussels may be responsible for their slower growth (Thompson, 1984). Seasonal changes in wet meat weight result from the storage and utilization of food reserves in relation to the complex interaction of food availability and temperature with growth and reproductive processes (Dare and Edwards, 1975). In the present study, the wet meat weight and meat yield decreased in larger mussels from March to April and May to June, in connection with spring spawning. The wet meat weight and meat yield increased from February to March and from April to May while new gonad reserves were built. Meat yield positively correlated with chlorophyll *a*, POM and seston ($p<0.05$). These findings are identical to reports from Holland, England and Scotland (Dare and Edwards, 1975; Okumus, 1993; Karayücel and Karayücel, 1997).

Kautsky (1982) and Hilbish (1986) reported that shell and meat increments exhibit different seasonal patterns of growth without any correlation between them. Similarly Dare (1976) reported that the meat weight of intertidal mussels exhibited a pronounced annual cycle independent of shell growth but related to spawning and other factors, possibly temperature and food availability. In the present study, the shell growth rate was high during spring and summer and lower during autumn and winter due to low temperature and availability of food. The correlation of growth with POM, its clear seasonal growth pattern and the fact that wet meat weight and meat yield did not show a clear seasonal pattern are almost identical with the findings of Mason and Drinkwater (1981), Stirling and Okumus (1994, 1995) and Karayücel and Karayücel (2000 a,b). Meat yield and condition indices in *Mytilus* vary according to body size (Baird,

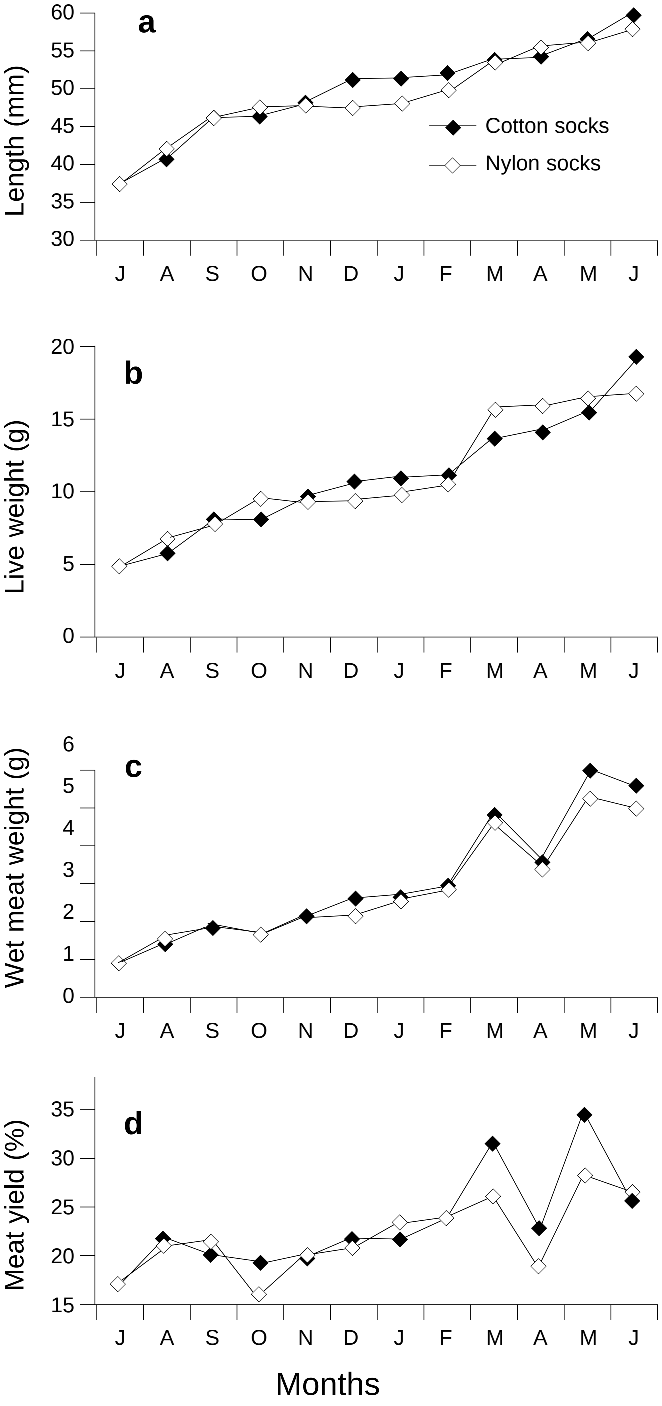

Fig. 3. Monthly length (a), live weight (b), wet meat weight (c) and meat yield (d) of cultured mussels.

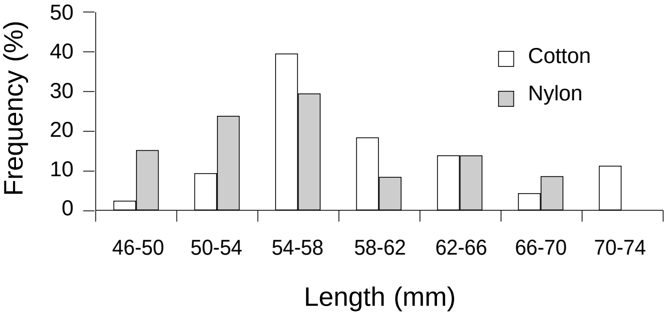

Fig. 4. Shell lengths of mussels grown in cotton or nylon socks at the end of experiment.

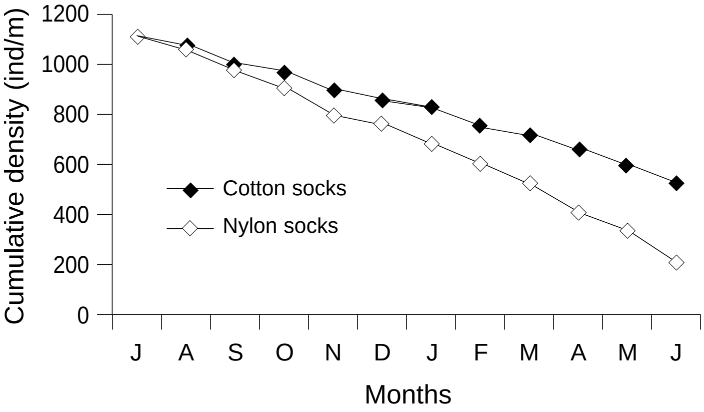

Fig. 5. Monthly changes in mean cumulative density of mussels in cotton socks and nylon socks.

1958), season (Dix and Ferguson, 1984; Karayücel and Karayücel, 1997), level of parasitic infection (Theisen 1987) and local environmental conditions, especially the availability of food and degree of aerial exposure (Seed, 1980; Yamada, 1989). Seasonal changes are due to a complex interaction of factors such as temperature, food supply and salinity, which are thought to influence somatic growth and reproductive development.

In natural mussel populations, production is limited by physiological stress (Koehn and Bayne, 1989), food availability (Newell et al., 1989), primary space (Navarette and Castilla, 1990), predation (Gardner and Thomas, 1987) and carrying capacity (Karayücel and Karayücel, 1998). Population density also affects the growth of mussels in the natural environment (Broom, 1982; Petersen and Beal, 1989). Losses were caused mostly by currents during the first two months of the experiment, due to weak byssus thread attachment of the newly suspended mussels on the biodegradable cotton socks, and partly by massive fall-off due to insufficient space on the rope that was occupied by larger mussels.

Final densities were 211±7.5 mussels (>47 mm) per meter in the cotton socks and 532±13.2 mussels per meter in the nylon socks. Karayücel and Karayücel (1999) reported 393 mussels (>50 mm) in Loch Etive and 360 mussels in Loch Kishorn for *M. edulis* in cotton socks on the west coast of Scotland. Dare and Davies (1975) recorded 200 mussels of 55 mm in Wales. Dare and Davies (1975) and Mason and Drinkwater (1981) used live weight to determine harvestable production. In the present study, production was 4.1 kg in cotton socks and 8.7 kg per meter of rope in the nylon socks whereas Okumus (1993) reported 6.1 kg on the west coast of Scotland, Mason and Drinkwater (1981) reported 6.2 kg in England and Karayücel and Karayücel (1999) reported 6.8 kg in Loch Etive and 5.4 kg in Lock Kishorn.

According to the present findings, mussel growth and production are higher in nylon socks than in cotton socks in long line systems in the Black Sea. Culture requires two years from spat settlement until harvest in May through October. Consequently, mussels can be cultured economically by using nylon socks in the well-designed long line system in the Black Sea and further experiments are needed on suspended mussel culture systems (long line and raft) to initiate mussel culture in the Black Sea, Turkey.

References

Baird R.H., 1958. Measurement of conditioning mussels and oysters*. J. Cons. Int. Exp. Mer*., 23:249-257.

Broom M.J., 1982. Analyses of growth of *Anadora granosa* (Bivalve: Arcidae) in natural, artificially seeded and experimental populations. *Mar. Ecol. Prog. Ser*., 9:69-79.

Chatterji A., Ansari Z.A., Ingole B.S. and A.H. Parulekar, 1984. Growth of green mussel, *Perna viridis* L., in a seawater circulating system. *Aquaculture*, 40:47-55.

Dare P.J., 1976. Settlement, growth and production of the mussel, *Mytilus edulis* L., in Morecambe Bay, England. *Fishery Investigations, Min. Agric., Fish. and Food, Series II*, 28(1). Her Majesty's Stationery Office, London. 25 pp.

Dare P.J. and G. Davies, 1975. Experimental suspended culture of mussels, *Mytilus edulis* (L.) in Wales using spat transplanted from a distant settlement ground. *Aquacult.*, 6:257-274.

Dare P.J. and D.B. Edwards, 1975. Seasonal changes in flesh weight and biochemical composition of mussels, *Mytilus edulis* (L.), in the Conwy Estuary, North Wales. *J. Exp. Mar. Biol. Ecol.,* 18:89-97.

Dickie L.M., Boudreau P.R. and K.R. Freeman, 1984. Influence of stock and site on growth and mortality in blue mussels, *Mytilus edulis. Can. J. Fish. Aquat*. *Sci*. 41:134-141.

Dix T.G. and A. Ferguson, 1984. Cycles of reproduction and condition in Tasmanian blue mussels *Mytilus edulis* planulatus. *Aust. J. Mar. Fresh. Res*., 35:307-313.

Figueras A.J., 1990. Mussel culture in Spain. *Mar. Behav. Physiol*., 16:177-207.

Gardner J.P.A. and M.I.H. Thomas, 1987. Growth, mortality and production of organic matter by a rocky intertidal population of *Mytilus edulis* in the Quoddy region of the Bay of Fundy. *Mar. Ecol. Prog. Ser*., 39:31-39.

Grizzle R.E. and P.J. Morin, 1989. Effect of tidal currents, seston and bottom sediments on growth of *Mercenaria mercenaria*: results of a field experiment. *Mar. Biol*., 102:85-93.

Hilbish T.J., 1986. Growth trajectories of shell and soft tissue in bivalves; seasonal variations in *Mytilus edulis* (L.). *J. Exp. Mar. Biol. Ecol*., 96:103-113.

Ivanov V.N. and K.V. Bulatov, 1990. Population genetic investigations of Black Sea *Mytilus galloprovincialis* Lam. *Hydrores*, 7(8):106-111.

Karayücel S., 1997. Mussel culture in Scotland. *World Aquacult.,* 28(1):4-14.

Karayücel S. and I. Karayücel, 1997. Influence of environmental factors on condition index and biochemical composition in *Mytilus edulis* L. in cultivated raft system, in two Scottish sea lochs. *Turk. J. Mar. Sci*., 3(3):149-166.

Karayücel S. and I. Karayücel, 1998. Estimating the carrying capacity of mussel raft systems in two Scottish sea lochs. *Israeli J. Aquacult. - Bamidgeh*, 50(1):12-19.

Karayücel S. and I. Karayücel, 1999. Growth, production and biomass in raft cultivated blue mussels (*Mytilus edulis* L.) in two Scottish sea lochs. *Israeli J. Aquacult. - Bamidgeh*, 51(1):65-73.

Karayücel S. and I. Karayücel, 2000a. The effect of environmental factors, depth and position on the growth and mortality of raft cultivated blue mussels (*Mytilus edulis* L.). *Res. Aquacult.,* 31:893-899.

Karayücel S. and I. Karayücel, 2000b. Influence of stock and site on growth, mortality and shell morphology in cultivated blue mussels (*Mytilus edulis* L.) in two Scottish sea lochs. *Israeli J. Aquacult. - Bamidgeh*, 52(3): 98-110.

Kautsky N., 1982. Growth and size structure in a Baltic *Mytilus edulis* L. population. *Mar. Biol.*, 68:117-133.

Koehn R.K. and B.L. Bayne, B.L., 1989. Towards a physiological and genetical understanding of the energetics of the stress response. *Biol. J. Linn. Soc*., 37:157-171.

Lutz R.A., 1980. *Mussel Culture and Harvest: A North American Perspective*. Elsevier Sci. Publ. Co., Amsterdam. 350 pp.

Mallet A.L., Carver C.E.A., Coffen S.S. and K.R. Freeman, 1987. Winter growth of the blue mussel *Mytilus edulis* L.: Importance of stock and site. *J. Exp. Mar. Biol. Ecol*., 108:217-228.

Mason J. and J. Drinkwater, 1981. *Experiment on Suspended Cultivation on Mussels in Scotland*. Pamphlet 4. Scot. Fish. Int., DASF, Aberdeen. 15 pp.

Muise B., 1990. Mussel culture in eastern Canada. *World Aquacult.*, 21(2):12-23.

Navarette S.A. and J.C. Castilla, 1990. Barnacle walls as mediators of intertidal mussel recruitment: effects of patch size on the utilization of space. *Mar. Ecol. Prog. Ser*., 68:113-119.

Newell C.R. Shumway S.E. Cucci T.L. and R. Selvin, 1989. The effects of natural seston particle size and type on feeding rates, feeding selectivity and food source availability of mussel *Mytilus edulis* Linnaeus, 1758, at bottom culture sites in Maine. *J. Shellfish Res*., 8:187-196.

Okumus I., 1993. *Evaluation of Suspended Mussel (Mytilus edulis L.) Culture and Integrated Experimental Mariculture (Salmon-Mussel) Trials in Scottish Sea Lochs.* Ph.D. thesis, Univ. Stirling. 336 pp.

Peterson C.H. and B.F. Beal, 1989. Bivalve growth and higher order interactions importance of density, site and time. *Ecology*, 70:1390-1404.

Quayle D. and G. Newkirk, 1989. *Farming Bivalve Molluscs: Methods for Study and Development*. World Aquacult. Soc. and Int. Dev. Res. Centre. 294 pp.

Rivonker C.U., Ansari Z.A. and A.H. Perulekar, 1993. Cultivation of green mussel, *Perna viridis* L., on a floating raft in an estuary along the west coast of India. *Aquaculture*, 112:47-56.

Rodhouse P.G., Roden C.M. and T.H. Ryan, 1984. Resource allocation in *Mytilus edulis* on shore and in suspended culture. *Mar. Biol*., 84:27-34.

Seed R., 1969. The ecology of *Mytilus edulis* L. (Lamellibranchiata) on exposed rock shores. II. Growth and mortality. *Ecologia*, 3:317-350.

Seed R., 1980. Shell growth and form in the bivalve. pp. 23-67. In: D.C. Rhoads and R.A. Lutz (eds.). *Skeletal Growth of Aquatic Organisms; Biological Records of Environmental Change*. Plenum Press.

Skidmore D. and K.K. Chew, 1985. *Mussel Culture in Puget Sound*. Washington Sea Grant, Tech. Rep., Univ. Washington, Seattle. 57 pp.

Stirling H.P., 1985. *Chemical and Biological Methods of Water Analyses for Aquaculturist.* Inst. Aquaculture, Univ. Stirling. 119 pp.

Stirling H.P. and I. Okumus, 1994. Growth, mortality and shell morphology of cultivated mussel (*Mytilus edulis*) stock cross-planted between two Scottish sea lochs. *Mar. Biol.*, 119:115-123.

Stirling H.P. and I. Okumus, 1995. Growth, mortality of mussels (*Mytilus edulis* L.) suspended at salmon cages and shellfish farms in two Scottish sea lochs. *Aquaculture*, 134: 193-210.

Theisen B.F., 1987. *Mytilicola intestinalis* Steurer and the condition of its host *Mytilus edulis* L. *Ophelia*, 27:77-86.

Thompson R.J., 1984. Production, reproductive effort, reproductive value and reproductive cost in a population of blue mussel, *Mytilus edulis* from a subarctic environment. *Mar. Ecol. Prog. Ser*., 16:249-257.

Thompson J.K. and F.H. Nickols, 1988.

Food availability controls seasonal cycle of growth in *Mocoma baltica* (L.) in San Francisco Bay, California. *J. Exp. Mar. Biol. Ecol*., 116:43-61.

Yamada S.B., 1989. *Mytilus californianus*, a new aquaculture species. *Aquaculture,* 81: 275-284.