# A comparison of nutritional state in long-line cultivated and natural rocky populations of *Mytilus edulis* (L.)

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## Abstract

Observations in the Tjärnö archipelago, revealed a great occurrence of the common mussel *Mytilus edulis* on rocky shores. The mussels were, however small in size compared with cultured mussels in the same area, and this raised the question whether the rocky mussels were starving. Large-scale spatial variation in condition indices, length, size distribution, density and biomass of approximately one year old *M. edulis* from cultivations and rocky shores at three areas on the Swedish west coast was investigated. Size distributions suggested a dominance of one-year old mussels in all sampling sites. The condition index showed no significant difference between habitats, while mussels from the area around Tjärnö had lower condition index than the other areas. Thus the small size of rocky shore mussels was not a consequence of starvation. Shell index, which describes the proportion of meat- and shell weight, differed between habitats as well as for the interaction area*habitat. Cultivated mussels had two times higher values than the ones at rocky shores. Mean length differed between habitats, 27-45 mm among cultivations, with Tjärnö mussels being largest and 16.2-17.6 mm on the rocky shores with no difference among areas. Density was about two times higher for cultivated mussels in the Ljungskile area but the biomass did not differ. The results from mussel cultures suggest an optimal biomass (500-650 g / meter of band) independently of a high density or a large mean length for one year old cultivations on the Swedish west coast. Density and biomass was lowest in the Ljungskile area on rocky shores with 2-3 times lower values.


## Introduction

The common mussel *Mytilus edulis* is capable of dominating rocky shore at wave exposed sites (Suchanek 1985). The abilities to withstand wide fluctuations in salinity, desiccation, temperature and oxygen tension, make it a common low littoral zone species in temperate habitats (Seed & Suchanek 1992). Mussels, especially those that live in exposed habitats, represent some of the most productive species on earth, rivalling the productivity of tropical rain forest trees and kelps (Whittaker 1975). Cultured *M.edulis* can be even more productive. A study at the Tjärnö archipelago showed that mussels in a cultivation measured shell lengths of 5-6 cm, 14-16 months after settling (Loo & Rosenberg, 1983).

In the summer of 1999, exposed rocky shores in the Tjärnö archipelago had large numbers of *M. edulis* probably caused by a massive settling the summer before (Loo, pers. com.). Mussels at rocky shores were, however small in comparison with cultured mussels in the same area, and this raised the question whether the rocky shore mussels were starving.

The allometric relation of weight of soft parts to shell length (condition index) is high in well fed, fast growing mussels, and in mussels prior to spawning (Jørgensen, 1976). Another index (shell index) in which dry weight of the meat is divided by shell weight and multiplicated with 100, can be interpreted as an index of growth (Smaal & Staben 1990) and as an indirect reflection of the food availability (Pérez Camacho et al 1995). Mature mussels may loose a large proportion of their bodyweight after spawning (Bayne 1976). The relations between shell length and weight of soft parts therefore vary with habitat and season, although time of spawning vary from one year to another depending on environmental factors. Temperature seems to be the most important factor, spawning occurs at approximately 10º C at the Swedish west coast and then the larvae has a pelagic period of 2-4 weeks depending on food availability (Loo 1991a). In the Tjärnö archipelago the temperature 10º C was first reached in the middle of May both 1999 and 1998. This means that the first settlings could be expected in mid or end June.

The aims of this study were to investigate if the nutritional state was poorer in rocky mussel populations than in the cultured populations. This was made by comparing condition indices and mean length of one year old mussels between habitats and among areas along the Swedish west coast. In this study, three areas was studied along the coast to achieve some generality. Histograms of size distribution were made to be sure that the mussels were of the same age. In addition, for further description of the sampling sites and areas, I estimated density and biomass. My hypothesis was that the mussels at rocky shores should have lower condition indices and lower shell lengths than cultivated mussels due to harsh living conditions and lower food availability.

## Material and Methods

### Area descriptions and sampling sites

The NW coastline of Sweden, is an archipelago of thousands of islands. The salinity above the haloklin (~15 m) is normally between 23-30psu. Tidal currents are weak and the amplitude 15-35 cm. *Mytilus edulis* were collected from three areas. In each area, both long-line cultivated and rocky shore mussels were sampled. In the first area, Tjärnö (58º 53´N 11º 09´E), mussels were collected from two wave exposed rocky shores, yttre Vattenholmen and Saltö, and two long-line cultivations in Nycklebyviken, a more protected archipelagic bay. In the second area, Hamburgsund (58º 35´N 11º 15´E), wave exposed rocky mussels were taken at Bogen and an islet south of Bogen, cultivated mussels were from two cultivations between Rågö and Brattö. In the third area, Ljungskile (58º 18´N 11º 55´E ), rocky mussels were taken north and south of Korsvik, a relatively sheltered area. Cultivated mussels were taken from cultivations east of Björkholmen, (Fig. 1.).

### Sampling long-line cultivated mussels

The cultivations sampled in this study varied in size from 3-10 long-lines. Three samples from each cultivation were taken between 1999/06/29-1999/07/09 (year, month, date). To get random samples a three-way randomisation were made, (long-line, barrel and band) with a random table at each level. The samples were taken by a scuba diver, with a device that enclosed a 0.10-m cluster of mussels. All samples were taken at 2-3 m depth and were deep frozen.

### Sampling rocky shore-living mussels

After locating rocky shore mussels the sample area was defined and split into sections and a random table was used to decide sample locations. Three samples were collected by a snorkler at approximately 0.5 m depth. A frame (0.25*0.25m) was placed over a surface with complete coverage of mussels. The mussels were cut out with a knife and placed in a plastic bag. All samples were taken 1999/07/07-1999/07/10, except at the Ljungskile area were we could not locate rocky shore mussels during the first visit due to bad weather. Mussels from this area were sampled one month later. All samples were deep frozen.

### Measurements

Three samples at each site were analysed. The shell length of mussels above 10 mm were measured. The size distribution of each sample was assessed using mm-classes. In each sample, thirty individuals representing the measured mussels length-interval, were taken for separate weight-measurements. The soft parts and shell were separated before weighting. The wetweight were noted before drying to a constant weight at 70º C. Dryweigth and shell length were used in length-weight regressions and shell index calculations. At each site, thirty mussels were ashed for four hours at 500º C and weighted again.

**Statistical treatments and calculations**

The length-weight relations were analysed with linear-regressions ($\alpha$=0.05) in Sys stat 7.0 after log10 transformation. The slopes from the length-weight regressions were checked for homogenous variances with Cochrans test and further analysed in a three-factorial nested analysis of variance (ANOVA). Factors were: Area (fixed, 3 levels), Habitat (fixed, 2 levels) and Site (random, 2 levels). Site was nested under the interaction Area*Habitat. Nested data with $P > 0.25$ were pooled for a more powerful test (Underwood 1997). Shell index was calculated as: SI=(dry meatweight/ dry shellweight)*100 (Freeman 1974) and the results were analysed with the same ANOVA model as above. Median length for all measured mussels at each site were also tested with the ANOVA model described above. The dryweigth of biomass was quantified using the relationship between log10-transformed values of shell length and dry weight for each size and each sample according to the formula: $w = iL^c$ , where w is shellfree dryweigth (g) , c is the regressioncoefficient, L is the shell length and I is the intercept. In its linearised logarithmic form this becomes $\text{Log } w = \text{Log } I + c \text{ Log } L$. The variations in biomass and density were checked with Cochrans test for homogeneity, and analysed in a two-factorial nested ANOVA. Habitat was excluded and two separate tests were made because of the different sample areas ( 0.0625 $m^2$ for rocky shores and 0.1 m band for cultivations). Data that showed heterogeneous variances were square-rot transformed before the analysis.

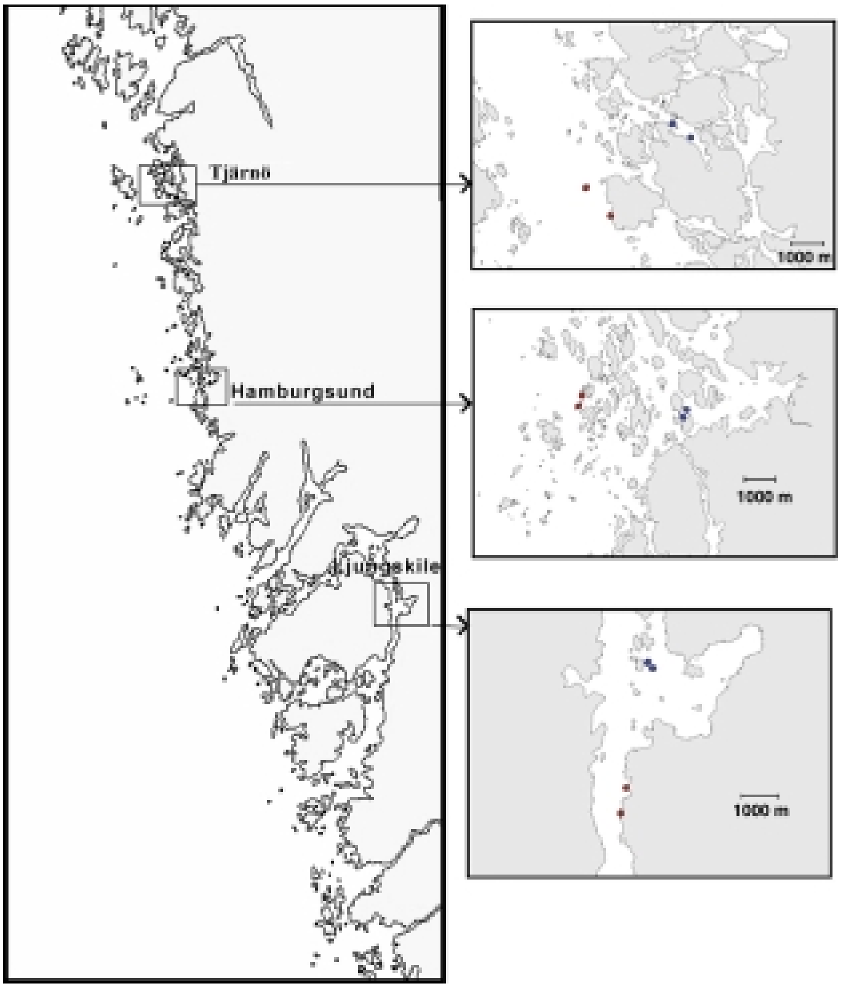



**Figure 1**. Sampling areas. Cultivated mussels were sampled (blue dots) in wave protected areas while rocky shore mussels (red dots) were from very exposed (Tjärnö, Hamburgsund) to mildly exposed (Ljungskile) areas.

# Results

## Length and Size distribution

The measurements were registrated on a total of 30465 mussels with shells above 10 mm. Size distribution for each sample is given in appendix A. Median length differed significantly between habitats (P=0.0001), tab.1. Shell length varied between 27-45 mm in the cultivations and 16.2-17.6 mm on the rocky shores, fig.2. The ANOVA was made inspite of heterogenety in the variances. Site also differed significant and figure 3 indicates larger mussels in cultivations in the Tjärnö area.

| Source | df | SS | F-value | P-value | Error term |
|---|---|---|---|---|---|
| Area | 2 | 181.6 | 2.68 | 0.15 | Site(Area,Habitat) |
| Habitat | 1 | 2468.4 | 72.80 | 0.0001 | Site(Area,Habitat) |
| Area*Habitat | 2 | 269.6 | 3.98 | 0.08 | Site(Area,Habitat) |
| Site(Area,Habitat) | 6 | 203.3 | 2.51 | 0.05 | Residual |
| Residual | 24 | 323.8 | | | |
| Dependent: Median length | | | | | |

**Table 1**. Statistical analysis (ANOVA) of median length for mussels sampled from different areas, habitats and sites.

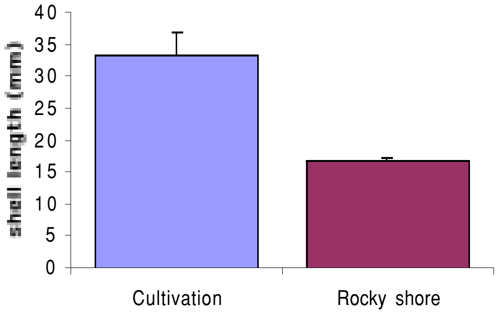



**Figure 2**. Median length with errorbars (SE) for mussel cultures and rocky shores.

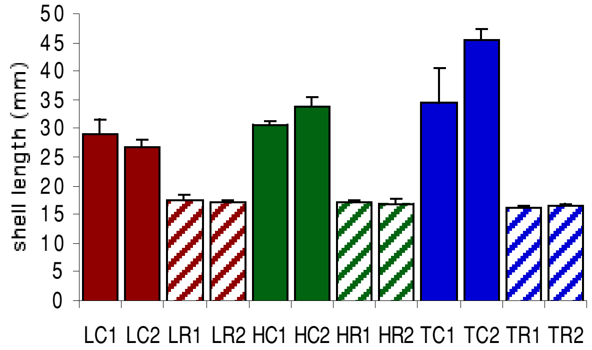



**Figure 3**. Median length with errorbars (SE) for sites. The first letter is for area: L=Ljungskile, H=Hamburgsund, T=Tjärnö. The second is for habitat: C=Cultivations (filled staples), R=Rocky shores (striped staples).

## Condition indices

All regressions of shell free dry weight and shell length were highly significant (P<0.05) with good precision ($r^2 \approx 0.932$). For detailed information of each sample see appendix B. All replicates (3) at each sampling site were tested in an multifactorial analysis of variance (ANOVA). Nested data with p > 0.25 were pooled for a more powerful test (Underwood 1997). After pooling nested data (tab. 2.) it became clear that there were no significant difference between habitats (P=0.55). However it seems like the area around Tjärnö has lower condition index than the other areas, although not significant (P=0.07), fig. 4. The great variation between sampling sites probably contributed to this result, fig. 5. The shell index analysis showed significant results for the factor habitat (P=0.0001) and the interaction area*habitat (P=0.03), tab 3. Figure 6 clearly shows that cultivated mussels have higher shell index than mussels from rocky shores. The factor area also have tendencies toward lower values for rocky shore living mussels in the Ljungskile area and cultivated mussels in the Tjärnö area.

(A)

| Source | df | SS | F-value | P-value | Error term |
|---|---|---|---|---|---|
| Area | 2 | 0.76 | 2.87 | 0.134 | Site(Area,Habitat) |
| Habitat | 1 | 0.05 | 0.36 | 0.569 | Site(Area,Habitat) |
| Area*Habitat | 2 | 0.01 | 0.04 | 0.962 | Site(Area,Habitat) |
| Site(Area,Habitat) | 6 | 0.79 | 0.99 | 0.454 | Residual |
| Residual | 24 | 3.20 | | | |
| Dependent: Slope | | | | | |
| (B) | | | | | |
| Area | 2 | 0.76 | 2.84 | 0.074 | Residual |
| Habitat | 1 | 0.05 | 0.36 | 0.55 | Residual |
| Area*Habitat | 2 | 0.10 | 0.04 | 0.96 | Residual |
| Residual | 30 | 3.99 | | | |
| Dependent: Slope | | | | | |

**Table 2**. (a)Statistical analysis (ANOVA) of condition index for mussels sampled from different areas, habitats and sites. (b) ANOVA after pooling nested data for a stronger test.

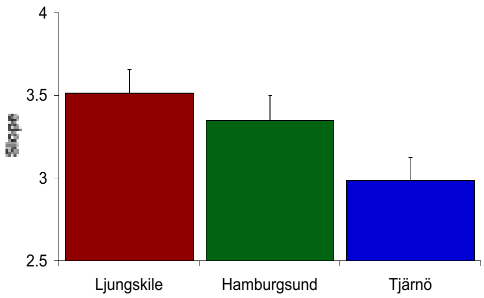



**Figure 4.** Mean Condition index for different areas with errorbars (SE).

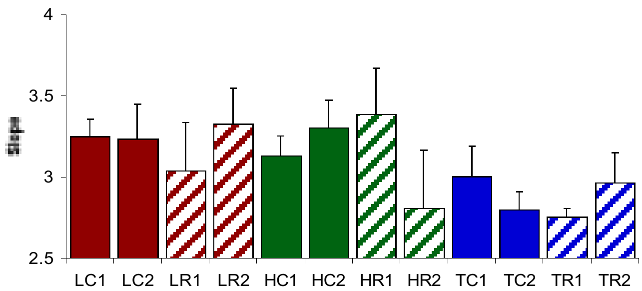
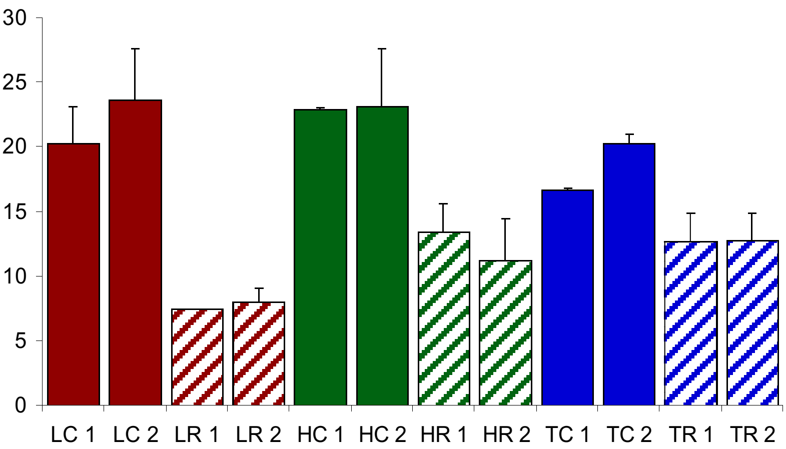



**Figure 5**. Mean Condition index with errorbars (SE) for each sampling site. Filled staples for cultivated mussels and striped for rocky shores. The first letter is for area: L=Ljungskile, H=Hamburgsund, T=Tjärnö. The second is for habitat: C=Cultivations, R=Rocky shores

| Source | df | SS | F-value | P-value | Error term |
|---|---|---|---|---|---|
| Area | 2 | 52.5 | 3.51 | 0.098 | Site(Area,Habitat) |
| Habitat | 1 | 943.7 | 126.02 | 0.0001 | Site(Area,Habitat) |
| Area*Habitat | 2 | 107.6 | 7.18 | 0.03 | Site(Area,Habitat) |
| Site(Area,Habitat) | 6 | 44.9 | 2.24 | 0.07 | Residual |
| Residual | 24 | 80.3 | | | |
| Dependent: Slope | | | | | |

**Table 3.** Statistical analysis (ANOVA) of shell index for mussels sampled from different areas, habitats and sites.

**Figure 6**. Mean Shell index with error bars (SE) Filled staples for cultivated mussels and striped for rocky shores. L=Ljungskile,H=Hambursund, T=Tjärnö. C=Cultivations, R=Rocky shores.



## Density and Biomass

The density differed significantly among areas for both habitats, tab. 4 and tab.5. The Ljungskile area differed significantly from the others by having a higher density in the cultivations (P=0.004), (fig. 7.) and a lower density at the rocky shores (P=0.001), fig.8. The cultivations had mean biomasses between 492-665 (g) shellfree DW per meter band, fig. 9. Despite differences among areas in density, biomass did not differ. On rocky shores there was a clear relationship among areas and biomass, tab. 6. The Ljungskile area showed 2-3 times lower biomass, fig 10.

| Source | df | SS | F-value | P-value | Error term |
|---|---|---|---|---|---|
| Area | 2 | 16657744 | 30.30 | 0.01 | Site(Area) |
| Site(Area) | 3 | 823816 | 0.29 | 0.83 | Residual |
| Residual | 12 | 11219466 | | | |
| Dependent: number/m band | | | | | |

**Table 4.** Statistical analysis (ANOVA) of density of culivated mussels per meter band for different areas and sites.

| Source | df | SS | F-value | P-value | Error term |
|---|---|---|---|---|---|
| Area | 2 | 7881 | 24.7 | 0.01 | Site(Area) |
| Site(Area) | 3 | 479 | 2.11 | 0.15 | Residual |
| Residual | 12 | 907 | | | |
| Dependent: number/m2 | | | | | |

**Table 5.** Statistical analysis (ANOVA) of density of rocky shore living mussels per square meter for different areas and sites.

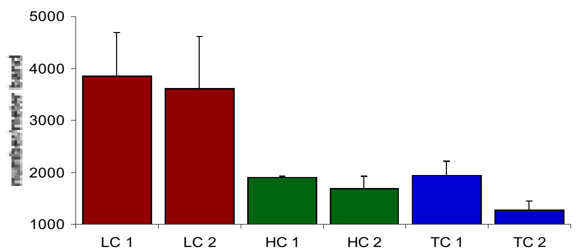



**Figure 7.** Mean Density with errorbars (SE) for culivated mussels per meter band for different areas and sites.

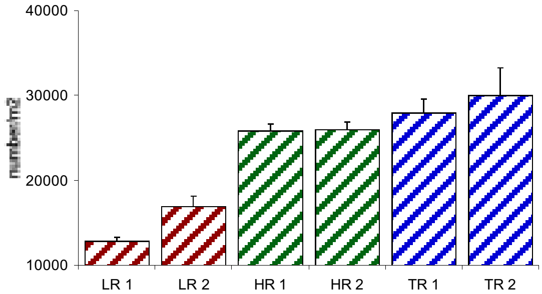



**Figure 8.** Mean Density with errorbars (SE) for Rocky shore living mussels per square meter for different areas and sites.

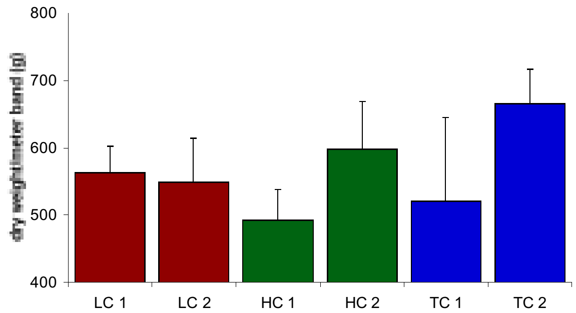



**Figure 9.** Mean Biomass (dryweight) of cultivated mussels with error bars (SE).

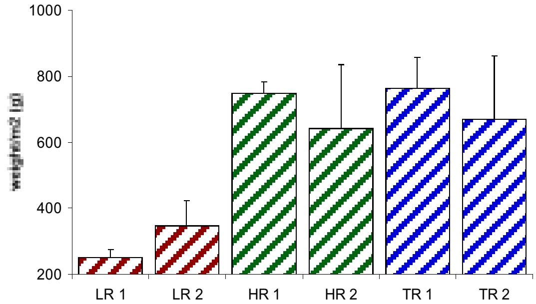



**Figure 10**. Mean Biomass (dryweight) for Rocky Shores, with error bars (SE).

| Source | df | SS | F-value | P-value | Error term |
|---|---|---|---|---|---|
| Area | 2 | 662831 | 23.2 | 0.015 | Site(Area) |
| Site(Area) | 3 | 42852 | 0.31 | 0.81 | Residual |
| Residual | 12 | 545331 | | | |
| Dependent: weight/m2 | | | | | |

**Table 6.** Statistical analysis (ANOVA) of biomass of rocky shore living mussels per square meter for different areas and sites.

## Discussion

The length distributions suggest that each sample was dominated by one year class of mussels settled in the end of June 1998. Presumably, at the time of sampling (late June-early July), the mussels were approximately one year old, and this makes possible a direct comparison of length distributions among samples. There is a clear relationship between mean length and habitat, with cultivated almost twice the length of rocky shore mussels (only lengths above 10 mm were measured). Condition index, however did not differ between rocky shore and cultivation mussels. The shell index differed between habitats. The interpretation of this difference is, however, confounded by significant interaction of area*habitat. Interactions are hard to interpret, but when considering one area at a time it becomes clear that the rocky shore mussels almost had two times lower values than the cultivated in each area. The Ljungskile rocky shore had significantly lower density and biomass than other areas. Density was about two times higher for cultivated mussels in the Ljungskile area but the biomass did not differ significantly.

My assumption, that the mussels sampled were approximately one year old, is based on the size-distribution and by personal communication with Lars-Ove Loo and the owners of the cultivations. The cultivations were set out the summer 1998. I decided to restrict my length measurements, to mussels larger than 10 mm, to exclude individuals younger than about 1 year. Size-distribution for each sample, appendix A, show clear peaks on all sampling sites on rocky shores and cultivations. Except for cultivation 1 in Tjärnö (A19-A21) and cultivation 2 in Hamburgsund (A28-A30) which point out two separate peaks each. One peek probably indicate one settling occasion, but two peaks is harder to interpret. However, studies around NE England has shown that spawning may occur throughout the summer until late August or September (Seed & Suchanek 1992) and several studies from the Swedish west coast show settling peeks in July and August, although settling in June seems most frequent (Loo 1991a ). It could depend on where in the cultivation the sample was taken, if the outer margin produced larger mussels than the inner area of the mussel culture, implying with-in species competition for food. However, no such correlation was found in an earlier study in the same area (Loo & Rosenberg 1983), and with good water flow through a cultivation there is no reason to propose competition for food. Of course it could be two separate settling occasions, probably one normal settling in June and one later settling in August. Length variations also differed among sites. They show a clear trend that the Tjärnö area have larger cultivated mussels than the other areas, fig. 3. A similar observation was made by Loo & Rosenberg (1983), where one year old mussel cultures around Tjärnö had 1.2 times larger mussels than cultures around Mollösund (Wiigh-Mäsak 1982). The mussel cultures I studied in Tjärnö consisted of 7 (C1) and 3 (C2) long-lines and this can probably explain a part of the observed trend, the other mussel cultures all had 10 long-lines.

With-in species competition for food in the larger cultivations could explain this observed trend. The maximum sizes attained on rocky shores can be correlated with the degree of wave impact, the size decreasing with increasing wave force (Jørgensen 1976). However, no such correlation was found in my study. Thus, you might expect that the rocky populations in the Ljungskile area would have larger mean length than the others, due to the lowest wave exposure. However, if all sizes had been measured, this could be the case.

My results regarding condition index in mussel cultures seems to correspond well with an earlier study from Sweden , tab. 7. Although the mussels in that study were two years old, it seems like the slope lies around 3.0 in the summer in these areas. There are no previous data on condition index from rocky shores in Sweden, but when comparing with studies from

England it seems like my values are slightly high. However, the tidal water in England have a much stronger influence. Thus, the values on rocky shores from England at high- and low level clearly illustrates the importance of air exposure and thereby decreasing possible filtration time (Seed 1968). The studies from Öresund (Petersen et al 1997) were made in the Autumn on mussels from bottom beds so one should be careful not to draw to sharp conclusions regarding the differences with this study. But, the data clearly show that the index vary from one year to another depending on the living conditions.

| Slope | Range(mm) | Area | Habitat | Season, year | Reference |
|---|---|---|---|---|---|
| 2.9 | 15-65 | Tjärnö | cultivations | Summer 1999 | this study |
| 3.22 | 15-65 | Hamburgsund | cultivations | Summer 1999 | this study |
| 3.05 | 15-53 | Tjärnö | cultivations | Summer 1983 | Loo 1991b |
| 2.97 | 15-53 | Hamburgsund | cultivations | Summer 1983 | Loo 1991b |
| 2.82 | 10-80 | Öresund | mussel beds | Autum 1994 | Petersen et al 1997 |
| 2.33 | 10-80 | Öresund | mussel beds | Autum 1997 | Petersen et al 1997 |
| 3.12 | 11-35 | Sweden, west coast | rocks | Summer 1999 | this study |
| 2.5 | 10-35 | England, Filey Brigg | rocks, high level | - | Seed, 1968 |
| 2.81 | 10-35 | England, Yorkshire | rocks, low level | - | Seed, 1968 |

**Table 7**. Condition index from this and other studies.

In this study I tried to collect the samples during the same time period to be able to compare areas and habitats. Unfortunately there were some problem locating rocky shore living mussels in the Ljungskile area. I sampled these a month later and I do not think that this affected the results much. Condition index did not differ as expected in my hypothesis. There was no difference between habitats what so ever. It seems like the mussels at rocky shores did not starve under the period when sampling occurred. This does not mean that they have favourable feeding conditions all the time. A study from Norway show that mussels starved under longer periods respond more rapidly, than normally fed, to feeding by increasing their growth rate (Strömgren 1976). However, that study only treated shell length and nothing was said about meet contents. Although the most logical conclusion must be that meet contents increase even more, relatively to shell length. Thus, if the feeding conditions were good prior and during the time of sampling, it would explain that there were no difference in condition index between habitats. However, when crowding interferes with normal growth, the shells of densely packed mussels become proportionately more elongate with higher length to height ratios than those from less crowded conditions (Seed & Suchanek 1992). This will probably result in lower intercepts, and could also affect the slope toward higher values. Consequently, even though the slope of the allometric equation of weight of soft parts to shell length is acknowledged internationally as a measure of the condition of the mussels (Salkeld 1995), the condition index used in this study is solely not adequate for finding out differences in growth- and feeding conditions for the two habitats. Nevertheless, the index can be useful when comparing areas, and this study shows a clear trend that the Tjärnö area has the lowest condition index.

The shell index showed highly significant results regarding the factor habitat and the interaction area*habitat. Interactions is hard to interpret but when splitting the habitats up it becomes clear that the rocky shore living mussels almost had two times lower values than the cultivated. This means that the shells are about two times thicker on rocky shore living mussels. Cultivated mussels are known for having thinner shells, perhaps as a phenotypic response to less predators.

The Ljungskile area had significantly lower density and biomass on rocky shores. This is probably due to a higher predation pressure on sheltered rocks, thus intense wave action will exclude predators (Reimer & Tedengren1997). However, the same study proves that mussels aggregates and form firmer byssal-threads when exposed to predators and this does not agree with my observations when sampling at the Ljungskile area. The mussels were very loosely attached to the substrata and did not hold together as one unit when they were cut out in a square. However, I only have wave exposed rocks to compare with, so I really can not say whether the mussels at Ljungskile area were firmly or loosely attached to the substratum. The Ljungskile area also differed significantly from the others by having almost two times higher density in the cultivations. This could probably result from a larger settling and an earlier stage of maturation considering the area had the lowest mean length in this habitat. However, the biomass did not differ in the cultivations tested for different areas, but the mean weight seems to differ when compared to other studies. A study of a one year old cultivation from Mollösund, the south-west side of Orust, show biomasses (800-1000 g) nearly twice as much as this study (500-650 g) from the same depths (Wiigh-Mäsak 1982). The differences are probably a result of currents, thus Mollösund has 3 times greater average speed than Tjärnö. Another study, with mussels of the same age from the Tjärnö area, show biomasses 2 times lower than my study (Loo & Rosenberg 1983).

## Conclusions

There is a clear correlation between shell length and habitat in this study, with cultivated mussels twice the length of rocky shore individuals. No difference between the relative condition of mussels were observed between the two habitats (cultures and rocks). The condition index is perhaps not solely a good tool to describe differences between habitats. The shell index on the other hand, show that cultivated mussels have thinner shells relative meat content than mussels on rocky shores. However, the cultivated mussels had mean lengths twice as high and this can also contribute to the result. The cultivated mussels around the Tjärnö area had the highest mean length, the lowest condition index as well as the lowest shell index. If :*condition index is high in well fed, fast growing mussels, and in mussels prior to spawning* (Jørgensen, 1976), it should reflect mean length as well, but then again, the condition index only reflect the conditions at the time of sampling and tells nothing about the rest of the year. When compared to the shell index the following scenarios come up: The cultivated mussels in the Tjärnö area had lower meat contents or thicker shells than mussels in the other areas. It could depend on the larger mean length to, if the slope of the length/weight regression declines after a certain length and thereby decreasing the mean condition index. Density was about two times higher for cultivated mussels in the Ljungskile area but the biomass did not differ significantly. The results from mussel cultures suggests an optimal biomass (500-650 g / band meter) independently of a high density or a large mean length for one year old cultivations on the Swedish west coast.The sheltered area around Ljungskile had the most deviating results on rocky shores, where shell index, density and biomass was significantly lower. Thicker shells is probably a reflection of a higher predation pressure. The more wave exposed areas had more than two times higher biomass and density.

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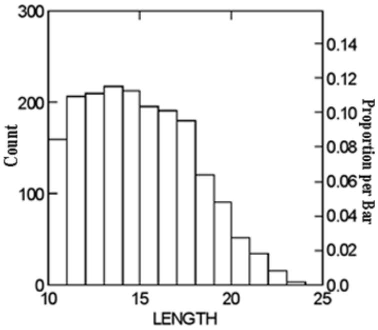
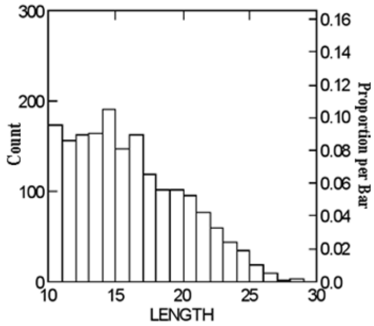
## Appendix A

Size distribution (mm) of mussels per sample (0.0625 m[2] on rocky shores and 0.1 meter band in cultivations). R=Rocky shore, C=Cultivation.




A1. Tjärnö, R 1

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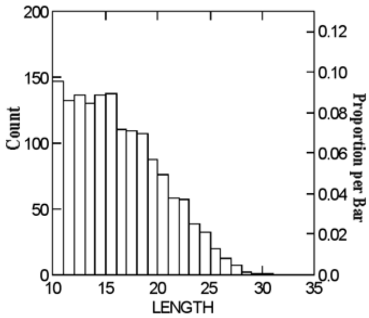


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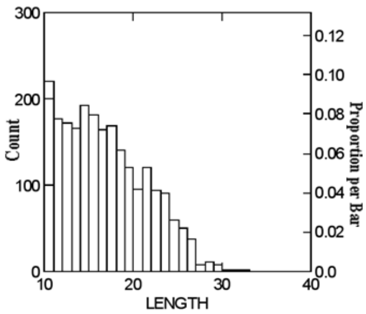


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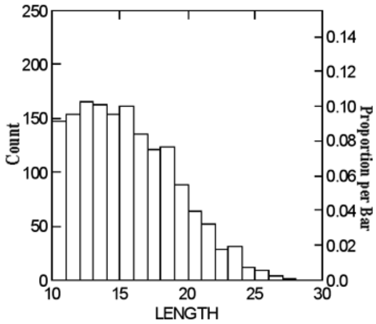


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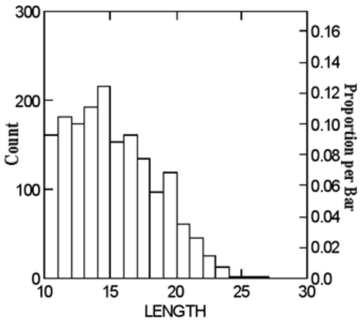


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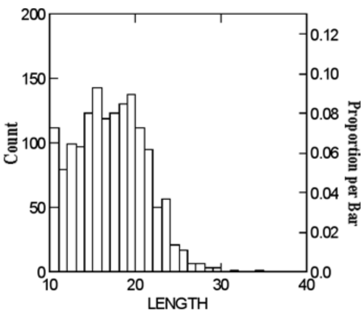
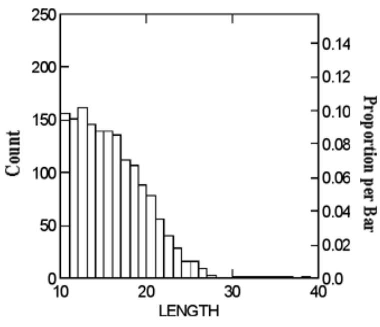



A7. Hamburgsund, R 1

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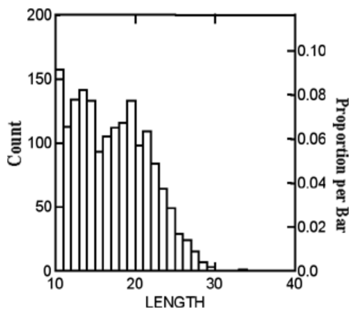


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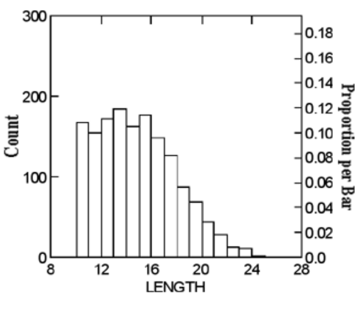


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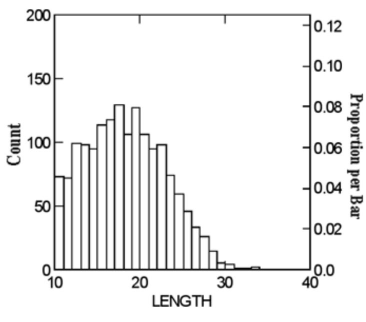


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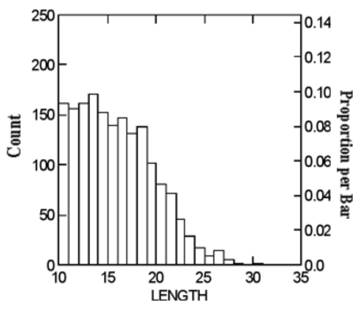
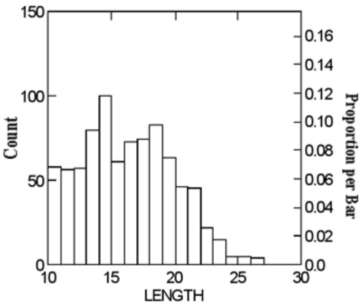


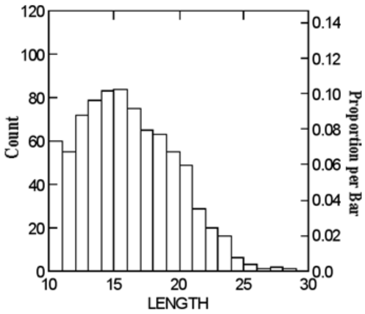

A12. Hamburgsund, R 2

## Appendix A

Size distribution (mm) of mussels per sample (0.0625 m$^2$ on rocky shores and 0.1 meter band in cultivations). R=Rocky shore, C=Cultivation.



A13. Ljungskile, R 1



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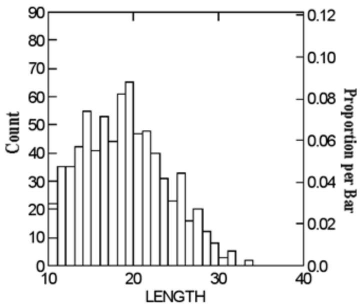

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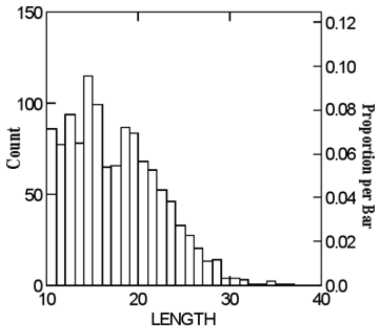

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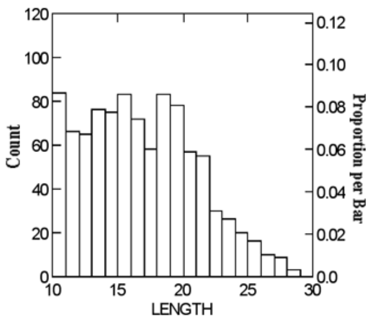

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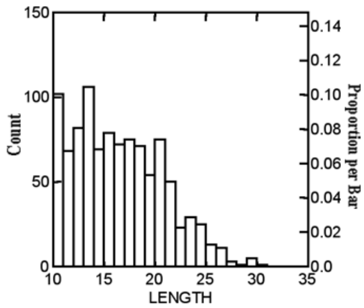

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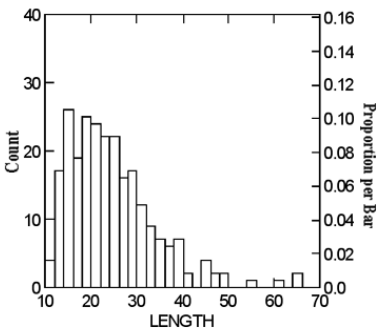
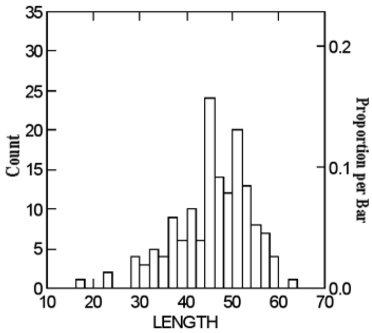


A19. Tjärnö, C 1



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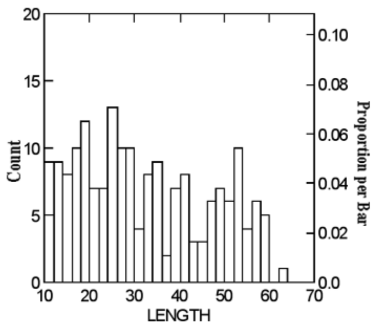

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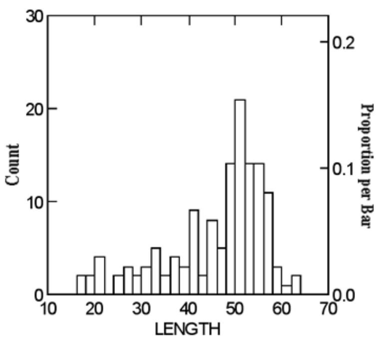

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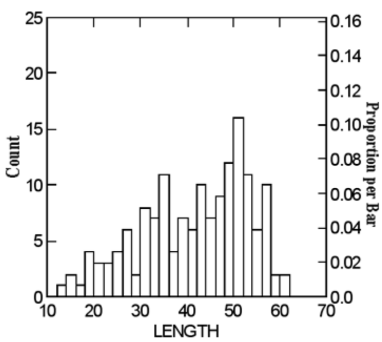

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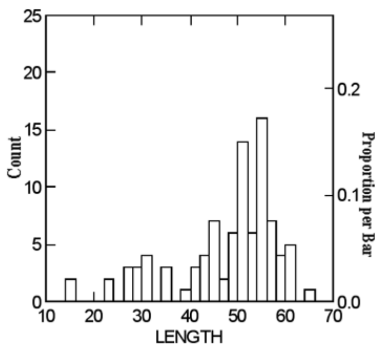
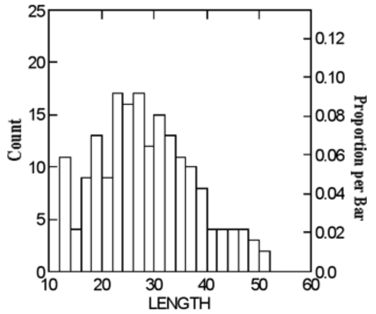


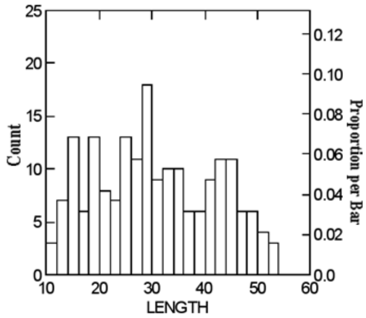
A24. Tjärnö, C 2

# Appendix A

Size distribution (mm) of mussels per sample (0.0625 m$^2$ on rocky shores and 0.1 meter band in cultivations). R=Rocky shore, C=Cultivation.



A25. Hamburgsund, C1



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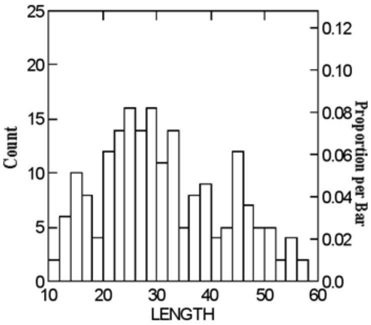
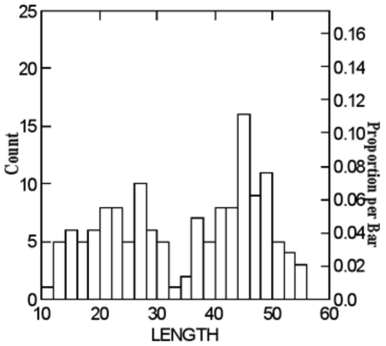


A27. Hamburgsund, C1



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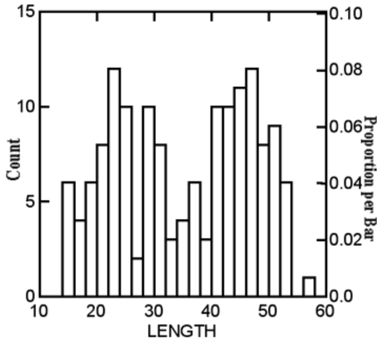

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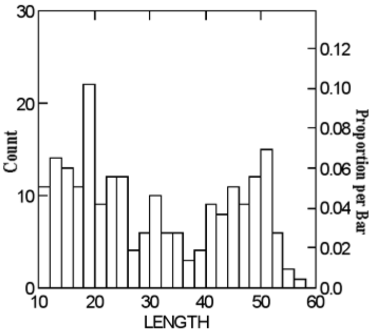

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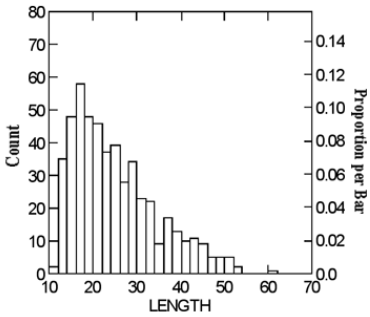
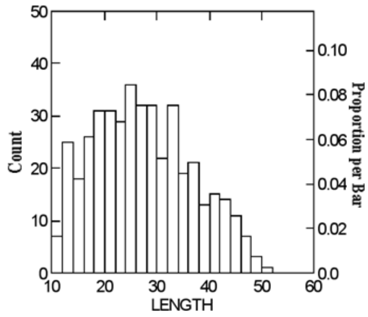


A31. Ljungskile, C 1



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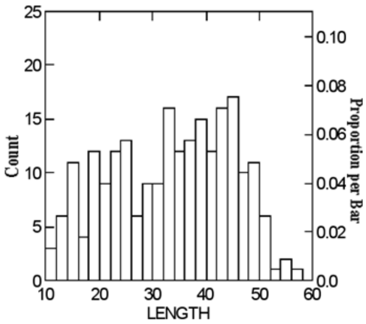

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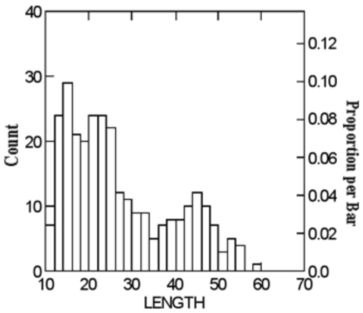
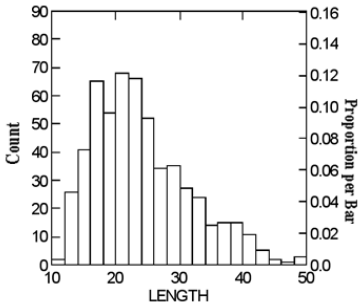


A34. Ljungskile, C 2



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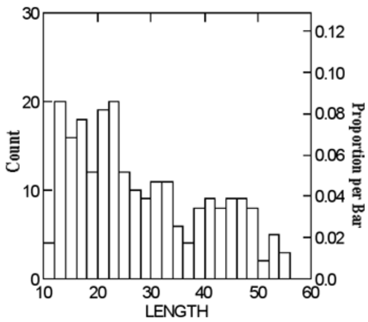

A36. Ljungskile, C 2

## Appendix B

(A) Intercept, slope and coefficient of determination for length/weight regressions on shell length and dry meat weigth. (B) Same as A except that regressions were made on ash free dry weigth. (C) Shell index calculated as: (dry meat weight/dry shell weight) * 100. (D) Quota, where wet weight/ dry weight describes water content. (E) The number of mussels used from each sample.
The letter in the site column stands for: L=Ljungskile, H=Hamburgsund, T=Tjärnö and R=Rocky shore, C=Cultivation.

| | A | | | B | | | C | D | E |
|---|---|---|---|---|---|---|---|---|---|
| Site | intercept | slope | r2 | intercept | slope | r2 | Shell index | WW/DW | n |
| LR 1 | -2.59 | 3.07 | 0.918 | -1.80 | 2.45 | 0.941 | 7.43 | 6.6 | 30 |
| LR 1 | -1.85 | 2.51 | 0.863 | | | | 7.58 | 6.3 | 30 |
| LR 1 | -3.28 | 3.55 | 0.929 | | | | 7.25 | 7.8 | 30 |
| LR 2 | -2.89 | 3.34 | 0.927 | -2.25 | 2.87 | 0.957 | 9.54 | 6.7 | 30 |
| LR 2 | -2.46 | 2.95 | 0.918 | | | | 7.34 | 7.3 | 30 |
| LR 2 | -3.49 | 3.70 | 0.922 | | | | 7.07 | 8.6 | 29 |
| LC 1 | -2.64 | 3.23 | 0.945 | | | | 22.42 | 5.1 | 30 |
| LC 1 | -2.51 | 3.08 | 0.964 | -2.36 | 2.96 | 0.982 | 17.97 | 5.4 | 30 |
| LC 1 | -3.06 | 3.44 | 0.935 | | | | 20.31 | 5.4 | 30 |
| LC 2 | -2.59 | 3.23 | 0.968 | | | | 25.35 | 4.9 | 30 |
| LC 2 | -3.31 | 3.62 | 0.958 | -3.07 | 3.44 | 0.975 | 20.61 | 5.3 | 30 |
| LC 2 | -1.99 | 2.86 | 0.960 | | | | 24.92 | 4.5 | 30 |
| HR 1 | -3.65 | 3.95 | 0.821 | -2.32 | 2.94 | 0.947 | 11.47 | 7.8 | 28 |
| HR 1 | -2.31 | 3.03 | 0.960 | | | | 15.35 | 5.2 | 30 |
| HR 1 | -2.52 | 3.19 | 0.968 | | | | 13.5 | 5.4 | 30 |
| HR 2 | -2.78 | 3.26 | 0.869 | -1.15 | 2.03 | 0.966 | 9.91 | 5.5 | 29 |
| HR 2 | -2.81 | 3.30 | 0.901 | | | | 9.8 | 6.4 | 30 |
| HR 2 | -2.33 | 3.02 | 0.972 | | | | 13.94 | 5.3 | 30 |
| HC 1 | -2.52 | 3.23 | 0.968 | | | | 23.44 | 5.2 | 30 |
| HC 1 | -2.62 | 3.28 | 0.958 | | | | 22.7 | 5.3 | 30 |
| HC 1 | -2.04 | 2.90 | 0.962 | -2.39 | 3.08 | 0.974 | 22.63 | 5.1 | 30 |
| HC 2 | -2.36 | 3.08 | 0.968 | | | | 22.8 | 5.4 | 30 |
| HC 2 | -3.26 | 3.64 | 0.980 | -3.08 | 3.50 | 0.990 | 20.49 | 6.4 | 30 |
| HC 2 | -2.47 | 3.19 | 0.933 | | | | 26.07 | 5.0 | 30 |
| TR 1 | -3.22 | 3.70 | 0.878 | -1.86 | 2.68 | 0.933 | 12.13 | 5.7 | 29 |
| TR 1 | -1.95 | 2.82 | 0.956 | | | | 14.83 | 4.9 | 30 |
| TR 1 | -2.07 | 2.80 | 0.949 | | | | 11.04 | 5.5 | 30 |
| TR 2 | -2.65 | 3.22 | 0.889 | -2.23 | 2.89 | 0.955 | 13.95 | 6.5 | 29 |
| TR 2 | -2.73 | 3.30 | 0.935 | | | | 13.69 | 6.6 | 30 |
| TR 2 | -2.37 | 2.95 | 0.953 | | | | 10.5 | 6.2 | 30 |
| TC 1 | -2.85 | 3.32 | 0.964 | | | | 16.35 | 6.5 | 30 |
| TC 1 | -1.76 | 2.67 | 0.966 | -1.78 | 2.64 | 0.985 | 16.35 | 5.4 | 30 |
| TC 1 | -2.38 | 3.02 | 0.949 | | | | 17.33 | 5.5 | 30 |
| TC 2 | -1.82 | 2.71 | 0.891 | | | | 20.84 | 5.4 | 30 |
| TC 2 | -1.774 | 2.68 | 0.935 | -1.94 | 2.75 | 0.964 | 21.01 | 5.5 | 30 |
| TC 2 | -2.338 | 3.02 | 0.832 | | | | 19.04 | 5.6 | 30 |