Estuarine Mammal Baseline for the proposed Suriname River Dredging ESIA Update Project

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Photo 1 Guiana dolphins spy-hopping (Source: Collection Green Heritage Fund Suriname photographer: Luzmila Samson)

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List of Abbreviations

CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
EBS	N.V Energiebedrijven Suriname/ Energy Company Suriname
ESIA	Environmental and Social Impact Assessment
GHFS	Green Heritage Fund Suriname
IUCN	International Union for Conservation of Nature
LME	large marine ecosystem
MAS	Maritieme Autoriteit Suriname
MUMA	Multiple Use Management Area
NIMOS	Nationaal Instituut voor Milieu en Ontwikkeling in Suriname
SRDP	Suriname River Dredging Project
SRK	SRK Consulting
THSD	Trailing Hopper Suction Dredger
TSHD	trailing suction hopper dredges
WAMSI	Western Australian Marine Science Institution
WID	Water Injection Dredger
WWF	World Wildlife Fund

Executive summary

Introduction

Studies for the proposed Suriname River Dredging Project (SRDP) were carried out in the early 2000s. However, the SRDP was suspended and no dredging was undertaken. The Ministry of Public Works, Transport and Communication, on behalf of the Government of the Republic of Suriname, now intends to reactivate the SRDP and the *Nationaal Instituut voor Milieu en Ontwikkeling in Suriname* (NIMOS) has advised that an ESIA Update will suffice. SRK was appointed to update certain aspects of the previous ESIA, including an Estuarine mammals baseline.

Study Area

Suriname is part of the Guiana Shield which is located in northeastern South America and covers a wide area between the Atlantic Ocean and the Orinoco and Amazon rivers. Along this shield lies a large marine ecosystem (LME) stretching along the northeastern coast of South America from the border with the Caribbean Sea to the estuary of the Parnaíba in Brazil. This North Brazil Shelf Large Marine Ecosystem is under the influence of the Amazon and Orinoco, and the many other rivers that originate in the Guiana Shield basin and is area with a high productivity.

Suriname alone has eighteen species of cetaceans that are confirmed to occur in our seas, the fact that off the coast of French Guiana several humpback whales were observed, some accompanied by calves, and in Suriname a mother and calf were observed near the mouth of the Suriname River could suggest the area performs as a marine mammal corridor.

Dredging Project Area

The project area covers a 68 km stretch of the lower section of the Suriname River, which provides a shipping link for the industrial centers of Paranam and Paramaribo to the Atlantic Ocean. It islocated along the northern part of the Suriname River estuary just outside the mouth of the Suriname River north of Braamspunt (6.118411°N, -55.220970°W) to Paramaribo, south of the Wijdenbosch Bridge (5.722347°N, -55.102610°W). The Suriname river drains on average around 4,800 m3/s (756 mm/year) of freshwater into the Atlantic ocean with a mean discharge at outfall of 426 m3/s.

Estuarine areas are those places where the land and water of marshes, lagoons, pans, creeks and rivers are under the influence of freshwater and seawater. An estuary is a funnel-shaped creek or river mouth that is in open connection with the sea. In the estuary seawater mixes with freshwater from the river and the estuary is also under the influence of the tide. Estuaries are special areas in which the environment is very much subject to change.

Subdivision of the Project Area

The project area can be broadly divided up in the outer area stretching from the northern point (6.118411°N, -55.220970°W) up to where the Commewijne River flows into the Suriname River (see Figure 2). The middle area stretches from Nieuw Amsterdam up to the Wijdenbosch bridge is characterized by developed river banks on both the left and right side of the Suriname River. The upper area stretches from the south of the Wijdenbosch bridge to several kilometers past Dijkveld Bank at km 68 (see Fig. 1).

Short hydrological description

The Suriname River estuary and the lower course of the Suriname River and Commewijne are tide-dominated. The floods enter twice daily in the estuary of the Suriname and Commewijne Rivers making it a semi-diurnal regime with a tidal wave approaching Suriname from the north, from a direction almost perpendicular to the coast.

General descrption of the biodiversity

High silt contents affect the plant life that can occur in the water of the estuary, such as phytoplankton, algae but also of submerged water plants. The basis of life in the estuary should be sought not so much with the aquatic producers but with the organic material (dead plant and animal remains) originating from the rivers upstream, from the mangrove forests along the banks, from the estuary itself but also from organic waste originating from Paramaribo and surrounding communities discharged into the river. The flora in the estuarine area consists of salt tolerant plants, of which the most common species belong to the *Rizophora spp.* (mangro Sr),*Avicennia germinans* (parwa Sr)and *Laguncularia racemosa* (akira Sr).Mangrove forests fulfill many functions, such as providing food and shelter to all kinds of organisms and a nursery function for various types of sea and river fish and shrimp.

Fauna

The fauna in the estuary of the Suriname River is highly diverse. The fauna can be divided on the basis of their occupancy of the estuary,such as permanent residents and visiting animals. And also on the basis of where they occur, such as species remaining close to the sea that are not able to survive large differences in salinity, are animals that are able to survive large differences in salinity in the environment and species that have a low tolerance for salty water and they are found in the part of the estuary with a low salinity.

Cetaceans

One delphinid that can be regularly seen in the Suriname River Estuary is the *Sotalia guianensis,* Guiana dolphin (profosu Sr). The Guiana dolphin is classified by the IUCN as data deficient. In Suriname the species is protected under the 1954 game law. The population size of these animals in the Suriname River Estuary is estimated at between 80 to 100 animals. As the animals are poorly studied the main concerns based on current knowledge are that since they are coastal and estuarine species, maintenance of their coastal habitat and conservation of their prey species seem to be important issues. In addition, the degradation of this habitat would strongly affect the species, since they feed high in the food chain and contamination of their prey species would lead to bioaccumulation of pollutants in their body. In addition, other sources of anthropogenic impacts include seismic surveys in the near shore, dredge and fill, both of which displace their prey species and the dolphins themselves, effluents from coastal communities, and oil exploitation in nearshore areas.

Sirenians

Suriname is home to one Sirenian species, the Antillean manatee. Based on an IUCN status review in 2007 both subspecies of the West Indian Manatee, *Trichechus manatus latirostris* and *Trichechus m. manatus* are listed as threatened with extinction. In Suriname the species is protected under the 1954 game law. As the animals are poorly studied the main concerns based on current knowledge are that since they are coastal and estuarine species, maintenance of their coastal habitat and providing for migration corridors as well as quiet protected areas for resting and for cows with young calves seem to be important issues. The degradation and loss of habitat would strongly affect the species, as well as seismic surveys, dredge and fill, pollution from agriculture and mining. The factors that limit the population's ability to withstand these anthropogenic impacts include low fecundity, slow growth, limited dispersal, and restricted range.

Chelonians

Three sea turtle species are currently regularly seen on the nesting beaches along the coast of Suriname. These are *Dermochelys coriacea* (leatherback), *Chelonia mydas* (green sea turtle), *Lepidochelys olivacea* (olive ridley). The most regularly seen sea turtles on the beaches of Braamspunt are the leatherback and green sea turtle. Leatherbacks are listed as Critically Endangered on the IUCN's Red List and are also listed on annex 1 of CITES. Their biggest threats are the result of anthropogenic activities such as illegal harvest of their eggs, habitat loss and degradation, dredge and fill, entanglement in fishing gear, climate change and pollution. These sea turtles are especially vulnerable to ingestion of floating marine debris like discarded plastics.

The IUCN red list has classified green sea turtle populations as endangered and they are listed on the annex 1 list of the CITES. Just as other sea turtles they face many threats such as habitat loss and degradation, incidental by-catch, dredge and fill, climate change and pollution. The green sea turtles are also sought after for their meat, and their eggs are illegally harvested on the nesting beaches. Another threat are diseases such as fibropapilloma, a deadly tumorous disease. The increase in the occurrence of this disease is believed to be the result of land and marine pollution that have decreased the immune system of turtles. The nesting season for sea turtles in Suriname is from February to August.

Dredge and Fill Impacts

Impacts of dredging on marine mammals are not yet well understood, while positive and negative impacts on marine flora, benthic infauna, and the seabed are relatively well documented. Impacts of dredging on sea turtles are well documented. Two types of dredgers are proposed for the Suriname River Dredging Project, of which Water Injection Dredging is a fairly new method, the impacts of which are not yet well studied.

Impacts can be divided in direct impacts and indirect impacts for marine mammals. Direct impacts include collisions, noise levels and turbidity. Indirect impacts on marine mammals from dredging stem from changes to their physical environment, or to their prey. Indirect effects can be positive or negative, but are most likely highly species-specific, so it is unclear how effects from dredging influence various marine organisms. As the Guiana dolphin and the Antillean manatee are resident species, the impact of changes to their physical environment and for the Guiana dolphin to its prey are likely to have a greater negative impact than on a migrating marine mammal species.

Direct Impacts on Marine Mammals

For the Suriname River Dredging Project it is unlikely that collisions will occur with the Guiana dolphins or Antillean manatees as the dredgers most likely will be either stationary or moving at slow speeds, a collision with a humpback whales and their calves, however, in the outer area cannot be ruled out. Impacts related to noise levels of dredging operations are anticipated to be limited to non-lethal effects, such as masking effects or behavioral disturbance. Direct impacts of water injection dredging may generate a potential impact on water quality, the physical environment or the habitat. Effects of turbidity caused by dredging activities are often localized with minimal direct impact on marine mammals inhabiting naturally turbid and dark environments.

Indirect Impacts on Marine Mammals

Indirect effects of dredging on marine mammals are more complex and include changes to the physical environment, removal of prey species and disturbance of sediments with potential release of toxicants. In addition, nursery and spawning grounds could be severely affected by entrainment, leading to significant reductions in prey species for marine mammals and other fauna feeding on such prey species. The effect on the marine mammals could be that they have to look for new foraging grounds, or increase the time spent foraging. The effects of prey loss on the population of Guiana dolphins in the Suriname River Estuary could be severe as this is a resident population.

Disturbance of sediments can release contaminants into the environment increasing the potential uptake by marine organism. As marine mammals are on the top of the foodweb harmful contaminants could be biomagnified in these species.

On shore impacts on sea turtles

Sea turtles are impacted by dredging activities as a result of the presence of the dredge which disrupts nesting activities, and which can potentially lead to the destruction of nests and nesting habitat. The presence of the dredge itself, as well as the sound generated and lights on the dredge may deter sea turtles from approaching the beach

In water impacts on sea turtles

Entrainment is the most severe impact on sea turtles, as both adults, subadults and juveniles may be sucked up by the dredger and sustain physical harm (e.g., massive injuries, fractures, crushed tissues and hemorrhage) and mortality. In addition, indirect impacts such as alteration or destruction of foraging habitat might also occur, especially when dredged material is placed on rocky bottom habitats commonly used by sea turtles as foraging grounds. In addition, dredging may stir up toxic pollutants that have settled and become trapped by bottom sediments.

General mitigation measures

The literature suggests that additional studies to develop maps dividing the dredge area into different regions may be warranted so that risks associated with dredging during turtle breeding season, fish nursery and spawning season, humpback whale migration season and manatee breeding season can be avoided or reduced.

Mitigation measures for Marine Mammals

Mitigation measures can limit the adverse impacts from dredging, these may include environmental windows which ensure that dredging activities do not occur in important habitats or at times when marine mammals or their prey are most sensitive, for example, during breeding or spawning seasons. In case dolphins remain close to dredgers because they operate in good feeding grounds, this does not rule out that longer-term impacts will be absent.

Sea turtle mitigation measures

Common measures used to reduce the likelihood of turtle and hopper dredger interactions include: working during times of year when turtles are less likely to occur at the project location; using deflectors and specially designed dragheads; relocating turtles from the project area via net capture prior to dredging operations.

Introduction

Background

In the early 2000s the State of Suriname embarked on studies for the proposed Suriname River Dredging Project (SRDP). *Maritieme Autoriteit Suriname* (MAS) appointed SRK Consulting (SRK), a consultancy with extensive experience in Suriname, to undertake an Environmental and Social Impact Assessment (ESIA) for the SRDP. However, the SRDP was suspended and no dredging was undertaken. The Ministry of Public Works, Transport and Communication, on behalf of the Government of the Republic of Suriname, now intends to reactivate the SRDP and the *Nationaal Instituut voor Milieu en Ontwikkeling in Suriname* (NIMOS) has advised that an ESIA Update will suffice. SRK was appointed to update certain aspects of the previous ESIA, including an Estuarine mammals baseline. The aim of the dredging program is to alter the existing navigation channel and create a larger and more defined channel and anchorage area of sufficient depth to allow an increase in the operational draught of vessels – and hence increase the cargo efficiency (imports and exports) from Suriname. It is anticipated that the improved navigational environment will stimulate trade and development in a number of sectors, such as oil and tourism (Maritieme Autoriteit Suriname & SRK consulting, 2019).

Approach to the update of the Estuarine mammals baseline

An extensive review of existing literature on marine mammals and dredging was made. The study area was then divided into different sections based on available current knowledge of the estuary. The use of the dredging area by marine mammals was described based on a dataset collected over many years by the volunteers of the citizen-science dolphin monitoring and research program of the Green Heritage Fund Suriname. Potential threats and the severity of those threats were then listed.

In addition, SRK Consulting requested to update the evaluation also for sea turtles. The evaluation for sea turtles was made based on literature studies and the current knowledge of the use of the dredging area by sea turtles. As well as the threats and severity thereof of dredging to sea turtles.

Study Area

The North Brazil Shelf Large Marine Ecosystem

Suriname is located in the region known as Amazonia and is more specifically part of the Guiana Shield. The Guiana Shield is located in northeastern South America and covers a wide area between the Atlantic Ocean and the Orinoco and Amazon rivers. Brazil, Colombia, Guyana, French Guiana, Suriname and Venezuela are situated on the Guiana shield, which is one of the oldest - Proterozoic dating to 3.6 and 0.8 billion years ago - and most stable geological formations in the world. Along this shield lies a large marine ecosystem (LME) stretching along the northeastern coast of South America from the border with the Caribbean Sea to the estuary of the Parnaíba in Brazil. Large Marine Ecosystems are relatively large areas of the ocean of about 200,000 km^2 or more, adjacent to the continents in coastal waters, where primary productivity is generally higher than in open ocean areas (Ekau & Knoppers 2003).

The North Brazil Shelf LME is under the influence of the Amazon and Orinoco, and the many other rivers that originate in the Guiana Shield basin. The Amazon originating in the Andes has a length of 5,400 km and flows through Brazil to the Atlantic Ocean. The river is 200 km wide at the mouth and discharges 200,000 m^3/sec of water laden with sediment into the Atlantic Ocean. Of the more than 1 trillion tons of silt transported by this river, 20 to 40% is transported westward by the Guyana current to the coasts of French Guiana, Suriname and Guyana. The Amazon waters cause turbidity of the ocean waters up to 40 km from the coast. The North Brazil Shelf LME covers an area of 992,523 km^2, contains 0.005% of the world's tropical coral reefs and 0.06% of the world's human population (Pauly & Zeller, 2016), and is considered to be a highly productive ecosystem. The latter may account for the significant and previously unsuspected abundance of cetaceans revealed in French Guiana by aerial surveys – REMMOA I 2008 and REMMOA II 2017 (Van Canneyt et al., 2010; Observatoire PELAGIS - UMS 3462, 2017) – and in Suriname by boat-based surveys (De Boer, 2015; De Boer & Willems, 2015; De Boer, 2017; De Boer, 2018). For Suriname alone, 18 species of cetaceans are confirmed (see Annex 1), while for French Guiana at least 14 species are confirmed. During the last aerial survey off the coast of French Guiana several humpback whales were observed, some accompanied by calves, and in Suriname a mother and calf were observed near the mouth of the Suriname River; this could suggest that the area performs as a marine mammal corridor.

The Dredging Project Area

The project area covers a 68 km stretch of the lower section of the Suriname River from Domburg to the sea, which provides a shipping link for the industrial centers of Paranam and Paramaribo to the Atlantic Ocean. The estuarine portion of the dredging area that is of interest in this study is located along the northern part of the Suriname River estuary just outside the mouth of the Suriname River north of Braamspunt (6.118411°N, -55.220970°W) to Paramaribo, south of the Wijdenbosch Bridge (5.722347°N, -55.102610°W).

Figure 1: Sighting location of humpback whale with calf in April 2013 (yellow ring) (Location source: De Boer & Willems, 2015) relative to proposed Outer Bank dredging (in red) and disposal locations (in white)

The Surinamese rivers together drain on average around 4,800 m^3/s (756 mm/year) per annum of freshwater into the Atlantic Ocean with a mean discharge at outfall for the Suriname River of 426 m^3/s. As the water in the sea along the Suriname coast shows lower salinities (under the influence of the Amazon) and further exhibits properties that more closely resemble estuarine ecosystems (such as soft mud soils, relatively shallow waters and associated fauna), the transition between estuarine coastal waters and the marine ecosystem occurs at a water depth of around 30 m, about 75 km from the coast. This means that the estuary of the Suriname river almost invisibly transitions into the brackish coastal sea.

The mean tidal range at Paramaribo is 1.8 meters, with a tidal volume of $125x10^6$ m^3 (Staatsolie 2018). The Suriname River behaves as a freely meandering river in its lower reaches and comes under the influence of the tide near the mouth, thus changing the morphology of the river in such a manner that in the curves (at Paramaribo and between Leonsberg and Voorburg) the river width is considerably less than in the straighter river sections (Figure 1) and the water depth increases.

Estuaries

Estuarine areas are those places where the land and water of marshes, lagoons, pans, creeks and rivers are under the influence of freshwater and seawater. An estuary is a funnel-shaped creek or river mouth that is in open contact with the sea. In the estuary, seawater mixes with freshwater from the river and the estuary is also under the influence of the tide. Estuaries are influenced by their formation history, geomorphology of the river basin, vegetation, quantity and seasonality of precipitation and properties of the nearby sea such as depth, salinity, currents and tides. For these reasons, estuaries are unique environments subject to frequent change.

As a result of the mixing of fresh water from the rivers and salt water from the sea, brackish water is formed. This brackish water is not of a constant composition and has a salt content that is constantly changing, with seasons playing an important role. The mixing process can be affected by various factors such as wave and tidal effects and deeper currents in the estuary. These deeper currents are possible because the salt water is heavier than fresh water and therefore the deeper water often has a higher salinity than the surface water. As a result of the differences in specific gravity between waters with different salinity, circulation flows can occur. All life that occurs in these changing brackish water environments is more or less adapted to these natural fluctuations in salinity.

Another peculiarity of estuaries is that the water from the creeks and rivers flowing into the sea is rich in minerals and organic material. And because the mouths are subject to the tide, a movement takes place in the water that ensures that these minerals and organic substances remain in the estuary and that relatively little is lost to the deeper seas and oceans. The continuous supply of these nutrients ensures that in this relatively small ecosystem those plants and animals that are adapted to changing salt levels can occur in very large numbers.

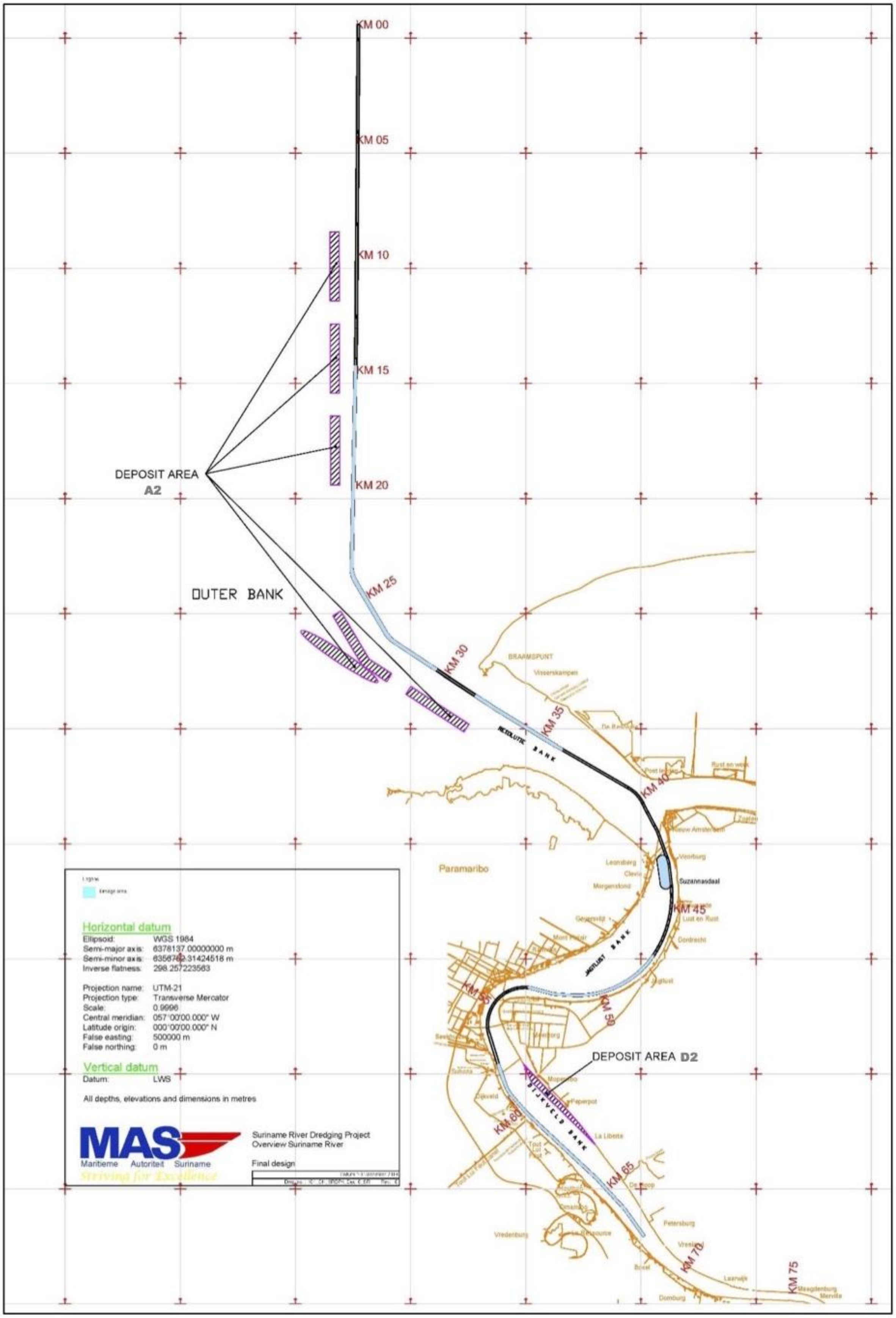

Figure 2: Proposed dredging and disposal areas. Source: (Maritieme Autoriteit Suriname & SRK consulting, 2019)

The Subdivision of the Project Area

The project area can be broadly divided into an outer , middle and upper area.

The **outer area** stretches from the northern point (6.118411°N, -55.220970°W) up to where the Commewijne River flows into the Suriname River (see Figure 3). Mixing of the waters of the two

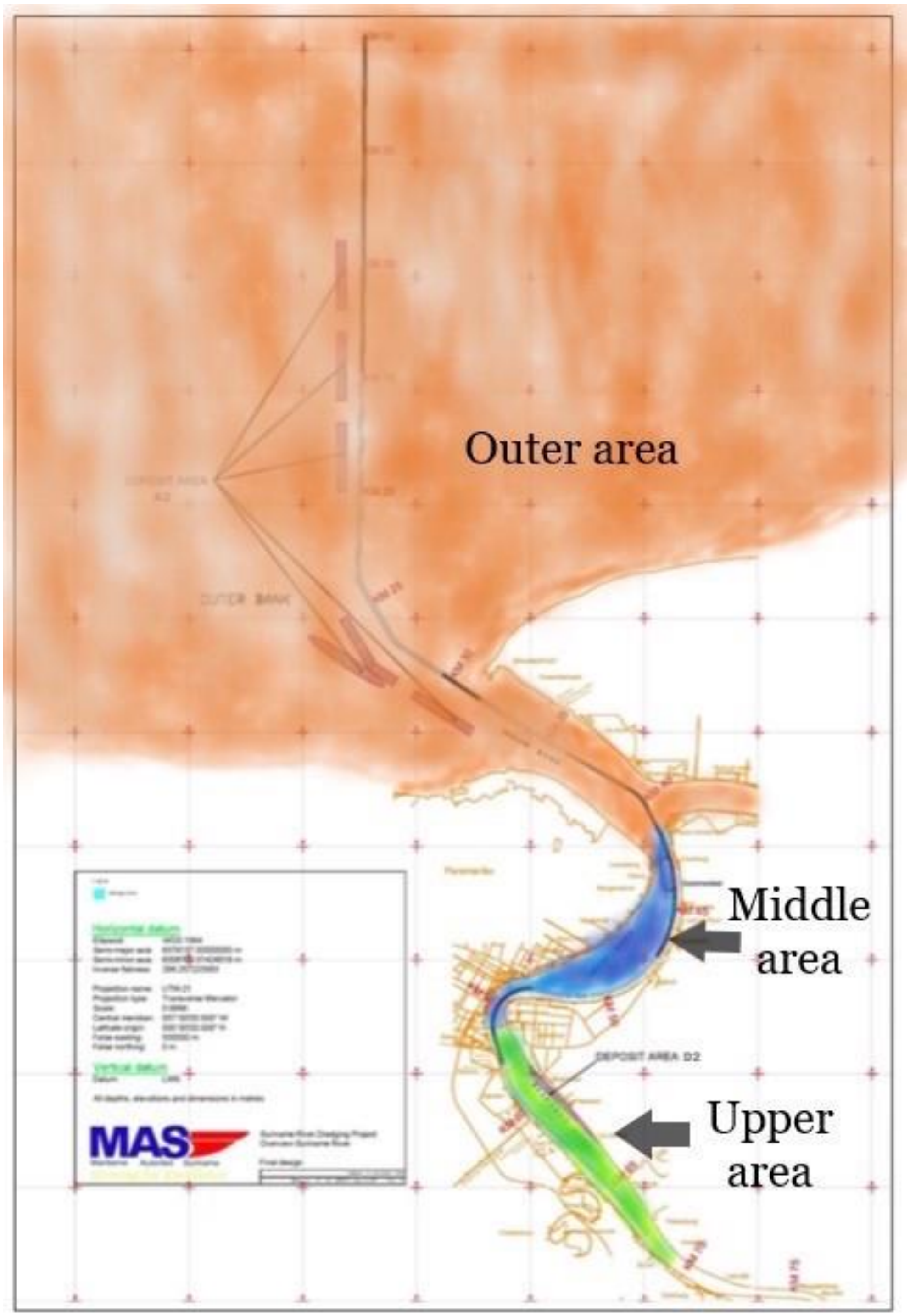

Figure 3: Subdivision of the study area, adapted from Maritieme Autoriteit Suriname & SRK Consulting, 2019

rivers occurs here and a clear separation between the two estuaries is difficult to draw. Often a clear front can be distinguished in the water where the two rivers meet, especially when the water flowing out of the Commewijne is much clearer. However, even when a clear front cannot be distinguished from the difference in the water color of the two rivers, the water surface shows wave action and turbulence at the confluence with the Commewijne River.

This outer area has little to no developed river banks or infrastructure, and retains mainly contiguous mangrove vegetation on both the left and right river banks. The right bank is part of the North Commewijne Marowijne Multiple Use Management Area (MUMA) that was established in 2002. In front of the Suriname River mouth a silt bar is present known as Outer Bank and along the right bank lies Resolutie Bank.

There is a population of 1,102 on the right bank of the Suriname River and Commewijne River in the administrative jurisdictions of Margaretha and Bakkie (Bouterse, Karwofodi, & Janki-Ramcharan, 2014). Although the left bank of the Suriname River is part of Greater Paramaribo, because of the form of the administrative jurisdictions it is not possible to estimate the population in this outer area on the left bank.

Braamspunt, a sand spit on the right bank of the mouth of the Suriname River - the westernmost point of the District of Commewijne on the coast - is part of a sandy beach system that slowly moves to the west along the coast of Suriname. Braamspunt is build up from a mix of sand and shells. The sand arrives from the sandy beaches migrating from the east. The shells found on the Surinamese coast originate from shell animals living on the bottom of the sea within the zone of the coastal waters. After the death of the shell animals, the shells are transported to the coast (Augustinus, 1971).

As a result of the shifting of the sandy beaches from east to west, nesting beaches for sea turtles also shifted west. With the disappearance of beaches to the east of Braamspunt, an increase of sea turtles nesting at the beach of Braamspunt has occurred (Pool, 2013; Samson, 2017). Around 25 fishermen camps can be found at Braamspunt, however, officially there is no permanent resident population, but mainly migrating fishermen.

The **middle area** extends from Nieuw Amsterdam up to the Wijdenbosch bridge and is characterized by developed river banks on both the left and right side of the Suriname River. Most mangrove vegetation in this middle area has been removed and a dyke was built to reinforce parts of the right bank where erosion was occurring between Nieuw Amsterdam and Jagtlust. A silt bar is present along the right bank known as Jagtlust Bank. In an attempt to accrete more land on the left bank, land owners dumped rubble and tires in the river at different locations along the left bank. Especially on the left bank many infrastructural works have been built, including at the Waterkant, the Central Market, the Energy Company (EBS) and the Port of Paramaribo. Paramaribo, the capital of Suriname, has 228,887 inhabitants, approximately 45% of the total national population, of which 90,862 live in administrative jurisdictions adjacent to the Suriname River (Blauwgrond, Rainville, Centrum and Beekhuizen). On the right bank of the Suriname River, the administrative jurisdictions of Nieuw Amsterdam and Meerzorg together account for 16,003 inhabitants (Bouterse, Karwofodi, & Janki-Ramcharan, 2014).

The **upper area** stretches from the south of the Wijdenbosch bridge to several kilometers past Dijkveld Bank at km 68 (see Fig. 1). This area is characterized on the left by a developed river bank from which most original mangrove vegetation has been removed. Along the left bank are infrastructural works, including the Molen (Flour Mill), Kuldipsingh Port Facility and the Refinery of Staatsolie at Tout Lui Faut. The Saramacca canal, along which many industries are located, on the left bank of the Suriname River discharges partially into the Suriname River only a few kilometers south of the Wijdenbosch bridge.

The right bank in the upper area is less developed and contains more mangrove vegetation. A silt bar is present here known as Dijkveld Bank. On the left bank of this area a population of 27,312 inhabitants lives in the administrative jurisdictions of Livorno, Houttuin and Domburg, and the population on the right bank overlaps with the administrative jurisdiction of Meerzorg, which accounts for 10,381 inhabitants.

Short hydrological description

According to Gersie (Gersie, Augustinus, & Van Balen, 2016) the Suriname River estuary and the lower courses of the Suriname River and Commewijne River are tide-dominated. The floods enter twice daily in the estuary of the Suriname and Commewijne Rivers making it a semi-diurnal regime with a tidal wave approaching Suriname from the north, from a direction almost perpendicular to the coast. In the Suriname River the construction of the hydropower dam at Afobaka caused a decrease in the regime of the river since 1965 so that the lower course of the Suriname River is almost entirely determined by the tides. The flood flow causes a reversal of the flow direction in the estuary twice a day, because the flood flow is stronger than the river discharge. Due to the supply of river water from upstream, the total amount of water discharged to the sea is greater than the amount transported upstream at high tide resulting in the pushing up of the river water. The seawater flows in via a shallow channel along the east side of the estuary with the rising tide and during the ebb tide the deep westerly channel functions as an ebb channel. In the narrow passage between Leonsberg and Voorburg the outflowing fresh river water and in- and outflowing salty tidal water concentrate in the outer bend.

General description of the Biodiversity

Life in the Estuary

High silt contents affect the plant life that can occur in the water of the estuary, such as phytoplankton, algae but also of submerged water plants. Because the silt content is high, the possibility of light to penetrate the water is low, so that plants that need light for photo synthesis cannot live in waters with so much silt. That is why the basis of life in the estuary should be sought not so much with the aquatic producers but with the organic material (dead plant and animal remains) originating from the rivers upstream, from the mangrove forests along the banks, from the estuary itself but also from organic waste originating from Paramaribo and surrounding communities discharged into the river.

This organic matter is digested by microorganisms ensuring that this organic material obtains a higher nutritional value. This naturally provides a qualitatively better food source for the animals that live off the detritus, the detritivores. The group of detritivores in the estuary of the Suriname river are numerous. For example, crustaceans, worms, fish and insect larvae, but also larger animals such as water bugs, crabs, swamp shrimps and the young stages of economically important fish and shrimp species. These detritivores form the basis for the next group of consumers in the food chain of the estuary.

Micro-organisms

Phytoplankton species occur in the water of the estuary but also on the mud banks. In and near the mouth, diatoms, golden algae (Chrysophyta) and fire algae (Pyrrhophyta) were found in the water. Around 16 species of diatoms were identified. Plankton species were also found on the mud banks, including *Navicula spp.* and *Nitzschia spp*. At low tide these diatoms come to the surface and provide a yellow, almost golden, tint to the mud bank. At high tide these algae go back into the upper layer of the mud bank. While on the surface they are able to photosynthesize. These diatoms play an important role in primary production and form a food source for other benthic species of the mud banks, but also for "mud" eating fish species.

Flora

The flora in the estuarine area consists of salt tolerant plants, also called halophytes. These plants are able to live in environments with a high salt content in the soil. The plants have special adaptations, for example they exclude salt intake or have developed a system to excrete excess salt.

The vegetation of the river mouth consists largely of mangrove species. Mangroves have adapted to sites with a soft, completely water saturated soil and a brackish to salty environment, with the root system as most striking adaptation. The most common species belong to the *Rizophora spp.* (mangro Sr), *Avicennia germinans* (parwa Sr) and *Laguncularia racemosa* (akira Sr). Mangrove forests fulfill many functions, such as providing food and shelter to all kinds of organisms and a nursery function for various types of sea and river fish and shrimp. Mangrove forests thus offer opportunities for commercial fishing along the river banks in the lower reaches of rivers and in estuaries. In addition to fish, shrimps and game, mangrove forests are used for firewood and charcoal, and the bark of the mangrove trees, which contains tannin, is used for tanning fishing nets for the swamp fishery (“trapun-srepi").

On the sandy beaches of the Braamspunt sand spit several pioneer plant species can be found, such as *Hibiscus tiliaceus*, beach hibiscus (maho Sr)., *Ipomoea pes-caprae,* goat’s hoof (geitenhoefblad Sr), *Canavalia rosea,* beach bean (zeeboon Sr), *Sesuvium portulacastrum,* shoreline purslane (strandpostelein Sr) and *Batis maritima,* (zeepostelein Sr), which fulfill the important function of stabilizing the sand with their root system.

Fauna

The fauna in the estuary of the Suriname River is highly diverse. The fauna can be divided on the basis of their occupancy of the estuary:

- There are permanent residents, also called the "estuarine component", of which the entire life cycle takes place in this area.
- Other animals are considered visitors, as they stay temporarily in the estuary, also called the "visiting component". These mainly consist of birds, fish, shrimps and cuttlefish that visit the estuary to look for food, to grow up or to reproduce, including some species that come from far and overwinter in Suriname.
- Other species remain close to the sea above the Continental Shelf in front of our coast, also called the "stenohaline component”, which consist of animals that are not able to survive large differences in salinity, and they are limited to the part of the estuary with a high salt content, namely that bordering the sea.
- There are also marine species that are spread over the entire estuary, "the euryhaline component”, which are animals that are able to survive large differences in salinity in the environment.
- Finally, there are species that make up the "freshwater component", which are only a few salt-tolerant species that mainly occur in freshwater and they are found in the part of the estuary with a low salinity.

Some animals can be easily observed, for example the birds and the crabs on the mud banks, the birds in the mangrove trees, but also the dolphins that often show themselves. However, a very large part of the fauna in the estuary is difficult to observe due to the turbidity of the water. The visibility is so poor that the fish and shrimp diversity cannot be seen. And animals living in the bottom of the estuary are the least visible. Typically for fauna in the estuary is that populations can consist of a large number of individuals. Especially the fish and shrimp populations can consist of very large numbers.

Fauna in the muddy bottom of the estuary

Various species live in the muddy bottom of the polyhaline part of the estuary, some of which in very high numbers:

- Molluscs in the soil near the mouth include snails (Gastropoda) and bivalves (Bivalvia). Snails are found more in the mud banks and the bivalves in the "stream channel".
- Although not in large numbers, scaphopods (tusk shells or tooth shells) also occur in the soil.
- Polychaetes (marine bristle worms) also occur in the top layer of the mud banks. The type of bristle worms found in this area makes corridors in the soil in which the animal stays permanently. Bristle worms play an important role in the food chain. They are in turn prey of many benthic fish species. Their function within the process of conversions of detritus and mineralization is also of great importance.
- Oligochaeta (aquatic and terrestrial worms) have also been found and, like the polychaeta, these marine worms can live in the upper layer of the mud and feed on detritus.
- Tanaids were also found in the estuary in a mudbank near Pomona, representing three species (*Discapseudes surinamensis, Discapseudes holthuisi, Halmyrapseudes spaansi*). These animals can occur locally in very large numbers and are a very important food source for various birds that forage on the mud banks, especially the migratory waders from North America.

Fauna on structures in the river mouth

Especially along the river banks, but also on the piles of jetties, poles of fishing nets and buoys, life has adapted to the extreme conditions that occur in the estuary in terms of the fluctuating salinity levels and periods of drought during the ebb tide. Actinaria (sea anemones), Mytiloidae (*Mytella charruana*) and Cirripedia (barnacles) inhabit the same habitat in the estuary. These animals mainly feed on detritus and food particles that they collect from the water.

Shrimps and Crabs

Many shrimp and crab species have a benthic existence. The *Xiphopenaeus kroyeri* (seabob) spends part of its life cycle in the estuary. Adult shrimps occur in the coastal seas in depths between 7 m and 20 m. In this area the females deposit the eggs. The larvae undergo the various larval stages characteristic of crustaceans and when the final stage (post larva) is reached, these young animals enter the estuary en masse. In the estuary, they stay for about three months and grow into juvenile shrimps and then move back to sea to become adults. The females reach a length of about 15 cm, the males are smaller with a length of 13.5 cm.

Different types of crabs spend their lives in the estuary. The *Goniopsis cruentata,* mangrove root crab (didibri krabu Sr), is very striking because of the colors of the shield and the legs that are deep red, while the belly is yellow. It is considered a semi-terrestrial species that spends part of its life on land and part in the water. Large numbers can be seen on the mudbanks at low tide, and they are often seen between the mangrove trees which they also climb, but they always stay at a short distance from the water. The mating of this crab takes place on land. When the eggs are mature, the female releases them in the water at night during a springtide. The larvae hatching from the eggs are taken to the sea with the ebb tide. In the coastal waters they undergo the various larval stages characteristic of crustaceans and at the end of this larval development or as very young crabs they come back into the estuary to become adults.

The *Uca spp,* fiddler crabs (odi odi botoman Sr), can be seen on the mud banks in large numbers at low tide. Fiddler crabs are, in general, known to be deposit feeders. Their mouth parts are constructed in such a way that they are able to sift out bacteria, protozoa, algae and detritus from the mud. Bacteria occur in large quantities on the mud banks and mainly break down the fallen mangrove leaves. Typically, crabs, including the fiddler crabs, are known as shredders of fallen mangrove leaves. The fiddler crabs in turn provide food for various birds, fishes, turtles and mammal species. To protect themselves against predation, the crabs hide in holes in the mud banks. The larvae of these crab species are also eaten by various pelagic and benthic animals in the coastal seas and estuaries.

Picture 2: Fish catch from the Suriname River. (Source: Collection Green Heritage Fund Suriname)

Fish

The *Anableps anableps,* a largescale four-eyed fish (kutai Sr), can be observed in large schools along the water line at the mud banks, both in the estuary and along the coast. The fact that they often occur in these locations is not coincidental, because the diatoms that occur on the mud banks are a source of food for these fish. The kutai is a viviparous estuarine fish species, of which the entire life cycle is accomplished in the brackish water area.

Although the *Bagre marinus,* the gafftopsail sea catfish (barbaman Sr), is considered a coastal marine fish, it often enters the estuaries. The males are mouth brooders. The barbaman is a predator that feeds on invertebrates, crustaceans and small fish.

The *Csiades proops*, the crucifix sea catfish (kupila Sr) has been observed in both salt, brackish and freshwater areas but is especially prevalent in shallow waters with muddy soils. Both adult and young fish are found in the estuary. The kupila is a predator that mainly feeds on shrimps and fishes.

The *Aspredo aspredo,* banjo catfish (trompetfisi Sr), is a benthic fish species that lives on the bottom. The front of the body is broad and flat, followed by a round and narrow middle part followed by a long tail. When it is disturbed the animal makes a sound with the pectoral fins, probably to deter the attacker. The trompetfisi has special brood care where the female, after spawning, wears the eggs attached to her belly. After hatching, the fish larvae remain close to her ventral side for a period, mostly likely to seek protection.

The *Batrachoides surinamensis,* pacuma toadfish (lompu Sr) is a fish regularly caught by fishermen in the estuary. The lompu has a very wide and flat head with a wide mouth giving it a toadlike resemblance. It is a predatory fish and has an extensive range of prey animals, namely molluscs, crabs, shrimps and fishes, the majority of which can be considered bottom dwellers. The lompu therefore is not actively swimming, but lingers over the substrate.

The *Anchoviella lepidentostole,* broadband anchovy, is found in the sea up to a depth of 50 m, the brackish coastal water, the estuaries up to the freshwater parts upstream of the rivers. This anchovy needs freshwater to spawn, which takes place in the rainy season. During the dry season, adult fish, juveniles and larvae migrate into the estuary where salinity is higher, and from here the fish continue their way to the sea. Anchovies feed on phytoplankton and zooplankton, small invertebrates and larvae of crustaceans and other fish species. The anchovy itself is considered an important food fish for predatory fish. This species can occur in very large numbers in the estuaries.

The *Megalops atlanticus,* tarpon (trapun Sr), has the habit of swimming up rivers. This means that this species is able to live in waters ranging from freshwater to seawater. It swims to the coast to spawn. The eggs and fish larvae are transported to the coast with the sea current. In the brackish water areas along the coast, but also in the estuaries, the larvae grow to fish of about 3 cm. They stay in the brackish water areas until they have reached a length of about 10 cm. Then they swim upstream to the freshwater part of the river. When the fish are around 40 cm long, they return to the sea where they continue to grow. The fish reaches maturity at a length of around 1 m. From the larval stage to the adult fish, the trapun is a carnivore. Very young fish eat zooplankton such as ostracoda and copepods as well as mosquito and fish larvae. Larger fish eat sardines, anchovies, mullets, pike, shrimps and crabs.

The *Myrophis punctatus, s*peckled worm-eel (snek'fisi Sr)*,* occurs in both the deep and brackish coastal seas. It can occur in different habitats, from seagrass beds, mangrove areas to coral reefs. In the mouth of the Suriname river the snek 'fisi is also found. Adults move to open sea to spawn. During the day the snek'fisi is not very active, in the evening they hunt for various crustaceans such as shrimps, crayfish and isopods.

The *Mugil curema,* white mullet (aarder Sr), is found in the mouth of the Suriname River. The adults move to open seas where the fish spawns with the female producing millions of pelagic eggs. These eggs hatch at sea and the juvenile fish move to the estuaries to grow up in the brackish water area. The aarder seeks his nutrition especially in shallow waters, often with soils rich in organic matter. Here the fish often "eats" mud and digests the plant component (phytoplankton and vegetable detritus), but also the animal component (small crustaceans, worms and molluscs).

The *Cynoscion acoupa,* acoupa weakfish (banban Sr), is found in the estuary. As an adult fish, it is mainly found in the coastal seas. Young fish are only found in brackish and freshwater. It is a predatory fish that feeds on fish and shrimps.

The *Achirus achirus*, drab sole (boki Sr), is a flatfish with a typical shape, resembling a flat oval or round disc. The boki has the habit of hiding in the soft soil, with only the eyes protruding above the surface to look out for predators but also prey. Bokis are predators and mainly feed on benthic animals, such as crustaceans and fish. They themselves are a beloved prey of rays and sharks.

The *Larimus breviceps*, shorthead drum, is a silvery grey medium-sized to small fish that can be found in brackish to marine waters up to a depth of 60 m over mud and sandy mud bottoms.

The *Trichiurius lepturus,* largehead hairtail, is an extremely elongated fish that resembles a snake and has a bright silvery color. It is found in the estuary of the Suriname River and moves over the muddy bottoms of shallow coastal waters. The hairtails are predators that eat fishes and sometimes squids and crustaceans.

Birds

Birds mainly belong to the "visiting component" of the estuary, where they mainly come to search for food, to mature or to reproduce. This group also includes species that come from very far and overwinter in Suriname.

The *Fregata magnificens*, American frigate bird, is a striking appearance in flight in the estuary, where they often can be seen circling high above the water. These birds are very active near the fishing boats where they try to catch the by-catch thrown overboard by the artisanal fishermen. They are also regularly observed trying to steal food from other fish-eating birds during flight. Frigate birds can also be observed trying to catch fish that jump out of the water while being chased by dolphins. These birds sometimes occur in large numbers in the estuary during the mating season, but the birds do not breed in Suriname. Grand Connétable, a rocky island on the French Guianese coast, is the closest breeding ground.

The *Pelecanus occidentalis*, brown pelican (kodjo Sr), is also an impressive appearance in the estuary. Although the bird is usually only seen on fishing stakes or on scaffolding, its striking appearance makes it stand out among the other usually smaller birds. The pelican has webbed toes and is therefore able to swim.

The *Ardea cocoi*, cocoi heron (kumawari Sr), is usually only observed on the dry mud banks along the banks. It is a large heron species, dark gray in color. The kumawari eats fish and insects. In the great rainy season this bird breeds together with the great egret in the old parwa forests.

The *Egretta caerulea*, little blue heron, is frequently observed on the mud banks in the estuary. Sometimes a few together, usually in the company of other birds. When grown, this species has a dark blue feather suit. Young birds are completely white. When the bird is one year old, the white feathers are swapped for blue ones and show a colorful appearance. The breeding takes place in very large groups (many thousands of pairs), together with other small herons in the young parwa. They breed in the great rainy season. The little blue heron mainly eats fish, crabs, shrimps and insects.

The *Egretta thula*, snowy egret (sabaku Sr), is regularly observed on the mud banks. The bird also stands out because of its black beak, dark legs and yellow feet. During the breeding season the adult birds adorn themselves with beautiful ornamental feathers on the head, chest and back. It is these ornamental feathers that make it easy to distinguish the little egret from the young blue heron. This species also breeds in large colonies of thousands of pairs, together with other small herons in the young parwa during the long rainy season. In the evening the small heron species have common sleeping places along the coast in both old and young parwa. The sabaku mainly feeds on fish.

The *Eudocimus rubur*, scarlet ibis (korikori Sr), is very frequently observed in the mouth, flying in small to larger groups, sitting in the mangrove trees or looking for food on the mud banks. The bird stands out immediately because of the beautiful bright red plumage. The breeding season coincides with the long rainy season. The breeding grounds are in the young parwa along with other heron species. This bird also shares its roost with different heron species, although it is not a heron species. The food is formed by fish, crabs, shrimps and insects.

The *Pandian haliaetus*, western osprey (fisi-aka Sr.), is regularly observed in the estuary. Originally it is not a bird from Suriname or the region, but originates from North America. They occur in the largest numbers from September to March, the period that birds from the far north migrate south to winter. The bird eats larger fish species. When a prey has been observed, the bird stays in a spot in the air, vigorously hitting its wings and then dives down to grab the fish from the water with its claws. Sometimes the bird goes completely under water for a moment.

The *Buteogallus aequinoctialis*, rufous crab-hawk (krabu aka Sr.), is also a common inhabitant of the estuary and is mainly seen in the mangrove trees. The breeding season coincides with the long rainy season and the nest is built high up in old parwa trees. There is only one egg and the chick stays in the nest for a relatively long time. The krabu aka only eats crabs belonging to different species, such as the *Callinectis bocourti*, brown crab (srika Sr), *Ucides cordatus,* blue crab (woyokrabu), and mangrove root crab.

The *Anas bahamensis*, white-cheeked pintail (anaki Sr), is seen in small numbers on the mud banks along the banks. The preference of these birds for certain areas is related to the food supply, including the seeds of the *Ruppia maritima*, beaked tasselweed (sewar Sr), but also *Batis maritima* and *Sesuvium portalucastum*. In addition to plant-based foods, water bugs and copepods are also on the anaki's menu. The breeding ground is on the ground between low vegetation. The breeding season starts in the long rainy season and can last until the beginning of the long dry season.

The *Calidris alba*, sanderling (snepi Sr), is a cosmopolitan species. These birds breed in the far north and after the breeding season when winter begins, move south to areas where they find food. Like other wading birds, they come to Suriname to winter. Although they are seen throughout the year, they are most numerous between September and December. This species is found on the beach at Braamspunt along the waterline looking for food. Because this wading bird has no webbed toes, he cannot move on soft mud banks.

The *Larus atricilla*, American laughing gull (Sedoifi Sr), is regularly observed in the estuary and is mainly active near fishermen. Although not numerous, this bird is observed throughout the year. This bird does not breed in Suriname, the closest breeding places are the islands off the coast of French Guiana, however, birds are observed in breeding plumage in the estuary. Their diet consists of fish and shellfish that they catch themselves or pick up from fishermen.

The *Sterna maxima*, royal tern (fisiman Sr), is regularly observed in the estuary. They also appear scattered along the coast where it looks for resting places at the end of beach plains or dried up lagoons. The fisiman breeds in both North and South America. The closest breeding grounds are the islands of Grand Connétable and Battunes de Malmanoury off the coast of French Guiana. The royal tern mainly finds his food at sea and is a real fish eater.

Cetaceans

Picture 3: Guiana dolphin feeding. (Source: Collection Green Heritage Fund Suriname photographer: Willem Meijlink)

Suriname is home to 18 different cetacean species. Of these, six are baleen whales and twelve are toothed whales, the largest of which is the sperm whale (De Boer, 2015, de Boer & Willems, 2015, De Boer, 2017, Marijke de Boer, 2018). Most of them occur only in the clear waters of Suriname's offshore marine area. Opportunistic reports have shown that some of the larger baleen whales can occur quite close to the coast of Suriname, not far from the mouth of the Suriname River (de Boer & Willems, 2015). There is one exception, a delphinid that can be regularly seen in the Suriname River Estuary: the *Sotalia guianensis,* Guiana dolphin (profosu Sr).

Guiana dolphin Life History

The Guiana dolphin (*Sotalia guianensis*) is a dolphin in the clade of the Cetartiodactyla and the order of the Cetacea, as well as a member of the family of real dolphins delphinidae. The genus Sotalia recognizes currently two species, of which the *Sotalia guianensis* is the marine species and *Sotalia fluviatilis* the riverine species. The common name used for this species by the majority of scientists in South America is Guiana dolphin, however, other common names like costero, boto-cinza, tucuxi are still used by some, and can be found in the literature. It is a species endemic to the east coast of South America, with a range from Florianopolis in Brazil to Nicaragua in Central America.

The Guiana dolphin is a small coastal dolphin frequently described as looking similar to the bottlenose dolphin. However, the Guiana dolphin is typically smaller than the bottlenose, reaching a maximum length of 2.1 m and weighing an average of 80 kg. The Guiana dolphin is light to dark grey in color on its dorsal surface, which runs from its rostrum to the anus. Along its ventral surface, from the point of its beak to the anus across the lateral sides, it can be either pink (in a young dolphin) or white-yellow (in a fully-grown dolphin). Most dolphins have a lighter grey coloration between the anus on the lateral sides, the peduncle and the base of the fluke, which is sometimes even a bit pinkish.

The Guiana dolphins' lifespan is around 30 years. The males become sexually mature at around 7 years of age and the females between 5-8 years of age. They do not mate for life; both males and females are free to mate with different partners consistently. Based on their anatomy they are thought to have sperm competition, as the testis of the males make up 3% of their body weight. The gestation period is 12 months and each female gives birth to one young every two to three years. The baby dolphin measures at around 90 cm at birth and is nursed by the mother for around 8 months. The babies then stay with the mother for around 2 years, during which they learn what to feed on, how to hunt, and how to navigate their environment. The young animal learns these skills not only from its mother, but also from its siblings. A family group can consist of 6-8 individuals.

According to Pansard (Pansard, Gurgel, Andrade, & Yamamoto, 2011), in the Brazilian State of Rio Grande do Norte the Guiana dolphins are known to forage on 18 different bonefish species, primarily Haemulidae and Sciaenidae, and five cephalopod species. The *Larimus breviceps,* shorthead drum, was found to be the main prey species of the Guiana dolphin along the coast of Rio Grande do Norte. Interestingly, Pansard found there was a gender bias in preferred prey between the dolphins, with the *Haemulon plumieri*, white grunt, the preferred species of the males, and the *Trichiurius lepturus,* largehead hairtail, the preferred species of the females.

Their coastal presence is explained partially as they mainly seem to forage on small preys occurring mainly in coastal areas and estuaries. They seem to forage primarily near the water surface where their prey can be seen jumping out of the water. As described by Santos, the Guiana dolphins are often seen feeding in association with seabirds, something also often seen in the Suriname River Estuary.

Population Size

Currently, the size of the population of Guiana dolphins in the Suriname River estuary is estimated to be between 80-100 based on photo identification. Of these, 67 are identified using dorsal fin identification (see Figure 4) and mark and recapture methodology. Some of the animals are known since the start of the dolphin program's citizen science research and monitoring activities in 2007.

The population size appears to be stable, no strandings were reported since 2013, and calves are seen year around.

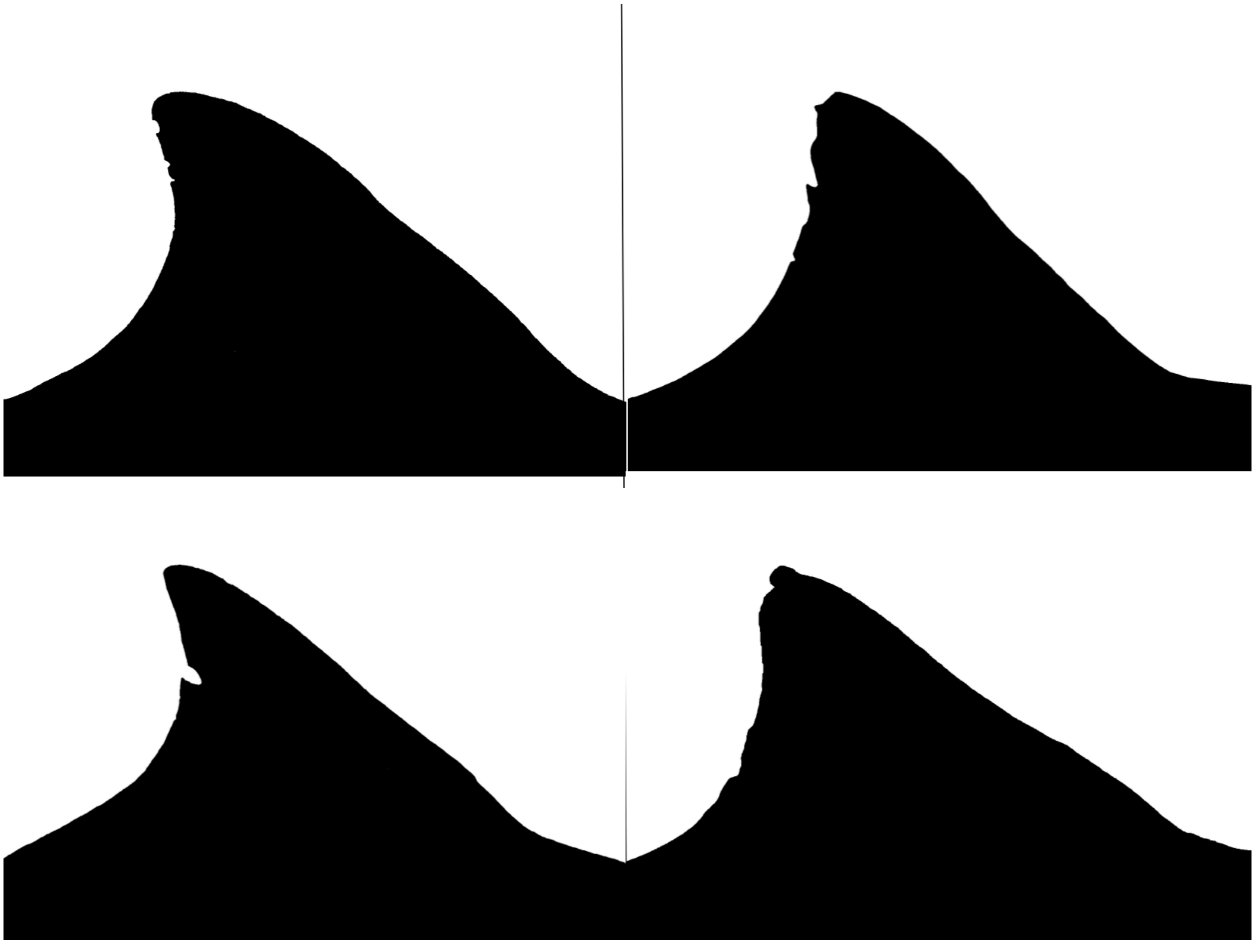

Figure 4: Four individuals recognizable by the fin form and nicks and notches at the fin edges (Source: Tsang, 2019)

Occurrence in the Suriname River

An analysis was performed by Lieuw (Lieuw, 2015) of data from the Green Heritage Fund Suriname collected during 272 boat surveys involving 1,088 hours of effort and 6,528 km over an area of 30 km^2 in the period of Jan 2008 – October 2014, during which 499 non sightings and 522 dolphin sightings were recorded. Average dolphin density reached 17.4 sightings/km^2, with an average of 2.26 sightings/survey and 40 surveys (14.7% of total surveys) with zero sightings over the whole period. To determine spatial preferences of the *S. guianensis* in the estuary, a kernel density map was produced with the complete dataset from the Green Heritage Fund from Jan 2008 – December 2013.

The specific behavior displayed and separate maps detailing the use of the estuary were not part of Lieuw's study.

For the purpose of this study conducted as part of the SRDP ESIA update, the dataset was organized in such a manner that only records that clearly detailed specific behaviors were selected, yielding 363 records out of 551. The dataset was also supplemented with sightings from the period from 2014 to 2016. Maps were produced showing the use of the estuary according to significant different behavioral categories, such as feeding, leaping, mating, resting, spy-hopping, swimming and travelling. The use of the estuary by these animals for important biological functions, such as feeding, mating and resting is of particular interest.

The dolphins in the Suriname River estuary are using the whole estuary in the outer area for different behaviors, and the data of the GHFS dolphin program shows that they are often seen near the left bank in the outer area over Resolutie Bank. However, this may also be as a result of the fact that the volunteers of the GHFS dolphin program had one fixed measuring point at 5.895150°N and -55.119850°W where there used to be an old meteorological measuring station. It is also noteworthy that the data of the GHFS dolphin program is mainly collected between Leonsberg and Braamspunt, which is only a part of the distribution of the Guiana dolphins in the Suriname River estuary. Only few surveys have been done in the middle or upper area, or the Commewijne River.

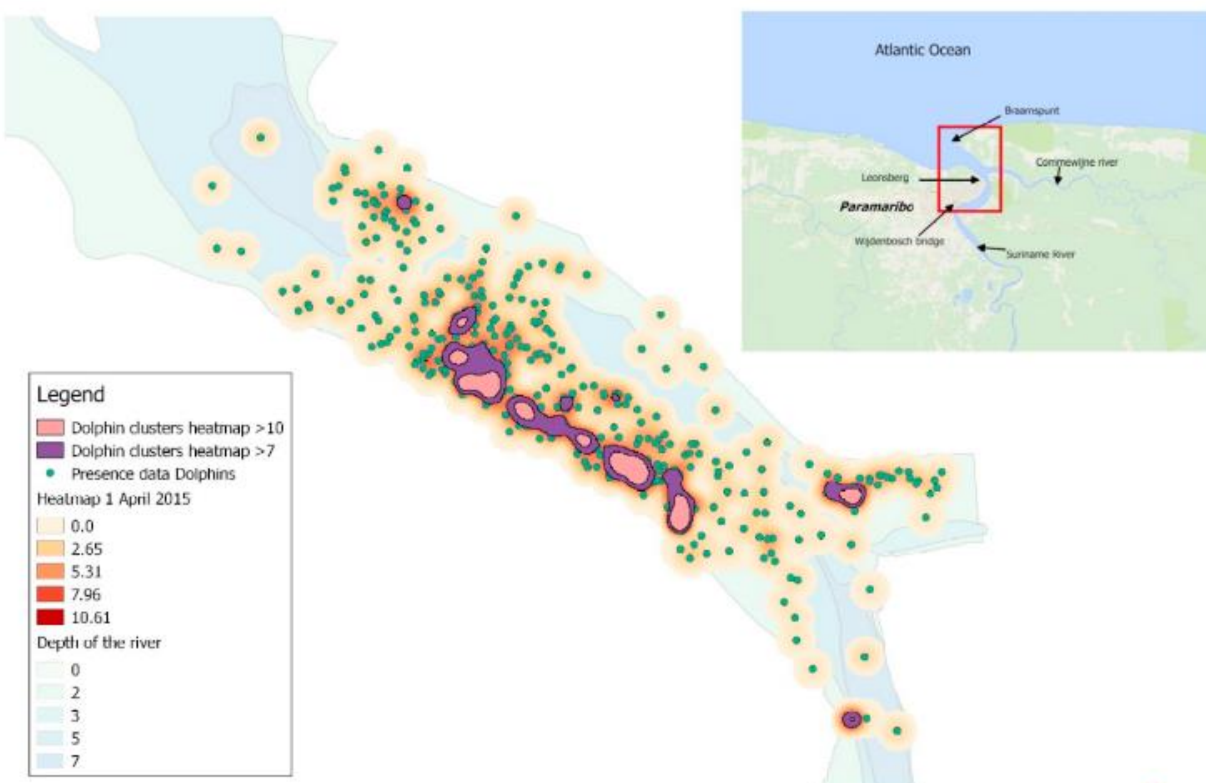

Figure 5: Kernel density map of Guiana dolphin presence (Source: Lieuw, 2015)

The dolphins do not seem to interact with the shipping traffic currently entering and leaving the estuary. However, a study to see how their behavior is influenced by the different vessels, from tourism boats to large ships, will provide more evidence on how these Guiana dolphins interact and react to the different vessels.

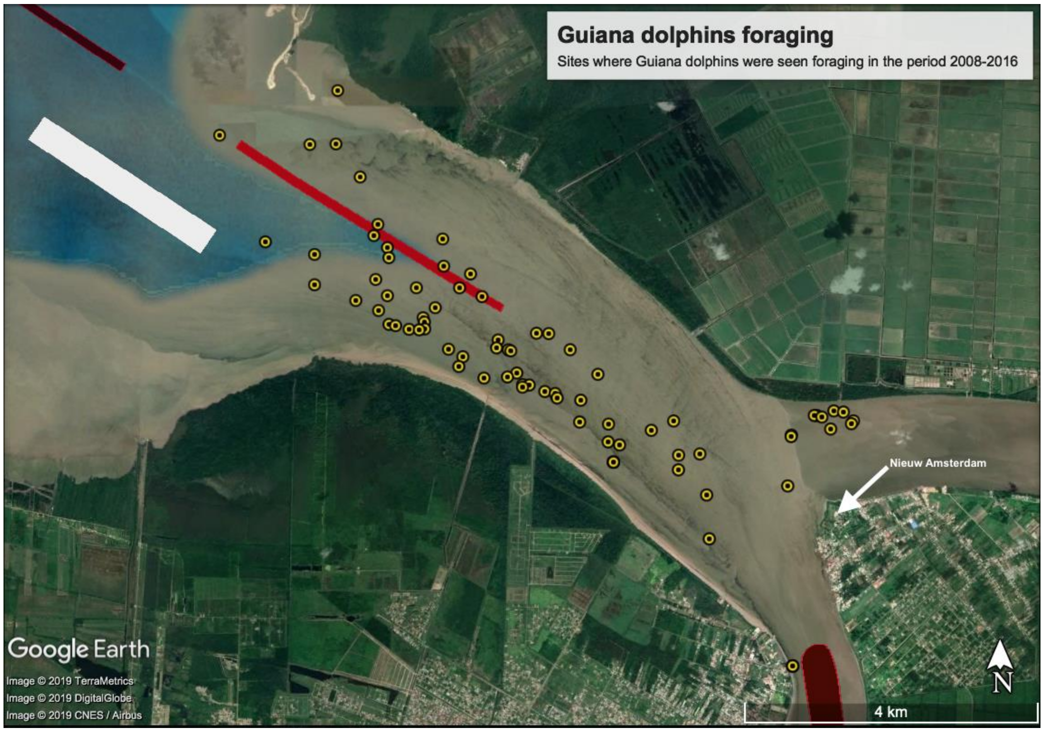

Figure 6: Guiana dolphins are seen foraging in different locations in the estuary, where they sometimes can be seen throwing their prey in the air. Dredge areas are indicated in red and deposit areas are in white.

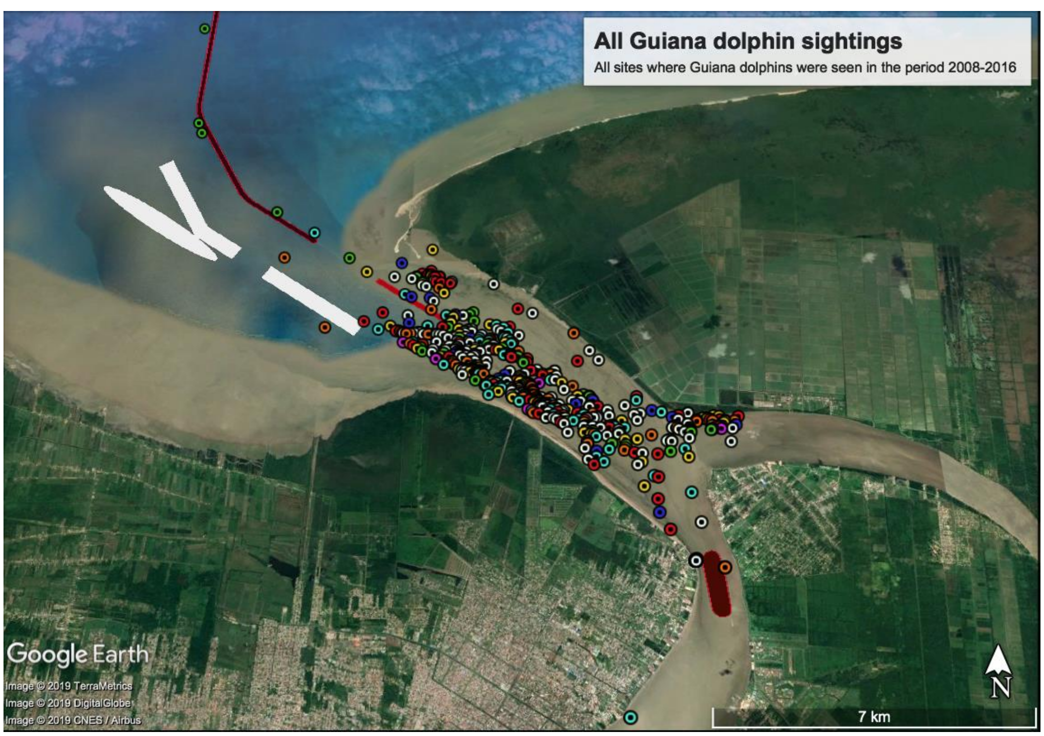

Figure 7: All sightings included in the dataset and subdivided by behavioral category for the period 2008-2016. Dredge areas indicated in red, deposit areas in white.

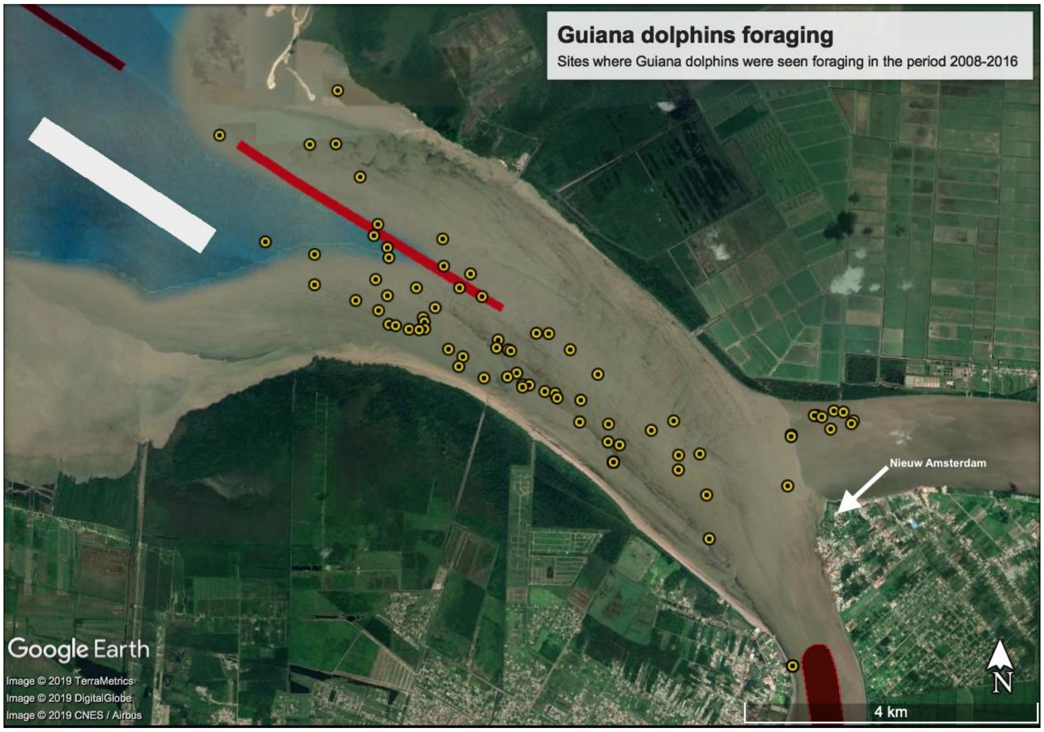

Figure 8: Sightings of animals feeding for the period 2008-2016. Dredge areas indicated in red, deposit areas in white.

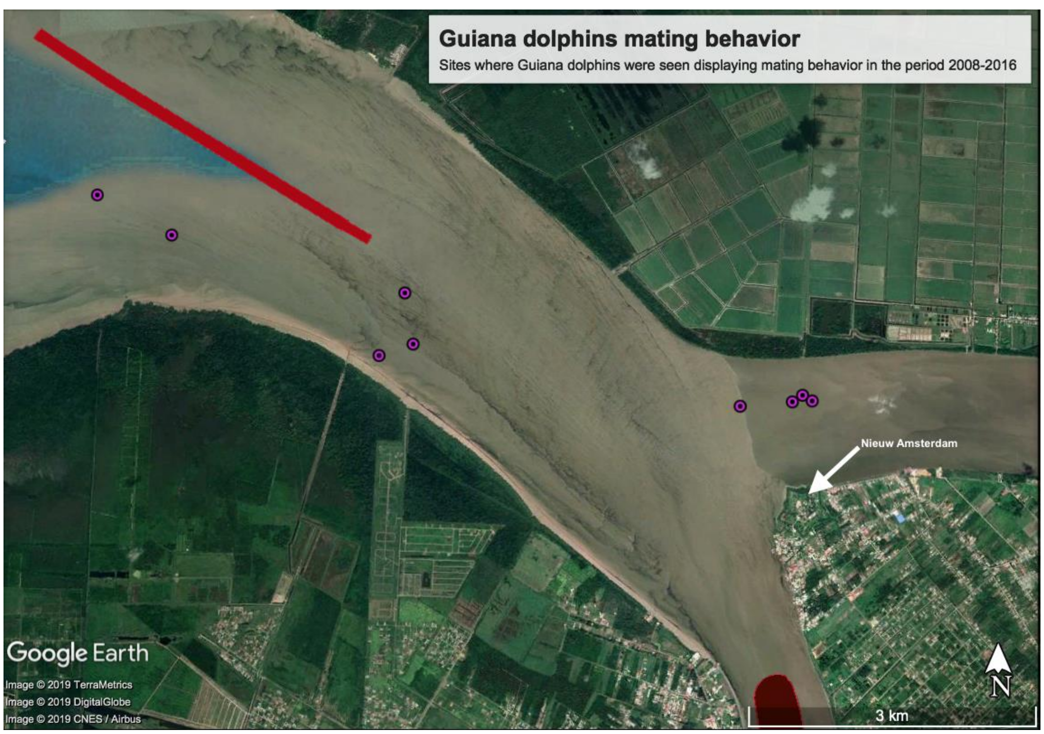

Figure 9: Although mating behavior was not observed often, the few times it was observed, suggests that the estuary is also used for reproductive encounters between males and females. Dredge areas indicated in red, deposit areas in white. According to one boatman, he witnessed the birth of one baby dolphin near the confluence of the Suriname River and the Commewijne River.

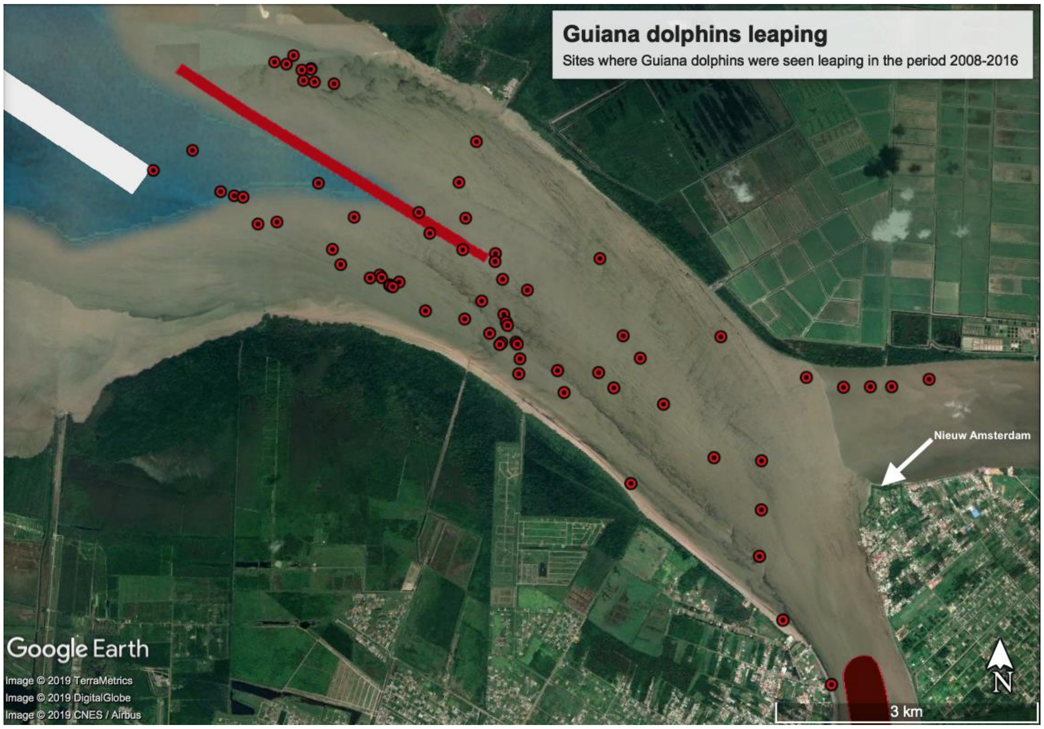

Figure 10: Aerial behavior of Guiana dolphins was regularly observed, either as part of traveling behavior or of social behavior where they were seen interacting with each other and sometimes with tourist boats.

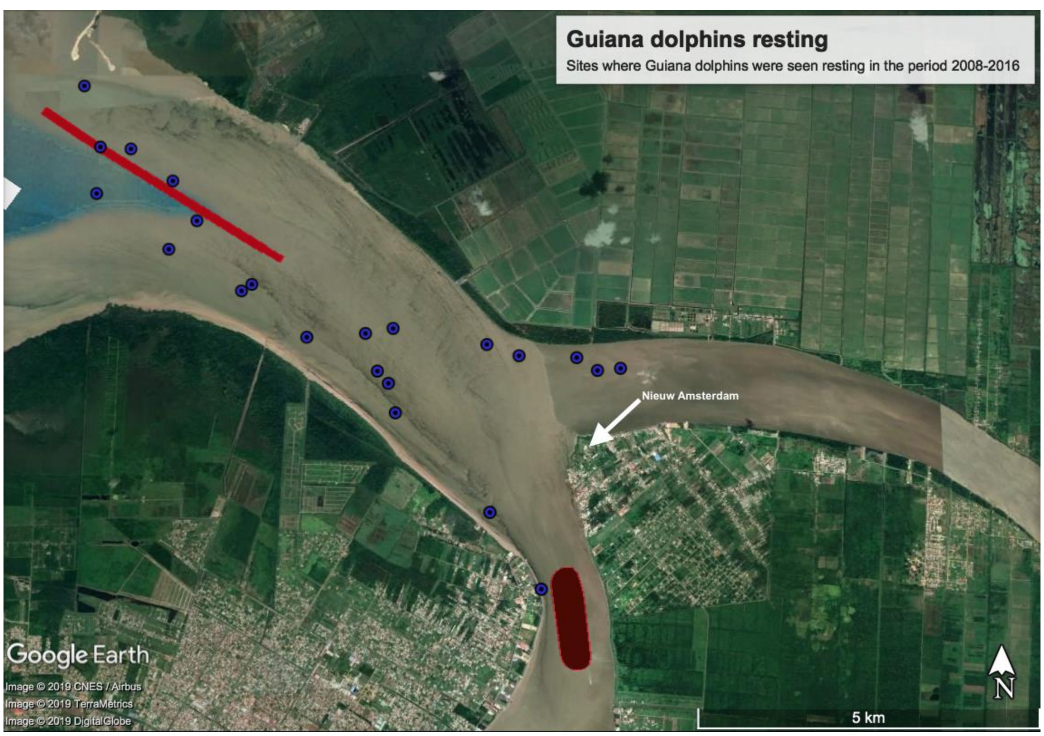

Figure 11: Animals were often seen displaying behavior that suggested they were resting. where they were almost still in the water in close formation of three to eight animals, slowly surfacing with their blowhole above the water..

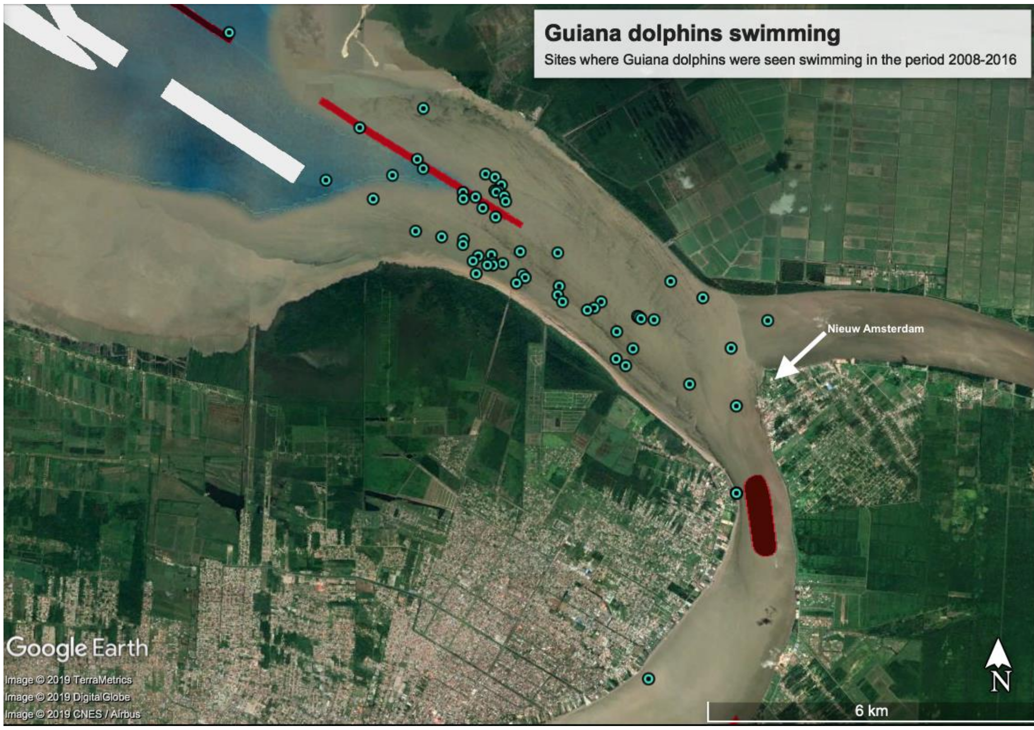

Figure 12: Guiana dolphins were regularly seen swimming in a direction without displaying any other specific behavior. Dredge areas are indicated in red, deposit areas in white.

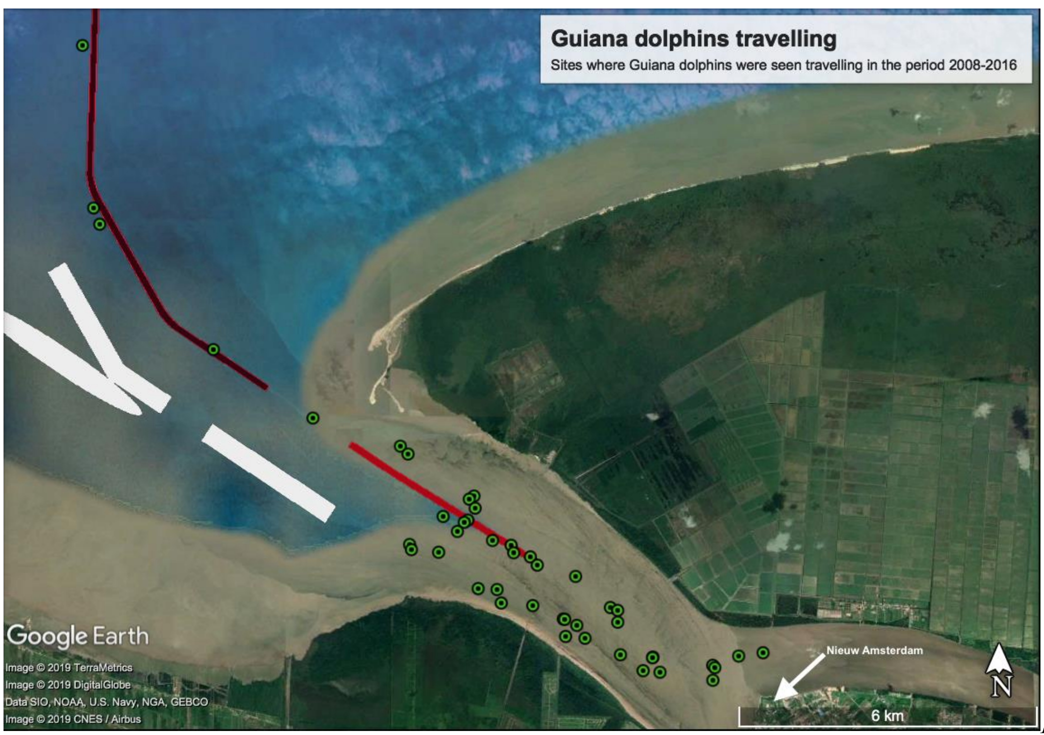

Figure 13: Guiana dolphins were regularly seen traveling, this behavior is distinguished from normal swimming behavior because of the aerial behavior as well as the speed with which they swim, where the animals are either seen porpoising where their body comes partially out of the waterwater and they have a clear direction into which they are traveling. Dredge areas are indicated in red, deposit areas in white.

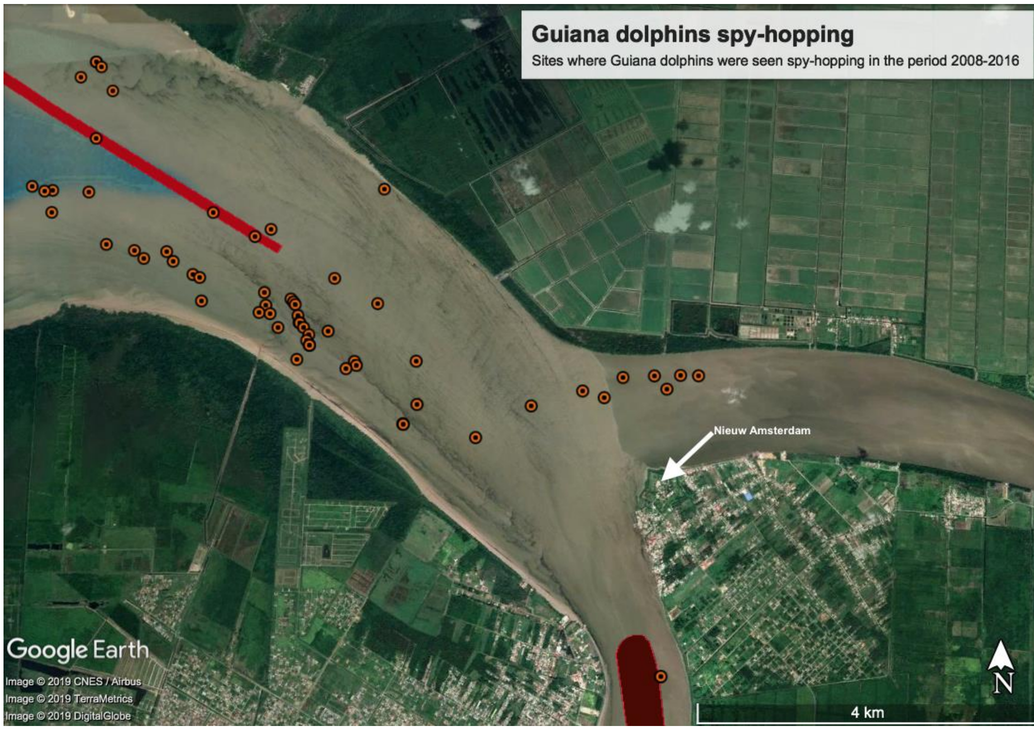

Figure 14: The dolphins were often seen near tourism boats or the boat of the GHFS dolphin program with their heads partially out of the water and looking at the boats, this behavior, known as spy-hopping, is also seen when the animals are interacting with birds, such as the frigate bird and other sea birds.

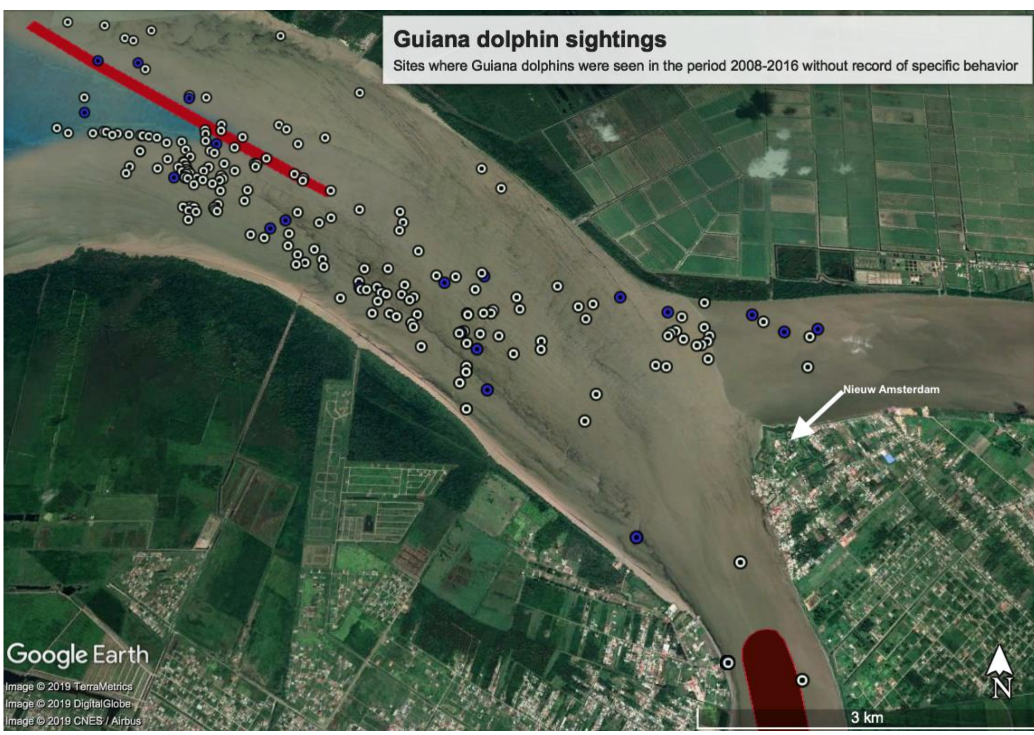

Figure 15: Many sightings of the Guiana dolphins were recorded for which no specific behavior was indicated.

IUCN Classification and Threats
The Guiana dolphin is classified by the IUCN as data deficient. In Suriname the species is protected under the 1954 game law.

As the animals are poorly studied, the main concerns based on current knowledge are that since they are coastal and estuarine species, maintenance of their coastal habitat and conservation of their prey species seem to be important issues. In addition, the degradation of this habitat would strongly affect the species, since they feed high in the food chain and contamination of their prey species would lead to bioaccumulation of pollutants in their body. In addition, other sources of anthropogenic impacts include seismic surveys in the near shore, dredge and fill, both of which displace their prey species and the dolphins themselves, effluents from coastal communities, and oil exploitation in nearshore areas.

Sirenians
Suriname is home to one Sirenian species, *Trichechus manatus manatus*, the Antillean manatee. Currently, three species of manatees are recognized: *Trichechus inunguis*, *T. manatus* and *T. senegalensis* (Domning and Hayek, 1986). Each has a different geographic range; *T. inunguis* and *T. manatus* are the New World species, while *T. senegalensis* is the Old World or African species. The geographic range of the West Indian Manatee, *T. manatus*, runs from southeastern North America to northeastern Brazil. Two subspecies of the West Indian Manatee are known: The Florida Manatee, T. *m. latirostris*, and the Antillean Manatee, *T. m. manatus* (Domning and Hayek, 1986).

Antillean Manatee Life History
The Antillean manatee (seku Sr) has a streamlined torpedo-shaped body full around the middle, two broad paddle-like flippers with three to four nails at the tips and a horizontally flattened and rounded paddle-shaped tail. It has a stubby snout, with small eyes and nostrils located at the end of the snout. Together with the two-fingered sloth, they are the only mammals that have six neck vertebrae, giving them a stocky appearance. For such a large animal they have relatively small eyes, and their eyesight is thought to be poor. Their snout is like a short trunk and is very muscular, mobile and highly sensitive. The Antillean manatee is typically bigger than the other two species, reaching a length of approx. 3.5 m and maturity weight of between 200 to 600 kg. The Antillean manatee is gray to brownish gray in color. Manatees are, despite their aquatic appearance, not closely related to cetaceans or pinnipeds. The closest relatives of the manatee are herbivorous land mammals: elephants and hyraxes. Manatees still have remnant toe nails on their flippers.

Most of the manatee's time is spent eating (around 8 hours per day), resting and traveling. Because they are mammals they must surface to breathe air. Manatees may rest submerged at the bottom or just below the surface of the water, coming up to breathe on average every three to five minutes. When resting, manatees have been known to stay submerged for up to 20 minutes. Contrary to land mammals the manatee does not have a fur, which may be an adaptation to live in an aquatic environment. However, they do have sparse hairs on their bodies which have the same structure as the whisker hairs on cats, that may serve to convey tactile cues. It is suspected that these hairs help the aquatic mammals distinguish the water currents in its surroundings, approaching animals, and large stationary objects.

They are the only marine mammals that are herbivorous. Their upper lip is split down the center, and each half can be moved individually to grasp vegetation. They are thought to eat around 10-15% of their body weight per day, which amounts to an average animal of 450 kg consuming 45-68 kg of aquatic vegetation per day. Like horses, manatees are hindgut fermenters, which means they do not ruminate. They have only flat cheek-teeth that are used to grind their food, which is very abrasive on the teeth. For that reason, manatees have a special adaption where teeth are replaced by migrating from the back to the front, with worn teeth falling out of their mouths. Because they feed on plants such as grasses and bushes close to the shore, including *Montrichardia arborescens* (mokomoko SR), *Machaerium lunatum* (brantimaka SR*)* and mangrove leaves, manatees have to move into shallow parts of the river and close to the shore, making them susceptible to hunting and boat strikes.

Manatees are a slowly reproducing species. Females appear to reach sexual maturity by the age of five and the males a little bit earlier, around the age of three to four years. They may live up to 60 years and continue to calve into their late thirties. The gestation period is estimated to be between 11 and 14 months and the calving interval is around 2.5 years. The calf will stay with its mother for one to two years. Litter sizes are usually one, but twins have been reported.

Figure 16: White dots show locations where manatees were sighted and stranded in the study area. Boatmen stated to regularly see the animals in the Outer area near Braamspunt (pers comm Zaid, 2019). Dredge areas are indicated in red and deposit areas in white.

Population Size
Estimates of the population size of manatees in Suriname range from 10 to 600 animals for the whole country (Pool, 2014). The Suriname River and Commewijne River both are home to this species. The population size estimate for the study area is 5-10 animals, based on observations by the boatmen and the volunteers of the Green Heritage Fund Suriname (GHFS) dolphin program. In addition to the few sightings recorded over the period from 2007 to 2015, two strandings occurred in the same period, of which one was on the left bank of the Suriname River in the middle area.

IUCN Classification and Threats
Based on an IUCN status review in 2007 that was revalidated on 25 September 2012, the Appendices of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) recognized and listed both subspecies of the West Indian Manatee, *Trichechus manatus latirostris* and *Trichechus m. manatus* as threatened with extinction (Pool, 2013). In Suriname the species is protected under the 1954 game law.

As the animals are poorly studied, the main concerns based on current knowledge are that, since they are coastal and estuarine species, maintenance of their coastal habitat and providing for migration corridors as well as quiet protected areas for resting and for cows with young calves seem to be important issues. The degradation and loss of habitat would strongly affect the species, as well as seismic surveys, dredge and fill, pollution from agriculture and mining. The factors that limit the population's ability to withstand these anthropogenic impacts include low fecundity, slow growth, limited dispersal, and restricted range.

Chelonians
Suriname used to be home to five different sea turtle species. Of these, only three are currently regularly seen on the nesting beaches along the coast of Suriname: *Dermochelys coriacea* (leatherback), *Chelonia mydas* (green sea turtle) and *Lepidochelys olivacea* (olive ridley). The most regularly seen sea turtles on the beaches of Suriname are the leatherback and green sea turtle. Sea turtles remain off the coast of Suriname throughout the year. During the nesting season males swim closer to the coast and even enter the estuary of the Suriname River, where they have been seen mating close to Leonsberg (pers comm Hiwatt, 2019).

Leatherback Life History
The *Dermochelys coriacea,* leatherback sea turtle (aitkanti Sr), is the only living member of the *Dermochelyidae* family, one of the two families of marine turtles. These animals are the largest living turtles and can reach lengths of up to 2.4 m and weigh about 300-500 kg. Their black skin is covered with white, pink or bluish spots. Their flippers are very long and extend nearly the entire length of their body. Unlike other sea turtles, the leatherback does not have a hard shell. Instead, its dark grey or black carapace with white spots is made of smooth and leathery oil-saturated tissue and strengthened by tiny bone plates. The hatchlings are the same color as the adults.

As a result of thermoregulatory adaptation leatherbacks are able to maintain core body temperatures in cold water. This is why these sea turtles are able to travel far south, such as the southernmost tip of New Zealand, and far north, such as the arctic circle, making them the most widely distributed of all sea turtles. These sea turtles are mainly pelagic deep-water turtles but sometimes forage in coastal waters. They travel to tropical and subtropical regions to mate and nest. Their carapace is highly specialized for diving to extreme depths of up to 1,200 m.

The global nesting population consists of approximately 34,000 to 36,000 females. The estimated age of sexual maturity is 5-15 years. The females nest every 2 to 3 years and, just as for other sea turtles, mating takes place at sea. The females then enter the nesting beaches every 10 days where they lay 70-80 fertilized and 30 unfertilized eggs per nest. After about 55-75 days these eggs hatch and the hatchlings move towards the sea by running towards the brightest horizon.

The period of time between entering the ocean as a hatchling and the sea turtle's return to the nesting beach as an adult is referred to as the lost years, as the migration ecology of juvenile leatherbacks is unknown. Leatherbacks are incredibly difficult to study because of their migratory and pelagic lifestyle, which is why little is known about their lives at sea. Most of the data that has been collected on this species comes from studies done during their reproductive phase when they migrate to tropical waters to nest on the beaches in these areas.

While leatherbacks can feed on fish, crustaceans and other marine invertebrates, their diet mostly consists of jellyfish. They have delicate scissor-like jaws which are ideal for eating soft-bodied

Picture 4: Green sea turtle on Braamspunt beach (Source: Collection Green Heritage Fund Suriname photographer: Stellar Tsang)

animals. Scientists suspect that their ability to dive deep helps them evade predators and regulate their temperature. Once the leatherback has caught and swallowed its prey the downward pointing spines in its mouth and throat move the prey further into their digestive system. While this adaptation is very convenient, it can also cause problems when they accidentally swallow plastic bags that they have mistaken for jellyfish.

Leatherbacks are listed as Critically Endangered on the IUCN's Red List and are also listed on annex 1 of CITES. The Northwestern Atlantic sub-population, however, is listed by the IUCN Red List as "least concern", even though the number of nests in the Guianas Region is on the decline (WWF, 2018). Their biggest threats are the result of anthropogenic activities such as illegal harvest of their eggs, habitat loss and degradation, dredge and fill, entanglement in fishing gear, climate change and pollution. These sea turtles are especially vulnerable to ingestion of floating marine debris like discarded plastics.

Green Sea Turtle Life History

The *Chelonia mydas*, green sea turtles (krapé Sr), are sea turtles in the order of Testudines and belong to the *Cheloniidea* family. This family of hard-shelled sea turtles is one of the two last surviving cryptodiran families. Sea turtles in this family have non-retractable, large, paddle-like flippers and one or two claws on each flipper. On their head, flippers, carapace and plastron they have keratinized epidermal scales. They can also partially withdraw their head beneath their carapace. Other sea turtles in this family are the hawksbill, olive ridley, loggerhead turtle, kemp's ridley and flatback.

With a carapace length of 83-114 cm and a weight of between 110-190 kg, the green sea turtle is the largest hard-shelled and second largest sea turtle in the world. Rather than two pairs of prefrontal scales, these sea turtles have a single pair which sets them apart from other sea turtles. Their paddle like flippers each have one claw, and while they are the largest hard-shelled sea turtles, they have a relatively small head with a serrated jaw. The color of their carapace is dark green to yellow or brown with radiating stripes or brown blotches. The plastron is white, yellow or dark grey. The hatchlings are dark brown to black with a white plastron and white flipper margins.

Green sea turtles can be found in subtropical and tropical water. Adult green sea turtles live near coastlines and around islands between 30° north and 30° south, especially in areas with seagrass beds. Nesting takes place in approximately 80 countries and they forage in the coastal waters of more than 140 countries. The global nesting population currently consists of 85,000 – 90,000 females.

During the breeding season adult males arrive in offshore water where they wait for the females. Males can breed every year, but the females breed every 2-5 years. During the nesting season the females nest every 2 weeks and lay about 100-120 eggs per nest. Once the nesting season is over, the adult females return to their foraging areas.

The eggs hatch after about 60-75 days and the hatchlings leave the nest. Once the hatchlings have entered the ocean, they remain epipelagic for an unknown number of years. After this period the juveniles move to the coastal waters. Sexual maturity is reached at 20 to 50 years. While the exact lifespan of these animals is unknown, they are expected to live up to 80-100 years.

While juvenile green sea turtles are omnivores, feeding on insects, seagrasses, crustaceans and more, the adult green sea turtles are herbivores and consume seagrass and algae, making them one of the largest marine herbivores. The green sea turtles play an important role in the health of the seagrass beds. They eat the older parts of the seagrass, not the roots. This allows the seagrass to grow new leaves and prevents accumulation of older leaves at the bottom. The disappearance of green sea turtles in the Florida bay and the Gulf of Mexico in 1980 has been directly linked to die-off of seagrass beds.

The IUCN red list has classified green sea turtle populations as endangered, and they are listed on the annex 1 list of the CITES. Just as other sea turtles, they face many threats such as habitat loss and degradation, incidental by-catch, dredge and fill, climate change and pollution. The green sea turtles are also sought after for their meat, and their eggs are illegally harvested on nesting beaches. Another threat are diseases such as fibropapilloma, a deadly tumorous disease. The increase in the occurrence of this disease is believed to be the result of land and marine pollution that have decreased the immune system of turtles.

Nesting season

The nesting season for sea turtles in Suriname is from February to August. During the nesting season every species has a peak period, a peak of nesting activity (Reichart, H. A and J. Fretey 1993). The nesting beaches of sea turtles are located in the east, along the coast of Suriname. Some well-known nesting beaches are: Braamspunt and Babunsanti. Previously, there were more beaches, however, as a result of the dynamic coastal system and erosion, Diana beach and Matapica have disappeared. Braamspunt is the main nesting beach for the leatherback sea turtle population, and accounts for 90% of all nests of this species in Suriname. Nesting trends are for all three species on the decline (pers comm Hiwatt, 2019). Sea turtles are protected under the Game Law in Suriname.

Population Size

Estimates of the population size of the green sea turtles and leatherback sea turtles in Suriname are not available, however, the number of nests counted gives an indication of the number of animals. In 2017 the number of nests on all nesting beaches of Suriname for green sea turtles was 35,343 and for the leatherbacks it was 842 (WWF, 2018). As the females are known to return during one breeding season on average three to five times for the green sea turtle and six to nine times for the leatherback, a very rough estimate of the average nesting population for a particular year can be obtained of around 7,000 for the green sea turtle and around 100 for the leatherback sea turtle. However, it should be noted that male turtles are also around to mate in the nearshore and estuarine area, and these are not included in the above nesting population estimate, which only consists of the females.

Potential Impacts of the SRDP on Estuarine Mammals and Turtles

This section discusses possible impacts from dredging on estuarine mammals and turtles at a general level. These are further analysed and rated in the ESIA Addendum Report.

Suriname River Dredging Project 2019

The Suriname River Dredging Project proposes the dredging and disposal of 4.9 million m3 (Mm3) of sediment and maintenance dredging over a period of 5 years. The dredged material will be disposed at specific sites in the Suriname River and estuary.

Section	Area	Km	Volume
Outer Bank	Open sea to Braamspunt	0 - 30	1.80 Mm^3
Resolutie Bank	Braamspunt to Nieuw Amsterdam	30 - 41	0.55 Mm^3
Jagtlust Bank	Anchorage Suzannasdal to Paramaribo	41 - 56	1.75 Mm^3
Dijkveld Bank	Suhoza south of Jules Wijdenbosch Bridge to Domburg	56 - 68	0.80 Mm^3
Total dredge volume			**4.90 Mm^3**

Table 1: Proposed dredge sites and volumes. Source: Maritieme Autoriteit Suriname & SRK consulting, 2019

Dredging of four sections between Km 0 and Km 68 (see Figure 1) is proposed and the disposal of dredge material at two deposit areas of which one is located at sea (deposit area A2) and one at the Dijkveld Bank in the Suriname River (deposit area D2). Most of the channel will be widened to 90 m, wide enough for one large cargo (Panamax) vessel. The channel has been designed to be ~5.5 m deep at low water.

Capital dredging is expected to be done using Trailing Hopper Suction Dredger(s) (THSD). A suction arm sucks loosened sediment into the hold of the ship, which transports the material in its hopper (hull) to deposit areas A2 (sediment from Outer and Resolutie Banks) and D3 (sediment from Jagtlust and Dijkveld Banks). Material is discharged through bottom gates or floating pipelines into the disposal areas. Maintenance dredging will use Water Injection Dredger(s) (WID) at the Outer and Resolutie Banks and Trailing Hopper Suction Dredgers at the Jagtlust and Dijkveld Banks. WIDs create a fluidized sediment layer that flows out of the dredged area through natural processes and eliminates the need for sediment transportation and disposal. Capital dredging will commence as soon as possible and last for up to 6 months. Maintenance dredging will be undertaken periodically during the subsequent 5-year period. It is expected that no dredging in the Suriname River will take place during fish spawning and breeding periods (April and

December). Dredging may take place during fishing periods (March and May – July), depending on sediment quality.

The deposit areas are naturally shallow areas. Disposal in the Suriname River will be underwater and precautionary measures will be taken to minimize the effect on the natural river profile. At the Outer Bank sediment could be used to create an artificial island in the Suriname River estuary, which may provide valuable habitat for off-shore birds or fish (Maritieme Autoriteit Suriname & SRK consulting, 2019).

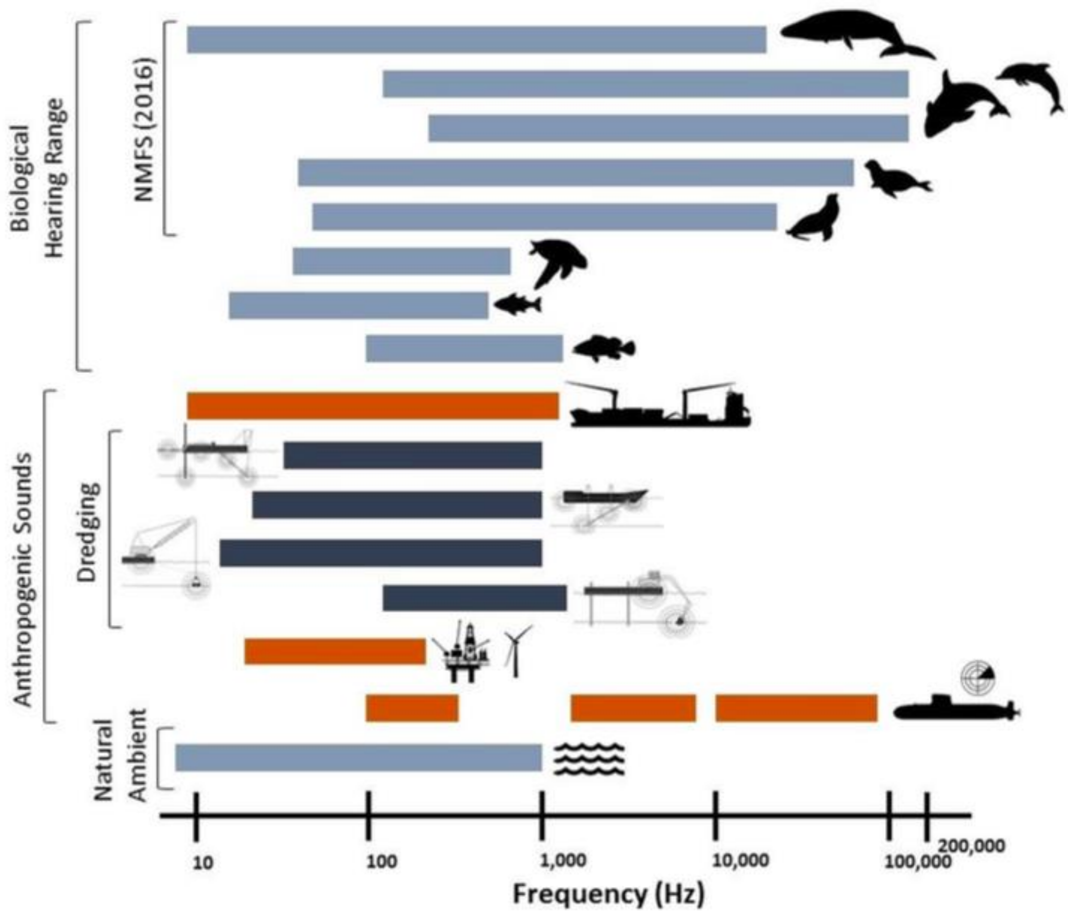

Figure 17: Hearing frequency ranges of selected fish and mammal species and main energy frequencies reported for anthropogenic and ambient sources (Source: McQueen, Suedel,Wilkens, & Fields, 2018)

Dredge and Fill Impacts

According to Todd (Todd et al., 2015) dredging is a worldwide common activity that involves removing sediment from a sea, river, or lake bed and depositing it at a new location. Uses are vast and include construction of ports, waterways, dykes, and other marine infrastructure, land reclamation, flood and storm protection, extraction of mineral resources to provide material for the construction industry.

Impacts of dredging on marine mammals are not yet well understood, while positive and negative impacts on marine flora, benthic infauna and the seabed are relatively well documented. Impacts of dredging on sea turtles are well documented. Two types of dredgers are proposed for the Suriname River Dredging Project, of which Water Injection Dredging is a fairly new method, the impacts of which are not yet well studied.

Impacts can be divided in direct impacts and indirect impacts for marine mammals:

- Direct impacts include collisions, increased noise levels and increased turbidity.
- According to Todd, indirect impacts on marine mammals from dredging stem from changes to their physical environment, or to their prey. Indirect effects can be positive or negative, but are most likely highly species-specific, so it is unclear how effects from dredging influence various marine organisms.

Impacts also depend on the nature of the baseline environment.

As the Guiana dolphin and the Antillean manatee are resident species, the impact of changes to their physical environment and for the Guiana dolphin to its prey are likely to have a greater negative impact than on a migrating marine mammal species.

Direct Impacts on Marine Mammals

Collision: For the Suriname River Dredging Project it is unlikely that collisions will occur with the Guiana dolphins or Antillean manatees, as the dredgers most likely will be either stationary or moving at slow speedsand these species will avoid the dredgers. A collision with humpback whales and their calves, however, in the outer area cannot be ruled out.

Increased noise levels: With regard to impacts related to noise levels, according to McQueen (McQueen, Suedel, Wilkens, & Fields, 2018), the effects of underwater sound emanating from dredging operations are anticipated to be limited to non-lethal effects, such as masking communication or behavioral disturbance. While trailing suction hopper dredges (TSHD) produce continuous sounds from the ship's propulsion during dredging and transit to the placement site, the sounds associated with dredging are discontinuous and cyclical because dredging stops when the hopper is full and the ship moves to and from the dredging area and placement site.

In addition, the draghead contacting the bottom substrate as it trails beneath the dredge during advancement produces continuous sounds during dredging (though it is noted that the substrate is generally soft and no cutting will be required). The sound produced during filling of the hopper is associated with propeller and engine sound with additional sounds emitted by pumps and generators.

The hydrodynamic method of water injection dredging is said to be less noisy by the developer and has been used in environmentally sensitive areas, such as sea turtle nesting areas. According to McQueen, dredging operations and other anthropogenic sounds, such as shipping vessels, can produce lower frequency sounds (20 to 1,000 Hz) that overlap the detectable frequency range of marine organisms (Figure 8).

Increased turbidity: Water injection dredging uses large quantities of water, which is pumped from the surface close to the dredger, and then is injected locally at low pressure into the sediment layer through a series of nozzles distributed along a horizontal beam. This creates a fluid water-sediment mix which is then transported horizontally along the sediment-water interface as a density current, under the influence of gravity and the currents related to the tide, waves or river discharges. The vertical movement of the sediments during water injection dredging is limited and the sediments are not put into suspension, adopting instead the form of a density current just above the bottom. These three direct effects of water injection dredging may generate a potential impact on water quality (turbidity, contaminants, etc.), the physical environment (nature of the bed, hydrosedimentary equilibrium) or the habitat (spawning and feeding areas). These direct or indirect impacts may then have effects on the living environment or on human activities (Sigwald, Ledoux, & Spencer, 2015).

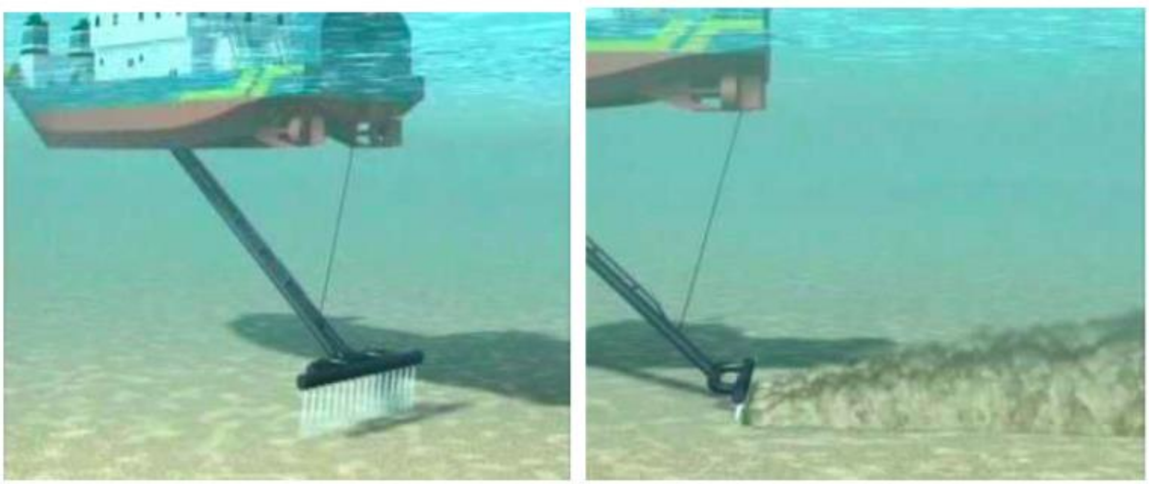

Figure 18: Water injection dredger (Source: Sigwald, Ledoux, & Spencer, 2015).

According to Todd, effects of turbidity caused by dredging activities are often localized, with minimal direct impact on marine mammals inhabiting naturally turbid and dark environments (such as the Suriname River). In addition, sirenians, for example, create plumes of sediment when feeding, indicating that individuals must have some level of tolerance to turbidity. Although the sediment plumes extend the impact of dredging over larger areas, research has shown that in general they do not last long, up to a maximum of four to five tidal cycles.

Indirect Impacts on Marine Mammals

Indirect effects of dredging on marine mammals are more complex according to Todd, and considerably less well understood. These impacts include, as stated above changes to the physical environment, impact on prey species and disturbance of sediments with potential release of toxicants.

Impact on prey species: Studies on potential marine mammal prey species are more numerous, including from the Western Australian Marine Science Institution (WAMSI) Dredging Science Node. A study of the impact on finfish by Wenger (Wenger et al., 2017) suggests there are a number of impacts on finfish (See Figure 19). These impacts may have a potential knock-on effect on marine mammals.

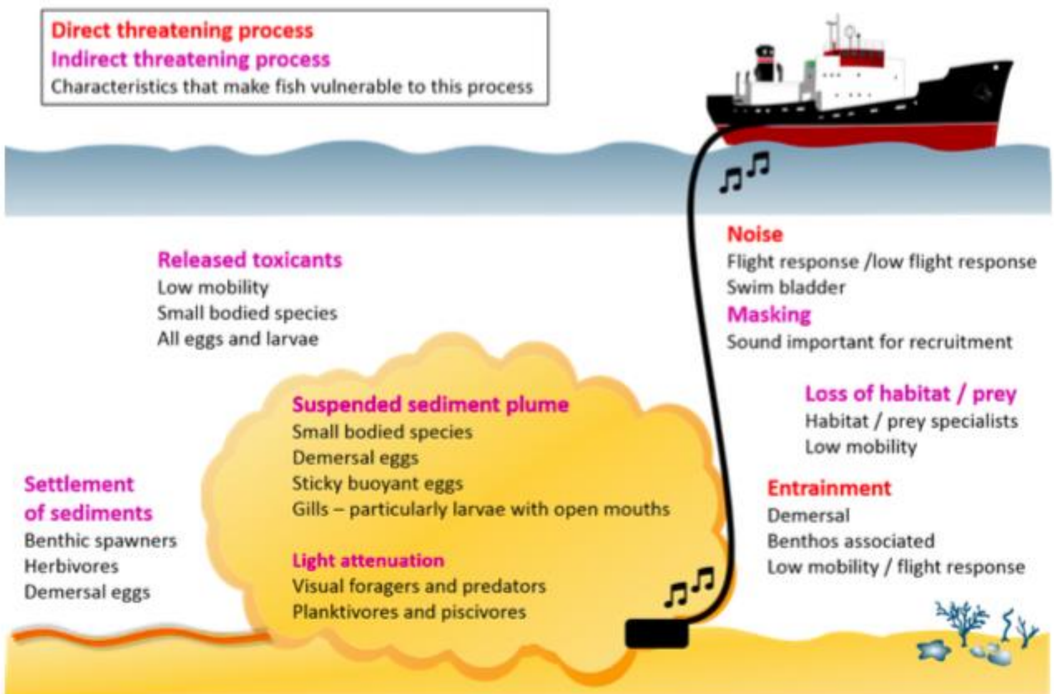

Figure 19: A schematic diagram of categories of potential effects of dredging on fish (Source: Wenger et al, 2017)

The direct potential impact on finfish is entrainment, which is defined as the direct uptake of aquatic organisms by the suction field generated at the drag head or cutterhead (Reine & Clarke, 1998). These organisms range from the micro-organism in the muddy bottom to the animals living in and around the bottom and the animals above the bottom, in particular those organisms that are slow and do not move away fast enough. In addition, nursery and spawning grounds could be severely affected by entrainment, leading to significant reductions in prey species for marine mammals and other fauna feeding on such prey species. The effect on the marine mammals could be that they have to look for new foraging grounds, or increase the time spent foraging, according to Todd. The effects of prey loss, if this occurs, on the population of Guiana dolphins could be severe as this is a resident population.

Release of toxicants: Disturbance of sediments can release contaminants into the environment, increasing the potential uptake by marine organism. As marine mammals are on the top of the food web, harmful contaminants could be biomagnified in these species. Guiana dolphins are in particular sensitive as a result of their feeding habits, their association with shallow coastal waters (in particular estuaries and bays), and their site fidelity, according to de Moura (de Moura, Hauser-Davis, Lemos, Emin-Lima, & Siciliano, 2014). Todd concludes that effects of disturbance of sediments are in most cases localized.

Changes to the physical environment: Permanent changes to the seabed (or riverbed) can occur that may lead again to loss of prey species. In case new species that occupy the same trophic levels replace the species lost, the impact on marine mammals could be reduced. There are potential positive effects from dredging, such as an increase in primary production and nutrient enrichment from sediment dispersal and entrainment. However, the recovery of habitats to pre-disturbance conditions can take years, according to Todd, while increases in populations due to increased primary production are often short-lived.

Onshore impacts on sea turtles

According to Dickerson (Dickerson, Wolters, Theriot, & Slay, 2004) sea turtles are impacted by dredging activities as a result of the presence of the dredge which disrupts nesting activities, and which can potentially lead to the destruction of nests and nesting habitat. The presence of the dredger itself, as well as the sound generated and lights on the dredger may deter sea turtles from approaching the beach. According to McQueen (McQueen, Suedel, Wilkens, & Fields, 2018), although the sound itself may not be harmful to the sea turtles, there may be potential for behavioral or masking effects of lower-frequency anthropogenic sounds.

In-water impacts on sea turtles

Entrainment is the most severe impact on sea turtles, as both adults, sub adults and juveniles may be entrained into the draghead according to Goldberg (Goldberg et al., 2015). Besides physical harm (e.g. massive injuries, fractures, crushed tissues and hemorrhage) and mortality, indirect impacts such as alteration or destruction of foraging habitat might also occur, especially when dredged material is placed on rocky bottom habitats commonly used by sea turtles as foraging grounds. In addition, dredging may stir up toxic pollutants that have settled and become trapped by bottom sediments.

General mitigation measures

The literature suggests that additional studies to develop maps dividing the dredge area into different regions may be warranted so that risks associated with dredging during turtle breeding season, fish nursery and spawning season, humpback whale migration season and manatee breeding season can be avoided or reduced. Such maps could then outline areas where the likelihoods of these risks are highest, including the environmental windows associated with them, such as peak of nesting season for sea turtles from February to August.

This would mean dividing the dredging areas into sections that are only dredged between September and January, which is outside of the peak nesting season, and areas that are dredged from February to August. In addition, day and night-time windows of operation should be established for these areas, more in particular it should be considered if dredging will continue only during the day or night taking into account potential disruption of nesting behavior of the sea turtles.

Mitigation measures for Marine Mammals

According to Todd, adverse impacts from dredging can be limited by implementing mitigation measures, such as the use of environmental windows which ensure that dredging activities do not occur in important habitats or at times when marine mammals or their prey are most sensitive, for example, during breeding or spawning seasons. More likely effects include masking, avoidance and short-term changes to behavior, and prey availability.

Context is however important when discussing impacts, because marine mammals are more likely to tolerate disturbance, and remain near active dredgers, if in a prime foraging location, where rewards are high. In this case, reactions may not be obvious to observers, but the absence of a measurable response does not mean longer-term impacts are absent.

Sea turtle mitigation measures

According to Reine (Reine & Clarke, 1998), certain types of dredging operations appear to pose sufficient risk to sensitive resources such that continued application of restrictions is justified. Notably, these exceptions include the conduct of dredging operations in narrow constricted river channels, particularly in channels seasonally occupied by sea turtles or other protected species. Common measures used to reduce the likelihood of turtle and hopper dredger interactions include:

- Working during times of the year when turtles are less likely to occur at the project location;
- Using deflectors and specially designed dragheads;
- Relocating turtles from the project area via net capture prior to dredging operations (Dickerson et al. 2004).

Conclusion

The Suriname River Dredging Project using Trailing Suction Hopper Dredgers poses a potential risk to the complex ecosystem of the joint Suriname River and Commewijne River Estuary, and the marine mammals that are a resident population of the estuary. The risk of entrainment for sea turtles in all stages of their development is a potentially significant impact on these already endangered species. One of the most important risks is entrainment as described above, which may severely impact the abundance of biodiversity in the estuary in general. For that reason, it is recommended that a pre-survey is conducted to establish the seasonality of fish spawning and nursery and sea turtle breeding and nesting. In addition, mitigation by using protected species observers on board of the dredges could be an important mitigation measure. In general the impact of Water Injection Dredging appears to be less severe, as this method mimics a natural process of sediment flow in the river. However, there are still impacts like with other types of dredging to be taken into account, such as potential impact on water quality, the physical environment or the habitat.

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Annexes

Annex I

	INFRAORDER CETACEA Parvoder Mysticeti: Baleen whales			
	Parvoder Mysticeti: Baleen whales			
	Superfamily Balaenopteroidea Family Balaenopteridae: Rorquals Subfamily Megapterinae Genus Megaptera			
1	Bultrug (Humpback whale)	*Megaptera novaeangliae*		
	Superfamily Balaenopteroidea Family Balaenopteridae: Rorquals Subfamily Balaenopterinae Genus Balaenoptera: slender rorquals			
2	Gewone vinvis (Fin whale)	*Balaenoptera physalus*		
3	Noordse vinvis (Sei whale)	*Balaenoptera borealis*		
4	Brydevinvis (Bryde's whale)	*Balaenoptera edeni*		
5	Dwergvinvis (Common minke whale)	*Balaenoptera acutorostrata*		
6	Antarctische dwergvinvis (Antarctic minke whale)	*Balaenoptera bonaerensis*		
	Parvorder Odontoceti: Toothed whales			
	Superfamily Physeteroidea: Sperm whales Family Physeteridae			
7	Potvis (Sperm whale)	*Physeter macrocephalus*		
	Superfamily Delphinoidea: Oceanic dolphins Family Delphinidae			
8	Witlipdolfijn (Melon-headed whale)	*Peponocephala electra*		
9	Zwarte zwaardwalvis (False killer whale)	*Pseudorca crassidens*		
10	Indische griend (Short- finned pilot whale)	*Globicephala macrorhynchus*		
11	Tuimelaar (Bottlenose dolphin)	*Tursiops truncatus*		
12	Snaveldolfijn (Rough-toothed dolphin)	*Steno bredanensis*		
13	Kaapse dolfijn (Long-beaked common dolphin)	*Delphinus capensis*		
14	Sarawakdolfijn (Fraser's dolphin)	*Lagenodelphis hosei*		
15	Slanke dolfijn (Pantropical spotted dolphin)	*Stenella attenuata*		
16	Atlantische vlekdolfijn (Atlantic spotted dolphin)	*Stenella frontalis*		
17	Langsnuitdolfijn (Spinner dolphin)	*Stenella longirostris*		
18	Guianadolfijn (Guiana dolphin)	*Sotalia guianensis*		