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Mapping and description of a population of the introduced seaweed *Fucus serratus* in the Hvalfjörður, Iceland

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ABSTRACT

This thesis is a description of a *Fucus serratus* population in the Hvalfjörður, Western Iceland. *F. serratus* is an about 200 to 300 years ago introduced species to Iceland and the examined population was first mentioned in 1998. Along a stretch of about 1.6 km eleven transects were examined and the horizontal as well as vertical distribution of the introduced *F. serratus* and native species were recorded. Further on specific morphological and reproductive features were analyzed and the abundance of the epifaunal polychaet *Spirorbis spirorbis* on *F. serratus*, *Fucus distichus* and hybrids was examined. It turned out that *F. serratus* has established a population probably limited by substratum conditions with partially high substratum covers in the lower examined levels. It covers in most cases more substratum than the native *F. distichus*. A test for correlation has shown that a significant negative correlation between *F. serratus* and *F. distichus* cover is given ($r=-0.45$; $r^2=0.21$; $p<0.05$). Hybrids are distributed only sparsely but beside the expected *F. serratus* x *F. distichus* hybrids also possible *F. serratus* x *Fucus vesiculosus* hybrids have been found. *F. serratus* is significantly taller than *F. distichus* and has a higher biomass per plant as well as per area. Hybrids are described as being morphologically intermediate. While *F. serratus* and hybrids possessed receptacles during the survey period, none were found on *F. distichus*. Hybrid receptacles are morphologically special and a description is given. Contrary to other habitats, *S. spirorbis* is most abundant on *F. distichus* ($t=3.91$; $df=61$; $p<0.05$) and possible explanations are discussed. Moreover, the fate of the hybrids and possible impacts of *F. serratus* on the native species assemblage in the relatively new habitat are discussed. It is assumed that *F. serratus* might have severe impacts on the local flora and fauna.

1. Introduction

An overview of an isolated population of the introduced brown alga *Fucus serratus* in Hvalfjörður, Iceland will be given. A main purpose of this study is to map the existing *F. serratus* population at the investigated site and with that to create a basis for further studies on its spreading from the present distribution, and the ecological and evolutionary effects of such a spreading.

It is well known that introduced species can dramatically alter the structure of existing ecosystems and related community structures, see e.g. Vitousek *et al.* (1997). *F. serratus* can form hybrids with *Fucus distichus*, and mature hybrids have been reported from the field. Hybrids may sometimes have the potential to become so successful that they may suppress the parental species. Hybridization can also allow gene-flow between the parental species through introgression (Coyer *et al.* 2007), and even result in speciation. In times of globalization it is important to understand the effects of global species exchange in order to preserve ecosystems and biodiversity. Data on the distribution, density, phenotype and reproduction status of *F. serratus* have been collected and analyzed, and compared with the same data for the native *F. distichus* and hybrids of these two species. During the first samplings, observations suggested that there might be a difference in abundance of the epifaunal polychaet *Spirorbis spirorbis* between thalli of *F. serratus* and *F. distichus*. Density measurements of *S. spirorbis* on thalli of *F. serratus*, *F. distichus* and potential hybrids were therefore included in the study.

1.1 Description of *Fucus sp.*

A *Fucus* thallus consists of a rhizoid (holdfast), a cauloid (steep) and a phylloid (leaf) with a mid-rib. Air bladders are present in *F. vesiculosus* but are absent in other *Fucus* species (Bold & Wynne, 1978). The growth emanates from one or a group of apical cells (Graham *et al.*, 2009). *F. serratus* can be easily distinguished from the other *Fucus* species by its characteristic serrations on the branch edges. It is perennial (3-5 years) and reaches sizes up to more than 1 meter in length (Knight & Parke, 1950). *F. distichus* has narrower blades and no serrations. The midrib of *F. distichus* is less distinct than the one of *F. serratus* (Coyer *et al.* 2002). Some controversy exists around the

separation between *F. distichus* and *F. evanescens*, and here the name *F. distichus* will be used for this entity (Coyer *et al.* 2006b).

1.2 Reproduction in *Fucus sp.*

Members of the order Fucales can be either dioecious (e.g. *F. serratus*, *F. vesiculosus*) or monoecious (e.g. *F. distichus*, *F. spiralis*).

The reproduction follows a seasonal rhythm and is exclusively sexual in *F. serratus* (Malm *et al.* 2001). *F. serratus* is described as being mainly reproductive in autumn and winter by Knight & Parke (1950), but exceptions to this pattern are found and variations can occur even within relatively small distances (see e.g. Malm *et al.* 2001; Berger *et al.* 2001). Also in *F. distichus* the reproductive pattern can vary according to location and environmental conditions (see Bird & MacLachlan 1976). At sites where hybrids of *F. distichus* and *F. serratus* can be found in the field the reproductive periods of these species must overlap.

1.3 Distribution and habitat demands

Fucus serratus is common as a belt forming species in the lower rocky intertidal zone in the North Atlantic. In this area it occurs from the northern Iberian Peninsula up to the White Sea, in south-western Iceland, the Faroes, Baltic Sea and in Nova Scotia (Coyer *et al.* 2003).

Coyer *et al.* (2006a) examined the origin of the Icelandic *F. serratus* populations and concluded that it has probably been present in Iceland for about 200-300 years. It has a small panmictic unit of 0.5 to 2 km (Coyer *et al.* 2003) and is not able to float over great distances due to a lack of air bladders or inflated parts of thallus. The possible places of origin are located at least 300 km away from Iceland (British Isles, Norway) and the migration would be against the Gulf Stream. Therefore it has most likely been introduced by man to Iceland. A microsatellite-based examination on the origin of Icelandic *F. serratus* indicated that the Icelandic *F. serratus* population was genetically closest to a population in the Småskjaer area at Oslofjorden in Norway. A likely introduction pathway is by ships from that region to Hafnarfjörður sometime in the mid-1700s to the late-1800s in the course of trading (Coyer *et al.*, 2006a). Nowadays *F. serratus* populations can be found in Iceland from Reykjavik to somewhere south of Stafnes, on Vestmannaeyjar, and in

Hvalfjörður. The examined population in Hvalfjörður was first mentioned in 1998 (Ingólfsson, 2008).

Usually, intertidal communities are bound to a certain height level. These levels and the species composition can vary due to environmental factors, e. g. exposure to wave action (Ingólfsson, 2006), periods of exposure to air or air humidity (Knight & Parke, 1950). *F. serratus* has a wide range of tolerance for salinity. Where it is found on the southwestern shores of Iceland, it copes with salinity from 31 to 34 during the year (Ingólfsson, 2006) and in the Baltic Proper with reported surface salinity of 6.5 (Malm *et al.*, 2001). The habitats of *F. serratus* also differ strongly in their temperature ranges: In northern Spain the surface temperature at the coast can reach temperatures of 22 °C in summer (Arrontes, 1993), whereas the sea temperatures on the west coast of Iceland regularly fall down to 5 °C at wintertime (Ingólfsson, 2006). What factors that will eventually determine the distributional limits for *F. serratus* in Iceland is not yet known (Ingólfsson, 2008).

1.4 Role of *Fucus serratus* in ecosystems

Generally, *F. serratus* forms communities with other algae. *Fucus* species share distributional patterns with *Ascophyllum* and *Pelvetia* (Nizamuddin, 1970). Icelandic *F. serratus* populations are normally situated between the kelp stands (*Laminaria digitata* or *Saccharina latissima*) below it, and vegetation consisting of *Ascophyllum nodosum* and *F. distichus* above it (Munda, 2004). The canopies of *Fucus* species affect the associated communities: On the one hand it protects understory algae, as well as juveniles from desiccation during low-water periods (Jenkins *et al.*, 1999). Additionally, the *Fucus* stands lower the effect of currents and waves and by that lower sediment movement and maintain water clarity. Like this, *F. serratus* positively affects the growth rate of understory algae (Nybakken & Bertness, 2005; Jones *et al.* 1997). On the other hand, the canopy leads to a severe decrease in sun irradiance (Schonbeck & Norton, 1980). The predation and grazing activities are also influenced by the canopy as both increases in its presence (Menge, 1978). Whiplashing effects can erase settling organisms around larger seaweeds (Nybakken & Bertness, 2005). Considering the aforemen-

tioned effects of Fucoids on intertidal communities and the definition of Jones *et al.* (1997), *F. serratus* must be treated as a mixed autogenic (e. g. providing settling habitat) and allogenic (e. g. shading understory populations) physical ecosystem engineer. Its importance lies not only in the above described direct community effects, but also on a large scale in the suspected increase of diversity of habitats within the intertidal zone and with that an increase in total species richness (Jones *et al.* 1997).

The competitive potential of *F. serratus* seems to differ depending on location. According to Schonbeck & Norton (1980) *F. serratus* outcompetes *F. vesiculosus* if both are continuously submerged. A dominance of *F. serratus* over *F. vesiculosus* has also been suspected by Arrontes (2002). Malm *et al.* (2001) found that both mixed as well as monospecific stands are widely spread on the Baltic coast of Sweden down to 6 m deep with alternating superiority. Ingólfsson (2008) calls *F. serratus* a rather weak competitor with small effects on the local flora of Iceland; it is assumed to be rather an addition to the total cover of canopy forming algae and seems to be able to use resources which are not available for other species. On the other hand he also found that the cover of *F. distichus* was significantly lower in the area where *F. serratus* has become established than in areas lacking *F. serratus* (Ingólfsson 2008), which suggests that *F. serratus* can supersede *F. distichus*.

1.5 *Spirorbis spirorbis* as epibiont on *Fucus* sp.

S. spirorbis is a filter-feeding polychaet with a spiral calcareous tube. The coil reaches 3.5 mm in diameter and has a peripheral flange to increase the surface for attachment. The body is light green and it has usually 9 tentacles (Knight-Jones & Knight-Jones, 1977). It is found on Atlantic coasts up to 30 meters deep (Van Guelpen *et al.* 2005). Fucoids are in general preferred over other algae as settling substratum for the planktonic larvae, where the adults are found abundantly. There are species dependent preferences for substratum choice and *S. spirorbis* larvae prefer *F. serratus* over other *Fucus* species. (DeSilva, 1962). Williams (1964) showed that the larvae of *S. spirorbis* settle on *F. serratus* plants in response to the presence of a certain substance adsorbed on the

plants surface. This substance is considered to be a more important criterion for the initiation of settlement than the physical properties of the substrate. It has been proven that this substance is produced by the plant itself. Furthermore, larvae settle next to established populations rather than on uninhabited substrate (Knight-Jones, 1951). *S. spirorbis* is hermaphroditic and self-fertilization is possible in isolated individuals even though the offspring is less viable than what is found during mating. Therefore self-fertilization seems to be evolutionary oppressed, but can maintain populations with individuals in low densities (Gee & Williams, 1965).

Species which are introduced to new areas, like *F. serratus* in Iceland, are released from co-evolved enemies which can inhibit plant performance in their old habitat (Enemy Release Hypothesis) (Keane & Crawley, 2002). Therefore it might be interesting to examine whether the settlement of *S. spirorbis* shows different preferences than in regions where *F. serratus* is native.

1.6 Hybrids between *F. serratus* and *F. distichus*

Hybrids of the two species have been reported from Denmark, Norway and Iceland (Coyer *et al.*, 2002; 2006a; 2007). The morphology of the hybrids is intermediate between the parental species (Coyer *et al.*, 2002) with slight serrations and a less distinct midrib than in *F. serratus*. Additionally, hybrids of the following combinations have been reported: *F. vesiculosus* x *F. spiralis* and *F. ceranoides* x *F. spiralis* (cited in Coyer *et al.*, 2002). Burrows & Lodge (1953) have also reported *F. vesiculosus* x *F. serratus* hybrids from laboratory experiments. Still, in natural communities the formation of *Fucus* hybrids seems to usually involve one dioecious and one monoecious parent (Coyer *et al.*, 2007). However, hybrids between *F. distichus* and *F. serratus* are not found in all reported regions where the two parental species are present (Coyer *et al.*, 2002). This might be a result of evolved barriers for hybridization, for example through genetic isolation (Coyer *et al.*, 2002).

1.7 Aim of study

The study was carried out on an isolated *F. serratus* population in a fjord north of Reykjavik. The population has probably become established here relatively recent. The aim of the study was to examine the distribution of *F. ser-*

ratus, *F. distichus* and possible hybrids between these two within this relatively new habitat, and if there were indications of that *F. serratus* has impact on the native species assemblage. Density of *F. serratus*, *F. distichus* and hybrids in four vertical levels of 11 transects along the shore was recorded. In addition, samples from 6 transects were analyzed in the lab. Morphological data, length, weight, and reproductive stage of receptacles from the individual *F. serratus* plants were recorded. In addition the density of *S. spirorbis* on *F. serratus*, *F. distichus* and hybrids were recorded.

This study was conducted as a Bachelor Thesis under the supervision of Associate Professor Kjersti Sjøtun of the University of Bergen, Norway and Prof. Dr. Kai Bischof from the University of Bremen, Germany.

2. Material & Methods

2.1 Sampling site and field work

The examination of the population took place on the southern side of the Hvalfjörður in the western part of Iceland during late September and early October in 2012. Eleven vertical transects were examined along the coastline on a stretch of 1.6 km. Nine transects were placed on the shore and two additional transects were placed on a small offshore island. Between the first five transects on the mainland an even distance of 60 m was held. The other transects on the shore were distributed evenly with estimated distances to cover the rest of the shore. The transects on the island were placed on the eastern and western side of it (see Figures 1 and 2).

Each transect was placed perpendicular to the shoreline and ranged from the Chart Datum level (0 m) to 2 m above it. The actual water level in relation to Chart datum for every day was obtained from the website <http://easytide.ukho.gov.uk/EASYTIDE/EasyTide/index.aspx>. Each transect was divided into four height-levels of 0.5 m each starting from chart datum. The stretch of the transect up the beach was measured to determine the inclination of each transect and to allow the standardized placing of the sample-plots.

The stretch of each height level was divided by five and at each of the calculated positions a sampling plot was placed. To create comparable data, a systematic pattern for the placement was chosen. The pattern was designed as follows: three of the sample squares were placed to the

right of the measuring tape alternating with two to the left in a distance of two meter to the measuring tape in the middle and with an equal difference in height between each of the five plots. Since the method for the determination of the height levels is not very exact, one meter of the total range of each level was subtracted before the division was made. The lowest and the highest plot were subsequently placed half a meter above, respectively below the limits. The validation with recorded data from the aforementioned website for Akranes showed that the actual water level differed on the sampling days in average 8.15 cm from the data used in the field. According to this information all sample units can therefore be treated as being in the desired height level.

Additionally to the inclination, sea temperature and salinity were recorded. A sensor was placed close to the first transect at the Chart datum level. The salinity shows little seasonal variation on the western coast of Iceland, while the water surface temperature changes approximately by 5 °C between summer and winter in the Faxa Bay (between the Reykjanes- and Snæfellsnes peninsula) (Ingólfsson, 2006). The Icelandic fjords frequently freeze over during winter, but ice-scraping in the intertidal is very little and has only limited effects on the intertidal communities (Ingólfsson, 2006).

The population can basically be treated as moderately sheltered as it is located in a fjord (Ingólfsson, 2006). However, regarding the level of exposure, the rocky shores of Iceland can be characterized as follows (with most exposed first): *F. distichus*- > *F. vesiculosus*- > *Ascophyllum nodosum*- dominated shores (Ingólfsson, 2006).

The sampling squares had a size of 0.5 x 0.5 m (0.25 m²) and were placed in the described manner along each transect. The following data were recorded for each plot: Percentage cover of *Fucus serratus*, percentage cover of *Fucus distichus*, percentage cover of hybrids, type of substratum and percentage cover of other algae (kelp (*Laminaria digitata* or *Saccharina latisima*), *Ascophyllum nodosum*, *F. vesiculosus*, understory algae). The percentage cover was estimated to the nearest 5 %. In the transects where no samples for further examination were collected (transects 4, 7, 8, 9, 10) individuals of *F. serratus*, *F. distichus* and hybrids in each sample square were counted. In all other tran-

sects, all individuals of *F. serratus*, *F. distichus* and the hybrids of each plot were harvested. The plants were cut off with a knife as close to the substrate as possible and stored in a fridge or cooling chamber until they were processed.

2.2 Laboratory work

In the laboratory the following data for *F. serratus* and hybrid individuals were recorded: Fresh weight and dry weight (g), maximum length (cm), number of dichotomies along the longest branch, branch width (cm), state of maturity of the receptacles (sorted in categories 1-4, see below) and weight of the receptacles (g). The fresh and dry weights were measured to the nearest 0.1 g and the lengths to the nearest 0.5 cm. In addition each individual was identified to sex, and the number of *S. spirorbis* individuals was counted and related to g fresh weight of *Fucus*. Finally each *F. serratus* plant was put into labeled aluminum bowls and dried for 48 hours in an oven at 65 °C. Since there was limited space in the oven some samples decayed before they could be processed. Individuals of *F. distichus* were weighted (fresh weight) and their lengths were measured, and numbers of *S. spirorbis* were counted per individual.

Internode length was calculated by dividing the longest branch by number of dichotomies along the branch. The internode length can be related to the growth rate of the plants and thus can give hints about the environmental conditions (Knight & Parke, 1950). The branch width was calculated as the average value of ten measurements whenever possible. If there were less than ten measurements, all were included. The measurements of branch width were taken three branches down from the tip of each randomly chosen axis. As well as the internode length, the branch width can be influenced by environmental impacts such as shelter. This has been reported for *F. distichus* (Rueness, 1977).

For the determination of maturity of the receptacles, all the receptacles were cut off and sorted into four categories according to the "Seaweed Reproductive Phenology Protocol" (from www.globe.gov, 2005). The categories were slightly modified for this survey by adding State 1 as a premature state:

State 1: There are no distinct conceptacles found on the surface, but light green dots can be seen and the midrib disappears. When the branch is held against the light, one can see the

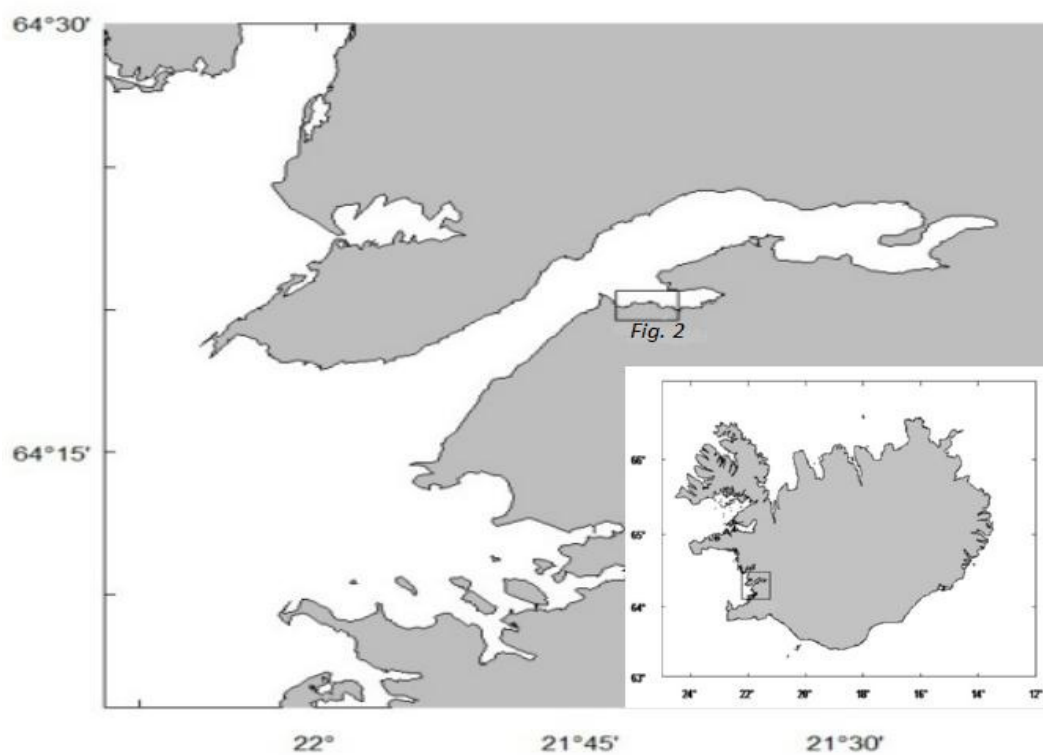


Figure 1: Map of Hvalfjorður area with indication on the inserted map of Iceland for orientation

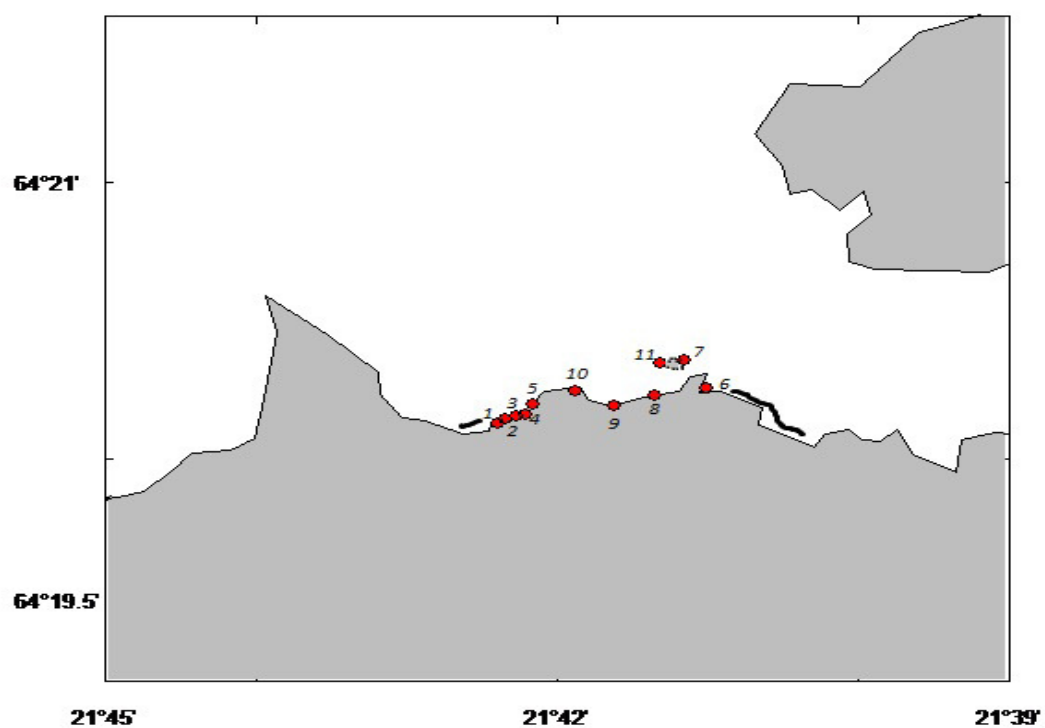


Figure 2: Location of the transects along the indicated shore in figure 1 in the Hvalfjorður. The black lines indicate the observed extension of *F. serratus* at the site. The transects cover the main population.

forming receptacles as an accumulation of darker dots in a definable area.

State 2: The conceptacles can be felt by stroking with the finger over the surface. The conceptacles are light green and smooth.

State 3: The conceptacles are not green anymore, but brown and easier to distinguish by both color and feeling. The receptacles are more distinct than in stage 1.

State 4: The whole receptacle is colored like the conceptacles in stage 2. Also red dots occur and the conceptacles are very distinct. The receptacles are partly ruptured.

Usually in states 1 to 3, the conceptacles are more abundant and clumped in the lower part of the receptacle and the total number per area decreases towards the tip. Also the state of maturity changes from a higher state to a lower state from the lower end to the top of the receptacle. The receptacles were sorted into the category that would fit at least for 50 % of the conceptacles. The categorization was difficult in mature male plants because the male receptacles can show red dots already in the second state. Moreover, the color of the receptacles changes from the usual brown-green of the plant to a yellowish color in an earlier state than in female plants. After the classification the receptacles of each category were counted to determine the maturity state of the plant. The total weight of all receptacles was recorded to determine the biomass of reproductive organs. The sex of the plants was determined by using a microscope. Therefore little piece of a receptacle was cut out and squeezed on a slide for the determination.

At last, the total number of *S. spirorbis* per plant was estimated. The average number of *S. spirorbis* in squares of 1 cm² of plant surface was determined. Like this the total number of *S. spirorbis* could be estimated for the whole plant according to its size. When very many individuals on a single plant were found or the plant was very big, the number was estimated. The *S. spirorbis* on a randomly selected part of the plant were counted. This part of the plant was weighed and the number of *S. spirorbis* per g was extrapolated to a total number for the whole plant. The weight of the selected part had to be at least equal or more than one third of the total fresh weight of the plant.

2.3 Statistical analysis

The intention was to run ANOVA tests on the collected data in order to detect significant differences among transects, height-levels and species within the aforementioned data-sets with Microsoft Office Excel 2007 with the "Data Analysis Toolpak" add-in (Excel version 12.0.6665.5003; SP3). When there was no normal distribution given in a data-set, the Kruskal-Wallis-test (KW_t), which can be treated as an ANOVA-test on ranked data, was used instead (Köhler *et al.*, 2007; Vargha & Delaney, 1998). Additionally, the Nemenyi-Test on sample-units with same size and the Dunn's Test on unequal sample sizes were used, to determine which of the tested groups were significantly different from each other as described in Köhler *et al.* (2007) for Nemenyi-Test, respectively Hinton (2004) for Dunn's Test. Hartley's F_{\max} test was used to check for homoscedasticity. If this was not given, the Welch-Satterthwaite equation was used as a robust alternative (Vargha & Delaney, 1998; Ruxton, 2006).

In simpler cases, where only two groups had to be tested, the level of significance was determined with the *t*-Test, respectively Welch's *t*-Test on ranked data in combination with the Satterthwaite-equation for the determination of degrees of freedom (Ruxton, 2006).

3. Results

3.1 Environmental conditions of the sampling site

Transects 1, 2, 4, 7, 10 and 11 had an average equal inclination of approximately 11°, whereas transects 3 and 5 had an average inclination of 17° and transects 6, 8 and 9 an inclination of 2°. Transects 8 and 9 were located next to a narrow river. These transects, and transect 6, were characterized by being almost completely muddy in the two lowermost height levels. Transect 9 had mainly muddy substratum up to the third height level with more rocks in the fourth. All other transects had more or less rocky substratum with slight differences.

Salinity and water temperature were recorded from the 28.9.2012 to 19.10.2012. Unfortunately no more data is available because the sensor was lost in a storm. The salinity ranged from 24 to 25 during high water periods. The water temperature ranged in the same time from 6 to 9 °C in the beginning and decreased

during the measurement period by approximately 1 °C. The tidal range at Akranes during the examination was about 3.40 m which is approximately 0.5 m less than on the western main coast.

The upper levels of the examined shore were dominated by *A. nodosum* and less *F. vesiculosus*, which together covered the shore on the higher levels completely and were very abundant even in the lower levels of some transects. Only in the transects 6 and 9 *F. vesiculosus* was prevalent, and in transect 2 the cover of *A. nodosum* and *F. vesiculosus* was equal.

3.2 Distribution of *F. serratus*, *F. distichus* and hybrids

F. serratus, *F. distichus* and hybrids were occasionally found on an approximately 850 m long stretch eastwards from transect 6. The western margin of the distributional range of *F. serratus* was located about 150 m from transect 1. Here the substrate changed from rocky to sandy.

F. serratus was found from the lowest height level (0 – 0.5 m) to the top of the second highest (1 – 1.5 m) level. It occurred in every transect except transect 9. The percentage cover ranged from < 5 % to 100 % in the sample squares. *F. distichus* was present in every transect except 4 and 10 and appeared on the same height levels as *F. serratus*. Hybrids were found in the field only in the transects 3 (height level 2), 5 (height level 1) and possibly also 9 (height level 4; see section 3.7). The cover ranged from 5 % to 30 % in the sample squares.

As can be seen in Figure 3, *F. serratus* covered in general more substratum than *F. distichus*. *F. serratus* was in general more abundant in the two lowermost levels, whereas *F. distichus* was most abundant in the second level. There was a strong heteroscedasticity of the scores within each height level for both species. Therefore no statistical testing was done between species per height level.

First height level (0 – 0.5 m above chart datum)
(see Figure 4)

On the lowest height level, *F. serratus* appeared in all transects except number 9. The second transect was not sampled due to too much wave-action, but some big *F. serratus* individuals could be spotted in this level. In transect 9 the substratum was only mud, with

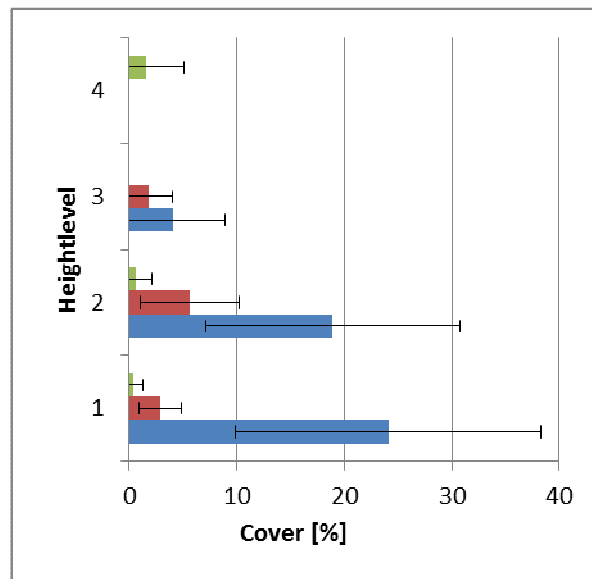


Figure 3: Average percentage cover of sample squares with 95 % confidence limits (n = 50 or 55) of *F. serratus* (blue), *F. distichus* (red) and hybrids (green) related to height-levels. Height levels: 1 = 0 - 0.5 m; 2 = 0.5 - 1.0 m; 3 = 1.0 - 1.5 m above chart datum. 95 % confidence intervals are given.

almost no macroalgae growing there. Only in one single sample square one individual of *F. distichus* was found. Except in transects 6, 8 and 9, the substrate consisted of rocks and pebbles. The transects 6 and 8 were characterized by rather muddy substrate, with some small stones and big rocks distributed sparsely within the sample plots. The results of the KWt and Nemenyi-Test showed that there was a significantly higher density of *F. serratus* in transect 7, located on the eastern shore of the small island, than in transects 5 and 8 (KWt = 7.84; KWcrit = 15.51; p < 0.05). No other significant density differences between the transects were detected. The average cover by *F. serratus* ranged from 0 % to 63 % with the lowest cover in 5 and the highest in 7.

F. distichus was found in transects 1, 3, 5, 6, 8 and 9. In transects 1, 3 and 6 the cover was less than that of *F. serratus*, in 5 it was slightly higher. Transect 8 contained an equal amount of both species (4 %). In transect 9 it occurred alone with an average cover of 5 %. The highest average value of *F. distichus* on this height level was 7 %.

Hybrids were only found in the transect 5, where their cover (4 %) was intermediate between the cover of *F. serratus* and *F. distichus*.

When comparing the results where two or three of the three examined groups were found

by using Welch's t-tests no significant inter-specific difference in cover was found on the first level.

Kelp plants were present in all transects except 6, 8 and 9 at the first height level, and covered between 30 and 50 % of the substratum. The highest density of kelp specimens was re-

corded for transect 11 with an average cover of 50 % (SD±38.1). The understory cover was low and covered in most cases less than 10 % of the substratum. An exception was transect 5 where the understory algae covered in average 22 % (SD±24.9) of the substratum. Only small amounts of *F. vesiculosus* and *A. nodosum* were recorded in this height level.

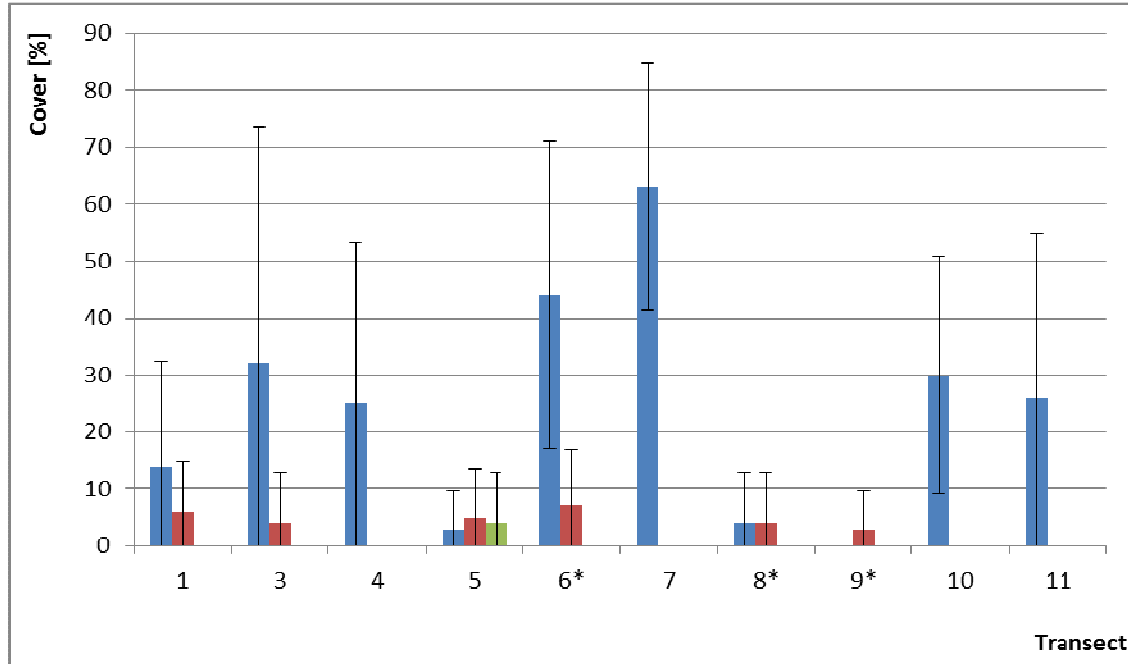


Figure 4: First height level (0 – 0.5 m above chart datum): Distribution of *F. serratus* (blue), *F. distichus* (red) and hybrids (green) along the examined transects. Average values with standard-deviation. *= muddy or partly muddy substrate as described in the text.

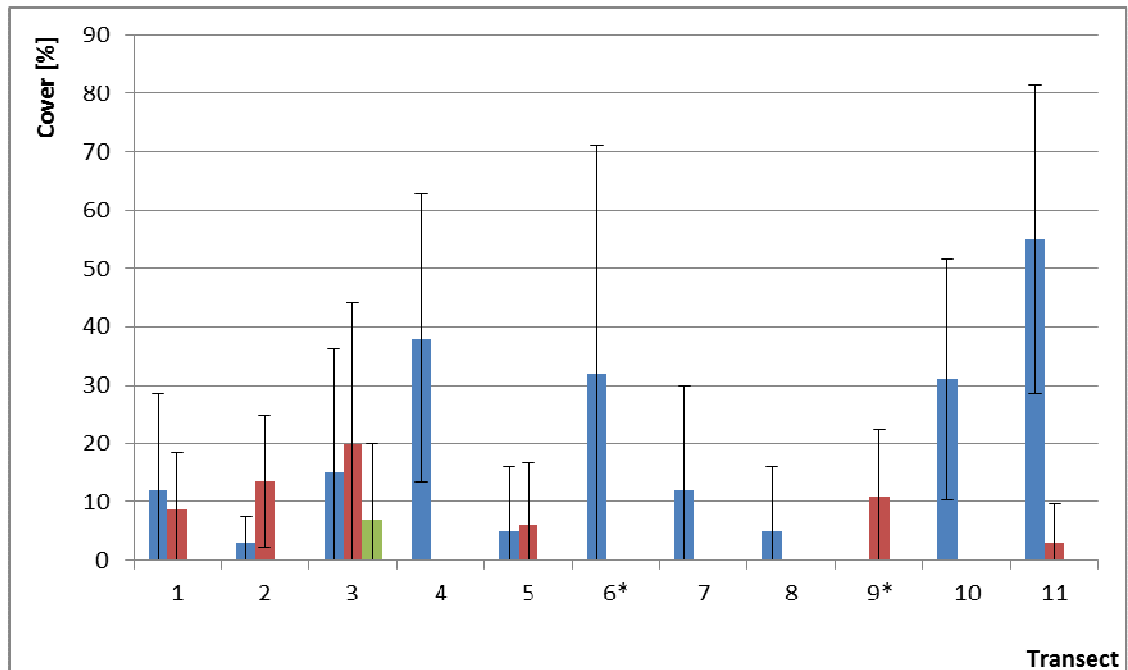


Figure 5: Second height level (0.5 – 1 m above chart datum): Distribution of *F. serratus* (blue), *F. distichus* (red) and hybrids (green) along the examined transects. Average values with standard-deviation. *= muddy or partly muddy substrate as described in the text.

Second height level (0.5 m to 1 m above chart datum) (see Figure 5)

The distribution of *F. serratus* in this height level was the same as in the first height level regarding the transects in which it was found, while *F. distichus* was found in the transects 1, 2, 3, 5, 9, 11 within this level. Hybrids were recorded in transect 3 within this level with an average cover of 7 %.

The average cover of *F. serratus* ranges from 0 % (transect 9) to 55 % (transect 11). The cover was significantly higher in transect 11 (on the western of shore of the island) than in transects 2, 5 and 8. (KWt = 23.66; KWcrit= 16.92; $p < 0.05$ combined with Nemenyi-Test on summed ranks). *F. distichus* was evenly distributed and showed no significant difference in cover between the transects. The cover ranged from 0 to 20 %.

A significant difference between the cover of *F. serratus* and *F. distichus* in the second height level was found in the transect 11, where *F. serratus* was highly more abundant (Welch's t-test = 5.87; df = 7; tcrit= 2.635; $p < 0.05$).

The substratum in this height level was rocky, except in transects 6 and 9 where mud dominated. Kelps were mostly absent within this level. Only in the transects 4, 5, 7 and 10 some specimens were noted. In the transects 4 and 5 the cover reached 19 % (SD±12.45) re-

spectively 27% (SD±19.24) of the total substratum, in the other two it was less than 10%. Understory algae were recorded in every transect except 7, 9 and 10. The cover was mostly less than 10 % of the examined substratum, but reached an average of 56 % (SD±23.02) in transect 5. Variable amounts of *F. vesiculosus* and *A. nodosum* were found within this level. In transect 7 the average cover of *A. nodosum* was almost 90% (SD±21.68). *F. vesiculosus* was most abundant in transect 6 where it covered on average 33.75 % (SD±24.28) of the substratum.

Third height level (1 m to 1.5 m above chart datum) (see Figure 6)

The third height-level was only poorly settled by *F. serratus* and *F. distichus*. *F. serratus* occurred in transects 4, 6 and 11, and *F. distichus* in transects 3, 5, 6, 9 and 11. The highest average cover of *F. serratus* was 17.5 % in transect 11. There were no significant differences in cover, neither inter- nor intraspecific.

Kelp species were only found in transects 1, 4, 6, 10 and 11, with very little cover (less than 5 %). Also very little understory species were recorded. Only in transects 1, 3, 4 and 6 understory algae were found with ≤ 10 % substratum cover. This height level, as well as the fourth, was dominated by *F. vesiculosus* and *A. nodosum*. There was no significant difference in cover of these species.

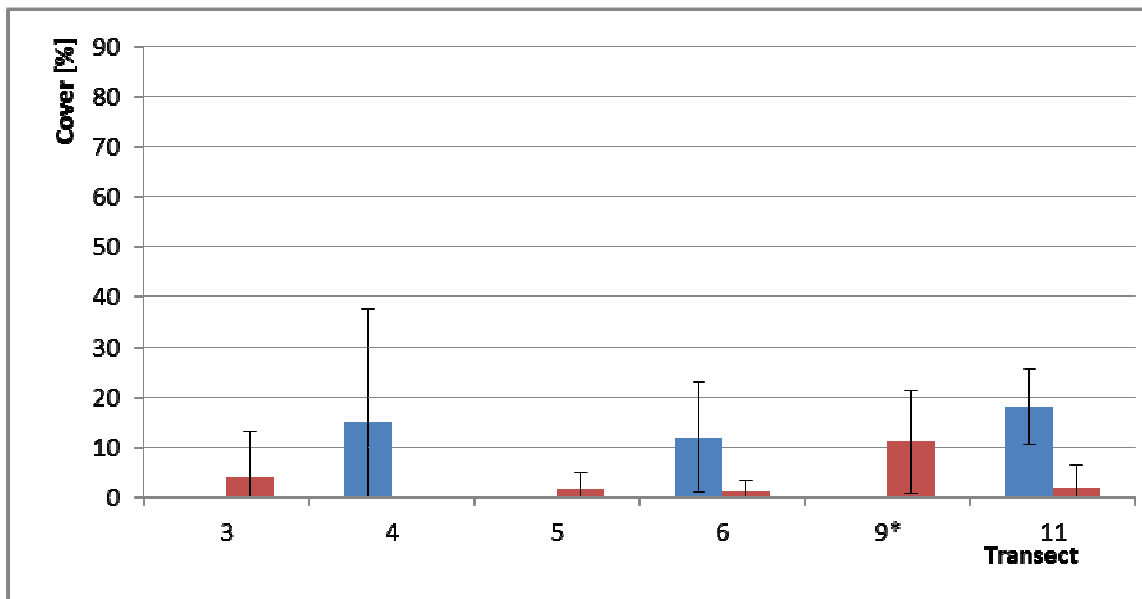


Figure 6: Third height level (1 – 1.5 m above chart datum): Distribution of *F. serratus* (blue), *F. distichus* (red) and hybrids (green) along the examined transects. Average values with standard-deviation. *= muddy or partly muddy substrate as described in the text.

On the uppermost height-level neither *F. serratus* nor *F. distichus* was found. Possible hybrids were found in transect 9 with an average cover of 7 %.

3.3 Relationship between *F. serratus* and *F. distichus* density

When comparing the average cover of *F. serratus* and *F. distichus* within each height level of each of the transects, no significant differences were found. However, a test for correlation on arcsine-transformed data for cover of *F. serratus* and *F. distichus* showed a significant negative correlation ($r = -0.4544$, $r^2 = 0.2065$; $n = 174$; $p < 0.0001$), indicating that an inverse relationship can be found between the two species (Figure 7). The removal of the outliers changed the value for r just slightly. To avoid interference by height level, correlation was tested within each level. Also this showed a significant negative relationship in each case (height level 1: $r = -0.3990$; $r^2 = 0.1289$; $p < 0.05$; $n = 62$; height level 2: $r = -0.4050$; $r^2 = 0.1640$; $p < 0.05$; $n = 86$; height level 3: $r = -0.7823$; $r^2 = 0.6120$; $p < 0.05$, $n = 14$).

3.4 Biomass distribution

The total biomass values show the same distributional pattern as the density values (data not show). The average biomass of the species and hybrids per sample square, based on fresh weight, is as follows:

	g/250 cm ²	Confidence interval (95%)
<i>F. serratus</i>	244.48	± 146.55
<i>F. distichus</i>	27.37	± 15.16
Hybrids	5.05	± 0.91

3.5 Comparison of plant size and internode length

Size of individuals

The size of sampled *F. serratus* ranged from 4.3 cm to 108 cm, the size of *F. distichus* from 3 cm to 36 cm and the size of the hybrids from 6 cm to 64 cm. When the specimens were very small, the determination of whether the plant was a hybrid or belonged to one of the species was difficult. The potential hybrid individuals were sampled for genetically analysis, which may allow making clearer criteria of determination for upcoming surveys.

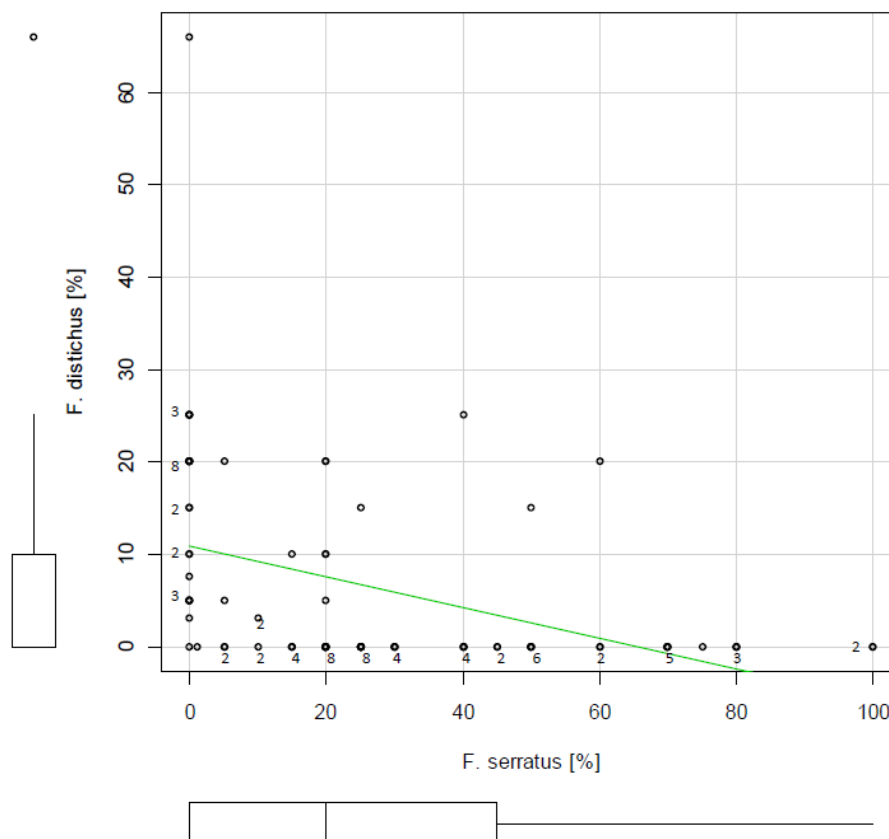


Figure 7: Cover of *F. serratus* density in relation to cover of *F. distichus* density. Many 0-points represent replicate values (as indicated by numbers). The least-square-line and boxplots on the axes for data aggregation are given.

The difference in size between *F. serratus* and *F. distichus* plants could only be tested for the transects 1, 2, 3 and 5, which contained sufficient samples for comparison. To avoid errors due to non-normality and heteroscedasticity, the statistical tests were done on ranked data. Figure 8 shows the average sizes in the three groups with 95 %-confidence intervals. A comparison of all pooled data from all transects is also shown in Figure 8. In transect 1 the *F. serratus* plants were significantly longer than the *F. distichus* and hybrid plants. (KWt = 7.30 with χ^2 crit; FG=2 = 5.99; $p < 0.05$ and Dunn's Test *F. serratus* vs. *F. distichus* = 24.23 with crit = 22.46). Dunn's Test detected no significant difference in size between *F. distichus* and hybrids. This may be due to the small number of hybrids that directly influences the variance.

An even more significant difference in size between *F. serratus* and *F. distichus* was found in the second transect with Welch's t-Test = 10.46 (df = 35; tcrit, = 2.030; $p < 0.05$). But, again, the test result is not very reliable due to the low sample size of *F. serratus*. In transect 3 the *F. serratus* specimens were significantly longer than the *F. distichus* specimens (KWt: χ^2 = 27.44 with χ^2 crit; F=2 = 5.99 and Dunn's Test *F. serratus* vs. *F. distichus* = 24.69 with critical = 13.77; $p < 0.05$). The hybrids showed a very wide confidence interval due to the small sam-

ple size. In transect 5 no significant difference between the *F. serratus* and *F. distichus* plants was detected (Welch's t-test = 0.15; df = 3; tcrit=3.182; $p < 0.05$). The comparison of all pooled data clearly showed a trend with *F. serratus* being significantly taller than *F. distichus*. The hybrids were intermediate.

Internode lengths

Data for internode lengths of *F. serratus* from transects 1, 3, 6, 11 and pooled data for hybrids were tested within the first height level (Figure 9). Four of the five compared average internode lengths of the first height level are similar (One-way ANOVA on log-transformed data: F = 9.47; Fcrit = 2.49; $p < 0.05$; n = 83). Only the pairs of transect 1 and 11 and 6 and 11 showed significantly different values, with the internode lengths of plants from transect 1 and 6 being shorter than those from transect 11. Also the average internode length measured for hybrids is significantly shorter than that of *F. serratus* in transect 11. The hybrid internodes are in general shorter in this level than those of *F. serratus*, but only significant in the aforementioned case.

In the second and third height level no significant differences were found among the examined transects. The internode lengths ranged from 3.17 cm to 4.26 cm. Data for height level 2

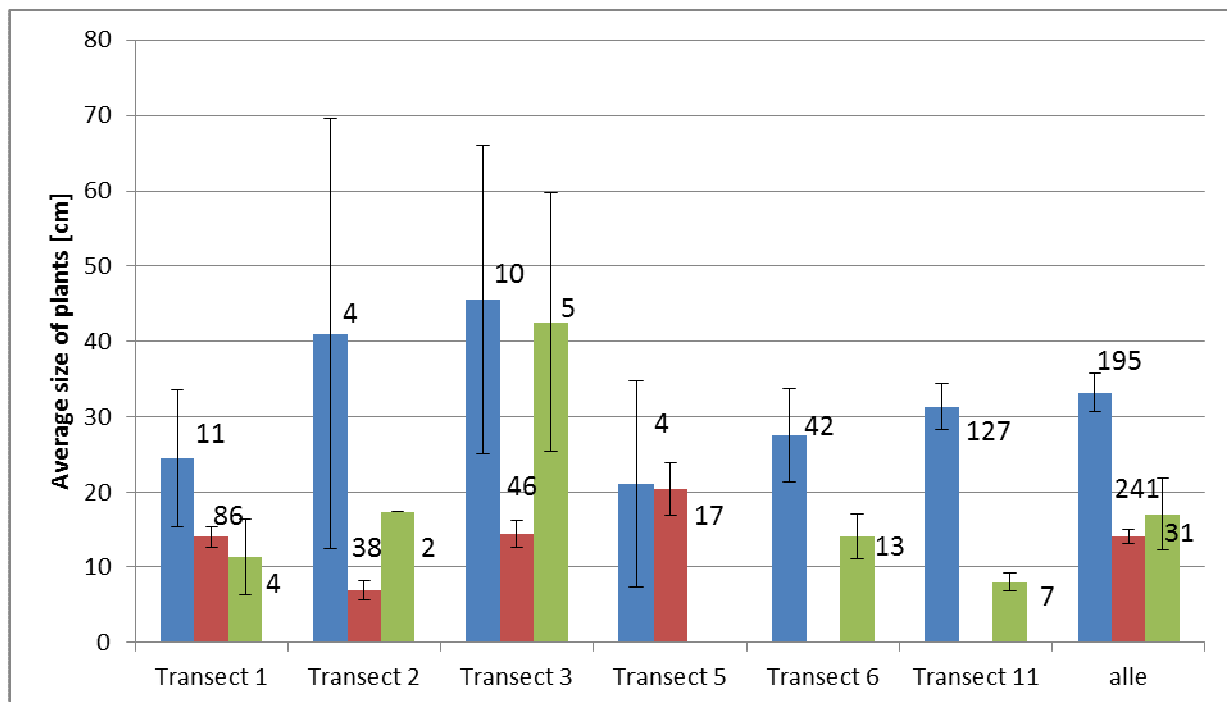


Figure 8: Average sizes of *F. serratus* (blue), *F. distichus* (red) and hybrid plants (green) with 95 %confidence intervals and total number of individual per column.

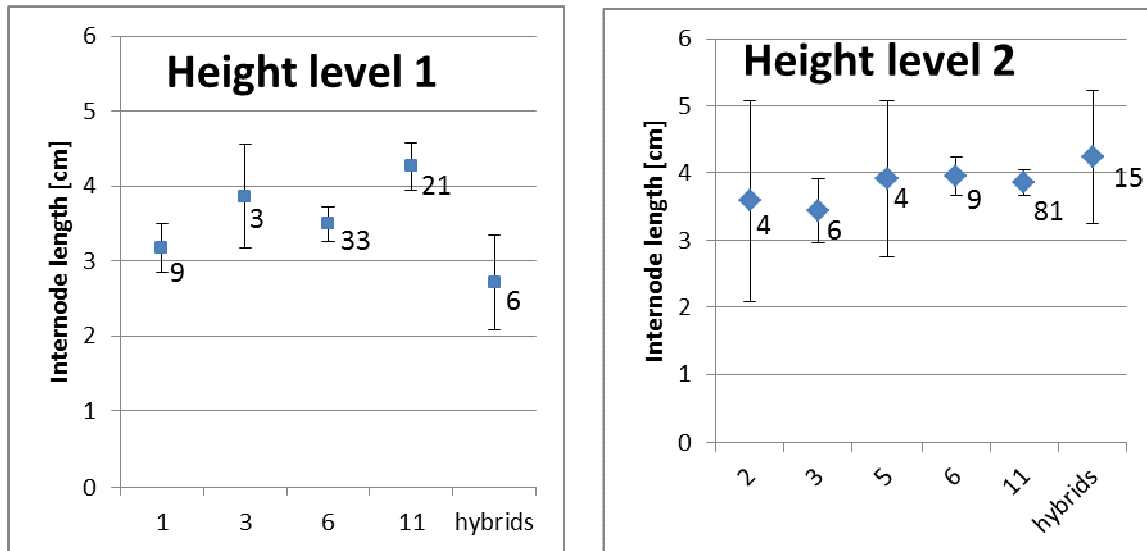


Figure 9: The average internode lengths of *F. serratus* (from transects 1, 3, 6 and 11) and hybrids for the first and second height levels. 95 % confidence intervals and number of measurements per value are given.

shown in Figure 9. Furthermore, no differences were found between the height levels.

The number of dichotomies was strongly correlated to the plant length ($r = 0.9375$; $r^2 = 0.8789$; $p < 0.05$; $n = 196$), with number of dichotomies increasing linearly to around 20 in plants around 80 cm long (Figure 10).

3.6 *Spirorbis spirorbis* distribution

Intraspecific tests on significant differences between the height levels in densities of *S. spirorbis* on the *Fucus* plants showed that there were none. This conclusion allowed pooling of all data and a comparison of *S. spirorbis* density between the three host types (*F. serratus*, *F. distichus* and hybrids).

A comparison of numbers *S. spirorbis* per gram fresh weight of *F. serratus* and *F. distichus* by using Welch's t-test showed that there was a significant difference in *S. spirorbis* density on the two species ($t = 3.91$; $df = 61$; $t_{crit} = 1.9996$; $p < 0.05$). *F. distichus* plants were significantly more covered with *S. spirorbis* individuals than *F. serratus* plants were (Figure 11). Hybrids had an intermediate cover, with densities not being significantly different from those of the two species.

3.7 Reproductive features

The sex ratio was 1.17:1 (34 male : 29 female from transects 3, 6 and 11. No more data was available due to mistakes in the determina-

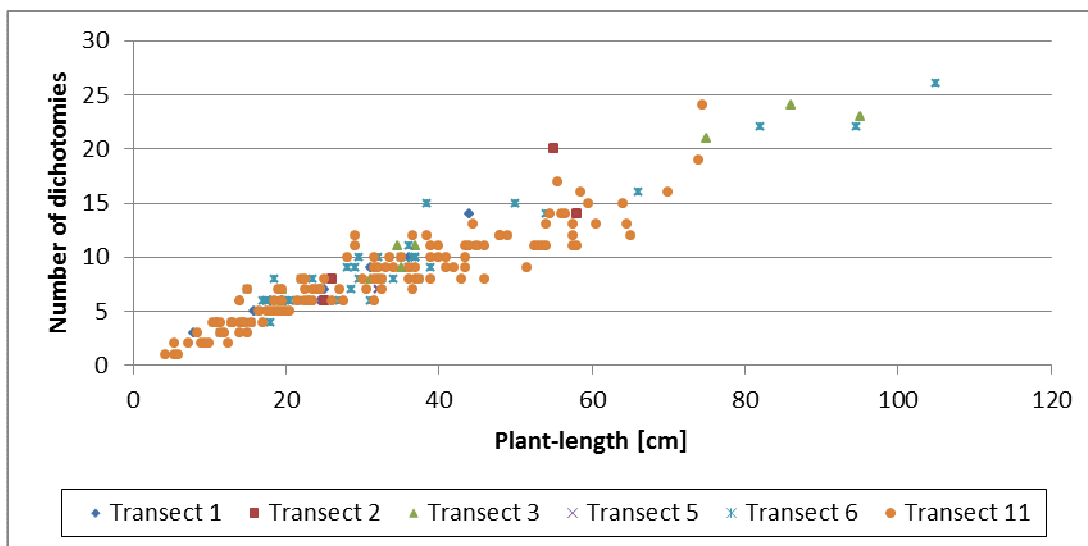


Figure 10: Maximum number of dichotomies related to individual plant length of *F. serratus*.

tion). The smallest specimen of *F. serratus* carrying receptacles was 19.5 cm long. This does not imply that every plant of this size or taller had receptacles. There were several taller plants without receptacles. The size of vegetative plants ranged from 4.5 to 41 cm. The average minimum size for mature plants from each transect per height level was 31.6 cm, ranging from 19.5 to 36 cm. The smallest plant is taken from the 2nd height level of transect 11, the tallest from the first height level of transect 1 and the

3rd height level of the transect 6. All others ranged from 25 cm to 35 cm. No receptacles were noticed on *F. distichus* plants. The receptacles of the hybrid plants often had a special morphology (Figure 13). While the receptacles on *F. serratus* plants covered the whole width of a branch tip, the hybrid receptacles often occupied only a section. This was often accompanied by an abrupt change in pigmentation of the branch.

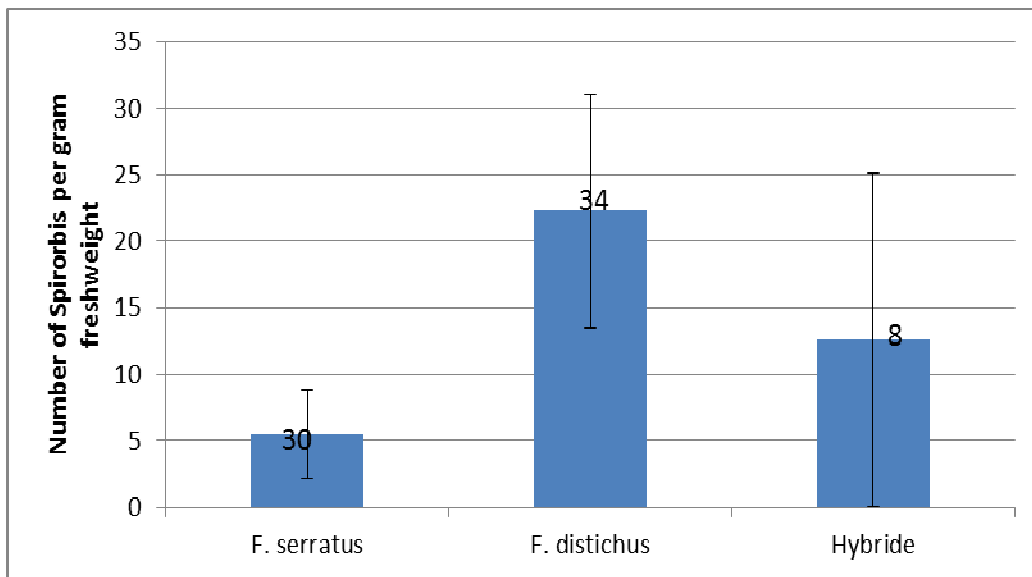


Figure 11: Comparison of the average number of *S. spirorbis* individuals per gram fresh weight of *F. serratus*, *F. distichus* and hybrids. Confidence interval (95 %) and number of individuals examined are given per column.



Figure 12: *F. serratus* (right) and *F. distichus* (left) with *S. spirorbis*. The picture was taken on 15 October 2012 eastwards from transect 6.

In the lowermost height level, the majority of the receptacles were in maturity state 3 and all were found on *F. serratus* plants (Figure 14). In transects 11, 6 and 3 between 50 % and 60 % of the receptacles were in this state, and in transect 1 around 30 %. Transects 3, 6 and 11 contained the smallest fractions of receptacles in maturity state 1 (1 % to 9 %), while plants from transect 1 had the largest fraction of receptacles in maturity state 1 (22 %). Fractions of the receptacles in maturity state 2 varied between 16 and 23 % in the transects, and the fractions of receptacles in maturity state 4 varied between 16 and 24 %. All in all, 72 plants with receptacles were found in this height-level, with altogether 3088 receptacles.

In the second height-level only 18 receptacles altogether were found in the sixth transect, which is much less than in the first height-level, where 1971 were counted. Due to the small number, this transect will not be considered further. Highest fractions of receptacles of the maturity states 2 or 3 were found in all transects at this height level, with the fraction of state 3 in two cases higher than of state 2 (Figure 14). Mature hybrids were also found within this level. Though 116 plants were examined (with four of them from the second transect, which was not examined for the first height-level), only 2615 receptacles were counted, suggesting



Figure 13: Branch tip of a hybrid carrying a receptacle. Note the section with conceptacles on only one side of the branch, the pigment variations and the slight serration of the edges of the branch.

a lower density of receptacles per individual at this height level than at the first.

For the third height-level only 21 receptacles from altogether 25 *F. serratus* plants were categorized, from transects 6 and 11. Also here the maturity states 2 and 3 dominated (Figure 14).

According to the number of receptacles per plants, the lowermost levels seem to be the more reproductive ones. However, when comparing the amount of the receptacles in relation

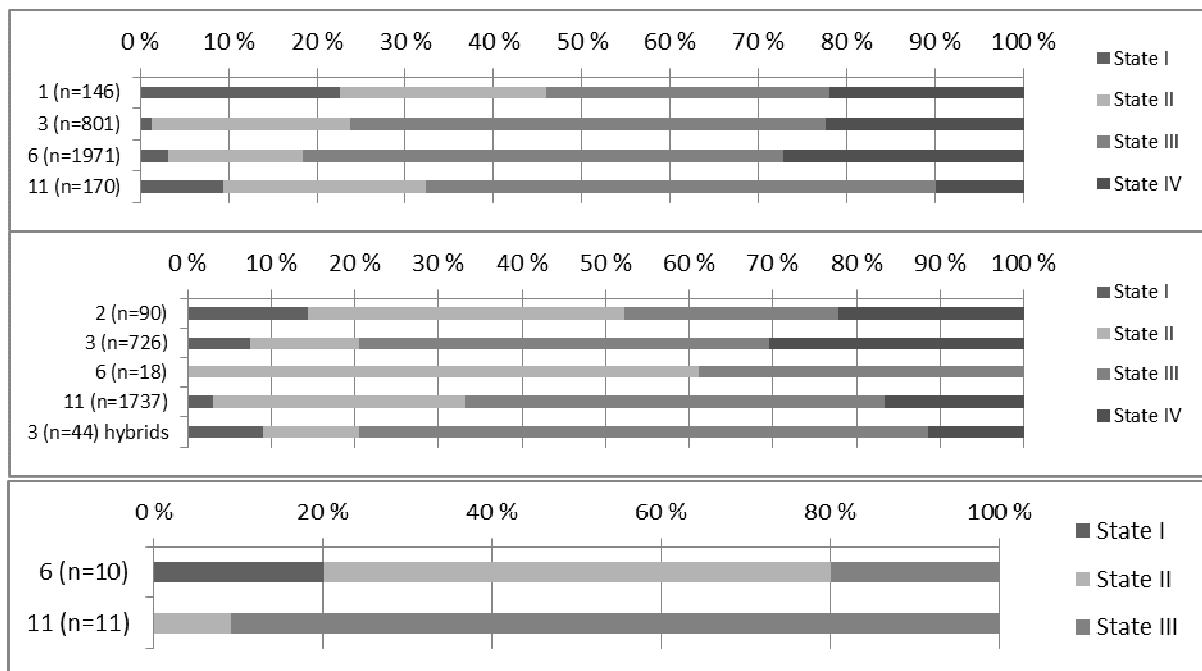


Figure 14: Comparison of the state of maturity of the receptacles from the different height levels. Graphs from top to bottom represent height levels 1 to 3. For each bar, the transect numbers (to the left) with numbers of counted receptacles (in brackets) are given.

to the total biomass of the plants between the height levels no differences in the ratio were found, though the third height-level does not include much data and is therefore not reliable. The total number of receptacles decreases, but so does the total biomass of *F. serratus* and hybrids, too. There is no evidence that the total amount of reproductive biomass in relation to the total plant weight decreases with a higher level.

3.8 Special morphological features of possible hybrids from the 4th height level

Some small *Fucus* individuals from height level 4 in transect 9 showed both small serrations and bladders (Figure 15). Beside these morphological and distributional features, they showed no difference in size, biomass or *S. spirorbis* settlement compared to the other hybrids. Samples for genetical analysis were taken.

4. Discussion

4.1 Habitat at the sampling site

The highest average values of *F. serratus* cover are found in transects 7 and 11 on the small island, and the lowest are found in transects 8 and 9 close to a creek with muddy substrate. According to Evans (1947) *F. serratus* requires a rather low inclination of the shore and must be sheltered from high surf impact and wave battering for successful settlement. The sampling site of the present study is mostly rocky and with inclinations ranging from 2° to 17°. The prevalence of *A. nodosum* and *F. vesiculosus* on the higher levels of all transects is an indicator for sheltered shores (Ingólfsson, 2006) which is to be expected within a fjord. Also the recorded salinity and temperature values are in the range described under 1.3. However, the recorded data gives just a small idea of the annual variation at the site. The prevalence of *F. vesiculosus* in some transects suggests more wave action here, but may also be caused by the scarcity of rocky substratum and crevices for *A. nodosum* settlement (Keser & Larson, 1984). Three transects (6, 8 and 9) are muddy in the lowermost height level. Two of these (8 and 9) are probably also affected by the freshwater runoff from a little river. East and westwards from the sampling site the substratum is mostly sandy which might function as a natural barrier for further spreading (Arrontes, 1993; Chapman & Fletcher, 2002).



Figure 15: Picture of a possible hybrid collected from the 4th height-level of transect 9. The arrows indicate a bladder and smooth serrations.

The internode lengths of *F. serratus* specimens only showed significant variations in the first height level, and the longest internodes on average were found in transect 11. Together with the data for cover from transect 11, this indicates good environmental conditions for the growth of *F. serratus* in this transect (Knight & Parke, 1950). However, the differences in internode lengths may also have another explanation. It has been shown for plants that a reduction in light supply or an altered light composition can lead to a higher elongation growth and less branching, since nearby plants can shade or change the light composition, thereby inducing competition (reviewed in Schmitt & Wulff, 1993). A high cover of kelps was found in transect 11 in the lowermost level, followed by transect 3 where the *F. serratus* plants also had long internodes. Since kelps form long and broad laminas they can possibly shade and thereby influence the elongation growth of *F. serratus*.

4.2 Distribution of *F. serratus*, *F. distichus* and hybrids

F. serratus and *F. distichus* were not always found together. Generally *F. serratus* was found in more transects without *F. distichus* than vice versa. Basically both species were found in the same height levels and were never found in the uppermost level. The total density of *F. serratus* decreased with increasing height level, whereas *F. distichus* showed no obvious preference of height level. The absence of *F. serratus* in transect 9 and the poor settlement in transect 8 could be due to the muddy substrate conditions here. However, also transect 6 is muddy in the

lowermost levels, but here one of the highest covers of *F. serratus* of this study was found. Furthermore, *F. distichus* was abundant in transects 8 and 9 with no less cover here than in other transects, while only small amounts were found in transect 6. Transects 8 and 9 separate from the other transects by being close to a little river. Narrow bladed *F. distichus* have been reported from tidal pools (Rueness, 1977), where salinity may vary substantially during low tide due to fresh water aggregation or water evaporation (Nybakken & Bertness, 2005). Therefore, it could well be that the freshwater runoff negatively affects the settlement or establishment of *F. serratus* zygotes, but not of *F. distichus* in this population. It has been reported by Malm et al. (2001) that a decrease in salinity dramatically reduces the fertilization success in *F. serratus*.

Hybrids of *F. serratus* and *F. distichus* were found within the distributional range of the parental species. Hybrids with an unexpected morphology were found in the fourth height level. These hybrids seemed to be a morphological mix of *F. serratus* and *F. vesiculosus*, showing both serrations and bladders. They were found higher up on the shore than *F. serratus*, in a zone dominated by *F. vesiculosus*. *F. vesiculosus* x *F. serratus* hybrids have been reported from the laboratory (Burrows & Lodge, 1953), and Knight and Parke (1950) found specimens in the field which resembled *F. vesiculosus* in vegetative features, but seemed to have receptacles with a typical *F. serratus* form. However, according to Coyer et al. (2007) *Fucus* hybrids observed in the field always seem to involve one monoecious and one dioecious parent (Coyer et al., 2007). In order to examine if the observed potential hybrids are *F. serratus* x *F. vesiculosus* offspring, samples for genetical analysis have been taken.

4.3 Substratum cover, biomass per area and plant size

F. serratus was generally more abundant than *F. distichus*. Due to a distinctive heteroscedasticity among the examined sample squares only a few significant differences between height levels and transects were found. According to Arrontes (1993), *F. serratus* zygotes settle rather patchy, and this may explain the great variances between the squares. Furthermore, a significant negative correlation in density was found between the two species. Canopy forming

fucoid algae can cause a severe shading of other species (Schonbeck & Norton 1980). *F. serratus* can grow a significantly longer thallus than *F. distichus*, and thereby shade and provide worse growth conditions for *F. distichus*. According to Ingólfsson (2008) *F. serratus* seems to have caused a decrease in *F. distichus* cover in the lower levels of the shore at the sites on Reykjanes where both are established. Although there are no significant differences in cover of *F. distichus* between the height levels, it can be seen that the second height level has twice the cover of the first height level and two times more cover than the third. It could be that *F. distichus* is negatively affected by *F. serratus* in the lowermost level and cannot settle in the upper levels where *A. nodosum* and *F. vesiculosus* cover the substrate by 100%.

Hybrids were found sparsely distributed and represent only a small part of the total examined population. Coyer et al. (2007) reported an amount of 13 % of a *Fucus* population as hybrids. In his study the two species (*F. serratus* and *F. distichus*) had been in contact for 60 to 100 years. If it is assumed that the examined population in Hvalfjörður has persisted for only maximum of about 15 years, this may be too short time for establishing a higher amount of hybrids. In the present study receptacles were only found on *F. serratus* and hybrid plants. It has been reported by Knight & Parke (1950) that receptacles on *F. serratus*, which have been formed in autumn, still release few gametes in the next January. Bird & McLachlan (1976) reported receptacles on *F. distichus* from late autumn to late spring, but great variances in timing of the fertile period have been reported for *Fucus* (Knight & Parke 1950; Malm et al., 2001; Berger et al. 2001). In Hvalfjörður the recruitment window for forming hybrids may be open only during a short period of the year, which may result in few hybrids being formed per generation.

F. serratus x *F. distichus* hybrids found in the field by Coyer et al. (2002) were exclusively the result of *F. distichus* eggs fertilized by *F. serratus* sperm, which makes successful crossing even more unlikely. This phenomenon can be explained by several theories: The asymmetrical mate choice hypothesis of Kaneshiro (1976) assumes that eggs of derived species can be fertilized by ancestral sperm, but not vice versa. The derived sperm might have lost char-

acteristics that are necessary for acceptance by the eggs. Alternatively, there might be an asynchronous release of *F. serratus* eggs and *F. distichus* sperm contrary to the reverse case (Coyer et al., 2002).

Coyer et al. (2002; 2007) assumed that selection is against hybrids in the natural environment. On the one hand the survivorship of hybrids is assumed to be comparable to that of the parental species (Coyer et al., 2007). On the other hand, the fitness of F1 hybrids may be low. The total amount of released eggs in hybrids was reported to be the same as in *F. serratus* and *F. distichus* (Coyer et al., 2007), but the development of the oogonia differed from those of the parent species. When compared to those of *F. serratus* and *F. distichus* the oogonia of hybrids contained fewer eggs and the eggs were of more variable sizes. Furthermore, offspring derived from fertilized F1 eggs was significantly less successful in laboratory experiments than offspring from parental crossings (Coyer et al., 2002). The comparison of plant sizes in the present study showed that hybrids were significantly smaller than *F. serratus*. Hence, a dense *F. serratus* canopy might suppress growth and performance of both *F. distichus* and hybrids. Therefore, selection may be against hybrids, for several reasons, in the natural environment (Coyer et al., 2002; 2007).

4.4 *Spirorbis spirorbis* distribution

While *S. spirorbis* has been found to prefer settling on *F. serratus* in earlier studies (Williams 1964), it was most abundant on *F. distichus* in the present study. This could have multiple reasons and could be explained by pre- as well as post-settlement events, such as discriminating settling behavior or unequal mortality on the different species.

S. spirorbis larvae have a system to discriminate between habitats (Gee & Williams, 1965). Where the preferred *F. serratus* is sparse, *S. spirorbis* have adapted to other algae as settling substratum (Knight-Jones & Knight-Jones 1977). Williams (1964) assumed that a single mutation in the genome could lead to an alteration in substratum preference. Even a single individual could give this mutation to the next generation, since *S. spirorbis* is capable of self-fertilization (Gee & Williams, 1965). Since *S. spirorbis* settles highly gregarious (Knight-Jones, 1951), a changed genetically determined substratum preference could persist and lead to

isolated populations and speciation (Williams, 1964). On Iceland the native *F. distichus* may be the preferred host, since it here has co-existed with *S. spirorbis* for a long time period. Native *S. spirorbis* larvae may not recognize the relatively newly introduced *F. serratus* as a host.

Alternatively, the different morphology of *F. serratus* and *F. distichus* may cause a differential settlement of *S. spirorbis* larvae. *F. serratus* has a thallus with open cavities with emerging hairs (called cryptostomata) on the surface, while *F. distichus* has a smooth thallus surface (Rueness, 1977). The presence of these cryptostomata with hair groups may possibly prevent settlement of *S. spirorbis* larvae (for description of exploratory stages in *S. spirorbis* larvae see Knight-Jones, 1951). This hypothesis is supported by the fact that the hybrids have a mixed phenotype of the parental species and also have an intermediate degree of settlement of *S. spirorbis*.

Epifauna may interfere with and have a negative impact on their hosts (e.g. Williams, 1996). It is known that the settlement of larvae on seaweeds can be inhibited by phlorotannin and phloroglucinol, which are both natural compounds of fucoids (Lau & Qian, 1997; Brock et al., 2007). As Wikström et al. (2006) have shown introduced species can have a higher content of defensive components in new environments and be less grazed by herbivores than in their original habitats. In a similar way a possible differential content of chemical defense compounds of *F. serratus* and *F. distichus* may explain the differential abundance of *S. spirorbis* on *F. distichus* and *F. serratus*.

Finally, one cannot exclude that post-settlement mechanisms (see Wikström & Pavia, 2004) play a major role for the observed pattern of abundance of *S. spirorbis* on *F. serratus* and *F. distichus*. *S. spirorbis* larvae might prefer *F. serratus* as settling substratum, but may possibly suffer a higher rate of mortality on *F. serratus* in comparison with *F. distichus* or the hybrids.

5. Conclusions and Outlook

F. serratus has established several patches among the examined site. Within the natural boundaries set by the muddy substratum conditions next to the site, an exponential growth of the *F. serratus* population is possible as de-

scribed by Arrontes (2002) for a population in Oleiros, Northern Spain. *F. serratus* seems to impact the floral and faunal association in Hvalfjörður, Iceland. It likely effects the distribution and abundance of *F. distichus* negatively, what is an important settling ground for *S. spirorbis*. The further spreading of *F. serratus* and a reduction of *F. distichus* abundance by *F. serratus* would affect the local *S. spirorbis* population either by reducing it or leading to a change in setting behavior. This effect may not only concern *S. spirorbis*, but also other epiphytic organisms or grazers of the local association. *F. serratus* may also have effects on the *Laminaria* population or understory species, since all are found most abundant within the same height levels. An effect on *F. vesiculosus* or *A. nodosum* might be less severe because these species seem to prefer other height levels. It has been shown by Wikström & Kautsky (2004) for *F. distichus*, as being invasive in Sweden, that an introduced *Fucus* species may be very successful at spreading but being a less used food source or habitat for associated flora and fauna. Although this conclusion was made by Wikström & Kautsky (2004), no evidence was found that a decrease in total species richness took place. However, further experiments are required to prove a possible effect of *F. serratus* on *F. distichus* and the associated community in Hvalfjörður.

The hybrids are able to form receptacles. Therefore introgression between hybrids and parents might occur. Some specimens were difficult to determine as belonging either to the parental species or being hybrids with extremely smooth serrations. These could have been just natural disturbances in plant growth or the result of introgression to the F2 generation. Although Coyer et al. (2002) reported F1 hybrids from the field, genetic analyses have shown that introgression was absent in the examined population but found in another survey to a little amount (Coyer et al., 2006a). Introgression can lead to gene flow between species with severe impacts on ecosystem structures (Rieseberg, 1998). This relatively young population of mixed *F. serratus* and *F. distichus* with possible formation of hybrids could be a good spot for further examinations on hybridization and speciation in seaweeds and its effects on intertidal seaweed communities.

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