Fish community structures on the island of Curaçao:

a functional comparison of five bays.

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On the cover:

A school of cottonwick grunts (*Haemulon melanurum*). Photo credit: Martijn Dorenbosch

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ABSTRACT

This study focuses on the relation between bays and coral reefs with respect to reef fish communities. It is thought that shallow coastal waters function as important nursery rooms for coral reef fishes. Earlier studies in shallow coastal waters only considered seagrass beds and mangroves. It appeared that these biotopes harbour high densities of juvenile fish. This study analyses nursery function of all available biotope types in several bays on the island of Curaçao, situated in the southern Caribbean. The fish community of each bay is compared with the fish community on the coral reef.

Fish communities were sampled both by the visual census technique and by capturing fish with several methods. Five different bays on the island were studied as well as the adjacent coral reefs. Spaanse Water bay was studied in more detail. In this bay, the fish communities of seven linked shallow water biotopes (mangroves, seagrass beds, algae fields, deep channels, rocks and niches) were examined on a spatial and temporal scale. Fish communities in each biotope type and differences in fish community between day and night, the lunar phases and different seasons were studied. Fish communities were analysed with multivariate statistic programs (TWINSPAN and CANOCO). Digestive tracts of captured fish were analysed to obtain a view of the diet of fish communities in different bays.

Several conclusions are presented in this report:

1. The bay biotopes mainly harboured juvenile fish. Grunts (Haemulidae) were dominant in bays with a high visibility that were located on the south coast of the island. Snappers (Lutjanidae) and mojarras (Gerridae) were dominant in turbid bays that were located on the north coast of the island. The reef of the south coast showed a high degree of structure and was characterised by the dominance of small fish species (e.g. damselfishes, wrasses). The reef of the north coast was exposed to strong waves and heavy winds and showed a low degree of structure. Here, only large fish species (e.g. chubs, groupers and jacks) were dominant. Snappers and grunts were mainly present on the reefs located on the south coast.

2. Results from the detail study of Spaanse Water showed a clear gradient of biotopes from deep reef to shallow reef to channels, rocks and niches in the entrance of the bay and extended to biotopes situated further into the bay such as mangroves, seagrasses and algae fields. This gradient was used by different diurnal fish communities. During night the bay was characterised by only one nocturnal fish community.

3. The fish community of Spaanse Water is divided into several groups. Spaanse Water functions as a nursery room for a number of coral reef fishes. Juveniles of these species are observed in the bay, while adults are observed on the reef. Especially mangroves, seagrasses and rocks harboured high densities of juvenile fish. Other species only use the shallow areas of the reef as a nursery room and are seldom observed in the bay. Finally, some species are observed in the bay only. These species complete their entire lifecycle in the bay.

4. Differences in biotope use of fish communities between day and night are related to the function of these biotopes. Mangroves and rocks provide much shelter but showed a low food availability. During day these biotopes are used for shelter. At night shelter becomes less important and fish species disperse and feed on the seagrasses and *Halimeda* fields. Parrotfishes and very small juveniles of grunts and snappers were only observed in the seagrasses and use this biotope both for sheltering and feeding.

5. When the reef fish communities are considered there is a strong difference between reef fish communities on the north coast and the south coast. This difference is also observed in fish communities between various bays. With respect to this, each analysed bay is characterised by a specific fish community. When the nursery function of bays is considered, nursery function of bays on the south coast is more evident than nursery function of bays on the north coast. In general, it can be concluded that from the five analysed bays only three bays have a significant contribution to the reef fish diversity on the island of Curaçao. This study shows complex relations between bays and the coral reef in several ways. It can therefore be concluded that conservation of the characteristic bay biotopes is of crucial importance for the existence of the fish community on the coral reef.

INTRODUCTION

In general

Caribbean coral reefs show a high biodiversity and are characterised by a well developed fish community. The coral reef fishes fulfil an important function in the feeding web of the coral reef community. Besides the coral reef, other biotopes, such as seagrass beds and mangroves, can fulfil an important function in the life cycle of reef fishes as well (e.g. Bealde, 1990; Ogden, 1980; Robertson & Duke, 1987; Lal, 1982). These biotopes are sometimes directly adjacent to the coral reef (shallow reef flats) or they can be situated at close distance, for example in bays or estuaries. Importance of these coastal shallow biotopes for reef fishes, varies on a temporal scale.

Reef fishes can use these adjacent biotopes on a daily scale. Typical day-night migration reflects this process. Coral reefs are used as a shelter place and adjacent seagrass beds are used as foraging biotopes (Baelde, 1990). McFarland *et al*. (1979) showed that during daytime, grunts were found in schools, that function as antipredator devices. At dusk, those schools migrated to seagrass beds to forage overnight. Movement to this night-time feeding ground is always at the same time and identical migration routes are used.

On a larger scale, fish use these biotopes for longer periods during their life cycle. The best studied process of this order, is the use of these biotopes by juveniles of coral reef fishes. A number of studies revealed that coastal bays and estuaries contain high numbers of juvenile coral reef fishes. Larger adults live on the coral reef and the small juveniles live in nearby situated seagrasses and mangroves where they complete there juvenile life stage. After reaching adult stage, they migrate to the coral reef. This led to the suggestion that these biotopes function as important nursery grounds for those juvenile fishes (Robertson *et al.*, 1987; Austin, 1971; Bell *et al.*, 1984; Robertson & Blaber, 1992; Baelde, 1990; Parrish, 1989; Pollard, 1984; Edgar *et al.*, 1995a).

Nursery function of shallow water biotopes

The nursery function has been attributed to different biotopes. A number of studies indicated a nursery function for mangroves (Robertson *et al.*, 1987; Austin, 1971; Bell *et al.*, 1984; Robertson & Blaber, 1992). Three hypothesis are proposed to explain those high densities of juvenile fish in mangrove biotopes (Robertson & Blaber, 1992). 1. Because of relatively high turbidity of these waters, hunting efficiency of large predators strongly reduces. Consequently, survival of prey fish increases and results in positive selection on these biotopes. 2. Mangroves might increase food availability and form optimal feeding grounds for juvenile fish. 3. Mangroves are characterised by the presence of proproots and pneumatophores and therefore show a high structural complexity. Compared with adjacent biotopes, mangroves provide better shelterplaces for juvenile fish to hide.

However, Blaber *et al*. (1985) could not report a significant nursery function of a mangrove creek. This was attributed to low turbidity and an unusual fish community consisting of many predators because the creek was readily accessible for predators during high tide. Penetration of mangroves by large numbers of piscivorous fish, related to biotope complexity is believed to be important in the role of mangroves as nursery grounds for juveniles of larger species that live in deeper water as adults (Blaber, 1986). Besides nursery grounds, mangroves may also be an important biotope for piscivores by means of harbouring juveniles that serve as a major food source (Robertson *et al.*, 1987).

Some studies have focussed on both mangroves and seagrasses and their interaction. Mangroves are important nursery biotopes and extends its role for small juveniles to the seagrass beds (Baelde, 1990). Mangroves and seagrasses probably intercept large numbers of recruits and may offer some advantages over coral reefs for early survival of young juveniles.

They may accumulate excess of recruits, providing a more constant flow of recruits to the reef. No clear evidence exists that reefs situated near such biotopes experience an enhancement of the fish community. However, the fact that reproduction and foraging can occur outside the reef, permits a higher standing crop of biomass and a more complex reef community with a higher level of total activity (Parrish, 1989; Ogden, 1980).

The nursery function of seagrasses separately, has also been a point of study. Utilisation of this biotope appears to be based on their provision of both adequate shelter for small fishes from predators and an abundant food source, particularly in the form of small epibentic crustaceans which in turn depend on the seagrass detritus cycle as the basis for their food resources (Pollard, 1984; Edgar *et al.*, 1995b).

Alternative nursery grounds have also been suggested. Beside coastal bays and estuaries, inshore marine environments can provide an alternative to these biotopes as a nursery area (Lenanton, 1982).

Environmental factors

There are many factors that can affect the fish community structure. These factors can be abiotic and biotic in nature. Examples of variables are: predation, competition, recruitment, colonisation, migration, physiological tolerance of fish, social interactions, biotope complexity, food quantity and availability, hydrological processes, seasonal influences, turbidity, temperature, salinity and substrate size. Difficulties in explaining results arise due to the multiple interactions between each of these variables. An effect can almost never be attributed to a single factor that is evident from the variety in literature (Beets, 1997; Booth, 1995; Caley & St. John, 1996; Collette & Talbot, 1972, Edgar & Shaw, 1995a).

Substrate, turbidity, depth and relatively calm water in estuaries, affect the distribution of juvenile marine fish (Blaber, 1980). Influence of turbidity in relation with predator success has also been found in fish communities in north-western Australia (Blaber, 1985). Although water visibility cannot always explain differences on a small scale (within a bay), it may be important in explaining variation in densities on larger scales, such as among different bays (Robertson *et al.*, 1987). Temperature can also have a structuring effect (Wallace, 1977). Shallow waters in the tropics can achieve high temperatures and can therefore limit colonisation by fish. Salinity has also been suggested to explain high densities of juveniles in mangroves. Some mangroves are hypersaline and an osmoregulating facility is suggested in small fish that is lost as growth increases, thereby making these biotopes more attractive for juvenile fish (Austin, 1971; Bell *et al*. 1984).

Economic value of shallow water biotopes

Besides scientific motivations, there are important economic motivations to determine how the various shallow-water tropical biotopes are used by fishes, and how their ecological interactions affect productivity of coral reef fish populations. A theoretical potential world harvest with a large share of fish from all coral reefs of 9 million tons yr^{-1} has been suggested (Parish, 1989). Various coral reef fishes depend on seagrasses and mangroves during part of their life cycle. Hence, bays contribute to reef fish stocks of many commercial fish species.

On Curaçao, diving tourism is an important economic factor. A dense and diverse fish community makes the coral reefs more attractive for divers. Besides commercial value for fishery, coral reef fishes are therefore important for maintaining diving on coral reefs on Curaçao attractive. Seagrass beds and mangroves are located primarily near the coast, making these biotopes very susceptible to human impacts resulting from coastal development. As a result, these valuable biotopes are destroyed world-wide by direct biotope destruction, increased soil erosion, sewage pollution, influx of insecticides and trampling by humans and boats. Reclamation of mangroves will reduce the annual production of organic detritus in an estuary, which will lead to reduction in fish and other fauna of commercial importance (Lal et al., 1982).

This study

Most studies are based on areas where shallow nursery grounds are adjacent to the coast and the coral reef and only one or two biotope types are examined, mostly seagrasses and mangroves (e.g. Robertson *et al.*, 1987; Austin, 1971; Bell *et al.*, 1984; Robertson & Blaber, 1992). Besides this focus on only two biotopes, most studies also include an estuary (e.g. Davis, 1988; Quinn, 1980). However, little ecological information is available about the function of these and other biotopes in relation to each other. In this study several bays on the island of Curaçao were sampled. Currently, a large development project is being planned along a part of the coastline of St. Jorisbaai, one of the sampled bays. Because St. Jorisbaai is rather undisturbed and contains seagrass beds and mangrove forests, this bay is studied to reveal natural value and nursery function. In this way the environmental value of St. Jorisbaai can be determined and suggestions can be made to minimise impacts resulting from planned coastal development. This study on several bays aims to reveal:

- whether nursery function is valid for each investigated bay;
- which biotope types are important in this process;
- which species are involved.

One bay, Spaanse Water is studied in detail. All available biotope types are analysed and compared to reveal which biotopes are important. This study is unique in this respect. By analysing all biotope types no important biotopes are missed and the total use of the bay can be evaluated. The fish community of Spaanse water is studied in detail on a temporal and a spatial scale: A comparison with coral reefs is made to reveal for which species a nursery function is valid and to which degree. The situation during day and night is compared to reveal whether the function of the bay is changing between day and night. On a larger temporal scale two seasons are compared to analyse temporal differences.

For Spaanse Water, preliminary studies demonstrated juvenile fishes in the bay associated with seagrass beds (*Thalassia testudinum*) and algae beds (*Halimeda opuntia* and *Halimeda incrassata*). No quantification was done and mangroves and rocks were not sampled (Kuenen *et al.*, 1995). Earlier studies showed a nursery function of Spaanse Water on the island of Curaçao (Briones, *manuscript*) and of Lac bay on the neighbouring island Bonaire (Nagelkerken, *in press*).

This detail study on Spaase Water aims to reveal:

- whether nursery function is valid for Spaanse Water;
- which biotope types are important in this process;
- what is the relation between these biotopes;
- which species are involved in the nursery function;
- which differences exist spatially in the bay;
- which differences exist between day and night;
- which differences exist at night between the four different moon phases;
- which differences exist between different seasons;

MATERIALS & METHODS

Study area

The island of Curaçao belongs to the Netherlands Antilles and is situated in the southern part of the Caribbean Sea, 66 km north of Venezuela. It has a length of about 63 km and is 4 to 13 km wide. The north coast is exposed to ocean winds and is characterised by strong waves and a rocky bottom. Parallel to this coast an algae field (dominated by *Sargassum* sp.) stretches out to depths of about 20 m and is followed by a short drop-off which forms a small fringing coral reef. At a depth of about 30 m an extending sand flat is situated. In contrast, the south coast is more sheltered. Here, a submarine flat extends about 100 m from the coast to a depth of about 10 m and is followed by a drop-off that extends to depths of 60-70 m. The southern coast is characterised by a typical fringing coral reef. Tidal amplitude is small (0.3 m), and constant through a year, water temperature varies between 26 and 29 °C and salinity is about 35 ‰. Several bays are present from which five are studied: Playa Grandi; Bartolbaai; Sint. Joris baai; Fuikbaai and Spaanse Water (figure 1). Playa Grandi and Bartolbaai are small sized and consequently more influenced by the sea compared with St. Jorisbaai, Fuikbaai and Spaanse Water, which are of large sized and connected to the sea by a narrow entrance that widens towards the land. Those three bays posses larger seagrass beds (*Thalassia testudinum*) and mangrove areas (*Rhizophora mangle*). St. Jorisbaai and Fuikbaai both posses large areas of shallow mud plains. The three studied bays on the north coast are relatively turbid compared with Fuikbaai and Spaanse Water.

Spaanse Water is liable to intensive human pressure, mainly by housing and recreation. Fuikbaai is characterised by a small harbour for a mining company which is using the backland. However, both bays posses a large natural undisturbed part. The other three bays, situated on the north coast, are in their natural state and barely influenced by human impact.

Scales of this study

This study concerned two scales: On a large scale, the fish communities of the five bays (figure 1) were analysed by means of collecting fish. Each bay was subdivided into several sites which enclosed main biotope types of that bay. Table I describes sampled biotope types and fish methods that were used. The reef in front of St. Jorisbaai was studied by means of visual census technique (described later).

Besides this large scale study, Spaanse Water was studied in more detail. Therefore, twelve sites were selected (figure 2). To obtain a complete spatially pattern, each spatial part of Spaanse Water was covered by a site. Selection of sites was based on high visibility, shallow depth (approximately 1-2 m, except deep *Halimeda* fields (6m) and channels) and sufficient coverage of all available biotope types in that part of Spaanse Water. A comparison was made with coral reefs on different locations. The situation of the studied coral reefs is presented in figure 1. All fish communities in this detail study were sampled by means of visual census technique.

Sampling methods: collecting fish

Eight different methods were used to collect fish:

1. A beach seine measuring 30 m in width and 1.8 m in height, with a mesh size of 1 cm (stretched). In shallow water (1-2 m depth), an area of 150 m^2 can be sampled in one haul.
2. Landing nets for collecting small fish in rocky and shallow areas (< 0.5 m depth).
3. An antillian fyke trap with an iron skeleton closed off with chicken wire, measuring 75 x 75 x 40 cm, with a narrowing opening in the front, baited with white bread.
4. A fishing line with hooks and lead, baited with fish (*Selar crumenophthalmus*), squid

(*Sepioteuthis* sp.).

5. The piscicide rotenone, hindering respiration and causing paralysation in low concentrations and death in high concentrations. Sufficient rotenone was used to paralyse fish. Rotenone was dissolved under water near target areas, where conventional fishing was impossible (mangroves, rocks).

6. A small Antillean fish trap for collecting wrasses and damselfishes. A plastic bottle baited with white bread was used for this purpose. The upper end was sawn off to create a larger opening. When a target fish entered the bottle, the entry was quickly covered by the hands of a waiting snorkeller .

7. A mosquito net for collecting small individuals. This net was positioned into a fyke form, measuring approximately 120 x 80 x 100 cm, with an opening in the front. Schools of small fish were chased into the net by snorkellers with landing nets.

8. A gill net measuring 60 x 2 m with a mesh size of ca. 10 cm for collecting larger fish on the coral reef. The net was positioned on the reef flat overnight. Fish were collected each morning.

Fish were collected in Fuikbaai, Spaanse Water, St. Jorisbaai, Bartol baai and Playa grandi. Only the first method was used in Fuikbaai, Bartolbaai and Playa grandi. In St. Jorisbaai, first and third methods were used. Spaanse Water was most intensively fished using all methods. Each collected fish was immediately put on ice. In the laboratory, total fresh weight (g) and standard length (cm) of each collected fish was measured and the digestive tract was taken out and stored in a freezer for further analysis.

Sampling intensity (area sampled / total area of the bay) was similar for Fuikbaai, St. Jorisbaai, Bartolbaai and Playa Grandi, making comparison between these bays possible. Spaanse Water could not be compared because sampling intensity was unknown since no locations existed to pull the seine on a beach. Spaanse Water has been analysed separately in detail using visual census data.

Sampling methods: visual census

With this technique, fish were observed and written down on an underwater slate by a trained observer. A well trained observer is able to estimate numbers and size classes (accuracy of 2.5 cm) of fish species in the transects.

Other studies discuss bias and efficiency of visual census (Thresher & Gunn, 1986). Difficulties arise due to lack of an absolute standard against which the effectiveness of a census technique can be evaluated. Evaluation of census precision and accuracy often reduces to assessing consistency of results and to elimination of conspicuous sources of observer error and sampling bias. In this study, efficiency or observer bias were not studied. Therefore, this study assumed that visual census is a correct way to obtain a representative view of the fish fauna of a specific area. Possible bias and inaccuracy were reduced by training observers in species recognition and in estimating both size and numbers. Estimation of size and numbers between different observers was adjusted to each other and repeatedly rehearsed. Compared to other in bays, Spaanse Water was relatively clear. Therefore, most areas in Spaanse Water were well suited to use visual census as a method for collecting data on the fish fauna. Sites have been selected accordingly. When visibility was too low to permit visual census by means of snorkelling, visual census was done by means of SCUBA diving, permitting the researcher to be closer to the bottom. A more accurate census was obtained in this way, since most fish are associated close to the bottom, finding shelter and food in the vegetation or rubble.

In another study, visual census techniques were found to consistently underestimate biomass. This underestimation was attributed to the normal behaviour of the target species which rarely remain on the reefs for extended periods. (Jennings & Polumin, 1995). This behaviour has not been noted for the species observed in this study.

Day census

Table II and table III describe biotope types in Spaanse Water and the coral reefs. Sampling fish data of a biotope on a specific site occurred by visual census of transects in that biotope. A transect was swum by a trained observer who estimated size frequency of the fish fauna. In Spaanse Water, shallow field transects (seagrasses and *Halimeda* fields, 1-2 m depth) were censussed by snorkelling. Visual census in less shallow transects (channel 6 m, *Halimeda* fields 6 m) and transects in a turbid area (*Halimeda* fields 2 m, site 10 and 12) was done by means of SCUBA diving. Visual census of all reef transects was done by means of SCUBA diving. Transect area in both *Halimeda* fields of 2 m and 6 m depth as well as seagrasses was 50 x 3 m. For the channel biotope, transect area was 25 x 3 m. A transect in a biotope was randomly chosen and marked by a 50 m line (or 25 m in the channels). After placing the transect line on the bottom, the transect was left undisturbed for 15 minutes to restore original fish community. After this restore-time, the transect was swum with a constant speed of approximately 5 m min^{-1} and size frequency of the fish fauna was estimated and noted on an underwater slate.

The biotopes mangroves, rocks and niches, were only small areas which in general did not enclose a transect length of 50 m. Therefore, visual census was done in the actual size of such a biotope. Visual cesus in mangroves was done by snorkelling slowly along the roots and carefully observing all fish which were hiding between them. Sometimes a small dive light was used to enlighten dark spaces deeper in the mangrove. Rocks enclose one single boulder as a transect. Such a transect was censussed by snorkelling around the boulder and carefully searching in cracks and niches for hiding fish. Niches were censussed by snorkelling slowly along the niche. Transect length of a wavedashniche was 25 m maximum. Only fish which truly used a mangrove, rock or wavedashniche were counted. Fish which swum into the biotope from a neighbouring biotope to hide, were not counted. A transect line was not used in those biotopes.

The coral reefs were all studied by means the visual census technique. Transect area was always 50 x 3 m. Four 50 m transect lines were placed shortly after each other (ca. 2 m interspace) at the same depth. When the transect line was placed on the bottom, the transect was left alone for 15 minutes to restore original fish community. Fish were counted 3 m above the transect line in despite of greater depth. Because of very high numbers of wrasses and damselfishes, counting was subdivided into two parts. Firstly, the transect was swum counting all larger fish species. Secondly, small abundant fishes, mainly wrasses and damselfishes, were counted. Therefore only an area of 25 x 1.5 m of the original transect was studied. All fish data of transects from both Spaanse Water and the coral reefs were finally expressed in densities per 100 m^2.

Night census

In general, the same procedure was followed as during day census. All transects of 50 (or 25 m, channel) x 3 m during day were subdivided into two parallel transects of 50 x 1.5 m and visual census was done by two trained observers. Two bright dive lights (30 Watt halogen lightbulb) with a focussed beam of 1.5 m at 1 m distance, were used to estimate size frequency of the fish fauna. Visual census of mangroves, rocks and niches was done by only one observer.

Table I. Bays and their biotopes sampled with a beach seine and other methods

	Bartol baai	Playa grandi	St Joris baai	Fuikbaai	Spaanse Water	Coral reef
number of sampled sites	3	3	5	7	4	2
number of beach seine hauls	3	3	25	7	>30(not precisely known)	-
used fish collecting methods	beach seine	beach seine	beach seine antillian fyke trap tree net	beach seine	all methods described	gill net antillian fyke trap line fishing
sampled biotope types (n=number of sites)	Seagrass (*Thalassia testudinum*) n=1 *Halimeda* sp./ mudfield (n=2)	rocks/*Sargassum* sp./ mudfield n=1 mudfield n=1 *Halimeda* sp.- mudfield n=1	seagrass (*Thalassia testudinum*) n=14 seagrass (*Thalassia testudinum*/*Halodule* sp.) n=1 mud field n=9 *Sargassum* sp. n=1 mangroves n=5	seagrass (*Thalassia testudinum*) n=3 mud field n=2 coral sand n=1 wire algae n=1	seagrass (*Thalassia testudinum)* n not known *Halimeda* sp. field n=3 mangroves n=6	reef flat n=2 drop-off n=2

Table II. Sites, biotope types and transect distribution in Spaanse Water (also figure 2). * not during night census; ** only 1 during night census; *** only 3 mangroves during night census; **** not during second period census.

Site	Biotope type *Halimeda* sp. field 2 m depth	*Halimeda* sp. field 6 m depth	seagrass (Thalassia testudinum)	rocks	niches	channel 6 m depth	mangroves (Rhizophorum mangle)
1	-	-	4	4	4	4	3
2	-	-	4	4	4 *	4	4
3	4	4 ****	4	4 **	4	-	4
4	2	4 ****	4	4	3	-	4 ***
5	4	4 ****	-	-	-	-	4
6	3	4 ****	4	-	-	-	4
7	-	4 ****	4	3	4	-	3
8	4	4 ****	4	-	-	-	4
9	-	3 ****	4	3	3 **	4	4
10	4	4 ****	4	-	-	4	4
11	4	-	4	-	2	-	4
12	4	-	4	-	-	-	4
number of sites	8	8	11	6	7	4	12
number of transects	29	31	44	22	24	16	46
percentage of total number of transects (n=212)	13.7	14.6	20.8	10.4	11.3	7.5	21.7

Table III. Sites, biotope types and transect distribution of studied coral reefs (also figure 1). * not during second census period ** only second census period

Reef site	Biotope type Reef flat 2 m depth	reef flat 5 m depth	drop-off 10 m depth	drop-off 15 m depth	*Sargasssum* sp. flat 9 m depth	drop-off 19 m depth
Barbara beach	4	4	4	4	-	-
Punti piku	4*	4*	4*	-	-	-
Jan Thiel	4	4	4	4	-	-
Princess beach	4	4	4	4	-	-
Slangenbaai	4	4	4	4	-	-
in front of St. Jorisbaai	-	-	-	-	4**	4**

Detail study in Spaanse Water

The detail study of Spaanse Water concerned two scales. Firstly, fish fauna was analysed with respect to spatial use of the bay. Therefore 12 sites were chosen all over the bay (figure 2 and table II). A specific site enclosed all biotope types in that area. From each biotope type a maximum of four replicas per site was used. A comparison with coral reefs was made (figure 1 and table III). To analyse the influence of Spaanse Water on coral reefs along the coast, reef sites were selected along a gradient with an increasing distance to the entrance of Spaanse Water bay.

Secondly, fish fauna was analysed with respect to temporal use of the bay related to day-night, lunar and seasonal influences.

Day-night influences

In the first census period, fish faunas of all sites were analysed during day. To compare those results with the use of the bay during night, fish faunas of all sites were analysed during night in the same period. Because of the low water level not all biotopes could be sampled (Table II). Visual census of the reef of Punti piku was not done during night because it was dangerous to enter this area with a boat during night. Visual census was started one hour after dusk when twilight migration had stopped. Visual census was stopped approximately one hour before midnight. The same procedure was followed for the reef sites.

Lunar influences

To analyse influence of the lunar cycle, fish faunas of selected sites were analysed during the four moon phases: new moon, first quarter, full moon and last quarter. The bay biotopes as well as the reef biotopes were investigated (Table IV). During new moon, first quarter and full moon, visual census was started one hour after dusk when the moon reached ambient light level and twilight migration had stopped. During the last quarter, visual census was started two hours after midnight when the moon reached ambient light level. The visual census technique was identical to normal night visual census technique. The biotopes of site 4 and 8 were censussed during the lunar cycle in February. The channel, *Halimeda* field 6 m and reef biotopes were censussed during the lunar cycle in March.

Table IV. Sites and distribution of biotopes during moon census

Biotopes	Site 4	Site 8	Site 2	Reef Barbarabeach
mangroves	3	5		
seagrasses	4	4		
rocks	4			
niches	3	1		
Halimeda field 2 m depth	2	6		
Halimeda field 6 m depth	4			
channel			4	
reef flat 2 m depth				4
reef flat 5 m depth				4
reef flat 10 m depth				4
reef flat 15 m depth				4

Seasonal influences

To analyse changes in the fish fauna during a year, visual census of all biotopes during day was done in two seasons. Two main seasons can be distinguished in the Dutch Antilles: summer and winter (*pers. comm.* I. Nagelkerken). The summer season is a dry and hot period while winter is characterised by rains and lower temperatures. Consequently, mean ocean temperature is lowest at end of winter and highest at end of summer. However, since differences in the tropics between summer and winter period are not extreme, we will refer to the winter period as the first census period and the summer period as the second census period in order to prevent confusion. Visual census of the first period extended from November 1997 until April 1998 and visual census of the second period extended from end June 1998 until August 1998. Therefore, visual census of all biotopes occurred once during the first period and once during the second period. Because of very low densities of fish during the first period, visual census of deep *Halimeda* fields (6m) was not repeated during the second period. Seagrasses of site 5 were omitted from the data because they were not representative for a natural seagrass bed. During the second period, the reef of Punti Piku was not censussed because it was dangerous to enter the area with a boat. Censussing is identical to earlier described methods.

Large scale study of bays

Digestive tract analysis

For fish collected in Fuikbaai, Spaanse Water and St. Jorisbaai, the digestive tract was extracted and its contents was identified. The following food items were distinguished: Tanaidacea, Decapoda, Amphipoda, Isopoda, Mysidacea, Copepoda, Ostracoda, Annelida, Echinodermata, Bivalvia, Gastropoda, Foraminifera, fish spp., algae, seagrass, sediment, and other material which could not be identified further. Two different forms of Tanaidacea have been distinguished, named Tanaidacea species I (a Tanaidacea sp. with short legs) and Tanaidacea species II (a Tanaidacea sp. with very long legs). Corresponding scientific species names of these distinguished Tanaidacea species I and Tanaidacea species II are not yet available. Algae have been subdivided into three different groups: unicellular algae, small filamentous algae and larger macro-algae. Polychaeta were considered as a group separated from others worms belonging to the phylum Annelida. Digestive tract content per group of food item was estimated in percentile share of total digestive tract content. Binocular dissecting scopes with magnification factors ranging from 4 to 25 were used for analysing the fish digestive tracts.

Sampling food availability

Food was quantified in two ways. To catch epifauna, a plankton net with an opening diameter of 25 cm, was pulled along a random 3 m transect by a snorkeller. The snorkeller was specially attended not to scrape bottom material into the net. In this way, only the area just above the bottom was sampled. To measure infauna, random bottom samples were taken using a cylindrical bottom core with a diameter of 5.4 cm and a length of 30 cm. The time of sampling was synchronised to late afternoon. Pilot studies revealed that the upper 3 cm of the bottom contained more than 90 % of all infauna. Therefore, only the 3 upper cm of all samples were analysed. Before analysing epifauna and infauna, all samples were coloured by incubating with Bengal Rose for 12 hours. This is a dye colouring proteins. As a result, invertebrates colour red and can easily be recognised in the sediment with a microscope (stereo-microscope, magnication 12 x). A 1 mm mesh size sieve and a 250 µm mesh size sieve were used to separate larger particles from the small sediment to facilitate analysis. In general, algae, seagrass and plantlike material were not quantified. In further analysis it was assumed that availability of algae and seagrass as food item, was non-limiting.

Food availability was established for St. Jorisbaai, Fuikbaai and Spaanse Water. Food availability was expressed in several ways. Epifauna and infauna were distinguished in the analysis. For each bay, frequencies of found invertebrate groups were expressed as the percentage from the total number of found items. Shannon-Weaver diversity index (H') was calculated for each sample:

$$\mathbf{H' = - \Sigma_{n=i} \ (p_i * \log \ p_i)}$$

p_i = proportion of frequency of invertebrate group $_I$ from total number of items

For both epifauna and infauna an index (I) was calculated for each sample. By obtaining a single food based variable which indicates variations in both food abundance and food diversity a multitude of different variables is prevented adding surveyability and aiding in interpreting results.

$I_{fauna} = H'_{fauna}$ * total number of items * number of invertebrate groups

For each sampled bay the Shannon-Weaver diversity index and the above mentioned index were calculated.

Correlation of fish communities with abiotic factors

To detect possible correlations of fish communities with differences in their environment, several variables were analysed. Water temperature, salinity and visibility were periodically measured. A digital thermometer was used to measure temperature. Therefore, a water sample was taken at a depth of 1 m and temperature was measured immediately. Salinity of this water sample was measured in a laboratory several hours later. Horizontal visibility was determined using a Secchi disk and expressed in centimetres. Temperature, salinity and visibility were always determined between 14:00h and 16:00h to exclude daily variation. Complexity of seagrass was established using the following method: a quadrat (0.5 x 0.5 m) was randomly chosen in a seagrass bed. Mean shoot length (cm), mean number of shoots and mean coverage percentage were determined for each sampled seagrass bed. Six replicas were used to calculate mean values. A complexity index was calculated for each seagrass bed, again to prevent a multitude of different variables:

I (complexity index) = log [mean shoot length (msl) · mean number of shoots (mns) · mean coverage percentage (mcp)]

Analysis and statistics

Silvery fishes forming large schools

Several species have been omitted from some analysis because of their erratic presence. These species form large schools and were consequently either present in extreme low numbers or in extreme high numbers, making estimation of numbers very hard and not precise. Including these species would disrupt results of some analysis. The omitted species were herrings, anchovies, redear sardine and hardhead silversides.

Seasonal differences

In order to analyse seasonal differences in fish fauna, census data of the first and second census period were compared. Five species were selected for analysis: french grunt, schoolmaster, striped parrotfish and yellowfin mojarra. The most abundant fish families were represented by these five species. Densities of these species of each biotope type in the first and second census period were tested against each other. Data was analysed for normality using a Kolmogorov Smirnoff test (Sokal & Rohlf 1995). When the data exhibited a normal distribution a paired student t test was performed, otherwise a Wilcoxon signed rank test.

Differences between reef sites

To detect whether Spaanse Water has an influence on size and abundance of fish species occurring on coral reefs at increasing distance of the entrance of Spaanse Water, seven species were analysed. Abundance and mean length of french grunt, bluestriped grunt, striped parrotfish, schoolmaster, yellowtail snapper, ocean surgeonfish and doctorfish were correlated with increasing distance of censussed coral reefs to the entrance of Spaanse Water. Species which occurred frequently on coral reefs and Spaanse Water were selected. Besides those seven species, total diversity of each reef and similarity with Spaanse Water was calculated and correlated with increasing distance to the entrance of Spaanse Water

Similarity index

Similarities were calculated for each possible combination of two fish faunas and expressed in percentage similarity (Smith, 1992):

$$\textbf{Percentage similarity: } \Sigma_{n=i} \quad P_i$$

P_i: lowest percentile value of common species i

Fish community structure for all sampled bays

Fish community structure was analysed for all the sampled bays. Dominance was based both on numbers and biomass. Furthermore, for 10 species differences in length between the different bays were analysed. The species were selected by abundance and represented all different families. Differences were tested when more than three replica's were available. A student t test was used to test for significance, proceeded by a f-test to select between equal or unequal variance. Mojarra spec. was split up for all bays except Spaanse Water, since mojarras collected there were not identified.

Diversity index

Shannon-Weaver diversity indices (Shannon & Weaver, 1963) were calculated for each biotope type using the census data collected during the second period:

$$H' = - \Sigma_{n=i} \ (p_i * \log \ p_i)$$

p_i = proportion of species $_I$ from total

The diversity index consists of two components of biodiversity; species richness and evenness, which can be separated from each other (Smith, 1992). Species richness and evenness were also calculated.

TWINSPAN

Fish data of beach seine sampled sites of Bartolbaai, Playa Grandi, St. Jorisbaai and Fuikbaai were classified by two-way indicator species analysis using TWINSPAN (Hill, 1979). Density classes (number of fish / per haul) were used as pseudospecies cutlevels: 0-2, 2-4, 4-8, 8-16, 16-32, 32-64, 64-128, 128-256 and >256. Range of classes followed a 2 power relation. For an unbiased analysis of the different bay transects, no transects were summed and averaged. Results of the classification were summarised in a synoptic table. The fish community of each cluster was calculated by summing all transect densities per observed species. The three most abundant species per cluster are highlighted.

Fish day census data of transects in Spaanse Water and studied coral reefs were classified using the TWINSPAN programme. Density classes (number of fish / 100 m^2) were used as pseudospecies cutlevels: 0-2, 2-4, 4-8, 8-16, 16-32, 32-64, 64-128, 128-256 and >256. Range of classes followed a 2 power relation. Mean densities of both the first and second census period are used. Results of the classification were summarised in a synoptic table. Fish community of each cluster was calculated by summing all transect densities per observed species. The three most abundant species per cluster are highlighted. For the night census data, same procedure was followed, but only data from the first census period are available.

To obtain an idea of the diet of fish communities in St. Jorisbaai, Fuikbaai and Spaanse Water, fish species were clustered with TWINSPAN on their mean digestive tract contents. For each food item found in a species, mean digestive tract contents was calculated based on the analysed individuals. In this way, each species is characterised by a specific diet. In the TWINSPAN which was run, fish species are now clustered on diet instead of sites. In this way TWINSPAN produce clusters of fish communities characterised by a specific diet. The following classes of volume percentages were used as pseudospecies cutlevels: 0-11.1, 11.1-22.2, 22.2-33.3, 33.3-44.4, 44.4-55.6, 55.6-66.7, 66.7-77.8, 77.8-88.9, >88.9 (not exceeding 100). Classes follow a linear relation. In the digestive tract data of Spaanse Water, several species are distinguished in size classes (cm): sea bream: 5-7.5/10-12.5/17.5-22.5; bluestriped grunt: 2.5-5/5-7.5/7.5-10/10-12.5/12.5-15/15-17.5/17.5-20/20-22.5/>22.5; french grunt: 0-2.5/2.5-5/5-7.5/7.5-10/10-12.5/12.5-15/15-17.5/17.5-20; grey snapper: 5-10/10-12.5/>12.5; schoolmaster: 0-2.5/2.5-5/5-7.5/7.5-10/10-12.5/12.5-15/15-17.5/17.5-20/20-22.5/>22.5; yellowtail snapper: 0-2.5/2.5-5/5-7.5/12.5-15/15-17.5/>17.5. Size classes were selected to include sufficient numbers of replica's. When a size class is missing, no fish were captured of that size. The remaining fish species in Spaanse Water and all fishes in Fuikbaai and St. Jorisbaai were clustered without consideration of their size. Up to 10 digestive tracts were analysed per species or size class and per sampled area. Mean digestive tract content per food item for each species or size class was calculated:

mean digestive tract content of a food item = sum of all volume percentages of that fooditem/ number of analysed individuals

For Spaanse Water, diets of fish communities were also analysed spatially. Therefore, the bay was subdivided into four different areas. The first area consist out of entrance and channel of the bay (site 1 and 2); the second area was formed by the western part (site 3, 4 and 5); the third area by the eastern part (site 10, 11 and 12) and the fourth area by the centre of the bay (site 6, 7, 8 and 9). Fish species and size classes were ordinated on area and clustered with TWINSPAN.

Furthermore, for each bay the general diet of the fish community was estimated and compared with each other. Although the maximum number of analysed individuals per species was 10, actual collected numbers were much higher for a number of species. To obtain a view of the general diet of all collected individuals, mean digestive tract contents of analysed species were extrapolated to individuals whose digestive tracts were not analysed. In Spaanse Water, some species were analysed per size class. Maximum number of analysed individuals per size class was 10. Mean digestive tract content was calculated based on all analysed size classes and extrapolated to total collected number of individuals. Because the abundance's of the fish species are also taken into account in the calculation of total diet (expressed as the summed volume percentage for each fooditem) this gives a good indication of the total use of food items.

Biotope selection

Visual census data were expressed as fish densities per 100 m^2. However, several biotopes possessed only very small transect sizes (< 100 m^2) from which data was transformed to densities per 100 m^2 (rocks and mangroves). This resulted in densities which were higher than actual observed numbers. Therefore, conclusions about biotope preference could be overrated when densities of different biotopes were compared. Absolute numbers of observed fish and total area of censused biotope should be considered also.

When there is no biotope selection, fish can be expected to be distributed uniformly over the censussed area. In that case, each biotope where a visual census was done would contain a percentage of the absolute number of all observed individuals of a species equal to the percentage of area of that biotope of the total area where visual was done This is called "expected percentage". When a species has a preference for a biotope, the "observed percentage" in that biotope is higher than the expected percentage (positive selection). In case of biotope avoidance, the observed percentage is lower than the expected percentage (negative selection). To indicate biotope selection of fish communities for a certain biotope in the censussed area, an index has been calculated. Of all observed fish species in Spaanse Water and censussed coral reefs, positive and negative biotope selections for a biotope are added to indicate a total selection coefficient for a biotope:

Total selection for a biotope j = $\Sigma_{n=i}$ Difference $\%_i$

Difference_i = Observed percentage of fish species i - Expected percentage of fish species i

in case of biotope preference:
Difference $\%_i$ = Difference $_i$ * maximum (100 - Expected) * 100%

in case of biotope avoidance:
Difference $\%_i$ = Difference $_i$ * minimum (Expected) * 100%

Observed percentage of fish species i = percentage of total number of i observed in all biotopes

Expected percentage of fish species i = percentage of area of biotope j of total censussed area.

Total biotope selection and biotope selection based on the ten most abundant bay species was calculated using daytime data and night-time data. Data of only the ten most abundant bay species was used to calculate biotope selection without interference of species only dominant on the coral reef. Difference between expected and observed is expressed as a percentage of its maximum (in case of positive selection) or minimum (in case of negative selection) in order to correct for different areas of the biotopes and to make comparison possible.

Fish community structure analysis using rank numbers based on mass

For each biotope type in all the bays, fish community structure was determined by assigning a rank score from 10 to 1 to the 10 most dominant fish species for each replica. This dominance was based on biomass. Scores of all the replica's of a single biotope type were then added per species. Dominance was then determined based on these total scores for the different biotope types in each bay. In this way, different replica's can be compared without running the risk of one replica determining the total view. Also, dominance of one or a few heavy individuals due to one single site is prevented.

Importance of Spaanse Water compared with coral reefs

For each species which was observed during the visual census, the importance of the Spaanse Water was expressed by calculating an index value:

Index: density of species I in Spaanse Water / density of species I on coral reefs

The value of this index is therefore an indication for the importance of the bay. It is assumed that the bay is a relatively important biotope when a fish species occurs in higher densities in the bay than on the coral reef.

CANOCO

Canonical Correspondence Analysis, a direct gradient analysis technique, was used to correlate fish data with environmental variables. CANOCO version 4.0 was used for this purpose. Three CCA procedures were executed: 1: correlation of fish data with environmental variables collected in all five bays, 2: correlation of fish data obtained with visual census in seagrasses with environmental variables in Spaanse Water, 3: correlation of fish data obtained with visual census in mangroves with environmental variables in Spaanse Water. Detrended Correspondence Analyses (DCA) was used to determine gradient length of the data. For all three analysis, results indicated a non-linear, Gaussian model for analysing environmental-species data. No drop in eigenvalues was observed when a Detrended Canonical Correspondence Analysis (DCCA) was run. Therefore, for all three analysis, no arch-effect was present when running a CCA. Correlations between the various environmental variables were calculated using Pearson's correlation coefficients. When two variables were strongly correlated (*P<0.05*) the variable which was ecological less relevant was omitted from analysis.

For the first CCA procedure, salinity, distance to mouth, index infauna, index epifauna, H' epifauna and H' infauna (no data available for all bays) were omitted. For the second and third CCA procedure, salinity, H' epifauna and H' infauna were omitted. When CANOCO was run, inter-species distance plotting was chosen. Significance levels of each correlation were computed by a Monte Carlo permutation test. The number of random permutations was 500.

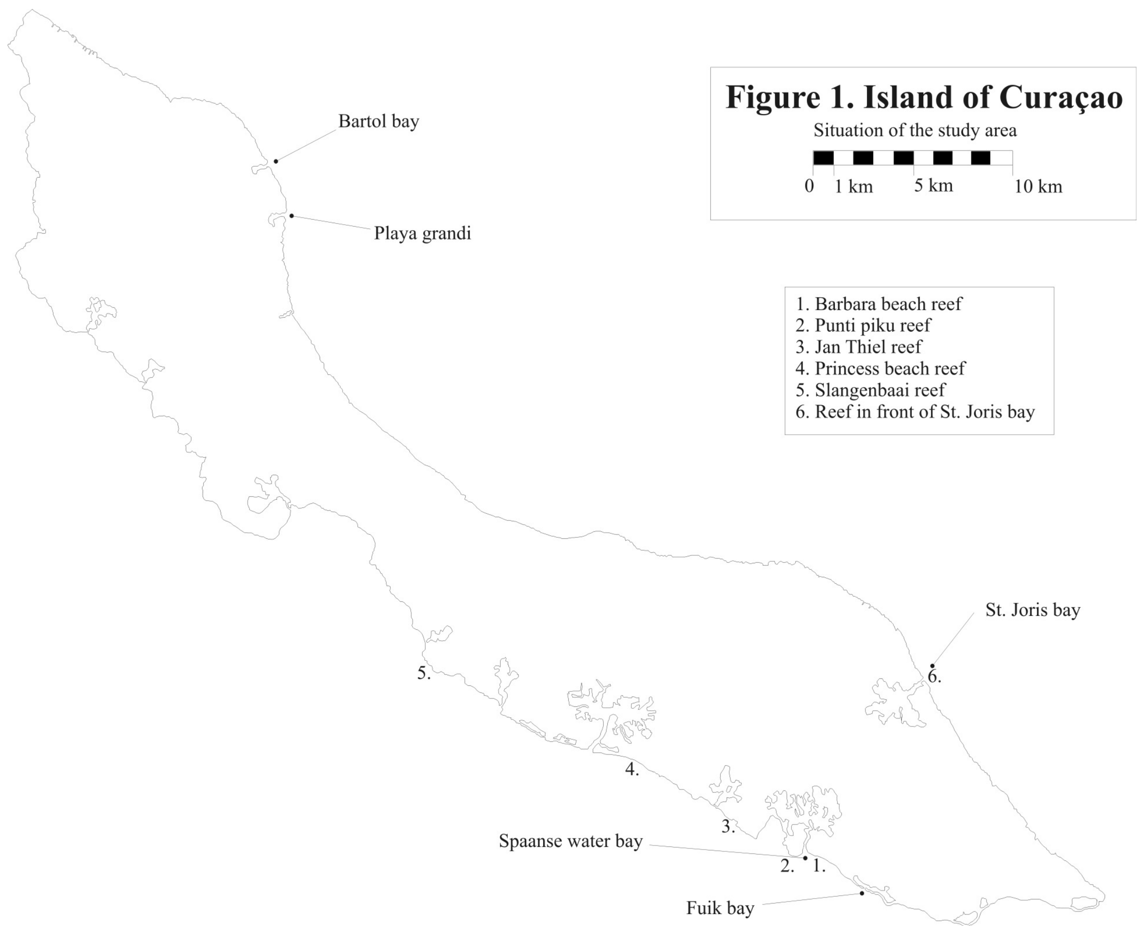


Figure 1. Island of Curaçao

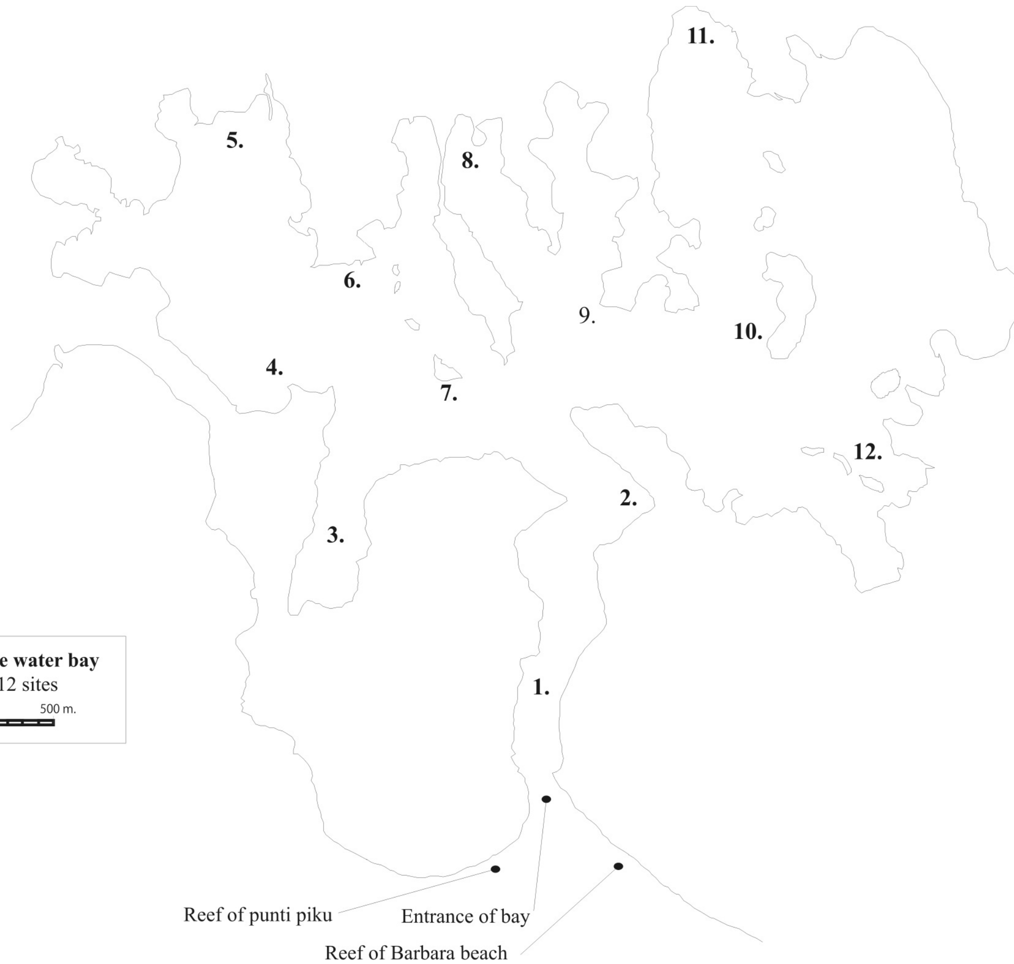


Figure 2. Spaanse water bay
Situation of 12 sites

RESULTS

LARGE SCALE STUDY OF BAYS

Classification of the fish community with TWINSPAN

TWINSPAN produced 14 clusters of transects based on the fish community (figure 3). Each cluster was characterised by a specific fish community (table VI).

The fish communities of clusters 1-12 showed much similarity because they were all dominated by mojarra's. The fish community of cluster 13 and 14 was separated from the fish community of clusters 1-12 and contained mostly sites from Fuikbaai. These sites were dominated by french grunt, redear sardine, hardhead silverside and bluestriped grunt. All seagrass sites from Fuikbaai were clustered in cluster 14. Only in this cluster, french grunt and bluestriped grunt occurred in high densities. The fish community of cluster 13 was dominated by anchovies, redear sardine and spanish sardine and was found on mud sites in both St. Jorisbaai and Fuikbaai. Redear sardines were only present in those two clusters.

The fish communities of cluster 11 and 12 were separated from those of cluster 1-10. The fish community of cluster 11 was found on an algae site in Playa Grandi and was dominated by bluehead wrasse. Balloonfishes dominated seagrass sites in Bartolbaai, clustered in cluster 12. The fish community of cluster 11 and 12 concerned fish species tat occurred only in low densities.

The fish community of cluster 1-10 was predominantly found on mud sites and seagrass sites in St. Jorisbaai. Distinguishing the fish community of those clusters was difficult, because they were all dominated by slender mojarra's. However, the fish community of cluster 4-7 was separated further, because they were co-dominated by silver jennies. The fish community of cluster 6 was separated because it was the single cluster containing irish pompanoes. The fish community of cluster 1 was characterised by the presence of fish larvae while the fish community of cluster 2 contained high densities of bonefish. The fish community of cluster 2 was found both on a seagrass site from Fuikbaai and on a seagrass site from St. Jorisbaai. Great barracudas achieved highest densities in these fish communities. The fish communities of cluster 8 and 9 were both characterised by high densities of bucktooth parrotfishes. The fish communities of these clusters were found in all sampled bays on seagrass sites that were situated closely to the bay entrance.

Fish community structure of each bay

For each sampled bay, Shannon-Weaver diversity index was calculated (Table VI). Highest diversity was found in Playa Grandi, shortly followed by Spaanse Water. Bartolbaai showed lowest diversity. Species richness was highest in St. Jorisbaai and lowest in Bartolbaai. Bartolbaai and St. Jorisbaai showed highest similarity (Table VIII). Lowest similarity was reached when bays situated at the north coast were compared with Fuikbaai.

Table VI. Shannon-Weaver diversity index and species richness of each bay, based on fish catches.

	Shannon-Weaver diversity index	Species richness (number of species)
Fuikbaai	2.01	34
St. Jorisbaai	2.56	58
Bartolbaai	1.56	16
Playa Grandi	2.87	24
Spaanse Water	2.77	40

Table VIII. Similarity percentages between the sampled bays.

	Fuikbaai	St. Jorisbaai	Bartolbaai	Playa Grandi
Fuikbaai	-			
St. Jorisbaai	25.1	-		
Bartolbaai	15.4	65.6	-	
Playa Grandi	20.5	40.6	41.6	-

The analysis of the fish community structure is shown in figure 4. When dominance was expressed in numbers, St Jorisbaai was dominated by mojarra's. When dominance was expressed in biomass, larger fish species like mutton snapper and white mullet became dominant.

When concerning both biomass and numbers, Fuikbaai was dominated by french grunts and bluestriped grunts and Bartolbaai was dominated by mojarra's. Playa Grandi was dominated in numbers by mojarra's and balloonfishes. Larger species like white mullet and mutton snapper dominated in biomass.

Spaanse Water was completely dominated by grunts. Yellowtail snapper and schoolmaster were co-dominant. Concerning biomass, redtail parrotfishes were also important. Great barracudas constituted an important part of the total biomass both in Fuikbaai and Spaanse Water.

For eleven selected species, mean lengths were compared between the five bays (figure 5). Compared with the other bays, Fuikbaai contained the smallest individuals of the selected species. This is not valid for the balloonfish. This species is much larger in Fuikbaai and Spaanse Water compared to St. Jorisbaai, Bartolbaai and Playa Grandi. Therefore, balloonfishes from bays situated on the south coast were larger than those from bays situated on the north coast. This is supported by observations in Boca Ascension, situated on the north coast. In June 1998, large numbers of small balloonfishes (> 100 individuals) were found in the shallow seagrass patches in this bay. In other bays situated on the south coast only larger balloonfishes have been observed.

Fish community structure of several biotope types: St. Jorisbaai

In order to make a comparison between all sampled biotopes, fish communities of each biotope type of each bay were analysed (Table IX). For St. Jorisbaai it appeared that seagrasses contained most fish species. They were dominated by slender mojarra's, followed by snappers and great barracudas. Mud plains were dominated by white mullets followed by silver jennies, great barracudas and bonefishes. The sampled mangroves appeared to contain the lowest number of species. Mojarra's were absent in mangroves. On the contrary, mangroves showed the largest numbers of bluestriped grunt and sailors choice. French grunts were only captured in the seagrasses. Concerning the whole bay, grunts contribute only little to total biomass of the fish community. Slender mojarra's dominated seagrasses and mud plains, while silver jenny was co-dominant in mud plains. Concerning only snappers and grunts, snappers dominated over grunts in all biotopes. The only parrotfish species that occurred in higher numbers, was the redtail parrotfish that was co-dominant in the seagrasses.

Table IX. Dominant species of each biotope type of sampled bay, based on biological index.

St. Joris						Bartolbaai			
Seagrass	Rank number	Mud	Rank number	Mangrove	Rank number	Algae-Mud	Rank number	Seagrass	Rank number
Slender mojarra	30	White mullet	23	Schoolmaster	10	Slender mojarra	19	Yellowfin mojarra	10
Schoolmaster	28	Silver jenny	21	Bluestriped grunt	9	Silver jenny	15	Balloonfish	9
Great barracuda	24	Great barracuda	20	Sailors choice	8	Spotted goatfish	10	Schoolmaster	8
Mutton snapper	24	Bonefish	17	Rainbow parrotfish	7	Trunkfish	10	Hairy blenny	7
Yellowtail snapper	24	Mutton snapper	14	Gray snapper	6	Yellowfin mojarra	9	Sailors choice	6
Redtail parrotfish	23	Irish pompano	10	4-eye butterflyfish	5	Schoolmaster	8		
Silver jenny	17	Yellowtail snapper	8			Houndfish	7		
Yellowfin mojarra	15	Schoolmaster	7			Horse-eye jack	6		
Bonefish	13	Slender mojarra	7			Bucktooth parrotfish	5		
French grunt	12	Redtail parrotfish	6			Slippery dick	5		
Horse-eye jack	11	Striped parrotfish	6			Stoplight parrotfish	3		
Redspotted scorpionfish	8	Yellowfin mojarra	6			Redtail parrotfish	2		
Smooth trunkfish	8	Bluestriped grunt	5			Smallmouth grunt	1		
Striped parrotfish	5	French grunt	5						
Bucktooth parrotfish	4	4-eye butterflyfish	3						
Spotted goatfish	4	Sergeant major	3						
Yellow goatfish	4	Gray snapper	2						
Gray snapper	3	Sailors choice	1						
Slippery dick	3	Sea bream	1						
Balloonfish	2								
Bluestriped grunt	1								
Checkered puffer	1								
Sergeant major	1								

Fuikbaai								Playa Grandi	
Seagrass	Rank number	Mud	Rank number	Algae	Rank number	Coral sand	Rank number	Algae-Mud-Rock	Rank number
Bluestriped grunt	27	Slender mojarra	14	Spotted trunkfish	10	Bonefish	10	Mutton snapper	18
French grunt	22	Great barracuda	10	White mullet	9	Peacock flounder	9	Slender mojarra	17
Redear sardine	16	White mullet	10	Anchovy spec.	8	Slender mojarra	8	Balloonfish	16
Yellowtail snapper	14	Balloonfish	9	Schoolmaster	7			Slippery dick	12
Redtail parrotfish	12	Bonefish	9	Great barracuda	6			White mullet	10
Great barracuda	11	Redear sardine	8	Redear sardine	5			Honeycomb cowfish	10
Spotted trunkfish	10	Schoolmaster	8	Yellowfin mojarra	4			French angelfish	9
Yellowfin mojarra	8	Silver jenny	8	Slender mojarra	3			Yellowtail snapper	8
Bonefish	6	Bandtail puffer	6	Bandtail puffer	2			Schoolmaster	8
Fringed filefish	6	Anchovy spec.	5	Silver jenny	1			Silver jenny	7
Schoolmaster	6	Striped parrotfish	5					Redtail parrotfish	6
Slender mojarra	5	Banded blenny	4					Houndfish	6
Yellow goatfish	5	Beaugregory	4					Bluehead wrasse	6
Mutton snapper	4	Yellowtail snapper	3					Tripletail	5
Striped parrotfish	4	Mahogany snapper	2					Puddingwife	5
Hardhead silverside	3							Bucktooth parrotfish	5
Stoplight parrotfish	3							Mahogany snapper	4
Smallmouth grunt	2							4-eye butterflyfish	4
								Jolthead porgy	3
								Ocean surgeon	2
								Spotted goatfish	1

Fish community structure of several biotope types: Fuikbaai

In Fuikbaai there was a clear difference in fish communities between seagrasses and mud plains. Bluestriped grunt and french grunt were dominant in the seagrass biotope while no grunts were observed in the mud biotope. As in St. Jorisbaai, mud plains were co-dominated by white mullets. The algae and coral sand plain contained less species compared to seagrasses and mud plains. Redtail parrotfish and yellowtail snapper were best represented in the seagrass biotope. Great barracudas were captured in all biotopes except coral sand plain. Dominance of bonefishes was typical for this coral sand plain. In the mud plains slender mojarra's were dominant over silver jennies, reverse to the situation in St. Jorisbaai. Concerning only snappers and grunts, grunts dominated over snappers in Fuikbaai. This is also in reverse with St. Jorisbaai.

Fish community structure of several biotope types: Bartolbaai and Playa Grandi

In Bartolbaai and Playa Grandi most dominant fish families were mojarra's and snappers. Playa Grandi showed no grunts and Bartolbaai showed only very low numbers of grunts. In Bartolbaai, parrotfishes were captured only in the algae-mud biotope and not in the seagrasses.

Environmental factors

For each bay several environmental variables were measured (Table X; see Materials and Methods for calculation methods). Seagrass complexity was highest in Spaanse Water and lowest in Playa Grandi and Fuikbaai. Mean visibility was highest in Spaanse Water and Fuikbaai. Visibility in other bays was much lower turbid. Compared with St. Jorisbaai, Bartolbaai and Playa Grandi, mean temperature in Spaanse Water and Fuikbaai was higher. In Spaanse Water, temperature was measured weekly during a one year period. Only values measured between 3-July-1998 and 26-August-1998 are shown. Temperature ranged from 27.0 °C (measured on 21 January 1998) to 31.4 °C (measured on 12 August 1998). Only small differences in mean salinity were observed. Epifauna and infauna were only sampled in St. Jorisbaai, Fuikbaai and Spaanse Water. Fuikbaai showed lowest diversity of both epifauna and infauna. However, epifauna and infauna index were highest in Fuikbaai due to high densities of copepods, gastropods and ostracods.

Table X. Mean values of the environmental variables of each bay (measured between 3 July 1998 and 26 August 1998).

	Seagrass complexity	Mean visibility (m)	Temperature (°C)	Salinity (‰)	H' epifauna	index epifauna	H' infauna	index infauna
Spaanse Water	5.31	6.37	30.66	35.88	1.70	10661.79	1.31	1800.08
Fuikbaai	3.22	3.57	30.36	35.24	1.02	17430.14	0.92	14137.25
St. Jorisbaai	3.86	1.45	29.12	36.21	1.33	7358.37	1.50	4202.56
Bartolbaai	4.03	1.78	29.45	36.14	-	-	-	-
Playa Grandi	2.61	1.60	29.97	35.53	-	-	-	-

Relation of fish community with environmental factors: CANOCO

Figure 6 shows the CCA plot of the fish communities of all sampled bays and relevant environmental variables. Temperature and biotope complexity appeared to be significant (*P<0.05*) (Table XI). Temperature explained most variance. The first axis showed the highest eigenvalue (0.663) and explained 12.4 % of the variance in species data and 68.6 % of the species-environment relation. Only the first and second axis are shown in the plot because they show total variance best.

Table XI. Monte Carlo permutation test significances of the CCA using bay data.

Monte Carlo permutation test significances	
Variable	P-value
Temperature	0.002
Habitat complexity	0.004
Mean visibility	0.214

Diets of fish communities

For each bay, total availability of epifauna and infauna were determined (figure 20). In addition, the diet of all analysed fish was summed for each bay to obtain a quantitative comparison with food availability. Total diet per bay is expressed as summed volume percentage of found food items of all analysed fish.

Decapoda were commonly found in the total diet but not in the bay samples. At the contrary, the item groups Cumacea, Acaridae and Insecta were frequently found in the bay samples but not in total fish diet. In general, most abundant item groups in the epifauna were crustaceans: Copepoda, Tanaidacea sp. I and Ostracoda. In the infauna, most abundant item groups were Ostracoda and Gastropoda and Nematoda.

In Fuikbaai, Tanaidacea were rarely found. However, in St. Jorisbaai and Spaanse Water they were abundant in both infauna and epifauna. The epifauna from Fuikbaai was dominated by Gastropoda which were less abundant in St. Jorisbaai and Spaanse Water. Compared with Fuikbaai and St. Jorisbaai, Spaanse Water contained relatively many Mysidacea in the epifauna. Gastropoda were less abundant in the infauna of Spaanse Water. The infauna of Fuikbaai contained relatively many Copepoda and Ostracoda.

When total diet was considered, most dominant item groups in Fuikbaai were Copepoda and Gastropoda. In St. Jorisbaai most dominant item groups were Tanaidacea sp. I and II. For Spaanse Water, dominance of a item group was less distinct. However, Tanaidacea sp. I, Decapoda and Copepoda were relatively abundant in the total diet.

Diet in Spaanse Water

TWINSPAN produced 21 clusters of fish species and size classes based on their diet (figure 21). Each cluster was characterised by a specific diet with dominant food items (table XXV). In general, four larger groups were distinguished: cluster 1-4, cluster 5-11, cluster 12-14 and cluster 15-21. The first group contained only herbivorous species with a diet of algae and seagrass. The other three groups were characterised by a crustacean dominated diet. The second group contained smaller size classes of grunts and snappers and specific species like balloonfish, mojarra's and bluehead wrasse. Their diet is dominated by Tanaidacea sp. I. The third group contained some size classes of grunts and snappers and the specific species slippery dick, yellow goatfish and bonefish. Their diet was diverse. The fourth group contained mainly the larger snappers and the largest size classes of bluestriped grunt. Other specific species were great barracuda, graysby, spotted goatfish, squirrelfishes, sardines, puddingwife and bandtail puffer. Their diet was dominated by Decapoda and fish.

When the first group of clusters is considered in more detail, cluster 2 is the only cluster where seagrasses were co-dominant in the diet. Therefore, only explicit herbivores (parrotfishes, surgeonfishes and damselfishes) were found in this cluster. The other clusters in this group contained less strict herbivorous fish species. Their diets were characterised by higher percentages of other item groups such as Copepoda, Annelida, Gastropoda, Bivalvia and polychaeta. The smooth trunkfish contained the highest percentage of Polychaeta. In the second group, cluster 6 was characterised by the smallest size class of schoolmaster and seabream. It contained the highest percentage of Amphipoda. Cluster 7 with the specific species balloonfish and yellowfin mojarra, was dominated by the highest percentages of Gastropoda and Bivalvia. Cluster 8 and 9 contained small grunts and snappers. Their diet was dominated by high percentages of Tanaidacea (both sp. I and II) and Copepoda. In cluster 10, the bluehead wrasse was a typical species. The highest percentage of Ostracoda was present in this cluster. In the third group of clusters, cluster 12 and 13 contained high percentages of Annelida. Typical species for cluster 13 were yelllow goatfish and slippery dick. Cluster 14 contained the highest densities of Mysidacea and Bivalvia. The bonefish was a typical species for this cluster. The diets of the fourth group of clusters (cluster 15, 16, 17, 18 & 20) were all dominated by high percentages of Decapoda and fish. This is most exclusive in cluster 20. Cluster 20 contained all larger fish species like great barracuda, graysby, mahogany snapper, mutton snapper and all larger size classes of gray snapper, yellowtail snapper, schoolmaster and bluestriped grunt. Other typical species in this cluster were squirrelfish and spotted goatfish. Cluster 19 contained only the puddingwife and the diet was co-dominated by Annelida and Gastropoda. Cluster 21 contained only the bandtail puffer and was next to a high percentage of Decapoda, characterised by Tanaidacea and seagrass.

In order to determine existence of spatial patterns in food preference, collected fish were subdivided into four regions: west, east, centre and entrance of Spaanse Water. Analysis with TWINSPAN was used to determine whether specific diets could be clustered into a specific region (figure 22). The capital letter in front of each species indicates the region in which it was collected. Clustering of diets into a specific region could not be observed.

Diet in St. Jorisbaai

TWINSPAN produced 11 clusters of fish species based on their diet (figure 23). Each cluster was characterised by a specific diet with dominant food items (table XXVI). Size classes were not included in the analysis.

The diet of the first cluster (anchovies, great barracuda and horse-eye jack) consisted mainly of fish. The diet of cluster 2 and 3 was dominated by Decapoda and Mysidacea. Corresponding fish species were mainly snappers. Cluster 4 contained the highest densities of Tanaidacea (sp. I and II) and echinoderms. Grunts and mojarra's were typical fish species for this cluster. Cluster 5 contained the highest densities of Polychaeta and Bivalvia. Squirrelfish, white grunt and soals were typical species for this cluster. Cluster 6 contained the balloonfish as important species. The diet was dominated by Decapoda and contained the highest percentage of Gastropoda. Cluster 7 was completely dominated by Amphipoda. The cluster contained species which were only collected in the entrance of the bay: smallmouth grunt, bicolor eel, comb grouper, redear sardine and reef croaker. Cluster 8-11 contained mainly herbivorous species. The diet of cluster 8 and 11 contained the highest percentage of seagrass. Most strict herbivores were found here: damselfishes, smooth trunkfish, parrotfishes, seabream and doctorfish. The diet of cluster 9 was completely dominated by algae and contained foureye butterflyfish and sergeant major as typical fish species.

Diet in Fuikbaai

TWINSPAN produced 8 clusters of fish species based on a characteristic diet (figure 24). Each cluster was characterised by a specific diet with dominant food items (table XXVII). Size classes were not included in the analysis.

The first cluster was dominated by algae and seagrasss and contained herbivores: white mullet, parrotfishes, beaugregory and foureye butterflyfish. Cluster 2 contained only the bonefish. Its diet was dominated by Bivalvia. Cluster 3-5 were dominated by Copepoda and Gastropoda. Grunts and mojarra's were typical species for those clusters. The diet of cluster 6 contained the highest densities of Bivalvia and echinoderms. Balloonfish and saucereye porgy were the only species. Cluster 7 and 8 were dominated by fish and Decapoda. All snappers and great barracuda were found in this cluster.

DETAIL STUDY OF SPAANSE WATER

Classification of the fish community with TWINSPAN

Day census data

TWINSPAN produced 19 clusters of transects based on the fish community (figure 7). Each cluster was characterised by a specific fish community with dominant species (table XII).

All coral reef transects were completely separated from bay transects. Species which dominated the reef transects were mainly small fishes: bluehead wrasse, yellowhead wrasse, blue chromis, brown chromis, threespotted damselfish and bicolor damselfish. Those species were abundant on the reef but were very uncommon in the bay. The fish community of the channel transects is clustered between the reef transects and the bay transects and this biotope therefore forms a transition between both the reef and the bay.

Cluster 1-4 contained mainly deeper reef transects (10 and 15 m) while cluster 5-7 contained the shallow reeftransects (2 and 5 m). Further, shallow reef transects clusters were closer to the bay transects than the deep reef clusters. This indicated that the shallow reef transects were more similar to the bay transects than the deeper reef transects. In those shallow reef transects, especially slippery dicks were dominant. This species also dominated the channel transect. Blue chromis was only dominant in the deeper reef transects while yellowhead wrasses and bluehead wrasse were mainly dominant in shallow reef transects. Fish community of reef transects was clustered more by depth than by site, indicating depth to be a more important structuring factor than location.

French grunt, herring and bluestriped grunt dominated the bay clusters. Other species which were mainly limited to the bay were herrings, mojarra's, bucktooth parrotfish, cocoa damselfish, beaugregory, seabream, leatherjacket, white mullet, white grunt, hardhead silversides, sardines, sailors choice, dusky damselfish, comb grouper and night sergeant.

Niches and rock biotopes were clustered closely to the reef transects in clusters 9-12. Typical species for those clusters were dusky damselfish, schoolmaster, cocoa damselfish, trumpetfish and bluehead wrasse. Species found exclusively in these transects were night sergeant, porcupine fish, highhat and spanish grunt.

Cluster 12 contained only transects situated in the entrance of the bay. They were dominated by bluehead wrasse, next to french grunt and herrings. Besides bluehead wrasse, other species typical for the coral reef occurred in this bay cluster: redfin parrotfish, bicolor damselfish, dusky squirrelfish, brown chromis, sharpnose puffer, spanish hogfish, graysby and yellowtail hamlet. The cluster also contained high densities of cocoa damselfish, blue tang, foureye butterflyfish, clown wrasse, slippery dick, puddingwife, doctorfish, beaugregory, redtail parrotfish, stoplight parrotfish, threespot damselfish, mahogany snapper, yellow goatfish, balloonfish, smallmouth grunt, squirrelfish and sergeant major. All those species occurred in relatively high densities on the coral reef.

Mangroves transects were clustered in cluster 13-15 and were dominated by french grunts and herrings. Compared to other clusters, very high densities of bluestriped grunt, schoolmaster, great barracuda, seabream, foureye butterflyfish, gray snapper, yellowtail snapper, yellowfin mojarra , anchovies and sailors choice were present.

Most seagrass transects were clustered in cluster 16-17. Striped parrotfish was dominant in those clusters with french grunt and herrings. White mullet and leatherjacket were virtually only present in these clusters. Yellowtail snapper reached high densities in these clusters.

Channel transects situated further inwards the bay (channel 10, channel 9) were clustered in cluster 18. This cluster was to some degree similar to the seagrass cluster. However, in this cluster foureye butterflyfish was dominant and herrings were absent.

Cluster 19 contained transects situated far from the entrance of the bay. Two algae transects were present (site 3 and 4). Here, totally different species were dominant: hardhead silversides, needlefish and squirrelfish.

Night census data

TWINSPAN produced 13 clusters of transects based on the fish community (figure 8). Each cluster was characterised by a specific fish community with dominant species (table XIII). In contrast with the day census, only deeper reef transects were clustered completely separated (5, 10 and 15 m). All shallow reef transects (2 m) were clustered between bay transects. Deeper reef transects were clustered rather on location, not on depth. Deeper reef transects (cluster 11-13) were dominated by blackbar soldierfish, longjaw squirrelfish, ocean surgeonfish and yellow goatfish. Individuals of diurnal species (brown chromis and parrotfishes) have been observed during the night census as well. However, these were inactive and corresponding densities were much lower compared to day densities.

All rock transects and some niche transects were clustered in cluster 1-3. The night sergeant was present only in these clusters. The first cluster contained only niche transects. Dusky damselfish, squirrelfish, french grunt and schoolmaster were dominant.

In the cluster 4-9, many different biotopes were represented. However, a specific biotope type was not completely clustered apart. Herrings and french grunt dominate those clusters. Cluster 4 was represented by niche transects and contained relatively high densities of schoolmaster, cubera snapper and foureye butterflyfish. Cluster 5 constituted only of mangrove transects. Along with herrings and french grunt, schoolmaster is dominant in these transects. Threespot damselfish and bluestriped grunt occurred in relatively high densities.

Cluster 6-9 contained a range of biotopes: all seagrass, channel, algae and shallow reef transects were clustered here. Next to french grunt and herrings, balloonfish was dominant. Bluestriped grunt, smallmouth grunt, yellow goatfish, doctorfish and ocean surgeonfish occur in relatively high densities. Mojarra's, sea bream, anchovies, bonefish, butter hamlet, gray snapper, great barracuda, sardines, white grunt, white mullet, yellowfin mojarra and yellowtail snapper were found only in these clusters. Some typical reef fishes were observed here: blackbar soldierfish, blue tang, boga, brown chromis, glaseye snapper, greater soapfish, dusky squirrelfish, longspine squirrelfish, redspotted scorpionfish, sand diver, redspotted hawkfish, peacock flounder, orangespotted filefish, redfin parrotfish, yellowtail damselfish and longjaw squirrelfish. Cluster 10 contained only one niche transect, where only a porcupine fish was observed.

Biotope use and biotope selection: situation during day

Species abundance was calculated for each biotope type in Spaanse Water and is shown in Figure 9. Seagrasses were dominated by french grunt and striped parrotfish. Bluestriped grunt, mojarra's and yellowtail snapper were abundant. Mangroves were dominated by french grunt and schoolmaster. Bluestriped grunt, yellowfin mojarra and foureye buterflyfish were also abundant. The channel biotope was dominated by striped parrotfish. Many species occurred frequently: bicolor damselfish, foureye butterflyfish, gray snapper, french grunt and threespotted damselfish were most abundant. The niche biotope was not dominated by one species. Most abundant species were dusky damselfishes, french grunts, schoolmasters, cocoa damselfishes, bluehead wrasses, beaugregories and bluestriped grunts. Rocks were dominated by french grunts and schoolmasters. Dusky damselfishes and bluehead wrasses were abundant. Sea breams, french grunts, mojarra's, striped parrotfishes and yellowtail snappers dominated the *Halimeda* fields. The coral reef was particulary dominated by small species: bicolor damselfish and bluehead wrasse. Larger species occurred less frequently. Most abundant larger species were ocean surgeonfish, blackbar soldierfish, striped parrotfish and redband parrotfish.

The degree of selection for each biotope type was calculated based on all observed species and is shown in figure 10. Based on all species, only the coral reef was positively selected for. When only the ten most abundant bay species are analysed, the results were different. Only mangroves were positively selected for by the fish species. All other biotopes show biotope avoidance. Algae fields are most avoided. In general, the mangrove biotope showed the highest selection. Mangroves were the most favoured biotope for french grunts, schoolmasters, bluestriped grunts, foureye butterflyfishes, yellowfin mojarra's and beaugregories. For striped parrotfishes and yellowtail snappers, seagrasses were the most favoured biotope. French grunt showed low selection for this biotope. *Halimeda* fields showed high avoidance by all abundant species. Niches showed high degree of selection by dusky damselfishes and beaugregories. Schoolmasters and bluestriped grunts showed only a low preference for this biotope. Rocks were most favoured by dusky damselfishes. Other species showed only low preference for this biotope. Yellowtail snappers showed high avoidance. The channel biotope was favoured by striped parrotfishes, foureye butterflyfishes, yellowtail snappers, gray snappers and beaugregories. French grunts, bluestriped grunts and schoolmasters showed high avoidence. The reef biotope showed only positive selection for dusky damselfishes and foureye butterflyfishes.

Biotope use and biotope selection: situation during night

Species abundance was calculated for each biotope in Spaanse Water (Figure 11). Seagrasses were dominated by french grunt, balloonfish and to a lesser extent by bluestriped grunt. Mangroves were dominated by french grunt and schoolmaster. Balloonfish and bluestriped grunt were also abundant. The niche was not clearly dominated by one species. French grunt, squirrelfish, schoolmaster and balloonfish were abundant here. The rocks are dominated by dusky damselfish, squirrelfish and french grunt. Night sergeant is abundant in both the niche and in the rocks. The dominant fish species in the channel, and the *Halimeda* fields is french grunt. Balloonfish is also abundant in these biotopes. Blackbar soldierfish dominates the reef, followed by ocean surgeon and longjaw squirrelfish.

The degree of selection for each biotope was also calculated for the night census (figure 12). When all species are included the coral reef is again the only positively selected biotope. When only the ten most abundant bay species are included, all biotopes exhibit avoidance. The mangrove is the biotope with the lowest degree of avoidance. It can be stated that when only common bay species are analysed, all biotopes show lower densities than expected.

Ten most abundant bay species

For the ten most abundant bay species during day and night, biotope selection was calculated for species separatly (figure 13). During day, seagrasses showed positive selection for french grunt, striped parrotfish and yellowtail snapper. The mangroves were favoured by all ten species except dusky damselfish, yellowtail snapper and striped parrotfish. Niches were avoided by striped parrotfish, yellowfin mojarra, yellowtail snapper, foureye butterfly fish and gray snapper. Damselfishes (beaugregory, dusky damselfish) showed positive selection for this biotope and all other species were indifferent. Most showed no selection for the rock biotope, with the exception of dusky damselfish and schoolmaster, which showed positive selection and yellowtail snapper, which showed a strong negative selection. The channel biotope was either avoided or preferred with beaugregory, yellowtail snapper, gray snapper, foureye butteflyfish and striped parrot showing positive selection. The *Halimeda* fields were avoided by all ten fish species. The reef was avoided by all ten species, except foureye butterfly fish and dusky damselfish.

During night, seagrasses showed only positive selection for french grunts and yellowtail snappers. Shallow *Halimeda* fields (2m) were favoured by bluestriped grunt, yellowfin mojarra and yellowtail snapper. The reef biotope showed positive selection for french grunt, balloonfish, squirrelfish, smallmouth grunt and foureye butterflyfish. The channel biotope was slightly favoured by foureye butterflyfish. Other species showed strong avoidence. Mangroves were strongly favoured by needlefishes. Other species showed lower degrees of preference. Smallmouth grunt and yellowtail snapper strongly avoided mangroves. French grunt and schoolmaster showed slight preference for niches and rocks. For the squirrelfish those were the most favoured biotopes. Deep *Halimeda* fields (6m) were avoided by all species.

Differences in dominance of each biotope between day and night showed a clear shift in species composition. Diurnal species in the bay such as parrotfishes and some species of damselfishes were replaced and nocturnal species such as balloonfish and squirrelfish became abundant. On the reef, chromis and wrasses species were replaced by squirrelfish such as blackbar soldierfish and longjaw squirrelfish. Also balloonfish was much more abundant.

There are also differences in biotope selection between day and night. Whereas the mangroves still show a positive degree of selection by fish during night, this is no longer the case during night. Preference for rocks also drops. *Halimeda* fields show weaker avoidance by fish during night.

Biotope preference differences of specific species were compared between day and night. French grunt showed a higher preference for *Halimeda* fields and the reef during night. Bluestriped grunt showed a higher preference for seagrass and *Halimeda* fields and much stronger avoidance for niches during night. Biotope avoidance of Schoolmaster for seagrasses, the reef and the channel decreased during night. Yellowfin mojarra showed a stronger preference for seagrass and *Halimeda* fields and stronger avoidance of rocks during night. Yellowtail snapper showed stronger avoidance of mangroves, rocks, reef and channel, while a higher preference was observed for *Halimeda* fields during night. During night, the foureye butterflyfish showed a stronger biotope avoidance of seagrasses, niche and rocks, while biotope preference was higher for the reef.

Diversity

The highest diversity index was recorded on the reef ($P<0.05$) that was significantly different from all other biotopes, except the channel biotope (figure 14). During day the fish community of *Halimeda* fields showed a significantly lower diversity index for all biotopes except niches. This difference was not observed during night. There was little difference between diversity indices during day and night. At both *Halimeda* fields (2 and 6 meter depth respectively) significantly higher indices were found during. During day species richness was significantly higher than during night for each biotope except for the *Halimeda* fields. At night, diversity eveness was higher for all biotopes.

During night the fish communities consisted of less species. However, because species eveness was much higher during night this did not result in large differences in Shannon-Weaver diversity indices between day and night. In deep *Halimeda* fields (6m), a higher number of species was observed during night than during that resulted in significantly higher diversity indices.

Similarity

Table XIV shows similarity percentages between the fish communities of different biotope types during day and night. Similarity between day and night of fish communities of each biotope type is also included. During day, fish communities of mangroves and rocks, seagrasses and mangroves and niches and rocks showed >50% similarity. Similarities were low when the fish communities of bay biotopes were compared with the coral reef and also when deep *Halimeda* fields (6m) were compared wth other biotopes.

During night, Lowest similarity was found between the fish community of the coral reef and bay biotopes (Table XIV). The fish community of seagrasses and *Halimeda* fields, seagrasses and mangroves and *Halimeda* 2m and 6m showed >60% similarity. The fish community of niches and rocks also showed a high similarity. When the fish communities of rocks were compared with other biotopes, similarities were low.

Only the fish communities of seagrasses, mangroves and rocks showed high similarities between day and night. Fish communities of other biotopes showed a much lower similarity. The fish community of the coral reef and *Halimeda* 6m, respectively showed the lowest similarity.

Seasonal influences

Seasonal influences were analysed by testing for differences in densities of french grunt, schoolmaster, striped parrotfish, yellowtail snapper and yellowfin mojarra between biotopes (Table XV). Significant differences in densities in seagrasses were observed for french grunt, striped parrotfish and yellowtail snapper. In rocks and mangroves significant differences in densities were observed for french grunt and schoolmaster. At the coral reef significant differences in densities were observed for french grunt and striped parrotfish. For all five species, densities during the first census period were higher than during the second census period.

Day-night differences: species composition, densities and size frequency of the fish community of each biotope type

Significant differences were observed in both fish densities and fish species composition between day and night. Densities of the five most abundant species in each biotope type were calculated (Table XVI). Table XVII shows the densities of ten most abundant bay species during day and night. In general, fish densities during night were significantly lower. Except *Halimeda* fields that showed higher densities of french grunts, bluestriped grunts and schoolmasters during night than during day. For french grunt and bluestriped grunt, those densities differed significantly. Higher densities of french grunt during night than during day were also observed in niche and channels. Densities of bluestriped grunt, schoolmaster and yellowtail snapper were lower during night than during day in these biotopes. Rocks, mangroves, seagrasses and the coral reef all showed much lower densities during night than during day.

French grunt was both during day and night the most abundant bay species. However, a clear shift in species composition was visible. During day, striped parrotfishes were dominant and relatively high densities of gray snapper, beaugregory, bicolor damselfish, cocoa damselfish and slippery dick were present. During night, those species were rarely present. However, during night, other species became active and abundant. Balloonfishes were dominant and relatively high densities of squirrelfish, smallmouth grunt, needlefish, night sergeant and spotted goatfish were observed.

Table XIV. Similarity between each possible combination of fish communities during day, during night and between day and night for each biotope type. (SP: similarity percentage)

Night		Day		Day-Night	
Biotope	SP	Biotope	SP	Biotope	SP
seagrass-*Halimeda* 2m	74	mangroves-rock	62	seagrass	52
Halimeda 2m-*Halimeda* 6m	73	seagrass-mangroves	58	mangroves	58
seagrass-*Halimeda* 6m	70	niche-rock	54	niche	28
seagrass-mangroves	62	seagrass-rock	49	rock	46
niche-rock	58	seagrass-channel	45	channel	24
mangroves-*Halimeda* 6m	58	seagrass-*Halimeda* 2m	41	*Halimeda* 2m	27
mangroves-niche	56	mangroves-niche	38	*Halimeda* 6m	12
mangroves-*Halimeda* 2m	55	channel-*Halimeda* 2m	36	reef	15
seagrass-channel	51	*Halimeda* 2m-*Halimeda* 6m	35		
channel-*Halimeda* 6m	50	seagrass-niche	28		
channel-*Halimeda* 2m	48	reef-channel	26		
mangroves-channel	46	niche-*Halimeda* 2m	24		
seagrass-niche	41	mangroves-*Halimeda* 2m	20		
niche-channel	37	niche-channel	20		
niche-*Halimeda* 6m	36	mangroves-channel	17		
niche-*Halimeda* 2m	34	rock-*Halimeda* 2m	17		
mangroves-rock	33	rock-channel	16		
rock-channel	29	channel-*Halimeda* 6m	15		
seagrass-rock	25	reef-branding	13		
rock-*Halimeda* 6m	23	seagrass-*Halimeda* 6m	12		
reef-channel	22	niche-*Halimeda* 6m	9		
rock-*Halimeda* 2m	22	reef-rock	8		
reef-seagrass	19	mangroves-*Halimeda* 6m	7		
reef-*Halimeda* 6m	19	reef-seagrass	6		
reef-mangroves	17	rock-*Halimeda* 6m	6		
reef-niche	15	reef-mangroves	4		
reef-*Halimeda* 2m	14	reef-*Halimeda* 2m	3		
reef-rock	10	reef-*Halimeda* 6m	2		

Table XV. Differences in densities between the first and second census period for five species in several biotopes. S: significant with paired t test. S**: significant with Wilcoxon signed rank test. NS: not significant -: species not present in biotope

	Seagrass	Mangroves	Niche	Rock	Channel	*Halimeda* 2m	Reef 2m	Reef 5m	Reef 10m	Reef 15m
French grunt	*S***	*S***	*NS*	*S***	*NS*	*NS*	*S***	*NS*	*S*	*NS*
Schoolmaster	*NS*	*S***	*NS*	*S***	-	-	-	*NS*	*NS*	-
Striped parrot	*S***	*NS*	-	*NS*	*NS*	-	*NS*	*NS*	*S***	*S***
Yellowtail snapper	*S***	*NS*	-	-	*NS*	*NS*	-	*NS*	*NS*	*NS*
Yellowfin mojarra	*NS*	*NS*	*NS*	*NS*	-	*NS*	-	*NS*	-	-

Table XVI. Differences in mean fish densities between day and night for five species in different biotope types. * Wilcoxon-Mann-Whitney U test ** unequal variance t-test

	french grunt			schoolmaster			bluestriped grunt			yellowtail snapper			dusky damselfish		
Biotope type	Day	night	P *	Day	night	P*	Day	Night	P*	day	night	P*	day	night	P*
Rocks	643.80	16.50	<0.0001	254.20	13.10	<0.0001	115.49	1.33	0.013	-	-	-	160.8	32.3	0.0002
Mangroves	98.00	3.00	<0.0001	35.80	3.00	<0.0001	23.60	1.00	<0.0001	-	-	-	-	-	-
Seagrasses**	27.80	1.40	<0.0001	0.20	0.10	0.107	3.50	0.40	<0.0001	3.00	0.20	<0.0001	-	-	-
Channel	1.80	2.80	0.758	0.40	0.20	0.591	0.08	0.00	<0.0001	1.83	0.08	0.013	-	-	-
Niche	9.00	32.30	0.363	12.20	1.80	0.009	1.56	0.00	<0.0001	-	-	-	-	-	-
Halimeda fied (2m)	0.18	1.20	<0.0001	0.10	1.30	1	0.07	0.51	0.005	0.32	0.18	0.603	-	-	-
Reef	2.71	0.56	<0.0001	0.18	0.06	0.156	0.24	0.03	0.007	0.43	0	<0.0001	-	-	-
Spaanse Water bay	92.51	3.0	0.005	38.05	2.1	0.004	20.65	0.56	0.0022	2.61	0.1	<0.0001	20.61	3.4	0.0714

Table XVII. The densities of ten most abundant bay species during day- and night (densites of all bay habitats, herrings and anchovies not included).

Day		Night	
Species	Density (100 m^2)	Species	Density (100 m^2)
French grunt	1.33	French grunt	16.68
Striped parrotfish	0.58	Balloonfish	7.51
Schoolmaster	0.36	Bluestriped grunt	3.86
Bluestriped grunt	0.31	Schoolmaster	3.13
Four-eye butterflyfish	0.17	Yellowfin mojara	1.82
Yellowfin mojarra	0.16	Yellowtail snapper	1.72
Dusky damselfish	0.12	Squirrelfish	1.06
Yellowtail snapper	0.10	Smallmouth grunt	1.04
Gray snapper	0.08	Needlefish	1.01
Beaugregory	0.08	Four-eye butterflyfish	0.95

Size frequencies of french grunt, bluestriped grunt, schoolmaster and yellowtail snapper during day and night were determined for all sampled biotope types (Table XVIII). In most biotope types, it appeared that compared with larger size classes, smaller size classes were significantly less abundant during night than during day. During day relatively more small individuals were observed than during night. This was especially valid for french grunt and bluestriped grunt. When the whole bay was concerned, this was also valid for yellowtail snapper. Such a difference was not observed for the schoolmaster. In the *Halimeda* fields, no differences were observed.

Lunar cycle

Only the balloonfish showed a significant difference in densities during the four moon phases. Highest densities were reached during new moon (14 ind./100m^2) and lowest densities were reached during full moon (4 ind./100m^2). Other abundant species showed no significant differences.

Table XVIII. Size frequency of french grunt, bluestriped grunt, schoolmaster and yellowtail snapper during day and night in the various bay biotopes. Size frequencies were compared with a Chi square test of a Fischer exact probability test. Symbols: x: Chi square test; f: Fisher exact probability test; * no significant difference, ** significantly lower frequency *($P<0.05$)* of smaller size classes during night.

Biotope	Seagrass					Mangroves				
Species	size	day	night	test	P-value	size	day	night	test	P-value
French grunt	0.0 - 2.5	60	0	x	0.0009	0.0 - 2.5	11	0	x	<
	2.5 - 5.0	178	3	χ^2=18.7		2.5 - 5.0	128	3	χ^2=37.	
	5.0 - 7.5	661	29	**		5.0 - 7.5	628	7	**	
	7.5 - 10.0	893	54			7.5 - 10.0	753	24		
	>10	42	7			10.0 -	106	13		
						12.5 -	19	0		
Schoolmaster	<12.5	8	1	f	0.201	<7.5	50	2	x	0.308
	12.5 -	7	6	*		7.5 - 10.0	130	12	χ^2=6.0	
						10.0 -	185	11	*	
Bluestriped	<7.5	31	1	x	<	<12.5	350	2	x	<
	7.5 - 10.0	123	3	χ^2=47.7		12.5 -	40	4	χ^2=82.	
	10.0 -	55	5	**	day	15.0 -	10	6	**	
	12.5 -	22	12			>17.5	6	2		
	>15.0	3	3							
Yellowtail	< 7.5	85	2	x	0.168					
	7.5 - 10.0	52	6	χ^2=5.1						
	10.0 -	43	5	*						
	>12.5	18	2							
biotope	Rocks					channel				
species	size	day	Night	test	P-value	size	day	night	test	P-value
French grunt	<10	285	3	x	<	<10	12	6	x	0.552
	>10	27	5	χ^2=19.5		>10	35	10	χ^2=0.4	
				**					*	
biotope	Algae 2m					niche				
species	size	day	night	test	P-value	size	day	night	test	P-value
French grunt	<10	2	34	f	0.088	<10	29	1	f	0.0049
	>10	6	19	*		>10	8	6	**	
Schoolmaster						<15	43	4	f	0.774
						>15	11	2	*	
Bluestriped	<12.5	1	11	f	1.063					
	>12.5	2	11	*						
Yellowtail	<10	10	4	f	0.582					
	>10	4	4	*						
biotope	Spaanse Water bay					reef				
species	size	day	night	test	P-value	size	day	night	test	P-value
French grunt	0.0 - 2.5	83	0	x	<0.000	<7.5	28	1	x	<
	2.5 - 5.0	441	9	χ^2=255.		7.5 - 10.0	2	6	χ^2=49.	
	5.0 - 7.5	1357	46	**		10.0 -	26	18	**	
	7.5 - 10.0	1759	116			12.5 -	119	19		
	10.0 -	206	67			>15	112	11		
	12.5 -	37	14							
	15.0 -	0	1							
Schoolmaster	2.5 - 5.0	10	0	x	0.643	<20	9	2	f	1.091
	5.0 - 7.5	41	2	χ^2=4.3		>20	14	2	*	
	7.5 - 10.0	138	13	*						
Bluestriped	<7.5	85	1	x	<0.000	<25	24	2	f	1.206
	7.5 - 10.0	298	5	χ^2=101.		25.0 -	8	1	*	
	10.0 -	200	17	**						
	12.5 -	68	23							
	15.0 -	14	8							
	17.5 -	11	2							
	>20	9	6							
Yellowtail	2.5 - 5.0	23	0	x	0.0003					
	5.0 - 7.5	94	21	χ^2=25.4						

	7.5 - 10.0	103	46	**			
	10.0 -	89	49				
	12.5 -	58	28				
	15.0 -	10	0				
	>17.5	4	0				

Differences in fish size between coral reef and bay

Differences in mean length of french grunt, bluestriped grunt, striped parrotfish, schoolmaster and yellowtail snapper in six different bay biotopes and on the reef were tested for significance. Results show small individuals in the bay biotopes and large individuals on the reef (figure 15). This is also valid for other species. Also small individuals (2-30 cm) of the predator great barracuda were found in the bay, whereas larger individuals (>50cm) were found on the reef (personal observations authors).

Effect distance coral reef - entrance bay

In order to determine whether Spaanse Water has a clear influence on the reef fish community situated closely and further from the entrance of the bay, five reef sites were compared. Those sites varied in distance to the entrance of the bay. Mean size and mean density of five species, occurring in both the bay and on the reef were compared for these locations (figure 16). Size differed significantly between the bay and the different reefsites. However, no significant correlation was found between distance to the entrance and size of the species. For all species, densities were highest in Spaanse Water, except for striped parrotfish. When tested for significance with the striped parrotfish excluded, density was significantly higher in Spaanse Water for the remaining species (one-way ANOVA, $P= 0.046$). Again, only a weak non-significant correlation was found between distance to the entrance and density of the species (R^2=0.31).

Similarity percentages between the different reef sites and Spaanse Water were calculated (table XIX). Similarity is highest between reef sites and lowest between Spaanse Water and one of the reefsites. Data on the fish community of the reef in front of St. Jorisbaai was also obtained using the visual census technique. Reef fish communities were found to be different between the north and south coast. Similarity percentages between the reef in front of St. Jorisbaai and the average of all reefs on the south coast was 41.8%. Personal observations (authors) confirm the marked difference between reefs situated on the north coast and reefs situated on the south coast. An example is the observation a large school (>25 individuals) of cottonwick (*Haemulon melanurum*), a species of grunt very rarely observed on the south coast, while other grunt species are virtually absent on the north coast.

Table XIX. Similarity percentages between different reef sites and Spaanse Water

	Spaanse Water	Barbara beach	Punti piku	Jan Thiel	Princess Beach	Slangenbaai
Spaanse Water	-					
Barbarabeach	12.43	-				
Punti piku	9.08	65.24	-			
Janthiel	13.16	80.64	72.27	-		
Princess Beach	9.68	71.89	59.90	76.66	-	
Slangenbaai	10.92	74.79	64.65	83.15	83.15	-

Large school of cottonwicks (*Haemulon melanurum*), observed on June 26, 1998 (photograph M. Dorenbosch).

Correlations of mean length with environmental factors in seagrasses and mangroves

Correlations of mean length of six fish species in mangroves and seagrasses with environmental variables were calculated (Table XX). In the mangroves, schoolmaster showed a significant negative correlation with seagrass complexity. Foureye butterflyfish showed a significant positive correlation with mean visibility. Bluestriped grunt showed no significant correlation with any of the environmental variables. French grunt showed a significant positive correlation with index epifauna. In the seagrasses, bluestriped grunt showed a strong significant correlation with index epifauna. Both french grunt and striped parrotfish showed significant positive correlations with distance to entrance within the bay, H' epifauna and salinity. Yellowtail snapper showed no significant correlation with any of the environmental variables. Mean temperature showed no correlation with any species both in the mangroves and in the seagrasses. Mean visibility was more strongly correlated with size in the mangroves than in the seagrasses.

Correlations of environmental variables with densities of six fish species in both mangroves and seagrasses were calculated (Table XXI). In the mangroves, densities of both grunt species showed significantly negative correlations with distance to entrance and H' epifauna. French grunt also showed a significantly negative correlation with complexity of seagrass. Bluestriped grunt also showed a strong negative correlation with complexity of seagrass, however, this correlation was not significant. Bluestriped grunt also showed a significantly negative correlation with mean salinity. Both schoolmaster and foureye butterflyfish showed no significant correlation with any of the environmental variables. In the seagrasses no significant correlations of with the environmental variables with the densities of any of the species was found.

Table XX. Correlations of mean length of six fish species in mangroves and seagrasses with environmental variables. Pearson correlation test, * = *P<0.05*, ** = *P<0.01*.

	Mangroves				Seagrasses			
Species	Schoolmaster	Foureye butterflyfish	Bluestriped grunt	French grunt	Bluestriped grunt	French grunt	Striped parrotfish	Yellowtail snapper
Distance to entrance within the bay	-0.492	-0.343	0.294	0.51	0.164	**0.848	**0.926	0.152
Mean visibility	0.496	*0.714	0.389	0.545	0.391	-0.008	0.051	-0.42
Index epifauna	-0.23	0.175	0.325	*0.626	**0.857	0.344	0.319	-0.008
Index infauna	-0.461	-0.241	-0.437	0.088	0.014	-0.025	-0.248	0.282
H' epifauna	-0.542	-0.431	0.061	0.512	0.346	**0.770	*0.797	0.066
H' infauna	-0.313	0.166	0.071	0.189	-0.284	-0.608	-0.542	0.383
Complexity seagrass	*-0.631	-0.185	-0.205	-0.085	-0.202	0.07	0.53	0.26
Mean salinity	-0.461	-0.437	0.224	0.256	-0.203	**0.769	*0.782	-0.118
number of samples	11	10	11	11	10	11	8	11

Table XXI. Correlations of total densities of six fish species in mangroves and seagrasses with environmental variables. Pearson correlation test, * = *P<0.05*, ** = *P < 0.01*.

	Mangroves				Seagrasses			
	Schoolmaster	Foureye butterflyfish	Bluestriped grunt	French grunt	Bluestriped grunt	French grunt	Striped parrotfish	Yellowtail snapper
Distance to entrance	-0.225	-0.22	*-0.709	*-0.621	0.079	-0.055	-0.521	-0.178
Mean visibility	0.233	0.295	0.47	0.236	0.001	0.373	0.379	-0.123
Index epifauna	0.338	0.009	-0.117	-0.193	0.063	0.569	0.284	0.41
Index infauna	-0.009	-0.316	-0.109	-0.331	-0.111	-0.275	-0.457	0.029
H' epifauna	-0.253	-0.351	*-0.714	*-0.632	0.086	-0.13	-0.528	-0.081
H' infauna	-0.03	-0.348	0.205	-0.106	0.206	-0.096	-0.008	0.224
Complexity seagrass	-0.128	-0.473	-0.521	**-0.789	0.458	0.115	-0.337	0.249
Mean salinity	-0.095	-0.088	*-0.662	-0.423	0.207	-0.206	-0.494	-0.174
number of samples	11	10	11	11	8	10	8	10

Correlation of fish data with environmental factors, using CANOCO.

A CCA was executed using the seagrass data (Figure 17). It appeared that mean temperature, distance to the entrance, index epifauna and mean visibility were significant factors determining the fish community (*P<0.05*) (Table XXII). Most variation was explained by distance from the entrance. The first two axis showed the highest eigenvalues. Plots of the third and fourth axis appeared to be non-relevant.

A CCA was executed using the mangrove data (Figure 18). It appeared that seagrass complexity, distance from the entrance, mean visibility and index epifauna were significant factors with respect to the fish community. (*P<0.05*) (Table XXIII). Most variation was explained seagrass complexity and distance to the entrance. The first two axis showed the highest eigenvalues. Plots of the third and fourth axis appeared to be non-relevant.

Table XXII. Monte Carlo permutation test significances of the CCA in seagrasses.

Monte Carlo permutation test significances	
Variable	P-value
Temperature	0.002
Distance to the entrance	0.006
index epifauna	0.008
mean visibility	0.008

Table XXIII. Monte Carlo permutation test significances of the CCA in mangroves.

Monte Carlo permutation test significances	
Variable	P-value
Seagrass complexity	0.002
Distance to the entrance	0.006
Mean visibility	0.02
index epifauna	0.036

Comparison fish densities reef – fish densities Spaanse Water

The extent to which Spaanse Water was used is determined by calculating an index for all observed species by dividing the densities found in Spaanse Water with the densities found on the reef (Table XXIV; figure 19). Considering the range of this index, four groups of fish species could be distinguished; group 1: 0.0-0.2 (71 species), group 2: 0.2-4.0 (24 species), group 3: 4.0 - 20.0 (7 species), group 4: >20.0 (20 species). Species observed only at the reef were classified in group 1 and species observed only in the bay were classified in group 4.

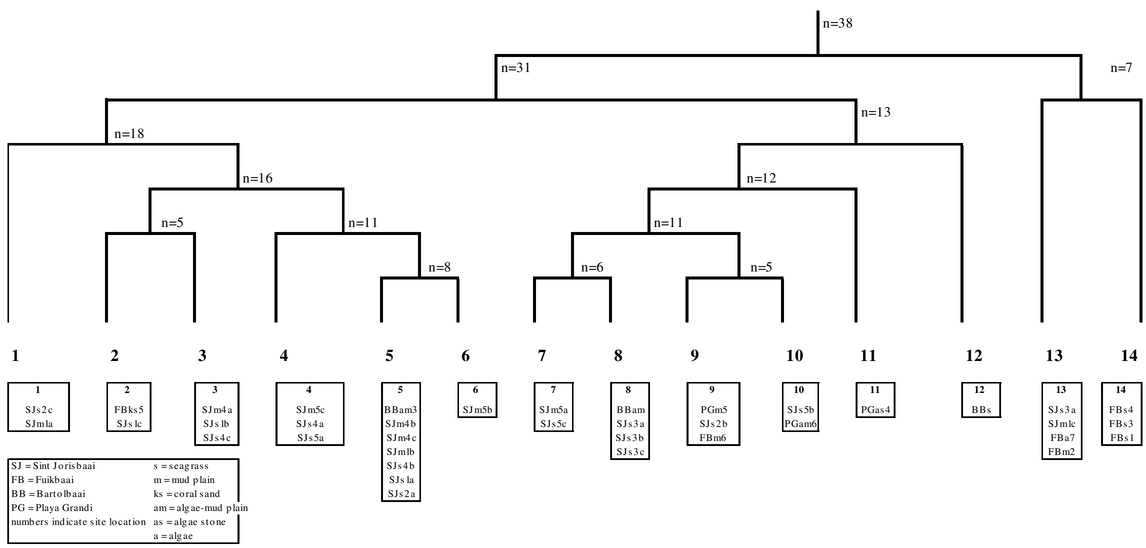


Figure 3. TWINSPAN results, showing fish clusters in all sampled bays.

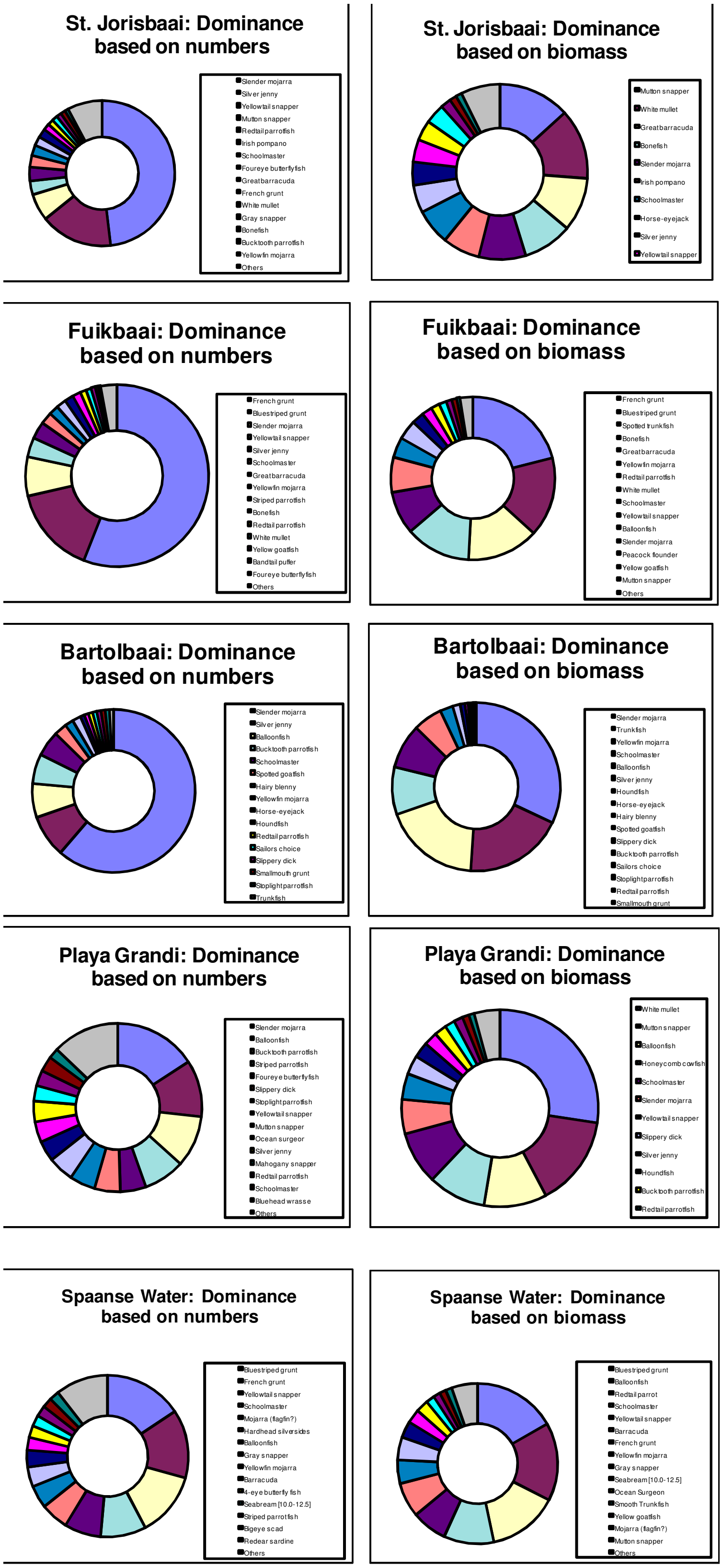


Figure 4. Percentual contribution of dominant fish species to total fish biomass and fish numbers of all sampled biotopes of St. Jorisbaai, Fuikbaai, Bartolbaai, Playa Grandi and Spaanse Water.

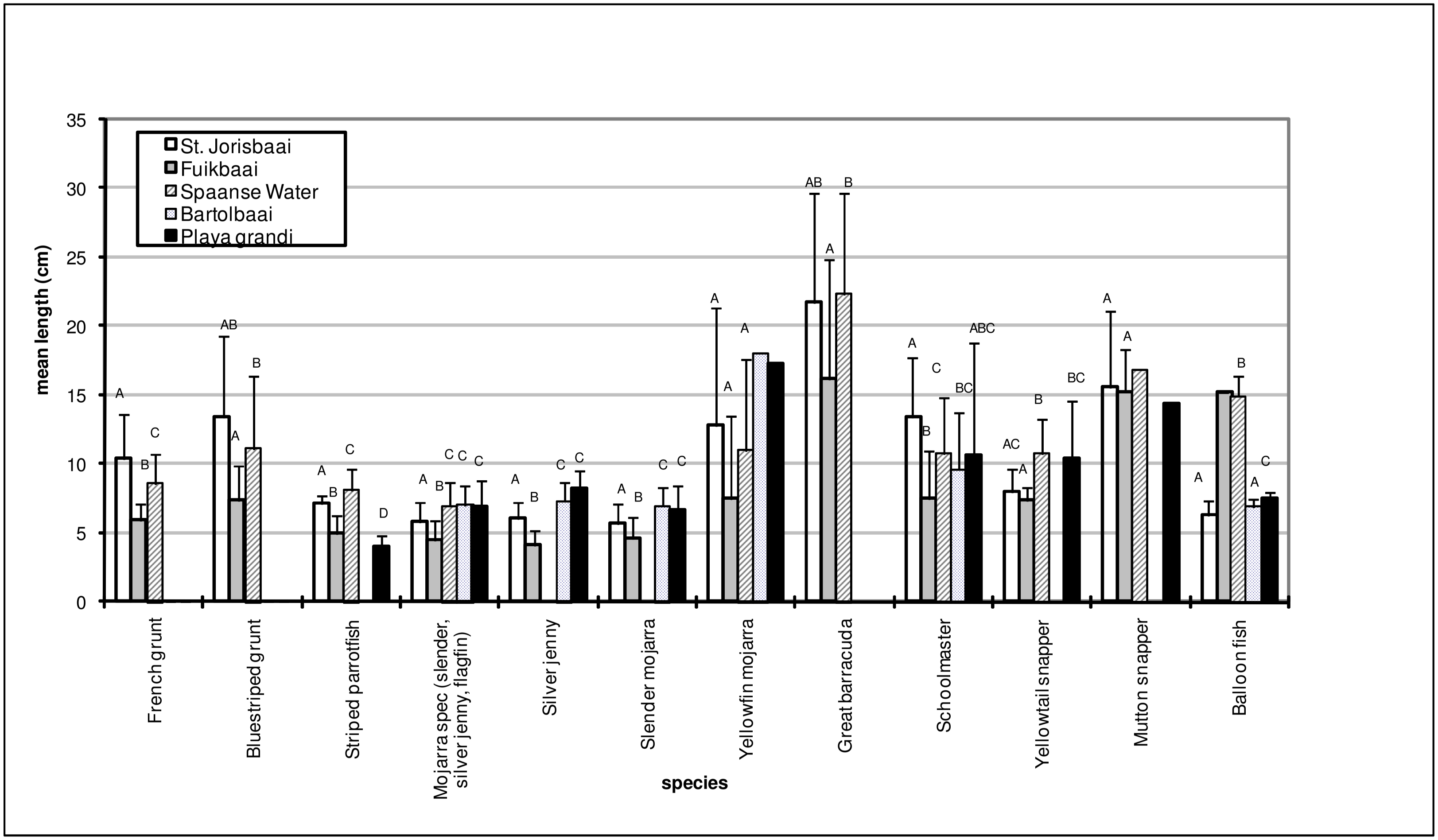


Figure 5. Mean length of eleven species in the five sampled bays. Non-identical letters above standard error bars indicate significant differences (Student t-test; *P<0.05*)

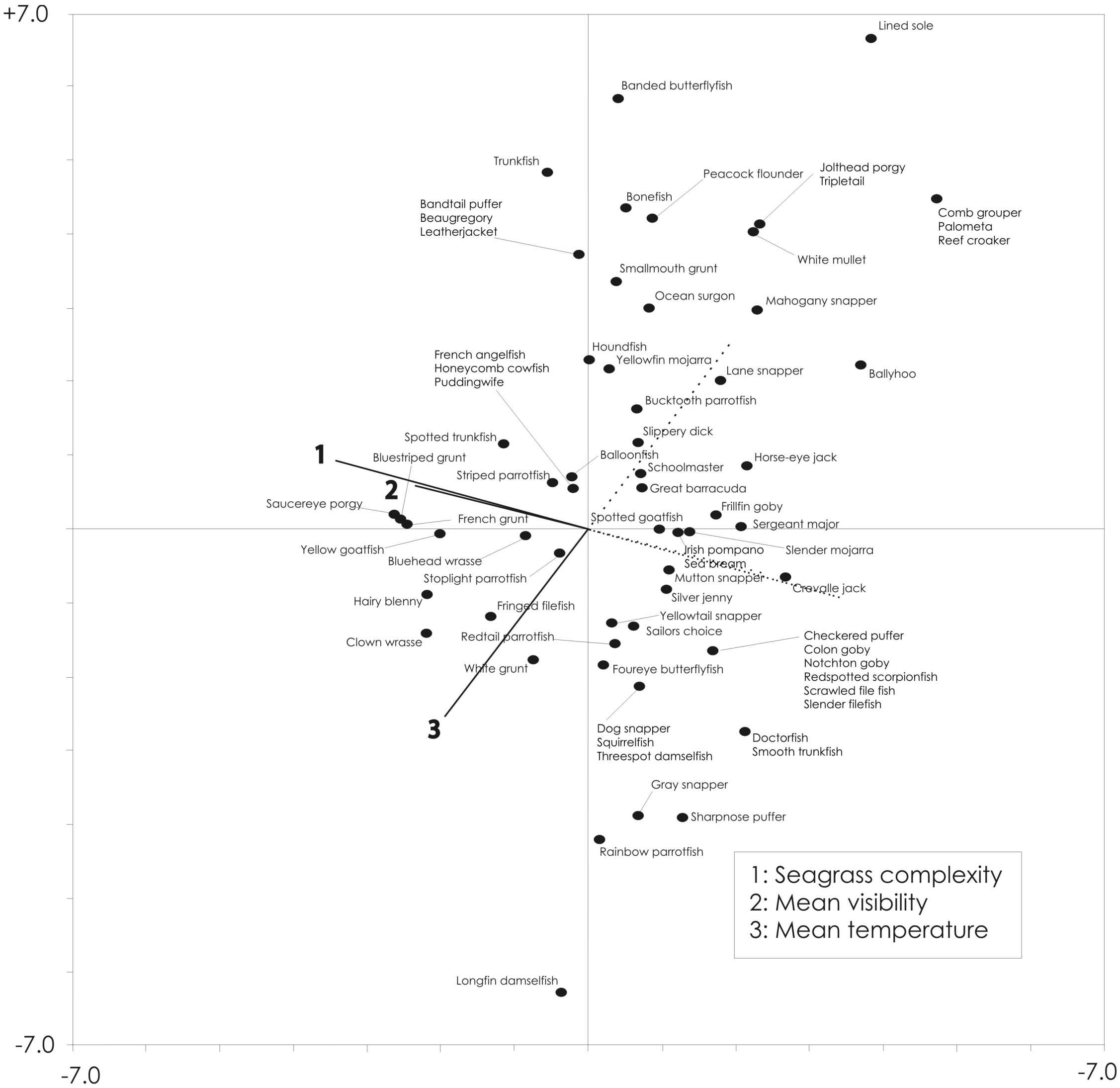


Figure 6: Canonical Correspondence Analysis plot of the fish fauna of all sampled lagoons and the relevant environmental facors. Only the first two ordination axis are shown.

: positive correlation

: negative correlation

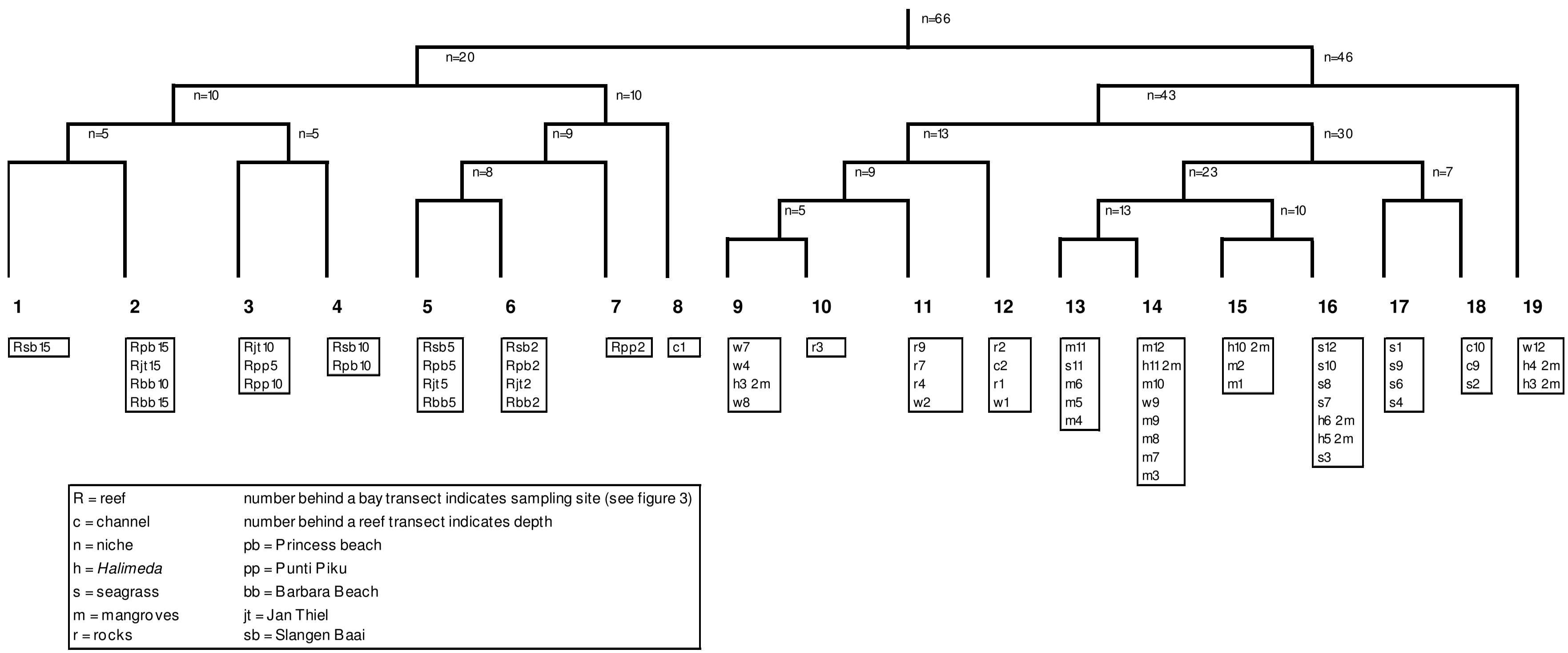


Figure 7. TWINSPAN results during day, showing fish clusters in all biotopes of Spaanse Water.

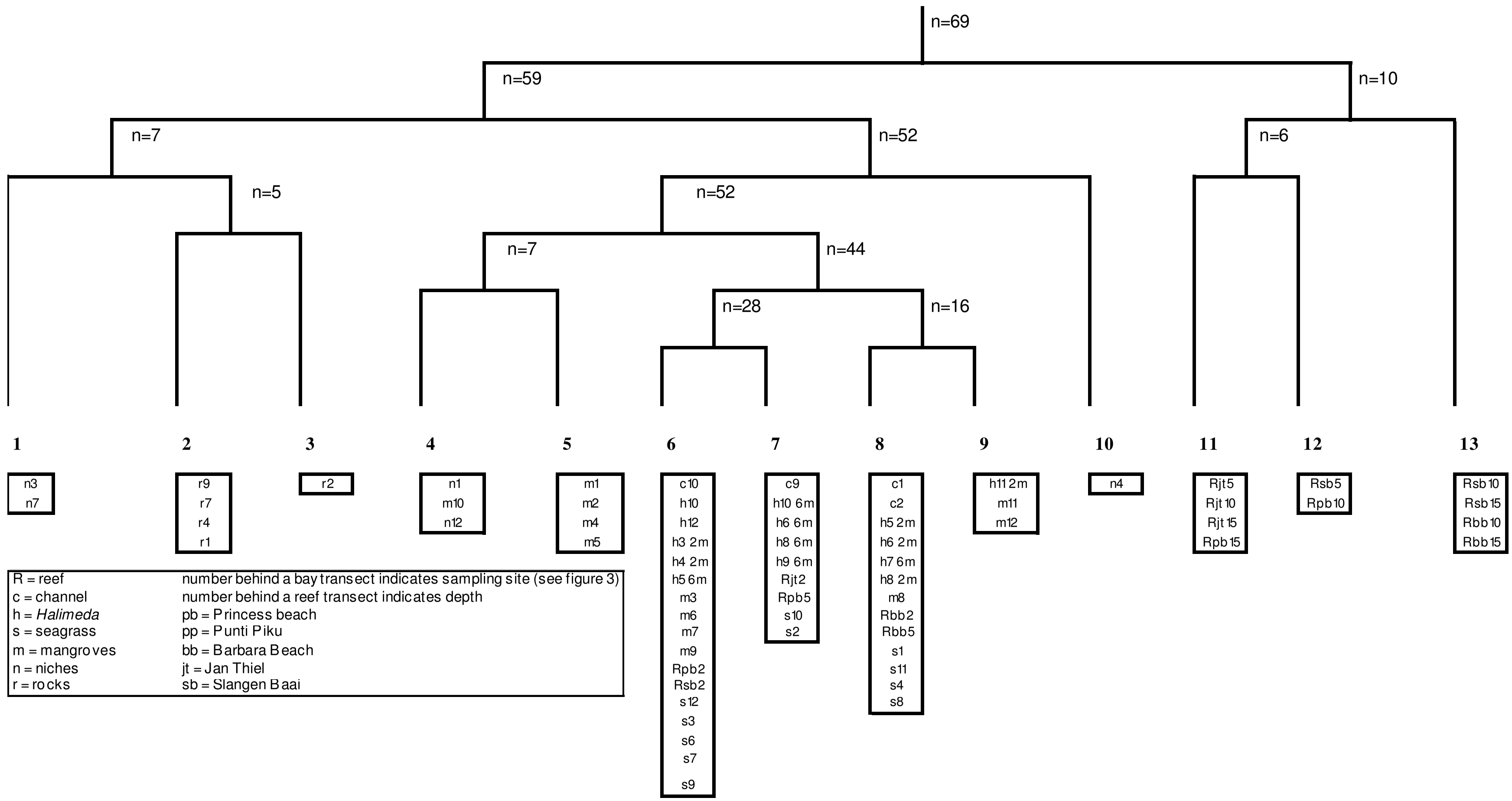


Figure 8. TWINSPAN results during night, showing fish clusters in all biotopes of Spaanse Water.

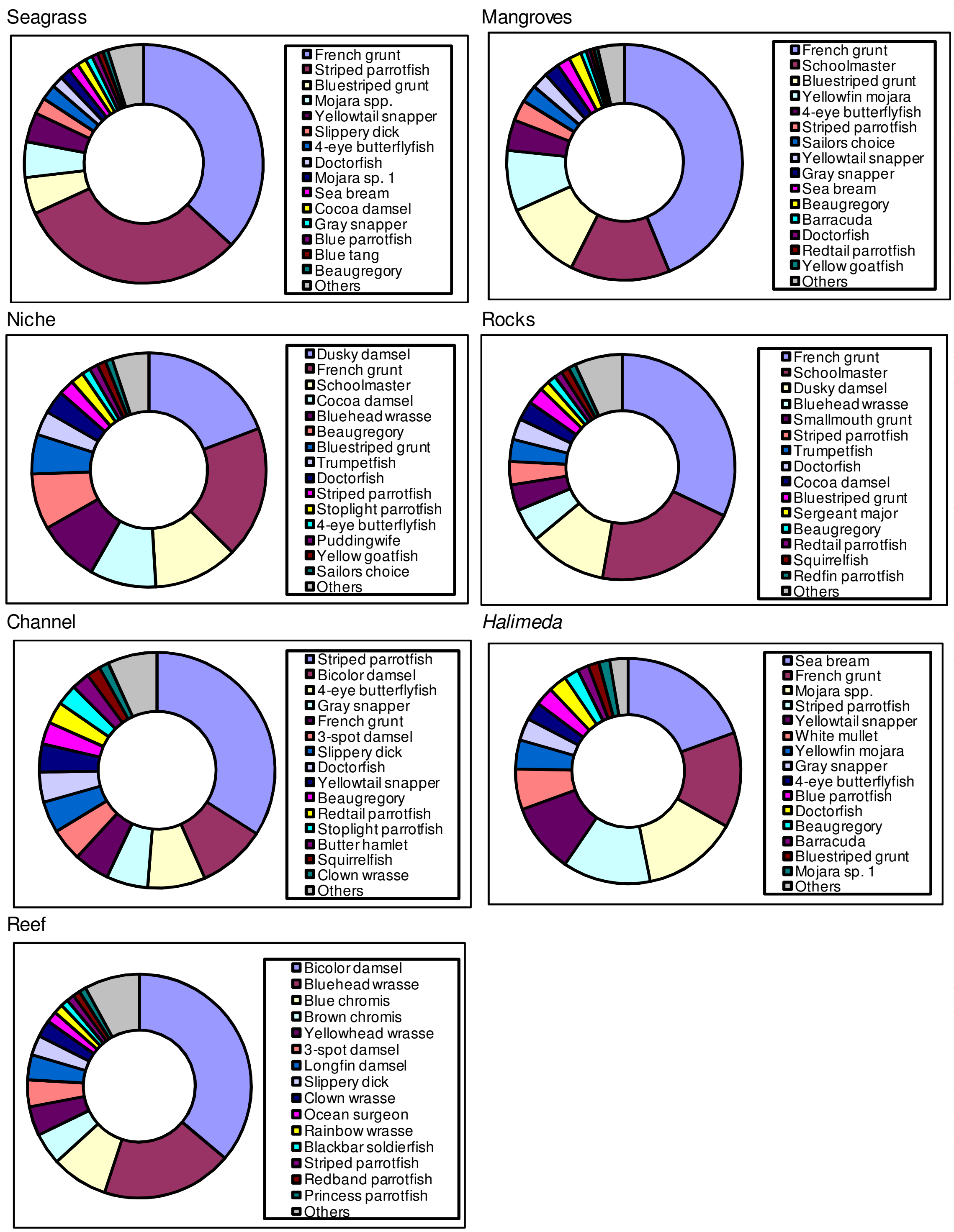
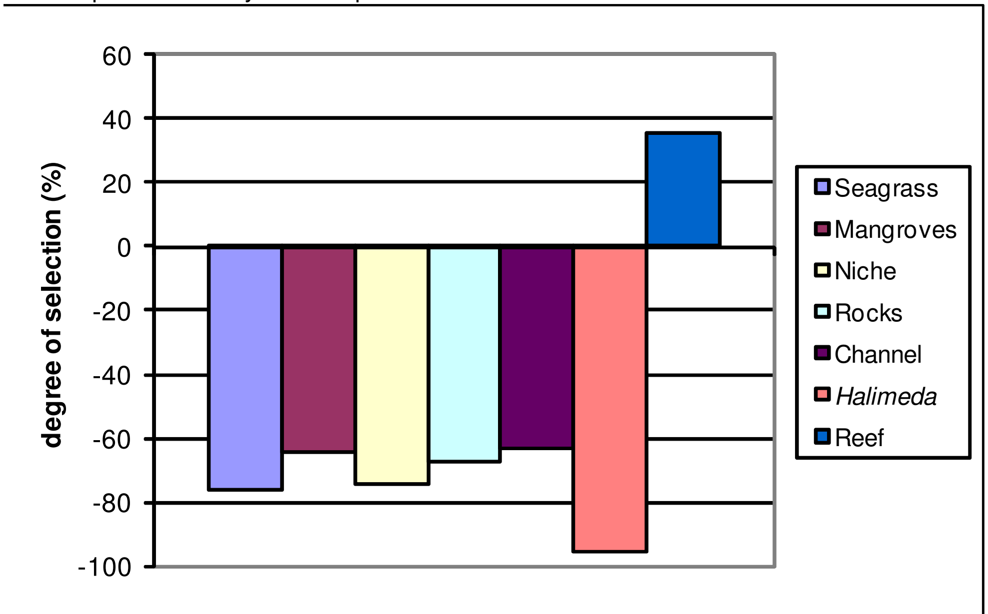


Figure 9. Species abundance (%) during day of each biotope type of Spaanse Water.

A: biotope selection by all fish species



B: biotope selection by the ten most abundant bay species

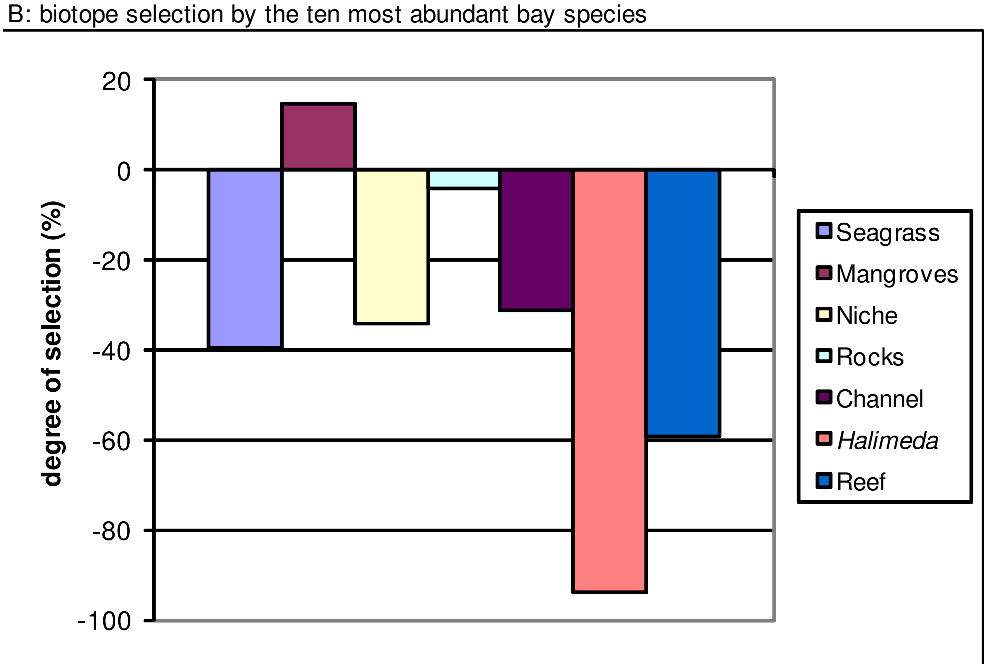


Figure 10. Selection of biotopes by the fish community in Spaanse Water Water during day, based on all fish species (A) and based on the ten most abundant bay species (B).

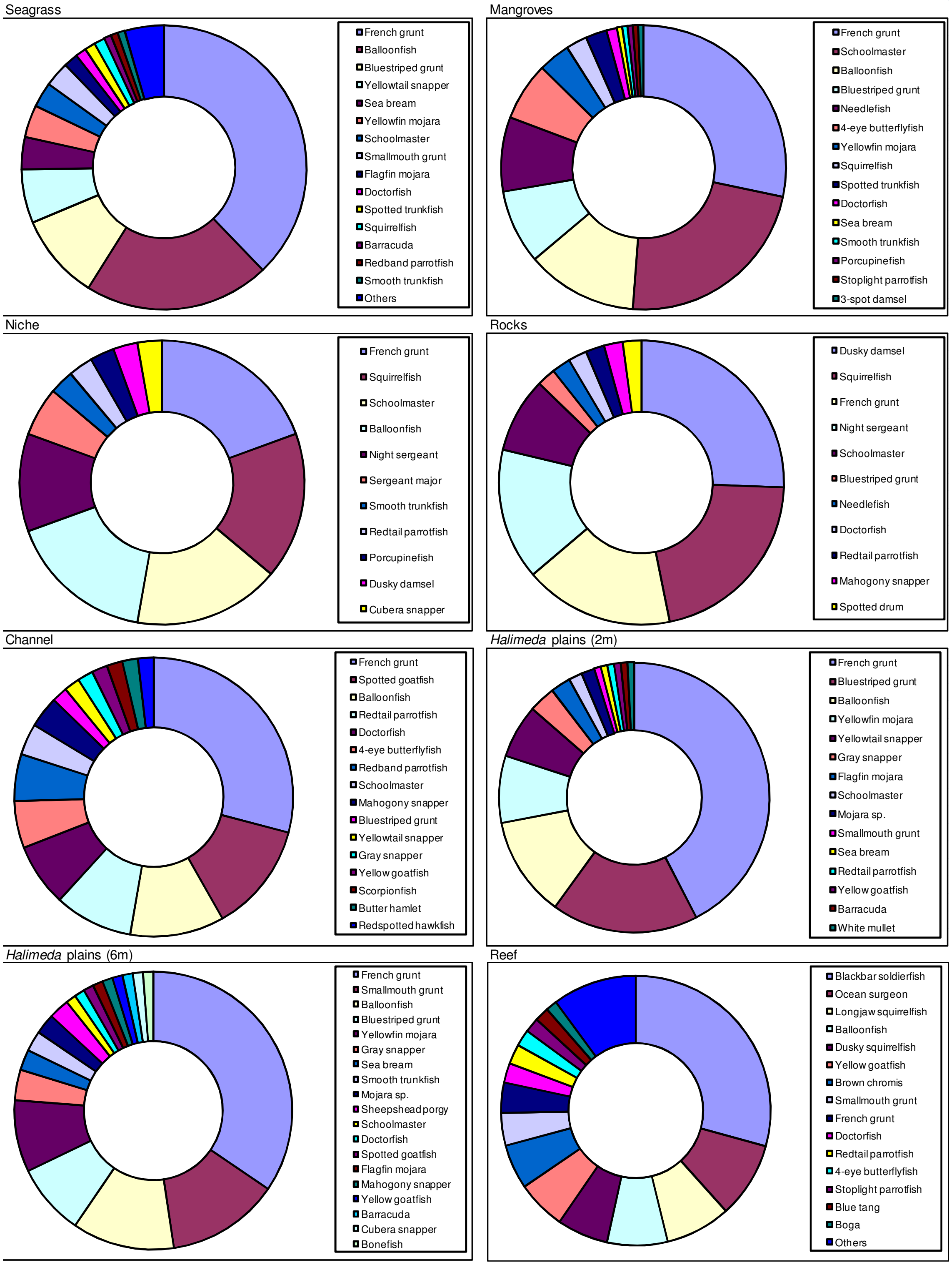
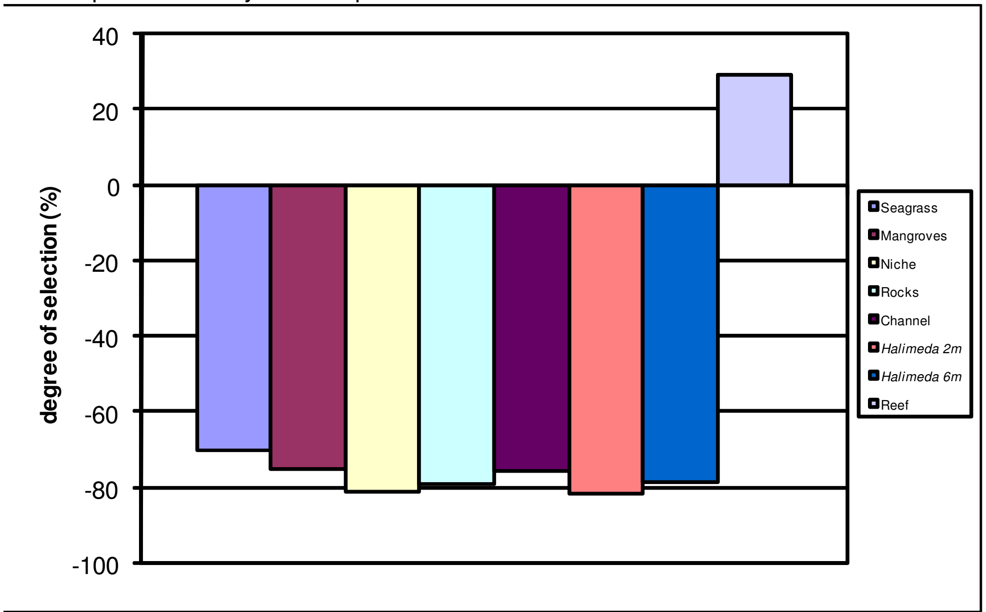


Figure 11. Species abundance (%) in all biotope types of Spaanse Water during night.

A: biotope selection by all fish species



B: biotope selection by the ten most abundant bay species

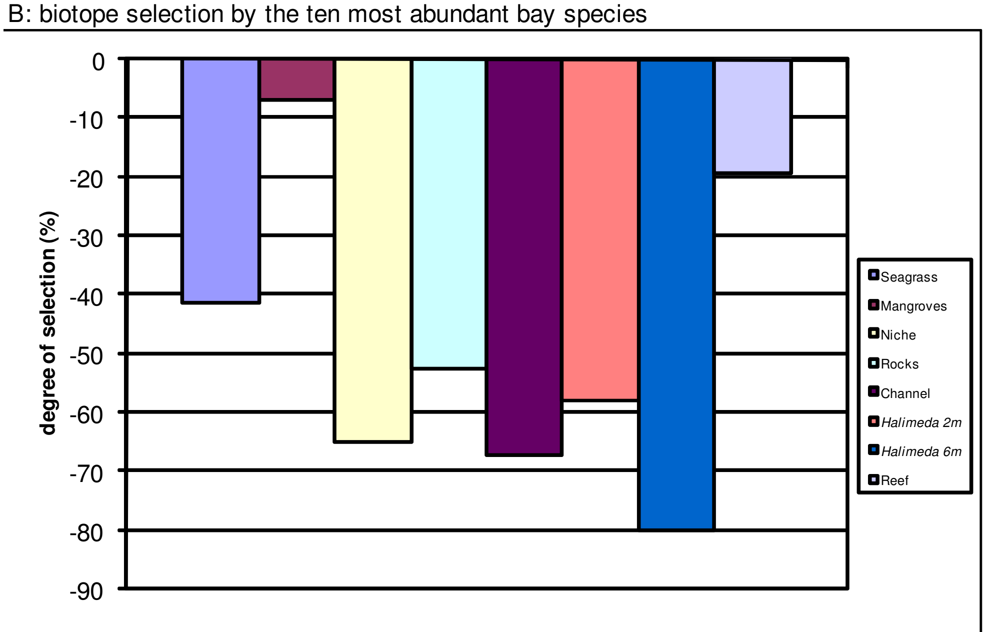


Figure 12. Selection of biotopes by the fish community in Spaanse Water Water during night, based on all fish species (A) and based on the ten most abundant bay species (B).

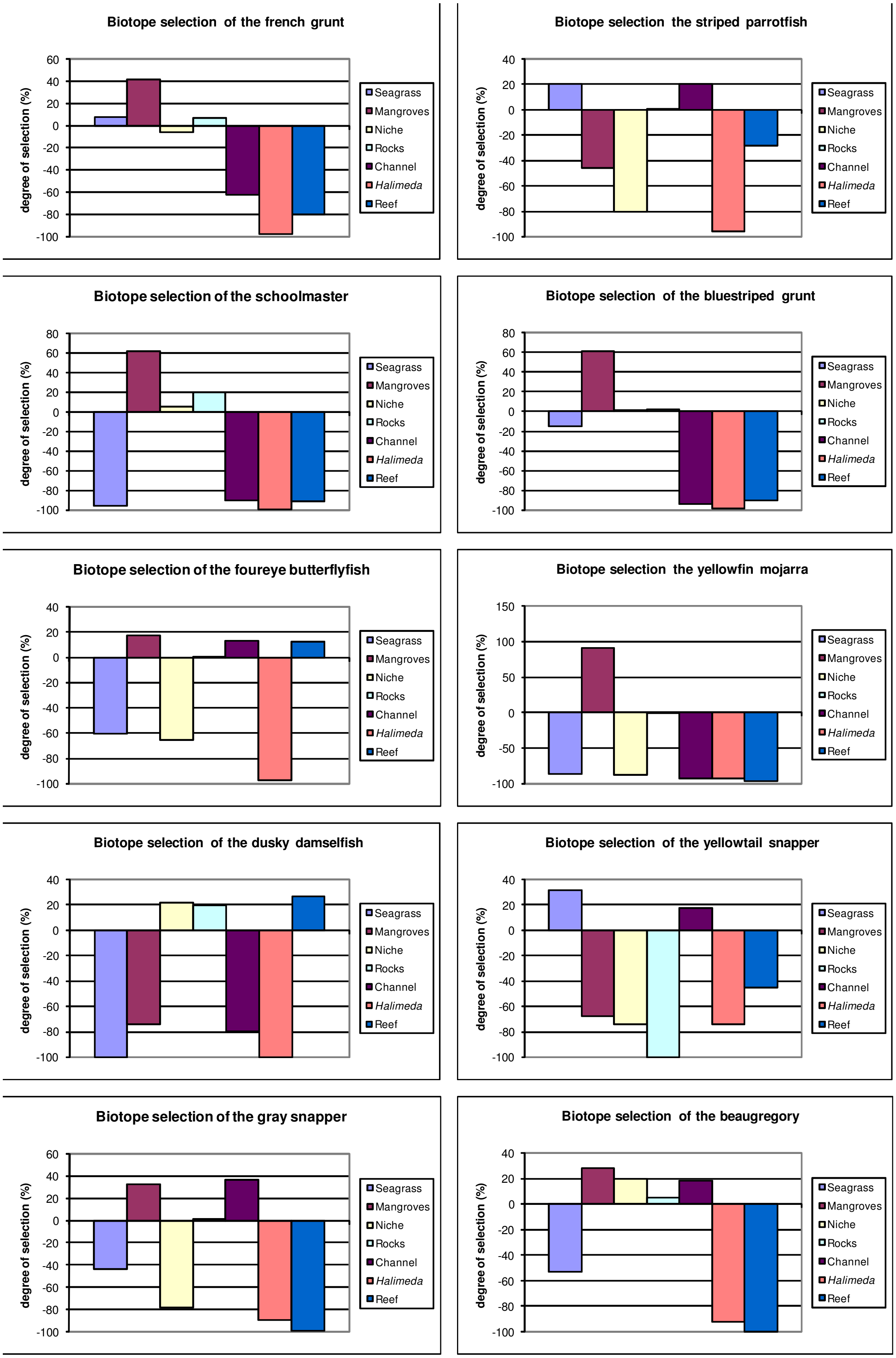


Figure 13 A. Biotope selection of the ten most abundant bay species during day.

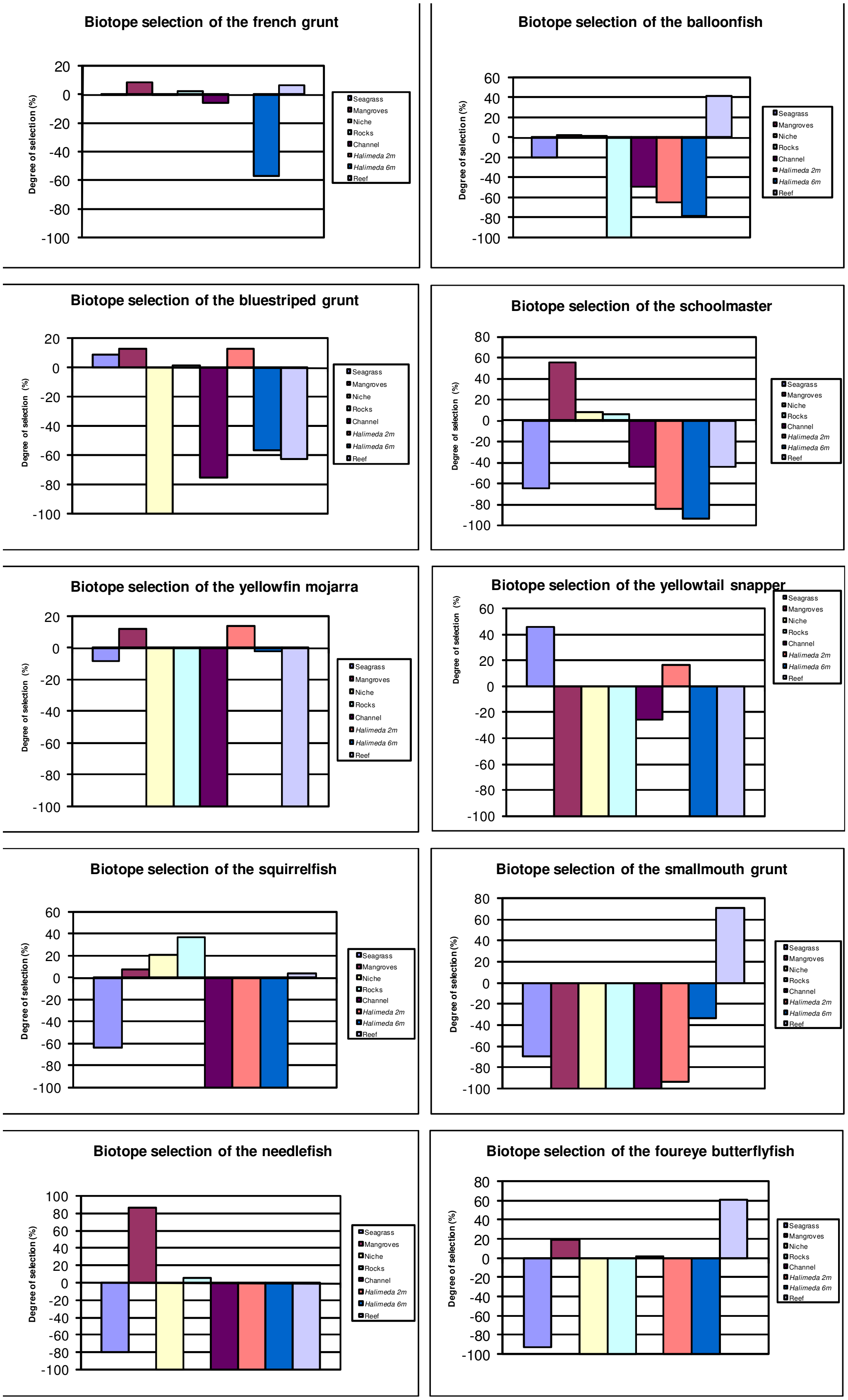
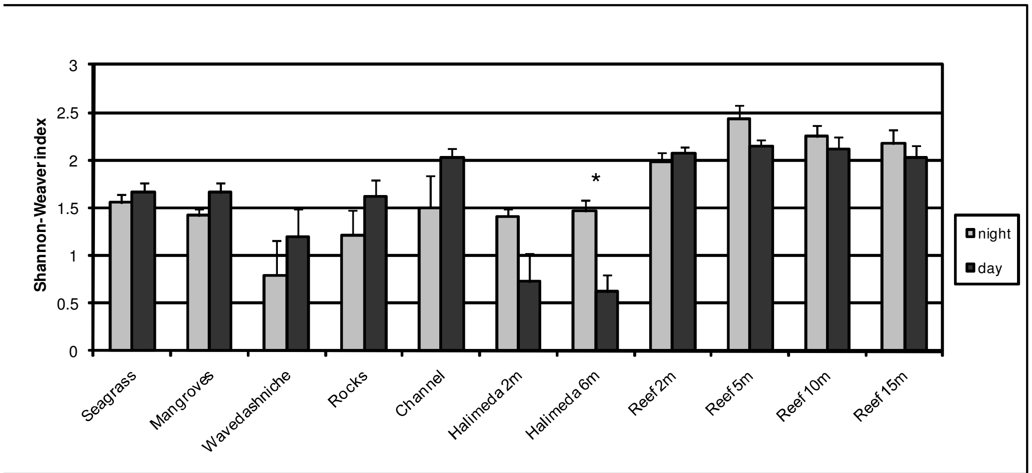
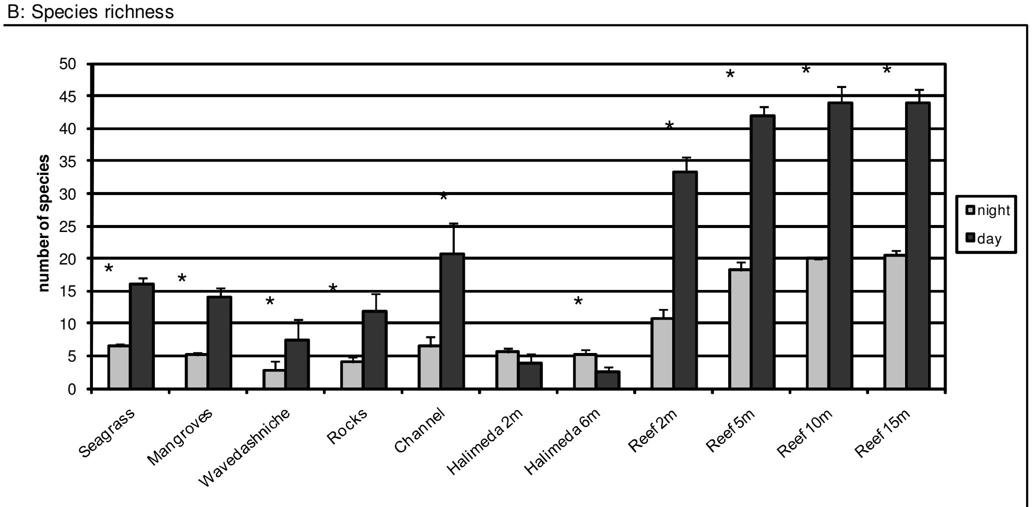


Figure 13 B. Biotope selection of the ten most abundant bay species during night.

A: Shannon - Weaver diversities



B: Species richness



C: Eveness of diversity

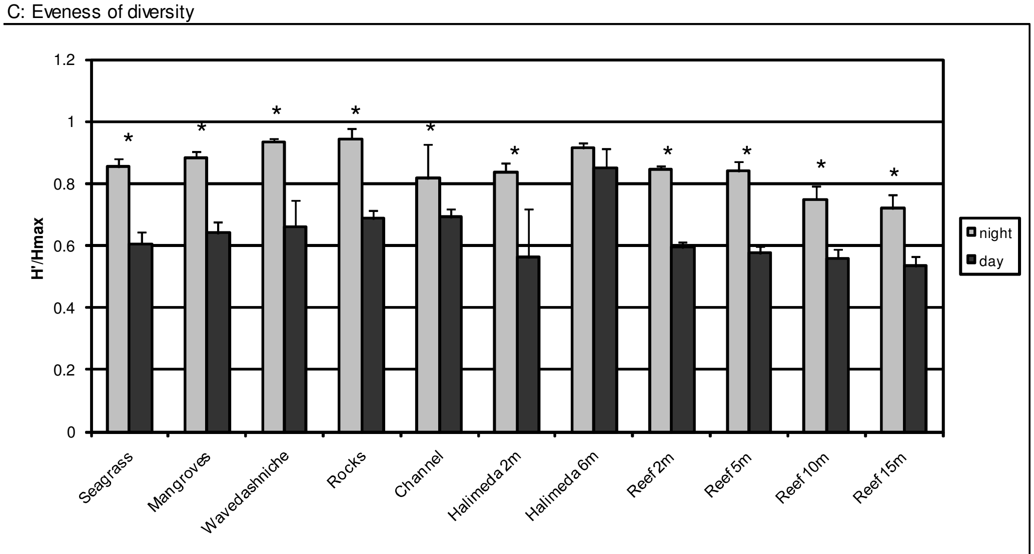
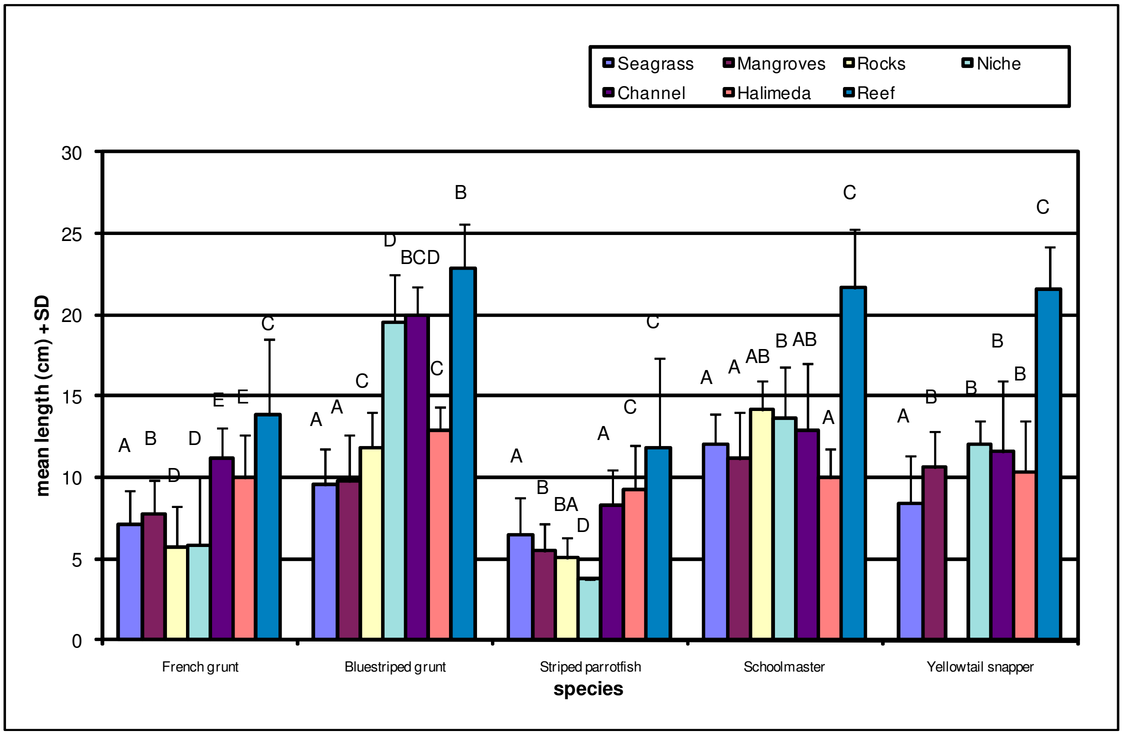


Figure 14. Comparison of Shannon-Weaver diversities (A), species richness (B), and Eveness of diversity for each biotope between day and night (C). Asterisks indicate significant differences (Student t test: *P<0.05*), standard errors are shown. *Erratum*: Wavedashniche must be replaced by niche

A: mean length of five analysed fish species in Spaanse Water.



B: Mean density offive selected fish species in Spaanse Water.

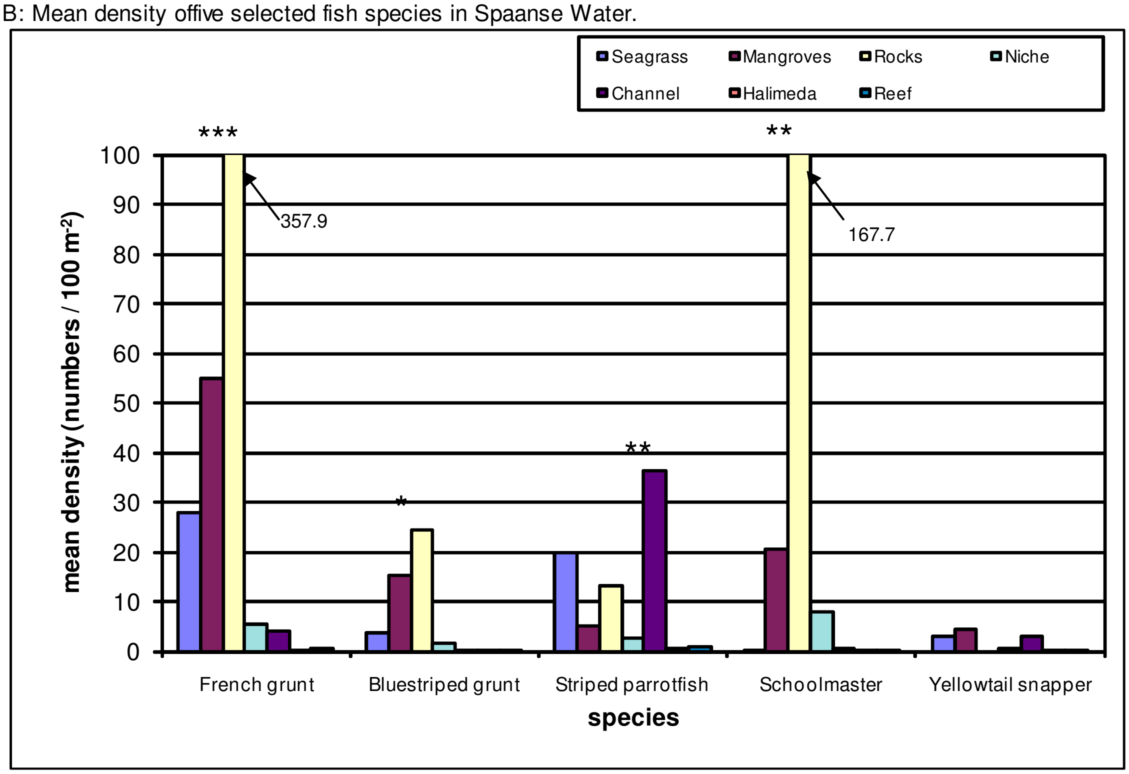
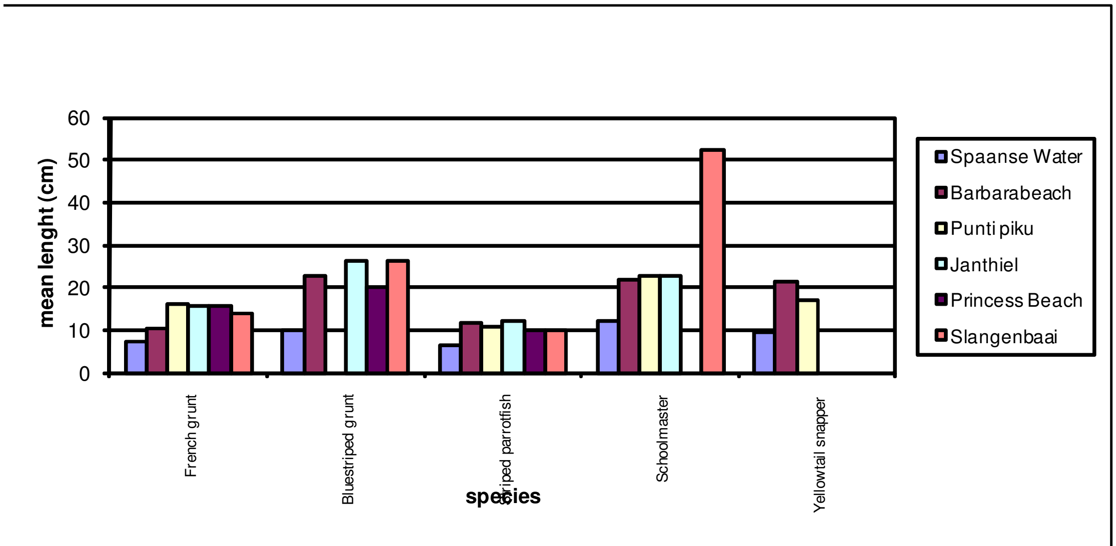


Figure 15. Mean length (A) and mean density (B) of five analysed fish species in various biotopes in Spaanse Water during day. Capital letters (Student t-test, $P<0.05$) and asterisks (ANOVA) indicate significant difference,* $P<0.05$, ** $P<0.01$, *** $P<0.001$

A: Mean length of five analysed fish species.



B: Mean density of five analysed fish species.

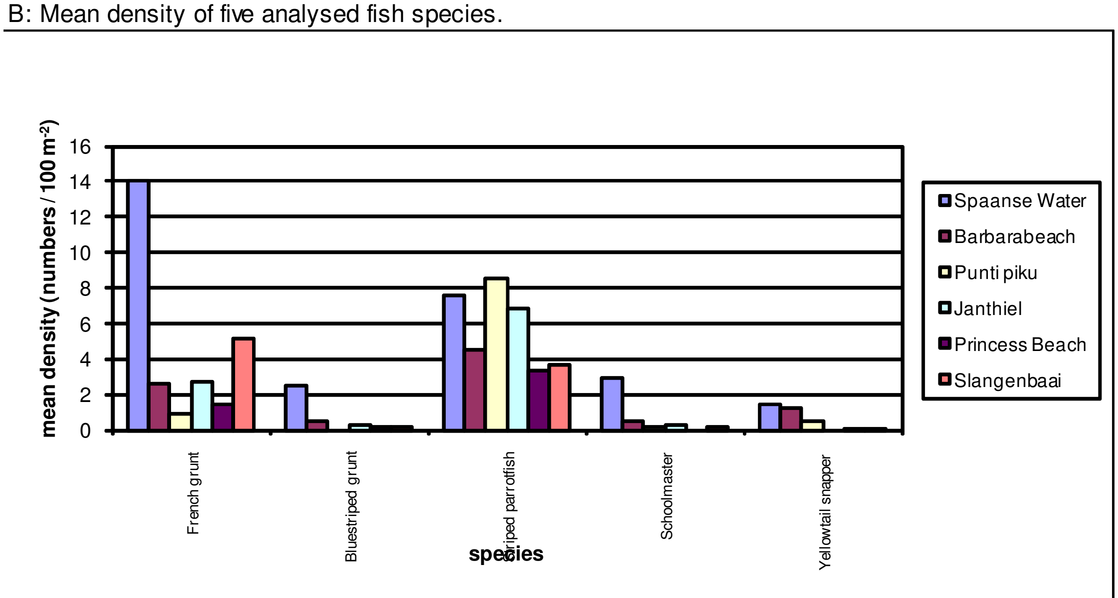


Figure 16. Mean length (A) and mean density (B) of five analysed fish species for Spaanse Water and five reef sites.

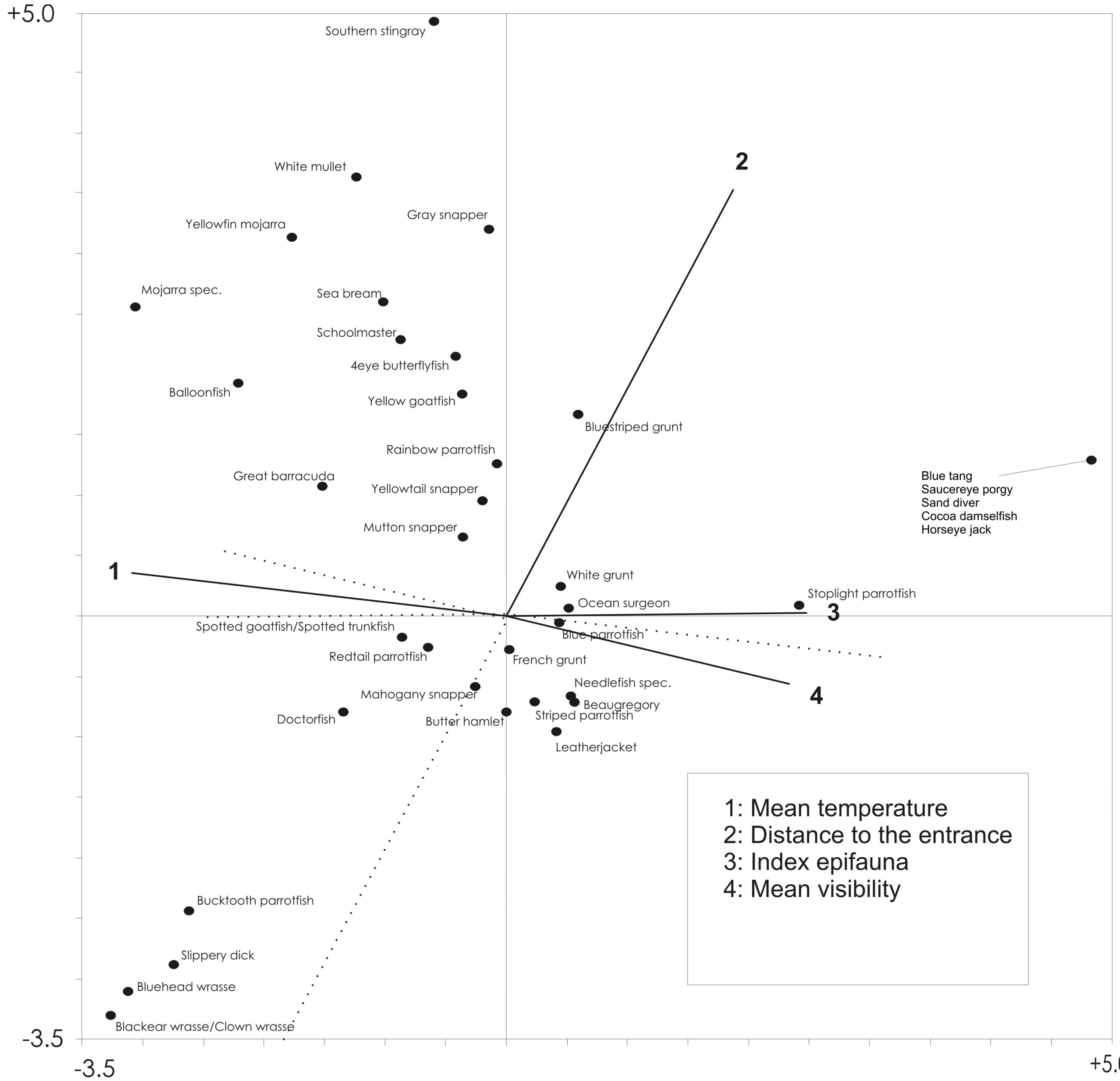


Figure 17: Canonical Correspondence Analysis plot of the fish fauna in the seagrass beds of Spaanse Water and the relevant environmental factors. Only the first two ordination axis are shown.
: positive correlation
: negative correlation

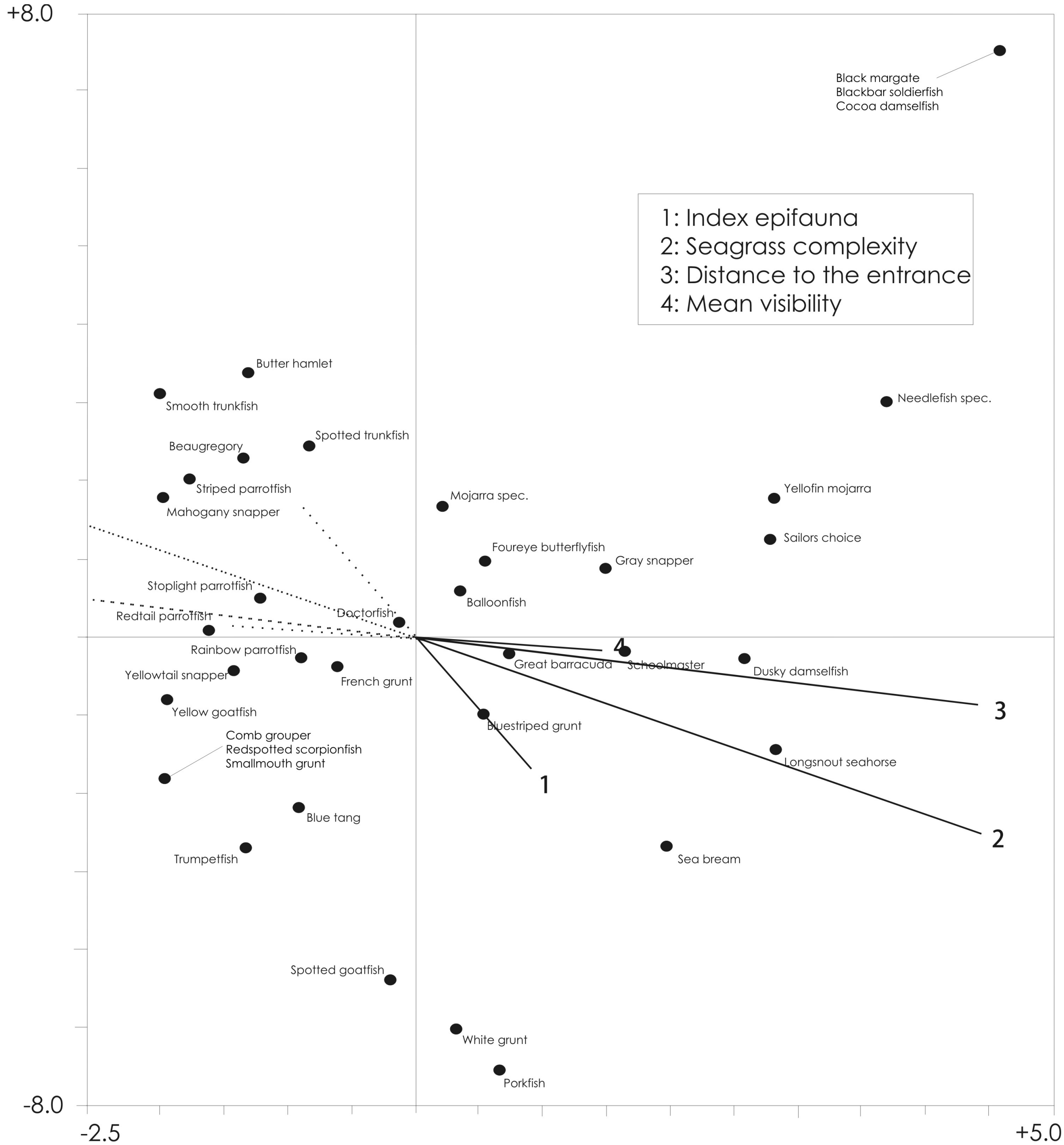


Figure 18: Canonical Correspondence Analysis plot of the fish fauna in the mangroves of Spaanse Water and the relevant environmental factors. Only the first two ordination axis are shown.
: positive correlation
: negative correlation

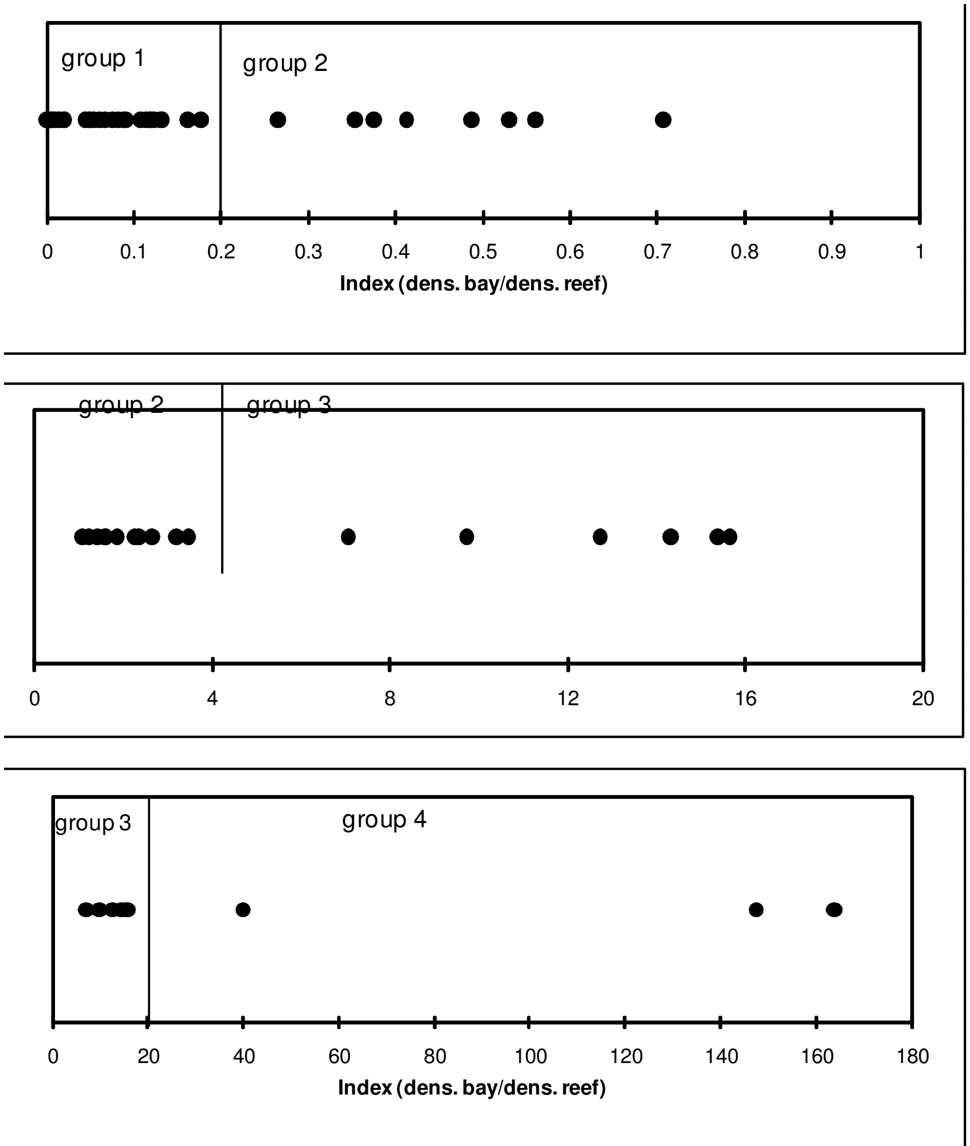
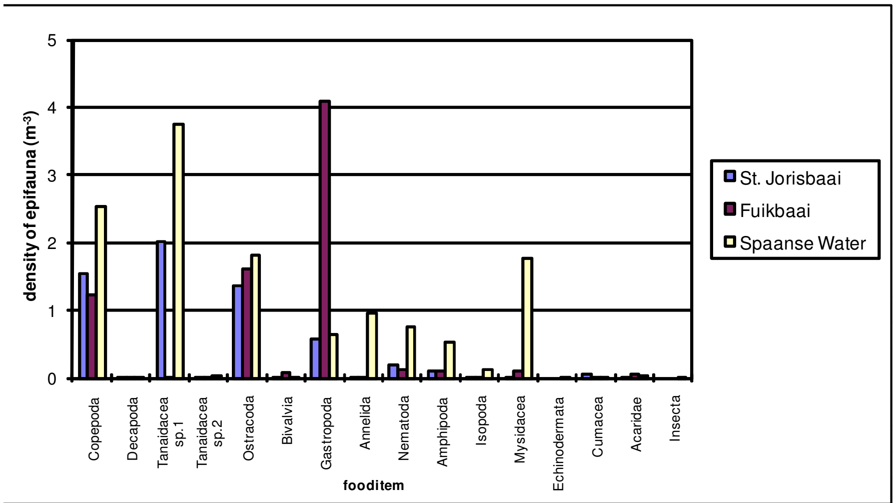


Figure 19. Plot of all index values of fish species observed in Spaanse Water and/or on the coral reef (expressed as density bay/density reef). Three different scale are plotted. Based on this index values, the importance of the bay for each fish species was determined.

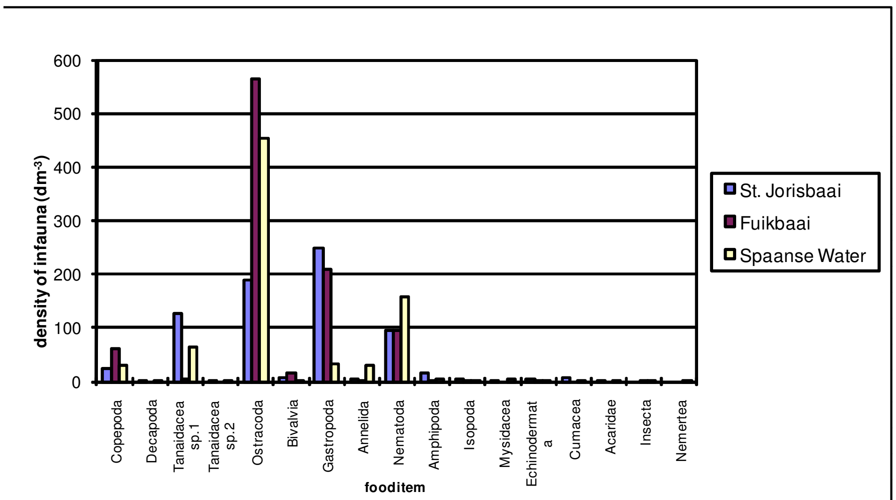
Based on this index, four groups were distinguished:

group 1:	0.0-0.2	71 'reef' species
group 2	0.2-4.0	24 'less significant nursery' species
group 3	4.0-20.0	7 ' significant nursery' species
group 4	>20.0	20 'bay' species

A



B



C

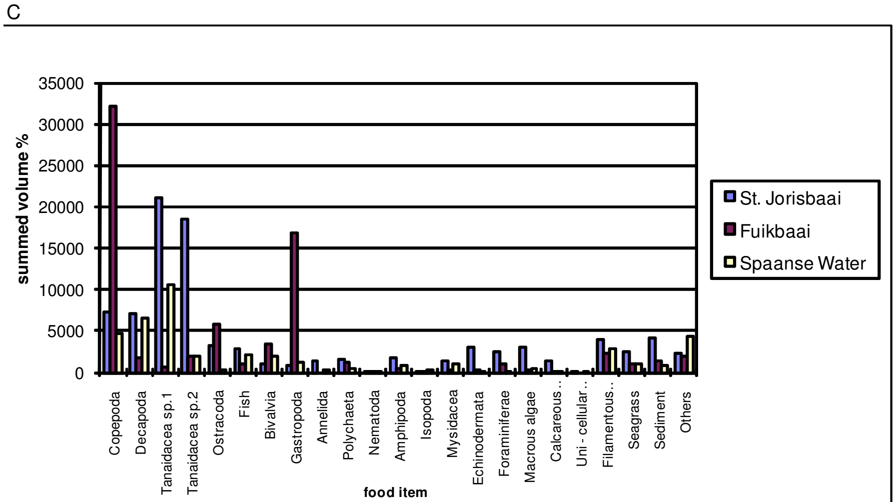


Figure 20. Epifauna density (m^{-3}) (A), infauna density (dm^{-3}) (B) and total diet of fish communities (C) for Spaanse Water, Fuikbaai and St. Jorisbaai.

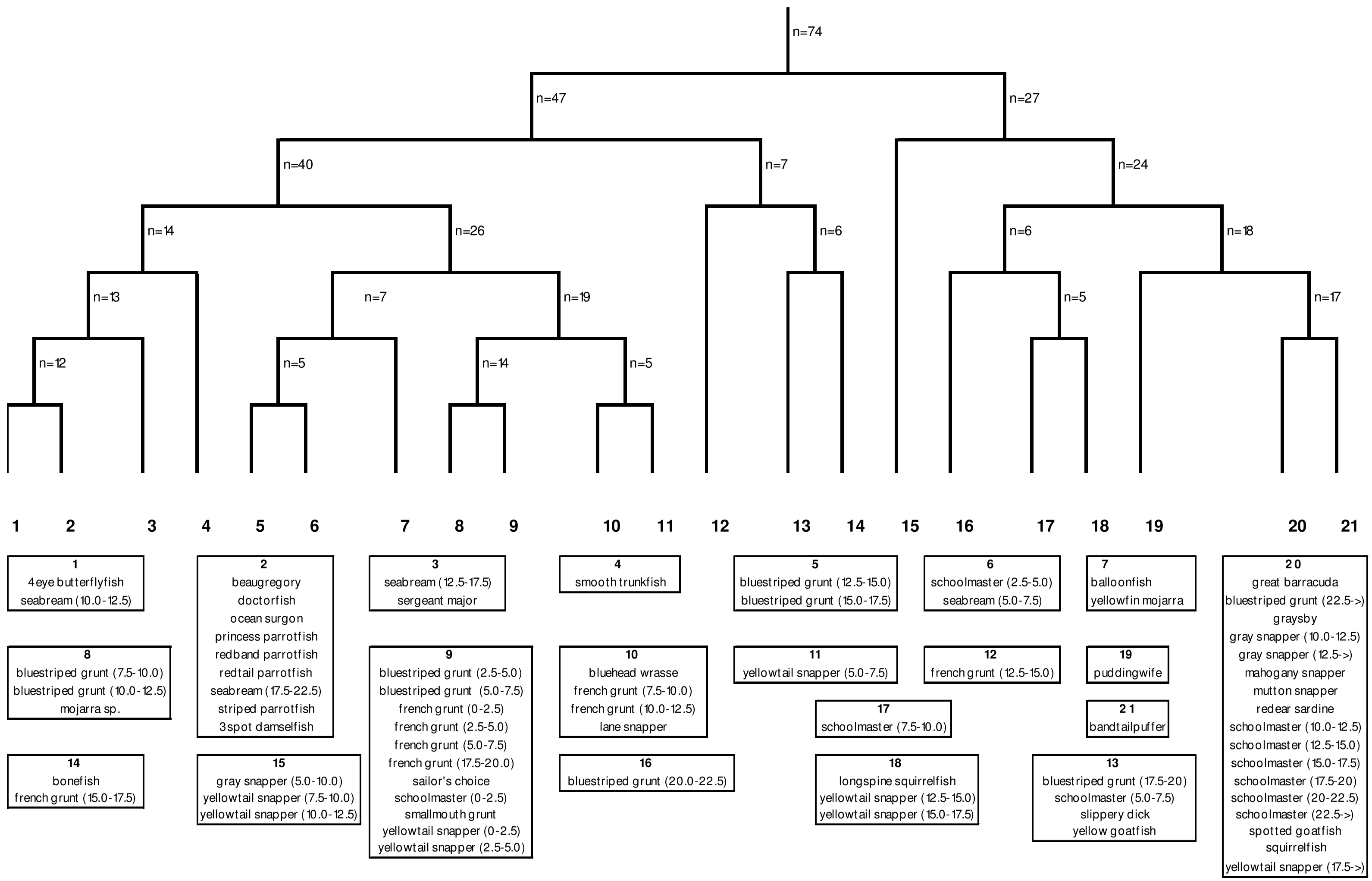
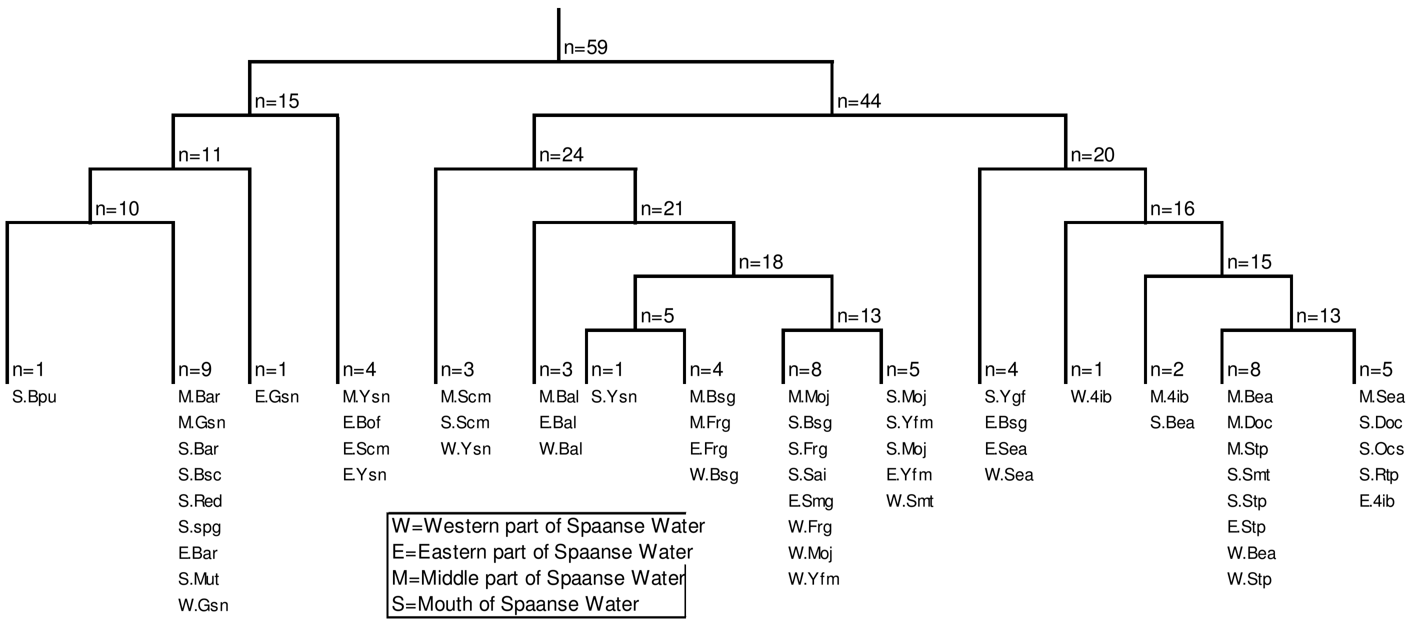


Figure 21. TWINSPAN results, showing feeding clusters in Spaanse Water. Fish were captured on seagrasses.



4ib	foureye butterflyfish
Bal	Balloonfish
Bar	Great barracuda
Bea	Beaugregory
Bof	Bonefish
Bpu	Bandtail puffer
Bsc	Bigeye scad
Bsg	Bluestriped grunt
Doc	Doctorfish
Frg	French grunt
Gsn	Gray snapper
Moj	Mojarra sp.
Mut	Mutton snapper
Ocs	Ocean surgeon
Red	Redband parrotfish
Rtp	Redtail parrotfish
Sai	Sailor's choice
Scm	Schoolmaster
Sea	Seabream
Smg	Smoot goat
Smt	Smooth trunkfish
Spg	Spotted goatfish
Stp	Stoplight parrotfish
Yfm	Yellowfin mojarra
Ygf	Yellow goatfish
Ysn	Yellowtail snapper

Figure 22. TWINSPAN results, showing feeding clusters in different areas (indicated with a capital letter) in Spaanse Water. Fish were captured on seagrasses.

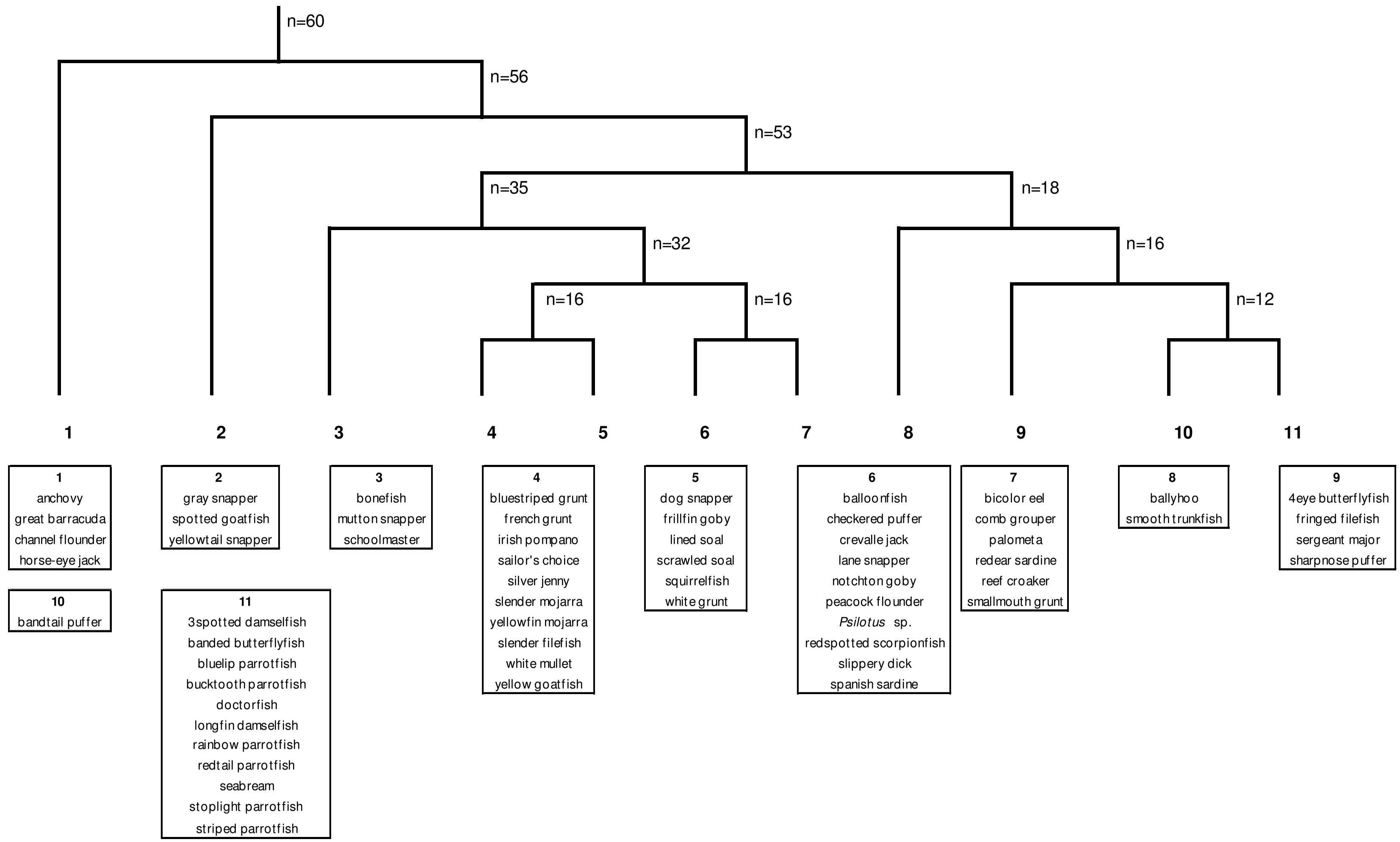


Figure 23. TWINSPAN results, showing feeding clusters in St. Jorisbaai. Fish were captured on seagrasses and mud plains.

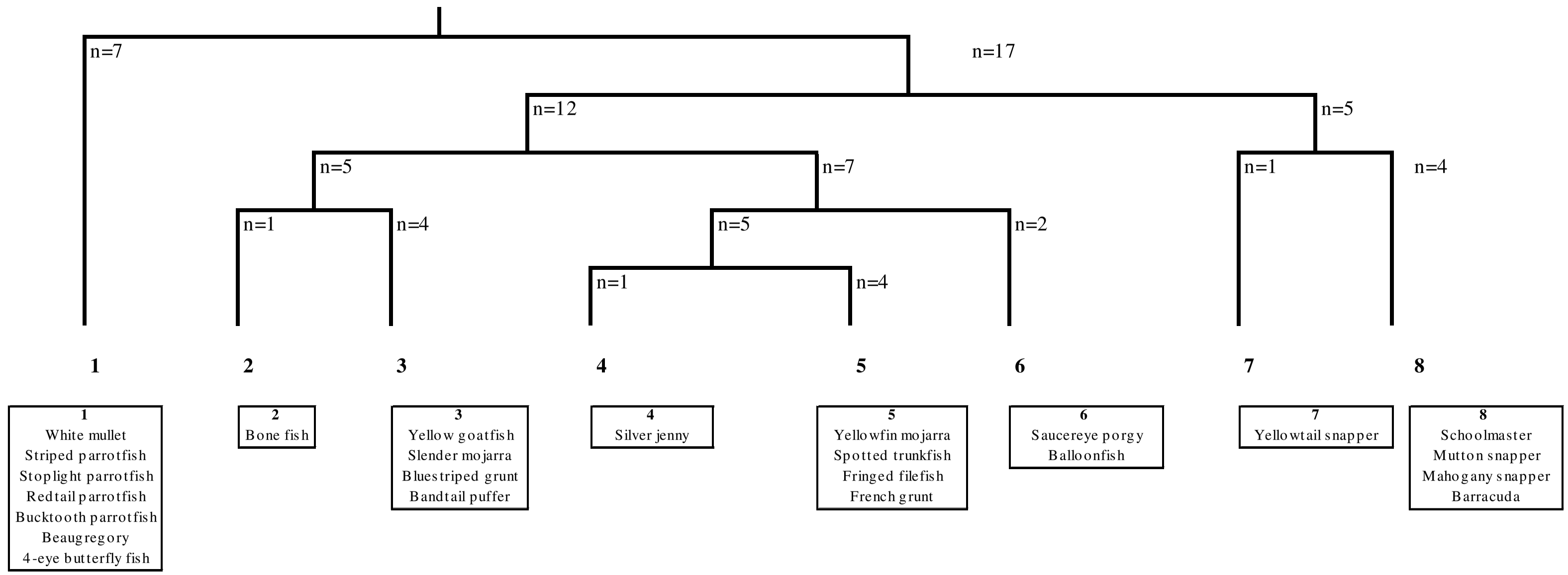


Figure 24. TWINSPAN results, showing feeding clusters in Fuikbaai. Fish were captured in seagrasses,mudplains and algae beds.

Table VI. Fish numbers corresponding with clusters shown in figure 3.
The three highest densities are highlighted for each cluster.

	cluster													
Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Anchovy	-	-	-	-	-	-	-	-	-	-	-	-	**400**	100
Balloonfish	-	-	-	4	-	-	-	-	2	**11**	-	**8**	-	-
Ballyhoo	-	-	-	-	-	-	-	1	-	-	-	-	4	-
Banded blenny	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Bandtail puffer	-	-	-	-	-	-	-	-	1	-	-	-	3	-
Beaugregory	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Bluehead wrasse	-	-	-	-	-	-	-	-	-	-	**2**	-	-	1
Bluestriped grunt	-	-	-	1	-	-	1	-	1	-	-	-	3	114
Bonefish	1	**9**	-	5	1	1	-	-	-	-	-	-	3	1
Bucktooth parrotfish	-	-	-	2	-	-	-	**11**	**6**	7	-	-	1	2
Checkered puffer	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Clown wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Colon goby	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Comb grouper	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Crevalle jack	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Doctorfish	-	-	-	-	-	-	-	2	-	-	-	-	-	-
Dog snapper	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Fish larvae	**100**	-	-	-	-	-	-	-	-	-	-	-	-	-
Foureye butterflyfish	-	-	-	3	2	-	5	-	-	**12**	**1**	-	1	3
French angelfish	-	-	-	-	-	-	-	-	-	-	1	-	-	-
French grunt	-	-	-	7	2	-	-	-	4	-	-	-	1	**422**
Frillfin goby	-	-	1	1	-	-	-	-	-	-	-	-	-	-
Fringed filefish	-	-	-	-	-	-	-	1	-	-	-	-	-	3
Gray snapper	-	-	-	-	4	-	6	1	-	-	-	-	-	-
Great barracuda	1	1	**5**	3	3	1	2	-	1	-	-	-	10	4
Hairy blenny	-	-	-	-	-	-	-	-	-	-	-	**2**	-	-
Hardhead silverside	-	-	-	-	-	-	**100**	-	-	-	-	-	100	**200**
Honeycomb cowfish	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Horse-eye jack	-	**3**	-	-	-	-	-	3	2	1	-	-	2	-
Houndfish	-	-	-	-	1	-	-	-	-	2	-	-	-	-
Irish pompano	-	-	-	-	-	**24**	-	-	-	-	-	-	-	-
Jolthead porgy	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Lane snapper	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Leatherjacket	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Lined sole	1	-	-	-	-	-	-	-	-	-	-	-	-	-
Longfin damselfish	-	-	-	-	-	-	1	-	-	-	-	-	-	-
Mahogany snapper	-	-	-	-	-	-	-	1	4	-	-	-	1	-
Mutton snapper	-	-	1	**20**	2	-	3	1	2	3	-	-	-	1
Notchtongue goby	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Ocean surgeonfish	-	-	-	-	-	-	-	-	1	3	-	-	-	-
Palometa	-	-	-	-	-	-	-	-	-	-	-	-	1	-
Peacock flounder	-	1	-	-	-	-	-	1	-	-	-	-	-	-
Puddingwife	-	-	-	-	-	-	-	-	-	-	1	-	-	-
Rainbow parrotfish	-	-	-	1	-	-	1	-	-	-	-	-	-	-
Redear sardine	-	-	-	-	-	-	-	-	-	-	-	-	**300**	**300**
Redspotted scorpionfish	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Redtail parrotfish	-	-	1	7	1	1	10	9	-	2	1	-	-	8
Reef croaker	-	-	-	-	-	-	-	-	-	-	-	-	2	-
Sailors choice	-	-	-	3	1	-	1	-	-	-	-	1	-	-
Saucereye porgy	-	-	-	-	-	-	-	-	-	-	-	-	-	2
Schoolmaster	1	-	-	3	3	-	6	6	5	-	-	**5**	17	3
Scrawled sole	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Sea bream	-	-	-	-	-	1	-	-	-	-	-	-	-	-
Sergeant major	2	-	-	-	-	-	1	1	-	-	-	-	-	-
Sharpnose puffer	-	-	-	-	-	-	1	2	-	-	-	-	-	-
Silver jenny	-	-	1	**65**	**51**	**10**	**18**	10	2	3	-	-	22	2
Slender filefish	-	-	1	-	-	-	-	-	-	-	-	-	-	-
Slender mojarra	**14**	**10**	**21**	**140**	**185**	**7**	**11**	**84**	**24**	**13**	**1**	-	97	6
Slippery dick	-	-	-	-	1	-	-	2	-	4	1	-	-	-
Smallmouth grunt	-	-	-	-	-	-	-	1	-	-	-	-	1	1
Smooth trunkfish	-	-	-	-	-	-	-	2	-	-	-	-	-	-
Spanish sardine	-	-	-	-	-	-	-	-	-	-	-	-	**200**	-
Spotted goatfish	-	-	-	-	2	-	-	6	-	2	-	-	-	-
Spotted trunkfish	-	-	-	-	-	-	-	-	-	-	-	-	1	1
Squirrelfish	-	-	-	-	-	-	-	-	-	1	-	-	-	-
Stoplight parrotfish	-	-	-	-	-	-	3	1	-	5	-	-	-	2
Striped parrotfish	-	-	-	-	-	-	-	-	**6**	9	-	-	1	10
Threespot damselfish	-	-	-	1	-	-	-	-	-	-	-	-	-	-
Tripletail	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Trunkfish	-	-	-	-	-	-	-	1	-	-	-	-	-	-
White grunt	-	-	-	1	-	-	-	-	-	-	-	-	-	1
White mullet	1	-	**9**	-	-	-	2	-	3	-	-	-	6	-
Yellow goatfish	-	-	-	-	-	-	-	-	1	-	-	-	-	6
Yellowfin mojarra	-	1	-	4	3	-	-	-	-	-	-	1	12	1
Yellowtail snapper	**3**	1	3	5	**10**	-	8	**15**	5	10	-	-	2	25

Table XII. Fish densities (numbers/100m^2) corresponding with clusters shown in figure 7. The three highest densities are highlighted for each cluster.

Species	cluster 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Anchovies	-	-	-	-	-	-	-	-	-	-	-	-	-	11.3	**1,625.8**	-	-	-	0.2
Balloonfish	0.3	0.6	0.8	1.3	2.0	0.6	0.2	0.3	1.7	-	-	15.0	2.0	2.3	0.5	0.4	0.2	0.3	-
Banded butterflyfish	-	2.1	1.3	0.3	0.9	1.3	0.5	-	-	-	-	-	-	-	-	-	-	-	-
Bandtail puffer	-	0.1	0.2	-	0.4	0.2	-	0.8	-	-	-	0.3	-	-	-	-	-	-	0.1
Bar jack	0.2	0.8	0.4	0.2	0.4	0.3	0.2	-	-	-	-	2.6	-	-	-	1.2	-	-	-
Barred hamlet	0.7	1.3	0.1	0.3	-	-	-	0.2	-	-	-	0.5	-	-	-	-	-	0.2	1.4
Beaugregory	-	-	-	-	-	-	-	2.3	-	-	28.1	178.9	3.3	5.3	48.3	1.3	1.9	0.8	-
Bicolor damselfish	**188.0**	**933.7**	**627.7**	**490.0**	**539.4**	**169.0**	11.3	**33.2**	-	-	-	4.5	-	-	-	-	-	-	-
Bigeye snapper	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black durgeon	-	-	-	-	2.0	-	1.5	-	-	-	-	-	-	-	-	-	-	-	-
Black hamlet	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Black margate	-	-	-	-	-	-	0.2	-	-	-	-	-	1.4	-	-	-	-	-	-
Blackbar soldierfish	28.7	21.1	34.3	3.5	3.0	0.1	2.0	-	-	-	-	-	0.4	-	-	-	-	-	-
Blackear wrasse	-	-	-	-	-	3.2	-	-	-	-	-	-	-	-	-	-	0.6	-	-
Blue chromis	**53.3**	**354.2**	**96.0**	54.0	11.3	-	0.7	-	-	-	-	-	-	-	-	-	-	-	-
Blue parrotfish	-	-	0.2	-	-	0.8	-	-	-	-	-	-	-	-	-	0.2	4.2	3.7	-
Blue tang	1.5	6.2	3.2	2.3	2.7	7.4	28.7	0.2	-	-	-	28.4	-	0.3	-	-	4.6	-	0.3
Bluehead wrasse	9.3	133.7	**274.3**	**90.0**	**315.3**	**464.3**	**170.0**	2.8	-	-	-	**548.8**	3.0	-	-	-	1.3	0.1	-
Bluelip parrotfish	-	-	-	-	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Bluestriped grunt	0.3	1.1	0.5	0.7	0.7	0.2	-	0.3	2.7	-	46.0	274.9	193.5	80.3	68.8	9.5	13.7	0.4	0.3
Bluestriped lizardfish	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Boga	20.8	-	-	-	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Brown chromis	16.0	**161.0**	69.0	9.3	36.7	7.0	14.0	-	-	-	-	1.8	-	-	-	-	-	-	-
Bucktooth parrotfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1	0.2	2.6	0.6	-
Butter hamlet	0.3	0.9	1.3	0.7	0.5	0.3	-	1.2	1.2	4.4	-	4.0	0.6	1.2	5.9	0.1	0.4	4.7	-
Caesar grunt	-	0.2	0.3	-	0.3	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Cero	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cherubfish	-	1.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Clown wrasse	-	2.7	9.3	11.3	40.4	129.4	12.0	4.8	0.9	-	-	103.3	-	-	-	-	2.1	-	-
Cocoa damselfish	-	-	-	-	-	-	-	-	**38.5**	15.6	41.7	136.2	2.5	-	0.6	-	7.6	-	0.3
Comb grouper	-	-	-	-	-	-	-	-	-	-	-	0.7	-	1.0	0.7	-	-	-	-
Coney	0.3	0.1	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Creole fish	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Creole wrasse	8.7	33.4	16.9	-	-	-	4.0	-	-	-	-	-	-	-	-	-	-	-	-
Doctorfish	-	3.5	0.3	-	0.8	0.2	-	3.5	2.1	-	86.5	216.6	0.9	4.9	6.3	2.6	5.3	7.3	-
Dusky damselfish	-	-	-	-	-	30.0	-	-	**106.2**	28.1	**360.2**	359.6	11.4	3.9	1.1	-	-	-	-
Dusky squirrelfish	0.2	0.1	-	-	0.2	-	-	-	-	-	-	4.4	-	-	-	-	-	-	-
Foureye butterflyfish	0.2	8.8	13.5	4.8	12.4	8.4	1.5	1.8	-	9.5	-	50.0	28.2	51.7	29.1	5.7	3.3	**24.0**	0.2
French angelfish	0.2	0.8	0.6	-	0.2	-	-	-	-	-	-	2.5	-	-	-	-	-	-	7.0
French grunt	7.5	5.4	4.4	10.2	16.9	1.8	0.8	0.2	**34.9**	**509.0**	**397.4**	**1,566.1**	**448.3**	**389.1**	**439.1**	**69.7**	**109.7**	**26.8**	-
Glaseye snapper	0.3	0.2	-	-	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-
Gray snapper	-	0.1	-	-	-	-	-	-	-	-	15.4	10.5	48.3	13.4	10.0	4.3	0.4	11.5	0.5
Graysby	2.5	4.4	3.1	1.5	0.2	-	0.2	-	-	-	-	0.2	-	-	-	-	-	-	-
Great barracuda	-	0.1	0.1	-	0.1	-	-	-	-	-	-	-	4.5	9.1	5.8	0.6	0.3	-	-
Greater soapfish	-	0.2	0.1	0.3	0.5	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-
Green razorfish	-	-	-	0.2	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Greenblotch parrotfish	-	0.5	-	0.8	0.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Hardhead silversides	-	-	-	-	-	-	-	-	21.9	-	-	16.0	17.4	**307.4**	-	16.7	-	-	**1,012.5**
Harlequin bass	0.7	10.2	5.8	6.3	7.1	0.8	0.8	-	-	-	-	-	-	-	-	-	-	-	-
Herrings	-	-	-	-	-	-	-	-	-	-	-	**6,389.0**	**7,077.5**	**3,000.4**	270.1	**1,052.8**	**42.9**	-	-
Highhat	-	-	-	-	-	-	-	-	-	-	-	4.4	-	-	-	-	-	-	-
Hogfish	-	0.1	-	-	-	-	-	0.2	-	-	-	-	-	-	-	-	-	0.8	-
Honeycomb cowfish	-	-	0.6	-	0.3	0.1	-	0.2	-	-	-	-	-	-	-	-	-	-	-
Horseye jack	-	-	-	-	2.0	-	-	-	-	-	-	0.8	0.8	1.0	0.6	0.8	0.1	-	-
Lane snapper	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-
Leatherjacket	-	-	-	-	-	-	-	-	-	-	-	1.3	-	-	-	0.3	0.6	-	-
Longfin damselfish	-	8.3	87.7	22.7	65.0	53.0	**97.3**	-	-	-	-	-	-	-	-	-	-	-	-
Longjaw squirrelfish	1.0	1.4	1.0	0.3	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Longsnout butterflyfish	-	0.3	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Longsnout seahorse	-	-	-	-	-	-	-	-	-	-	-	-	0.9	-	-	-	-	-	-
Longspine squirrelfish	-	0.1	0.2	-	-	-	-	-	-	-	24.7	0.2	-	-	-	-	-	-	-
Mahogony snapper	0.3	1.0	0.8	0.2	0.2	-	-	-	-	-	-	51.5	0.5	-	14.6	0.1	0.3	0.2	2.7
Midnight parrotfish	-	0.1	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mojarra sp.	-	-	-	-	-	0.1	-	-	-	-	-	-	22.7	17.8	8.1	4.0	9.2	7.6	0.2
Mutton snapper	-	-	-	-	0.2	-	-	-	0.2	-	-	0.2	-	0.3	0.2	0.2	0.1	0.3	-
Needlefish	-	-	-	-	-	-	-	-	-	-	-	0.3	11.0	0.5	1.3	0.3	-	-	**16.7**
Night sergeant	-	0.3	-	-	-	-	-	-	1.1	-	4.8	-	-	-	-	-	-	-	-
Ocean surgeonfish	0.8	6.6	7.0	20.5	20.8	59.8	17.5	0.2	-	-	-	-	-	-	-	-	0.3	-	-
Orangespotted filefish	-	-	0.8	0.7	0.8	0.5	0.8	-	-	-	-	-	-	-	-	-	-	-	-
Peacock flounder	-	-	-	0.2	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Porcupinefish	-	-	-	-	0.2	-	-	-	0.3	-	1.6	-	-	-	-	-	-	0.7	-
Porkfish	-	0.1	-	-	-	-	-	-	0.2	-	-	0.2	-	0.2	-	-	-	-	-
Princess parrotfish	9.8	34.3	13.8	7.8	6.2	9.5	2.5	-	-	-	-	-	-	-	-	-	-	-	-
Puddingwife	-	0.7	0.1	1.3	6.8	10.7	0.7	-	-	-	-	80.4	-	-	-	-	-	-	10.4
Queen parrotfish	1.2	1.4	4.6	2.5	4.5	7.5	6.2	-	-	-	-	-	-	-	-	-	-	-	-
Rainbow parrotfish	-	-	0.1	-	-	-	-	-	-	-	-	1.5	0.4	2.1	7.3	0.2	0.2	-	-
Rainbow wrasse	0.7	5.8	75.3	25.3	34.7	2.7	-	-	-	-	-	-	-	-	-	-	-	-	-
Redband parrotfish	5.0	19.9	18.7	14.5	19.0	9.8	2.0	-	-	-	-	3.0	-	-	-	-	0.3	0.2	1.7
Redfin parrotfish	-	0.1	0.2	-	1.1	3.4	4.7	-	-	-	-	158.8	-	-	-	-	-	-	-
Redspotted hawkfish	-	0.1	0.3	0.2	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Redtail parrotfish	0.2	0.8	0.9	-	0.8	5.3	0.3	3.7	0.2	-	10.1	153.6	0.4	2.2	19.1	1.3	1.5	2.4	-
Reef squirrelfish	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rock beauty	-	0.6	1.0	-	-	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Royal gramma	2.3	22.1	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table XIII. Fish densities (numbers/100m^2) corresponding with clusters shown in figure 8. The three highest densities are highlighted for each cluster.

	cluster												
Species	1	2	3	4	5	6	7	8	9	10	11	12	13
Anchovies	-	-	-	-	-	4.55	-	-	**5.18**	-	-	-	-
Balloonfish	**8.22**	-	-	9.46	7.80	**18.04**	2.33	**9.03**	1.85	-	4.33	2.83	3.17
Banded butterflyfish	-	-	-	-	-	-	-	-	-	-	0.67	-	-
Bandtail puffer	-	-	-	-	-	-	-	-	-	-	-	-	-
Bar jack	-	-	-	-	-	-	-	-	-	-	-	-	-
Barred hamlet	-	-	-	-	-	-	-	-	-	-	-	-	0.17
Beaugregory	-	-	-	-	-	-	-	-	-	-	-	-	-
Bicolor damselfish	-	-	-	-	-	-	-	-	-	-	-	-	0.17
Bigeye scad	-	-	-	-	-	-	-	-	-	-	-	-	-
Bigeye snapper	-	-	-	-	-	-	-	-	-	-	0.17	-	0.17
Black durgeon	-	-	-	-	-	-	-	-	-	-	-	-	-
Black grouper	-	-	-	-	-	-	-	-	-	-	-	-	-
Black margate	-	-	-	-	-	-	-	-	-	-	-	-	-
Blackbar soldierfish	-	-	-	-	-	-	1.83	1.83	-	-	**32.67**	**7.00**	**26.00**
Blackear wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Blue chromis	-	-	-	-	-	-	-	-	-	-	-	-	0.17
Blue parrotfish	-	-	-	-	-	-	-	-	-	-	0.17	-	-
Blue tang	-	-	-	-	-	-	0.83	1.00	-	-	0.33	0.33	1.83
Bluehead wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Bluelip parrotfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Bluespotted cornetfish	-	-	-	-	-	-	-	-	-	-	0.17	-	0.17
Bluestriped grunt	-	8.87	-	-	8.16	6.97	1.00	4.89	0.76	-	0.33	0.17	-
Bluestriped lizardfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Boga	-	-	-	-	-	-	1.50	-	-	-	0.17	1.33	0.17
Bonefish	-	-	-	-	-	-	0.17	-	-	-	-	-	-
Brown chromis	-	-	-	-	-	-	0.33	0.67	-	-	1.33	0.17	**10.00**
Bucktooth parrotfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Butter hamlet	-	-	-	-	-	-	-	0.33	-	-	-	-	-
Caesar grunt	-	-	-	-	-	-	-	-	-	-	-	-	-
Cero	-	-	-	-	-	-	-	-	-	-	-	-	-
Chain morray	-	-	-	-	-	-	-	-	-	-	-	-	-
Chekered puffer	-	-	-	-	-	-	-	-	-	-	-	-	-
Clown wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Cocoa damselfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Comb grouper	-	-	-	-	-	-	-	-	-	-	-	-	-
Coney	-	-	-	-	-	-	-	-	-	-	0.17	-	0.33
Creole fish	-	-	-	-	-	-	-	-	-	-	-	-	-
Creole wrasse	-	-	-	-	-	-	-	-	-	-	-	-	0.17
Cubera snapper	-	-	-	2.63	-	0.17	-	-	-	-	-	-	-
Doctorfish	-	8.69	-	-	-	1.22	1.00	1.00	0.76	-	1.33	0.17	4.50
Dog snapper	-	-	-	-	-	-	-	-	-	-	-	-	-
Dusky damselfish	1.85	**172.43**	**14.37**	-	-	0.33	0.17	-	-	-	0.17	0.17	0.17
Dusky squirrelfish	-	-	-	-	-	1.50	**5.17**	1.50	-	-	3.17	1.50	1.50
Flagfin mojara	-	-	-	-	-	-	-	-	-	-	-	-	-
four-eye butterflyfish	-	-	-	**12.55**	0.72	0.72	0.83	0.83	-	-	3.17	0.83	0.17
French angelfish	-	-	-	-	-	-	-	-	-	-	-	-	-
French grunt	**7.26**	20.33	**62.30**	10.83	**14.96**	**26.49**	**4.83**	**13.84**	0.92	-	1.50	1.50	1.33
Glaseye snapper	-	-	-	-	-	-	0.17	-	-	-	0.33	-	1.17
Gray snapper	-	-	-	-	-	0.67	0.50	0.33	0.17	-	-	-	-
Graysby	-	-	-	-	-	-	-	-	-	-	-	0.17	0.50
Great barracuda	-	-	-	-	-	0.17	-	0.33	-	-	-	-	-
Greater soapfish	-	-	-	-	-	0.17	0.50	0.17	-	-	0.83	0.50	0.67
Green morray	-	-	-	-	-	-	-	-	-	-	-	-	-
Green razorfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Greenblotch parrotfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Hardhead silversides	-	-	-	-	-	-	-	-	-	-	-	-	-
Harlequin bass	-	-	-	-	-	-	-	-	-	-	-	-	-
Herrings	-	-	-	**436.82**	**94.55**	**714.69**	**163.00**	**10,041.85**	**566.44**	-	5.00	0.83	-
Highhat	-	-	-	-	-	-	-	-	-	-	-	-	-
Hogfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Honeycomb cowfish	-	-	-	-	-	-	-	-	-	-	0.33	-	0.17
Horseye jack	-	-	-	-	-	-	-	-	-	-	-	-	-
Lane snapper	-	-	-	-	-	-	-	-	-	-	-	-	-
Leatherjacket	-	-	-	-	-	-	-	-	-	-	-	-	-
Longfin damselfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Longjaw squirrelfish	-	-	-	-	-	0.33	1.67	0.50	-	-	**7.83**	2.83	**5.83**
Longsnout butterflyfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Longsnout seahorse	-	-	-	-	-	-	-	-	-	-	-	-	-
Longspine squirrelfish	-	-	-	-	-	-	0.17	0.17	-	-	0.17	-	-
Mahogony snapper	-	-	12.32	-	-	-	0.33	0.83	-	-	-	-	0.17
Midnight parrotfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Mojarra sp.	-	-	-	-	-	1.00	0.67	0.33	-	-	-	-	-
Mutton hamlet	-	-	-	-	-	-	-	-	-	-	-	-	-
Mutton snapper	-	-	-	-	-	-	-	-	-	-	-	-	-
Needlefish	-	9.58	-	-	3.54	6.43	-	-	-	-	-	-	-
Night sergeant	**5.68**	27.54	-	-	-	-	-	-	-	-	-	-	-
Ocean surgeonfish	-	-	-	-	-	0.83	4.33	0.33	-	-	**9.67**	**3.67**	2.50
Orangespotted filefish	-	-	-	-	-	-	0.17	-	-	-	-	-	-
Peacock flounder	-	-	-	-	-	-	-	0.17	-	-	-	-	-
Porcupinefish	-	-	-	-	1.25	0.17	0.17	0.17	-	**1.69**	-	0.17	0.17
Porkfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Princess parrotfish	-	-	-	-	-	-	-	-	-	-	0.17	-	0.33
Puddingwife	-	-	-	-	-	-	-	-	-	-	-	-	-
Queen parrotfish	-	-	-	-	-	-	-	-	-	-	-	-	-

Continuation of Table XIII.

Species	cluster 1	2	3	4	5	6	7	8	9	10	11	12	13
Rainbow parrotfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Rainbow wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Redband parrotfish	-	-	-	-	-	0.17	0.17	1.50	-	-	1.50	0.33	0.33
Redfin parrotfish	-	-	-	-	-	-	0.67	-	-	-	0.17	0.33	-
Redspotted hawkfish	-	-	-	-	-	-	-	0.33	-	-	-	-	-
Redtail parrotfish	-	-	8.11	2.63	-	0.33	1.00	1.67	-	-	2.50	1.17	0.67
Reef squirrelfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Rock beauty	-	-	-	-	-	-	-	-	-	-	-	-	-
Royal gramma	-	-	-	-	-	-	-	-	-	-	-	-	-
Sailors choice	-	-	-	-	-	-	-	-	-	-	-	-	-
Sand diver	-	-	-	-	-	0.17	-	-	-	-	-	-	-
Sardine	-	-	-	-	-	0.17	-	-	-	-	-	-	-
Saucereye porgy	-	-	-	-	-	-	0.33	-	-	-	-	-	-
Schoolmaster	2.50	**51.59**	-	**12.50**	**15.02**	5.23	0.17	2.25	**9.85**	-	0.33	0.17	-
Scorpionfish	-	-	-	-	-	-	-	0.33	-	-	0.17	-	-
Scrawled filefish	-	-	-	-	-	-	-	-	-	-	0.17	-	-
Sea bream	-	-	-	-	-	0.46	0.33	1.50	0.17	-	-	-	-
Sergeant major	-	-	-	-	-	-	-	-	-	-	0.17	-	0.17
Sharpnose puffer	-	-	-	-	-	-	-	-	-	-	-	-	-
Shy hamlet	-	-	-	-	-	-	-	-	-	-	-	-	-
Slender filefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Slippery dick	-	-	-	-	-	-	-	-	-	-	-	-	-
Smallmouth grunt	-	-	-	-	-	4.50	1.83	1.83	-	-	0.67	2.67	0.50
Smooth trunkfish	2.17	-	-	-	1.14	0.17	0.33	0.33	-	-	0.83	0.17	0.50
Southern stingray	-	-	-	-	-	-	-	-	-	-	-	-	-
Spanish grunt	-	-	-	-	-	-	-	-	-	-	-	-	-
Spanish hogfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Spotted drum	-	46.30	-	-	-	-	0.17	0.17	-	-	0.17	0.33	0.67
Spotted goatfish	-	-	-	-	-	-	0.50	2.67	-	-	-	0.33	0.83
Spotted morray	-	-	-	-	-	-	-	-	-	-	-	-	-
Spotted trunkfish	-	-	-	2.58	0.66	0.67	0.33	-	2.18	-	-	0.17	-
Squirrelfish	4.71	**85.36**	**22.48**	6.01	1.19	1.70	0.50	0.17	-	-	-	-	0.33
Stoplight parrotfish	-	-	-	-	1.11	-	0.33	0.17	-	-	1.67	0.33	1.67
Striped parrotfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Threespot damselfish	-	-	-	-	1.19	-	-	-	-	-	-	-	0.67
Tiger grouper	-	-	-	-	-	-	-	-	-	-	0.33	-	-
Tobaccofish	-	-	-	-	-	-	-	-	-	-	-	-	-
Trumpetfish	0.88	-	-	0.53	-	-	-	-	-	-	0.17	0.17	1.83
White grunt	-	-	-	-	-	0.33	-	-	-	-	-	-	-
White mullet	-	-	-	-	-	0.17	-	-	-	-	-	-	-
Whitespotted filefish	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellow goatfish	-	-	-	-	-	1.50	1.83	1.72	-	-	1.83	**6.00**	2.00
Yellowfin mojarra	-	-	-	-	3.64	1.67	0.33	2.33	1.26	-	-	-	-
Yellowhead jawfish	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellowhead wrasse	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellowmouth grouper	-	-	-	-	-	-	-	-	-	-	-	-	-
Yellowtail damselfish	-	-	-	-	-	-	0.17	0.17	-	-	-	-	0.17
Yellowtail hamlet	-	-	-	-	-	-	-	-	-	-	-	-	0.17
Yellowtail snapper	-	-	-	-	-	2.83	-	1.39	-	-	-	-	-

Table XXIV. Mean densities (based on all transect data) of all observed fish species (numbers/100m^2) in Spaanse water and on the coral reef during day and night. * index: density bay/density reef; bay observed only in the bay reef: observed only on the coral reef.

Common name	Scientific name	density lagoon	Day density reef	Index *
Index between 0.0 - 0.2 or only observed on the reef				
Banded butterflyfish	*Chaetodon striatus*	0.000	0.370	reef
Bigeye snapper	*Priacanthus cruentatus*	0.000	0.006	reef
Black durgeon	*Melichthys niger*	0.000	0.130	reef
Black hamlet	*Hypoplectrus nigricans*	0.000	0.006	reef
Blue chromis	*Chromis cyanea*	0.000	35.617	reef
Bluelip parrotfish	*Cryptotomus roseus*	0.000	0.012	reef
Bluestriped lizardfish	*Synodus saurus*	0.000	0.006	reef
Boga	*Inermia vittata*	0.000	0.833	reef
Caesar grunt	*Haemulon carbonarium*	0.000	0.056	reef
Cero	*Scomberomorus regalis*	0.000	0.006	reef
Cherubfish	*Centropyge argi*	0.000	0.099	reef
Coney	*Epinephelus fulvus*	0.000	0.037	reef
Creole fish	*Paranthias furcifer*	0.000	0.006	reef
Creole w rasse	*Clepticus parrae*	0.000	3.611	reef
Fairy basslet	*Gramma loreto*	0.000	1.685	reef
Glaseye snapper	*Priacanthus cruentatus*	0.000	0.031	reef
Green razorfish	*Hemipteronotus splendens*	0.000	0.043	reef
Greenblotch parrotfish	*Sparisoma atomarium*	0.000	0.086	reef
Harlequin bass	*Serranus tigrinus*	0.000	1.654	reef
Longfin damsel	*Stegastes diencaeus*	0.000	15.852	reef
Longjaw squirrelfish	*Holocentrus marianus*	0.000	0.204	reef
Longsnout butterflyfish	*Chaetodon aculeatus*	0.000	0.019	reef
Midnight parrotfish	*Scarus coelestinus*	0.000	0.012	reef
Orangespotted filefish	*Cantherhines pullus*	0.000	0.154	reef
Peacock flounder	*Bothus lunatus*	0.000	0.012	reef
Princess parrotfish	*Scarus taeniopterus*	0.000	4.420	reef
Queen parrotfish	*Scarus vetula*	0.000	1.395	reef
Rainbow w rasse	*Halichoeres pictus*	0.000	6.006	reef
Redspotted haw kfish	*Amblycirrhitus pinos*	0.000	0.049	reef
Rock beauty	*Holacanthus tricolor*	0.000	0.105	reef
Scraw led cow fish	*Lactophrys quadricornis*	0.000	0.006	reef
Scraw led filefish	*Aluterus scriptus*	0.000	0.019	reef
Shy hamlet	*Hypoplectrus guttavarius*	0.000	0.068	reef
Slender filefish	*Monacanthus tuckeri*	0.000	0.049	reef
Spanish hogfish	*Bodianus rufus*	0.000	0.241	reef
Spotted morray	*Gymnothorax moringa*	0.000	0.006	reef
Tiger grouper	*Mycteroperca tigris*	0.000	0.012	reef
Whitespotted filefish	*Chantherhines macrocerus*	0.000	0.062	reef
Yellow head jaw fish	*Opistognathus aurifrons*	0.000	0.012	reef
Yellow head w rasse	*Halichoeres garnoti*	0.000	18.333	reef
Yellow tail damselfish	*Microspathodon chrysurus*	0.000	4.395	reef
Blackbar soldierfish	*Myripristis jacobus*	0.003	4.691	0.001
Brow n chromis	*Chromis multilineata*	0.036	20.074	0.002
Ocean surgeon	*Acanthurus bahianus*	0.013	6.883	0.002
Bicolor damsel	*Stegastes partitus*	0.668	157.043	0.004
Graysby	*Epinephelus cruentatus*	0.003	0.605	0.005
Bluehead w rasse	*Thalassoma bifasciatum*	0.550	81.969	0.007
Yellow tail hamlet	*Hypoplectrus chlorurus*	0.003	0.346	0.009
Redband parrotfish	*Sparisoma aurofrenatum*	0.062	4.549	0.014
Threespot damselfish	*Stegastes planifrons*	0.327	16.765	0.020
Clow n w rasse	*Halichoeres maculipinna*	0.213	10.728	0.020
Sharpnose puffer	*Canthigaster rostrata*	0.043	2.117	0.020
Bar jack	*Caranx ruber*	0.007	0.148	0.044
Spotted drum	*Equetus punctatus*	0.003	0.068	0.048
Slippery dick	*Halichoeres bivittatus*	0.609	12.370	0.049
Yellow goatfish	*Mulloidichthys martinicus*	0.187	3.432	0.054
Puddingw ife	*Halichoeres radiatus*	0.062	1.025	0.061
Honeycomb cow fish	*Lactophrys polygonia*	0.003	0.049	0.066
Greater soapfish	*Rypticus saponaceus*	0.003	0.043	0.076
Blue tang	*Acanthurus coeruleus*	0.196	2.420	0.081
Barred hamlet	*Hypoplectrus puella*	0.016	0.185	0.088
Spotted goatfish	*Pseudupeneus maculatus*	0.020	0.216	0.091
Redfin parrotfish	*Sparisoma chrysopterum*	0.043	0.395	0.108
French angelfish	*Pomacanthus paru*	0.010	0.086	0.114
Spotted trunkfish	*Lactophrys bicaudalis*	0.007	0.056	0.118
Smooth trunkfish	*Lactophrys triqueter*	0.029	0.247	0.119
Smallmouth grunt	*Haemulon chrysargyreum*	0.219	1.784	0.123
Stoplight parrotfish	*Sparisoma viride*	0.308	2.364	0.130
Sand diver	*Synodus intermedius*	0.003	0.025	0.133
Sergeant major	*Abudefduf saxatilis*	0.056	0.346	0.161
Blackear w rasse	*Halichoeres poeyi*	0.023	0.130	0.177

Common name	Scientific name	density lagoon	Night density reef	Index *
Index between 0.0 - 1.0 or observed only on the reef				
Banded butterflyfish	*Chaetodon striatus*	0.000	0.167	reef
Barred hamlet	*Hypoplectrus puella*	0.000	0.042	reef
Bicolor damsel	*Stegastes partitus*	0.000	0.042	reef
Bigeye snapper	*Priacanthus cruentatus*	0.000	0.083	reef
Blackbar soldierfish	*Myripristis jacobus*	0.000	17.125	reef
Blue chromis	*Chromis cyanea*	0.000	0.042	reef
Blue parrotfish	*Scarus coeruleus*	0.000	0.042	reef
Blue tang	*Acanthurus coeruleus*	0.000	1.000	reef
Bluespotted cornet fi	*Fistularia tabacaria*	0.000	0.021	reef
Boga	*Inermia vittata*	0.000	0.792	reef
Brow n chromis	*Chromis multilineata*	0.000	3.125	reef
Coney	*Epinephelus fulvus*	0.000	0.125	reef
Creole w rasse	*Clepticus parrae*	0.000	0.042	reef
Dusky squirrelfish	*Holocentrus vexillarius*	0.000	3.583	reef
Glaseye snapper	*Priacanthus cruentatus*	0.000	0.417	reef
Graysby	*Epinephelus cruentatus*	0.000	0.167	reef
Greater soapfish	*Rypticus saponaceus*	0.000	0.708	reef
Honeycomb cow fish	*Lactophrys polygonia*	0.000	0.125	reef
Longjaw squirrelfish	*Holocentrus marianus*	0.000	4.583	reef
Longspine squirrelfis	*Holocentrus rufus*	0.000	0.125	reef
Ocean surgeon	*Acanthurus bahianus*	0.000	5.333	reef
Peacock flounder	*Bothus lunatus*	0.000	0.042	reef
Princess parrotfish	*Scarus taeniopterus*	0.000	0.125	reef
Redfin parrotfish	*Sparisoma chrysopterum*	0.000	0.292	reef
Scraw led filefish	*Aluterus scriptus*	0.000	0.042	reef
Southern stingray	*Dasyatis americana*	0.000	0.042	reef
Tiger grouper	*Mycteroperca tigris*	0.000	0.083	reef
Trumpetfish	*Aulostomus maculatus*	0.000	0.500	reef
Yellow tail damselfish	*Microspathodon chrysurus*	0.000	0.125	reef
Yellow tail hamlet	*Hypoplectrus chlorurus*	0.000	0.042	reef
Stoplight parrotfish	*Sparisoma viride*	0.005	1.042	0.005
Yellow goatfish	*Mulloidichthys martinicus*	0.026	3.458	0.008
Spotted drum	*Equetus punctatus*	0.005	0.375	0.014
Redtail parrotfish	*Sparisoma chrysopterum*	0.042	1.375	0.030
Threespot damselfisl	*Stegastes planifrons*	0.005	0.167	0.031
Redband parrotfish	*Sparisoma aurofrenatum*	0.026	0.667	0.039
Doctorfish	*Acanthurus chirurgus*	0.058	1.375	0.042
Smallmouth grunt	*Haemulon chrysargyreum*	0.100	2.292	0.043
Foureye butterflyfish	*Chaetodon capistratus*	0.079	1.167	0.067
Smooth trunkfish	*Lactophrys triqueter*	0.031	0.417	0.075
Porcupinefish	*Diodon hystrix*	0.016	0.167	0.094
Sergeant major	*Abudefduf saxatilis*	0.010	0.083	0.126
Spotted scorpionfish	*Scorpaena plumieri*	0.005	0.042	0.126
Balloonfish	*Diodon holocanthus*	0.577	4.250	0.136
Spotted goatfish	*Pseudupeneus maculatus*	0.052	0.375	0.140
Spotted trunkfish	*Lactophrys bicaudalis*	0.037	0.167	0.220
Dusky damsel	*Stegastes fuscus*	0.068	0.250	0.273
Mahogony snapper	*Lutjanus mahogoni*	0.026	0.083	0.314
French grunt	*Haemulon flavolineatum*	1.326	2.125	0.624
Squirrelfish	*Holocentrus adscensionis*	0.121	0.167	0.723
Index 1.0 -> or observed only in the inbay				
Schoolmaster	*Lutjanus apodus*	0.314	0.167	1.887
Bluestriped grunt	*Haemulon sciurus*	0.362	0.125	2.893
Anchovies	*Anchoa* sp.	0.177	0.000	lagoon
Bonefish	*Albula vulpes*	0.005	0.000	lagoon
Butter hamlet	*Hypoplectrus unicolor*	0.005	0.000	lagoon
Cubera snapper	*Lutjanus cyanopterus*	0.010	0.000	lagoon
Gray snapper	*Lutjanus griseus*	0.047	0.000	lagoon
Great barracuda	*Sphyraena barracuda*	0.021	0.000	lagoon
Mojarra sp.	Gerreidae sp.	0.063	0.000	lagoon
Needlefish sp.	Belonidae sp.	0.084	0.000	lagoon
Night sergeant	*Abudefduf taurus*	0.058	0.000	lagoon
Orangespotted filefis	*Cantherhines pullus*	0.005	0.000	lagoon
Redspotted haw kfish	*Amblycirrhitus pinos*	0.005	0.000	lagoon
Sand diver	*Synodus intermedius*	0.005	0.000	lagoon
Sardine	*Sardinella spec.*	0.003	0.000	lagoon
Saucereye porgy	*Calamus calamus*	0.006	0.000	lagoon
Sea bream	*Archosargus rhomboidalis*	0.068	0.000	lagoon
Sheepshead porgy	*Calamus penna*	0.010	0.000	lagoon
White grunt	*Haemulon plumieri*	0.010	0.000	lagoon
White mullet	*Mugil curema*	0.005	0.000	lagoon
Yellow fin mojara	*Gerres cinereus*	0.168	0.000	lagoon
Yellow tail snapper	*Ocyurus chrysurus*	0.126	0.000	lagoon

Continuation of Table XXVI.

Common name	Scientific name	Day density lagoon	density reef	Index *
	Index between 0.2 - 1.0			
Dusky squirrelfish	*Holocentrus vexillarius*	0.007	0.025	0.265
Saucereye porgy	*Calamus calamus*	0.003	0.012	0.265
Night sergeant	*Abudefduf taurus*	0.007	0.019	0.353
Balloonfish	*Diodon holocanthus*	0.095	0.253	0.375
Bandtail puffer	*Sphoeroides spengleri*	0.023	0.056	0.412
Dusky damsel	*Stegastes fuscus*	1.057	2.173	0.486
Horseye jack	*Caranx latus*	0.039	0.074	0.530
Trumpetfish	*Aulostomus maculatus*	0.242	0.432	0.560
Spotted scorpionfish	*Scorpaena plumieri*	0.013	0.019	0.707
Foureye butterflyfish	*Chaetodon capistratus*	1.816	2.568	0.707
	Index between 1.0 - 4.0			
Black margate	*Anisotremus surinamensis*	0.007	0.006	1.060
Porkfish	*Anisotremus virginicus*	0.007	0.006	1.060
Redtail parrotfish	*Sparisoma chrysopterum*	0.494	0.463	1.067
Mahogony snapper	*Lutjanus mahogoni*	0.154	0.142	1.083
Butter hamlet	*Hypoplectrus unicolor*	0.265	0.216	1.227
Longspine squirrelfish	*Holocentrus rufus*	0.026	0.019	1.414
Tobaccofish	*Serranus tabacarius*	0.029	0.019	1.590
Striped parrotfish	*Scarus croicensis*	7.507	4.679	1.604
Mutton snapper	*Lutjanus analis*	0.023	0.012	1.856
Yellow tail snapper	*Ocyurus chrysurus*	1.037	0.457	2.271
Doctorfish	*Acanthurus chirurgus*	0.792	0.340	2.333
Porcupinefish	*Diodon hystrix*	0.016	0.006	2.651
Hogfish	*Lachnolaimus maximus*	0.020	0.006	3.181
Blue parrotfish	*Scarus coeruleus*	0.236	0.068	3.470
	Index between 4.0 - 20.0			
French grunt	*Haemulon flavolineatum*	16.677	2.364	7.054
Great barracuda	*Sphyraena barracuda*	0.180	0.019	9.720
Squirrelfish	*Holocentrus adscensionis*	0.180	0.019	9.720
White grunt	*Haemulon plumieri*	0.079	0.006	12.724
Rainbow parrotfish	*Scarus guacamaia*	0.088	0.006	14.314
Bluestriped grunt	*Haemulon sciurus*	3.129	0.204	15.359
Schoolmaster	*Lutjanus apodus*	3.865	0.247	15.653
	Index 20.0 -> or only observed in the inbay			
Yellow fin mojara	*Gerres cinereus*	1.725	0.043	39.914
Mojara sp.	Gerreidae sp.	0.910	0.006	147.385
Gray snapper	*Lutjanus griseus*	1.011	0.006	163.820
Anchovies	*Anchoa* sp.	29.237	0.000	lagoon
Beaugregory	*Stegastes leucostictus*	0.952	0.000	lagoon
Bucktooth parrotfish	*Sparisoma radians*	0.043	0.000	lagoon
Cocoa damsel	*Stegastes variabilis*	0.641	0.000	lagoon
Comb grouper	*Mycteroperca rubra*	0.013	0.000	lagoon
Hardhead silversides	*Atherinomorus stipes*	24.855	0.000	lagoon
Highhat	*Equetus acuminatus*	0.007	0.000	lagoon
Lane snapper	*Lutjanus synagris*	0.003	0.000	lagoon
Leatherjacket	*Oligoplites saurus*	0.016	0.000	lagoon
Longsnout seahorse	*Hippocampus reidi*	0.003	0.000	lagoon
Needlefish sp.	Belonidae sp.	0.072	0.000	lagoon
Sailors choice	*Haemulon parrai*	0.497	0.000	lagoon
Sardine	*Sardinella spec.*	2.257	0.000	lagoon
Sea bream	*Archosargus rhomboidalis*	0.602	0.000	lagoon
Southern stingray	*Dasyatis americana*	0.003	0.000	lagoon
Spanish grunt	*Haemulon macrostomum*	0.023	0.000	lagoon
White mullet	*Mugil curema*	0.046	0.000	lagoon

Table XXV. Mean diet (volume percentages of food items) corresponding with fish clusters shown in figure 21. The three highest percentages are highlighted.

	cluster																				
Food item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Deacapoda	-	-	-	-	0.7	7.8	**10.9**	0.1	1.2	3.0	-	9.5	**17.3**	-	**31.7**	**50.0**	**47.3**	**52.7**	**70.0**	**69.0**	**85.0**
Tanaidacea sp. I	3.8	0.3	-	-	**24.0**	**38.7**	7.6	**40.7**	**44.5**	**28.8**	**54.3**	**30.0**	9.0	-	**20.2**	0.5	**21.3**	0.7	-	1.2	**10.0**
Seagrass	4.6	**31.7**	-	-	9.5	-	4.3	-	-	-	-	-	-	-	-	-	-	-	-	-	**5.0**
Fish	-	-	-	-	-	-	-	-	-	2.9	-	7.0	4.9	-	5.6	-	**18.2**	**14.1**	-	**41.6**	-
Others	**18.6**	5.7	**45.0**	2.5	**19.0**	1.6	6.2	**11.4**	13.6	**54.2**	-	**27.8**	8.1	-	12.2	**18.8**	1.8	3.3	-	**5.6**	-
Mysidacea	-	-	-	-	-	7.7	-	1.4	-	0.4	**14.4**	-	3.6	**47.5**	**15.7**	-	7.3	**8.0**	-	1.6	-
Annelida	0.9	0.1	-	12.5	0.4	-	-	-	-	0.2	-	**14.0**	**10.2**	-	0.1	0.8	-	3.3	**14.0**	0.9	-
Isopoda	0.1	0.7	-	-	7.4	3.9	1.5	0.4	0.5	3.5	0.3	-	1.3	-	0.6	-	-	-	-	0.6	-
Amphipoda	0.1	-	10.0	-	3.8	**20.7**	0.5	0.7	1.3	2.8	0.9	-	4.7	-	0.3	-	1.0	-	-	0.2	-
Copepoda	2.2	2.0	7.5	-	1.7	9.8	2.6	10.9	**34.9**	1.2	5.9	0.2	2.1	**2.5**	5.0	-	-	-	-	0.0	-
Gastropoda	1.3	0.5	-	5.0	3.1	-	**18.6**	5.4	0.6	2.1	-	1.0	5.7	-	1.6	-	-	7.2	**10.0**	-	-
Sediment	-	8.7	-	**15.0**	**12.3**	-	1.1	8.5	0.6	2.5	-	6.0	**10.1**	-	3.2	-	-	4.5	5.0	-	-
Bivalvia	-	0.0	5.0	-	6.7	0.1	**37.1**	3.6	0.1	0.7	-	0.5	8.9	**50.0**	0.8	-	-	0.7	1.0	-	-
Polychaeta	6.4	0.2	-	**30.0**	4.0	-	2.2	1.4	1.0	-	-	3.5	2.3	-	-	-	-	5.1	-	-	-
Calcareous algae	-	4.2	**30.0**	5.0	0.5	-	0.1	0.1	-	-	-	-	1.4	-	-	**30.0**	-	0.3	-	-	-
Tanaidacea sp. II	1.7	0.7	-	-	-	**15.6**	6.9	**12.7**	**15.5**	4.0	**24.4**	-	1.6	-	6.5	-	2.7	-	-	-	-
Filamentous algae	**50.1**	**58.6**	10.0	**20.0**	2.1	-	0.3	1.3	0.0	-	-	-	-	-	0.0	-	0.5	-	-	-	-
Foraminifera	-	1.8	-	-	-	-	-	0.3	-	-	-	-	-	-	0.5	-	-	-	-	-	-
Echinoderma	-	-	-	10.0	2.0	-	1.2	0.5	0.3	-	-	-	6.6	-	-	-	-	-	-	-	-
Macrous algae	**14.1**	**12.5**	**37.5**	-	1.3	15.0	0.4	-	0.0	-	-	0.5	1.5	-	-	-	-	-	-	-	-
Ostracoda	-	0.1	-	-	1.4	-	2.0	3.9	0.5	**8.0**	-	-	0.6	-	-	-	-	-	-	-	-
Nematoda	-	0.0	-	-	-	-	-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Uni-cellular algae	-	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table XXVI. Mean diet (volume percentages of food items) corresponding with fishclusters shown in figure 23. The three highest percentages are highlighted.

	cluster										
Food item	1	2	3	4	5	6	7	8	9	10	11
Filamentous algae	-	-	0.1	1.4	-	-	-	7.5	**42.4**	**35.0**	**67.3**
Amphipoda	-	6.9	5.6	0.3	-	1.5	**92.0**	3.0	0.1	**25.0**	-
Macrous algae	-	0.1	0.2	**11.9**	**15.8**	0.2	**2.6**	**16.5**	**21.4**	**20.0**	2.3
Sediment	0.1	1.6	1.2	1.7	5.0	0.6	**2.8**	**15.0**	-	10.0	**5.2**
Tanaidacea sp. I	0.4	4.7	1.9	**20.6**	9.2	2.5	-	-	**6.1**	5.0	0.9
Polychaeta	-	-	1.9	2.0	**40.0**	1.5	-	10.0	5.8	5.0	-
Seagrass	-	-	0.2	0.2	-	-	-	**16.5**	5.0	-	**19.8**
Foraminifera	-	0.2	2.3	2.6	1.7	0.0	-	7.5	0.4	-	1.4
Calcareous algae	-	0.2	0.8	7.6	3.3	-	-	10.0	4.2	-	1.4
Deacapoda	-	**33.1**	**56.0**	4.1	4.2	**46.5**	1.0	-	-	-	1.4
Others	**1.0**	4.9	**5.8**	3.9	5.0	**36.5**	-	12.0	0.8	-	0.2
Annelida	0.4	3.2	3.1	1.5	1.7	1.0	-	-	0.0	-	0.1
Echinoderma	-	2.7	2.4	8.3	-	-	-	2.0	4.2	-	0.0
Copepoda	-	1.7	0.8	4.2	-	1.0	-	-	0.9	-	0.0
Tanaidacea sp. II	-	**18.6**	0.5	**20.8**	-	1.0	-	-	5.1	-	-
Ostracoda	-	0.6	-	4.9	-	3.0	-	-	2.2	-	-
Uni-cellular algae	-	-	0.6	-	-	-	-	-	1.0	-	-
Bivalvia	-	0.7	5.3	2.8	**14.2**	0.6	-	-	0.1	-	-
Mysidacea	**5.0**	**13.0**	**6.2**	0.0	-	-	-	-	0.1	-	-
Gastropoda	-	0.1	0.7	1.0	-	**3.7**	1.7	-	-	-	-
Nematoda	-	0.0	0.5	0.0	-	0.5	-	-	-	-	-
Isopoda	-	0.1	0.0	0.0	-	-	-	-	-	-	-
Fish	**93.1**	7.6	3.7	-	-	-	-	-	-	-	-

Table XXVII. Mean diet (volume percentages of food items) corresponding with fish clusters shown in figure 24. The three highest percentages are highlighted.

	cluster							
Food item	1	2	3	4	5	6	7	8
Fish sp.	-	-	-	-	-	-	10.0	**60.0**
Deacapoda	-	-	2.5	-	-	-	**20.0**	**40.0**
Polychaeta	-	-	1.2	0.7	-	-	**33.8**	-
Tanaidacea sp. II	-	-	4.4	-	-	-	**18.0**	-
Mysidacea	-	-	-	-	-	-	12.0	-
Others	-	-	6.2	8.6	4.7	**12.5**	3.0	-
Tanaidacea sp. I	-	-	1.6	-	-	-	2.0	-
Copepoda	0.4	-	**23.0**	**35.7**	**16.9**	-	1.0	-
Ostracoda	-	-	5.3	**17.1**	2.8	-	0.2	-
Bivalvia	-	**62.1**	7.7	15.7	3.5	**67.5**	-	-
Echinoderma	-	-	**9.0**	-	-	**20.0**	-	-
Gastropoda	0.4	-	**23.6**	**18.6**	**42.3**	-	-	-
Macrous algae	-	-	-	-	**21.7**	-	-	-
Amphipoda	-	-	0.1	1.4	6.0	-	-	-
Calcareous algae	-	-	-	-	1.9	-	-	-
Foraminifera	0.1	**9.3**	1.9	0.7	0.3	-	-	-
Sediment	**8.3**	**27.1**	7.5	1.4	-	-	-	-
Filamentous algae	**53.4**	-	5.3	-	-	-	-	-
Nematoda	-	-	0.8	-	-	-	-	-
Isopoda	-	1.4	-	-	-	-	-	-
Seagrass	**37.5**	-	-	-	-	-	-	-
Annelida	-	-	-	-	-	-	-	-
Uni-cellular algae	-	-	-	-	-	-	-	-

DISCUSSION

Spaanse Water

Different forms of use of the bay

A relatively high diversity of reef fishes was observed in Spaanse Water. The bay therefore functions as an important life biotope for reef fishes. When fish densities in Spaanse Water are compared with densities on the coral reef, it appeared that the bay functioned as a life biotope in several ways. Firstly, there were species that were almost completely dependent on the bay (n=20). These species were rarely observed on the reef and use the bay as a lifetime biotope where they complete their entire life cycle. Conversely, there were species that were almost completely restricted to the reef (n=71). These 'strict coral reef species' were rarely observed in the bay and complete their entire life cycle on the coral reef.

Beside these two distinct groups, there were species that were found both on the reef and in the bay (n=31). These species can be divided into two subgroups. The first subgroup consists of species that were found predominantly on the reef and only in low densities in the bay (n=24). They were mainly found in the entrance area and showed little affinity with the rest of the bay. For these species, the bay should be considered as an extension of the coral reef.

The species of the second subgroup were found in similar or higher densities in the bay compared to the coral reef (n=7). Beside the entrance area, they could also be observed in other parts of the bay. For those species, the bay fulfils a more important role. The nursery model suggested by Robertson & Blaber (1992) can explain the high densities of those species in the bay. According to this model, the bay is used as a nursery room and high densities of juvenile fish are present. When reaching adult life stage, they migrate to the reef and disperse. Because the area of reef is much larger than the area of the bay and because of natural mortality processes, densities of adults on the reef are much lower than densities of juveniles in the bay.

Nursery function can be considered at different levels. The first group of strict coral reef species has no affinity with the bay and consequently no nursery function of the bay can be ascribed to these species. They use other biotopes than the bay for recruitment and settlement, for example the shallow reef flat. In contrast, 'bay species' complete their entire life cycle in the bay. Consequently, nursery function of the bay for these species is clear.

The first subgroup of species that occurs both on the reef and in the bay, use the bay only to a small extent. Although small individuals have been observed, explicit nursery function of the bay is not evident. A study of Lenanton (1982) revealed that shallow reef biotopes such as the reef flat can function as a nursery room. It is therefore suggested that the entrance area of Spaanse Water should be considered as a shallow extension of the coral reef that is used as a nursery room. The species of this subgroup recruit in shallow reef biotopes including the entrance area of the bay and migrate directly to the coral reef when reaching adult life stage. Therefore, they have no affinity with the biotopes situated further into the bay. Whether this is an unique situation for Spaanse Water or that it is valid for all other bays on the island of Curaçao remains unclear.

For the second subgroup of species found both on the reef as in the bay, nursery function of the bay is more evident. For some of these species, high densities of juveniles are observed in the bay while larger adults are observed on the coral reef. This has been analysed and proved for french grunt, bluestriped grunt, schoolmaster, striped parrotfish and yellowtail snapper (Student t test, $P<0.05$). Mean length of these species is smaller in the bay than on the reef while density is highest in the bay and lowest on the reef. Beside those five analysed species, most other species of this subgroup most probably use the bay as a nursery ground.

Biotope utilisation and community structure

The diurnal fish community of Spaanse Water was separated by TWINSPAN into smaller fish communities characteristic for a specific biotope type. A clear gradient of biotope types is visible in the arrangement of clusters. This gradient of biotope types extends from the deeper reef transects to transects situated far into the bay and is used by different fish communities. The fish communities of biotopes in the entrance of the bay (channel site 1, rocks and niches) were clustered together and ordinated closely to the fish communities of the shallow reef transects. Because the fish community of the entrance area showed high similarity with the communities of the shallow reef, the biotopes in the entrance area should be considered as an extension of the shallow reef. Therefore, fish communities change from deep reef to shallow reef to bay biotopes. The fish community of the channel biotope in the entrance area of the bay forms a transition between the fish communities of the shallow reef in front of the bay and the biotopes situated further into the bay (niches and rocks of site1 and site 2).

Mangroves and seagrasses are situated at larger distance of the reef and harbour the typical fish communities of the bay. Similarities and diversities of fish communities between those different biotopes are in accordance with this. The fish communities of *Halimeda* fields and seagrasses were most different from the coral reef. In general, it can be concluded that fish communities change within a gradient of changing biotope types from deep reef to bay.

During night a clear shift in species composition occurs and a nocturnal fish community replaces the diurnal fish community. This is also reported by other studies (Starck & Davis, 1966; Collette & Talbot, 1972; Hobson, 1973; Sbikin, 1977). In contrast to the diurnal fish communities in the different biotopes, the nocturnal fish communities in the different biotopes were not clearly separated from each other by TWINSPAN. Whereas the fish communities formed by diurnal fish species showed a gradient from deep reef transects to bay transects, such a gradient is not visible for the fish communities formed by the nocturnal fish species.

During day, the fish communities of rocks and niches showed high similarity to the reef. The fish communities of those biotopes can therefore be viewed as a transition between reef and bay. However, during night the situation was reversed and the fish communities of rocks and niches showed lowest similarity to the reef indicating two completely different fish communities. In contrast to this, fish communities of seagrasses, *Halimeda* fields, channels and shallow reef showed high similarity during night but formed completely different fish communities during day.

Differential use of these biotopes can be explained by a shift in function of these biotopes between day and night. During day nocturnal species such as grunts and snappers are sheltering while diurnal species such as parrotfishes, damselfishes and surgeonfishes are foraging. Mangroves and rocks are favoured by sheltering species while seagrasses are used as a feeding ground (parrotfishes, surgeonfishes). Because different species and their size classes select different biotope types for sheltering or foraging, a number of different fish communities can be distinguished. During night diurnal species are inactive (parrotfishes, surgeonfishes) and no longer contribute to the fish communitiy. Nocturnal species that used different biotopes during day for shelter become active and start foraging by dispersing over a large area. This is illustrated by the activity pattern of the french grunt that is abundant both during day and night. During day relative large schools of french grunt are observed in a number of biotope types. Each biotope type is used by specific size classes of french grunts. However, during night all those schools migrate towards seagrasses and *Halimeda* fields and start foraging. Because they forage solitaire, the school disperses. During day several fish communities with french grunts can be distinguished over a number of biotope types while during night fish communities with french grunts can only be distinguished in seagrasses and *Halimeda* fields.

Importance of different biotope types

It appeared that biotope types in Spaanse Water were not of equal importance for fish species. Importance of a biotope depends not only on the degree of selection by fish species, but also on the total area of the biotope. Both mangroves and seagrasses cover a large part of total bay area and in both biotopes is a large share of the total fish numbers of the bay present. Only the fish community in mangroves shows a biotope preference indicating the importance of this biotope. In contrast, the fish community in seagrasses shows a biotope avoidance. However, calculated from the area of seagrasses, this biotope still holds large amounts of fish. Generalising seagrasses as a relatively less important biotope is therefore a misunderstanding. When species are considered solely, it appeared that striped parrotfish and yellowtail snapper have a positive selection for seagrasses. Seagrasses harbour high densities of these species and are therefore more important than mangroves for these species.

Halimeda fields also cover a large area but show a very strong avoidance by fish species (>90%). Therefore, they are of less importance. Rocks, niches and channels show a low degree of avoidance but these biotopes do not cover a large area, especially in the case of rocks. It can be concluded that each biotope differs in importance with respect to specific species, making a general conclusion of importance of each biotope difficult.

When comparing importance of each biotope for fish between day and night, many biotopes show higher avoidance during night than during day, especially mangroves, channels and rocks. Selection for seagrasses by fish during day and night is similar. *Halimeda* fields are more avoided during day than during night showing higher fish densities during night. However, importance of this biotope for fish species must not be over estimated because actual numbers of fish in *Halimeda* fields are very low.

A general trend in biotope preference by fish during day and night can be distinguished. Biotopes with a high complexity (much shelter possibilities) but a relative low food availability, such as rocks, channels and mangroves, are more preferred during day than during night. Biotopes with a lower complexity but a high food availability, such as seagrasses and *Halimeda* fields are more preferred during night than during day. During night, shelter becomes less important while other factors such as food availability become more important. Lower light conditions during night probably reduce predation efficiency, making the need for shelter less important. With respect to this, fish species that school and rest during day, migrate at dusk and feed during night (for example snappers and grunts). Other species such as parrotfishes, mojarras, damselfishes and foureye butterflyfish are more restricted to a particular biotope where they both feed and rest.

Size classes

During night, a shift in size frequency towards larger individuals was observed. This was significant for french grunt and bluestriped grunt (χ^2 test, $P<0.01$). Small individuals that were found above the seagrass canopy during day, are missed during night. Those small individuals are thought to forage deeper into the seagrass beds close to the bottom. (McFarland *et al.*, 1979). Therefore they are easily missed during a night census. Larger size classes of grunts are foraging above the seagrass canopy during night. During day they rest in the mangroves and are infrequently observed in the seagrasses.

The complexity of seagrasses can influence the fish community of adjacent mangroves. Seagrass complexity is negatively correlated with mean length of fish species living in mangroves adjacent to those seagrasses (bluestriped grunt) while it is positively correlated with mean length of fish species living in these seagrasses (striped parrotfish, yellowtail snapper). When seagrass complexity is low, larger fish use the adjacent mangroves for shelter because the shelter provided by those seagrasses is insufficient. However, when seagrass complexity is high, larger fish leave the mangroves because the shelter provided by these seagrasses is sufficient enough.

Lunar phases

The lunar phases only had a significant effect on the densities of the balloonfish and not on other studied fish species. This in contrast with the result of another study in a shallow coastal area in Indonesia (van Riel & Wijnhoven, 1997). Here, the lunar phases significantly influenced the fish communities. The study area in Indonesia was part of a typical coastal bay and was directly exposed to the ocean. In contrast, Spaanse Water and the studied coral reef in front of Spaanse Water are relatively sheltered areas. It can be suggested that beside the changing light conditions, other processes caused by the lunar phases influence the fish community in Indonesia that are not present on the island of Curaçao. The density of the balloonfish was highest when light conditions were minimal (new moon) and densities were lowest when light conditions were maximum (full moon). Balloonfish have large eyes and are therefore well adapted to low light conditions. It can be speculated that foraging of this species on both Mollusca and Decapoda is most successful during minimal light conditions when competition from other species is lowest.

Seasonal differences

The densities observed in the first period were significantly higher than those observed in the second period. Just after the second period a recruitment wave was observed. Mainly yellowtail snappers and to some extent french grunts and mahogany snappers were involved in this recruitment. Therefore, end “summer” - early “winter” fish densities in the bay were highest. Fish densities can decrease throughout the year due to several factors such as migration of adults to the coral reef and natural mortality e.g. by predation. Therefore, fish densities decrease until a recruitment wave renews the fish community. Environmental factors such as salinity, visibility and tidal regime were relatively constant during the year. It is therefore assumed that those factors do not influence fish densities and recruitment on a seasonal basis.

A number of examples of seasonal variation in tropical coastal fish communities exist. For a tidal swamp in tropical Australia it was shown that the seasonal abundance of many fish was determined by their breeding patterns and the dispersal abilities of their juveniles and not by environmental parameters such as temperature and salinity that were highest in December and January (Davis, 1988).

Different fish species have developed ecological adaptive mechanisms by coupling their life histories with physical conditions of the biotope, and also diminishing biological interaction such as competition and predation. These interactions are extremely intense in high-diversity, tropical, coastal communities. In a study executed in a Terminos Bay in the southern Gulf of Mexico highest biomass of fish for a high-salinity fringing mangrove - *Thalassia testudinum* biotope occurred during the dry season (February - May/June) when aquatic primary production was highest (Yåñez-Aranciba, 1988).

Other studies report no seasonal variation. In an East African mangrove creek sampling with a beach seine resulted in no systematic spatial or temporal variation in the community structure (Little *et al.*, 1988).

Other functions of the bay

Besides the nursery function of Spaanse water for a number of reef fish species, the bay has other ecological functions that are not described. In June 1998 a large school (>10,000 individuals) of redear sardines was observed for a period of three weeks in the seagrasses in the entrance area of the bay (site 2). These sardines could no longer be qualified as juveniles. This large school used the bay during a short period as a refuge to feed and shelter. Also species that are rare on the island of Curaçao have been observed in Spaanse Water and use the bay for some extend. Spotted eagle rays (*Aetobatus narinari*) and southern stingrays (*Dasyatis americana*) were observed to enter the bay at dusk (personal observation authors). Green turtles (*Chelonia mydas*) were found in the bay both during day (foraging) and night (sheltering). Foraging of green turtles on seagrasses was also observed by another study (Ogden, 1980). Beside the nursery function, a bay can also functions for other purposes such as temporal feeding or shelter habitat.

Comparison between bays

Fuikbaai

The fish community of Spaanse Water is most similar to the fish community of Fuikbaai. Fuikbaai is also situated on the south coast and mean visibility is relatively high. Like Spaanse Water, the fish community of Fuikbaai is dominated by french grunt and bluestriped grunt. Especially the seagrasses are important biotopes for these species. Since the fish community of Fuikbaai is similar to that of Spaanse Water, this bay also should be considered as a possible nursery ground for a number of species. It appeared that for five species mean size was even smaller in Fuikbaai than in Spaanse Water. Thus, Fuikbaai functions as a nursery for french grunt, bluestriped grunt, schoolmaster, striped parrotfish and yellowtail snapper.

St. Jorisbaai

St. Jorisbaai serves as an important biotope for several economically important fish species such as the yellowtail snapper, mutton snapper and schoolmaster. Especially the mutton snapper is more abundant in St. Jorisbaai than in Spaanse Water and Fuikbaai. In contrast to Fuikbaai, the abundance, number of fish species and fish biomass of the mud plains of St. Jorisbaai, Bartolbaai and Playa Grandi were similar to those of the seagrasses. This suggests that the difference in abundance, number of fish species and fish biomass of mudplains compared to seagrasses, does not exist in relatively turbid bays. Low visibility probably reduces predation risk and the need for shelter. Mud plains with a low visibility are more attractive than mud plains with a high visibility. Although mojarras are abundant in all bays, they only dominate the fish communities of bays situated on the north coast (especially St. Jorisbaai) where large areas of mud plains are present. Compared to other biotope types, mudplains are believed to be important feeding ground for mojarras (personal observation).

Bartolbaai & Playa Grandi

The fish communities of Bartolbaai and Playa Grandi show lower fish densities and diversities. This could be related to the small size of these bays and to the exposure to the reef. Both bays are in open connection with the sea and lack a channel as in Spaanse Water and St. Jorisbaai. They are therefore not protected from wave action and there is only a low barrier for large reef associated predators. Both bays are therefore relatively unattractive for fish and have no significant nursery function. Some species were only observed in Bartolbaai or Playa Grandi, for example the tripletail.

Relation between coral reefs and bays

Similarity between reefs on the north coast and the south coast

Results show the fish community of the reef on the north coast in front of St. Jorisbaai to be different from those of the reefs on the south coast. Personal observations (authors) show a similar pattern for other reef locations on the north coast (Terra Cora, Boca Ascension, and Playa Canoa). Also a clear difference in reef structure between both coasts exists. The north coast is strongly exposed to heavy winds and strong waves. Therefore, shallow areas have a very rough and dynamic character. They are dominated by *Sargassum* algae while the coral reef starts at a larger depth of approximately 18 meter. In contrast, the south coast is much more sheltered. The shallow areas are dominated by dead and living corals and are rich in structure. This structural difference can explain the marked difference in fish communities. The south coast shows high densities of typical small fish species (e.g. wrasses, damselfishes, gobies and blennies) while predominantly larger fish species occur at the north coast (e.g. triggerfishes, black durgons, chubs and groupers). Many small fish species only occur in structure-rich shallow water that is present on the south coast. Because those biotopes are not available on the north coast, larger species, more characteristic for deeper water, are dominant.

Differences between sampled bays

Grunts show higher densities in both Spaanse Water and Fuikbaai, while snappers show higher densities in the bays situated on the north coast. Several explanations for this distribution pattern can be made.

First of all, differences in environmental conditions within the various bays can cause differences in fish communities. Bays situated on the south coast are characterised by high visibility and bays situated on the north coast are characterised by low visibility. Visibility is thought to be an important structuring factor in relation to predation. Snappers show high densities in biotopes with low visibility. In those biotopes, predation risk is lower and consequently survival may be higher. The areas in Spaanse Water with a low visibility also showed higher densities of snappers.

Secondly, differences in structure between the reefs in front of the bays can cause differences in fish communities between the various bays. For example, in the mangroves of St. Jorisbaai only low numbers of juvenile fish have been collected. Most fishes in these mangroves were of such a large size that they could no longer be classified as juveniles. This is in contrast to the mangroves of Spaanse Water and Fuikbaai that harbour high densities of juvenile fishes (especially grunts and snappers). The mangroves of St. Jorisbaai function more as a life time habitat for fishes than as a nursery. This may be caused by the dynamic character of the north coast and the presence of many predators (jacks, mackerels and sharks). The reef is therefore less suitable for grunts and snappers, thereby forcing them to use the bays as a life time habitat.

The dynamic character of the reef in front of St. Jorisbaai may also influence recruitment and settlement of juveniles into the bay. The reef flat on the north coast is characterised by extensive algae fields that lack structure and hardly provides any shelter places. On the contrary, the reef flat of the south coast is characterised by structure rich shallow areas of rocks, dead and living corals. In these areas many juvenile reef fish have been observed, including grunt and snapper species (personal observation). Since the reefs are situated differently and have a different structure the flow of recruits may be different also. This could also be an explanation for the different species composition between bays situated on the north coast and those situated on the south coast. This is illustrated by differences in size distribution of balloonfishes in various bays. Balloonfishes collected from bays situated on the south coast were larger than those collected on the north coast. This could be the result of differences in recruitment waves induced by different weather conditions between north and south coast. It is earlier described that recruitment of these species happens in distinct waves (Debrot & Nagelkerken, 1997).

Influence of Spaanse Water on the reef

A significant difference was observed when mean density and size of five analysed species was compared between Spaanse Water and reef sites. Those species recruit and spend their juvenile life stage in the bay and migrate in adult life stage to the reef. It would be expected that densities decrease and mean size increases on coral reefs situated further from the bay. However, for the five analysed species no significant correlations were found between mean size and distance to the entrance of Spaanse Water and between density and distance to the entrance of Spaanse Water. A clear influence of Spaanse Water on the coral reef is therefore not visible for the analysed species. This does not mean that there is no influence. Possibly adults of the selected species migrate freely along the coast. Also the presence of other bays can mask a clear influence of Spaanse Water on the structure of the fish community of the reef.

No juveniles or small individuals of fish species occurring both on the reef as in the bay (for example gray snapper, yellowtail snapper, french grunt, bluestriped grunt, striped parrotfish and great barracuda) are observed on the reef while no large adults are observed in Spaanse Water. This means that the adult individuals on the reefs near Spaanse Water use the bay as a nursery ground. When they reach a certain length they migrate and disperse over the reefs. Most probably they dwell on large areas of reef by which a gradient in occurrence along the coast is not visible. To reveal the specific influence of Spaanse Water on the coral reef fish communities, further research that includes the total south coast of Curaçao is necessary.

Influence of environmental factors on fish communities

Food

The results on the diet of the fishes are similar to results found in other studies, indicating crustaceans to be the most important (Austin & Austin, 1971; Parrish, 1989; Edgar & Shaw, 1995b; Booth, 1995; Hutomo & Peristiwady, 1996). There are marked differences in food quantity between Fuikbaai, Spaanse Water and St. Jorisbaai. These differences are also reflected by total fish diet. The fish community of Spaanse Water differs from that of St. Jorisbaai. However, abundance of the different food items is similar for these two bays. Because food quantity and food quality do not differ between bays, other factors such as visibility may cause the difference in fish community structure. Fish collected in Fuikbaai are smaller than other those collected in other bays. Ontogenetic shifts in the diet are well documented for a number of species, mostly fish feeding on crustaceans (Austin, 1971) and was also found in this study. These fish show clear preference for copepods at small size. Their diets shifted to Tanaidacea with increasing size. Possibly, a fish cannot sustain growth beyond a certain point on copepods alone. Therefore they start feeding on other sources. Since Tanaidacea are virtually absent in Fuikbaai and copepods are most dominant, this suggests that fish adapt to the food availability in a particular biotope. Because the biomass of copepods is smaller than the biomass of Tanaidacea (differences in sizes), this may cause the difference in mean length between fish collected in Fuikbaai and fish collected in Spaanse Water and St. Jorisbaai.

No spatial distribution of fish communities in Spaanse Water caused by differences in food availability is evident from the clustering with TWINSPAN. Differences in distribution of fish communities occur due to differences in densities of specific fish species between clusters and can not be related to the food availability of a specific region in the bay.

Multivariate factors in Fuikbaai, St. Jorisbaai, Bartolbaai and Play Grandi

The results of the CCA of Fuikbaai, St. Jorisbaai, Bartolbaai and Playa Grandi showed temperature and biotope complexity to have a significant structuring effect ($P<0.05$) on the fish communities. No significant structuring effect was found for mean visibility.

Two groups of fish species can be distinguished. The first group is positively correlated with seagrass complexity. French grunt, striped parrotfish and bluestriped grunt belong to this group. These species are also frequently found in Spaanse Water and Fuikbaai that both harbour extensive seagrasses and have high visibilities. The second group of fish species is negatively correlated with seagrass complexity (and also mean visibility) and consists of several mojarra species (irish pompano, slender mojarra, and silver jenny) and the mutton snapper. Mud plains are believed to be important for these species, which is in accordance with the results given by CANOCO. Mutton snapper was also captured in Spaanse Water, but only in the more turbid mud plains.

Mean temperature in the bay is positively correlated with distance to mouth, since ocean water temperature is lower than temperature in the bay. Bucktooth parrotfishes are negatively correlated with temperature. This may indicate rather a negative correlation with distance to the mouth than to temperature. Census data support this because the species was only observed in the entrance of the bay.

Multivariate factors in the seagrasses of Spaanse Water

The results of the CCA of the seagrasses of Spaanse Water showed mean temperature, distance to entrance within the bay, index epifauna and mean visibility to have a significant structuring effect on the fish communities ($P<0.05$). Seagrass complexity and the infauna index were not significant with respect to the structuring of the fish community. However, only seagrasses with high cover thus with comparable complexities were used for the transects. The infauna index is thought to be unimportant. Fish probably forage on the epifauna mainly. This is supported by the correlations of size and density with the epifauna index for four species.

Three groups of fish species within the fish community can be distinguished. The first group is negatively correlated with distance to entrance within the bay and consists of species such as bucktooth parrotfish and some species of wrasses. These wrasses are dominant on shallow reef flats and use the entrance of the bay as an extension of their lifetime biotope. The bucktooth parrotfish was found only on seagrasses in the entrance area was not observed on the reef or deeper into the bay

The second group consists mainly of fish species normally found in mangroves such as yellowfin mojarra, schoolmaster, foureye butterflyfish, rainbow parrotfish, great barracuda and balloonfish. The demand a high degree of shelter that is normally provided by mangroves. When seagrass complexity is high, shelter provided by the seagrasses is high enough to leave the mangroves.

The third group, situated in the middle of the plot, consists of generalist species. Biotope demands for these species are low and these species are consequently found in seagrasses within a range of environmental variables. Examples are french grunt, striped parrotfish, ocean surgeon and beaugregory.

Multivariate factors in the mangroves of Spaanse Water

Four groups are distinguished. The first group of bluestriped grunt and seabream is positively correlated with seagrass complexity. Especially bluestriped grunt favours mangroves and complex seagrasses in front of the mangroves make this biotope more attractive for these fish species. The second group is negatively correlated with seagrass complexity. This group of fish species including species such as beaugregory, mahogany snapper, smooth trunkfish and striped parrotfish, favours seagrasses. High seagrass complexity provides more shelter, reducing the importance of the shelter provided by the mangroves.

The third group is positively correlated with visibility and includes great barracuda and schoolmaster. Both are predators, with great barracuda preying mainly on fish and schoolmaster preying mainly on Decapoda and Mysidacea. Predation efficiency increases with visibility and therefore biotopes with high visibility are favoured by these fish species.

The fourth group includes three parrotfish species, stoplight parrotfish, rainbow parrotfish and redtail parrotfish and is negatively correlated with distance to entrance within the bay and mean visibility and. For stoplight and rainbow parrotfish, only juveniles were observed. These parrotfishes use the mangroves close to the entrance of Spaanse Water as a nursery. Of the redtail parrotfish only adults were observed. This species uses the entrance of the bay as an extension of the shallow coral reef.

General view of multivariate factors

Other studies also report that environmental factors are able to influence the structure of a fish community in a biotope. Biotope complexity can directly influence a fish community by providing shelter (Main, 1987; Jenkins, 1997; Eggleston, 1997) or indirectly by influencing recruitment (Caselle & Warner, 1996). Also food availability (Robertson, 1984; Orth, 1984; Edgar & Shaw, 1995b) and mean visibility (Blaber, 1980; Blaber, 1985; Robertson *et al.*, 1987) are known to influence the structure of a fish community significantly. The factor ‘distance to the entrance within the bay’ can be translated as an increasing influence of the reef on biotopes situated closely to the entrance of the bay. The influence of the coral reef on seagrasses has also been shown in other studies (e.g. Baelde, 1990). Although some studies showed no effects of temperature on the fish community (Davis, 1988), other studies did show significant effects (Wallace, 1977; Quinn, 1980) of temperature. In the present study variations in temperature between various sites, measured on the same day, were situated in a range of 1.4 °C, with very shallow sites (<0.5m) having highest temperatures. Preferred temperature for yellowtail snapper ranges between 24-30 °C (Wallace, 1977). Temperatures over 30 °C have been noted in the second census period, indicating that temperature can have a structuring effect. Medic and Miller (1979) showed preference for higher temperatures for juveniles of certain fish species. Considering nursery function, bays with higher temperatures can be favoured over bays with lower temperatures. Exposure of the north coast to heavy winds and different ocean currents (e.g. upwelling of cold seawater) can influence temperature of bays situated on the north coast. It is therefore reasonable that temperature is a structuring variable in fish communities within the various bays.

Main conclusions of this study

When the results of this study are summarised some main conclusions can be made. When Spaanse Water is considered, it is evident that for a number of fish species the bay functions as a significant nursery room. Especially mangroves, rocks and seagrasses harbour high densities of juvenile fish. On the contrary, other species only use the shallow areas of the reef as a nursery and are seldom observed in the bay. Within the bay, there is a continuation of fish communities where communities close to the entrance are most similar to reef fish community and communities further in the bay are most distinguished from the reef fish community. When the reef fish communities are considered there is a strong difference between reef fish communities on the north coast and the southcoast. This difference is also observed in fish communities between various bays. With respect to this, each analysed bay is characterised by a specific fish community. When the nursery function of bays is condidered, nursery function of bays on the south coast (Fuikbaai and Spaanse Water) is more evident than nursery function of bays on the north coast (Bartolbaai, Playa Grandi and St. Jorisbaai)

Several environmental variables are thought to be related with the fish communities in these bays, e.g. visibility, food availability and structure and exposure of in front laying coral reefs. Within the bays with high visibility, biotope complexity (of mangroves, seagrasses and rocks) is an important environmental variable with respect to providing shelter for fish communities. In general, it can be concluded that from the five analysed bays especially St. Jorisbaai, Fuikbaai and Spaanse Water have a significant contribution to the reef fish diversity on the island of Curaçao. This study shows complex relations between bays and the coral reef in several ways. It can therefore be concluded that conservation of the characteristic bay biotopes is of crucial importance for the existence of the fish community on the coral reef.

Notes for further research

There were species, which were almost completely dependent on the bay. These species were rarely observed on the reef and use the bay as a life time biotope. It is interesting to investigate why these species only use the bay as a life time biotope and how these species colonise other bays.

CANOCO is used to model the influence of environmental data on fish communities. This model should be considered as a pilot study. For a stronger model, a more extended data set of environmental variables is necessary. Except fish communities, also size classes of abundant bay species can be analysed. In this model also other variables can be analysed . For example, the degree of predation (Carr & Hixon, 1995; Beets, 1997; Main, 1987; Caley, 1996; Eggleston, 1997; Connell, 1997; Hixon & Beets, 1993; Blaber, 1986) and competition (Booth, 1995; Bruggemann *et al.*, 1994) may be important. The main predator observed in Spaanse Water is the great barracuda, but also other predators such as bar jack and horse eye jack were regular observed. Some large predators (bar jack, horse-eye jack, barracudas, and mackerels) only hunt short periods in the bay and are limited to the entrance area of the bay because they come from the reef. The degree of predation may therefore decrease with increase of distance to the entrance area within the bay. Beside predation biotope complexity variables such as mean depth of a biotope, number of proproot in mangroves, coral diversity and the presence of mud can be important.

It appeared that mean length of some fish species on seagrasses near the entrance was lower than on seagrasses situated further in the bay (significant for french grunt, bluestriped grunt, yellowtail snapper and striped parrotfish, $P<0.01$). Several explanations are possible: Larger individuals in the entrance of the bay migrate to the adjacent rocks and niches. Those biotopes provide more shelter and are abundant in the entrance area and less frequent in the rest of bay. The seagrasses in the entrance have a lower complexity than seagrasses further in the bay. For smaller individuals, the complexity of seagrasses is sufficient for shelter. Larger individuals migrate to adjacent rocks and niches for shelter. This is supported by the presence of larger grunts and snappers in rocks and niches in the entrance area. Another explanation may be that recruitment of fish takes place only in the entrance area of the bay. Fish species recruit on the entrance area and migrate to other parts of the bay when they become larger. Mean length is therefore larger in parts situated far from the entrance. However, recruitment only in the entrance area is not probably because small recruits of yellowtail snapper (<2.5 cm) were observed in August at all sites in high numbers. However, for species, which recruit predominantly in shallow reef biotopes, this might be possible. A third explanation might be the presence of large predators from the reef in the entrance area of the bay. Large predators such as horse eye jack, bar jack, large barracudas and mackerels were observed on seagrasses and in the channel in the entrance area. Because of large predation pressure, only very small individuals survive in the low-complex seagrasses. The larger individuals are being predated or migrate to other biotopes. Further research can deal with those question. Tagging is necessary for identifying individuals and follow their migrations. Registration of recruitment processes is necessary to investigate whether the whole bay is used for recruitment or only specific areas.

Another interesting observations that can not be explained by this study is the partition of nursery species in species that are abundantly observed in the bay and species that are only observed in very low densities or only at the entrance area of the bay. It is hypothesized that the first group of species depends on the bay for a large extend and can not recruit and settle on the reef and the second group is able to recruit and settle in shallow biotopes on the reef and only use the bay as an extension of the reef. Further research is needed to confirm this hypothesis.

Finally, with the data collected in this study, no clear influence of Spaanse Water on densities and size of nursery species on the reef could be proven. Further research on the entire southcoast, taking into account all bays could reveal significant correlations between distance to the mouth of a bay and size and densities of nursery species. This would demonstrating the influence and importance of Spaanse Water -and possibly other bays such as Fuikbaai- for nursery species.

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