# Impact of Guyana seabob trawl fishery on marine habitats and ecosystems:

# A preliminary assessment

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# Abstract

This study aimed to make a preliminary assessment of the impact of Guyana seabob shrimp *Xiphopenaeus kroyeri* trawl fisheries on marine habitats and ecosystems, related to the fishery's efforts to comply with the certification standards of the Marine Stewardship Council (MSC). Research on the ecological impact of seabob trawling has recently been concluded in neighboring Suriname. The current study collected information on the coastal ecosystem of Guyana, to estimate whether the findings from Suriname might also apply to the Guyana fishery. A trawl survey was conducted in which 20 locations across the Guyana shelf and along a depth gradient from 6 to 34 m were sampled both in the rainy (May 2017) and dry (November 2017) season. To allow for direct comparison, the study design, sampling gear and procedures were identical to Suriname research. Environmental characteristics, and the communities of both epibenthos (benthic invertebrates) and demersal (bottom dwelling) fish showed a marked inshore-offshore depth gradient. *Coastal* assemblages of epibenthos and fish occurred at 6, 13 and 20 m depth, in relatively turbid waters over muddy seabed sediments. From 27 m onward, *offshore* assemblages were discerned, characterized by higher epibenthic species richness, clearer waters and coarser sediments. These results show that the marine environment on the Guyana shelf is very similar to Suriname, and characterized by a major shift around the 30 m isobath between a coastal and offshore ecosystem. Like in Suriname, the impact of trawling on marine habitats (MSC principle P2.4) is likely limited due to the naturally dynamic nature of the seabeds in the coastal ecosystem. While the fishery's influence on the wider ecosystem (P2.5) might be limited as well, the Guyana seabob fishery is characterized by a larger trawling fleet and trawling grounds extending into shallower areas closer to the coast. These differences do not allow for a direct extrapolation of the findings from Suriname related to P2.5. It is advised to quantify the ecosystem impact through further research. Precautionary management measures that reduce the fishing mortality of target and/or bycatch species could reduce to overall ecosystem impact of the fishery in absence of such research.

# 1. Introduction

## 1.1 Background

The trawl fishery for Atlantic seabob shrimp *Xiphopenaeus kroyeri* off Guyana is currently in a fisheries improvement program (FIP), with the final aim to comply with the Marine Stewardship Council (MSC) standard for sustainable fisheries. The MSC standard includes three main principles: sustainable fish stocks (P1), minimizing environmental impact (P2) and effective management (P3). The second principle states that "*fishing operations must be managed to maintain the structure, productivity, function and diversity of the ecosystem*" (MSC, 2016). To assess environmental impact, P2 is further subdivided in five components. Three of these deal with the impact of the fishery on non-target species, either retained species (P2.1), bycatch (P2.2) or Endangered, Threatened and Protected (ETP) species (P2.3). Further, the wider impact of the fishery on the habitat (P2.4) and the entire ecosystem (P2.5) is considered.

Interactions with non-target species (P2.1, P2.2 and P2.3) are currently being monitored by the fishing industry, in collaboration with the Guyana Fisheries Department (FD) and World Wildlife Fund Guianas (WWF), and with the support of Cefas (UK). Efforts include the analysis of 'last hauls' by the FD to assess bycatch composition, a sea-going observer program coordinated by WWF and recording of ETP species interactions by trawler captains. The aim of this study was to conduct a preliminary assessment of the impact the Guyana seabob fishery on habitat (P2.4) and ecosystem (P2.5) aspects.

## 1.2 Fisheries impact on habitats and ecosystems

In the MSC standard (v.2.0), 'habitat' is defined as *"the chemical and bio-physical environment, including biogenic structures, where fishing takes place".* 'Ecosystem' is defined as the *"broader ecosystem elements such as trophic structure and function, community composition, and biological diversity"(MSC, 2016).*

Recently (2012-2016), research on the ecological effects of seabob trawl fisheries on marine habitats and ecosystems has been conducted in neighboring Suriname, related to conditions to the MSC certification of the fishery in 2011 (Southall et al., 2011). The research concluded that impact on marine habitats (P2.4) is limited, due to the naturally dynamic, muddy seabed in the areas trawled for seabob shrimp (Willems, 2016). Communities of benthic invertebrates (epifauna) appeared to be dominated by seabob shrimp, with little other species present on seabob trawling grounds (Willems et al., 2015b). Communities of demersal fish were, however, very diverse (Willems et al., 2015a), and might be affected by the fishery through bycatch. Further, seabob shrimp was found to be an important low trophic level species in the marine foodweb, channeling energy up the food chain from

low trophic level prey and primary production to (commercially important) predatory fishes (Willems, 2016). According the MSC indicators, however, seabob shrimp did not classify as a “key low trophic level species” (Acoura Marine Ltd., 2016). In Suriname, the seabob stock seems to cope well with the current fishing pressure (based on stock assessment models). As such, it was concluded that the overall impact of seabob trawling in Suriname has a limited impact on the broader ecosystem (P2.5) as well (Acoura Marine Ltd., 2016).

The seabob fishery in Guyana is similar to the fishery in Suriname in terms of the boats and gear used, and the general operation of the fishery. The fleet is, however, is much larger compared to Suriname, and is allowed to operate in shallower waters (down to 7 fathoms, versus 10 fathoms in Suriname; D. Maison, pers. comm.). Marine habitats and ecosystems off Guyana are expected to be similar to Suriname, as the continental shelf of both countries is part of the Guianan Ecoregion of the North Brazil Shelf ecosystem (Spalding et al., 2007). However, very little biological research is currently available to verify this. Published information on the distribution of marine habitats and communities on the Guyana shelf seems limited to a few trawl surveys, dating back from the 1960ties (Lowe-McConnell, 1966; Lowe-McConnell, 1962) and 1990ties (Bianchi, 1992). Due to the differences in scale of the fishery, and the lack of information, the findings on the impact of seabob trawling on marine habitats and ecosystems off Guyana cannot simply be extended from neighboring Suriname.

This report presents the results of a trawl survey conducted on the inner Guyana shelf in 2017. Information on the distribution and abundance of demersal (bottom-dwelling) fish, epibenthos (epibenthic invertebrates), sediment and water characteristics was collected during two different campaigns, covering a depth range from 6 to 34m along four transects. The study design and sampling procedures were similar to the Suriname surveys to allow for direct comparison. The results are analyzed and discussed in the light of the findings from Suriname, leading to a first evaluation of the impact of the seabob fishery on marine habitats and ecosystems off Guyana.

# 2. Material and Methods

## 2.1 Study area

The study was conducted on the continental shelf of Guyana (ca. 57 - 60 °W, 6 - 8.5 °N), part of the Guianan Ecoregion of the North Brazil Shelf, and situated between the estuarine outflows of the Amazon an Orinoco Rivers (Spalding et al., 2007) (Fig. 1). The Guyana shelf is profoundly influenced by the turbid freshwater discharge from the Amazon River (Heileman 2008), which is carried north-west by the North Brazil Current and the Guiana Current (*e.g.* Hellweger & Gordon 2002). As a consequence, shelf waters in the region can be characterised by three major zones parallel to the coast (Lowe-McConnell 1962). The *brown* nearshore waters have a high turbidity and low salinity due to suspension of the muddy deposits and freshwater input of both the Amazon and local rivers. Between 20 and 50 km offshore, the combination of riverine nutrient input and decreased turbidity creates a productive zone with high chlorophyll concentrations, termed the *green water zone*. Offshore from this zone irradiance further increases, while nutrients become limited for primary production, causing *blue waters*. Blue waters cover most of the EEZ and receive nutrients from upwelling along the continental slope (Artigas *et al.* 2003). Sea surface temperatures are around 27-29°C throughout the year, and wind and wave patterns in the area are dominated by north-eastern trade winds (Miloslavich *et al.* 2011). Most rainfall, and peak river discharge in the Guianas occurs between December and July (Amatali 1993). From August to November, the Guiana Current weakens and the weather is drier and calmer, causing warmer sea surface waters (*e.g.* Augustinus 2004).

Guyana has a humid-tropical climate, with mean temperatures between 26 and 28°C, and annual rainfall >2000 mm (Bovolo *et al.* 2012). The climate is influenced by the Inter-Tropical Convergence Zone (ITCZ), which passes over the country twice a year, creating two major seasons. The dry season roughly lasts from August to November and the rainy season from December to July (Bovolo *et al.* 2012). The seasonality in rainfall determines the amount of freshwater discharged into the coastal waters from four major rivers. From south-east (Suriname border) to north-west (Venezuela border) these are respectively the Corantyne, Berbice, Demerara and Essequibo River.

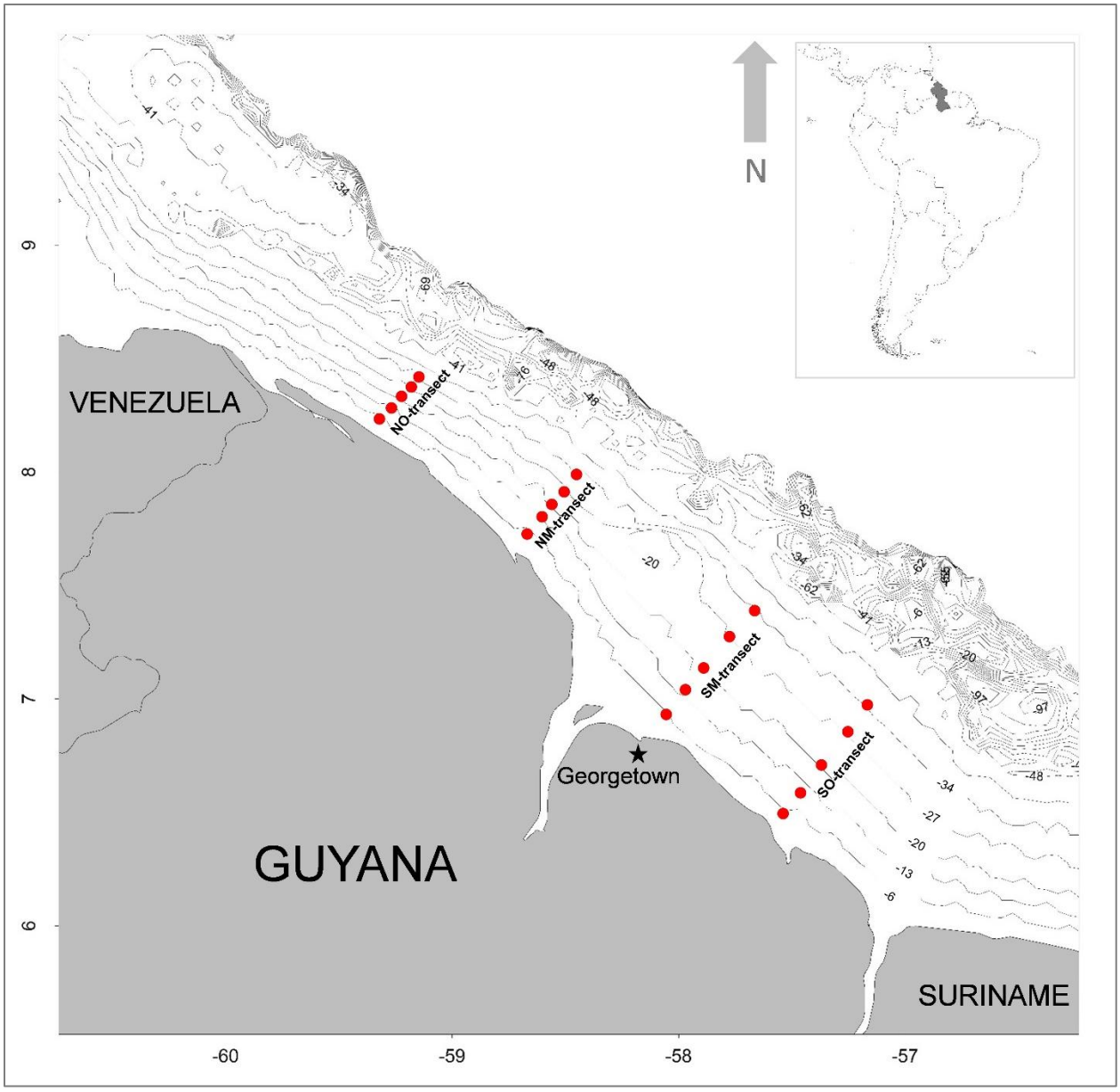



**Figure 1. Map of the inner Guyana shelf. Red dots represent the 20 sampling sites (stations), at five depths (6, 12, 20, 27 and 34m), along four transects (NO = north, NM = north-middle, SM = south-middle, SO = south). Depth contours are drawn up to 100m depth. The location of Guyana is shown on the insert.**

## 2.2 Sampling and data origin

Data originated from two trawl surveys for epibenthos and demersal fish, in May (17/5 - 22/5) and November (13/11 – 18/11) 2017. During each survey, samples were collected at 20 locations situated on 4 transects along the coast. In analogy with the research in Suriname, each transect consisted of 5 stations along an inshore-offshore depth gradient, at 6, 13, 20, 27 and 34 m depth (Fig. 1). Stations were coded by a combination of transect name (NO = north, NM = north-middle, SM = south-middle, SO = south) and depth (e.g. NM13, SO27, etc.).

Sampling was done onboard *Lady Fish* (May 2017) and *Maria A/F* (November 2017), both commercial outrigger trawlers of the Guyana seabob shrimp trawling fleet, owned respectively by Noble House Seafood Ltd. and Pritipaul Singh Investments Inc. A small otter trawl (4.3 m horizontal spread and 45 mm stretched cod-end mesh size) was used for sampling, operated from the stern of the vessel. This trawl (an oversized *trynet*) was chosen because it is known to be efficient in catching both shrimp (epibenthos) and demersal fish. To allow for direct comparison with the recent trawl surveys on the Suriname shelf (Willems *et al*., 2015a, 2015b), the trynet dimensions and rigging were exactly the same as the trawl used in Suriname. During each sampling campaign, one trawl sample was collected at each station by towing the trawl for 40 minutes in north-westward direction at a speed of approximately 2.5 knots. Sampling time, start and stop coordinates and sampling depth were noted to enable a correct conversion towards sampled surface units. One trawl sample could not be taken (SM34, May) due to technical problems. As such, a total of 39 samples (19 in May, 20 in November) were collected during the survey.

Upon retrieval of the trawl, all fishes were sorted from the catch, identified and measured to the nearest cm (total length for finfish, disc width for rays). Species identification was based on Aizawa et al. (1983), Cervigón et al. (1993) and Léopold (2005). Fish names followed Eschmeyer (2015) and higher classification was according to Nelson (2006). Epibenthos was sorted from the catch and stored on ice onboard. In the lab, organisms were identified to species or higher taxon level, counted and weighted (wet weight; 0.1 g precision). Species identification was based on, among others, Holthuis (1959), Walenkamp J.H.C. (1976), Takeda & Okutani (1983) and Cervigón et al. (1993).

Several *in-situ* environmental parameters were determined per location. Water depth was recorded from the vessels depth echo-sounder, to make sure the sample locations were at the depth as planned in the study design. Water clarity was measured with a marine *Secchi*-disk (white, 30 cm diameter). Water parameters were recorded from water collected at 5 m depth with a Niskin bottle. Sub-surface water temperature was measured onboard with a temperature/conductivity pen (EcoSense EC 30A). A subsample of 1 L was stored onboard on ice. In the lab, sub-surface water turbidity was determined with a portable turbidity meter (LaMotte 2020 we). Sub-surface total suspended matter concentration (SS-TSM) was obtained by filtering at least 500 ML seawater on pre-

washed, pre-weighted GF/F filters. Filters were subsequently dried (48h at 70 °C) and re-weighted (0.0001 g precision) to calculate SS-TSM. A Van Veen grab was used to collect sediment samples. A sediment subsample was dried in the lab (48h at 70 °C), and analyzed for grain size composition at the Geological lab of the Anton de Kom university of Suriname. This yielded percentages per sample of sand (grain size 62.5 – 2000 µm), silt (3.9 – 62.5 µm) and clay (<3.9 µm).

## 2.3 Data analyses

Variability in abiotic data was explored graphically by plotting each parameter against the factors 'depth', 'transect' and 'season'.

Prior to analysis, fish and epibenthos data were recalculated to numbers and biomass per surface unit (1000 $m^2$). This was done using the swept-area technique, which assumes that the area swept by a bottom trawl equals the length of the path times the width of the trawl. The swept area, *a*, can be estimated from

$$a = D*hr*X_2, \quad D = V*t$$

where *V* is the velocity of the trawl over the ground when trawling, *hr* is the length of the head-rope, *t* is the the time spent trawling, $X_2$ is that fraction of the head-rope length, *hr,* which is equal to the width of the path swept by the trawl (the 'wing spread'), $hr*X_2$ (Fig. 2) (Sparre & Venema, 1992).

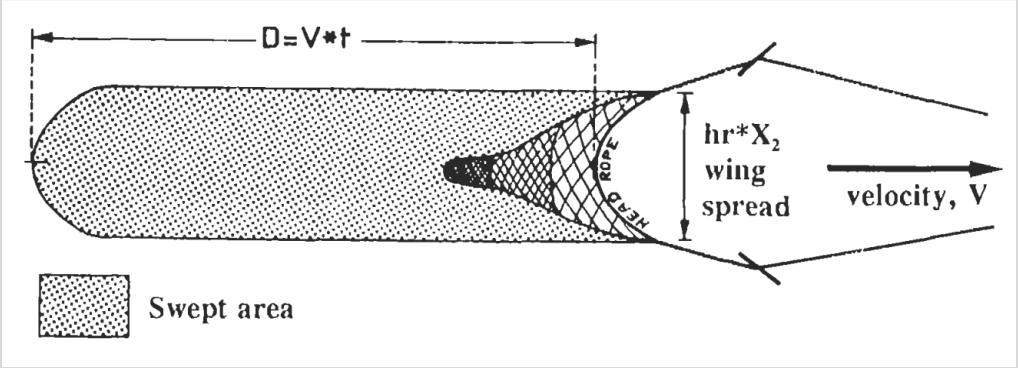



**Figure 2. Estimation of area swept by a bottom trawl (see text). Source: Sparre & Venema, 1992**

First, general characteristics of the densities, species composition and species richness of demersal fish and epibenthos were assessed. Length distributions of the most common fish species were explored graphically.

Patterns in the multivariate structure of the epibenthos and demersal fish community were explored using non-metric multi-dimensional scaling (MDS). To reveal ecological patterns in the dataset, the samples were plotted as symbols according to the following factors:

- Season: *wet* (May 2017) and *dry* (November 2017)
- Transect: *NO-, NM-, SM-* and *SO-transect*
- Depth: *6, 13, 20, 27* and *34 m*

A fourth factor 'Community Suriname' was introduced to allow for direct comparison with the epibenthos and fish assemblages distinguished in Suriname. This factor had three levels, assigning samples at 6, 13 and 20 m depth as *coastal*, 27 m as *transition* and 34 m as *offshore* (Willems *et al*., 2015a, 2015b).

Difference between sample groups obvious in the MDS-plots were tested with a one-way Analysis of Similarity (ANOSIM) for the respective factor. Finally, the species characterizing MDS sample-groups were explored using a Similarity Percentage analysis (SIMPER).

All analyses were based on standardized abundance data (individuals per 1000 $m^2$) in analogy with the work of Willems *et al*. (2015a, 2015b). For the multivariate analyses, the data were square-root transformed to reduce the influence of highly abundant species. MDS and ANOSIM analyses were based on a resemblance matrix constructed using Bray-Curtis similarity index. Data analyses were performed in PRIMER v.6.1.13 (Clarke & Gorley, 2006). A significance level of p=0.05 was used in all tests. Throughout the text, averages are always given together with their standard deviation (SD).

# 3. Results

## 3.1 Abiotic environment

Depth recorded at the sampling locations generally corresponded very well with the depths as foreseen in the study design. Sub-surface water temperature was on average 29.3 ± 0.8 °C. Secchi depth was on average 2.8 ± 2.8 m, sub-surface turbidity averaged 5.0 ± 8.0 NTU (Nephelometic Turbidy Units) and sub-surface total suspended matter (SS TSM) 46.4 ± 25.4 g/m$^3$. On average, the seabed sediment consisted of 20.6 ± 31.7 % sand, 40.8 ± 17.7 % silt and 38.6 ± 19.4 **%** clay (Table 1).

**Table 1. Summary of environmental parameters. The minimum, maximum, average and standard deviation (SD) of eight parameters are given. SS = sub-surface, TSM = Total Suspended Matter**

| | Depth (m) | Secchi depth (m) | SS water temperature (°C) | SS water turbidity (NTU) |
|---|---|---|---|---|
| **Minimum** | 6.1 | 0.4 | 28.0 | 0.1 |
| **Maximum** | 34.7 | 12.0 | 31.0 | 49.1 |
| **Average** | 19.8 | 2.8 | 29.3 | 5.0 |
| **SD** | 9.6 | 2.8 | 0.8 | 8.0 |

| | SS water TSM (g/m$^3$) | Sediment sand fraction (%) | Sediment silt fraction (%) | Sediment clay fraction (%) |
|---|---|---|---|---|
| **Minimum** | 20.1 | 0.0 | 8.5 | 1.3 |
| **Maximum** | 166.5 | 89.1 | 77.1 | 63.3 |
| **Average** | 46.4 | 20.6 | 40.8 | 38.6 |
| **SD** | 25.4 | 31.7 | 17.7 | 19.4 |

Graphic explorations revealed that most abiotic parameters were influenced by the factor ‘depth’, with little differences between transects and seasons. Water clarity (Secchi depth) increased with depth (and hence distance to the coast; Fig. 1), corresponding to decreasing values of sub-surface turbidity and total suspended matter (TSM). Seabed sediments showed a marked gradient as well. The sand fraction increased with depth and distance from shore, while the clay fraction declined. No clear depth gradients were observed in sub-surface water temperature and sediment silt fraction (Fig. 3).

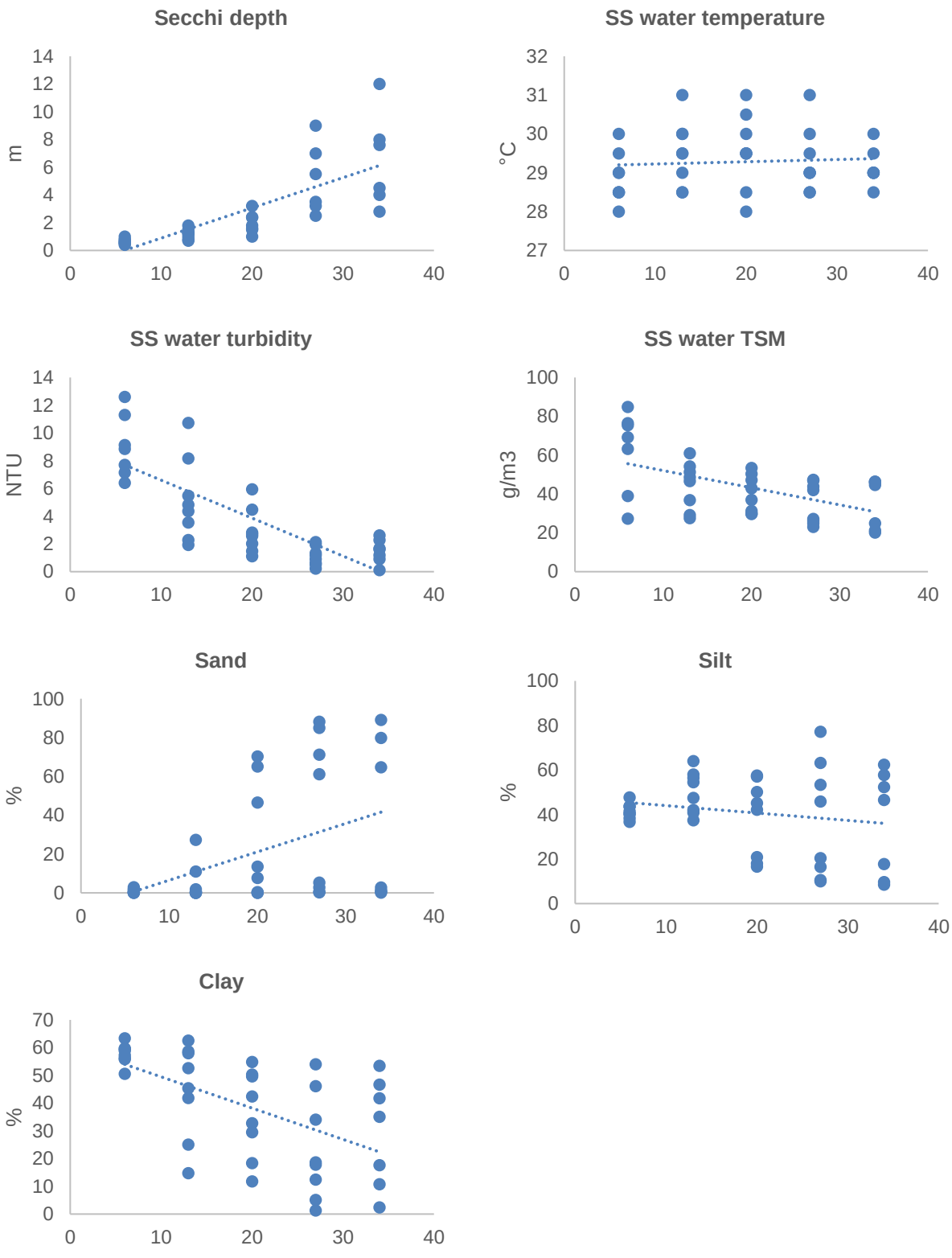



**Figure 3. Values of 7 environmental parameters, plotted against depth (x-axis, in m). SS = sub-surface, TSM = Total Suspended Matter. One outliers was removed from the plots of both turbidity and TSM.**

## 3.2 Fish community

In the 39 bottom-trawl samples, 3991 fishes were caught. In total, 72 fish taxa were identified, which are further referred to as 'species' (Table 2). Fish species belonged to 36 families in 11 orders, with Perciformes (34 species) being the dominant order. Samples contained between 2 and 23 fish species, with an average of 11.7 ± 5.1 species per sample. Total fish density at the sampling stations averaged 7.1 ± 3.1 ind.1000 $m^{-2}$, and ranged from 0.1 to 24.7 ind.1000 $m^{-2}$.

Ten species accounted for 70% of all the fishes caught in the survey. The four most abundant species made up 50% of the catches: Rake stardrum *Stellifer rastrifer,* Bigtooth corvina *Isopisthus parvipinnis,* Smalleye stardrum *Stellifer microps* and Jamaica/Tonkin weakfish *Cynoscion jamaicensis/similis*. Next to these, the species with the highest frequency of occurrence (present in >50% of the samples) also included *Macrodon ancylodon*, *Dasyatis guttata* and *Cynoscion virescens* (Table 3). The species accumulation curve (Fig. 4) shows that species diversity was covered well by our survey. Length-frequency analysis revealed that most fishes had peak length-distributions below 25cm (Fig. 5).

**Table 2. Fish taxa identified from 39 bottom-trawl samples off Guyana. n = total number of specimens caught during the survey.**

| Order | Family | Species | n | Order | Family | Species | n |
|---|---|---|---|---|---|---|---|
| **Aulopiformes** | | | | | Sciaenidae (cont.) | *Nebris microps* | 145 |
| | Synodontidae | *Synodus foetens* | 3 | | | *Paralonchurus brasiliensis* | 56 |
| | | *Trachinocephalus sp.* | 3 | | | *Stellifer microps* | 365 |
| **Batrachoidiformes** | | | | | | *Stellifer rastrifer* | 1055 |
| | Batrachoididae | *Batrachoides surinamensis* | 6 | | Serranidae | *Diplectrum sp.* | 17 |
| **Carcharhiniformes** | | | | | Trichiuridae | *Trichiurus lepturus* | 14 |
| | Triakidae | *Mustelus higmani* | 3 | **Pleuronectiformes** | | | |
| **Clupeiformes** | | | | | Achiridae | *Achirus achirus* | 16 |
| | Clupeidae | *Harengula jaguana* | 18 | | | *Apionichthys dumerili* | 7 |
| | | *Opisthonema oglinum* | 17 | | | *Trinectes sp.* | 12 |
| | Engraulidae | *Anchoa spinifer* | 43 | | Bothidae | *Bothus ocellatus* | 7 |
| | | *Anchoviella lepidentostole* | 5 | | | *Etropus crossotus* | 12 |
| | Pristigasteridae | *Odontognathus mucronatus* | 41 | | Cynoglossidae | *Symphurus plagusia* | 44 |
| | | *Pellona fharroweri* | 34 | | Paralichthyidae | *Cyclopsetta chittendeni* | 2 |
| **Perciformes** | | | | | | *Syacium papillosum* | 66 |
| | Carangidae | *Chloroscombrus chrysurus* | 6 | | | *Paralichthys sp* | 3 |
| | | *Selene brownii/setapinnis* | 28 | **Rajiformes** | | | |
| | | *Trachinotus cayennensis* | 2 | | Dasyatidae | | |
| | Centropomidae | *Centropomus ensiferus* | 18 | | | *Dasyatis geijskesi* | 10 |
| | Ephippidae | *Chaetodipterus faber* | 28 | | | *Dasyatis guttata* | 44 |
| | Echeneidae | *Echinaeis sp.* | 1 | | Gymnuridae | *Gymnura micrura* | 7 |

| | | | | | |
|---|---|---|---|---|---|
| Gerreidae | *Diapterus auratus* | 22 | **Scorpaeniformes** | | |
| | *Eucinostomus argenteus* | 67 | Dactylopteridae | *Dactylopterus volitans* | 5 |
| Haemulidae | *Conodon nobilis* | 6 | Scorpaenidae | *Scorpaena sp.* | 2 |
| | *Genyatremus luteus* | 4 | Triglidae | *Prionotus punctatus* | 60 |
| | *Haemulon boschmae* | 6 | **Siluriformes** | | |
| | *Orthopristis ruber* | 25 | Ariidae | *Amphiarius phrygiatus* | 132 |
| | *Pomadasys corvinaeformis* | 12 | | *Amphiarius rugispinis* | 60 |
| Lutjanidae | *Lutjanus synagris* | 3 | | *Aspistor quadriscutis* | 15 |
| Polynemidae | *Polydactylus oligodon* | 2 | | *Bagre bagre* | 91 |
| Rachycentridae | *Rachycentron canadum* | 2 | | *Notarius grandicassis* | 25 |
| Sciaenidae | *Bairdiella ronchus* | 26 | | *Sciades parkeri* | 3 |
| | *Ctenosciaena gracilicirrhus* | 102 | | *Sciades proops* | 1 |
| | *Cynoscion jamaicensis/similis* | 220 | Aspredinidae | *Aspredo aspredo* | 1 |
| | *Cynoscion microlepidotus* | 2 | Auchenipteridae | *Pseudauchenipterus nodosus* | 21 |
| | *Cynoscion virescens* | 93 | **Tetraodontiformes** | | |
| | *Isopisthus parvipinnis* | 406 | Diodontidae | | |
| | *Larimus breviceps* | 64 | Monacanthidae | *Stephanolepis hispidus** | 1 |
| | *Lonchurus elegans* | 69 | Ostraciidae | | |
| | *Lonchurus lanceolatus* | 23 | Tetraodontidae | *Colomesus psittacus* | 6 |
| | *Macrodon ancylodon* | 198 | | *Sphoeroides testudineus* | 7 |
| | *Menticirrhus americanus* | 57 | **Torpediniformes** | | |
| | *Micropogonias furnieri* | 13 | Narcinidae | *Narcine bancoftii* | 1 |

**Table 3. Ten most common (by occurrence) fish species caught in 39 bottom-trawl samples off Guyana. %FO = % Frequency of Occurrence; abund% = % contribution to the catches (by abundance); cum.abund% = cumulative abund%**

| species | %FO | abund% | cum.abund% |
|---|---|---|---|
| *Macrodon ancylodon* | 64.1 | 5.0 | 5.0 |
| *Stellifer microps* | 59.0 | 9.1 | 14.1 |
| *Stellifer rastrifer* | 56.4 | 26.4 | 40.5 |
| *Dasyatis guttata* | 53.8 | 1.1 | 41.6 |
| *Cynoscion virescens* | 51.3 | 2.3 | 44.0 |
| *Cynoscion jamaicensis/similis* | 48.7 | 5.5 | 49.5 |
| *Isopisthus parvipinnis* | 48.7 | 10.2 | 59.7 |
| *Bagre bagre* | 43.6 | 2.3 | 61.9 |
| *Nebris microps* | 43.6 | 3.6 | 65.6 |
| *Anchoa spinifer* | 38.5 | 1.1 | 66.6 |

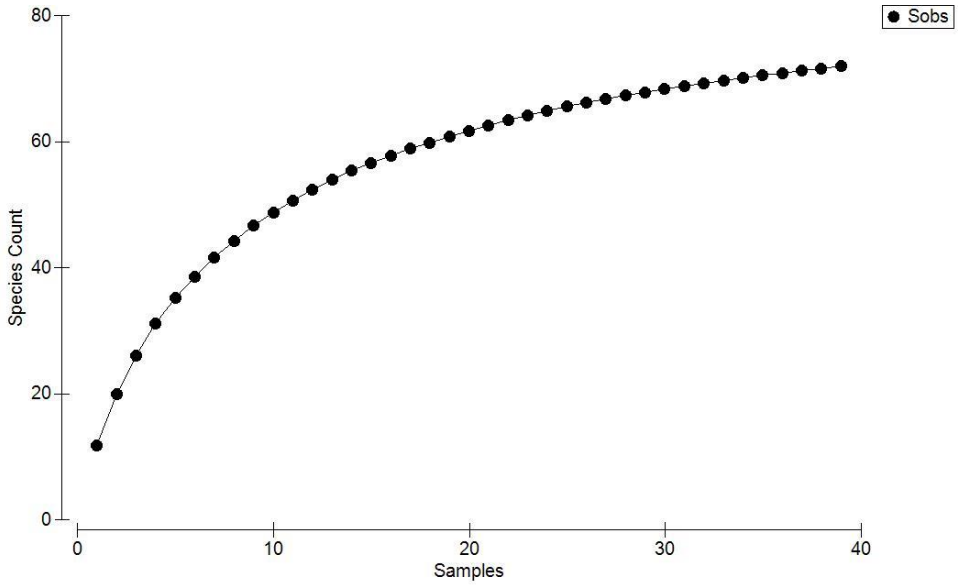
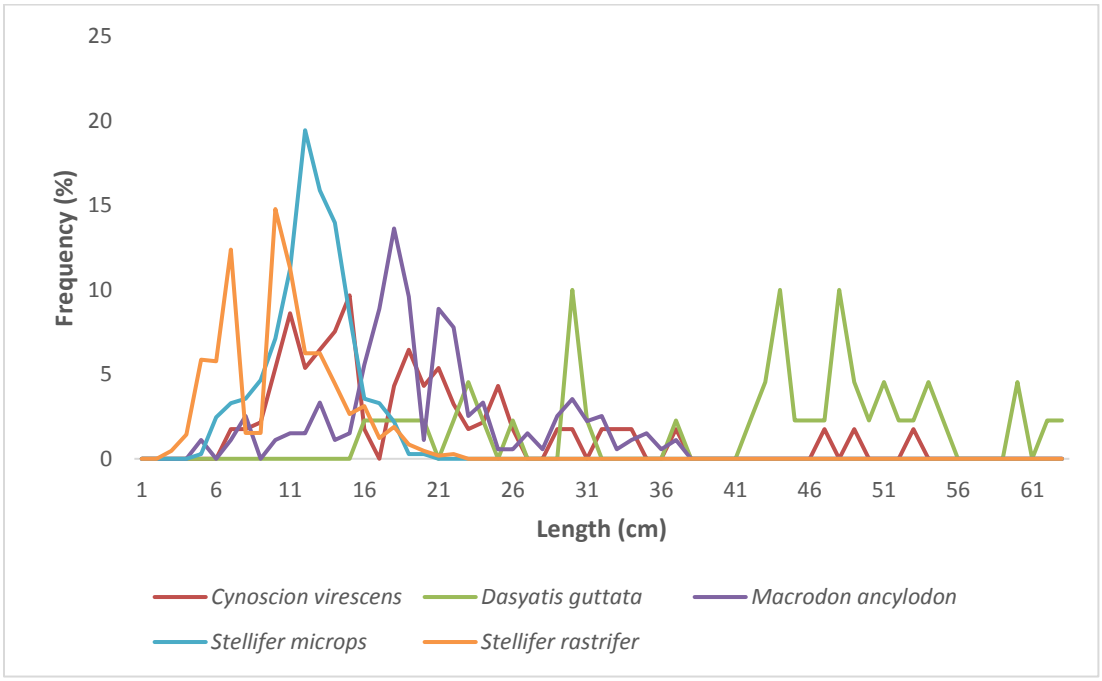



**Figure 4. Species accumulation curve for fish species caught in 39 bottom-trawl samples off Guyana.**



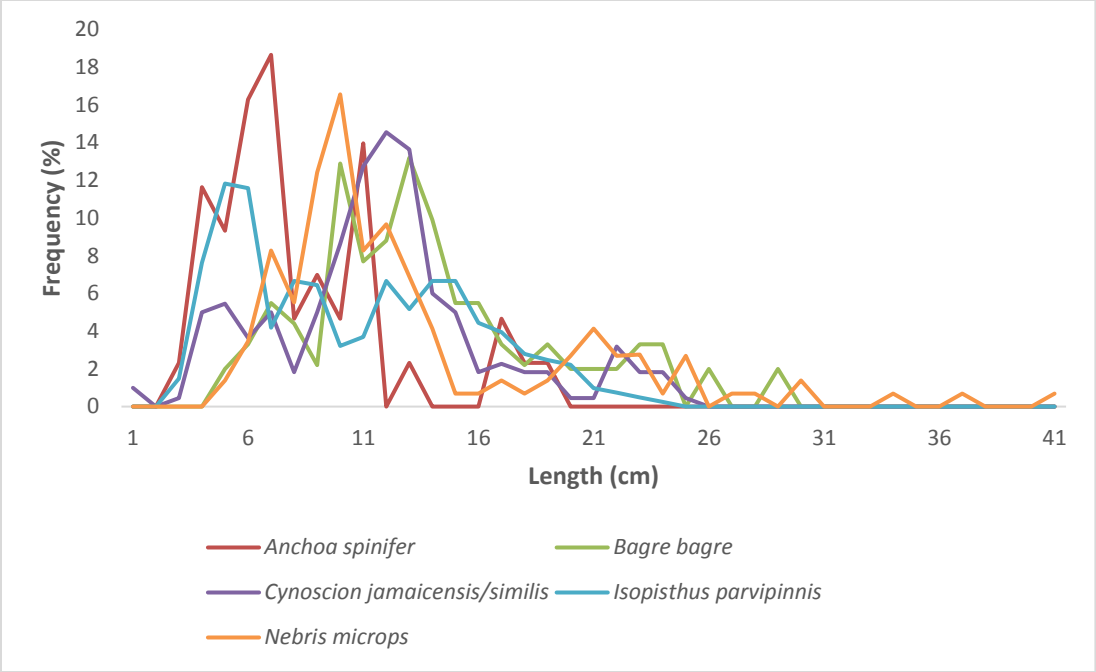



**Figure 5. Length-frequency distributions of the 10 most common fish species caught in 39 bottom-trawl samples off Guyana. Length frequencies were standardized by totals to yield a probability length-distribution (by %). Note the different axis scales in both graphs.**

MDS analyses of the samples showed that the data was structured by depth (Fig.6a). No obvious patterns in the samples could be seen for the factors 'season' or 'transect'. A one-way ANOSIM analysis for the factor 'depth' found that the fish community differed significantly among sampled depths ($R = 0.403$; $p = 0.0001$). The MDS (Fig. 6a) further showed that samples at 6, 13 and 20 m depth clustered together, and apart from those at 27 and 34 m depth, which were more scattered. This was confirmed by the pairwise ANOSIM tests, where significant differences ($p < 0.05$) were found between all depths, except between the samples at 13 and 20 m depth, and between those at 27 and 34 m depth.

When plotting the samples as symbols according to the depth-structured fish assemblages in Suriname, a 'coastal' group could be distinguished from a 'transition-offshore' group (Fig. 6b). These two groups within the fish community will be referred as *coastal assemblage* (6, 13 and 2 0m depth) and *offshore assemblage* (27 and 34 m depth), because a third (transition) assemblage could not be discerned. A SIMPER analysis identified the species characterizing each assemblage, which are shown in Table 4, together with the summarized environmental parameters.

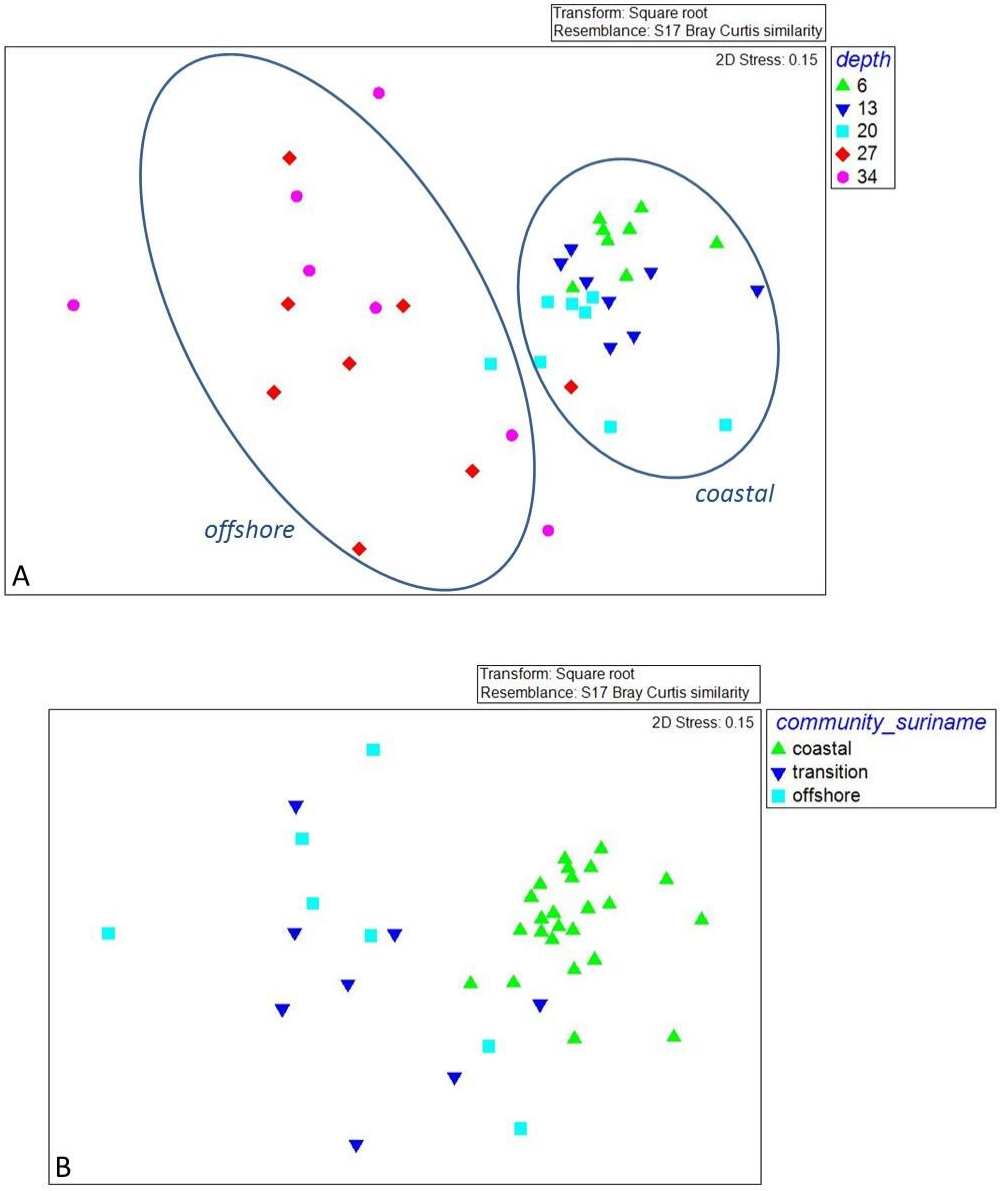



**Figure 6. Non-metric multi-dimensional scaling (MDS) plot of 39 bottom-trawl samples off Guyana, based on abundance of demersal fish species. Samples are presented by symbols according to depth (A) or the communities corresponding to these depths in the research conducted off Suriname (B) (Willems *et al*., 2015a, 2015b).**

**Table 4. Characterization of the two demersal fish species assemblages as defined by MDS and ANOSIM analyses, based on a one-way SIMPER analysis fish abundance data. Species accounting for 90% cumulative contribution to 'within group' similarity are listed along with their contribution (Contrib%). Further, average (±SD) values of environmental variables are given per assemblage. SS = sub-surface, TSM = Total Suspended Matter**

| | Coastal assemblage | | | Offshore assemblage | | |
|---|---|---|---|---|---|---|
| | **Species** | | **Contrib%** | **Species** | | **Contrib%** |
| | *Stellifer rastrifer* | | 24.7 | *Dasyatis guttata* | | 18.0 |
| | *Stellifer microps* | | 14.2 | *Cynoscion jamaicensis* | | 12.5 |
| | *Macrodon ancylodon* | | 11.5 | *Syacium papillosum* | | 10.3 |
| | *Isopisthus parvipinnis* | | 8.6 | *Diapterus auratus* | | 8.7 |
| | *Bagre bagre* | | 6.1 | *Prionotus punctatus* | | 7.2 |
| | *Cynoscion virescens* | | 6.0 | *Ctenosciaena gracilicirrhus* | | 5.3 |
| | *Nebris microps* | | 5.5 | *Symphurus plagusia* | | 4.3 |
| | *Cynoscion jamaicensis* | | 4.4 | *Selene brownii* | | 3.6 |
| | *Anchoa spinifer* | | 2.7 | *Odontognathus mucronatus* | | 2.9 |
| | *Cathorops rugispinis* | | 2.2 | *Anchoviella lepidentostole* | | 2.9 |
| | *Paralonchurus elegans* | | 2.0 | *Diplectrum sp* | | 2.3 |
| | *Chaetodipterus faber* | | 1.9 | *Menticirrhus americanus* | | 2.3 |
| | *Dasyatis guttata* | | 1.9 | *Larimus breviceps* | | 2.2 |
| | | | | *Eucinostomus argenteus* | | 1.9 |
| | | | | *Harengula jaguana* | | 1.9 |
| | | | | *Stellifer microps* | | 1.8 |
| | | | | *Micropogonias furnieri* | | 1.7 |
| | | | | *Trichiurus lepturus* | | 1.2 |
| **Secchi depth (m)** | 1.2 | ± | 0.7 | 5.8 | ± | 2.9 |
| **SS water temperature (°C)** | 29.3 | ± | 0.9 | 29.2 | ± | 0.7 |
| **SS water turbidity (NTU)** | 7.4 | ± | 9.5 | 1.3 | ± | 0.8 |
| **SS water TSM (g/m$^3$)** | 53.3 | ± | 29.3 | 35.4 | ± | 11.3 |
| **Sediment sand fraction (%)** | 10.5 | ± | 20.7 | 36.8 | ± | 39.6 |
| **Sediment silt fraction (%)** | 43.3 | ± | 12.2 | 36.8 | ± | 24.0 |
| **Sediment clay fraction (%)** | 46.2 | ± | 15.8 | 26.4 | ± | 18.8 |

## 3.3 Epibenthic community

In the 39 bottom-trawl samples, 10,748 invertebrate specimens were caught. A total of 715 jellyfish (Scyphozoa sp.) were caught, which were not further considered in the analyses because they were presumably not sampled quantitatively due to their pelagic lifestyle. From the samples, 42 epibenthic taxa, further referred to as 'species', were identified. Crustaceans were the most abundant group with 24 species, followed by mollusks (10 species), echinoderms (7 species) and cnidarians (1 species) (Table 5). Samples contained between 1 and 14 epibenthic species, with an average of 6 ± 3.6 species per sample. Total epibenthic invertebrate density at the sampling stations averaged 17.8 ± 16.1 ind.1000 $m^{-2}$, and ranged from 0.3 to 59.7 ind.1000 $m^{-2}$.

Atlantic seabob shrimp *Xiphopenaeus kroyeri* dominated the epibenthos, accounting for 63% of all specimens captured and occurring in 69% of all samples. Other common species (present in >40% of the samples) included Blue swimming crab *Callinectes ornatus*, Brown shrimp *Penaeus subtilis* and Whitebelly shrimp *Nematopalaemon schmitti*. The ten most common epibenthic species accounted for 92% of all specimens captured (Table 6). The species accumulation curve (Fig. 7) shows that the survey covered epibenthic diversity relatively well.

**Table 5. Invertebrate taxa identified from 39 bottom-trawl samples off Guyana. n = total number of specimens caught during the survey.**

| species | n | species | n |
|---|---|---|---|
| ***CRUSTACEA*** | | ***ECHINODERMATA*** | |
| **Decapoda - Penaeoidea** | | **Asteroidea** | |
| *Penaeus notialis* Pérez Farfante, 1967 | 1 | *Astropecten americanus* Verrill, 1880 | 2 |
| *Penaeus subtilis* Pérez Farfante, 1967 | 253 | *Echinaster guyanensis* A.M. Clark, 1987 | 10 |
| *Penaeus schmitti* Burkenroad, 1936 | 2 | *Luidia clathrata* Say, 1825 | 29 |
| *Parapenaeus politus* Smith, 1881 | 7 | *Luidia senegalensis* Lamarck, 1816 | 81 |
| *Sycionia* sp. H. Milne Edwards, 1830 | 50 | **Ophiuroidea** | |
| *Xiphopenaeus kroyeri* Heller, 1862 | 6298 | *Ophioderma brevispina* Say, 1825 | 506 |
| **Decapoda - Anomura** | | *Ophiolepis elegans* Lütken, 1859 | 141 |
| *Clibanarius foresti* Holthuis, 1959 | 35 | **Holothuroidea** | |
| *Dardanus fucosus* Biffar & Provenzano, 1972 | 9 | Holothuroidea sp. Blainville, 1834 | 6 |
| **Decapoda - Brachyura** | | ***MOLLUSCA*** | |
| *Achelous spinimanus* Latreille, 1819 | 4 | **Bivalvia** | |
| *Calappa nitida* Holthuis, 1958 | 4 | *Argopecten gibbus* Linnaeus, 1758 | 485 |
| *Calappa sulcata* Rathbun, 1898 | 1 | Bivalvia sp. Linnaeus, 1758 | 1 |
| *Callinectes bocourti* A. Milne-Edwards, 1879 | 1 | *Pitar arestus* Dall & Simpson, 1901 | 5 |
| *Callinectes ornatus* Ordway, 1863 | 1225 | **Cephalopoda** | |
| *Collodes inermis* A. Milne-Edwards, 1878 | 2 | *Doryteuthis sp.* Naef, 1912 | 17 |
| *Hepatus gronovii* Holthuis, 1959 | 14 | **Gastropoda** | |
| *Hepatus pudibundus* Herbst, 1785 | 4 | Cassidae sp. A.G. Beu, 1981 | 2 |
| *Lupella forceps* Fabricius, 1793 | 61 | *Distorsio clathrata* Lamarck, 1816 | 1 |

| | | | |
|---|---|---|---|
| *Paradasygyius tuberculatus* de Castro, 1949 | 35 | *Marsupina bufo* Bruguière, 1792 | 8 |
| *Persephona lichtensteinii* Leach, 1817 | 66 | Strombidae sp. Rafinesque, 1815 | 1 |
| *Portunus gibbesii* Stimpson, 1859 | 6 | *Terebra taurina* Lightfoot, 1786 | 1 |
| *Stenorhynchus seticornis* Herbst, 1788 | 7 | *Tonna galea* Linnaeus, 1758 | 2 |
| **Decapoda - Caridea** | | ***CNIDARIA*** | |
| *Exhippolysmata oplophoroides* Holthuis, 1948 | 2 | **Anthozoa** | |
| *Nematopalaemon schmitti* Holthuis, 1950 | 238 | *Renilla muelleri* Kölliker, 1872 | 403 |
| **Stomatopoda** | | ***SCYPHOZOA*** | |
| *Squilla lijdingi* Holthuis, 1959 | 7 | Scyphozoa sp. Götte, 1887 | 715 |

**Table 6. Ten most common (by occurrence) epibenthic species caught in 39 bottom-trawl samples off Guyana. %FO = % Frequency of Occurrence; abund% = % contribution to the catches (by abundance); cum.abund% = cumulative abund%**

| species | %FO | abund% | cum.abund% |
|---|---|---|---|
| *Xiphopenaeus kroyeri* | 69.2 | 62.8 | 62.8 |
| *Callinectes ornatus* | 66.7 | 12.2 | 75.0 |
| *Penaeus subtilis* | 66.7 | 2.5 | 77.5 |
| *Nematopalaemon schmitti* | 46.2 | 2.4 | 79.9 |
| *Ophiolepis elegans* | 25.6 | 1.4 | 81.3 |
| *Paradasygyius tuberculatus* | 23.1 | 0.3 | 81.6 |
| *Hepatus gronovii* | 20.5 | 0.1 | 81.8 |
| *Luidia senegalensis* | 20.5 | 0.8 | 82.6 |
| *Ophioderma brevispina* | 20.5 | 5.0 | 87.6 |
| *Renilla muelleri* | 20.5 | 4.0 | 91.6 |

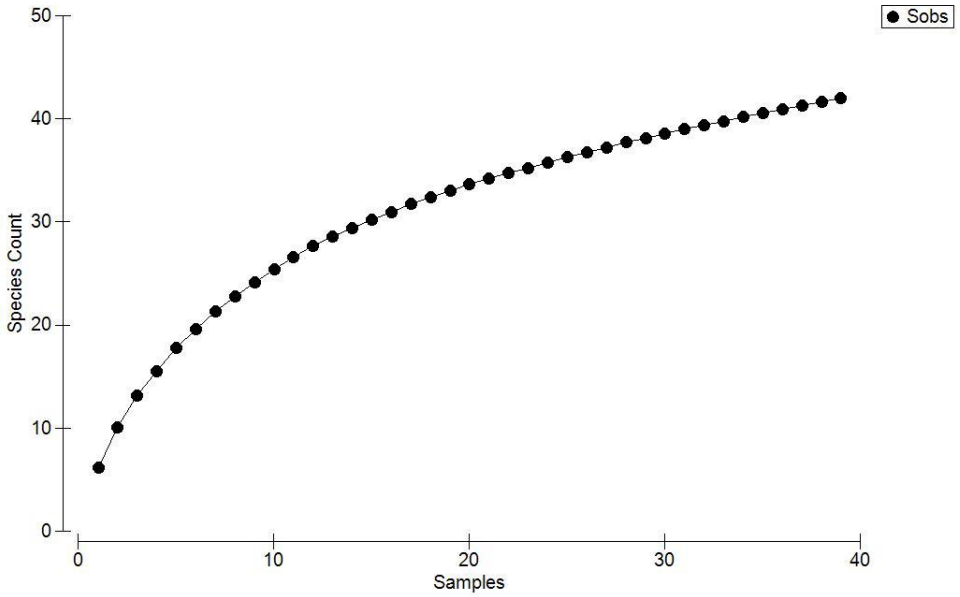



**Figure 7. Species accumulation curve for epibenthic species caught in 39 bottom-trawl samples off Guyana.**

An MDS plot of the samples revealed a clear depth structure in the samples (Fig. 8a), in a pattern similar to the demersal fish data. Again, no obvious patterns in the samples could be seen for the factors 'season' or 'transect'. An ANOSIM analysis for the factor 'depth' found that the differences among depths were less pronounced (R = 0.228) compared to the fish data (R = 0.403), but still statistically significant (p = 0.0001). The difference between a *coastal* (6, 13 and 20m depth) and *offshore* (27 and 34m depth) group was obvious here as well (Fig. 8a, 8b). These groups were confirmed by the ANOSIM pairwise tests among depths, which revealed significant differences among depths, except between 6 and 13m, 13 and 20m and between 27 and 34m. A SIMPER analysis identified the species characterizing each assemblage, which are shown in Table 7, together with the summarized environmental parameters.

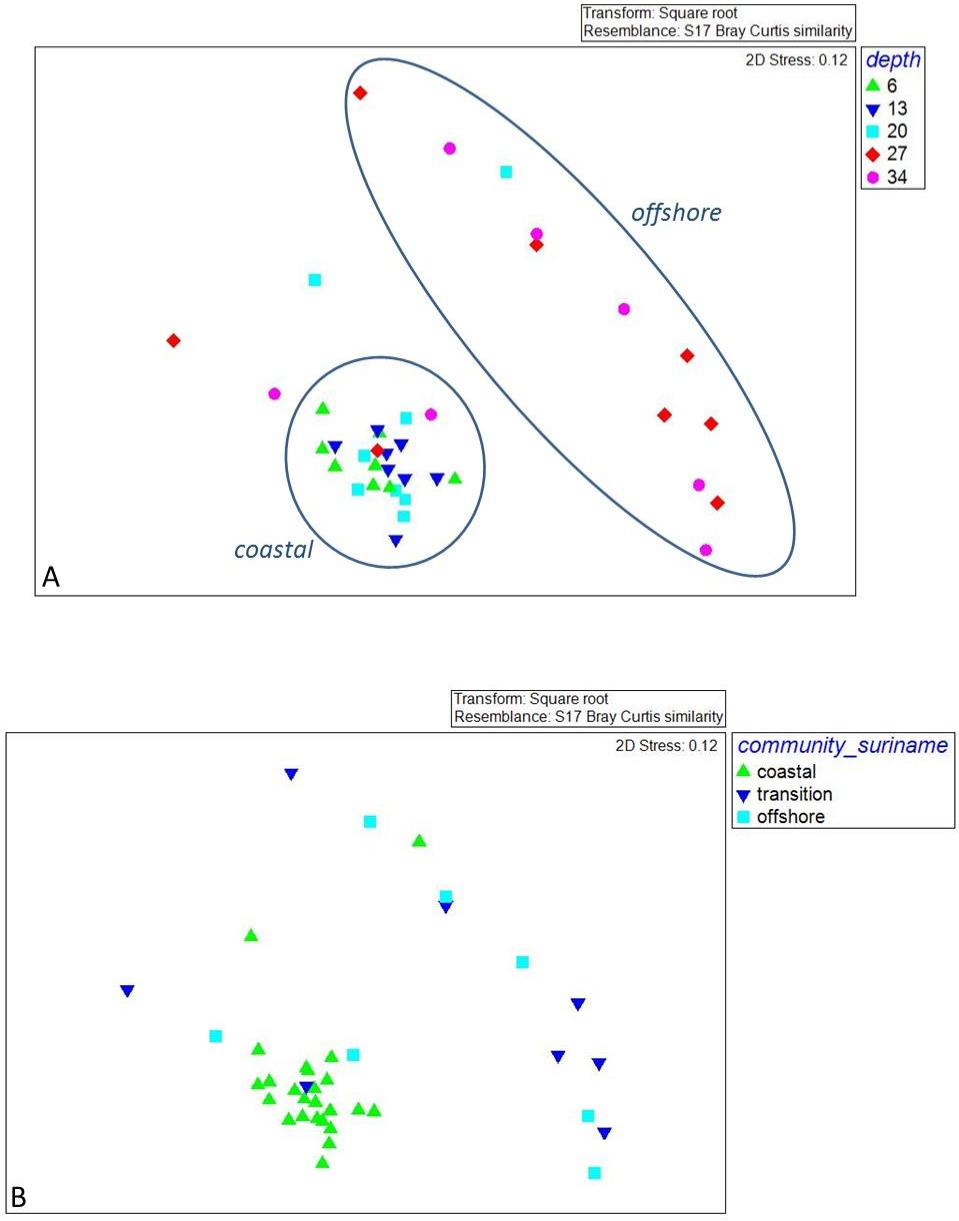



**Figure 8. Non-metric multi-dimensional scaling (MDS) plot of 39 bottom-trawl samples off Guyana, based on abundance of epibenthic species. Samples are presented by symbols according to depth (A) or the communities corresponding to these depths in the research conducted off Suriname (B) (Willems *et al*., 2015a, 2015b).**

**Table 7. Characterization of the two epibenthic species assemblages as defined by MDS and ANOSIM analyses, based on a one-way SIMPER analysis epibenthos abundance data. Species accounting for 90% cumulative contribution to 'within group' similarity are listed along with their contribution (Contrib%). Further, average (±SD) values of environmental variables are given per assemblage. SS = sub-surface, TSM = Total Suspended Matter**

| | Coastal assemblage | | | | Offshore assemblage | | | |
|---|---|---|---|---|---|---|---|---|
| | Species | | | Contrib % | Species | | | Contrib% |
| | *Xiphopenaeus kroyeri* | | | 76.8 | *Penaeus subtilis* | | | 14.5 |
| | *Callinectes ornatus* | | | 8.9 | *Callinectes ornatus* | | | 14.2 |
| | *Penaeus subtilis* | | | 6.2 | *Ophioderma brevispina* | | | 11.9 |
| | | | | | *Ophiolepis elegans* | | | 11.4 |
| | | | | | *Xiphopenaeus kroyeri* | | | 10.7 |
| | | | | | *Luidia senegalensis* | | | 8.8 |
| | | | | | *Lupella forceps* | | | 8.6 |
| | | | | | *Renilla muelleri* | | | 5.5 |
| | | | | | *Loligo sp* | | | 3.6 |
| | | | | | *Luidia clathrata* | | | 3.5 |
| **Secchi depth (m)** | 1.2 | ± | 0.7 | | 5.8 | ± | 2.9 | |
| **SS water temperature (°C)** | 29.3 | ± | 0.9 | | 29.2 | ± | 0.7 | |
| **SS water turbidity (NTU)** | 7.4 | ± | 9.5 | | 1.3 | ± | 0.8 | |
| **SS water TSM (g/m$^3$)** | 53.3 | ± | 29.3 | | 35.4 | ± | 11.3 | |
| **Sediment sand fraction (%)** | 10.5 | ± | 20.7 | | 36.8 | ± | 39.6 | |
| **Sediment silt fraction (%)** | 43.3 | ± | 12.2 | | 36.8 | ± | 24.0 | |
| **Sediment clay fraction (%)** | 46.2 | ± | 15.8 | | 26.4 | ± | 18.8 | |

# 4. Discussion

This study presents the result of a trawl survey along the Guyana coast, sampling benthic communities and abiotic parameters up to 34 m depth. The aim of this work was to get insight into the characteristics of the marine habitats and ecosystems impacted by seabob trawl fisheries. *In-situ* data collection was deemed necessary, as very little recent information was available, with trawl surveys dating back decades (e.g Lowe-McConnell, 1962). A detailed discussion of the results of the trawl survey and comparison with historical data are beyond the scope of this report. Rather, the findings are compared with similar recent work in Suriname, and the implications for the likely impact of seabob trawling on the marine habitats and ecosystems off Guyana are discussed.

## 4.1 Habitats and ecosystems compared with Suriname

The setup of the trawl survey resembled recent trawl surveys off the coast of Suriname (Willems *et al*., 2015a, 2015b) as closely as possible. The study design and sample depths were exactly the same, with one extra transect in the current survey to account of the longer coastline of Guyana compared to Suriname. Most of the sampling equipment, except some measuring devices for environmental parameters, was the same as used in the Suriname surveys. This is especially important for the trawlnet, as the use of different trawling gear can significantly affect the catches, creating bias in the comparison even when recalculating catches to sampled surface units. The main difference with the work in Suriname was the amount of replicate samples per location (2 replicates, versus 10 in Suriname). This resulted in a much smaller dataset, and less elaborate data analysis, particularly the multivariate community analysis. Despite the smaller number of samples, they were well spread across the inner Guyana shelf (Fig. 1), and collected both in the rainy (May) and dry (November) season to account for both spatial and environmental variability in the data. This allows for a valid comparison with the benthic communities and ecosystems off Suriname.

From the 39 trawl samples, 72 fish taxa and 42 epibenthic taxa were identified. This is less than the 98 and 92 species of respectively fish and epibenthos identified in Suriname. As seen in the species-accumulation curves (Fig. 4 and Fig. 7), more sampling effort would have caused a greater sampled diversity, especially for the epibenthos. Nevertheless, many species were rather rare (Table 2 and Table 5), and had therefore little influence on the data analysis. The multivariate community analysis revealed that both the epibenthic and fish communities were structured by depth, with little differences between transects and seasons. Coastal assemblages of both demersal fish and epibenthos could be discerned at 6, 13 and 20 m depth. The coastal epibenthos assemblage was very species poor (Table 7), and dominated by seabob shrimp *X. kroyeri.* The coastal fish assemblage, on the other hand (Table 4) was more diverse. The abiotic environment in these coastal assemblages was characterized by turbid waters and muddy sediments with a high clay fraction and

low sand fraction. At 27 and 34m depth, very different species assemblages occurred. These offshore assemblages were more diverse in both fish and epibenthic species, and occurred in waters with lower turbidity, over coarser sediments with a higher sand fraction.

The coastal assemblages of fish and epibenthos, and the abiotic environment where they occur, are very similar to those observed in Suriname. This could be expected based on historical surveys (e.g. Lowe-McConnell, 1962), but is now confirmed by recent data. In contrast to Suriname, no transition assemblages (at 27 m depth) were discerned, as samples at 27 m depth clustered together with those at 34 m depth. Possibly, these transition assemblages were not distinguished due to the relatively small dataset in the current study. Nonetheless, we are mostly interested in the coastal assemblages, were seabob trawling mainly takes place. These coastal assemblages were clearly distinguished from the offshore assemblages at 27 and 34 m depth, and resembled the Suriname coastal assemblages in environmental characteristics and species composition. The only major difference between the coastal assemblages in Guyana and Suriname seemed to be the densities of organisms. On average, 9.3 fishes and 21.6 epibenthic invertebrates were observed per 1000 $m^2$ in the coastal assemblages of Guyana. This is markedly lower than the values reported for Suriname, which average 12 indiv./ 1000 $m^2$ for fish 183 indiv./ 1000 $m^2$ for epibenthos (mainly *X. kroyeri*). A plausible reason for the lower densities in Guyana, especially of epibenthic invertebrates, is the higher fishing pressure exerted by a larger seabob trawling fleet.

## 4.2 Impact of seabob trawling

The shift between coastal and offshore assemblages around the 30m isobath seems to be the most important feature of the benthic ecosystem of the inner Guyana shelf, and corresponds to the community structure observed in Suriname. This shift coincides with a transition between two principal ecosystems: a coastal, river influenced system fuel by detritus, versus an open shelf system based on primary production (Bianchi, 1992). Seabob trawl fisheries, both in Suriname and Guyana mainly operate below the 30m isobath, i.e. in the coastal ecosystem. Research in Suriname concluded that the impact of of seabob trawl fisheries on marine habitats is limited, due to the naturally dynamic, muddy seabed in the areas trawled for seabob shrimp (Willems, 2016). The benthic invertebrate community in this ecosystem, both in Guyana and Suriname, is dominated by seabob shrimp, with few other species present on seabob trawling grounds. It seems therefore safe to conclude that in Guyana, like in Suriname, the impact of seabob trawling on marine habitats, defined as the 'chemical and bio-physical environment including biogenic structures, where fishing takes place' *(P2.4; MSC, 2016)* is limited.

While the assemblages of epibenthos in the coastal ecosystem are species poor, demersal fish assemblages are more diverse. This was observed in Suriname (Willems *et al*., 2015a), and

confirmed in the current study for Guyana. Fish assemblages are affected by seabob trawling through bycatch. Although bycatch aspects are considered under P2.1, 2.2 and 2.3 of the MSC standard, fishes are inherently part of the ecosystem (P2.5), which is defined by the MSC as 'the broader ecosystem elements such as trophic structure and function, community composition, and biological diversity' (MSC, 2016*).* Like in Suriname, the length frequency distributions of the most common fish species (Fig. 5), revealed that most fishes were small-sized, including juvenile stages of larger and commercially important fish species such as *N. microps* (butterfish), *M. ancylodon* (bangamary) and *C. virescens* (trout). This suggests that the coastal waters act as nurseries for these fish species, which could be disturbed by trawling activity.

In Suriname, seabob shrimp was found to be an important low trophic level species in the marine foodweb, channeling energy up the food chain from low trophic level prey and primary production to (commercially important) predatory fishes (Willems, 2016). According the MSC indicators, however, seabob shrimp did not classify as a "key low trophic level species" (Acoura Marine Ltd., 2016). Based on this fact, and because inshore waters are well-protected from trawling, it was concluded that the overall impact of seabob trawling in Suriname has a limited impact on the broader ecosystem (P2.5) as well (Acoura Marine Ltd., 2016).

The current research has shown that the ecosystem where seabob trawling takes place is very similar in Suriname and Guyana. In terms of operational characteristics and trawling gear (including bycatch reduction (BRD) and turtle excluder devices (TED)), the Guyana seabob fishery is identical to the Suriname seabob fishery. Two major aspects of the Guyana seabob fishery, however, differ from the Suriname fishery, and are likely to affect the overall impact the fishery has on the ecosystem. Firstly, the seabob trawling fleet is much larger in Guyana, creating a larger fishing mortality in both the target seabob stock as well as the populations of fish that occur in the bycatch. Secondly, while a major part of the inshore (nursery) area in Suriname is protected from trawling, seabob trawling occurs from 7 fathoms (13 m) onward in Guyana, versus 10 fathoms (18 m) in Suriname.

There is currently little or no information available to assess what implications these differences between the Suriname and Guyana seabob fishery have for the overall ecosystem impact of the fishery. Such an analysis was beyond the scope of the current report, which aimed to make a preliminary impact assessment by collecting basic ecosystem information. To evaluate to what extend the fishery is impacting the nursery function of the inshore waters, it should be assessed how much trawling effort is actually directed towards the shallow parts of the seabob trawling grounds (between 7 and 10 fathoms), and what the bycatch composition looks like in these areas. Further, effects of hypothetical management measures could be explored using quantitative ecosystem modelling (e.g. Ecopath with Ecosim mass-balance models; Pauly *et al.,* 2000).

In absence of these quantitative assessments, precautionary measures could be taken to mitigate the fisheries ecosystem impact. These include the overall reduction of fishing effort by restricting the number of licenses or total days-at-sea to reduce total fishing mortality of both target and bycatch populations. Further protection of the coastal ecosystem could be achieved by shifting the inshore trawling line to from 7 to 8, 9 or 10 fathoms. Finally, to reduce the bycatch of juvenile (commercial) fishes, the fishery could further test the effectiveness of alternative bycatch reduction devices or TED designs that exclude small fishes from the trawls.

# 5. Conclusion

The results of the trawl survey show that the coastal marine ecosystem off Guyana is very similar to Suriname. The seabob trawl fishery operates in a naturally dynamic habitat of the inner shelf below 30 m depth. No habitat structures are present in this area, and seabeds are muddy with a high clay content. Like in Suriname, it can therefore be concluded that the impact of the Guyana seabob fishery on marine habitats (P2.4) is limited.

While the ecosystem is similar, the Guyana seabob fishery differs in two main aspects from the Suriname fishery. The larger trawling fleet causes higher fishing mortality of both the target seabob shrimp and bycatch fish species. Second, trawling in shallower areas (up to 7 fathoms) might impact the likely nursery function of the inshore waters for demersal fish. These two characteristics of the Guyana seabob fishery hamper a simple extrapolation of findings from Suriname. The fisheries impact on the wider ecosystem (P2.5) could further be assessed using quantitative ecosystem research. In absence of such research, it is recommended to mitigate the ecosystem impact of the fishery through input restrictions, spatial restrictions or alternative fishing gear that reduces bycatch.

# 6. Acknowledgements

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# 8. Annexes

## 8.1 Annex 1: Pictures of trawl catches



















17/11/17
So06
16/11/17
SM06
17/11/17
So13
16/11/17
SM13
17/11/17
So20
16/11/17
SM20
17/11/17
So27
16/11/17
SM27
17/11/17
So34
16/11/17
SM34

## 8.2 Annex 3: Pictures of sediment samples









21/5/17
S008


20/5/17
SM06


21/5/17
S013


21/5/17
S020


20/5/17
SM20


21/5/17
S027


20/5/17
SM27


21/5/17
S034


14/11/17
No06


15/11/17
NM06


14/11/17
No13


15/11/17
NM13


14/11/17
No27


15/11/17
NM20


14/11/17
No27


15/11/17
NM27


14/11/17
No34


15/11/17
NM34


17/11/17
So06


16/11/17
SM06

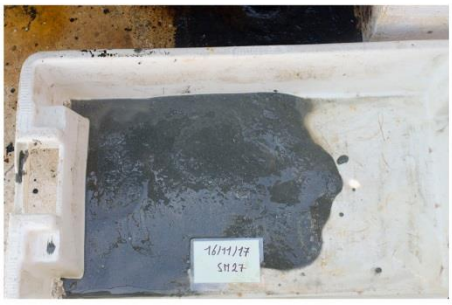

17/11/17
So13


16/11/17
SM13


17/11/17
So20


16/11/17
SM20


17/11/17
So27


16/11/17
SM27


17/11/17
So34


16/11/17
SM34

## 8.3 Annex 3: Coordinates of sampling locations

| Station | Decimal degrees North | Decimal degrees West |
|---|---|---|
| NM06 | 7.689593 | -58.5915 |
| NM13 | 7.79527 | -58.5658 |
| NM20 | 7.865011 | -58.568 |
| NM27 | 8.019486 | -58.4534 |
| NM34 | 8.098481 | -58.562 |
| NO06 | 8.28588 | -59.1865 |
| NO13 | 8.395574 | -59.1458 |
| NO20 | 8.43221 | -59.1228 |
| NO27 | 8.469533 | -59.1031 |
| NO34 | 8.484603 | -59.0807 |
| SM06 | 6.861387 | -57.9423 |
| SM13 | 6.987467 | -57.8835 |
| SM20 | 7.026729 | -57.848 |
| SM27 | 7.14624 | -57.7384 |
| SO06 | 6.471272 | -57.4993 |
| SO13 | 6.53116 | -57.3907 |
| SO20 | 6.573346 | -57.3621 |
| SO27 | 6.748587 | -57.2664 |
| SO34 | 6.957794 | -57.1235 |