Comparison of growth of the reef fish species *Haemulon flavolineatum* (French grunt) between seagrass beds, mangroves and the coral reef, as a test for the nursery hypothesis

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Abstract

Juvenile French grunts (*Haemulon flavolineatum*) were caught, measured in length and weight and introduced in cages for 6 to 8 weeks to grow in their natural environments, the reef, the seagrass beds and the mangroves. After this period, weighing and measuring length was repeated and the growth could be calculated. The mangroves and seagrass beds are identified as nursery habitats for juvenile reef fish and are supposed to increase their survival chances. The nursery hypothesis claims nurseries are beneficial to the juveniles in several ways, including higher growth rates. This research, conducted on the Caribbean islands of Curaçao and Aruba proved the opposite for juveniles between 3.5 and 4 cm. The growth in length and weight of the fishes were higher, although only significantly in Aruba, in the reef habitat compared to the nurseries. Food samples collected on Aruba at each site were comparable with the growth results, because the highest food availability was found in the reef habitat. When comparing the growth of the fishes between two different locations (each location containing all three habitats) on the island of Aruba, significant differences in growth in length were found. Apart from the fact that the highest growth was found on the reef on both islands, there were little similarities found in growth between the islands. The correlation between environmental factors and the growth of the fishes were small, with only a correlation detected between water clarity and growth in weight and weight/length ratio on Aruba. Differences between the two main areas on Aruba and between the islands could, however, not be explained by this. In conclusion, mangrove and seagrass nurseries do not contribute to a higher growth rate of small juvenile French grunts.

1. Introduction

Most coral reef fish have a 2-phase life cycle. The first phase consists out of a pelagic phase (living in open water), when the fishes are still in a larval stage. The second phase shows a demersal life style, where juveniles and adults live close to the bottom of the sea. In this life cycle adults spawn on the coral reefs, from which the eggs drift off into the open ocean (pre-settlement). Finally settlement takes place (post-settlement) on the reef after a period of days to weeks, depending on the species (Őhman, 1998). However, in some species of coral reef fish, another stage forms part of the life cycle (Fig. 1), namely larval settlement in habitats closer to the shore, before moving to and settling on the reef. This life cycle is called Post-settlement Life Cycle Migration (PLCM), because another migration takes place after settlement (Cassele et al., 1996; Cocheret de la Morinière, 2002a).

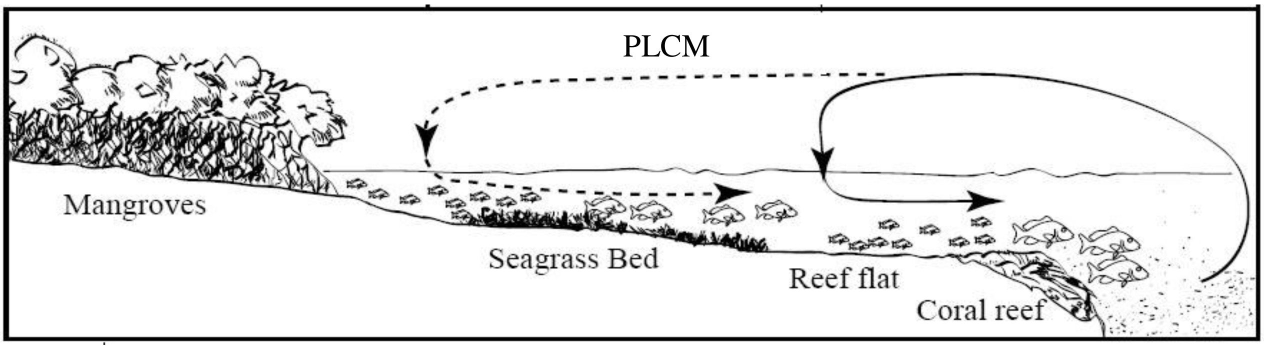


Figure 1: reproduction of lifecycles from reef fish, in which the Post-settlement Life Cycle Migration (PLCM) is shown (Cocheret de la Morinière et al., 2002b)

In many studies (Nagelkerken et al., 2000a and 2001; Cocheret de la Morinière et al., 2002b; Nagelkerken et al., 2000a and 2001; Sheridan et al., 2003), mangrove forests and seagrass beds are identified as the habitats where many reef fish settle in their juvenile phases. Because there is mainly a large amount of juveniles found in these habitats, these habitats were appointed to as nursery habitats, which offer more protection for the young fishes. For example, on the island of Curaçao (Dutch Antilles), research showed that an inland marine bay with seagrass beds and mangroves served as a nursery habitat for at least 17 coral reef species (Nagelkerken et al., 2000b).

Beck et al., (2001) developed a nursery hypothesis, in which is stated what a nursery is:
'A habitat is a nursery for juveniles of a particular species if its contribution per unit area to the production of individuals that recruit to adult populations is greater, on average, than production from other habitats in which juveniles occur.' Several studies (Shulman, 1985; Parrish, 1989; Cocheret de la Morinière, 2000a; Nagelkerken et al,. 2000b, 2002a, and 2002b; Sheaves, 2005; Verweij et al., 2005) have also stated (hypothesized) this importance of these nursery habitats for the survival and great diversity of reef fish species. Multiple hypotheses are given to explain the importance of the nurseries for juvenile fishes:

a) The structural complexity of the habitats provides shelter against predators;
b) A greater amount of food is provided in the mangroves and seagrass beds, which results in higher growth rates;
c) Predator efficiency is lowered in these habitats by the presence of more shade and a higher turbidity;
d) Predator presence is lower in these habitats compared to the reef habitat;
e) Planktonic fish larvae are more easily intercepted in these places, because of their wide abundance;

Moreover, the nurseries could not only provide a “safe haven” for juveniles, but can also contribute to higher adult recruitment on the reef. This contribution can be the result of four factors that could be higher in nurseries: (a) density of juveniles, (b) growth of juveniles, (c) survival of juveniles, and (d) movement of juveniles to adult habitats (Beck et al., 2001; Sheridan et al., 2003).

Limited research has been done to emphasize the importance of the nursery habitats and to verify the given hypotheses. Most research that has been carried out so far is done by means of visual census; monitoring the habitats and fishes by looking at them for certain periods of time, count the number of fish and estimate their sizes. Such research has pointed out that there are more juvenile fishes of some reef fish species in the supposed nursery habitats, and that the adults are mainly found on the reefs (Nagelkerken et al., 2000b). Additional research showed higher abundance of reef fishes on the reef adjacent to nursery habitats, compared to coral reefs in absence of nearby nursery habitats (Dorenbosch et al., 2004; Nagelkerken et al., 2001). These studies provided partial evidence for the important function of the nurseries for the survival of juvenile reef fish. However, all these studies are done by mean of visual census (Harvey et al., 2002).

In order to get more insight in the importance of nursery habitats, more experimental research is needed. These include measurements of predation presence, the monitoring of environmental factors and the growth of juveniles. This research focuses mainly on the latter subject and thereby complementing the existing research on the nursery hypothesis.

This research was conducted on the Caribbean islands of Curaçao and Aruba. The research started in 2005 on Curaçao in which the growth of juvenile reef fishes was monitored at three different habitats, namely the reef and two nursery habitats; the mangroves and seagrass beds. To get additional data, to verify the outcome and to make comparisons, this research has been replicated on the Caribbean island of Aruba in 2006. In both studies the French grunt (*Haemulon flavolineatum*), an economically and commercially important species with a life cycle including PLCM, was used as the research object. Former research has pointed out the importance of mangroves and seagrass beds as nurseries for this specific reef fish (Nagelkerken et al., 2000a).

The aim of this research is to show if the nursery habitats have indeed a positive effect on the growth of the juvenile fish. Expected is to find higher growth rates in the nursery habitats in comparison with the coral reef. These growth rates are expected to be caused by a higher food availability in the nurseries. This leads to a higher growth rate for the juveniles, which points at the importance of nursery habitats. This would confirm the idea of the importance and advantage of mangroves and seagrass beds as nurseries, at least with regard to growth.

This hypothesis is tested by measuring the growth in length and weight as well as the weight/length ratio of caged juvenile French grunts. This has been done to compare the growth between three habitats: the coral reef, the mangroves and the seagrass beds, and between both Caribbean islands. Possible differences could be explained by different values of food availability and environmental parameters, like temperature, salinity and water clarity, which were also taken into account in this research.

This study can also have economical and environmental important implications. A higher survival rate of the juveniles means more adult fish on the reef habitat. Indirectly, this means nurseries are an important link for the fisheries, in order to sustain high yields. Many people are dependent on these reef fisheries world-wide. A better understanding of the importance of supposed nurseries could lead to higher fish stocks and eventually to a better conservation of these habitats (Nagelkerken et al., 2002a).

2. Methods

2.1 Study areas

The present study was carried out at the south-coast of the Caribbean islands of Curaçao and Aruba. Per island the research locations will be discussed.

2.1.1 Curaçao

The study was carried out at Spanish Water Bay, on the south-west side of the island from August to November 2005. The shoreline of the bay is fringed by *Rhizophora mangle* mangrove trees. Monospecific *Thalassia testudinum* seagrass beds are located in front of the mangroves. Finally, outside of the bay, the coral reefs are found. In every habitat 4 cages were placed, with one additional cage in the seagrass beds. In total there were 8 sites chosen for the cages, as shown in Table 1. Figure 2a shows the whereabouts of all these sites.

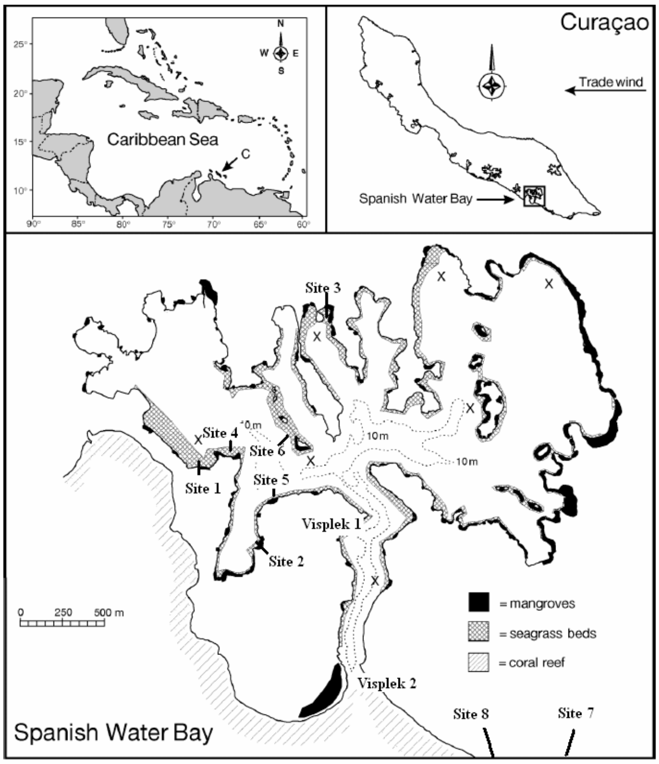
Table 1: The site numbers, habitat types and the number of cages and names of the research sites on Curaçao

Site no.	Habitat	No. of cages + names
1	MG	2, Boor left + right
2	MG	1, Baya
3	MG	1, Turtle
4	SG	2, Boor large + small
5	SG	1, Big stone
6	SG	2, ARS and no ARS
7	Reef	2 Reef left and right
8	Reef	2 Reef left and right

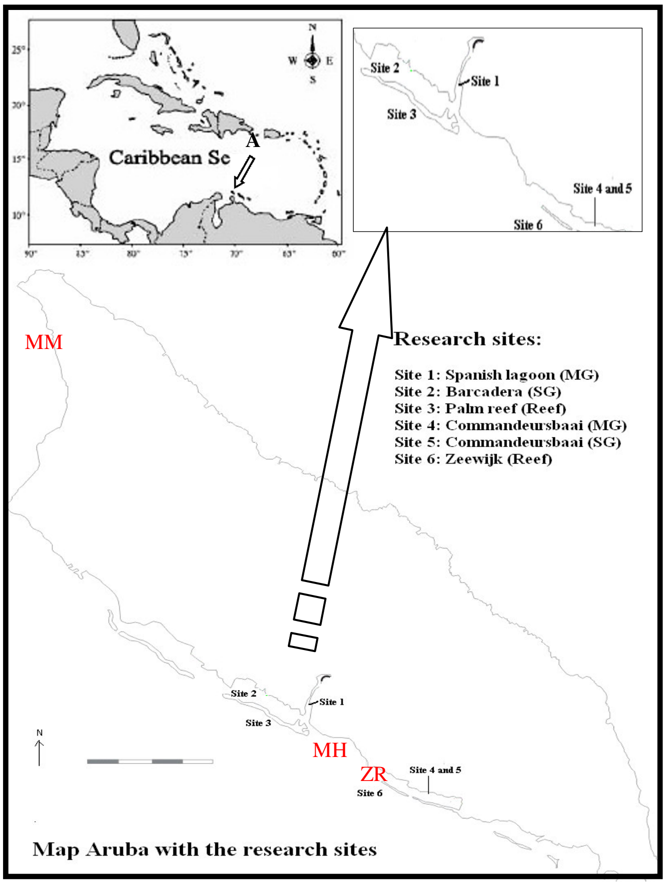
2.1.2. Aruba

In Aruba, research was done from July to August 2006. It was conducted in the Red mangroves (*Rhizophora mangle*), on the seagrass beds, Turtle grass (*Thalassia testudinum*) and on the coral reef, consisting of a wide variety of hard and soft corals. Two main areas were chosen to conduct the research at, the area around Barcadera, consisting of site 1, 2, 3 and the area surrounding Commandeurs baai, site 4, 5 and 6 (Fig. 2b).

a) Curaçao



b) Aruba



Figures 2a and b: Areas of research on Curaçao and on Aruba: Sites numbers and fish sites Malmok (MM), Mangel Halto (MH) and Zeerover (ZR) are given

Both areas consisted out of the three habitats to study, the coral reef, mangroves (MG) and the seagrass beds (SG). The nursery habitats were chosen in such a way, that a reef habitat was nearby, which is an important characteristic for a nursery. By choosing to work at two main locations, comparison could be made between the results of these areas, which could point out the importance of abiotic factors, like temperature.

2.1.3. Studied species

The species used in this study, was the common reef fish species French grunt (*Haemulon flavolineatum*). This species was chosen it is a suggested nursery species, of which the juveniles reside in the mangroves and seagrass beds, and the adult French grunts on the reef (Nagelkerken et al., 2000a). Research done by McFarland et al. (2003) found, while monitoring the settlement of post larval grunts on the Virgin Islands, that French grunts settle at all times of the year, but with maxima during May-June and October-November. During this period the amount of juvenile French grunts, which are used in this research are at a maximum.

The main food of French grunts consists of invertebrates. French grunts however change in dietary patterns throughout their lives, starting as planktonic feeders (mainly copepods) during the daytime when juvenile and switching to nocturnal benthic feeders (more decapods and tanaids) when grown up (Ogden et al.,1977; Helfman et al., 1982). A study done in the mangroves and seagrass beds of Spanish Water Bay, on the feeding behaviour of juvenile French grunts (< 5 cm) also showed that these fish still fed on planktivores (Verweij et al., 2006). The change in dietary pattern happens at a mean length of 5 cm, at which copepods make out more than 50 % of their diet. After that, mainly more tanaids are eaten, approximately 20 to 70 % (Cocheret de la Morinière et al., 2003, Table 2).

Table 2: The dietary pattern of the French grunt per size class, adapted from Cocheret de la Morinière et al., 2003

size class (cm)	Tanaidacea	Copepoda	Isopda	Amphipoda	Mysidecea	Bivalvia	Gastropoda	Decapoda	Fish	Sediment	Rest	Unidentified
0,0 - 2,5	12,7	66,4	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	20,9
2,5 - 5,0	12,0	83,8	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	4,2
5,0 - 7,5	66,9	0,4	0,0	8,5	0,0	0,0	0,0	8,5	0,0	0,0	7,7	8,1
7,5 - 10,0	75,0	0,0	0,0	4,6	0,0	0,0	3,3	0,0	0,0	0,0	0,0	17,1
10,0 - 12,5	22,5	0,2	0,0	3,8	1,2	2,1	2,9	0,0	1,7	7,5	0,4	57,8
12,5 - 15,0	50,0	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,5	5,0	42,2

2.2 Experimental design

The growth of the French grunt was examined by placing cages in the 3 mentioned habitats and adding fishes to these. By measuring the length and weight of the fishes before and after entering the cages, growth could be calculated. Most research was done by daily SCUBA diving or snorkelling. In Curaçao, eight sites where chosen as research sites, some containing one and others two cages, with a total of thirteen cages. In Aruba a total of twelve cages were placed, two cages at each site a couple of meters apart. Each cage was made out of a concrete-iron frame, covered with wire netting with a mesh size of 6 mm. Each cage was 1,5 m in length and width and 0,7 m in height (Fig. 3). On both sides of the cages, hatches of 30 x 30 cm were included to introduce and remove fish from the cages.

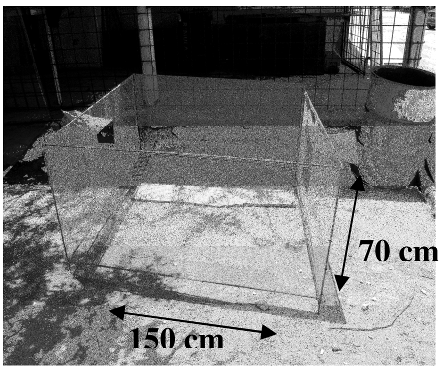


Figure 3: The appearance and sizes of a cage

The cages were placed in the three habitats, the natural environments of the French grunt, at a place where the seagrass density, height and cover or the mangrove prop-root density and length were high and similar between habitats. Note that the cages on the reef were not placed upon corals, but small reefs were created on sandy patches between corals, containing loose pieces of coral. Coral reef composition and cover were kept similar between each site. By putting the cages in the habitats themselves, the most natural situation was created, only excluding predation in these experiments by caging the fishes. The depths of the cages varied per habitat, but were comparable within habitats and between Curaçao and Aruba. The mangrove cages were standing at a depth between 1 and 2 meters. The cages in the seagrass beds were placed at a depth of 3 to 4 meters. And the cages in the reef habitat were situated the deepest, at 5 to 6 meters in depth.

In each cage 20 fishes were introduced, of a length between 3.5 to 4 cm, keeping the difference between fishes in one cage not more than 0.3 cm. This makes the differences in individuals as small as possible, which is important as no distinction can be made between the individuals. Both total length and the wet weight of the fishes were measured before filling the cages, by the usage of a water resistant pair of scales and an instrument to measure the length. During 6 to 8 weeks (depending on the mortality rate) the fishes resided in the cages and could grow naturally. However, extra fishes were added to a maximum amount of 20 to cages in which mortality was very high (especially in the mangroves) within the first week. In some cases, the fishes were removed sooner than 6 to 8 weeks when mortality was increasing rapidly or cages were deteriorating. To remove algal growth and to preserve the flow of water and plankton through the cages, weekly cleaning of the outside of the cages took place with brushes.

In total, 240 juvenile French grunts were used per island, recovering at the end of the experiments 93 juveniles from the cages on Curacao (n_{mg}= 34, n_{sg} = 40, n_{reef} = 19) and 88 juveniles on Aruba (n_{mg}= 30, n_{sg} = 43, n_{reef} = 15). These remaining fishes were caught, by using squid as bait and catching the fishes in a fish trap, attached to one of the hatches of the cage. Again the length and weight of each individual was measured. By measuring the length (L) and weight (W) of the individual fishes at the beginning and at the end of the growth experiments, the average increase (growth) in length and weight per day could be calculated as well as the weight/length ratio (W/L ratio) and be compared between the 3 habitats and the two islands. The growth had to be divided by the amount of days each individual fish had spent in the cages. Because no exact value was known per fish, averages have been used. The equation below shows how the growth in length (GL) was calculated, in which L_i is the mean initial length of all fish pooled per cage before caging, L_f the final length of each individual fish after caging and t is the duration of the experiment for each individual fish. Mean growth per cage or per habitat was calculated by pooling all fish from the same cage or same habitat. Note that the growth rate in weight (GW) was calculated similarly.

$$GL = \frac{L_f - L_i}{t}$$

To get extra information about the growth in length and weight and the W/L ratio of the fishes, classes of these variables have been formed (e.g. 1-2, 2-3, 3-4 etc). The frequencies (percentages) in which each class contributes to the total growth in length and weight and W/L ratio, will be shown per habitat and per island.

2.2.1. Fishing


Figure 4: design of the fish trap

Fishing was done by the use of two nets placed in a V-shape with at the end of these a fish trap closing up the nets (Fig. 4). Three divers were placed next to each other and chased the fishes into the fish trap.

At Curaçao two main fishing areas (Fig. 2a) could be distinguished, one on a seagrass bed and one on a rubble (small pieces of dead coral) habitat. Fishes from the seagrass habitat were placed in the cages in the first period (August to November) and the ones from the rubble were used in the second (September to November). In Aruba three fishing areas were used, fishes residing in the Barcadera area were derived from the rubble at Mangel Halto (MH), fishing was done at Zeerover (ZR) to fill the cages at the area of Commandeurs baai and for the additional data of the mangroves fishing was done at the rubble at Malmok (MM). Fish sites are showed in red in Figure 2b.

2.2.2. Additional research

In Curaçao the growth experiment was repeated, being conducted during the periods of August-September and September-November of the year 2005. Furthermore, at one site (site 4, boor large) a bigger cage (2 x 3 x 0,7 meter) was used to make sure that a shortage of space did not negatively influence growth. As a side experiment the fishes in three cages were treated with Alizarine RedS (ARS), a pigment used for colouring the otoliths within the fishes, which would make the determination of the age of the fishes easier. Important is to look if this pigmenting has an effect on the fishes and their growth.

The growth experiment in Aruba was done once in the period of July-September 2006. However, an additional round of research was done in the mangrove habitats to create more replicates. By making use of two main areas (Barcadera and Commandeurs baai), each containing all three habitat types, a comparison could be made concerning differences in environmental factors, such as water temperature, clarity and salinity.

In Aruba food samples have been collected to give an indication of the food availability to the fishes. Because the initial length of fishes used in this experiment was between the 3.5 – 4 cm, their diets may still consist mainly of planktonic food according to the literature. A study done in the mangroves and seagrass beds of Spanish Water Bay, Curaçao, on the feeding behaviour of juvenile French grunts confirmed the latter (Verweij et al., 2006).

Still both planktonic and benthic food samples have been taken. Food samples were taken and compared inside and outside each cage to exclude the possibility that food availability in the cages was limiting for growth. Densities of macro fauna were quantified in the water column and the top layer of the substratum at each site. The water column was sampled twice inside and outside each cage by hauling a plankton net above the substratum. Sediment sampling was done four times in and outside the cages by using a plastic cylindrical jar. After sieving and dyeing the samples the total number of invertebrates and composition was quantified by using a stereomicroscope. These results will be included in this research to combine the growth and food results.

2.2.3. Abiotic factors

Specific abiotic factors could have an important influence on the survival of fishes, which need these factors to be in certain ranges to survive. Therefore weekly measurements of temperature, salinity and water clarity were done at each site. Temperature and salinity were measured using a waterproof hand-held conductivity/TDS meter (CON 410), and water clarity by the use of a Secchi-disk. When comparing these factors with the growth rates per site, it is possible to determine a correlation of each of these environmental factors with the growth.

2.3 Statistics

In this section is shown how different statistical tests in SPSS for WINDOWS (version 15.0 are applied to this study. Note that a level of significance of $p < 0.05$ is used in all the statistical tests. Significance differences between two variables will be shown as *.

2.3.1. Curaçao

An *independent-samples t-test* was used to compare the length, the weight and the W/L ratio of the fishes at the beginning of the two periods of research done in Curaçao. This could show a difference between the fishes caught at the different fishing sites, in which case the two periods cannot be joined as one. *Independent t-tests* were also used for comparing the growth in length and weight and the W/L ratio of the fish at the end of the experiments at Curaçao, by comparing the fishes from the seagrass beds treated with and without ARS and also between the fishes residing in a normal sized cage and the bigger cage on the seagrass bed. These *t-tests* have to show if there is a difference in growth when the fishes are treated different. Finally, a *one-way ANOVA* was used to make a comparison in growth and the W/L ratio between the different habitats on Curaçao. Furthermore, before each test a Levene's test was performed to be sure of homogeneous distribution of the variances.For multiple comparisons, the post hoc test Games-Howell was used.To complete the analysis, linear regressions were done to show the influence of several environmental variables on the growth rates and the W/L ratio. Linear regression estimates the coefficients (the fitting) of the linear equation (Y=aX + b), involving one or more independent variables that best predict the value of the dependent variable. R^2 gives the fit of the measurements to the line from the linear equation. R^2 is only of importance if the value is high which is in this paper, more than 75% (Field, 2005).

2.3.2. Aruba

For the data collected in Aruba, a *t-test* was done to look at the difference in weight, length and W/L ratio at the beginning of the experiments, between the fishing sites and between the two periods, to show if there were initial differences between the fishes. A *t-test*, using weight, length and W/L ratio at the end of the experiments was also done to look if the growth rates differed between the periods. Another *t-test* was done to compare the growth in length and weight and the W/L ratio between the two main research areas, Barcadera and Commandeurs baai. To conclude, a *one-way ANOVA* was done to compare the growth in weight, length and the W/L ratio between the three different habitats on this island. For Aruba too, Levene's tests and Games-Howell tests were performed. A *independent t-test* was also performed to look if there was a significant difference between the same habitats on both islands in the ratios of W/L before and after the experiment and in growth in length and weight. For Aruba too, linear regressions have to point out if the differences in growth could be due to differences in environmental factors.

3. Results

This chapter is divided in six main parts, each separated in the results of Curaçao and Aruba. In the first part, the results of the several *t-tests* which were conducted to determine which results could be included in the research, will be discussed. The second part shows the division of the growth rates and the W/L ratio in classes, in which for each class the frequency is given. In the third part the growth per habitat is detailed and the significances of the differences between these habitats will be presented. In the fourth part a comparison between the two islands will be made based on these results. In the fifth section the correlation between the environmental factors and the growth of the fishes in each site is tested. In the sixth and last part, the results of the food availability in all three habitats on the island of Aruba will be shown. Significant differences will be shown in the figures by * and only the p-value of the significant numbers will be given in the text.

3.1 Tests of confounding factors

3.1.1. Curaçao

The growth per day was needed to make a comparison between the habitats, in which the fishes had been for different amounts of time. If the W/L ratio does not differ substantially between the days the fishes were captured and measured, it would be safe to use the W/L ratio which is not corrected for the amount of days. Below the W/L ratios of the fishes for the two different periods of the experiments in Curaçao are put against time. Figures 5 and 6 show that there was no relationship (R^2= very small) between the W/L ratios and time in days, so these did not have to be divided by the amount of days the fishes were in the cages.

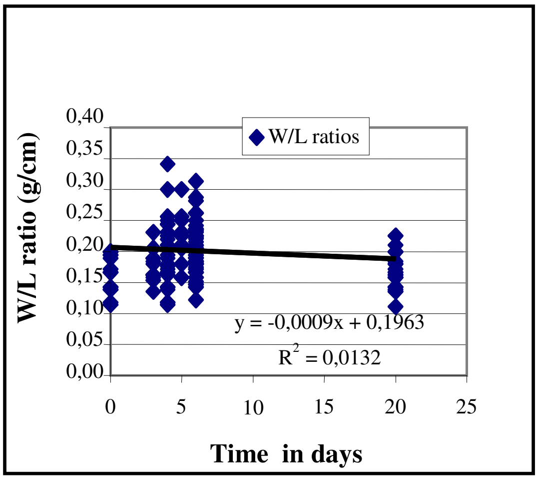


Figure 5: W/L ratio in g/cm against capture time in days for the period Aug-Sept on Curaçao

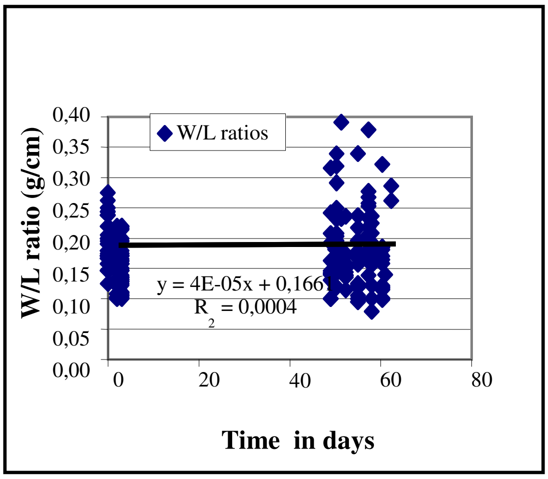


Figure 6: W/L ratio in g/cm against capture time in days for the period Sept-Nov on Curaçao

To find out which data could be joined *t-tests* were performed. A *t-test* to compare the different fishing sites, and with that the different periods of research, in Curaçao showed that the L_{in} ($p < 0,001$), W_{in} ($p = 0,002$) and W/L ratio ($p < 0,001$) were all significant different between the periods. This meant that the experiments done from August-September and from September-November could not be joined (Appendix 8.1).

In Appendix 8.2 is shown that a comparison of the growth in length and weight and the W/L ratio $_{out}$, between ARS treated fishes and not ARS treated fishes in seagrass beds, led to only a significant difference in the W/L ratio ($p = 0,019$). Still it was preferable to leave the treated fishes out of the research, since there is no certainty that the pigment has had no influence on the fishes in a different way.

The difference in growth in length and weight and the W/L ratio $_{out}$ between the cages of different sizes in the seagrass habitat, was significant in case of the growth in weight (p = 0,008). Since there were enough replicates from the seagrass beds, no consideration had to be made to include the bigger cage and was therefore left out (Appendix 8.3).

In period 1 (August-September) after leaving out the large seagrass cage and the seagrass cage with the fishes with ARS treatment, almost no data remained. The reef cages were destroyed by very bad weather and therefore all data from the reef cages was missing and little data was left from the mangrove cages due to high mortalities. Because period 1 and 2 also differed significantly, period 1 was left out for the remainder of the research.

3.1.2. Aruba

The W/L ratios per fish on a certain day, did not differ over the time of the experiment ($R^2 = 0.023$). The W/L ratio therefor did not have to be corrected for the amount of days the fishes spent in the cages (Fig. 7).

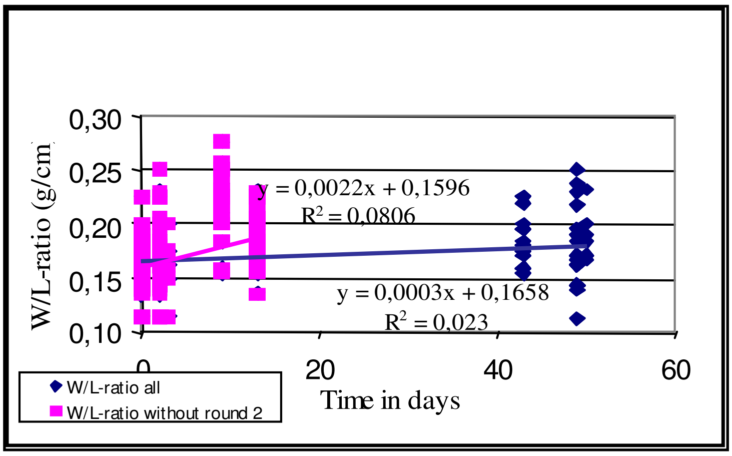


Figure 7: W/L ratio in g/cm against time in days for Aruba. The additional round in the mangroves included (blue) and excluded (pink)

The first *t-test* run for the data of Aruba was used to compare the two different rounds of research in the mangroves. This *t-test* showed a significant difference in the length (p < 0,001) and weight (p < 0,001) and the W/L ratio (p = 0,001) of the fishes that went into the cages (Appendix 8.4). Growth in weight (p = 0,002) and in the W/L_{out} ratio (p = 0,002) between the periods also showed significant differences using a *t-test* (Appendix 8.5). Only growth in length did not show a significance and therefore was similar between the periods. However, all data from the second round in the mangroves were included in the comparison between the two main areas of research in Aruba to get enough replicates, supported by the fact that the length of fishes that entered the cages was of a certain chosen size class, that could have created this overall difference.

When looking at the variety in W/L $ratio_{in}$ of the fishes between fish sites by doing a *t-test*, this ratio does not differ (p = 0,552) between the two fishing sites, it is therefore allowed to join this data together (Appendix 6). This means that the data of the two main areas of research will be joined for the rest of this research.

3.1.3. Comparison of two main areas in Aruba

In Aruba the research was conducted at two main areas, Barcadera and Commandeurs baai, which are useful to compare. Differences in growth could possible be influenced by other prevailing abiotic factors between the areas. To compare the Barcadera area and the Commandeurs baai area a *t-test* was done, in which growth in length and weight were used as variables (Appendix 8.7). By lack of results from the reef habitat in Barcadera this habitat was excluded from the comparison. As seems from Table 3, there was only a significant difference between the two main areas in the growth in length between the mangroves (p = 0.019).

Table 3: Significance of difference in growth in length and weight and W/L ratio of fishes in the mangroves and seagrass beds, between the two main areas on Aruba

	Growth length	Growth weight	W/L ratio
Mangroves	P = 0.019 *	P = 0.128	P = 0.080
Seagrass beds	P = 0.180	P = 0.761	P = 0.873

3.2 Frequencies

Per habitat the growth in length, weight and the W/L ratio were divided into multiple classes and the percentages that each class was represented with are shown in Figures 8–13. This pointed out a difference in the amount of growth per habitat or the size of the ratio per habitat.

3.2.1. Curaçao

Mangroves and the seagrass beds showed the highest percentages of growth in length in the 0 – 0.05 class (Fig. 8), which indicates that most fishes grew on average between the 0 and 0.05 mm per day, while on the reef most fishes showed a negative growth. Furthermore, the most widespread representation of the classes was found in the mangroves and on the reef. Also eminent became the fact that the class of the highest growth in length had the highest percentage in the reef habitat. Fishes residing in the cages on the reef grew larger than in the other habitats.

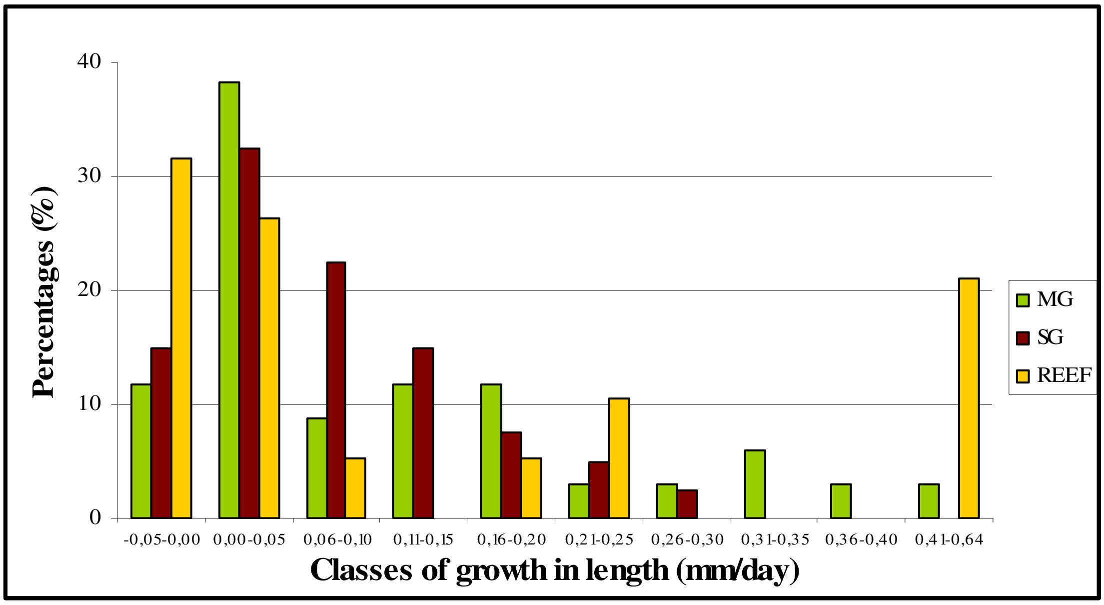


Figure 8: Percentages of the growth in length (mm/day) per class in the mangroves (MG), seagrass beds (SG) and on the coral reef (REEF) for Curaçao

Looking at the growth in weight, the growth class of -5 - 0 mg/day was the most common class in all three habitats, followed by the 0 – 5 mg/day for the seagrass beds and the mangroves (Fig. 9). Only fishes growing up on the reef represented the higher weight classes and showed a much more spread out distribution.

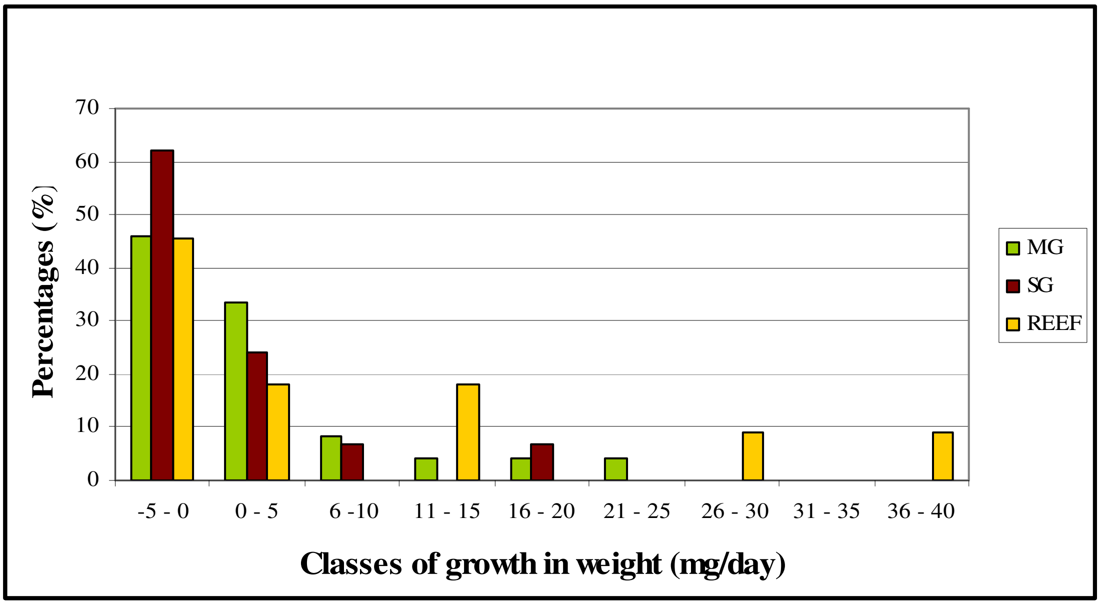


Figure 9: Percentages of the growth in weight (mg/day) per class in the mangroves (MG), seagrass beds (SG) and on the coral reef (REEF) for Curaçao

Most fishes showed a W/L ratio between 0.11 and 0.15 mg/mm (Fig. 10). Again the reef habitat is more represented in the higher classes and wider spread out in comparison with the other two habitats.

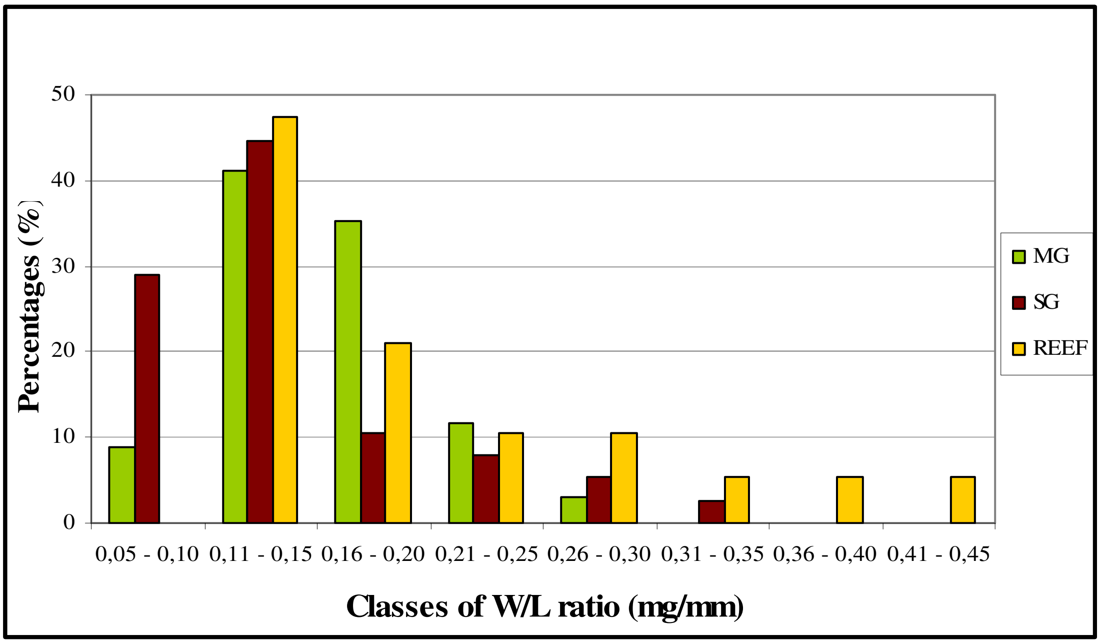


Figure 10: Percentages of the W/L ratio (mg/mm) per class in the mangroves (MG), seagrass beds (SG) and on the coral reef (REEF) for Curaçao

3.2.2. Aruba

The percentages of the growth in length per class were the highest for the reef and the seagrass beds in the class 0.26 – 0.30 mm/day. For the mangroves most fishes had a growth in length between the 0.16 and 0.20 mm/day. Moreover, the fishes of the mangrove and seagrass habitats were represented in the first 7 classes, while the fishes in the reef cages had growth rates in length in the last 5 classes (Fig. 11).

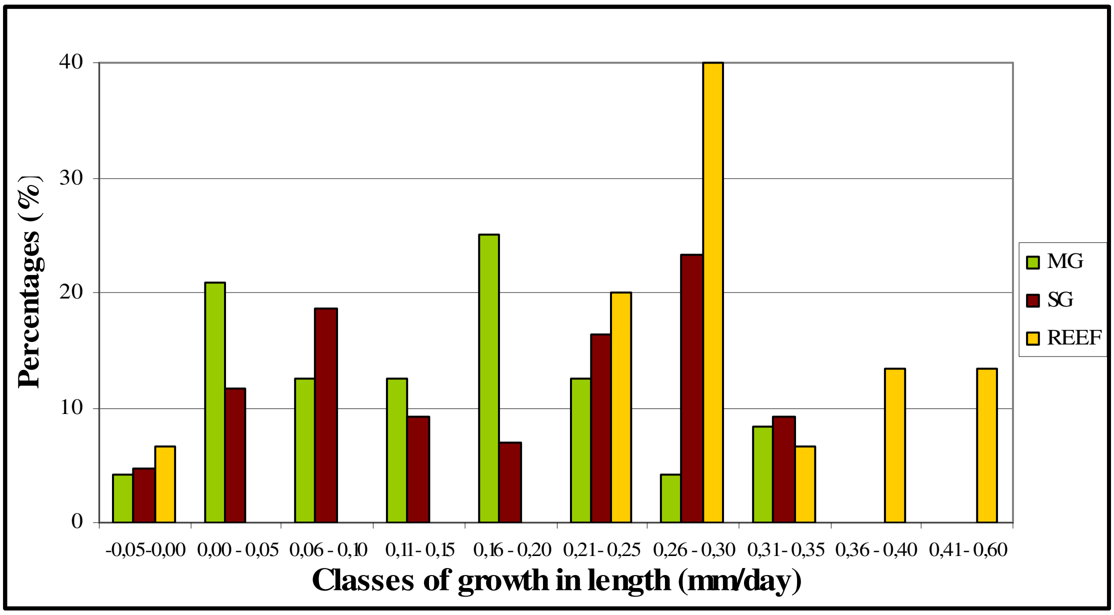


Figure 11: Percentages of the growth in length (mm/day) per class in the mangroves (MG), seagrass beds (SG) and on the coral reef (REEF) for Aruba

Looking at the growth rates in weight in Figure 12, the fishes in the mangroves had the highest percentage of growth between the -5 and 5 mg/day, for the seagrass beds this was the class in which fishes had a growth between 11 - 15 mg/day, and in the reef habitat most fishes grew between the 21 and 25 mg/day. The fishes in the reef habitat were the only fishes represented in the higher growth classes, while the fishes in the other two habitats were only represented in the lower 6 classes.

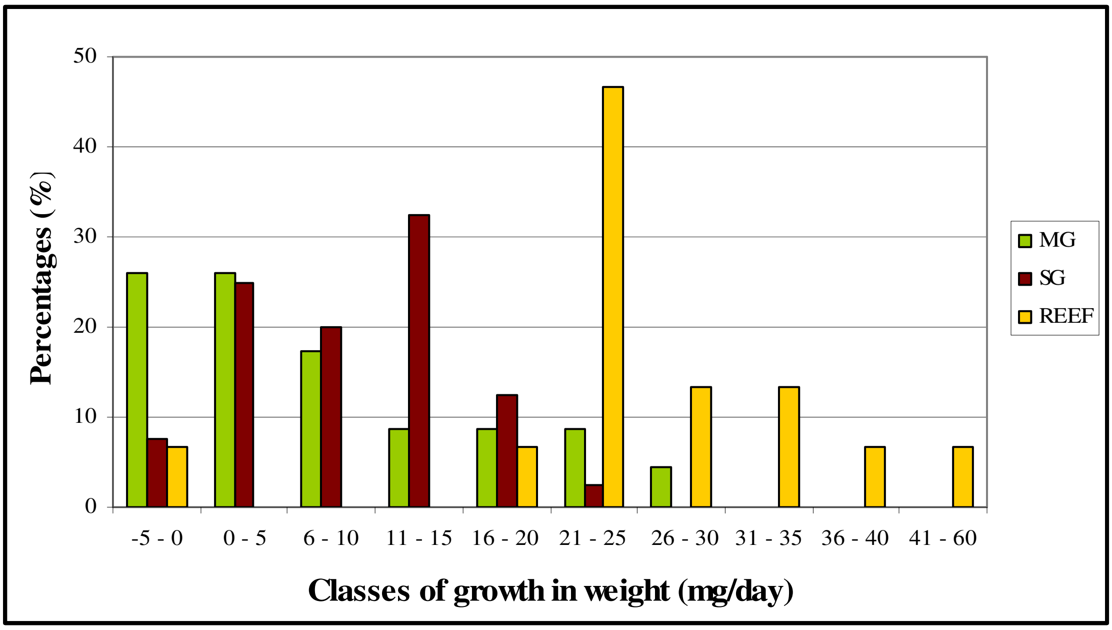


Figure 12: Percentages of the growth in weight (mg/day) per class in the mangroves (MG), seagrass beds (SG) and on the coral reef (REEF) for Aruba

The W/L ratio per class were highest between the 0.16 and 0.20 mg/mm for the fishes in the mangroves and the seagrass beds and between the 0.31 and 0.35 mg/mm for the reef (Fig. 13). Fishes in the reef habitat represented the higher classes, while the mangroves and seagrass beds mainly represented the lower classes.

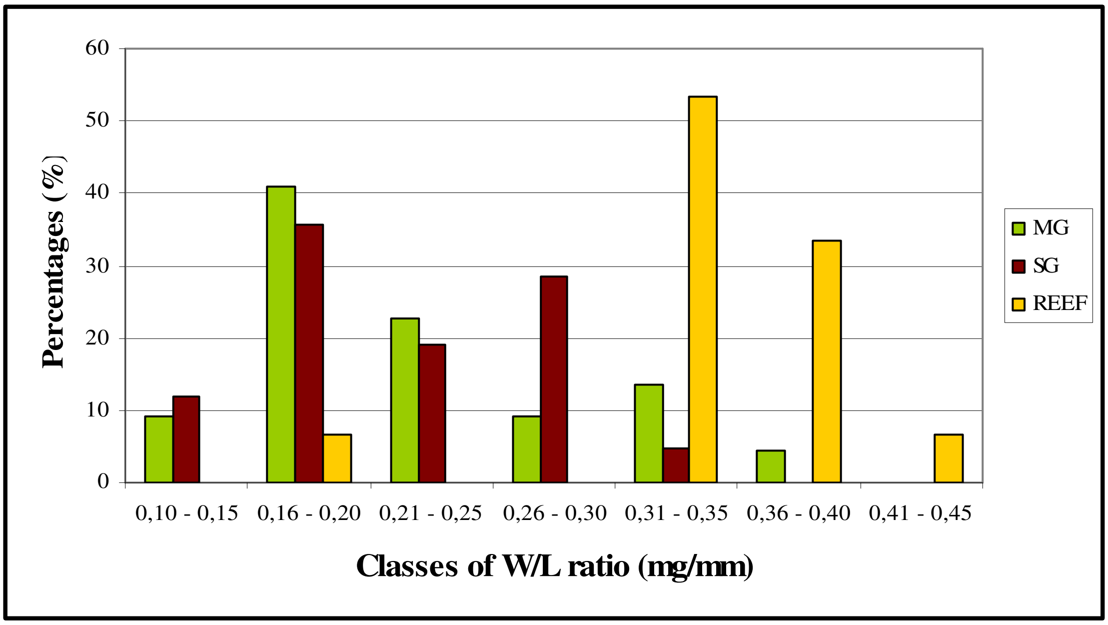


Figure 13: Percentages of the W/L ratio (mg/mm) per class in the mangroves (MG), seagrass beds (SG) and on the coral reef (REEF) for Aruba

3.3 Growth per habitat

3.3.1. Curaçao

A one-way ANOVA was performed to compare the growth in length and weight and the W/L ratio at the end of the experiments between the habitats. The growth in length and weight, as well as the W/L ratio were the highest in the reef habitat and the lowest in the seagrass beds, although the differences in growth rates were not significant (Fig. 14–16), except for the W/L ratio between the seagrass beds and reef habitats. The W/L ratio was significantly lower (Games-Howell, $p = 0.044$) in the seagrass beds compared to the reef habitats (Fig. 16).

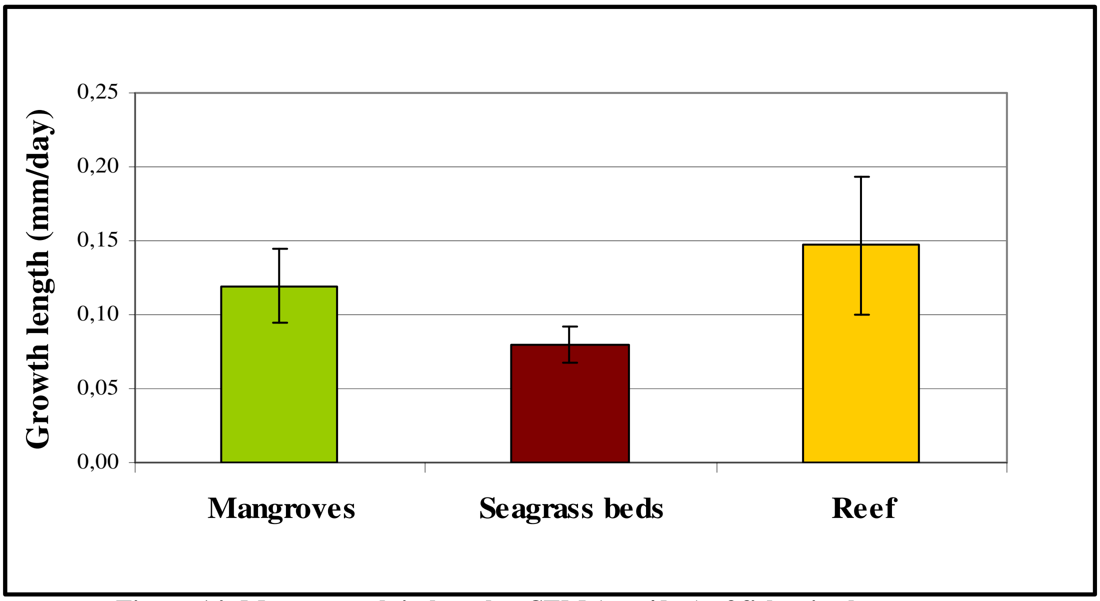


Figure 14: Mean growth in length ± SEM (mm/day) of fishes in the mangroves, seagrass beds and the reef for Curaçao

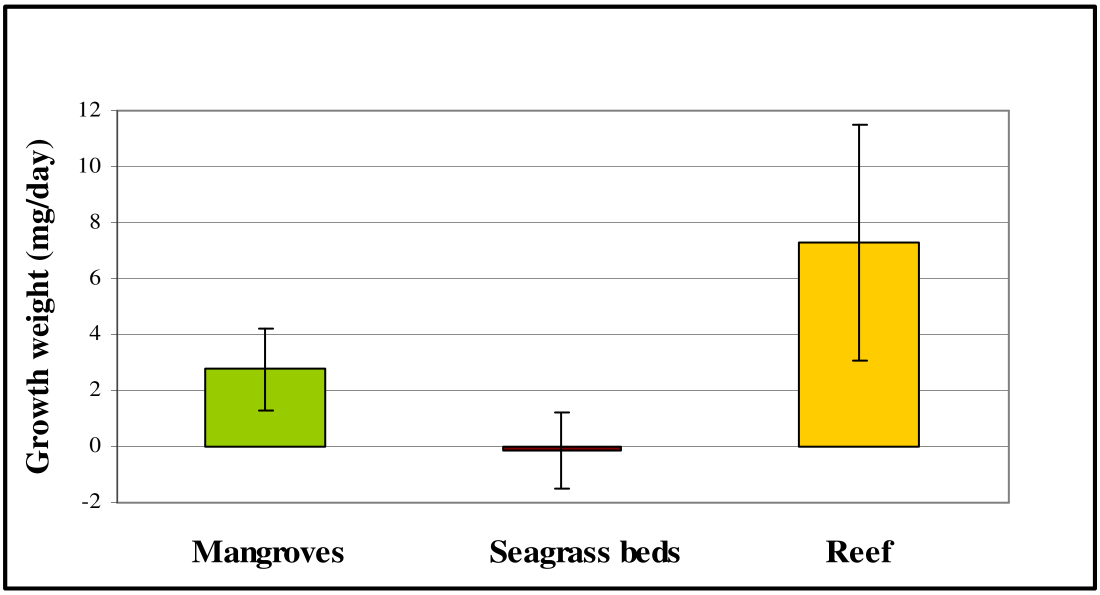


Figure 15: Mean growth in weight ± SEM (mg/day) of fishes in the mangroves, seagrass beds and the reef for Curaçao

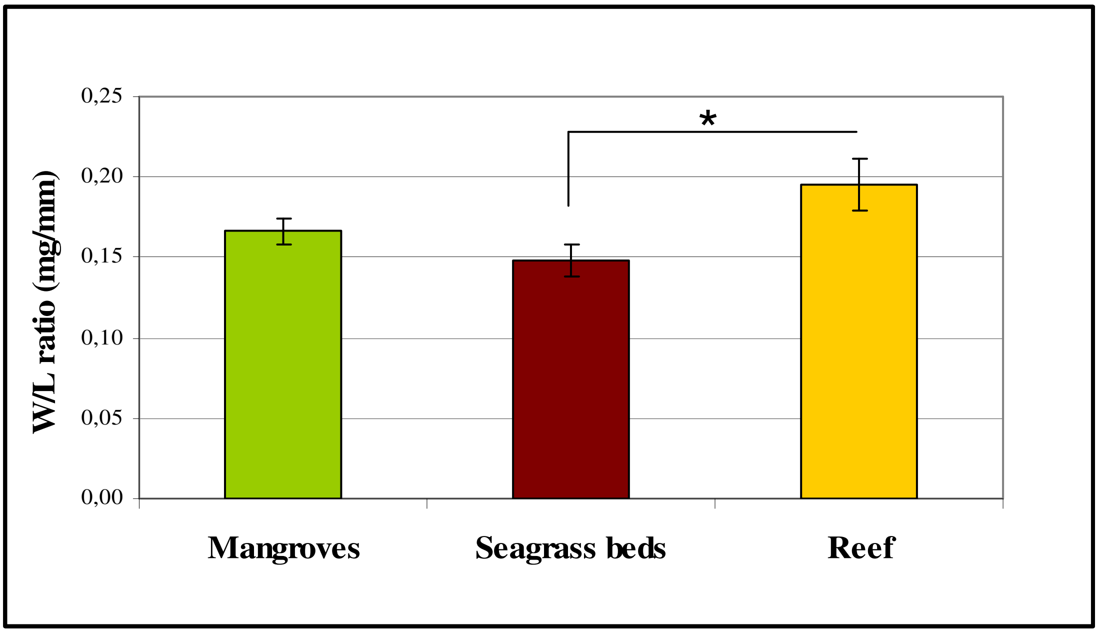


Figure 16: Mean W/L ratio ± SEM (mg/mm) of fishes in the mangroves, seagrass beds and the reef for Curaçao

3.3.2. Aruba

A one-way ANOVA was conducted to look at the differences in growth in length and weight and in the W/L ratio between the fishes residing in the three habitats (Fig. 17-19). A significantly higher value of both growth rates, length and weight, is present on the reef compared to the mangroves (Fig. 17 and 18). Looking at the W/L ratio it became apparent that the highest numbers were found again on the reef, followed by the mangroves (Fig. 19). Growth in length and weight and W/L ratio were significantly higher on the reef, compared to the nursery habitats (Fig. 17-19). All differences were significant between the mangroves and the reef using Games-Howell as a multiple comparison test (Growth in length: $p = 0.003$, growth in weight: $p < 0.001$, W/L ratio: $p < 0.001$) as well as between the seagrass beds and the reef (Growth in length: $p = 0.015$, growth in weight: $p < 0.001$, W/L ratio: $p < 0.001$). There were, however, no significant differences for all three variables between the mangroves and the seagrass beds.

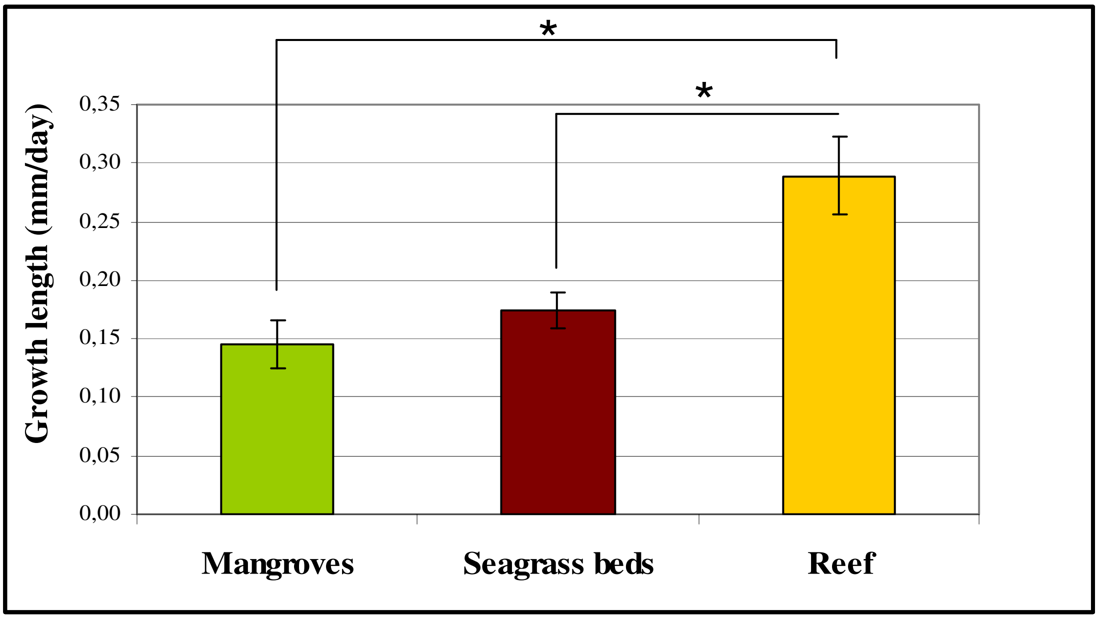


Figure 17: Mean growth in length ± SEM (mm/day) of fishes in the mangroves, seagrass beds and the reef for Aruba

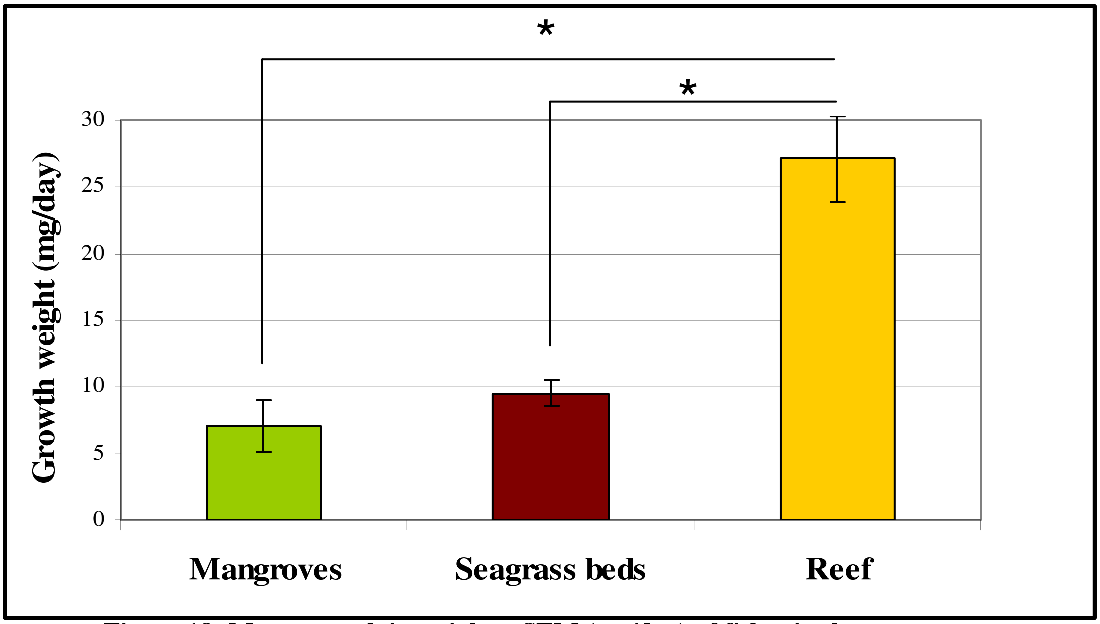


Figure 18: Mean growth in weight ± SEM (mg/day) of fishes in the mangroves, seagrass beds and the reef for Aruba

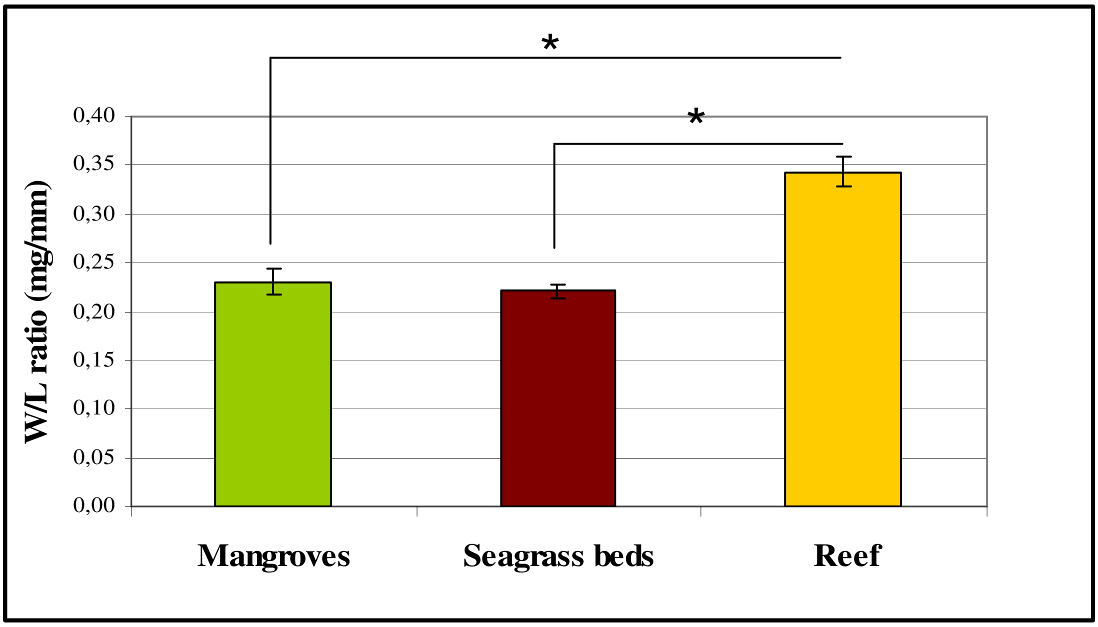


Figure 19: Mean W/L ratio ± SEM (mg/mm) of fishes in the mangroves, seagrass beds and the reef for Aruba

3.4 Comparison Curaçao and Aruba

After looking at the islands separately, *a t-test* was performed to look if there was a significant difference between the islands in the ratios of W/L after the experiment and in growth in length and weight per habitat. This test showed that all the differences between the islands were significant (Fig. 20-22). On both islands, the fishes in the reef habitat showed the highest numbers in growth rates and in W/L ratios. On Aruba there was in all three variables the same hierarchy visible from lower values in the mangroves to higher values in the reef habitat. On Curaçao the levels of growth in length and of the W/L ratio were lower in the seagrass beds compared to the mangroves. The last difference between the islands is the fact that in all three variables and habitats higher numbers were always found on Aruba compared to Curaçao.

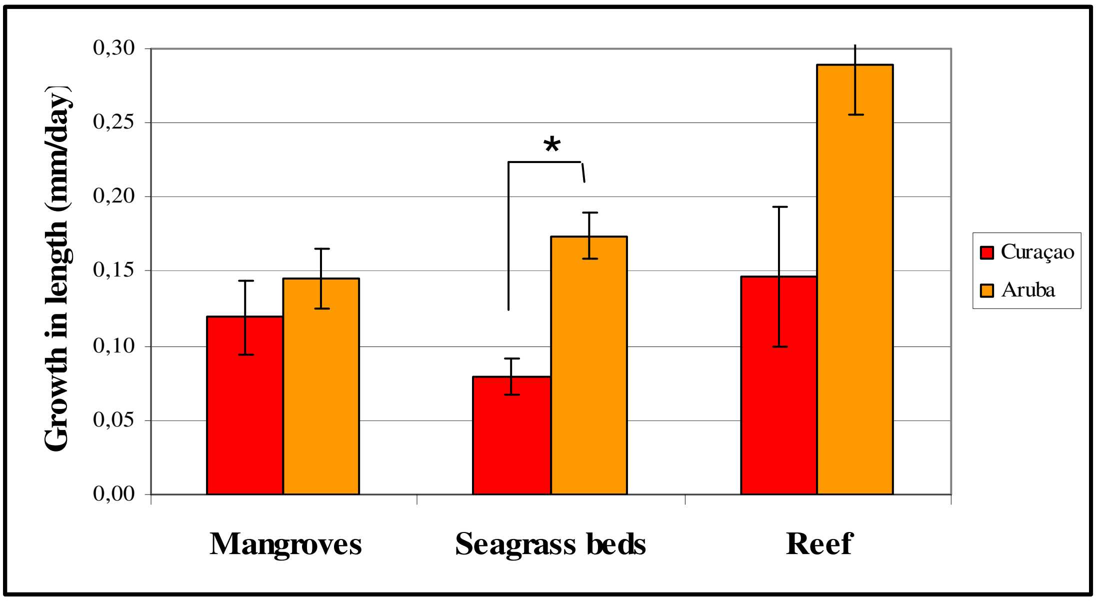


Figure 20: Mean growth in length ± SEM (mm/day) per habitat for both islands

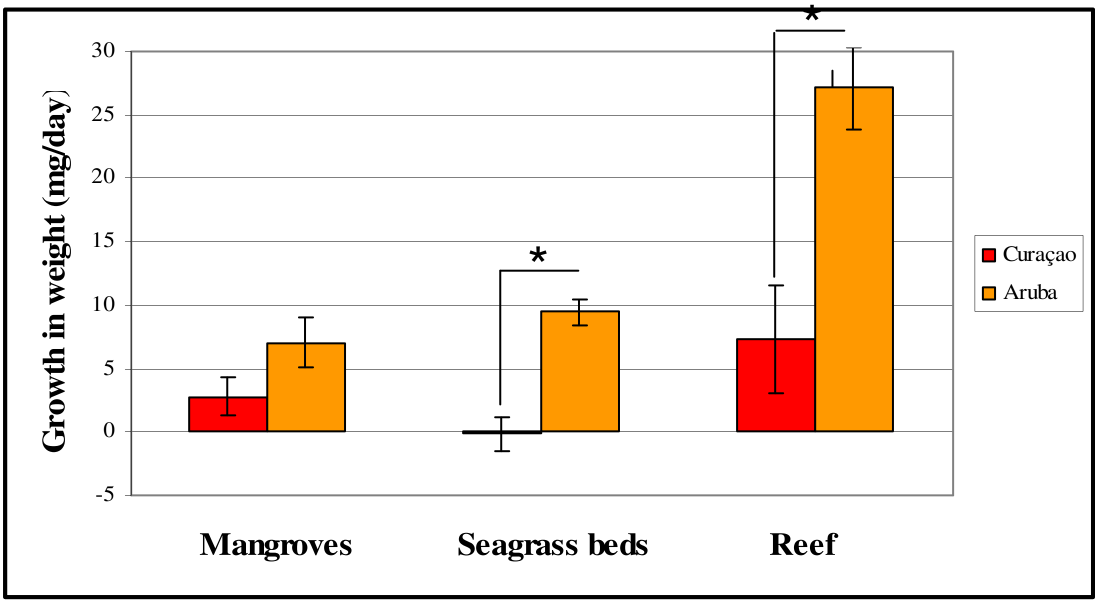


Figure 21: Mean growth in weight ± SEM (mg/day) per habitat for both islands

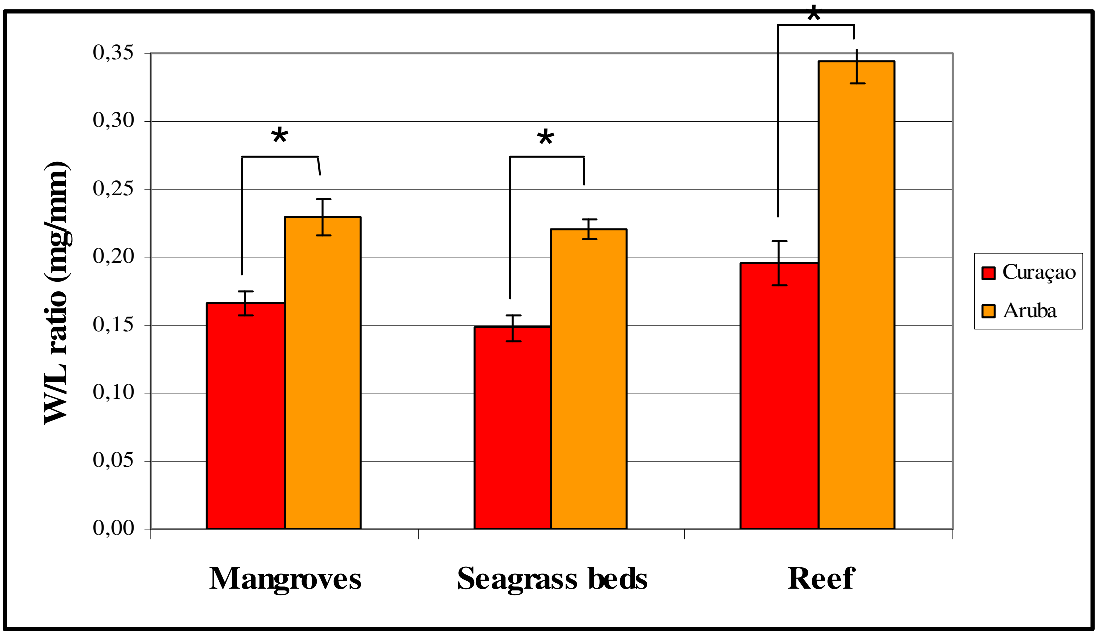


Figure 22: Mean W/L ratio ± SEM (mg/mm) per habitat for both islands

Looking specifically at the significant differences between the islands and between the three habitats, t-tests have been done. Using a Games-Howell as a multiple comparison test, a significant difference in growth in length between the seagrass beds on the islands was found ($p = 0.040$), in which the fishes grew significantly faster on Aruba (Fig. 20). The growth in weight was significantly higher on Aruba, when comparing both the seagrass beds ($p < 0.001$) and the reef ($p = 0.014$) (Fig. 21). Finally, the W/L ratios between the islands differed significantly between all three habitats (MG: $p = 0.003$, SG: $p < 0.001$, Reef: $p < 0.001$) in which Aruba had larger values compared to Curaçao (Fig. 22).

3.5 Growth and abiotic factors

Mean water temperature, salinity and water clarity are shown per habitat for Curaçao (Fig. 23) and Aruba (Fig. 24). A one-way ANOVA was performed to look at the differences in temperature, salinity and water clarity between the habitats. There was only a significant difference found in temperature on Curaçao by means of Hochberg's GT2 multiple comparison test ($p = 0.025$) between the reef and the mangroves. Water clarity was only measured on Aruba and was different for all three habitats, being the highest in the reef habitat. Significant differences in water clarity were found between the reef and both the nursery habitats (both $p < 0,001$), by using Gabriel's Multiple comparisons test. For both islands the mean growth in length and weight and W/L ratio were taken per site and linear regressions were done by using the mean water temperature, salinity and water clarity for that site.

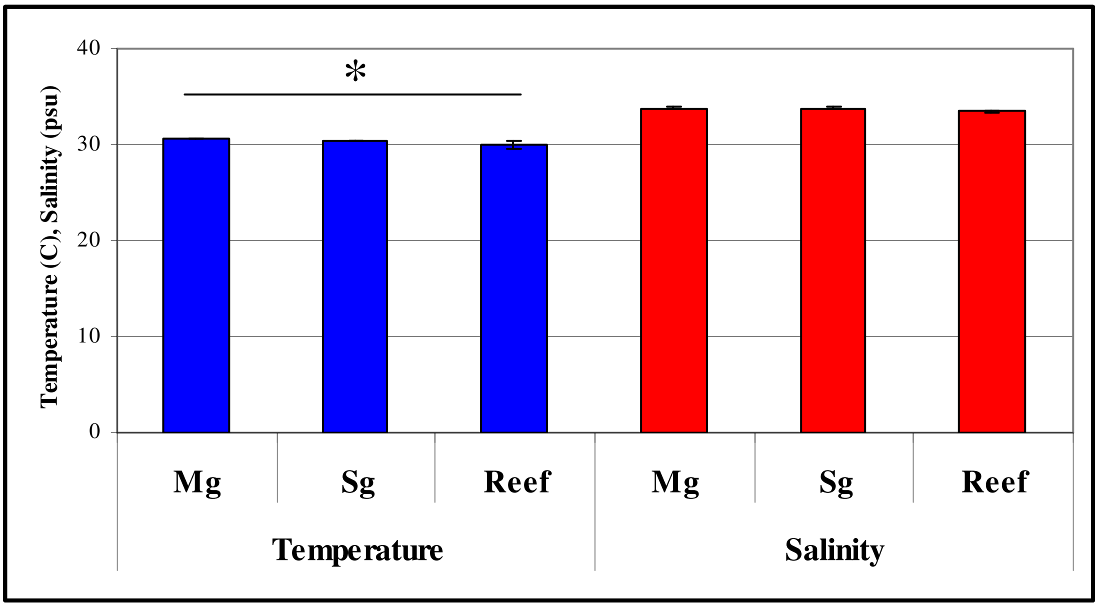


Figure 23: The mean water temperature and salinity per habitat for the island of Curaçao

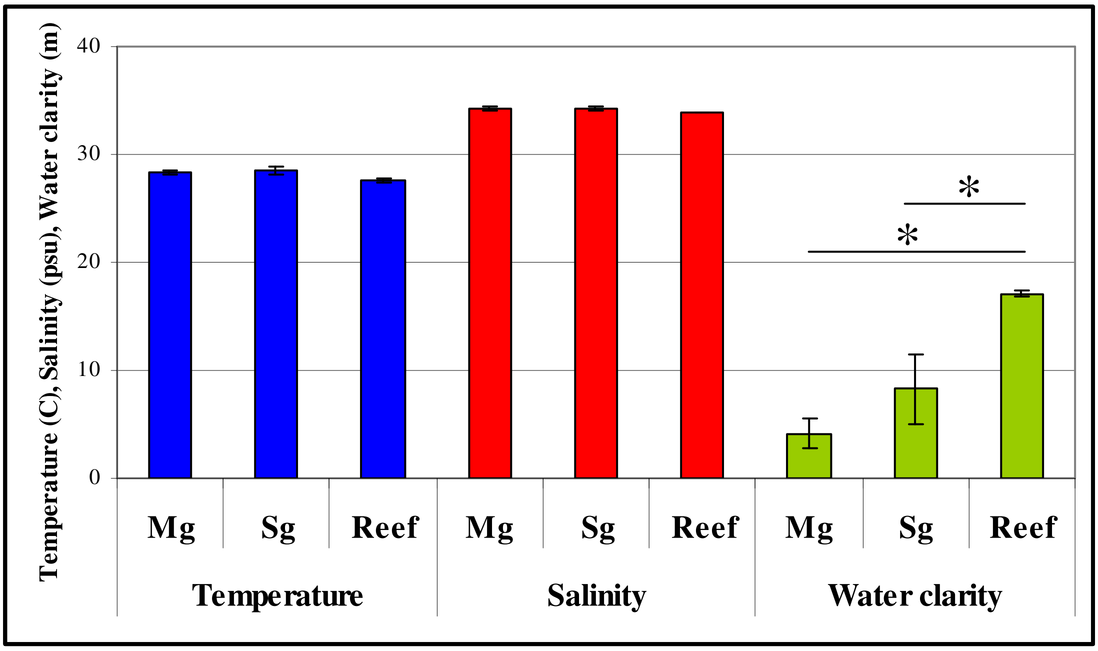


Figure 24: The mean water temperature, salinity and water clarity per habitat for the island of Aruba

3.5.1. Curaçao

Only water temperature and salinity were measured in Curaçao. A regression analysis was performed and only a correlation was found between salinity and the growth in length and the W/L ratio of the fishes. Looking at the growth in length, the salinity correlated significantly (R^2= 0,501, p = 0,050) to changes in this growth. As with the growth in length, the salinity also correlated significantly to the W/L ratio (R^2=0,586, p = 0,027). Looking at the growth in weight it became clear salinity correlated almost significantly to changes in growth (R^2=0,556, p = 0,054).

3.5.2. Aruba

In Aruba, linear regressions showed that the abiotic factors temperature and salinity did not correlate with growth in length, in weight and with the W/L ratio. However, regressions for water clarity did show a correlation with the growth in weight and W/L ratio. From the regression analysis conducted for Aruba became evident that the factor water clarity was significantly related to the growth in weight (R^2 = 0,952, p = 0,004) and the W/L ratio (R^2 = 0,896, p = 0,015). Water clarity was not significantly correlated to growth in length (R^2 = 0,730, p = 0,065).

3.6 Growth and food availability

Growth rates and the W/L ratio were all significantly higher in the reef habitat on Aruba, compared to the other two habitats (Fig. 17-19). Food samples were taken inside and outside the cages in all the habitats and the number of invertebrates in the food samples were quantified. Food availability in and outside the cages did not vary, and using a *t-test* no significant differences were found in number of invertebrates per m^2 in the sediment or per m^3 in plankton inside and outside the mangrove cages, the seagrass cages or the reef cages (Appendix 8).

When looking at the total number of invertebrates in the sediment (Fig. 25), significantly higher numbers were found in the sediment of the seagrass beds and of the reef compared to the number of invertebrates in the mangroves (Games-Howell, both $p < 0{,}001$). Total invertebrate numbers in the sediment was thus the lowest in the mangroves and equally high in seagrass beds and the reef.

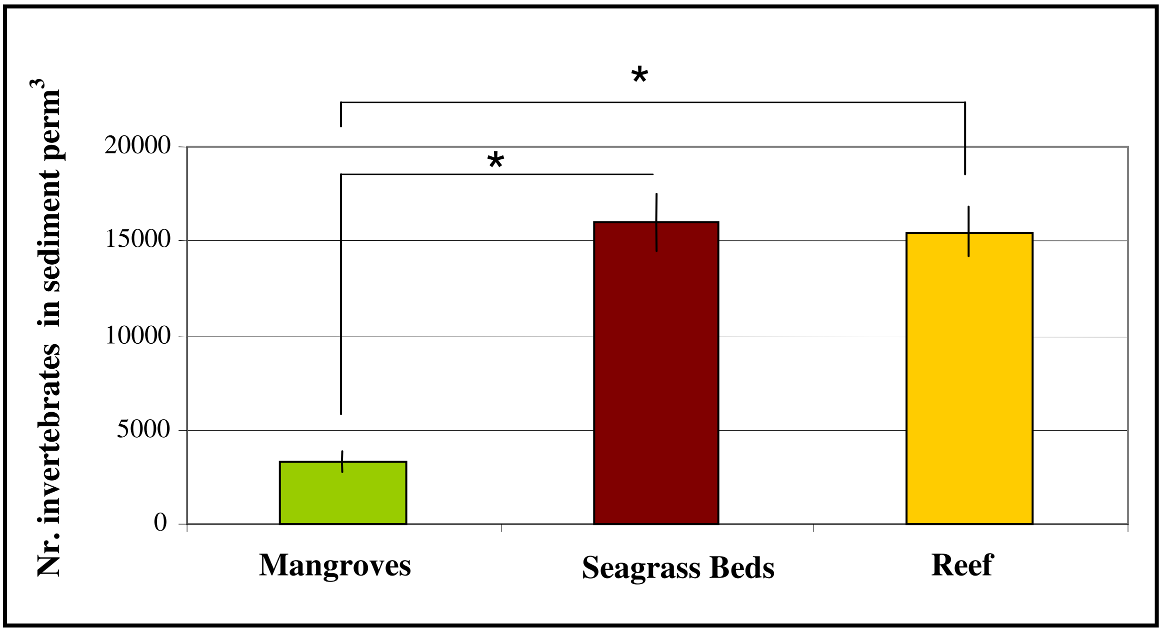


Figure 25:**Average total invertebrate numbers per m^2 (± SEM) in the sediment for the mangroves, seagrass beds and reef habitats**

Figure 26 showed the mean total invertebrate numbers per m^3 in the plankton for all three habitats. There seems to be an increase in average invertebrate numbers from the mangroves to the reef. The number of invertebrates per m^3 in the plankton did, however, not significantly differ between all habitats according to a one-way ANOVA. The total invertebrate numbers in the plankton were highest on the reef. However, this difference was not significant between the reef and the nursery habitats.

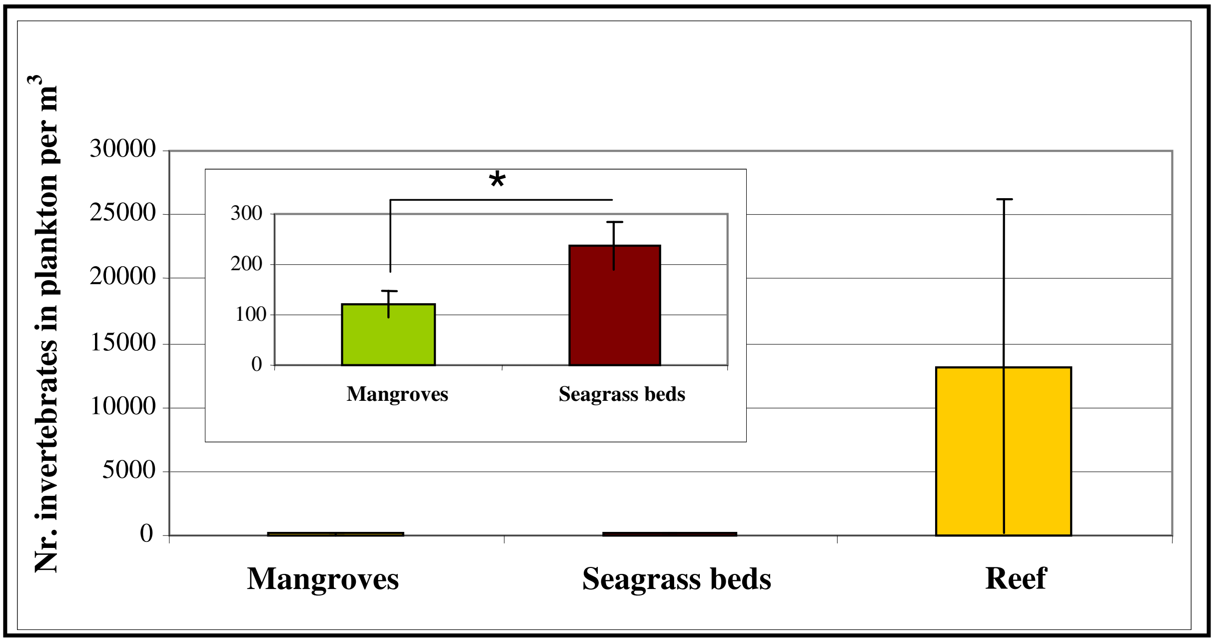


Figure 26: Average invertebrate number per m^3 ($\pm$ SEM) in the plankton for the mangroves, seagrass beds and the reef

4. Discussion

4.1 Growth and the nursery hypothesis

The aim of this research was to show if nursery habitats have a positive effect on the growth of juvenile fish. Expected was to find higher growth rates in the nursery habitats in comparison with the coral reef. It became clear from the results of the division of the growth into classes that there was a tendency for fishes in the reef habitats to be in higher growth classes, compared to the nursery habitats. The data of mean growth rates and W/L ratio per habitat showed the same higher growth of the fishes living on the reef. While growth on the reef was significantly higher compared to the two nurseries, no significant differences in growth between the fishes residing in the two nurseries, mangroves and in the seagrass beds, was found. However, the differences in growth between the reef habitat and the nurseries proved to be significant only on the island of Aruba. These growth results do not support the hypothesis formulated at the beginning of this paper, in which higher growth rates were expected in the nursery habitats, in comparison to the coral reef. The hypothesis is therefore rejected.

In this study, a higher growth rate, as an advantage provided by nursery habitats, is not the factor why juveniles of the nursery species *Haemulon flavolineatum* choose to grow up in the mangroves and seagrass beds, as was hypothesized in the beginning. This does not imply that the nursery hypothesis is wrong, it only means a higher growth rate is not the explanation for the usage of the nurseries by juveniles. Because it became clear in previous research (Nagelkerken et al., 2000b) that juveniles of this fish species spent most of their time in the supposed nurseries, other factors than growth must be the reason why juveniles choose to grow up in the mangroves and the seagrass beds. Several hypotheses were mentioned in the beginning of this paper to explain the importance of nursery habitats. Predation pressure could for example influence the habitat choice of small juvenile fishes. Laboratory based research (Laegdsgaard et al., 2001) has shown that small juvenile fish adapt their habitat preference to the presence or absence of predators. They choose a more sheltered habitat, like the mangroves, when predators are around. Larger fish are less vulnerable to predators and do therefore not have to adapt their habitat. Other research resulted in the finding that there is an overall lowered predator presence in the nurseries (Nagelkerken et al., 2000b). The structural complexity of a habitat and the amount of shade provided by a habitat are mentioned also several times as a way to modify the influence of predators on young fishes (Beukers et al., 1997; Cocheret de la Morinière et al., 2004). To find out which of the above factors contributes to the importance of nursery habitats, experimental research, concerning these hypotheses is needed.

This study only compared the growth of fishes in mangroves and the seagrass beds to the reef, but literature describes other habitats as possible nurseries. Other important shallow-water biotopes are shallow reefs, algal beds, marshes, tidal flats, muddy bottoms, sandy bottoms and intertidal beaches (Nagelkerken et al., 2000b; Beck et al., 2001; Aguilar-Perera, 2004). Minello et al. (2003) looked at the density, survival and growth of fishes in salt marshes. The studie showed that the growth of fishes in marshes did not differ significantly from that in open water or algal beds. The growth was however significantly lower, compared to the growth in seagrass beds.

4.2 Comparison between Curaçao and Aruba

The results of a comparison between the two islands showed the same pattern on both islands, concerning growth in weight and length of the French grunt. It showed that on both islands fishes were having a faster growth in the reef habitat, compared to the nursery habitats, and on Aruba the overall growth rates were higher in all three habitats, compared to Curaçao. It also became apparent that the W/L ratio and the growth in weight and length differed significantly between the two islands. A reason for this might be related to seasonal or geographical effects.

There can be a variability in the amount of advantages a nursery brings to the fishes. Beck et al. (2001) stated that there are three main factors that create site-specific variability in nursery quality, namely biotic, abiotic, and landscape factors. Biotic factors such as predator abundance and competition could state the importance of the nurseries. Abiotic factors, include water depth, salinity and disturbance regime. Landscape factors are divided into spatial patterns (e.g. size and fragmentation) and relative location (e.g. to larval supply) of the nurseries. This means every nursery can have a different value as a safe house for each species.

The differences between the islands of Aruba and Curaçao are of a geographical order, which means the size, shape and fragmentation of the islands could have influenced the differences in growth. Depth and salinity were looked upon and did not differ much among the islands. The disturbance regime could have been different between Aruba and Curaçao, because of their geographical differences and the difference in periods of research. Because both experiments have been done in different time periods as well, the condition of the larvae of *Haemulon flavolineatum* could differ as well, which could influence the growth of the fishes.

4.3 Abiotic factors

It is important to realise that the relation between the abiotic factors and the growth results is probable not causal, which means the abiotic factors do not influence the growth directly. The correlation of these factors with the growth rates and the W/L ratio have been shown in the results.

The results for Curaçao showed that salinity could possibly have a minor indirect impact on the growth in length and the W/L ratio, however no clear pattern is visible between the sites in the different habitats and the mean growth rates.

Water clarity on Aruba probable correlates to changes in growth when looking at the differences in growth and water clarity (Appendix 8.9, Table 4) between sites. Because it is known now that the growth in length and weight as well as the water clarity are higher in the reef habitats, expected is that higher water clarity contributes indirectly to a higher growth. However, this does not mean that a higher water clarity contributes to a higher growth directly. It could for example be the case that because of the higher water clarity, the juvenile French grunts have a better sight on predators and food, which could then, by taken into account lower stress and higher food availability, increase their growth rate.

When comparing the growth rates and the W/L ratio between the islands on basis of environmental factors, it becomes clear that the most important abiotic factor differs between the islands, salinity on Curaçao and water clarity on Aruba. Doing a full comparison is not possible, because information on water clarity is lacking on Curaçao. As stated before other factors could be of influence on the growth of fishes which have not been taken into account in this research, like the availability of light, dissolved oxygen, disturbance and tidal regime and other stress factors (Beck et al., 2001).

4.4 Food availability

The food availability on Aruba could contribute to the viability of the growth results of small juvenile French grunts. According to the literature (Cocheret de la Morinière et al., 2003) juvenile French grunts up to 5 cm in length still feed on planktivores and switch to a zoobentivores food pattern when growing larger. Therefore, the results of the invertebrates in the plankton were most important, because the fishes used in these experiments are between 3.5 and 4.0 cm and are in the phase of their life in which they feed mainly on plankton.

A significantly higher amount of planktonic food was found in the seagrass beds compared to the mangroves. The reef habitat in which the growth in length and weight and the W/L ratio was significantly higher than in the other two habitats, the planktonic food availability was also higher. However, this higher availability of food in the reef habitat was not significant, though it does seem substantial. An explanation for this discrepancy is the high error bar in the food availability in the reef habitat. More replicates could reduce this discrepancy.

The amount of invertebrates in the sediment was however significantly higher in the seagrass beds and the reef, compared to the amount of invertebrates in the sediment of the mangroves. If the fishes in the experiments did already make use of the food available in the bottom this could explain why the fishes in the seagrass beds grow faster in length and weight, compared to the fishes in the mangroves, even if this difference is not significantly. Similar results were found by Cocheret de la Morinière (2002a), who showed that the mean densities of food items in the sediment cores were higher in the seagrass beds, compared to the reef and the mangroves.

These results show that the contribution of food sources from the mangrove habitat for the French grunt is minor. Earlier done research by Nagelkerken et al. (2004) in Spanish Water Bay, Curaçao, in which stable carbon and nitrogen isotope analyses were performed on several potential food items from seagrass beds and mangroves, and on fish tissues, also showed greater food abundances in the seagrass beds, compared to the mangroves. This research also showed that these results are area dependent, because the food results in the mangroves and seagrass beds for the Indo-Pacific are contrasting. In these regions mangroves are important feeding habitats during high tide (Nagelkerken et al., 2004).

The results that there is a higher food availability in the seagrass beds compared to the mangroves, could also coincide with earlier done observations (Ogden et al., 1977; Nagelkerken et al., 2004) in which is found that several supposed nursery species migrate for example from the mangroves to the seagrass beds at night to feed on invertebrates. After having fed it is supposed that these fish return to the mangroves to complete feeding.

With this higher food availability found in the seagrass beds compared to the mangroves, a higher growth rate could be expected too in the seagrass beds. However, there were no significant differences in growth found between the nursery habitats. A possible explanation for this is the unproportional low contribution of the slower growing fishes from the mangroves in the Commandeurs Baai.

Overall, the highest food availability was still found in the reef habitat, as well as the highest growth rates. These results implied that the reef habitat is the best habitat for juvenile French grunts to grow up in when no other factors are at hand. This again shows, there must be another reason included which makes seagrass beds and mangroves beneficial for the survival of juveniles.

4.5 Larger size classes and other nurseries

Beside doing research on the other given hypotheses to explain the nursery hypothesis, several other additional experiments could complement this research.

Within this research the size range (3.5 - 4 cm) of the juveniles that were chosen was small. Nothing can be said about the growth rates of different sized juveniles. Cocheret de la Morinière et al. (2002a), already showed that nursery species behave differently throughout their life cycle. Juveniles smaller or larger than the used fishes, could show different growth patterns. Especially fishes from 5 cm and larger have a different life pattern than fishes between 3.5 – 4 cm, because 5 cm is the length at which the fishes change from planktonic to benthic feeders. The food results namely showed a high invertebrate availability in the sediment of the seagrass beds, comparable with the invertebrates amount at the reef. This could indicate that fishes of 5 cm and larger, which are bethic feeders, would have more food available and with that higher growth rates in the seagrass beds compared to the mangroves.

This research only considered one nursery species, the French grunt. If food availability is an important factor for growth, the growth results could be very different for other species. As shown in previous research (Cocheret de la Morinière et al., 2002a) each species has a different dietary pattern, with dietary shifts at other sizes. Therefore, it is not correct to generalize the results found on the growth of juvenile *Haemulon flavolineatum* between the 3.5 – 4 cm with fishes of different size or different species. To know more about the growth of other fish species in nursery habitats additional research is needed.

During this research, another observation was done in Aruba, using visual census. Besides finding most juvenile French grunts in the nursery habitats, many were found on the reef flat, inhabiting the rubble. It was mentioned before in literature that the shallow coral reef could be an important nursery habitat (Nagelkerken et al., 2000 a and b). But visual census in this research showed even more juveniles between a size of 2.5 – 5.0 cm were found on the reef flat, compared to other habitats. More research about habitat complexity, growth and predator presence could show the importance of the nursery function of this habitat.

Other shallow-water biotopes have been appointed as nurseries. Beck et al., (2001) for example showed a hypothetical comparison of the nursery value, concerning the productivity of adults of several different habitats (Appendix 10), in which the marches and oyster reefs were important nurseries. The study of Aguilar-Perera, (2004) from southwestern Puerto Rico also showed that not only mangroves and seagrass beds are important in terms of harboring high densities of juveniles, but also shallow coral reefs.

4.6 Trade off

The choice of the juvenile for a habitat to live in at a certain development stage could also be part of a trade off, meaning that fishes have to make a compromise between two habitats (Cocheret de la Morinière et al., 2002b). In the case of nursery species it could for example be a trade off by choosing for the habitat that has the lowest predator numbers, but comes with lower growth rates. When fishes grow up to adults, the trade off becomes less strong, because they are better armed against predation. At this moment, fishes can go and live on the reef habitat, where they also have the advantage of a higher food availability.

In the present study, the trade off between predator and food abundance could be at hand, because at present predators were not included in the experiment (in the cages) and the highest growth was found on the reef. Outside of this experiment, predators are not excluded and more juvenile fish are seen to grow up in the mangroves and seagrass beds (Nagelkerken et al., 2000b). This could be due to the fact that there is indeed less predation in these nursery habitats (Nagelkerken et al., 2000b), but in exchange (as a trade off) for lower growth.

4.7 Conservation

Besides contributing to science, research done on nursery habitats could also contribute to a better conservation of these nurseries. When shown that these habitats are so important for the survival of certain fish species (Dorenbosch et al., 2004), it becomes more interesting for other sectors to maintain these habitats. For example, many of the nursery species are also important fishery species (Nagelkerken et al., 2002a). To keep high fishing stocks, fish have to survive first and this is where the nursery habitats seem to be important. Besides being important for high yields, the two mentioned nursery habitats are also deteriorating themselves and research could contribute to their survival (Beck et al., 2001; Aguilar-Perera, 2004; Manson et al., 2005)

Although this research does not show the importance of the nursery habitats yet, many studies still point in that direction, so plans of conservation have to be executed still. A policy recommendation for turning nursery habitats into marine reserves could help sustain these habitats. Marine reserves or no-take zones are used as conservation and fishery management tools all over the world. They may provide insurance against recruitment failure and with that enhance fish yields. Turning nursery habitats into marine reserves could be favourable for several fish species, as the French grunt, and could end deterioration of the mangroves and seagrass beds (Chapman et al., 1999; Jennings, 2001; Aguilar-Perera, 2004).

5. Conclusion

Coming back to the nursery hypothesis and the question if the presence of fishes in nursery habitats contributes to a higher growth in weight and length, compared to growing up at the reef, the next becomes evident. First of all, the growth of the French grunt, a presumable nursery species, was not higher within the nursery habitats compared to the reef. The opposite even looks to be true. Although, not significant in Curaçao, the growth in length and weight in both Curaçao and Aruba was higher at the reef habitat compared to the nursery habitats. Comparing this to the food availability in Aruba, there was also more food available at the reef. However, a higher food availability and a higher growth rate are not the factors that make the nursery areas contribute to a higher survival rate of juvenile nursery fishes. The abiotic factors water temperature and salinity could not clearly explain these differences in growth, however, on Aruba a higher water clarity was related to higher growth rates in weight and W/L ratios. With this research the importance of nursery habitats is not explained, it did, however, eliminate high growth rates as the solution. More research needs to be done to examine the real advantage of growing up in a nursery habitat, by rejecting or accepting the other multiple hypotheses given. In the mean time, assuming the nurseries contribute to a higher survival rate, investments have to be made in a better conservation of the nurseries.

6. Acknowledgements

- Supervisors of the Radboud University of Nijmegen (RUN): Drs. M.G.G. Grol (PhD) and Dr. I. Nagelkerken
- My examinator of the University of Amsterdam (UvA): Jeff Huisman
- My Fellow research students: Jeroen Meijer, Rik van der Kant and Jasper de Bie
- The project was largely funded by the Netherlands Organisation for Scientific Research (NWO) through a Vidi grant to Dr. I. Nagelkerken
- Ministry of Agriculture and Fisheries of Aruba (DLVV)
- Seafood shop Zeerover
- All other people assisting and supporting our work in Aruba

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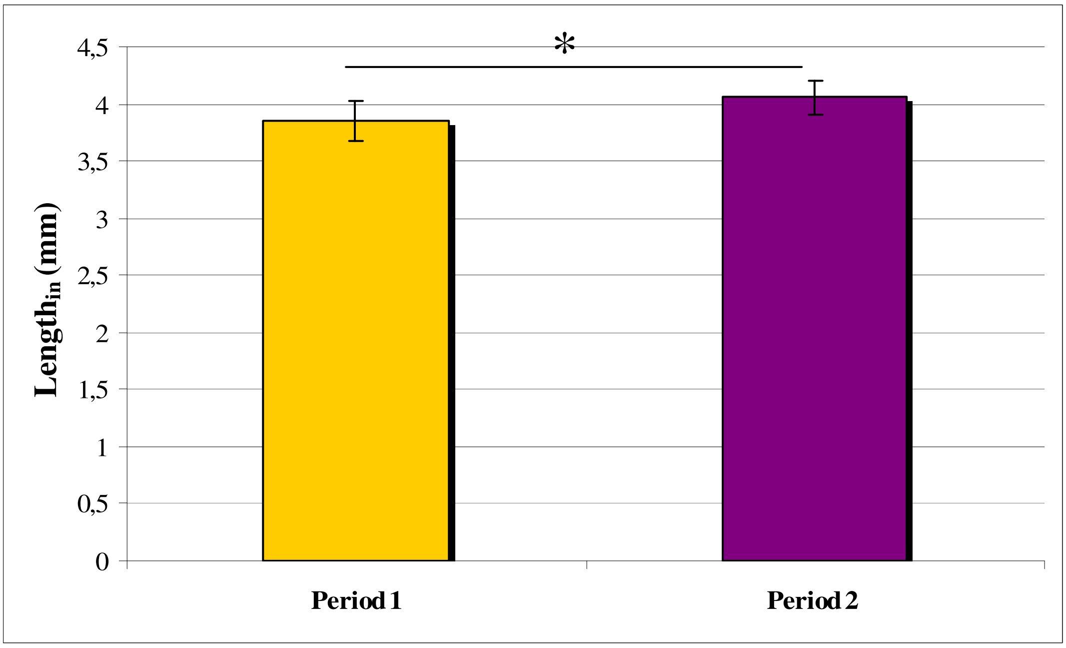
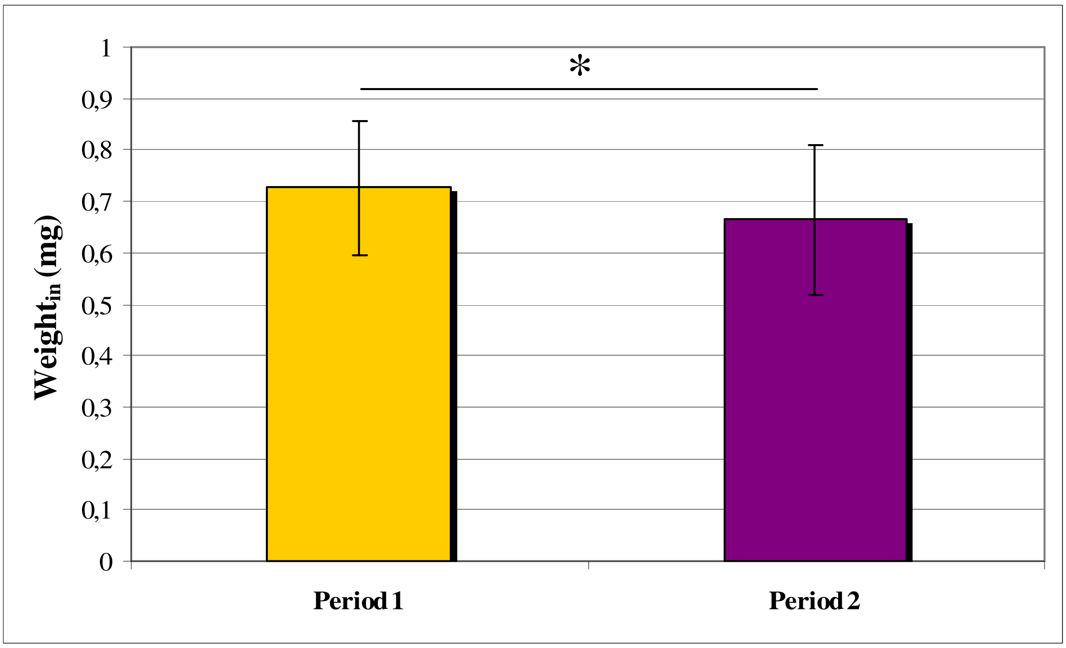
8. Appendixes

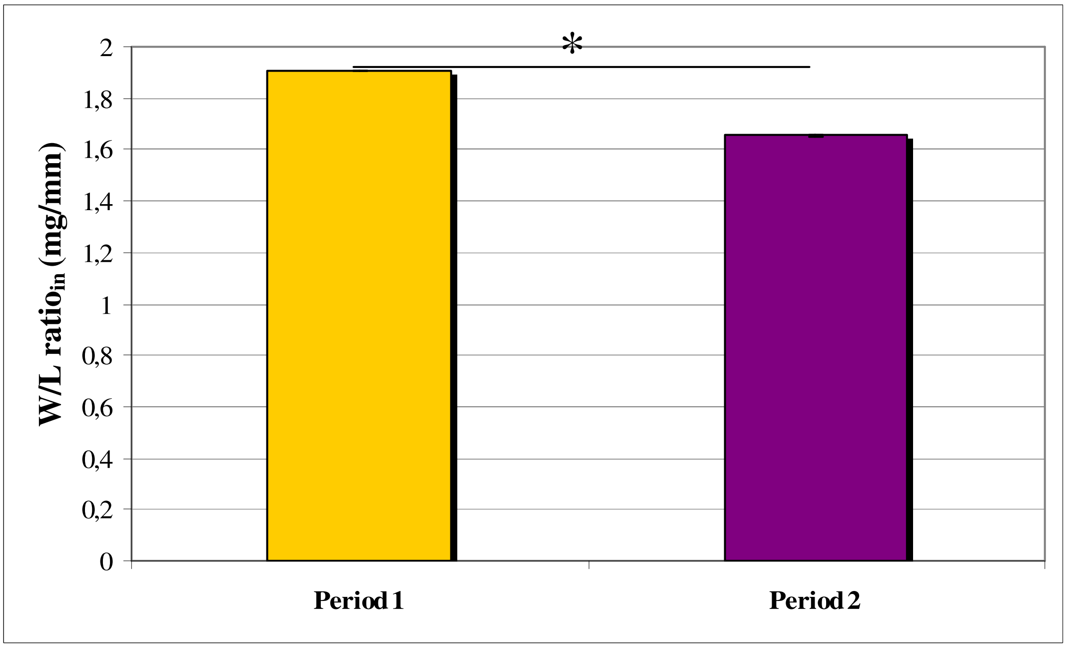
8.1 Appendix 1



Appendix 1.1: Mean length of the fishes in mm ±SEM at the beginning of the experiment for period 1 (August-September) and period 2 (September-November) in Curaçao

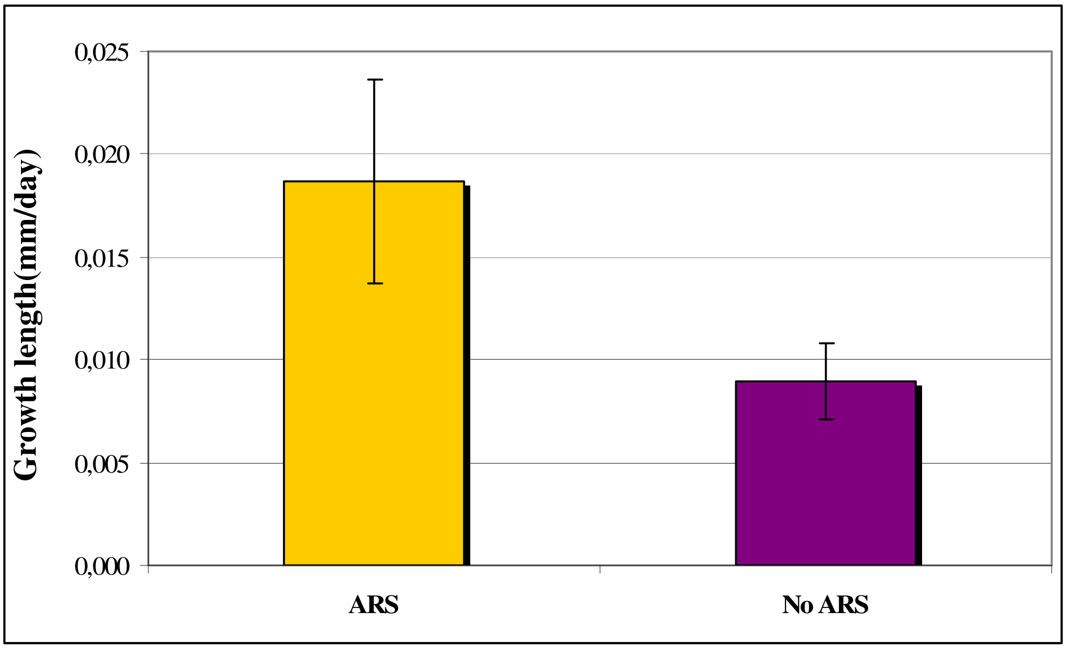


Appendix 1.2: Mean weight of the fishes in mg ±SEM at the beginning of the experiment for period 1 (August-September) and period 2 (September-November) in Curaçao

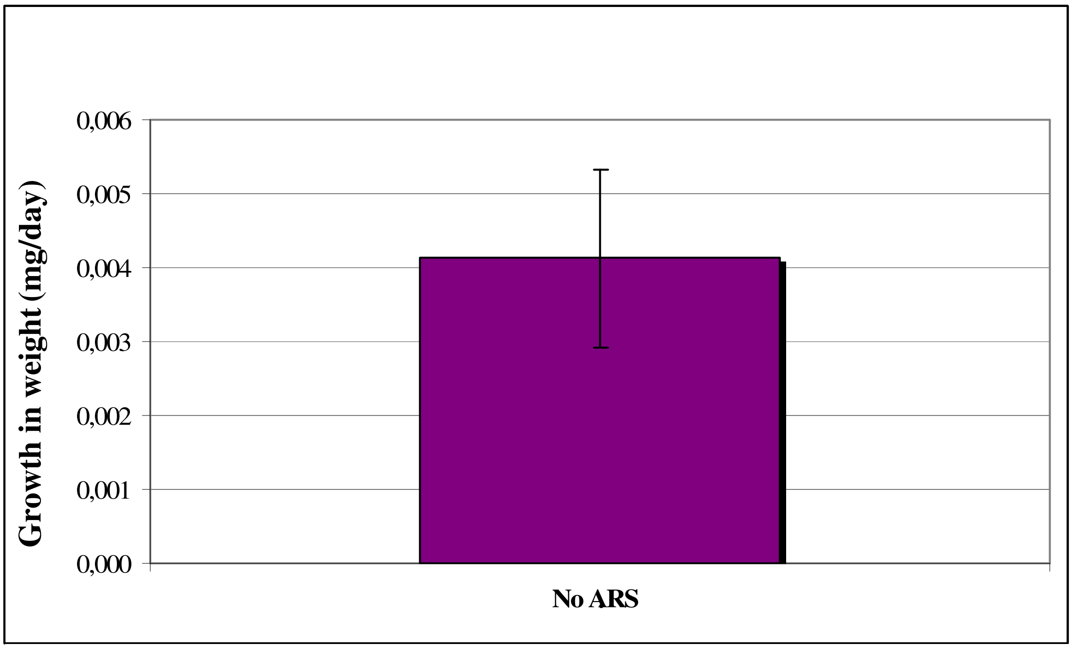


Appendix 1.3: Mean W/L ratio of the fishes in mg/mm ±SEM at the beginning of the experiment for period 1 (August-September) and period 2 (September-November) in Curaçao

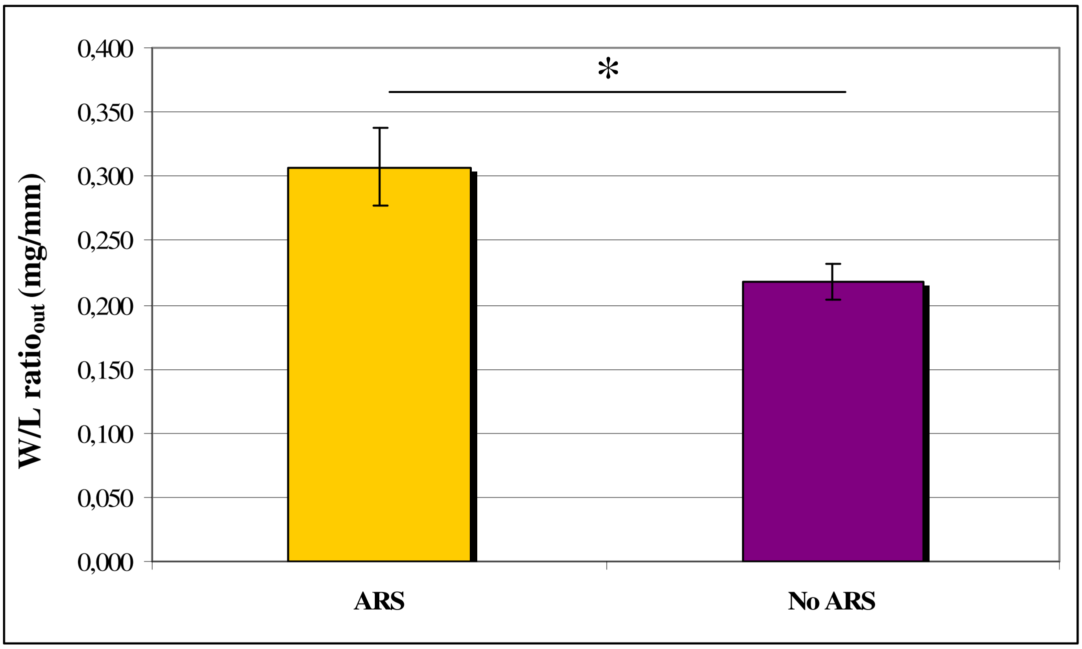
8.2 Appendix 2



Appendix 2.1: Mean growth in length of the fishes in mm/day ±SEM in seagrass cages for fishes with ARS treatment and fishes without treatment in Curaçao

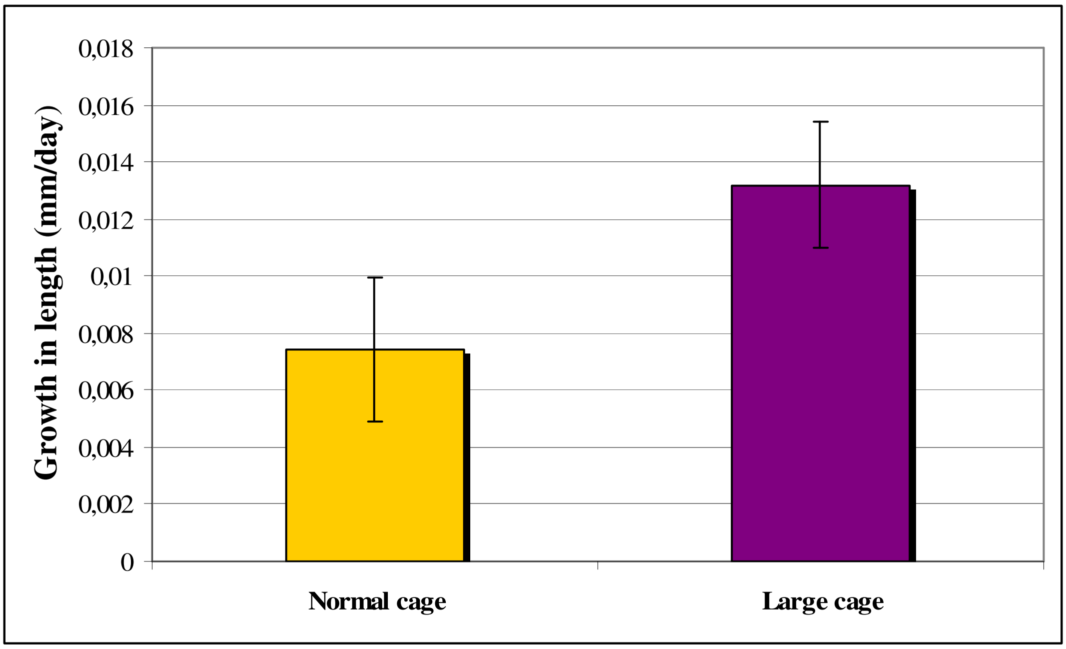


Appendix 2.2: Mean growth in weight of the fishes in mg ± SEM in seagrass cages for fishes without treatment in Curaçao. Fishes with ARS treatment were not weighed

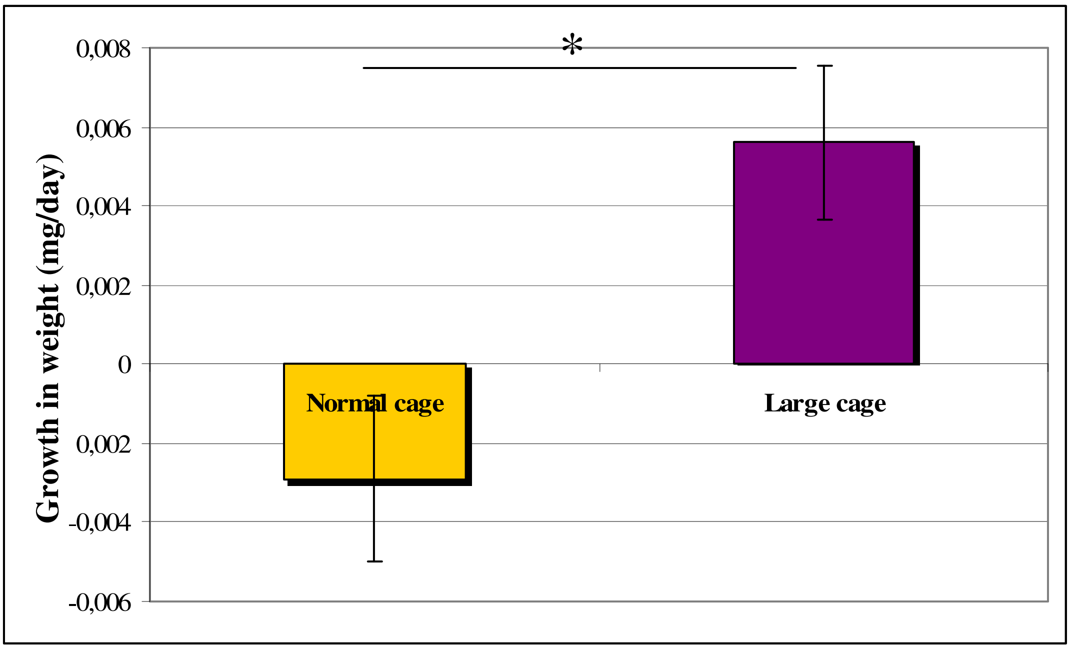


Appendix 2.3: Mean W/L ratio of the fishes in mg/mm ±SEM in seagrass cages for fishes with ARS treatment and fishes without treatment in Curaçao.

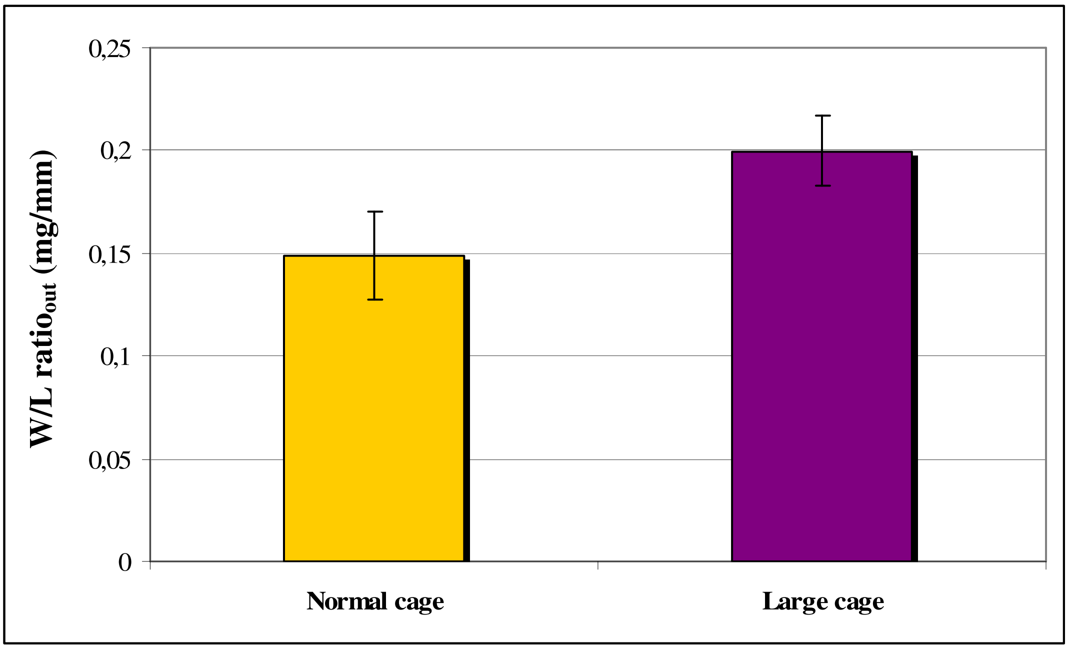
8.3 Appendix 3



Appendix 3.1: Mean growth in length of the fishes in mm/day ±SEM in seagrass cages for fishes in a normal sized cage and fishes in a larger cage in Curaçao

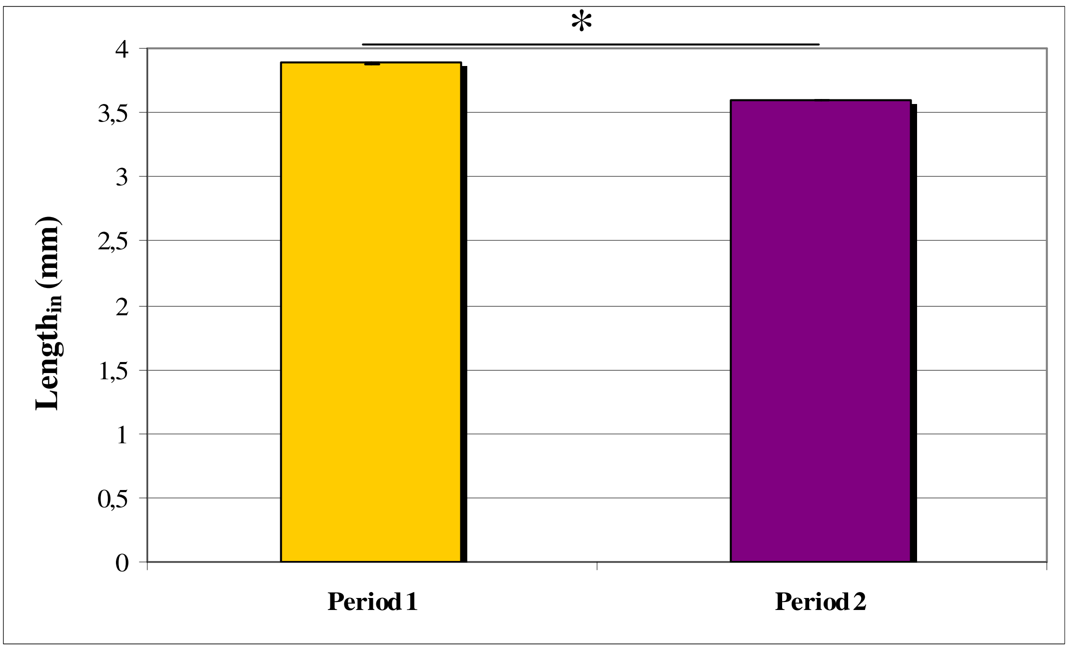


Appendix 3.2: Mean growth in weight of the fishes in mg/day ±SEM in seagrass cages for fishes in a normal sized cage and fishes in a larger cage in Curaçao

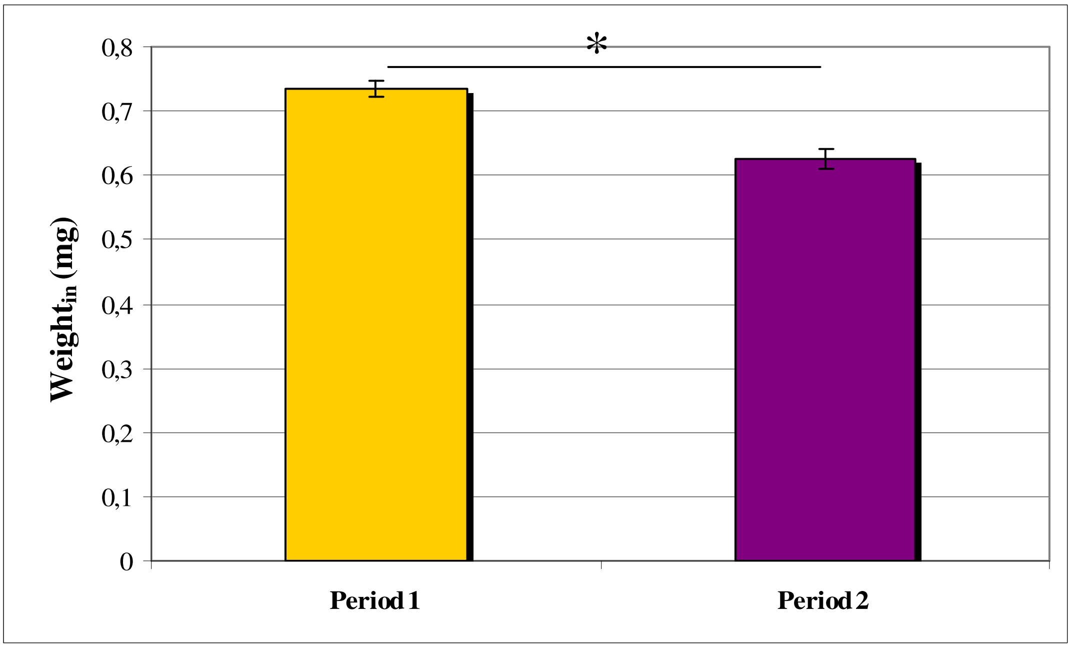


Appendix 3.3: Mean W/L ratio of the fishes in mg/mm ±SEM in seagrass cages for fishes in a normal sized cage and fishes in a larger cage in Curaçao

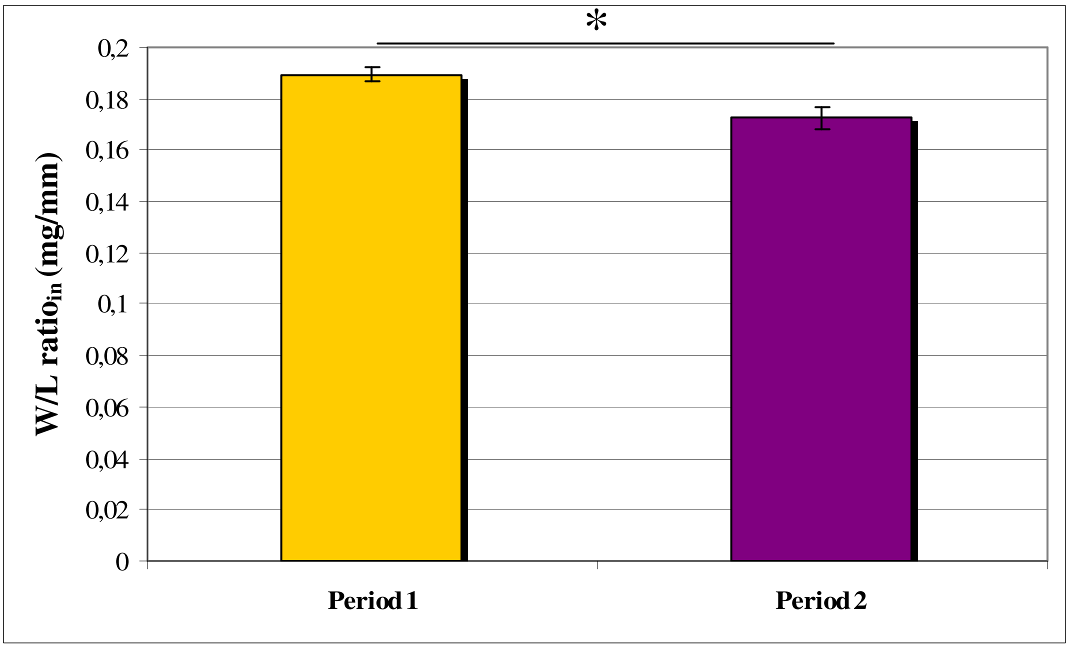
8.4 Appendix 4



Appendix 4.1: Mean length of the fishes in mm ±SEM at the beginning of the experiment for period 1 and period 2 in Aruba

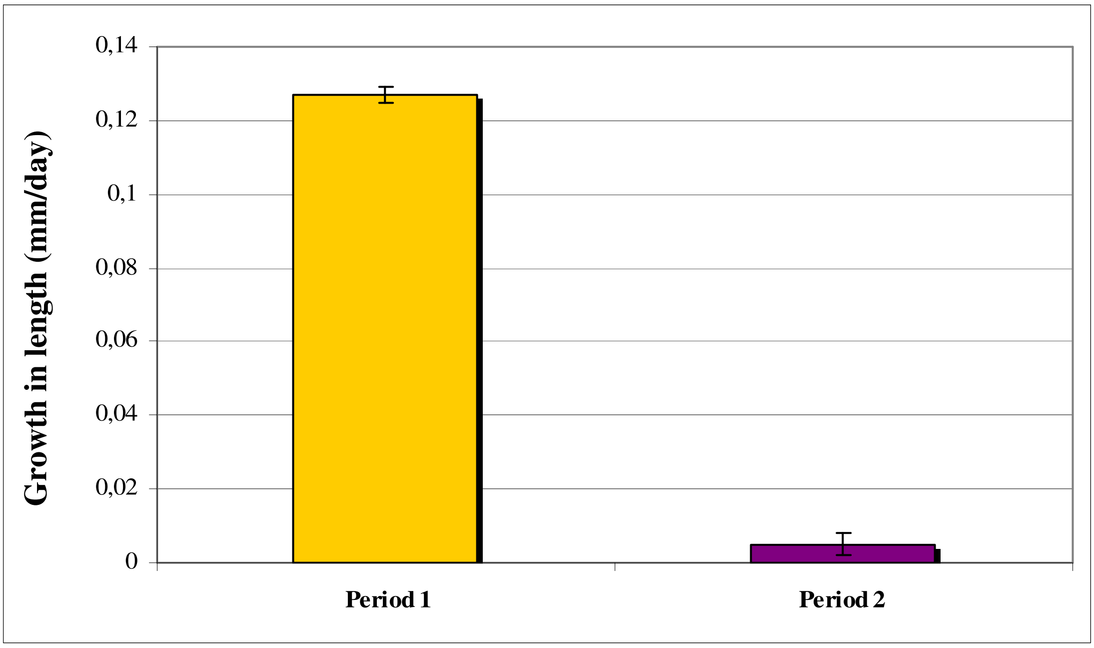


Appendix 4.2: Mean weight of the fishes in mm ±SEM at the beginning of the experiment for period 1 and period 2 in Aruba

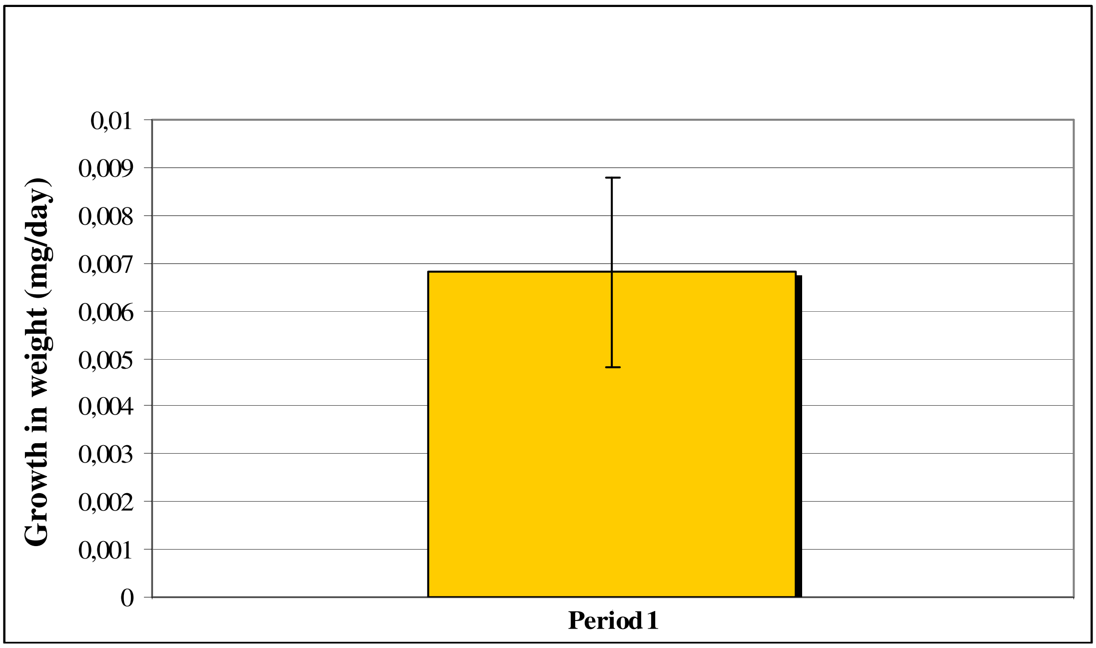


Appendix 4.3: Mean W/L ratio of the fishes in mg/mm ±SEM at the beginning of the experiment for period 1 and period 2 in Aruba

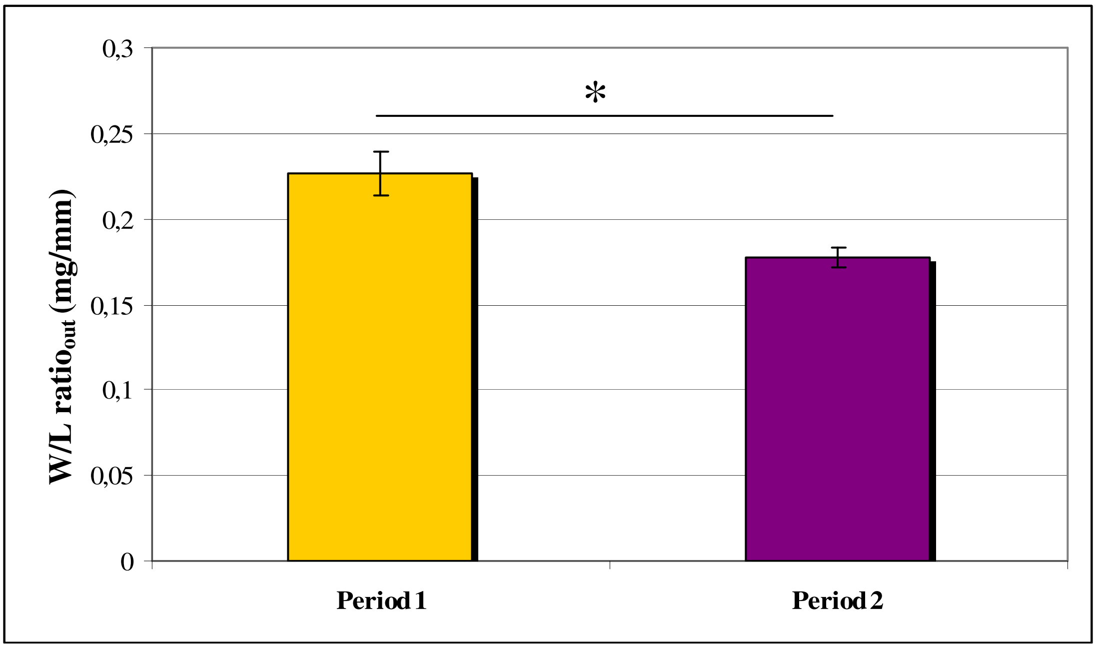
8.5 Appendix 5



Appendix 5.1: Mean growth in length of the fishes in mm/day ±SEM for fishes for period 1 and period 2 in Aruba

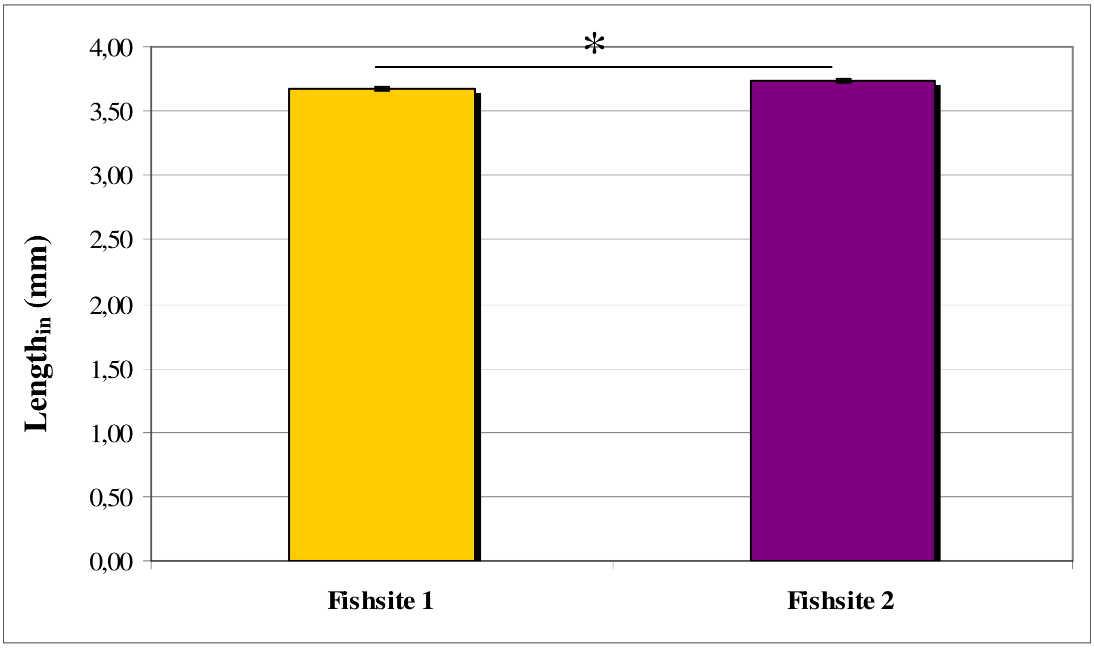


Appendix 5.2: Mean growth in weight of the fishes in mg/day ±SEM for fishes for period 1 and period 2 in Aruba. In period 2 there was a growth of 0

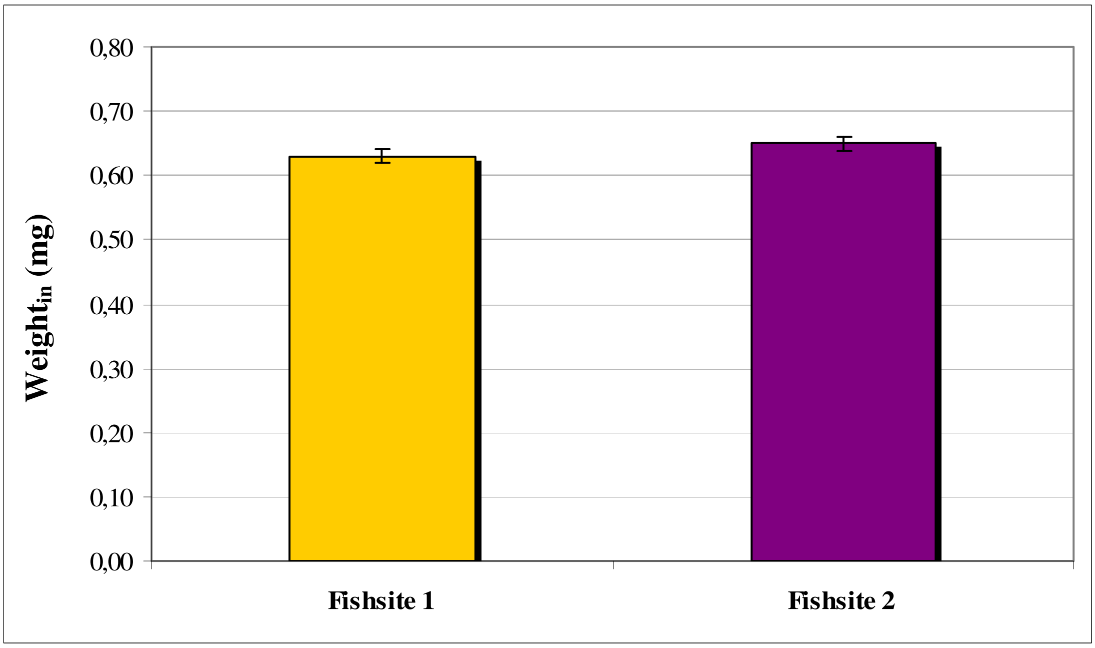


Appendix 5.3: Mean W/L$_{out}$ ratioof the fishes in mg/mm ±SEM for fishes for period 1 and period 2 in Aruba.

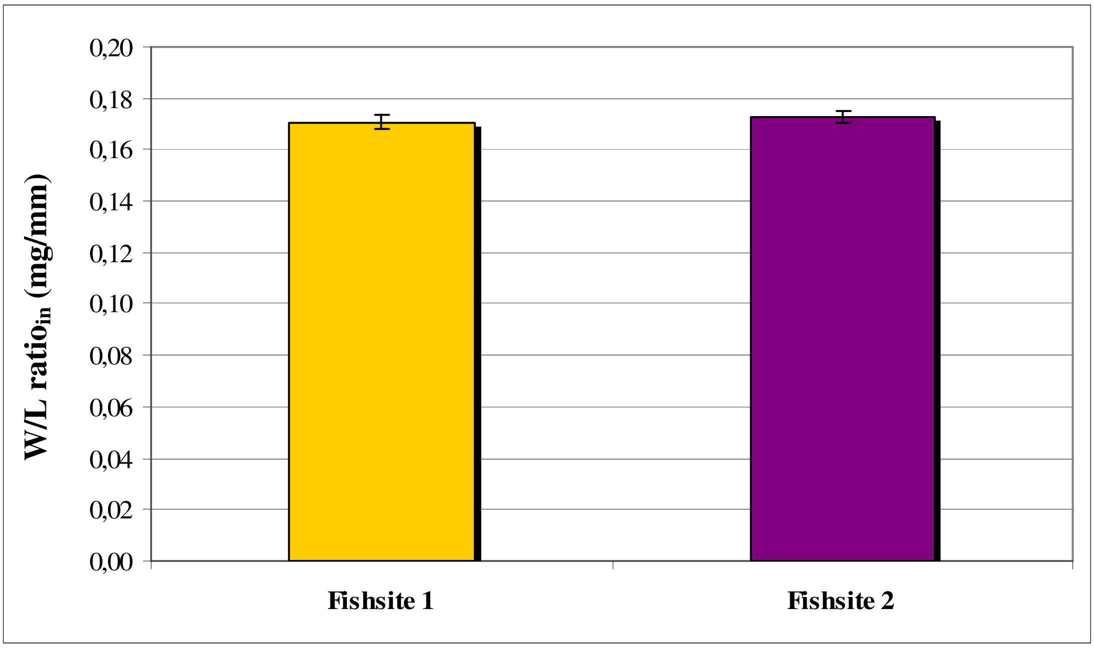
8.6 Appendix 6



Appendix 6.1: Mean length of the fishes in mm ±SEM at the beginning of the experiment for fishsite 1 (Mangel Halto) and fishsite 2 (Zeerover) in Aruba

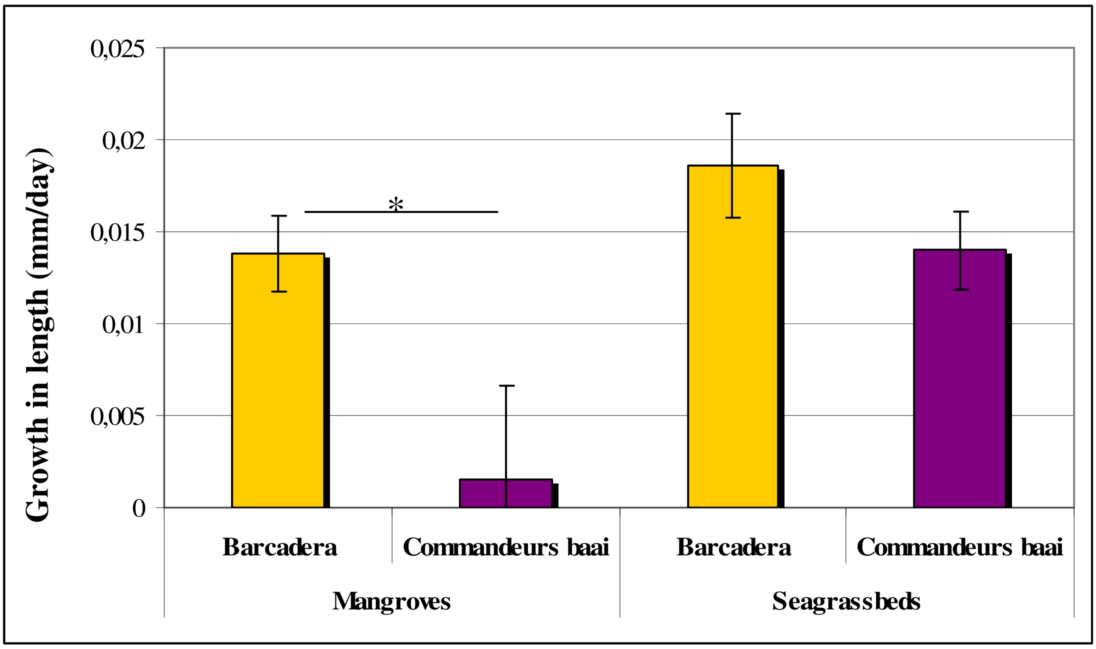


Appendix 6.2: Mean weight of the fishes in mg ±SEM at the beginning of the experiment for fishsite 1 (Mangel Halto) and fishsite 2 (Zeerover) in Aruba

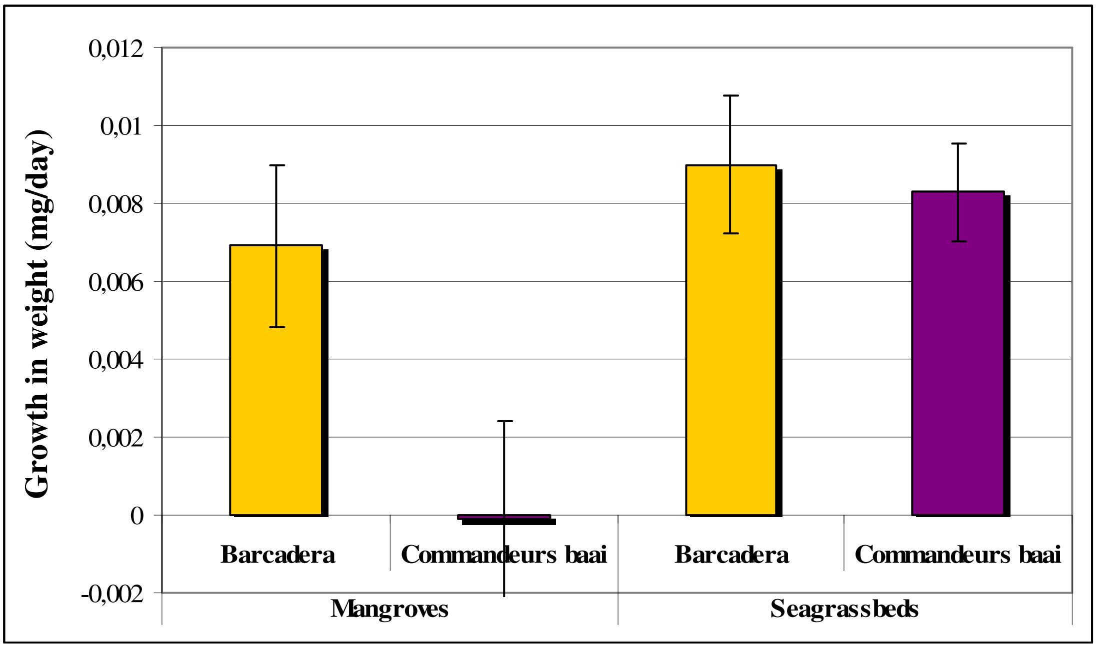


Appendix 6.3: Mean W/L ratio of the fishes in mg/mm ±SEM at the beginning of the experiment for fishsite 1 (Mangel Halto) and fishsite 2 (Zeerover) in Aruba

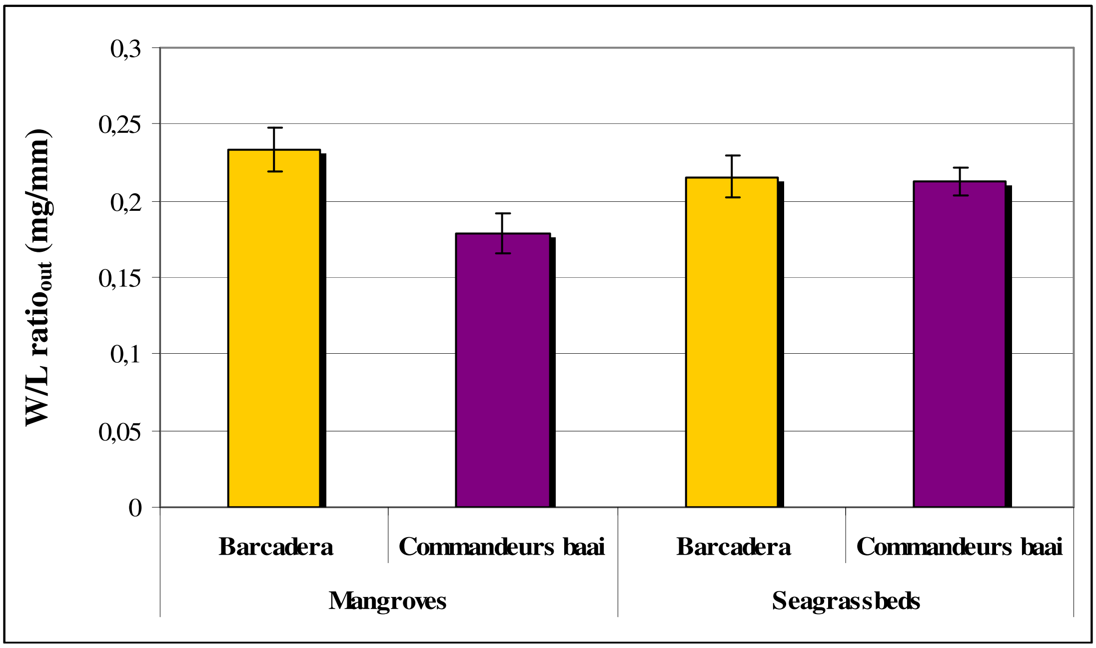
8.7 Appendix 7



Appendix 7.1: Mean growth in length of the fishes in mm/day ±SEM. For fishes in both area's of Aruba for the seagrass beds and the mangroves

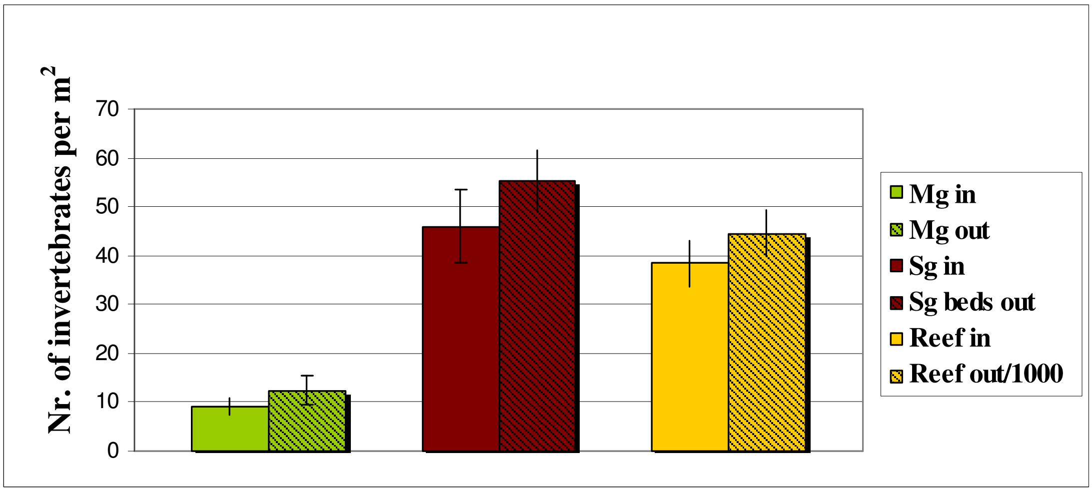


Appendix 7.2: Mean growth in weight of the fishes in mg/day ±SEM. For fishes in both area's of Aruba for the seagrass beds and the mangroves

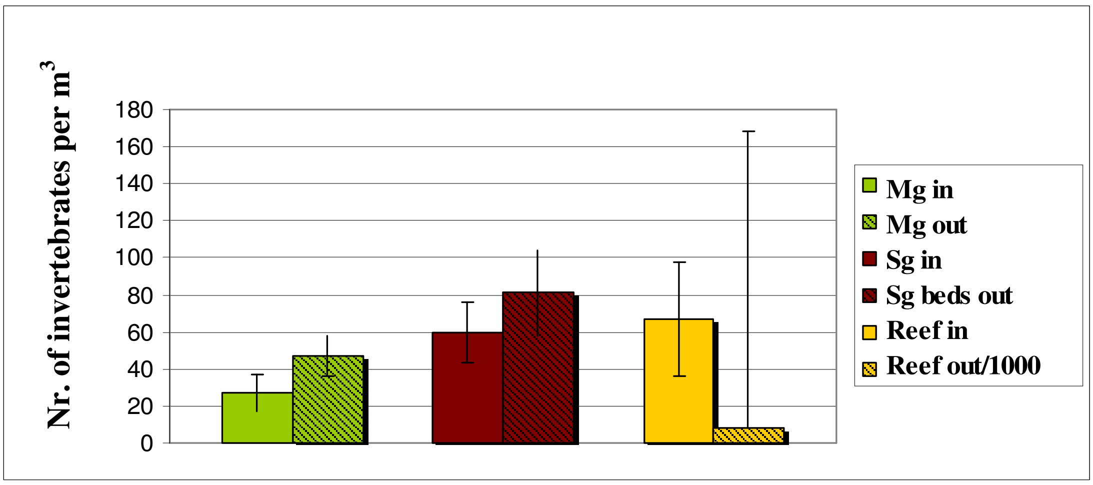


Appendix 7.3: Mean W/L ratio of the fishes in mg/mm ±SEM. For fishes in both area's of Aruba for the seagrass beds and the mangroves

8.8 Appendix 8



Appendix 8.1: Average number of invertebrates per m^2 (± SEM) in the sediment samples in and outside the cages for the mangroves, seagrass beds and the reef habitats



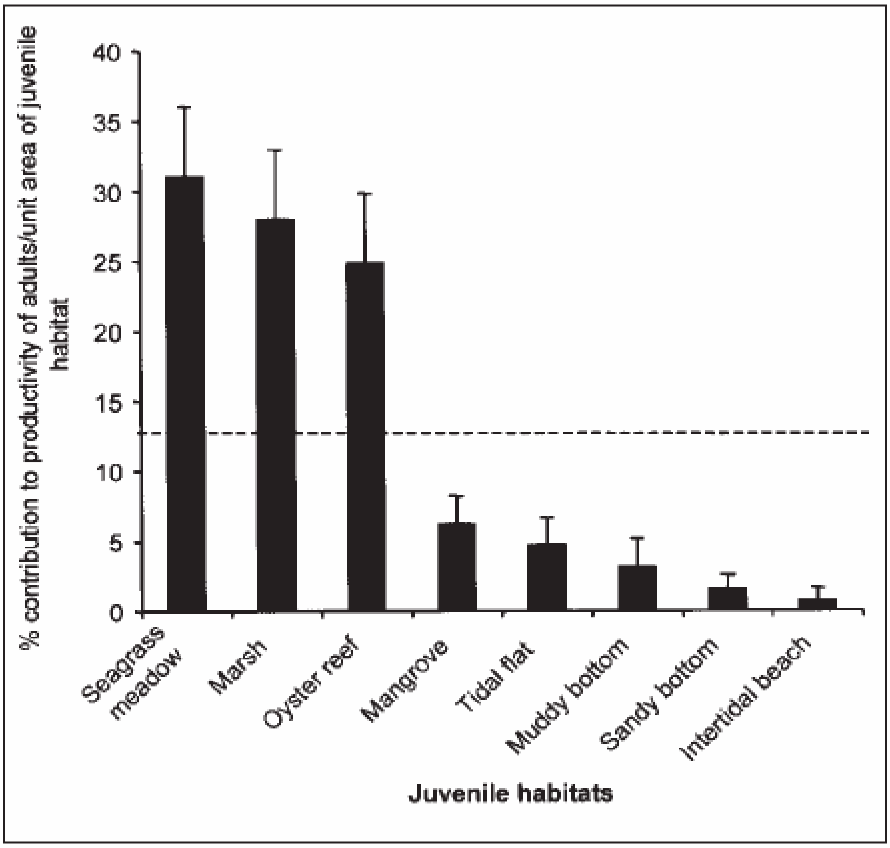
Appendix 8.2: Average number of invertebrates per m^3 (± SEM) in the plankton samples in and outside the cages for the mangroves, seagrass beds and the reef habitats

8.9 Appendix 9

Table 4: The growth in lenght, weight, W/L ratio per site, as well as the mean temperature, salinity, water clarity and conductivity.

	Growth Length	Growth Weight	W/L ratio	Temperature	Salinity	Water clarity
Mg sp lag	0.014	0.007	0.2273	28.2	24.5	5.5
Mg combaai	0.001	0.000	0.1789	28.5	24.1	2.8
Sg zandduin	0.023	0.011	0.2322	28.8	24.4	11.5
Sg combaai	0.014	0.008	0.2130	28.2	24.1	5.0
Reef zeerover	0.029	0.027	0.3435	27.5	23.9	27.4

8.10 Appendix 10



Appendix 10: Percentage of contribution of juvenile habitats (nurseries) to adult productivity per unit area (Beck et al., 2001)