A Review of the Ecology and Economics of Curaçao's Marine Resources

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1. Executive Summary

Curaçao is a constituent country in the Kingdom of the Netherlands, located in the southern Caribbean Sea, north of the Venezuelan coast. Development, industry, and the majority of the population are concentrated along the leeward and southeastern coast near the capital of Willemstad. The island is surrounded by fringing coral reefs which are most developed along the leeward coast. Curaçao's bays contain seagrass and mangrove habitats, which are important nursery and feeding grounds for a number of coral reef fish. Although Curaçao's reefs are considered relatively healthy compared to elsewhere in the Caribbean, there was a 42% decline in coral cover from 1980 to 2010. Major threats to coral reef ecosystems include pollution from coastal development and untreated sewage discharge, overfishing, disease, bleaching events, and the destruction of nursery grounds in inland bays.

Curaçao has two major fisheries: a troll fishery that targets pelagic fish and a reef fishery that targets demersal and some reef species. Total annual landings are estimated to be between 900 and 1200 tons. The troll fishery accounts for over half of all landings, and wahoo (*Acanthocybium solandri*) is the top landed species. Barracuda (Sphyraena), groupers (Serranidae), and snappers (Lutjanidae) account for the largest portion of reef fishery landings. Although there is no permanent fishery monitoring program in Curaçao, several short-term monitoring studies have been conducted over the last 15 years by the government and university students. Reefs around Curaçao appear to be overfished based on the trophic levels of species present, the average size of species, and the absence of previously important fishery species from current landings.

Tourism plays an important role in Curaçao's economy and accounted for 18.5% of the national GDP in 2009. Cruise ships frequent Curaçao and the dive industry also contributes substantially to tourism. Petroleum processing is also a major part of the island's economy. A large refinery was built in 1920 and oil accounts for up to 90% of the value of Curaçao's exported goods. Curaçao also has several ports that are used for industrial, recreational, and commercial purposes.

There are currently no no-take marine protected areas on Curaçao, but an underwater marine park was established in 1983 and is managed by CARMABI, a marine research institute. A large undeveloped area on Curaçao's eastern tip has been protected from degradation caused in other areas by development. The marine habitat in this area is relatively pristine and has some of the highest coral cover in the Caribbean. Plans have been drafted to develop this area, but whether this development will occur is currently unclear.

2. General Description

Curaçao is the largest of the Dutch Caribbean islands (61 km long; surface area of 444 km^2), located 60 km north of Venezuela in the south Caribbean Sea (Bruckner and Bruckner 2003a). Curaçao's territorial waters extend from 0- 12 nautical miles. Its Exclusive Economic

Zone (EEZ) extends to the north with an area of 68,783 km^2 and is shared with the other southern Dutch Caribbean islands, Aruba and Bonaire (Debrot and Sybesma 2000). Curaçao had an estimated population of 146,836 in 2013, most of which is concentrated on the leeward and southeastern coast near the capital of Willemstad (Bruckner and Bruckner, 2003a).

3. Physical Description

Curaçao's coastline is approximately 364 km long and can be divided into two sections: windward and leeward. The windward side, which includes the east and northeast coastline, is exposed to persistent trade-winds, resulting in a high wave energy environment and steep cliffs (Bak 1977; Duyl 1985). The leeward coast of the island (south, west, and southwest) is more calm and sheltered (Duyl 1985). Fifteen bays are found around Curaçao's coastline (Figure 1). The largest, Schottegat and Spanish Water Bays, serve as natural harbors for the densely populated southwest coast (Nagelkerken et al. 2001).

Curaçao has approximately 1,833 km^2 of shelf area, and on average, the 200 meter isobath occurs within 1 km of shore (Bak 1977). The general bathymetric pattern around Curaçao includes shallow waters extending out to between 20 and 250 m from shore (Duyl 1985). Two steep drop-offs occur, with a gradually sloping submarine terrace in between. The first drop-off occurs at a depth of approximately 5-15 m and the second at a depth of between 80 and 90 m (Duyl 1985). Currents around Curaçao are usually generated by tradewinds, with occasionally occurring countercurrents and eddies; currents on the leeward side typically flow towards the northwest (Govers et al. 2014).

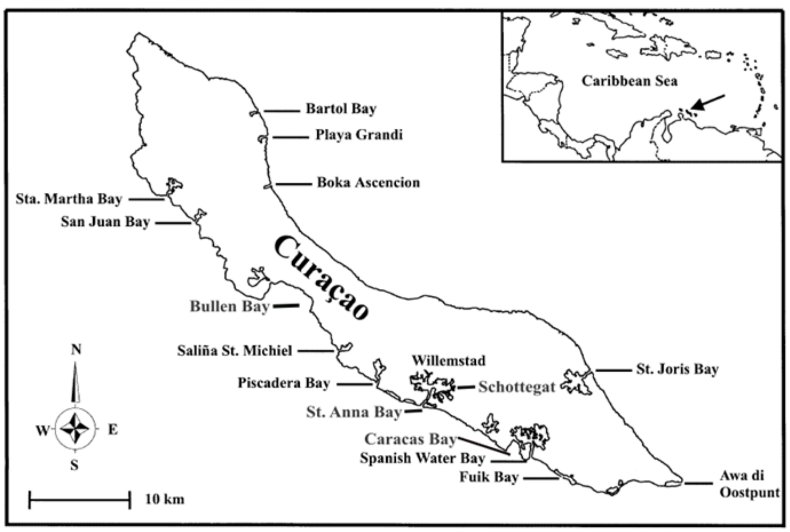

Figure 1. *Map of Curacao's inland bays from Nagelkerken et al. 2001*

Although Curaçao sits on the southern fringe of the Atlantic hurricane belt, hurricanes are rare (Duyl 1985). Tropical storms pass within 200 km of the island approximately every four years, causing unusually high waves from the western direction (Meteorological Service Netherland Antilles and Aruba 2010). The most recent major storms to have an impact on Curaçao's swell were Hurricane Brett in 1993, Hurricane Lenny in 1999, Hurricane Omar in 2008, and Tropical Storm Tomas in 2010 (Bries et al. 2004) . Westerly winds from tropical storms create unusually high waves, causing damage to shallow, normally more sheltered reefs on the leeward coast (Duyl 1985).

4. Marine Ecosystems: Description, Status and Threats

4.1. Research

Habitat monitoring and a significant number of benthic surveys and fish counts have been conducted along Curaçao's leeward shelf to help characterize Curaçao's marine and coastal ecosystems (Table 1; Figure 2). Rough ocean conditions have made surveys and research more difficult on the windward side, and limited data have been collected from this area.

Table 1. *Summary of major benthic surveys conducted on Curacao's coral reefs. Locations of sites are presented in Figure 2.*

Survey Type	Study	Time Period	Survey Description	# of Sites Surveyed
Benthic Surveys	1. Van Duyl 1985	1981-1983	Classified wave energy environments and benthic habitat using aerial photography and deep reef transect surveys	entire leeward coast
	2. Reefcare Coral Monitoring	1997-2007	Transect surveys were used to classify benthic cover and data on coral cover, state of health, amount and algae cover and type. Four sites are surveyed at a depth of 7 and 14 m every 3 months	8
	3. Bruckner and Bruckner 2003	1997,1998, and 2000	Belt transect surveys to determine coral abundance, diversity, and health	9
	4. Bak et al. 2005	1973-2005	Photo quadrats along 4 transects at each site to determine coral species composition, mortality, and cover	2
	5. Nagelkerken et al. 2005	1973-2003	Transect surveys to quantify benthic cover	9
	6. Njissen and Vermeij 2010	2010	Photo quadrats of 3 transects per site to calculate % average coral and sand cover	21

4.2. Seagrass Beds

Curaçao has an estimated 8 hectares of seagrass habitat, mostly found in the shallow, calm waters of inland bays (Green and Short 2003). The species distribution is controlled largely by water turbidity. Less turbid areas have a higher light intensity, and are associated with higher species richness (Kuenen and Debrot 1995). The largest seagrass bed is found in Spanish Water Bay and is dominated by *Thalassia testudinum*, which is common in all of Curaçao's bays (Kuenen and Debrot 1995). Manatee grass, *Syringodium filiforme,* is another abundant species (Nagelkerken et al. 2001). Seagrass habitat in Curaçao serves as an important nursery and feeding ground for a number of coral reef fish species, offering juveniles protection from predators (Nagelkerken et al. 2000, 2002; Nagelkerken et al. 2005). The presence of seagrass habitat near coral reefs in Curaçao is significantly correlated with presence and density of a number of fish species (Nagelkerken et al. 2002; Nagelkerken and Van der Velde 2002). Eutrophication of coastal waters is currently the largest threat to Curaçao's seagrass habitat (Govers et al. 2014; Green and Short 2003). Sewage discharge and leakage around Curaçao's coast has led to increased nutrient levels and algal blooms, which block out the light that seagrass requires for photosynthesis (Vermeij 2012). Evidence indicates that this has occurred in two of Curaçao's bays with sewage outflow sites: St. Anna (or Harbor) Bay and Piscadera Bay. Seagrass habitat in these bays is either no longer present or found only in very shallow areas (Govers et al. 2014). In Piscadera Bay, trace metals have been found in the remaining seagrass beds, indicating that the habitat has been affected by pollution from sewage, boats, ports, and other terrestrial origins (Govers et al. 2014).

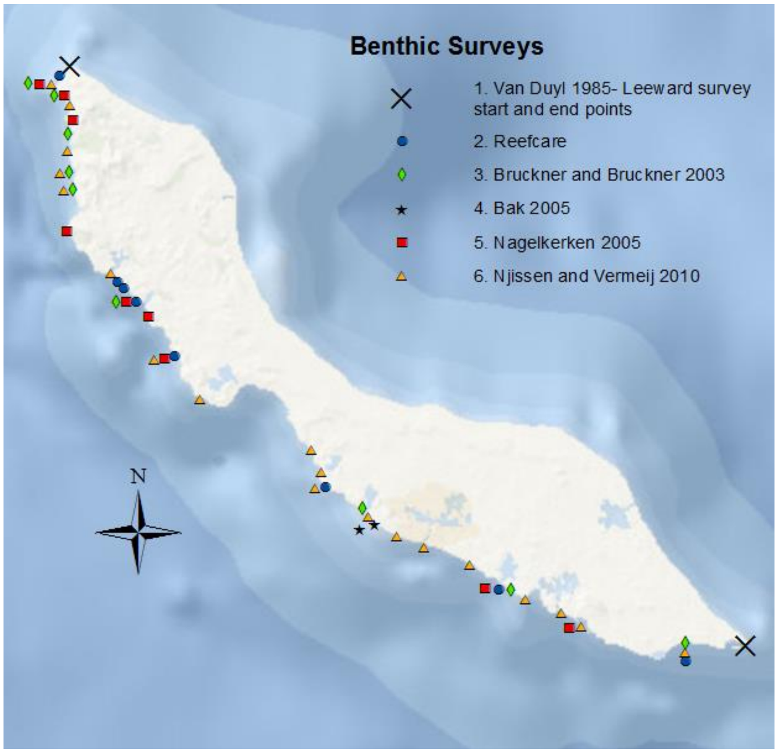

Figure 2. *Locations of key benthic surveys conducted in Curaçao. Descriptions of surveys are presented in Table 1.*

4.3. Mangroves

In the late 1990s, an estimated 55 ha of mangrove habitat covered the coastline of Curaçao (Nagelkerken et al. 2001; Pors and Nagelkerken 1998), less than half of what existed a century ago (Pors and Nagelkerken 1998). The largest mangrove area is currently found in Spanish Water Bay (FAO 2007), but mangroves are also found along the northeastern and eastern shoreline, and in many of Curaçao's inland bays (FAO 2010). *Rhizophora mangle* is the dominant species, and other species include *Laguncularia racemosa*, *Avicennia germinans*, and *Conocarpus erecta* (Pors and Nagelkerken 1998). Like seagrass, mangroves provide structure and habitat that serve as an essential nursery and juvenile feeding habitat for a number of reef species (Nagelkerken and Van der Velde 2002).

Coastal development has destroyed a large portion of mangrove habitat throughout the Lesser Antilles, including in Curaçao over the last century (Angelelli and Saffache 2013), and continues to be a major threat (FAO 2010). Eutrophication of coastal waters can also damage mangrove habitats (Pors and Nagelkerken 1998).

4.4. Coral Reefs

4.4.1. Corals

Curaçao is surrounded by a narrow fringing reef that occurs between 20 and 250 m from the coast and covers an estimated area of 7.85 km^2 (Vermeij 2012). Differences in oceanographic conditions have resulted in dramatic differences in coral reef structure and abundance on the windward and leeward sides of the island (Duyl 1985). On the windward shore, the narrow shelf, fast water movement, and high wave energy restrict coral to depths greater than 12 m (Duyl 1985). The relatively calm waters on the leeward side have resulted in more developed reefs, with higher coral cover (Vermeij 2012). Here, shallow, fringing reefs slope gradually for 100-140 m distance, and then drop off steeply (at a 45-90° angle) around a 5 -15 m depth (Bak 1977). A gently sloping sandy terrace begins around 50-60 m depth, followed by a second steep drop-off that begins between 80 and 90 m (Duyl 1985; Pors and Nagelkerken 1998).

Over 65 species of corals are found in Curaçao's waters, and live coral cover is currently estimated to be 23.2% on average (Vermeij 2012). In general, coral diversity is highest on the reef slope and decreases quickly with depth below 30-40 m (Bruckner and Bruckner 2003a). A general pattern of vertical zonation of species indicates that species' distributions are influenced primarily by depth and wave energy (Duyl 1985). The most abundant live corals in Curaçao's shallow waters (< 20 m depth) are *Montastraea faveolata*, *M. annularis*, and *M. franksi*. *Montastraea spp*. are stony, reef-building species that provide the structural backbone for Curaçao's shallow, fringing reefs (Bruckner and Bruckner 2003a). The maximum depth that these corals reach is between 80-100 m (Duyl 1985).

Over the last three decades, coral cover, health, and species composition on Curaçao's reefs have changed significantly (Vermeij 2012). Overall, live coral cover has decreased by as much as 24%, and coral reef growth has declined (Bak et al. 2005; Vermeij, 2012). This degradation is most pronounced along the leeward coast of the island, where population densities are high (Bak and Nieuwland1995). *Acropora spp*., a branching coral that once dominated shallow waters, is now only found in a few small patches around the island (Bruckner and Bruckner 2003a; Duyl 1985). In many reef areas, turf algae are now the dominant benthic cover (Sandin et al. 2007; Vermeij 2012)

A number of natural and anthropogenic events have influenced the changes in Curaçao's reefs since the 1970s (Figure 3). In 1980, a white-band disease outbreak caused a major die-off of the dominant *Acropora spp.* (Vermeij 2012). A recovery of *Acropora spp.* has not occurred and has likely been hindered by a population explosion of *Stegastes planifrons. S. planifrons* garden turf algal 'yards' for a food source and often kill live coral to maintain and expand their algal yards (Vermeij 2012). Furthermore, in 1983, there was a Caribbean-wide die-off of *Diameda* urchins, an important grazer in coral reef ecosystems (Debrot and Nagelkerken 2006).

Branching shallow water corals on the leeward coast have also sustained significant damage from waves generated by hurricanes and tropical storms (Bruckner and Bruckner 2003a; Van Veghel and Hoetjes 1995). While hurricanes and tropical storms typically pass within 200 km of Curaçao every four years, rare west-to-east moving hurricanes damage Curaçao's leeward reefs, causing fragmentation, tissue damage, and even toppling of massive coral colonies (Bries et al. 2004; Meteorological Service Netherland Antilles and Aruba 2010). Severe tropical cyclones have historically hit Curaçao about once every hundred years, but this incidence may increase with climate change, leading to more frequent damage to coral reefs (ECLAC 2011). Several major bleaching events have also impacted corals in Curaçao; the largest in 2010 killed an estimated 1% of Curaçao's live reef (Vermeij, 2012).

Coastal development, pollution in freshwater runoff and outflow, and overfishing are the major factors responsible for the decline of Curaçao's coral reefs over the last 30 years (Bouchon et al. 2008; Vermeij 2012). Coastal development has resulted in sedimentation of corals, blocking out the light they require for photosynthesis. Development has also caused direct physical damage to reefs in some areas (Vermeij 2012). Freshwater runoff and outflow can result in eutrophication, where high nutrient levels in the water stimulate algae and plankton growth that reduce light availability. In coral reef areas where eutrophication has occurred, conditions allow turf algae to grow over and out-compete coral (Sandin et al. 2007). This has occurred to coral reefs in Curaçao in close proximity to or down current of sewage outfalls (Lapointe and Mallin 2011). Overfishing of grazers and the die-off of *Diadema*, which have both historically restricted algal growth, have likely exacerbated the problem (Vermeij 2012).

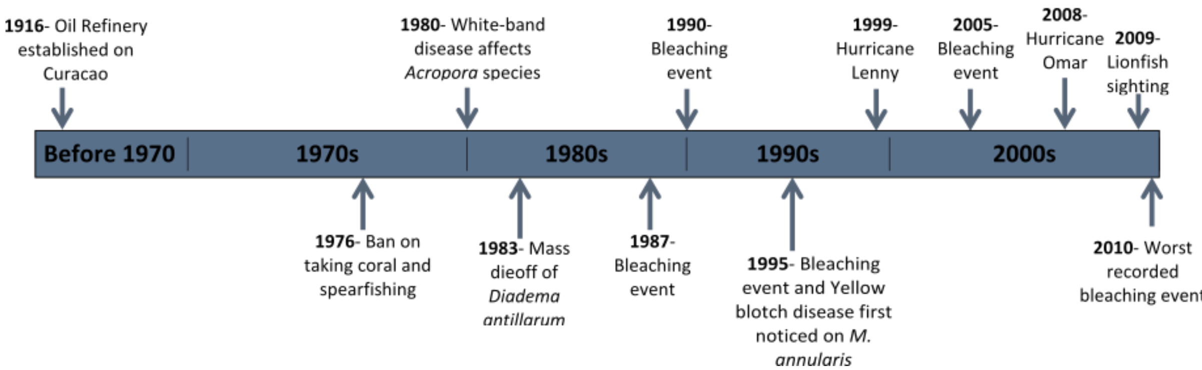

Figure 3. *Timeline of major natural and anthropologic events that have impacted coral reef habitats in Curaçao.*

Although coral cover has declined substantially over the last three decades, Curaçao still harbors some of the best reefs in the Caribbean region(Bouchon et al. 2008; Sandin et al. 2007; Vermeij 2012). In many areas, coral cover exceeds 30%, higher than the Caribbean-wide average of 20% (Jackson et al. 2014). Coral reefs at Westpunt and Oostpunt, far removed from coastal development, demonstrate continued coral growth, and in some areas coral cover is as high as 70% (Vermeij 2012).

4.4.2. Coral Reef Fish

The diversity, abundance, and size of ecologically important reef-associated species on Curaçao's leeward reefs are generally low (Bruckner and Bruckner 2003b). Average biomass of reef fish on Curaçao's leeward reefs is 67 g/m^2, and ranges from 30 g/m^2 to 118 g/m^2, depending on the location (Bruckner and Bruckner 2003b). Fish biomass appears to be associated with reef habitat quality and proximity to development (Vermeij and Nijssen

Table 2. *Summary of major fishery-independent surveys conducted on Curacao's coral reefs.*

Survey Type	Study	Time Period	Survey Description	# of Sites Surveyed
Fishery-Independent Surveys	Nagelkerken et al. 2005	1973-2003	Fish counts of grouper species using transects to estimate density	9
	Nagelkerken et al. 2001	1998	Fish counts using visual census and beach seines in Curacao's bays to estimate density	11
	Bruckner and Bruckner 2003	1998	Fish counts using transects to estimate density	4
	Nagelkerken et al. 2002	1999-2000	Fish counts using a point-count method to estimate density	4
	Sandin et al. 2008	2007	Fish census using quadrats to estimate density	5
	Johnson 2010	2008	Fish trap surveys to determine composition and weight of catch	3
	Vermeij and Nijssen 2011	2010 and 2014	Fish counts using transects to estimated density	20

2011). Small herbivores account for 42.8% of reef fish biomass, comprising primarily grunts, parrotfish, surgeonfish and butterfly fish with lengths between 15-25 cm (Bruckner and Bruckner 2003b; Vermeij and Nijssen 2011). Commercially valuable reef fish species account for only 4% of total fish biomass (Vermeij 2012). Moray eels (*Muraenidae spp*.) are the dominant predator on many reefs (Johnson 2011). Apex predators are largely absent, making up only 5.8% of total reef fish biomass (Sandin et al. 2007; Vermeij and Nijssen 2011).

The degradation of coral reef, mangrove, and seagrass habitats has negatively impacted reef fish biomass (Nagelkerken and Van Der Velde 2002). The die-off of *Acropora*, which provided important habitat and structure for many reef species, has led to an estimated 67% decline in fish biomass and a loss of one-third of species diversity (Vermeij 2012).

Another threat to reef fish biomass and diversity is the invasion of lionfish (*Pterois volitans*). In October 2009, the first lionfish was observed in Curaçao's waters, and lionfish quickly spread along the island's western coast. This is potentially a major threat to Curaçao's coral reef ecosystems because lionfish can reduce the abundance of small reef fish by an estimated 80% (Vermeij 2012). In 2012, the Lionfish Elimination Team was established to help with eradication efforts through spearfishing (LET 2011).

4.5. Water Quality in Marine Ecosystems

Water quality on Curaçao's leeward coast, around the populated city of Willemstad, is significantly impacted by land-based nutrient pollution (Gast et al. 1999; Lapointe and Mallin 2011; Wieggers 2007)Sewage, industrial effluents, oil, and storm water are discharged into Schottegat and Spanish Water Bay (see Figure 1), and carried out to the ocean during tidal fluxes (Gast et al. 1999; Lapointe and Mallin 2011). Reefs in close proximity and down current of these areas are degraded, have exceeded eutrophication thresholds, and are dominated by macroalgae, an indicator of nutrient pollution (Lapointe and Mallin 2011).

Inadequate wastewater treatment is a major cause of Curaçao's poor coastal water quality near populated areas (van Buurt 2002). Only about 40% of the population is connected to the sewage system, which does not always function correctly and has limited capacity (Van Buurt 2002). Thus, discharged sewage is often not adequately treated (Gast et al. 1999). Pipe breaks and overflows during the rainy season are also common, resulting in raw sewage being dumped into the ocean (Gast et al. 1999; van Buurt 2002). Approximately 12 sewage discharge sites are found in or around Schottegat Bay, and high levels of nitrates, bacteria, and phytoplankton are found in waters up to 10 km downstream of the bay (Wieggers 2007). At Town Reef, fecal matter and high bacteria levels have been found in water samples, indicating sewage contamination (Gast et al. 1999). At Piscadera Bay, a broken pipe has frequently discharged raw sewage, resulting in high concentrations of nutrients (Wieggers 2007). The other 60% of the populatio n uses septic tanks. Curaçao's porous limestone structure allows sewage in septic tanks to seep into groundwater, some of which eventually makes it out to sea (van Buurt 2002).

The Royal Dutch oil refinery was established in Curaçao in 1918 after the discovery of oil off the coast of Venezuela. The refinery was built in Schottegat Harbor, and was the largest refinery in the world at that time. In the past, the refinery has not been required to comply with environmental standards or permitting requirements (Wetzel and Pulster 2010). Frequent spills have resulted in oil slicks over the water and tar-covered shores in Schottegat, Caracas and Bullen Bays (Govers et al.,2014). Dumping of waste from the refinery is believed to be responsible for high levels of heavy metals found in some areas (van Buurt 2002). Tar from an oil spill in 1986 was responsible for an estimated 36% decline in mollusc communities in the nearshore environment seven years later (Nagelkerken and Debrot 1996). In 2010, toxic levels of Polycyclic Aromatic Hydrocarbons (PAHs) were found in the sediments of Schottegat and Caracas Bays, indicating oil contamination (Wetzel and Pulster 2010). The long-term impacts of PAHs on Curaçao's marine ecosystems have not been well studied. A 2012 report on the sustainable future of Curaçao by Beumer et al. 2012 concluded that the current oil refinery is outdated and repeatedly exceeds international environmental standard emissions. For oil refinery activities to continue a new refinery needs to be built or the current refinery needs to be drastically updated (Beumer et al. 2012).

4.6. Threatened and Protected Species

Forty-one species of concern on the IUCN Red List are found in Curaçao's waters, including four species classified as critically endangered and seven species in the endangered category (Table 2). Nine fish and shark species are listed as threatened, and another 21 species of sharks, fish, turtles, and corals are listed as vulnerable.

4.6.1. Turtles

Curaçao is an important nesting and feeding ground for loggerhead (*Caretta caretta*), hawksbill (*Eretmochelys imbricata*), and green (*Chelonia mydas*) sea turtles (Debrot

Table 2. *IUCN list of critically endangered and endangered species found in Curaçao's waters.*

Species	Common Name	IUCN Red List Status
Acropora cervicornis	Staghorn coral	Critically Endangered
Etermochelys imbricata	Hawksbill turtle	Critically Endangered
Pristis pectinata	Smalltooth sawfish	Critically Endangered
Epinephelus itajara	Atlantic goliath grouper	Critically Endangered
Millepora striata	Fire coral	Endangered
Montastraea annularis	Boulder star coral	Endangered
Montastraea faveolata	Mountainous star coral	Endangered
Caretta caretta	Loggerhead turtle	Endangered
Chelonia mydas	Green turtle	Endangered
Sphyrna mokarran	Squat-headed hammerhead shark	Endangered
Epinephelus striatus	Nassau grouper	Endangered
Thunnus thynnus	Atlantic bluefin tuna	Endangered
Anguilla rostrata	American eel	Endangered
Balaenoptera borealis	Sei whale	Endangered

and Pors 1995). Leatherback (*Dermochelys coriacea*) and olive ridley (*Lepidochelys oliveacea*) sea turtles are also found in Curaçao's waters. Prior to major development, the island's large, sandy southwest beaches were turtle nesting sites (Debrot et al. 2005). In the 1960s and 1970s, over 100 sea turtles were landed annually by fishermen and processed at a local turtle slaughterhouse (Sybesma 1992). By the 1980s, sea turtle populations around Curaçao were believed to be overexploited. In 1985, CARMABI partnered with the Wider Caribbean Sea Turtle Recovery Team and Conservation Network (WIDECAST) to formulate a Sea Turtle Recovery Action Plan, which included basic data collection (Sybesma 1992). In 1992, a law was passed that prohibited the taking of sea turtles in the Exclusive Fishing Zone of the Netherlands Antilles (Vermeij and Chamberland 2012). In 1998, Curaçao's Reef Management Ordinance prohibited the taking, selling, or possessing of dead or live sea turtles or sea turtle eggs (Vermeij and Chamberland 2012)

Today, most turtle nesting areas are found on small beaches along the northeast coast, away from development and human impact (Debrot and Pors 1995). In 2004, several turtles were observed nesting on a southwest beach, suggesting turtle nesting may recover there (Debrot et al. 2005). Although demand for turtle meat is not high, at least one dealer is known to sell turtles that are illegally imported from Venezuela (BOI 2006; Sybesma 1992). Sea turtles were given additional protection in 2014, when the use of gill nets was banned and new Ramsar (wetland conservation) sites containing sea turtle habitat were established (DCNA 2014). A new turtle monitoring program was also launched by WIDECAST (DCNA 2014).

4.6.2. Sharks and Rays

There are 27 species of elasmobranchs found in Curaçao's waters (Van Beek and Graaf 2014). Despite this diversity of species known to occur in Curaçao's waters, sharks are practically absent from the reefs, leading some observers to the conclusion that historic overfishing has led to the functional extirpation of sharks in the area (Sandin et al. 2007). Nevertheless, local sport fishing and diving companies advertise the presence of sharks to potential customers. There is no targeted fishery for sharks in the Dutch Caribbean, but they do occasionally occur as bycatch in artisanal fisheries (BOI 2006). The Dutch Caribbean Nature Policy Plan 2013-2017 called for the implementation of shark protection in the Dutch Caribbean Exclusive Economic Zone (Van Beek and Graaf 2014).

4.6.3. Whales and Cetaceans

The most commonly sighted whales in Curaçao are the Bryde's whale, *Balaenoptera edeni,* and the shortfin pilot whale, *Globicephala macrorynchus* (Debrot et al. 1998). Other species of cetaceans found in Curaçao's waters include: dwarf sperm whale (*Kogia sima*), humpback whale (*Megaptera novaeangliae*), Antillean beaked whale (*Mesoplodon europaeus*), killer whale (*Orcinus orca*), sperm whale (*Physeter microcephalus*), striped dolphin (*Stenella coeruleoalba*), spinner dolphin (*Stenella longirostris*), pan-tropical spotted dolphin (*Stenella* *attenuate*), bottlenose dolphin (*Tursiops truncatus*), and the goose beaked whale (*Ziphius cavirostris*). Fishing for marine mammals is forbidden without a permit from the government; this permit is only granted for scientific or educational purposes (BOI 2006). In 2002, ten captive dolphins were imported to Curaçao from Honduras and the Dolphin Academy's Swim with Dolphins program was established as a tourist activity (BOI 2006).

4.6.4. Queen Conch

Queen conch, *Strombus gigas*, have been severely depleted in Curaçao (van Buurt 2001). Illegal fishing of juvenile conch is thought to be responsible for the decline, and adult conch are rarely seen (van Buurt 2001). Queen conch meat consumed in Curaçao is imported primarily from Venezuela, where conch fishing is illegal but still occurs (van Buurt 2001).

5. Seafood Production

5.1. Fisheries

5.1.1. Fisheries Description

Almost all fishing that occurs around Curaçao is artisanal, and except for the transition from sails to motors, little has changed from fishing methods described in 1907 (Leenstra 2005). Curaçao's fisheries can be broadly categorized into two classes: reef fisheries that primarily target demersal species, and trolling fisheries that target pelagic species (LVV 2003). A few vessels have also operated north of Curaçao in the Exclusive Fishing Zone (EFZ) waters, but are not currently in operation (Schultink and Lindenbergh 2006; Lindop et al. 2015)
There are 15 main fish landings sites; the largest is Caracas Bay, accounting for up to 40% of total catch (Figure 4) (Dilrosun 2002). Total annual landings from Curaçao's's fishery sector

***Table 3**. Description of fishery-dependent studies conducted in Curacao. Locations of surveys are presented in Figure 4.*

Survey Type	Study	Time Period	Survey Description	# of Sites Surveyed
Fishery-Dependent Surveys	1. Department of Agriculture, Marine Cultivation and Fisheries (LVV) 2003	May 2002-May 2003	Fishing ports were monitored 23 days per month. Days allocated to monitoring each port were proportionate to landings.	15
	2. Leenstra 2005	Sept. 2004- May 2005	Recorded landings, CPUE, and species composition for 171 fishing trips. Also collected life history information on the graysby and coney grouper	5
	3. Department of Agriculture, Marine Cultivation and Fisheries (LVV) 2006	May 2005- October 2006	Surveyed ~1500 trips in Caracas Bay	2
	4. Schultink and Lindenbergh 2006	Feb. 2006- May 2006	Recorded reef landings and species length at 1-2 daily. Collected data from 116 trips in total	5

Figure 4. *Fishery landing sites in Curaçao. Numbers in parenthesis correspond to studies listed in Table 4*

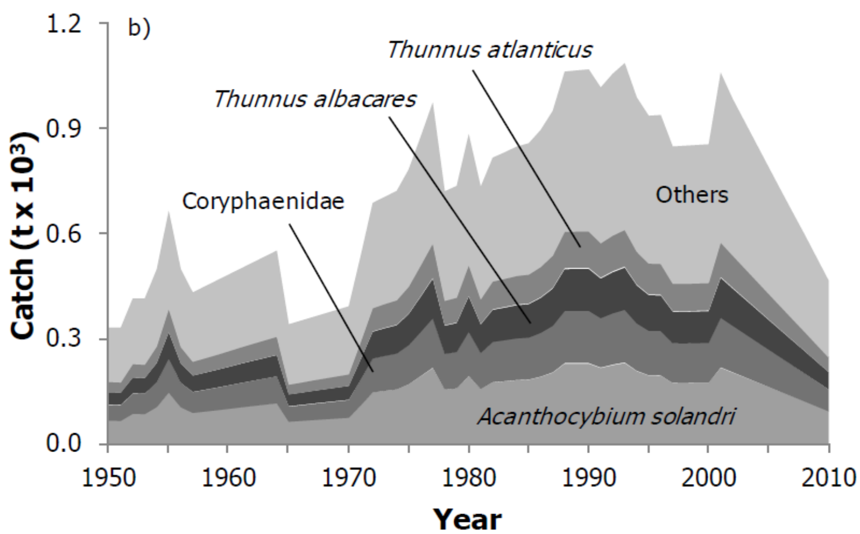

Figure 5. *Reconstructed Curaçao fishery landings from 1950-2010. Figure and estimated reconstruction from Lindop et al. 2015*

are estimated to be between 900-1200 tons (van Buurt 2001).

No long-term catch monitoring system currently exists in Curaçao, so a time series of catch is not available. Fishery landings reported to the FAO are estimated based on the number of observed vessels (van Buurt 2001) and were combined with fishery landings from all islands in the Netherlands Antilles until 2011. Several short-term catch monitoring programs have occurred from 2000-2006 (Table 3; Figure 4). Using population data and data from monitoring programs, Lindop et al. (2015) applied an extrapolation technique to reconstruct an estimate of Curaçao's historical catch (Figure 5).

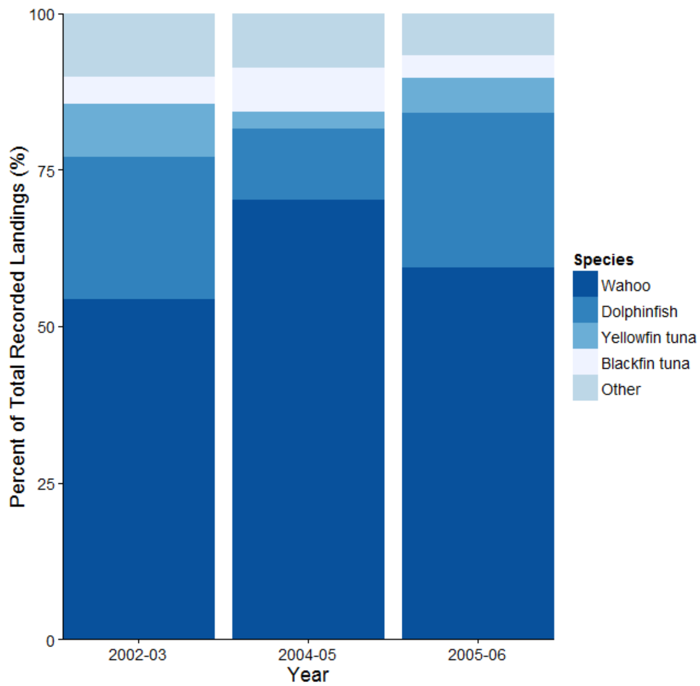

Figure 6. *Summary of pelagic landings by species based on monitoring results from LLV 2003, Leenstra 2006, and LLV 2006*

In general, the number of fishers participating in Curaçao's fishery has declined over the last 50 years (Johnson 2011). In 1959, there were 632 fishers and 332 boats participating in Curaçao's fishery. In 2002, there were 435 fishing vessels present in Curaçao's harbors, but only 111 were active in the fishery (Dilrosun 2002). The vast majority of fishing vessels remained unused because of mechanical or financial problems, migration of the owner, or other issues. High fuel prices and increased import duties on engines and parts, combined with low import duties on imported fish, contribute to fishers' financial difficulties, and are one of the main reasons why many fishers have migrated to the Netherlands, leaving boats unused (Dilrosun 2002). Of the 111 vessels in use in 2002, an estimated 44 were full-time, while the rest were operated by part-time or opportunistic fishers.

The troll fishery, targeting pelagic species, accounts for the majority (~70%) of landings (Dilrosun 2002). Vessels in this fishery are typically 7-12 m in length, and have inboard diesel engines. The relatively large vessel size allows them to fish in Curaçao's rough, northern waters, the waters off Klein Curaçao and Bonaire, and the open sea. In 2000-01 there were an estimated 164 active trolling vessels (LVV 2003). Trolling lines and hand lines are the most commonly used gear. The largest portion of landings from the troll fishery is landed at Caracas Bay (43.4%), followed by Westpunt (20.6%), but pelagic species are landed at all fishery landing sites.

The composition of species landed in the troll fishery is highly seasonal, but appears to have remained constant over the last decade (Dilrosun 2002). Wahoo (*Acanthocybium solandri*) and dolphinfish (*Coryphaena hippurus*) accounted for at least half of the observed troll fishery landings between 2002-2006 (LVV 2003; Leemstra 2005; LVV 2006) (Figure 6). Both of these species receive an average value of 13.50 NAf/kg (van Buurt 2004). There is little distinction between bycatch and target species in the troll fishery because even bycatch species receive a reasonable price (LVV 2003). Less desired species that are often landed include shark, tuna, and marlin (Dilrosun 2001; Figure 6).

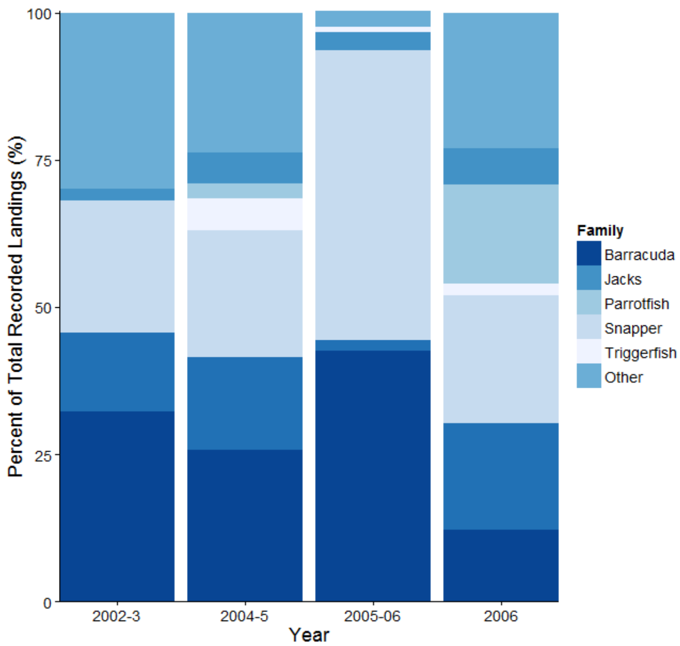

Figure 7. *Summary of reef fishery landings by major family/species from monitoring studies presented in Table 3.*

The reef fishery in Curaçao accounts for a much smaller portion of the catch (~10-15%) (Leenstra 2005). Fishing occurs mainly along the calm waters of the south shore due to the limited capacity of the small (<7m) vessels. In 2002-2003 there were an estimated 258 fishing vessels participating in Curaçao's reef fisheries (LVV 2003). The largest portion of landings from the reef fishery is landed at Westpunt, followed by Santa Cruz and Boca Sint Michiel (LVV 2003). Reef fish are also landed at Lagun Bay, Playa Kanoa, Jeremi Bay, and Caracas Bay OV (LVV 2003). The most commonly used gears are handlines, accounting for ~ 85% of the observed catch, and traps, which account for the remaining ~ 15% (Schultink and Lindenbergh 2006). Although spearfishing and gillnets are banned, some fishers still participate in this activity because regulations are not well enforced (van Buurt 2001).

Although vessels in the reef fisheries primarily target demersal species, up to 50% of landings are often pelagic reef fish caught with handlines (Schultink and Lindenbergh 2006). The species composition of landings likely fluctuates seasonally and by fishing location (Schultink and Lindenbergh 2006). For example, in November, there is typically a large increase in blackfin snapper landings (Leenstra 2005). The top landed species or families landed in Curaçao's reef fisheries from 2002-2006 are presented in Figure 7. Barracuda, yellowtail and blacktail snappers have consistently comprised a large portion of observed landings over the last decade. Groupers (Serranidae) command the highest price of 15.50 NAf/kg and red snapper (*Lutjanus buccanella*), one of the best-selling species, sells for 13 NAf/kg (van Buurt 2004).

5.1.2. Fisheries Importance

Although the fisheries sector contributes <1 % to Curaçao's national GDP, it provides an important source of protein and income for a relatively large number of Curaçao's residents (Van Buurt 2000). In 2001, an estimated 183 people relied on the fishing industry for full time employment (Dilrosun 2002). The average fisher in Curaçao is 49 years old and because most have been fishing their whole lives, finding employment in other sectors may not be an option (van Buurt 2001; Johnson 2011). Additional jobs related to the fishery sector in Curaçao include: boat builders (90% are manufactured locally), gear sellers, service trailer and crane hire companies, and work relating to the infrastructure of fishing ports (LVV 2003).

There is a large demand for seafood in Curaçao (van Buurt 2001). In 2007, Curaçao's per capita seafood consumption was estimated at 20.8 kg per capita, compared to a global per capita fish consumption of 17.7 kg, and of 9.5 kg in the Caribbean (FAO 2010). In an effort to increase fishery landings to meet this demand, in 1995, the government funded the installation of 5 fish aggregation devices (FADs) to increase efficiency and landings of the trolling fishery, but their effectiveness is not unknown (Van Buurt 2000). A large number of reef fish found in restaurants and grocery stores are imported from Venezuela, and are typically much cheaper than locally caught fish (Dilrosun 2002; BOI 2006). The total value of fishery imports to Curaçao in 2012 was $130,000 USD (FAO 2012).

Table 4.*Reef species that used to be abundant in catch and are now rarely seen (Schultink and Lindenbergh 2006).*

Species name	Common Name
Dermatolepis inermis	Marbled grouper
Epinephelus itajara	Atlantic goliath grouper
Epinephelus niveatus	Snowy grouper
Epinephelus striatus	Nassau grouper
Lachnolaimus	Hogfish
Lutjanus analis	Mutton snapper
Lutjanus cyanopterus	Cubera snapper
Scarus guacamaia	Rainbow parrotfish
Pagrus pagrus	Common seabream

Despite a high demand for seafood, a portion of pelagic landings are exported because they typically receive a higher value in other countries than they would receive at local markets (van Buurt 2001). Curaçao's exports in 2012 were valued at $305,000 USD (FAO 2012). Currently, Curaçao exports pelagic fish to EU countries. However, in 2014 the EU issued a warning ('yellow card') that they will ban fishery imports from Curaçao if the country does not increase cooperation to end illegal fishing (Amigoe 2014). All seafood exported to the EU must be certified from the exporting country as legally landed by a vessel from the exporting country in appropriate waters, and the current monitoring system in Curaçao is not adequate to assure all exported landings are legal.

5.1.3. Fisheries Status, Management, and Development

Fishery data are difficult to collect in Curaçao because of the large number of small vessels using a large number of ports over a large geographic area (Dilrosun 2002). The lack of data makes it difficult to formally assess the status of Curaçao's fisheries with certainty. However, a study on Curaçao's reef fisheries in 2006 found clear indicators that overfishing has occurred (Schultink and Lindenbergh 2006). A number of high value species that used to be landed frequently are now rarely seen (Table 4) (Schultink and Lindenbergh 2006). The lack of large predatory fish observed in a number of fishery-independent surveys over the

Table 5. *Current fishery regulations in Curaçao's (Vermeij and Chamberland 2012)*

Target of Regulations	Regulations
Fishing Permits	Only required for vessels that are >12 m in length, or that weight more than 6 tons, or deploy more than 4 fishing lines
Gear Restrictions	Fishing with drag nets, spears, harpoons, quinaldine, and explosives is prohibited. Fish traps must have a mesh size greater than 38 mm and an escape opening that is at least 20 x 2.5 cm and made of biodegradable material
Spatial Gear Restrictions	In waters 60 m or less fishing with gill nets and trammel nets is forbidden without a permit. In areas from Watamula to Oostpunt bottom longlines and beach seines are forbidden
Marine Mammals	Fishing for marine mammals is forbidden and using bait derived from marine mammals is also forbidden
Turtles	Catching of turtles or turtle eggs is forbidden
Lobsters	Egg-bearing lobsters and lobsters that are molting may not be landed
Corals	Taking or possessing of corals is forbidden

last decade also indicates that Curaçao's reefs have been overfished (Bruckner and Bruckner2003b; Sandin et al. 2007). Experienced fishers interviewed in 2010 noted that catch rates and individual sizes of fish have declined substantially in recent years, and that many species that were once abundant in catches are now absent (coneys, groupers, lobsters) (Johnson 2011).

The extrapolated time series of catch, which comprises primarily pelagic species, shows a sharp decline after 2000 (Figure 5). The reason for this decline is likely decreased effort and participation in the fishery (Lindop et al. 2015). High fuel prices and import taxes on fishing gear over the last 15 years have resulted in many fishers dropping out of the fishery sector (Dilrosun 2002). The most recent assessments on the Caribbean-wide stocks of the top two landed species, wahoo and dolphinfish, are associated with large uncertainties regarding life history and stock structure. Specifically, the western Atlantic stock of wahoo may be overfished but results are highly uncertain (George et al. 2000) and the western Atlantic stock of dolphinfish is neither overfished nor experiencing overfishing (Kleinsner 2008). Current fishing regulations are listed in Table 5 but are not well enforced.

5.2. Marine Aquaculture

In the 1950s, CARMABI was established as an aquaculture research facility to help investigate and establish aquaculture in the Netherlands Antilles. In the 1960s, this idea was abandoned and the center began focusing primarily on coral reef research (Hensen 1987). Currently no significant aquaculture production occurs on Curaçao.

6. Tourism

6.1. Trends and Contribution to GDP

Tourism is an important and rapidly growing component of Curaçao's economy. In 2004, tourism accounted for 10.5% of the island's GDP; in 2009, it was more than 18.5% of the GDP, with projections of a 28% contribution to GDP by 2014. The numbers of stay-over arrivals has increased from 2003 to 2013 (Table 6). The growth of the tourism industry has helped Curaçao reduce its economic reliance on financial services and the oil sector (Halcrow 2010).

In addition to stay-over tourists, Curaçao is receiving increasing numbers of excursionists (day trippers), cruise ship visitors, and yachters (Table 6). The numbers of cruise ship calls and cruise ship passengers, as well as the size of visiting cruise ships, are all increasing (Halcrow 2010).

Table 6. *Curaçao tourism data from Halcrow 2010; Curaçao Tourism Board*

Category	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Stay-over tourists	221,400	223,500	222,100	234,400	299,700	408,800	366,800	341,651	390,282	419,810	440,714
Excursionists	7,400	9,700	12,300	16,000	23,200	14,100	40,500	n/a	n/a	n/a	n/a
Cruise ship visitors	278,100	227,500	276,500	323,500	340,900	352,800	423,100	n/a	400,850	431,555	n/a
Yachting visitors	1,100	1,100	1,500	2,000	2,250	2,500	n/a	n/a	n/a	n/a	n/a

Over one-third of stay-over visitors in Curaçao come from the Netherlands. The other major markets are the US, Venezuela, other European countries, and other Caribbean countries. Most day-trippers come from Aruba, Venezuela, or Suriname. 93% of stay-over visitors come for vacation, and in 2006, tourists spent an average of US$147.00 per person per day. The tourism industry was hurt by the 2008 recession, especially as the number of visitors from Venezuela declined steeply (Halcrow 2010).

Curaçao's main tourist attractions are its beaches and water sports. Curaçao's strengths as a tourist destination include interesting reefs, beaches, and scenic areas. Threats to Curaçao's tourism industry include air and water pollution (including sewage), uncontrolled development, impacts from tourism, climate change, and reef degradation. Climate change is expected to negatively impact Curaçao's tourist industry through beach erosion, increased intensity of storms and hurricanes, summer droughts, coral bleaching, and reduced fish productivity (Halcrow 2010; ECLAC 2011).

The increase in tourism has led to increased environmental degradation, particularly through the impacts of the hotel industry, resulting in more solid waste sent to landfills; more demand for potable water; the creation of artificial beaches, which increase sedimentation and harm reefs; and increased production of wastewater. Because Curaçao does not have an island-wide sewage system, some hotels rely on septic tanks, which are susceptible to leaking (Dinica 2006).

6.2. Dive Tourism

Curaçao is a popular destination for dive tourism due to its consistently warm water temperatures, excellent visibility, and high quality reefs. Dive magazines rate Curaçao as one of the best Caribbean islands for diving and snorkeling. There are a total of 80 dive sites around the island, six of which are ranked among the best in the world. Almost all the dive sites are easily accessible, with the reefs located close to shore; shore diving is very popular (Halcrow 2010). There are 26 principal dive sites around the island (Figure 8). The Curaçao Tourism Board's website lists eighteen dive operators on the island, but this list is not comprehensive.

Figure 8. *Popular dive sites in Curacao. Figure from Halcrow 2010*

In 1995, a proposal for a dive improvement program was drafted by the Curaçao Tourism Development Board, but it has not yet been implemented completely (Halcrow 2010). In order to improve the quality of dive tourism in Curaçao, the island needs better management and monitoring of its marine resources, a culture of proper diving etiquette to protect reefs from diving impacts, assessment of the carrying capacity of beaches and dive sites, increased public awareness about conservation and the need to protect sensitive areas, improved waste management and infrastructure, and improved fisheries management. Specifically, the Curaçao Tourism Board's Strategic Tourism Master Plan for 2010-2014 called for the implementation of marine protection legislation to protect the Curaçao Marine Park and extend its boundaries, the introduction of a dive tag scheme whereby divers would pay a fee for the privilege of diving in Curaçao, better management and monitoring of reefs, improved regulation of the dive industry, and the creation of a marine park visitor center (Halcrow 2010). Curaçao had a dive tag program run by the Curaçao Hotel and Tourism Association in the 1990s, but it was unsuccessful, potentially due to its private sector leadership (de Groot and Bush, 2010).

Inexperienced or inattentive divers can cause damage to coral reefs (Dinica 2006). In response to this threat and the reality of limited marine protection in Curaçao, some dive operators in Curaçao are actively involved in marine conservation. For example, Easy Divers, based at Habitat Dive Resort, has established an unofficial marine protected area at the reef on which they dive (their "house" reef). Through private regulations and company standards, Easy Divers has asserted unofficial control over the house reef, establishing an entrepreneurial marine protected area (EMPA). Easy Divers' conservation measures include a mooring system to prevent anchor damage and a voluntary dive tag system through which customers pay a fee that goes to a local NGO's research and monitoring work. Furthermore, Easy Divers requires all of its customers to participate in an orientation program on proper diving practices. While Easy Divers has no legal authority to exclude divers who do not follow their rules, they can deny divers access to the beach that provides an entry point to the house reef (deGroot and Bush 2010).

6.3. Sport Fishing

Sport fishing is a popular activity in Curaçao, mostly targeting pelagic species such as marlin, tuna, and wahoo (F. Dilrosun, personal communication). Since 1966, the Curaçao Yacht Club has hosted an annual fishing tournament. There a number of charter boat operators who offer day trips to visitors. The Curaçao Tourism Board lists seven sport fishing operators on its website, although this list is not comprehensive. Shore fishing is also a popular recreational activity.

6.4. Other tourist ocean-related activities

In addition to diving and sport fishing, snorkeling, swimming, and yachting are popular tourist activities. Curaçao has about fifty beaches, the majority of which are open to the public for swimming and snorkeling. Dive magazines have highlighted the quality of Curaçao's snorkeling (Halcrow 2010). Other water sports are also popular in Curaçao, including kayaking, windsurfing, kite surfing, and boating (Dinica 2006). Curaçao receives at least 1000 yacht visitors per year and hopes to increase this number through increased moorings and berths, as well as management plans for its inland bays (Halcrow 2010). Lastly, Curaçao's northern coastline is also a tourist attraction: tourists visit Shete Boka National Park to see the rugged, undeveloped coastline (Halcrow 2010).

7. Other Ocean Uses

7.1. Shipping Lanes

The main shipping port in Curaçao is in Willemstad, out of Schottegat Bay. This port has multiple connections to the Caribbean region as well as South, Central and North America and the European Union. Smaller commercial ports are also located in Bullen Bay, Caracas Bay, Fuik Bay, St. Michiels Bay, and Spanish Water.

7.2. Oil Platforms/Refineries

Curaçao's naturally deep harbors have made it an ideal site for oil refineries and the docking of oil platforms. In the 1920s Royal Dutch Shell constructed Isla Refinery in Curaçao's Schottegat Bay. It is still in use today and produces approximately 320,000 barrels a day. It has not been required to comply with environmental standards because of inadequate enforcement (Wetzel and Pulster 2010). Beaches around the bay and in other areas of the island are often covered in tar, and oil slicks can be found in mangrove areas of the bay (Debrot et al. 1995; Wetzel and Pulster 2010).

8. Conservation Efforts

There are currently no no-take zones in Curaçao's waters, but the government does have the authority to establish them (Vermeij and Chamberland 2012). The Curaçao Underwater Park was established in 1983 off of Curaçao's southwest coast. It stretches along 20 km of shore and includes depths up to 60m. It contains 600 ha of fringing reefs and 436 ha of inland bays containing mangrove and seagrass habitat. The CARMABI research station is responsible for the park's management and has prohibited the collecting of coral and spearfishing within the park (Relles 2012). However, due to lack of resources for enforcement, the park has largely failed to meet its objectives of reef conservation and management, and coral cover inside the park is not higher than in unprotected areas (Relles 2012; Vermeij and Chamberland 2012).

Eastpunt is a large (60 km^2) uninhabited area on the eastern tip of Curaçao that contains inland bays, seagrass, mangroves, and coral reef habitats. The area is owned by one person, and due to lack of development and access, the habitats in this area are relatively pristine. Off the coast of this area, coral cover is on average 50%, *Diadema* urchins have started to reappear, and the inland bays contain some of the highest densities of seagrass in the whole Caribbean and serve as an important feeding area for sea turtles(Dinica 2006).This area is not deliberately protected and proposals to develop the area have been presented.

As part of the Kingdom of the Netherlands, Curaçao is party to the Convention on Biological Diversity, the Convention on International Trade in Endangered Species (CITES), the Convention for Migratory Species, the Cartagena Convention for the Protection and Development of the Marine Environment of the Wider Caribbean Region, the Protocol concerning Specially Protected Areas and Wildlife (SPAW), and the Inter-American Convention for the Protection and Conservation of Sea Turtles (Meesters et al. 2010). Curaçao has twelve wetland areas designated as Ramsar sites, sites that include wetlands of international importance under the Ramsar convention (BOI 2006). Curaçao is also a party to the United Nations Convention on the Law of the Sea, the UN Convention for

Conservation and Management of Straddling Fish Stocks and Highly Migratory Fish Stocks, and the FAO's Code of Conduct for Responsible Fisheries.

Curaçao is not currently a member of the Caribbean Regional Fisheries Mechanism, but it submitted an application for associate membership in April of 2014.

9. Key Researchers and Organizations

Curaçao Government (http://www.gobiernu.cw/ - written in Papiamentu)

- Ministry of Public Health, Environment, and Nature (http://www.gobiernu.cw/web/site.nsf/web/6F7D88F9166D819B042578570056602 5?opendocument)
- Mr. Gerard van Buurt – Head of Fisheries and Nature Division, Agriculture and Fisheries Service in 2002 (gvbuurt@dlvv34.gobiernu.com)
- Faisal Dilrosun – Fisheries Officer, Agriculture and Fisheries Service in 2002 (fdilrosun@yahoo.com)
- Mr. Paul Hoetjes – Senior Policy Advisor at Department of Environment and Nature, Netherlands Antilles in 2002 (paul@mina.vomil.an)
- Mr. Eric Newton – Policy Advisor at Department of Environment and Nature, Netherlands Antilles in 2002 (eric@mina.vomil.an)

CARMABI Research Institute (http://www.researchstationcarmabi.org)
A nonprofit marine research institute that focuses on marine and terrestrial ecological research, nature management of marine and terrestrial parks, environmental education, and public advice and consultancy.

- Dr. Mark Vermeij – Scientific Director (m.vermeij@carmabi.org)
- General inquiries at CARMABI: info@carmabi.org

Netherlands Antilles Coral Reef Initiative (http://www.nacri.org – last updated May 2010)
A group that was formed to bring together organizations, businesses, and agencies involved with coral reefs in the Netherland Antilles to draft action plans to preserve coral reefs in the area. Hosts an information database that contains all reef-related studies on coral reefs in the Netherland Antilles

- General inquiries: nacri@mina.vomil.an

Reef Care Curaçao (www.reefcare.org)
Citizen group formed in 1992 to promote coral reef research and education through monitoring and public outreach events.

- Mr. Dave Kolenouski – Chairman (info@reefcare.org; board@reefcare.org)

Atlantic Gulf Rapid Reef Assessment (http://www.agrra.org)
An international collaboration between scientists and managers aimed at determining the regional condition of reefs in the Western Atlantic and Gulf of Mexico. They conduct

surveys of reef health and have developed a database with assessment results form 39 sites in the region

- General inquiries: Info@agrra.org
- Report on Curaçao's reefs: http://www.agrra.org/ARB_volume/Curaçao's%20Fish4-27-03.pdf (report written by Andrew W. Bruckner [andy.bruckner@noaa.gov] and Robin J. Bruckner)

FORCE Project (http://www.force-project.edu)

- Rosanna Griffith-Mumby - Project Manager (r.griffithmumby@uq.edu.au)
- Ecological surveys of coral reefs

Curaçao Nature Conservation (CUNACO) (http://www.Curaçao'snature.org)
A nature organization focused on youth with the mission to inform, educate, and stop unnecessary nature destruction.

- Francis O'Connor – President

Dutch Caribbean Nature Alliance (DCNA) (http://www.dcnanature.org)
A nonprofit organization created to protect the natural environment and to promote sustainable management of natural resources on the six Dutch Caribbean Islands.

- info@dcnanature.org

Secore Foundation (http://www.secore.org/site/our-work/detail/tourism-and-coral-reefs-in-Curaçao's.26.html)
A nonprofit research organization focused on coral breeding research. One of the leading coral conservation initiatives of scientists and marine aquarists around the world.

- General inquiries: info@secore.org

Curaçao Sea Aquarium (http://www.Curaçao's-sea-aquarium.com/en/)
An aquarium that focuses on educating visitors. They are also involved in research projects on coral reef health, sea turtle conservation, and biodiversity assessments of deep reefs.

- General inquiries: aquarium@cura.net
- Katie O'Fallon: Katie@Curaçao's-sea-aquarium.com
- Steve Piontek: aquasearch@cura.net
- Heleen Visser: heleen@Curaçao's-sea-aquarium.com)

Wider Caribbean Sea Turtle Conservation Network (WIDECAST) (http://www.widecast.org/)
An expert network of biologists, managers, community leaders and educators representing over 40 nations and territories that focuses on an integrated, regional capacity that ensures the recovery and sustainable management of depleted sea turtle populations.

- Sabine Berendse – WIDECAST Country Coordinator, Director of Parks Department at CARMABI (sabine82@yahoo.com)

Natuur en Milieucentrum Curaçao
(http://www.liveincuracao.com/index.php?cat=926)
The NMC is the information center that promotes the sustainable use of Curacao's nature and environment

- General inquiries: velde@cura.net

10. References

Amigoe. (2014). Curacao given more time to combat illegal fishing. Retrieved from: *http://www.amigoe.com/english/189046-curacao-given-more-time-to-combat-illegal-fishing*

Angelelli, P., and Saffache, P. (2013). Some remarks on Mangroves in the Lesser Antilles. *Revista Da Gestão Costeira Integrada*, *13*(4), 473–489.

Bak, R. P. M. (1977). Coral Reefs and Their Zonation in Netherlands Antilles: Modern and Ancient Reefs, *45*, 3–16.

Bak, R. P. M., and Nieuwland, G. (1995). Long-Term Change in Coral Communities Along Depth Gradients Over Leeward Reefs in the Netherlands Antilles. *Bulletin of Marine Science*, *56*(2), 609–619.

Bak, R. P. M., Nieuwland, G., and Meesters, E. H. (2005). Coral reef crisis in deep and shallow reefs: 30 years of constancy and change in reefs of Curacao and Bonaire. *Coral Reefs*, *24*(3), 475–479. http://doi.org/10.1007/s00338-005-0009-1

Beumer, Leo, V., Nol, and de Velde, Ilse van. (2012). *A sustainable future for Curacao-Strategic options for ISLA and the ISLA site. Final Report* (p. 250). Rotterdam/Willemstad: ECORYS.

Blue Ocean Institute (BOI). (2006). *Country Profile: Curacao.* Project Global: Global Bycatch Assessment of long-lived species. pp. 13.

Bouchon, C., Portillo, P., Bouchon-Navaro, Y., Louis, M., Hoetjes, P., De Meyer, K., … others. (2008). Chapter 19. *Status of Coral Reefs of the Lesser Antilles: The French West Indies, The Netherlands Antilles, Anguilla, Grenada, Trinidad and Tobago. Status of Coral Reefs of the World: Global Coral Reef Monitoring and Reef and Rainforest Research Centre*, 265–279.

Bries, J. M., Debrot, A. O., and Meyer, D. L. (2004). Damage to the leeward reefs of Curaçao and Bonaire, Netherlands Antilles from a rare storm event: Hurricane Lenny, November 1999. *Coral Reefs*, *23*(2), 297–307.

Bruckner, A. W., and Bruckner, R. J. (2003a). Condition of coral reefs off less developed coastlines of Curacao(Part 1: Stony corals and algae). *Atoll Research Bulletin*, *496*, 370–393.

Bruckner, A. W., and Bruckner, R. J. (2003b). Condition of coral reefs off less developed coastlines of Curacao(Part 2: Reef fishes). *Atoll Research Bulletin*, *496*, 394–403.

Debrot, A.O., Bradshaw, J.E. & Tiel, A.B. (1995). Tar contamination on beaches in Curaçao, Netherlands Antilles. *Marine Pollution Bulletin*, 30, 689–693.

Debrot, A. O., De Meyer, J. A., and Dezentjé, P. J. E. (1998). Additional records and a review of the cetacean fauna of the Leeward Dutch Antilles. *Caribbean Journal of Science*, *34*, 204–210.

Debrot, A. O., Esteban, N., Le Scao, R., Caballero, A., and Hoetjes, P. C. (2005). New sea turtle nesting records for the Netherlands Antilles provide impetus to conservation action. *Caribbean Journal of Science*, *41*(2), 334–339.

Debrot, A. O., and Nagelkerken, I. (2006). Recovery of the long-spined sea urchin Diadema antillarum in Curaçao (Netherlands Antilles) linked to lagoonal and wave sheltered shallow rocky habitats. *Bulletin of Marine Science*, *79*(2), 415.

Debrot, A. O., and Pors, L. (1995). Sea turtle nesting activity on northeast coast beaches of Curaçao, 1993. *Caribbean Journal of Science*, *31*, 333–338.

De Groot, J., and Bush, S. R. (2010). The potential for dive tourism led entrepreneurial marine protected areas in Curacao. *Marine Policy*, *34*(5), 1051–1059.

Department of Agriculture and Fisheries (LVV). (2003). *Fisheries Monitoring Report* (p. 39).
Dilrosun, F. (n.d.). *Progress report on Curacao fishery monitoring programme*. FAO. Retrieved from <http://www.fao.org/docrep/005/Y4260E/y4260e05.htm#TopOfPage>

Dinica, V. (2006). *Sustainable tourism on Curacao: public policy and implementation initiatives*. The Netherlands: University of Twente. pp. 250

Duyl, F. C. van. (1985). Atlas of the living reefs of Curaçao and Bonaire (Netherlands Antilles). Retrieved from http://agris.fao.org/agris-search/search.do?recordID=US201300408356

ECLAC. (2011). *An assessment of the economic impact of climate change on the tourism sector in Curacao* (No. LC/CAR/L.302) (p. 47). Economic Commission for Latin America and the Caribbean, Subregional Headquarters for the Caribbean.

FAO. (2007). The world's mangroves 1980-2005. Retrieved April 13, 2015, from http://www.fao.org/docrep/010/a1427e/a1427e00.htm

FAO. (2010). *Global Forest Resources Assessment 2010. Country Report: Netherland Antilles* (No. FRA2010/146) (p. 10). Rome: Forestry Department, Food and Agriculture Organization of the United Nations.

FAO. (2010). *A regional shellfish hatchery for the Wider Caribbean: assessing its feasibility and sustainability* (FAO Regional Technical Workshop). Fisheries and Aquaculture Proceedings. Food and Agriculture Organization of the United Nations, Kingston, Jamaica. pp. 264.

FAO. (2012). *The state of world fisheries aquaculture 2012: opportunities and challenges.* Food and Agriculture Organization and the United Nations, Rome. pp. 280.

Gast, G. J., Jonkers, P. J., van Duyl, F. C., and Bak, R. P. M. (1999). Bacteria, flagellates and nutrients in island fringing coral reef waters: Influence of the ocean, the reef and eutrophication. *Bulletin of Marine Science*, *65*(2), 523–538.

George, S.S. (2000). *Assessment of wahoo (Acanthorcybium solandri) fishery using eastern Caribbean data* (CARICOM Fisheries Report No. 9). Report of the 2000 Caribbean pelagic and reef fisheries assessment workshop. Hastings, Barbados.

Govers, L. L., Lamers, L. P. M., Bouma, T. J., Eygensteyn, J., de Brouwer, J. H. F., Hendriks, A. J., van Katwijk, M. M. (2014). Seagrasses as indicators for coastal trace metal pollution: A global meta-analysis serving as a benchmark, and a Caribbean case study. *Environmental Pollution*, *195*, 210–217.

Green, E. P., and Short, F. T. (2003). *World Atlas of Seagrasses*. University of California Press.
Halcrow, C. (2010). *Strategic tourism master plan for the island of Curacao: 2010-2014* (p. 197).

Hensen, R. R. (1987). Development of aquaculture in the Netherlands Antilles and Aruba. *Proc. of the Fortieth Annual Gulf and Caribbean Fisheries Institute Curacao Netherland Antilles*. Retrieved from http://procs.gcfi.org/pdf/gcfi_40-38.pdf

Jackson, J., Donovan, M., Cramer, K., and Lam, V. (2014). *Status and trends of Caribbean coral reefs: 1970-2012* (Other Government Series) (p. 306). Washington, D.C.: Global Coral Reef Monitoring Network. Retrieved from http://pubs.er.usgs.gov/publication/70115405

Johnson, A. E. (2011). *Fish, Fishing, Diving and the Management of Coral Reefs*. UNIVERSITY OF CALIFORNIA, SAN DIEGO. Retrieved from http://gradworks.umi.com/34/45/3445262.html

Kleisner, K. M. (2008). *A spatio-temporal analysis of dolphinfish; Doryphaena hippurus, abundance in the western Atlantic: implications for stock assessment of a data-limited pelgaic resource*. University of Miami, Miami, Florida, 137 p.

Kuenen, M., and Debrot, A. O. (1995). A quantitative study of the seagrass and algal meadows of the Spaanse Water, Curaçao, The Netherlands Antilles. *Aquatic Botany*, *51*(3), 291–310.

Lapointe, B. E., and Mallin, M. (2011). Nutrient enrichment and eutrophication on fringing coral reefs of Bonaire and Curaçao, Netherlands Antilles. *Report to the United Nations Environment Programme for the NACRI Coral Reef Monitoring Program, Harbor Branch Oceanographic Institute, Ft. Pierce Fl*. Retrieved from http://www.dcbd.nl/sites/www.dcbd.nl/files/documents/Bonaire%20Curacao%20nutrient monitoring2011.pdf

Leenstra, N. (2005). *An analysis of commerical catch on Curacao (Netherlands Antilles) and a study on sexual maturation of the graysby, Epinephelus cruentatus*. Radboud University, Nijmegen, Netherlands, 93 p.

LET. (2011). The Lionfish Elimination Team. Retrieved from http://lionfisheliminationteam.com

Meesters, E., Slijkerman, D., de Graaf, M., and Debrot, D. (2010). Management plan for the natural resources of the EEZ of the Dutch Caribbean. *Institute for Marine Resources and Ecosystem Studies C100.19*, 79 p.

Meteorological Service Netherland Antilles and Aruba (MDNAandA). (2010). *Hurricanes and Tropical Storms in the Netherlands Antilles and Aruba*.12 p.

Nagelkerken, I. A., and Debrot, A. O. (1996). Mollusc communities of tropical rubble shores of Curacao: long-term (7 + years) impacts of oil pollution. *Oceanographic Literature Review*, *3*(43), 309.

Nagelkerken, I., Kleijnen, S., Klop, T., Van Den Brand, R., de La Moriniere, E. C., and Van der Velde, G. (2001). Dependence of Caribbean reef fishes on mangroves and seagrass beds as nursery habitats: a comparison of fish faunas between bays with and without mangroves/seagrass beds. *Marine Ecology Progress Series*, *214*, 225–235.

Nagelkerken, I., Roberts, C. M., Van Der Velde, G., Dorenbosch, M., Van Riel, M. C., De La Moriniere, E. C., and Nienhuis, P. H. (2002). How important are mangroves and seagrass beds for coral-reef fish? The nursery hypothesis tested on an island scale. *Marine Ecology Progress Series*, *244*(2002), 299–305.

Nagelkerken, I., and Van der Velde, G. (2002). Do non-estuarine mangroves harbour higher densities of juvenile fish than adjacent shallow-water and coral reef habitats in Curacao (Netherlands Antilles)? *Marine Ecology. Progress Series*, *245*, 191–204.

Nagelkerken, I., Van der Velde, G., Gorissen, M. W., Meijer, G. J., Van't Hof, T., and Den Hartog, C. (2000). Importance of mangroves, seagrass beds and the shallow coral reef as a nursery for important coral reef fishes, using a visual census technique. *Estuarine, Coastal and Shelf Science*, *51*(1), 31–44.

Nagelkerken, I., Vermonden, K., Moraes, O. C. C., Debrot, A. O., and Nagelkerken, W. P. (2005). Changes in Coral Reef Communities and an Associated Reef Fish Species, Cephalopholis cruentata (Lacépède), After 30 years on Curaçao (Netherlands Antilles). *Hydrobiologia*, *549*(1), 145–154. http://doi.org/10.1007/s10750-005-5448-8

Pors, L. P., and Nagelkerken, I. A. (1998). Curaçao Antilles. *Caribbean Coral Reef, Seagrass and Mangrove Sites. UNESCO, Paris. P*, 127–139.

Relles, N. J. (2012). *A Case Study in the Effectiveness of Marine Protected Areas (MPAs): the Islands of Bonaire and Curaçao, Dutch Caribbean*. The College of William and Mary. Retrieved from http://www.vims.edu/library/theses/Relles12.pdf

Sandin, S. A., Sampayo, E. M., and Vermeij, M. J. (2007). Coral reef fish and benthic community structure of Bonaire and Curaçao, Netherlands Antilles. *Caribbean Journal of Science*, *44*, 137–144.

Schultink, R., and Lindenbergh, S. (2006). *Intensity of the fishing of Curacao*. Van Hall Institute, Leeuwarden, Netherlands.

Sea Turtle Conservation | DCNA. (2013). Retrieved from http://www.dcnanature.org/projects/sea-turtle-conservat/

Sybesma, J. (1992). WIDECAST sea turtle recovery action plan for the Netherlands Antilles. *Caribbean Environment Programme Technical Report*, (11), 63.

Van Beek, I.J.M., D., A.O., and Graaf, M. de. (2014). *Elasmobranchs in the Dutch Caribbean: current population status, fisheries and conservation* (p. 12). IMARES, Wageningen University Research. Retrieved from http://www.dcbd.nl/sites/www.dcbd.nl/files/documents/vanBeekEtAl(2012)_ElasmobranchsDutchCaribbean.pdf

van Buurt, G. (2001). *Fisheries plan for island territory of Curacao*. Department of Agriculture and Fisheries (LVV), 42 p.

van Buurt, G. (2001). Queen Conch (*Strombus gigas*) in the Netherlands Antilles, and some remarks on the harvest of other shells. Department of Agriculture, Animal Husbandry and Fisheries, Curacao. In *Unpublished report presented at the 2 nd International Queen Conch Conference, held from* (pp. 18–21).

van Buurt, G. (2002). Coral decline, causes and effects: local variables, regional issues. In *Paper Meeting Stichting Reefcare, Curaçao (niet gepubliceerd)*. Retrieved from http://www.dcbd.nl/sites/www.dcbd.nl/files/documents/Buurt%202002%20Coral%20decline%20Curacao.pdf

van Buurt, G. (2004). *National Report of Aruba, Curacao, Bonaire 1993-2004* (FAO Fisheries Report No. 797). Report of the Second Meeting of the WECAFC Ad Hoc Working Group on the development of sustainable moored fish aggregating device fishing in the Lesser Antilles. Food and Agriculutre Organization of the United Nations, Bouillanted, Guadelouple.

Van Veghel, M. L., and Hoetjes, P. C. (1995). Effects of tropical storm Bret on Curaçao reefs. *Bulletin of Marine Science*, *56*(2), 692–694.

Vermeij, M. J. (2012). *The Current State of Curacao's Coral Reefs*. Report from Carmabi Research Station, 34 p.

Vermeij, M. J. A., and Chamberland, Valerie. (2012). *An overview of specific rules and regulations to protect Curacao's marine life*. Curacao: Carmabi Foundation, 8 p.

Vermeij, and Nijssen. (2011). *Biomass and biodiveristy of reef fish communties in Curacao* (Research Report). CARMABI and Hogeschool Zeeland, 41 p.

Wetzel, D.L., and Pulster, E.L. (2010). *Sediment polycyclic aromatic hydrocarbon (PAH) contanmination in Curacao: potential impacts from the isla refinery* . Mote Marine Laboratory, 2 p.

Wieggers, M. (2007). Impact of increased nutrient input on coral reefs on Bonaire and Curacao. *University of Utrecht. Student Report*, 66 p.