A review of the small pelagics fishery resources of the Dutch Caribbean and adjacent areas

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Contents

Summary

This deskstudy gives a review of small pelagic fish species and fisheries in the Dutch Caribbean, specifically species which distributions exceed the national boundaries and where international cooperation in research and management is required. The need for this study was recently identified as a high priority action in the 2010 EEZ management plan written for the Dutch Ministry of Economic Affairs. A list of schooling pelagic species with maximum sizes of 40 cm was prepared, based on the occurrence in waters deeper than 200m, in the Dutch Caribbean and Wider Caribbean Area. As a next step the (importance for) the fisheries and biology is described with a focus on the following four species (groups): Sardines (*Sardinella aurita)*, Scads (*Carangidae*), Anchovy (*Engraulidae*) and Flyingfishes, in particular *Hirundichthys speculiger* and *Cheilopogon cyanopterus*. A fifth group, consisting of clupeids (*Clupidae*) and halfbeaks (*Hemiramphidae*) are not truly pelagic because of their association with reefs and coastal distribution, but are locally abundant and important as bait fish.

From a management perspective, small pelagic fish in the Caribbean can be divided into three groups: (1) Species with pelagic behaviour, but coastally bound. 10-20 species, wide spread in the region, locally abundant and targeted as bait fish. This group consists of *Carangidae*, *Clupeidae*, *Engraulidae* and *Hemiramphidae*. These can be monitored in local sea going surveys because the species are more or less coastal (<less than 20 km). However, catches of small pelagic species are not monitored or surveyed, hence it is often not clear what species are involved. An appropriate survey method to monitor abundance of schooling pelagic fish is echo integration. (2) True pelagic (oceanic) species: all flying fishes, wide spread in the region. Heavily targeted as bait fish, locally for human consumption (Barbados). They are clearly crossing boundaries of EEZ's in the region. The species involved are wide spread and due to their behaviour difficult to monitor by means of a fisheries independent, sea going survey. (3) *Sardinella aurita*, off shore distribution, limited to an area of upwelling off the coast of Venezuela. The monitoring of the stock is a Venezuelan appointment, although at the margins, some EEC boundaries are crossed (Columbian, Dutch).

Given the importance for the ecosystem from a Dutch perspective the main focus for further research in the Dutch EEZ, should be given to coastal pelagic species in the pelagic area's adjacent to coastal reef zones around the archipelagos. This implies no international coordination for this group in the executional phase of the survey. The second group – flyingfishes - requires more international cooperation. This group should be surveyed within ecosystem focussed surveys, running multiple methodologies like visual observations of birds and mammals, biological sampling of fish and hydrographical observations.

The potential for a small pelagic fishery in the Dutch EEZ is discussed. Direct consumption of small pelagic fish, rather than using it in the reduction sector, is more efficient from a biological and an economical point of view. For the Dutch EEZ, as a first step a (bio-)economic study into the potential of the development of a sustainable fishery for small pelagic fish in the Dutch EEZ could be initiated. The flyingfish fishery in Barbados could be used as an example or a reference. Depending on the presence of local pelagic resources, such a study should not merely focus on flying fish but should include all small pelagic fish. The Barbados flying fish fishery could also be used as an example for a local experimental fisheries project.

Finally it is recommended to start collecting data in the pelagic area's adjacent to coastal reef zones by yearly fisheries independent sea going surveys. The best survey technique for small pelagic fish is fisheries acoustics. However, a holistic approach, incorporating observations of multiple trophic levels, using different strategies within a single survey would be highly preferable. This means that such a survey should be combined with systematic visual observations of seabirds and cetaceans as well as the collection of zooplankton and environmental data.

1. Introduction

Small pelagic fish species have traditionally formed a critical part, mainly as bait fish, of annual fishery landings in many areas of the Caribbean such as the Dutch Caribbean (Zaneveld, 1961), the French Caribbean (Blanchet et al., 2002), Colombia (Paramo and Roa, 2003), Barbados (Oxenford et al., 1995a; Oxenford et al., 1995d) and Venezuela (Fréon and Mendoza, 2003). They are not only of great importance as high quality human food, but also as bait species for fishing. In addition they form a vital part of the coastal and/or pelagic food web, and key food source for endangered species that frequent the Dutch Caribbean such as the whale shark (Debrot et al., in press) and many cetaceans (Debrot et al., in press; Debrot et al., 1998). Despite their ecological and economic importance the species concerned have been relatively understudied (Friedlander and Beets, 1997).

In the windward Dutch Caribbean islands (St Maarten, Saba and St Eustius) fishermen can fish on the expansive Saba Bank, the fisheries predominantly target demersal stocks of deep-water snappers, and reef-associated shellfish such as the Queen Conch, *Strombus gigas,* and Caribbean spiny lobster, *Panulirus argus* (Gerwen, 2014; Boonstra, 2014). Small shoaling pelagics are not an important part of the current fisheries of the windward Dutch Caribbean islands. The situation is different in the leeward Dutch Caribbean islands known as the ABC islands (Aruba, Bonaire, Curaçao) where most demersal reef-associated grouper and snapper stocks have been heavily depleted (Buurt van, 2001). Consequently on these ABC islands most catches are obtained from a combination of small coastal pelagics and large migratory pelagic piscivores such as tuna and wahoo.

The principal small shoaling species targeted are locally known as "masbangu", bigeye scad (*Selar crumenophthalmus*), "moulo", rough scad (Trachurus *lathami*), round scad (*Decapterus punctatus*), mackeral scad (*D. macarellus*), rough ear scad (*D. tabl*) and possibly other scad species, "sardinchi" or red-eared herring (*Harengula humeralis*). The masbangu is caught in beach seines and marketed fresh whereby it fetches a high price for consumption. Sardinchis are marketed as food for marine aquaria. Moulos, caught mainly by hook and line, are largely used as bait and for human consumption but are more perishable and are less abundant. A number of other species such as anchovies (*Anchoa sp. Anchoviella sp., Engraulis sp.*) and dwarf herring (*Jenkinsia lamprotaenia*), collectively referred to as "antjok", are important seasonal bait species for fishermen. In addition, a number of flyingfish species (*Exocotidae*), collectively referred to as "buladó" and "fleerchi", and well as halfbeaks (*Hemiramphidae*, locally named "boka largu") are also targeted, both for food and as bait.

Because of the seasonal and erratic nature of catches, the difficulty of distinguishing the various species, and the complete lack of structural fisheries data collection in the past, these species have generally not been included in the limited catch monitoring data available for these islands. Monitoring funded by the Dutch Ministry of Economic Affairs as carried out since 2012 on St. Eustachius and since 2013 on Bonaire does not cover these species because they are caught for bait and do not belong to the catch.

1.1 Objectives and scope

The purpose of this study was to compile and review the available information on small pelagic species for the Dutch Caribbean EEZ. The need for this study was recently identified as a high priority action in the 2010 EEZ management plan written for the Dutch Ministry of Economic Affairs and other fishery stakeholders (Meesters et al., 2010). Around the Leeward islands the Dutch Caribbean EEZ amounts to an area of about 70 000 km^2, whereas in the Windward Dutch Caribbean, the EEZ amounts to about 20 000 km^2 (in comparison: the North Sea is 750 000 km^2).

These areas span far-flung reaches of the Caribbean Sea, stretching from the continental shelf and upwelling regions of Venezuela off northern South America, across more than 800 km of oligotrophic Caribbean waters to the shallow Saba Bank, one of the largest sunken atolls of the Caribbean.

The Dutch EEZ consequently spans a multitude of hydro- and oceanographic regimes and depths from the intertidal to more than 4000m. Therefore, an prospective study as this portends to be, must necessarily include many species. Because of the almost total lack of information specific to the Dutch Caribbean, it was also essential to compile information based on studies done elsewhere. Wide-ranging ecological connectivity of these often trans-boundary migratory fish stocks, which represent a little-known and potentially underutilized resource, as well as the narrow association of these species to broad regional oceanographic features and phenomena, further dictated the need for an inclusive regional approach to this study. The last semi-comprehensive Caribbean regional fisheries review dates from 20 years ago (Sturm de, 1991), while the most recent review of small pelagics dates from 1978 (Reintjes, 1978). There is clearly need for new compilation and synthesis of information on small pelagics of the Caribbean, all the more because cumulative catches in this category of semi-related species are now also declining within the region (FAO, 2012). We incorporate and treat all information of known or potential importance for both sectors of the Dutch Caribbean EEZ, but focus most attention on the resources of the leeward Dutch islands because of the greater significance of small pelagics for these islands which lie within the upwelling zone of the southern Caribbean (Sturm de, 1991).

The specific objectives of this report are to:

- To identify small pelagic fish species and fisheries, including species of which the range clearly exceeds national coastal area’s
- Compile and review biological and fisheries knowledge on known and possibly relevant species based on work from elsewhere in the region
- Assess if possible, the current state of species in the region and fishery potential for the Dutch Caribbean EEZ
- Identify potential problems and information gaps regarding these species
- Make broad recommendations for routine monitoring and surveying to improve the ability to identify and address management issues within the Dutch Caribbean

By definition pelagic fish are those fish species that live through the water column, and are not connected to the bottom, coast and reefs. However, this description is often not satisfying as many pelagic species do make use of benthic or coastal areas during part of their lifecycle. Herring (*Clupea harengus*) in the North Sea for instance, which are considered to be pelagic fish are bound to spawn at the bottom (herring, *Clupea harengus*) and anchovies which are also considered to be pelagic species nevertheless typically migrate to coastal bays, inlets and tidal area’s to spawn. Some sandeel species live in the bottom in winter and/or at night, but swim in the water column in spring and/or during the day and form true pelagic schools. Furthermore, some typical “demersal” species are amongst the most frequently encountered species in pelagic surveys: two examples in the Northeast Atlantic are the Lumpsucker (*Cyclopterus lumpus*) which shows up in almost every pelagic haul in the Norwegian sea (Holst, 1993) and the grey gurnard (*Eutrigla gurnardus*), a benthic species which is one of the most frequently caught species in the North Sea Herring Acoustic Survey (Ybema, 2006). So while the definition is all but clear cut, in this review we excluded large pelagic species, like sharks, sailfish and tuna, most of which have received much more scientific attention than most small pelagics in the Caribbean. For the purpose of this study, we consider a species as a “small pelagic species” if it lives the greater part of its life in the water column and if they the maximum length is less than 40cm. As a next step we narrow the scope, on the basis of landings.

1.2 Area description

The Caribbean Sea Large Marine Ecosystem is bounded by the Antillean island chain, North America, Central and South America and according to the united Nations Environment Programme (UNEP) definition does not include the Gulf of Mexico, or the Bahamas and Bermuda, all areas which are typically considered to be part of the Wider Caribbean. This report focusses on the south-eastern half of the Caribbean LME (Figure 1).

The Caribbean LME is considered a class II moderately productive system of 150-300 gCm^{-2} yr^{-1} (Heileman and Mahon, 2009), but there is considerable heterogeneity in both space and time throughout the region. Highest productivity occurs in the south-eastern part, off the coast of Venezuela where surface productivity is about 500 gCm-2 yr-1 (Couper, 1983; Richardson and Young, 1987; Tyler, 2003). There is no information on the particulate organic carbon fluxes to deep waters but it is assumed to fit the pattern of productivity. It is known however, that the deep waters receive considerable inputs of organic carbon in the form of wood and *Thalassia testudimum* blades, particularly after hurricanes (Tyler, 2003).

Anderson et al. (1987) compiled information on the fish fauna for the deeper parts of the Caribbean basins (2000 m and deeper) and documented a depauperate fauna of 35 abyssal fish species which were dominated by Ophidiiformes (17 species) and alepocephalids (7 species). Along the continent of South America fresh water inflow from the Amazon, Orinoco and Rio Magdalena influence salinity and productivity along the north coast of south America (Muller-Karger, 1993). The Caribbean receives about 20% of the discharge of the world's rivers (Müller-Karger et al., 1989). Nevertheless, most of the area is influenced by clear, nutrient-poor surface waters of the North Equatorial Current and the South Equatorial Current (known as the Guiana Current after entry into the Caribbean) in a rough ratio of 3:1 (Sturm de, 1991). The total flow of oceanic water through the Caribbean amounts to about 50 Sverdrups (10^6 m^3 s^{-1}). Of these, about 10 Sv are believed to pass through the Windward Passage (sill depth of 1690 m) and fill into the Yucatan and Cayman Basins, while 15 Sv pass through the passages of the southern Lesser Antilles and 5 Sv through the remaining small passages (Tyler, 2003). The main passage feeding into the three eastern Caribbean basins is believed to be the Anegada-Jungfern passage, that has a sill depth of more than 1800 m (Tyler, 2003). With a total flow of roughly 50 Sv, turnover time for Caribbean waters is estimated to be 800 years (Sturges, 1975). A significant portion of deep water entering the Caribbean is Antarctic Intermediate Water. The deep water of the Caribbean has an average temperature of 3.8-4 ^oC and a salinity of 34.9 ppt. (Tyler, 2003). The average depth of the Caribbean LME is 2200 m while the deepest point is the anoxic Cayman Trench at 7100 m depth (Richards and Bohnsack, 1990).

Belkin et al. (2009) have mapped the most important ocean fronts affecting productivity in the region. Four key fronts play a role in the Eastern/Southern Caribbean. These are the East Venezuela Front, the West Venezuela Front, the Gulf of Venezuela Front and the North Colombia Front. These fronts are largely caused by wind-induced upwelling of nutrient rich water off Venezuela and Colombia. The Gulf of Venezuela Front is the smallest one likely principally caused by the outflow of brackish water from the Gulf of Maracaibo (Belkin et al., 2009). The most important upwelling region of the Caribbean is that off eastern Venezuela. A major submarine ridge (Aves Ridge) that deflects the Caribbean Current away from shore, plays an important role in reinforcing the wind-induced upwelling. Here westward advection during the first half of the year limits phytoplankton blooms to principally the southern half of the Caribbean. In the second half of the year, the influx of Atlantic water decreases and allows local Ekman transport driven by the trade winds to drive algal blooms to the northwest towards the central and north eastern Caribbean (Müller-Karger et al., 1989).

The Caribbean Sea has gone through three temperature phases in the last 50 years. Cooling to about 1974, a cold phase with cold-spells till about 1986, and a warming phase from 1986 forward. Almost all significant sea surface temperature minima and maxima correspond to El Nino and La Nina-related events (Belkin et al., 2009).

From the hydrography described here above, it is to be expected that substantial production in terms of small pelagic fish is to be expected in the upwelling region off eastern Venezuela.

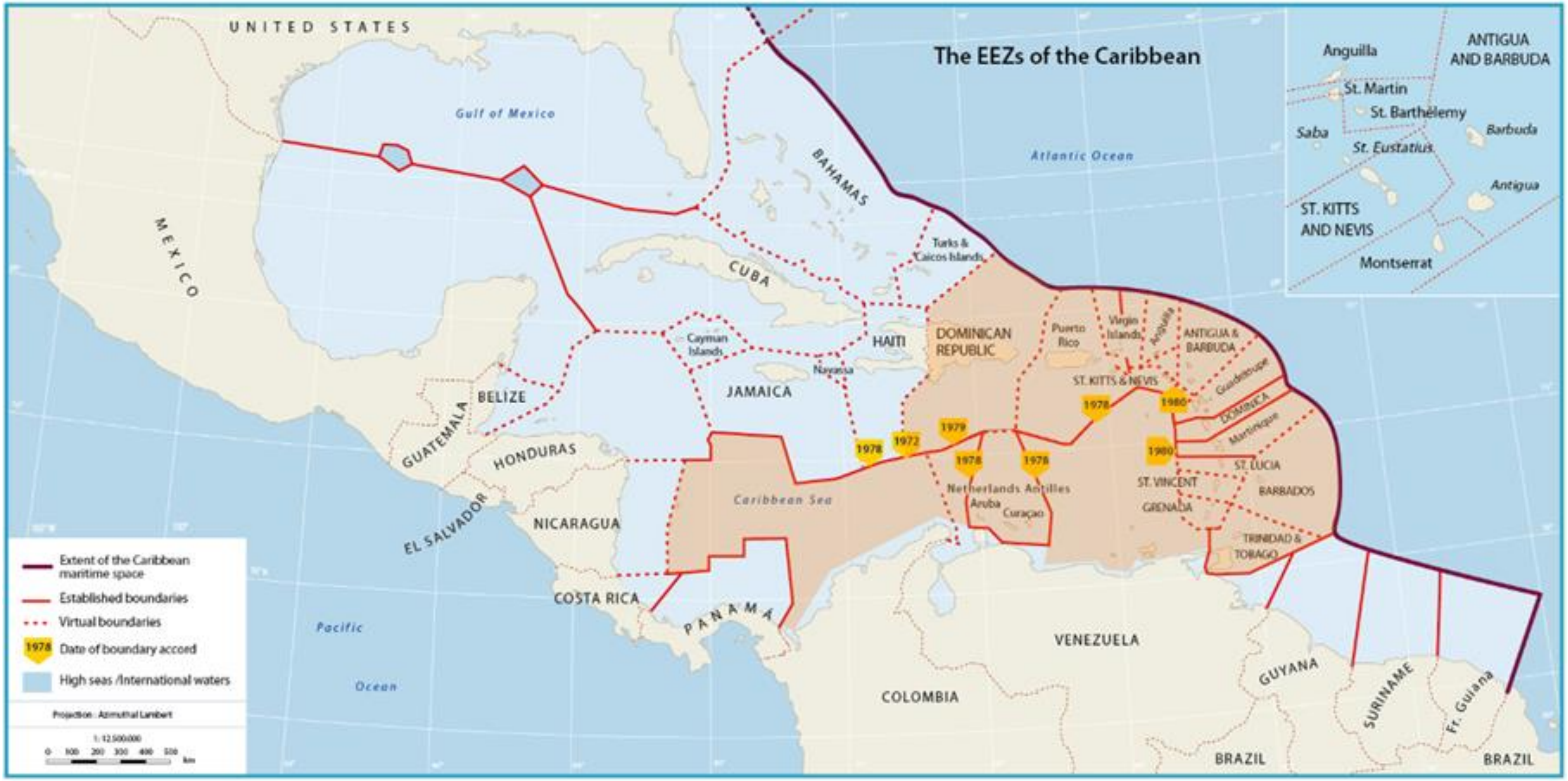

Figure 1 Map of the Wider Caribbean with indication of the working area in the study.

1.3 Fisheries management

While there are no Regional Fisheries Management Organizations in the Caribbean (Bos and Gumanao, 2012), several organizations do play limited roles.

These are the:
Western Central Atlantic Fishery Commission (WECAFC),
Caribbean Regional Fisheries Mechanism (CRFM),
Caribbean Fisheries Management Council (CFMC)
Association of Caribbean States (ACS)
Organization of Eastern Caribbean States (OECS)
National Oceanic and Atmospheric Administration (NOAA)
Latin American Organisation for Fisheries Development (OLDEPESCA),
Central American Organization for the Fisheries and Aquaculture Sector (OSPESCA).
International Commission for the Conservation of Atlantic Tunas (ICCAT).

Countries in the Wider Caribbean, especially the smaller island states/territories are highly dependent on the marine environment (Fanning et al., 2013). However the Wider Caribbean is an extremely complex region politically, with 26 states and 19 territories with a wide range of development and hence capacities for governance. Institutions at a regional and sub-regional level are numerous and interaction between them is not always effective. (FAO, 2012) mentions a number of institutional arrangements promoting and facilitating the management of the fisheries and other aquatic resources within FAO Area 31, which includes the wider Caribbean. These institutions seem to adapt to informal arrangements "that are agreed upon by these arrangements". WECAFC undertakes the assessment for flying fish, while CRFM takes care for other regional small pelagics. However, at present the main activity of CRFM is to draw attention to possible overfishing of fourwing-flyingfish. In practice, there does not seem to exist a trans boundary management of small pelagic fish. Large resources in the region are national responsibilities (i.e. *Sardinella* by Venezuela and the Gulf Menhaden (*Brevoortia patronus*) in the Gulf of Mexico by the USA). The emphasis in the Wider Caribbean is on large pelagics, while small pelagics are "forage fish" or "baitfish".

1.4 Methods

Our approach to this review consists of three steps:

1) We first identify the small pelagic fish species according to the known biology, behaviour and distribution, thus creating a "longlist" of small pelagic species in the study area (southeastern half of the LME). Emphasis has been put on whether species are reef associated, occur in waters deeper than 200m and occur in the Dutch Caribbean. The fisheries of these species are described in chapter 3.

2) The biology, temporal and geographical distribution of species(groups) is described more thoroughly (Chapter 2: Description of fisheries) with reference to their importance or potential importance for fishery.

3) We describe and discuss the temporal and geographical overlap of the species(groups), with emphasis on the (potential) fisheries in the Dutch EEZ. We discuss methodological requirements for possible survey designs to improve baseline data on stock abundance and distribution.

2. Description of fisheries for small pelagic fish

2.1 The fisheries

Fish has always been and still remains an important resource in the Eastern Caribbean on multiple levels: an important source of livelihood and sustenance for the local population, food security, poverty alleviation, employment, foreign-exchange earnings, the development of rural and coastal communities, recreation and tourism (Agard et al., 2007).
Data presented below come from FAO Fishstat with reference to the study area (Figure 1). In general terms, the fishery can be described as a multi-species, multi-gear, small-scale fisheries. Garcia et al. (2012) reports the majority of the fishing effort being of artisanal nature (87% wider Caribbean, 95 % island states, 71% mainland), with the shrimp and large pelagics fisheries forming the exceptions. Multi-gear, multi-species and artisanal fisheries though, is not necessarily a synonym for little impact on the ecosystem. Garcia et al. (2012) showed that especially in Dominica, Puerto Rico, Trinidad and Tobago, St. Kitts and Nevis, Antigua and Barbuda and St. Lucia high local scale fisheries densities can be observed.

The fisheries of the Wider Caribbean Sea are generally split up into these groups:

- Fishery for Deep-water Snappers and Groupers,
- Fishery for Large Pelagic Fishes (tunas and other mackerel-like fishes of the Scombridae family, jacks and pompanos (Carangidae) as well as dolphinfishes (Coryphaenidae),
- Fishery for Small Coastal Pelagic Fishes,
- Sardinella fishery
- Flyingfish fishery
- Fishery for Ground fishes,
- Shrimp fishery,
- Lobster fishery
- Conch fishery

As this study focuses on small pelagic fishes, it covers the fisheries for Small Coastal Pelagic Fishes, Flying fish and Sardinella. Targeted small pelagics are mainly sardines or herrings of the *Clupeidae* family, flyingfishes (*Exocoetidae*) and anchovies (*Engraulidae*) (Table 1).

Lacking sound knowledge about the effects of the different gear types used and the availability of the resource, makes it difficult to provide a valid impact assessment. Operating only in a relatively small area, the potential local impact of artisanal fisheries might be more detrimental on a local scale, compared to sophisticated industrial boats operating on a much larger area. Given the scale of artisanal fisheries in the area, a better understanding of the effects of the latter on the ecosystem appears to be vital but is still largely lacking.

FAO (2012) reported that the total landings in FAO area 31, which covers the wider Caribbean peaked during the mid-1980s but were in decline since then. 15 to 20 per cent of all landed species have continuously remained unidentified and little progress has been made on this. Declines in the overall catches were mainly attributed to lower catches in the groups of coastal fishes and small pelagic fish.

The importance of the small pelagic fish becomes evident when looking at their overall contribution to the reported landings. FAO reports 55 per cent of the total landings by weight in the WECAFC area to be comprised in the small pelagics group.

FAO divides the small pelagics into 6 families/groups: herrings, sardines and anchovies; 37 other miscellaneous pelagic fishes; *Exocetidae* – flyingfishes; *Engraulidae* – anchovies and anchovetas; *Carangidae* – jacks, pompanos and scads; *Hemiramphidae* – halfbeaks.

Fish remains an important food source in the region. On average fish and seafood consumption per capita per year is of 24 kg (for the years 1985-2009, comparison with the Netherlands: 17 kg). 35% are composed of pelagic species (8 kg per capita per year), which makes pelagic fish an important nutritional factor for the region (Source: FAO, Figure 2). In general the amount of seafood consumed by island states is higher than the quantities used by mainland countries. The highest average amount of seafood, fish and fish products are consumed in Antigua and Barbuda with an average of 46 kg per person per year. The largest amount of pelagic fish are consumed in Barbados with 19 kg per capita per year (56 % of total fish and seafood consumption of the country). The average amount of seafood consumed in these countries shows an increasing trend since the early 90s (Source: FAO; Figure 2).

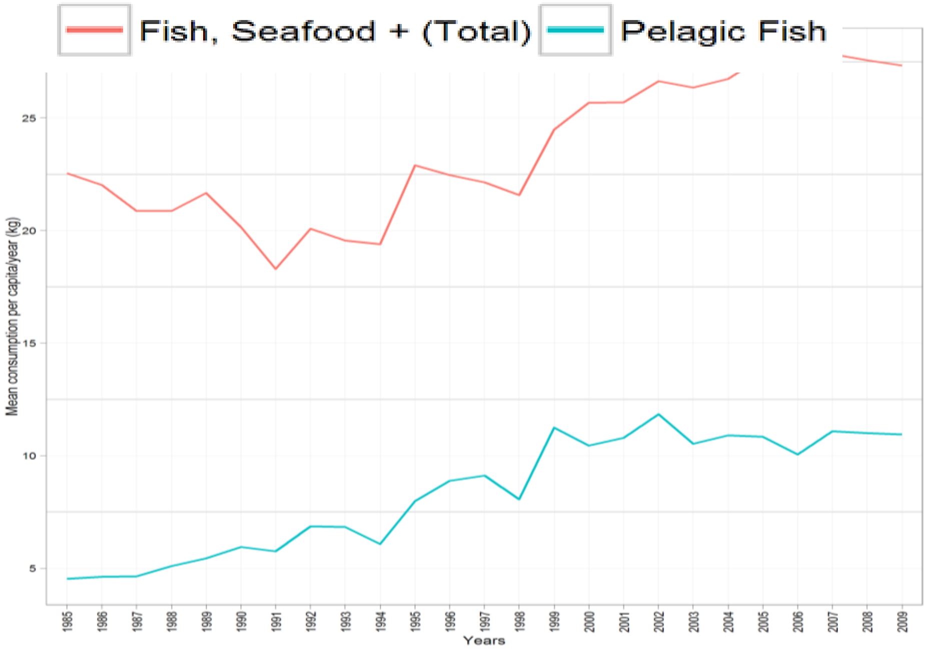

Figure 2 Annual fish consumption per capita in kg for the study area from 1985 – 2009 (Source FAO Fishstat)

2.2 Targeted species

Table 1. Targeted pelagic fish species in the study area (FAO fishstat; Metric tonnes, figures are rounded).

Order	**Catch**	**Suborder**	**Catch**	**Family**	**Common Name**	**Catch**
Beloniformes	130 (1.5 %)	Beloniformes	130 (1.5 %)	*Belonidae*	Needlefish	4 (0.05%)
				Exocoetidae	Flyingfishes	126 (1.5%)
				Hemiramphidae	Halfbeaks	0.4 (0.01%)
Clupeiformes	4100 (48 %)	Clupeiformes	4090 (48 %)	*Clupeidae*	Herring, sardines	3900(45%)
				Clupeoids sp.	other herring like	66 (0.8%)
				Engraulidae	Anchovies	134 (1.6%)
Perciformes Others	4300 (50 %)	Percoidei	730 (9 %)	*Carangidae*	Jacks	558 (6.5%)
				Coryphaenidae	Dolphinfishes	123 (1.4%)
				Pomatomidae	Bluefishes	49 (0.6%)
		Scombroidei	3500 (41 %)	*Istiophoridae*	Marlins	35(0.4%)
				Scombridae	Mackerels, tunas, bonitos	3400 (40%)
				Tuna-Like Fishes Nei	Tuna like	40 (0.5%)
				Xiphiidae	Swordfishes	6 (0.07%)
		Stromateoidei, Anabantoidei	28 (0.3 %)	*Stromateidae*	Butterfishes	28(0.3%)
		Other Perciformes Others	45 (0.5 %) 36 (0.4 %)	*Sphyraenidae* Others	Other	45 (0.5%)

According to FAO Fishstat, the pelagic fisheries fleet of the Eastern Caribbean landed a total of 47 identified species, of 5 orders and 15 families (including one Order and Family called Others containing species which could not be attributed to any other class, referred to by FAO as Pelagic Perciformes).Almost half (48%) of the total landed weight of pelagic fish from 1950 – 2010 belonged to the Order of Clupeiformes (Herrings). The total landed weight of clupeiformes (approximately 4000 tons) was bigger than the total landed weight of the large pelagic species, including mackerels, tunas, bonitos, marlins, dolphinfishes and swordfishes (3.6 million tons, 42%), which clearly highlights the importance of these small pelagic species (Table 1).

3. Descriptions by species or species groups

Of the species in the study area, *Sardinella aurita* turns out to be by far the most important for fisheries in terms of pelagic landings (85%). Of the remaining 15 species, anchovy, jacks/horse mackerel and flyingfishes are relatively important. Anchoveta, Atlantic thread herring and half beaks are not in the original list, but on the basis of the their relatively high landings and the fact that these species are widely distributed in the Caribbean, we add them to the selection. It is important to realize that the catches below by country, do not necessarily originate from their national waters.

Figure 3. A seine net for coastal small pelagic fish is being repaired (Photo by Martin de Graaf)

3.1 Fishery development

3.1.1 Anchovies

From the mid-1960s, to the mid -1980s there used to be a relatively big targeted anchoveta fishery in Venezuela, peaking in the early-1980s with annual reported catches of approximately 8000 tons (Figure 4). The fishery completely collapsed to virtually non-existence from the mid-1980s up to the early-2000s. For the last decade catches in the Eastern Caribbean remain relatively low (210 – 560 tons/year). No literature exploring the causes of the collapse could be found. Several reasons are imaginable, including environmental conditions (e.g. coastal upwelling) and overfishing.

Simultaneously, a building up fisheries targeting anchovies could be observed since the late 1990s.

The fishery reached a record high in 2011 with combined catches from St. Kitts and Nevis and St Vincent / Grenadines of almost 25.000 tons (Figure 5). Catches reported here as anchovies were registered in FAO Fishstat as European anchovy, given that this species does not occur in the Caribbean we assume a misidentification and categorised it as anchovies. The future of this very young fisheries still remains unclear. Given that these anchovies are known to be susceptible to environmental changes (E.g. E, fluctuations in the fishery are to be expected. No further literature on the fishery could be found.It is worth noticing, that on the Pacific side of Latin America, Peru reports that up to recent years anchovies were mainly targeted for indirect human consumption in the form of flour and oil. Lately though, the production of canned sardines shows increasing trend in response to a growing demand for local consumption as well as for exports.

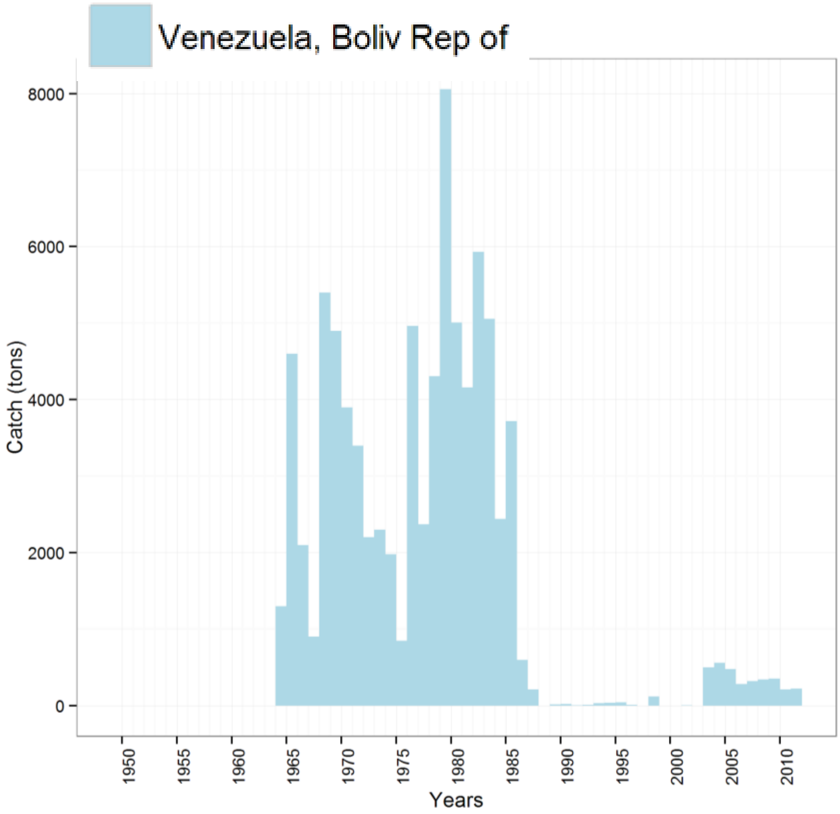

Figure 4. Catches of Atlantic anchoveta in the study area. Source: FAO Fishstat.

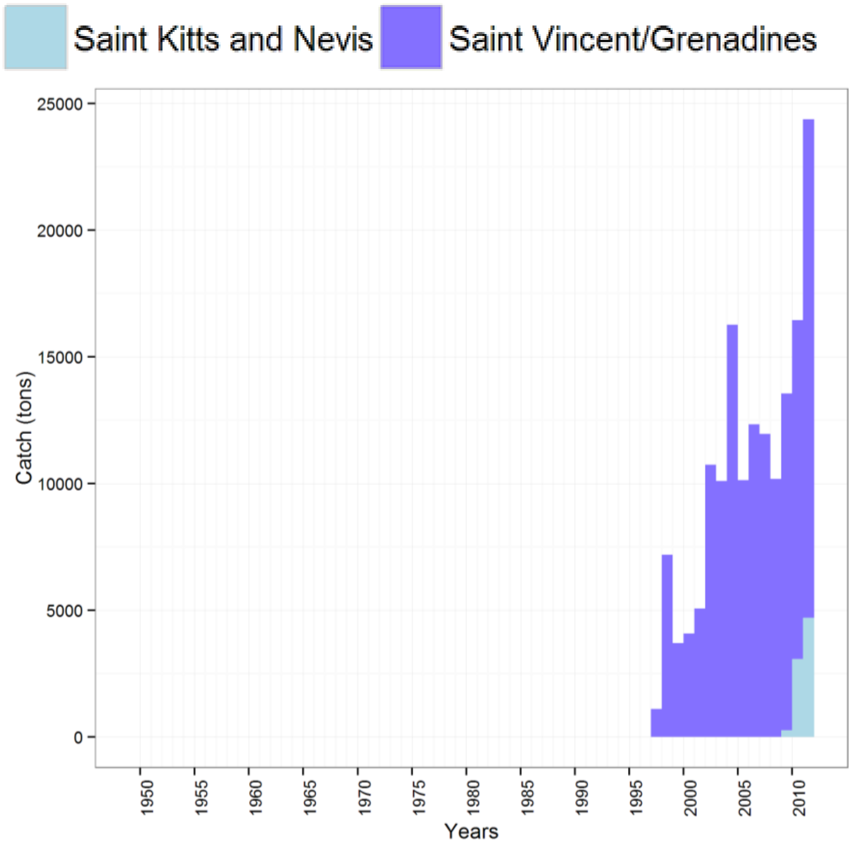

Figure 5. Catches of anchovy - all species except anchoveta- in the study area. Source: FAO Fishstat.

3.1.2 Atlantic thread herring

Venezuela is the main nation targeting Atlantic thread herring (Figure 6), partly used for direct human consumption, but mainly to produce fish meal and oils. A small proportions of the catches can be attributed to the Dominican Republic and Grenada. Catches show great fluctuations. The fishery started in the mid-1960s, growing rapidly until the mid-1970s, before collapsing. It took approximately 20 years until the fishery recovered and was built up again during the end of the 1990s, resulting in catches of approximately 15,000 tons in 2000. Since then the fishery is in a constant decline.

The species supports moderate artisanal and commercial seine fisheries in the Greater Antilles, the USA and Central America and is the most important small pelagic fishery of Caribbean Colombia (Páramo and Roa, 2003). Within the wider Caribbean catches are principally reported by the USA, Cuba and Venezuela and have fluctuated regionally in recent years between 4500 tons in 2002, 17700 in 2007 and 9000 tons in 2009 (FAO, 2012). In Jamaica the species was the main resource for a small clupeids fishery and during 1980-1983 yielded annual catches of up to 250 tons per year (Harvey et al., 2003). Due to its economic significance it has been better studied than most Caribbean baitfish species, and numerous studies have been conducted throughout its range (Cabellos, 1995; Fuss Jr et al., 1969; García-Abad et al., 1998; Harvey et al., 2003; Vega-Cendejas et al., 1997a). Nevertheless little remains known about its biology in the Caribbean.

Beets and LaPlace (1987) and Alvarado et al. (2008) suggest that restrictions on the use of beach seines may be needed to preserve this species and other baitfish stocks in Puerto Rico. No stock assessments for the region are available for this species (FAO, 2012).

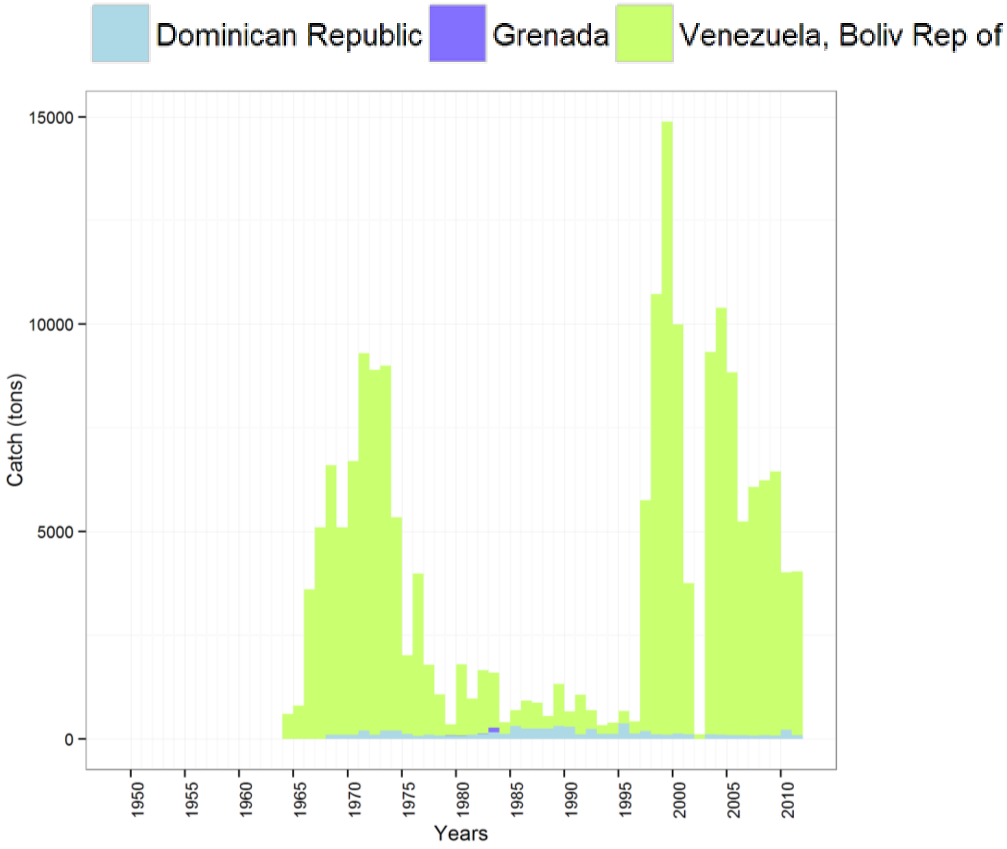

Figure 6 Catches of Atlantic thread herring in the study area. Source: FAO Fishstat.

3.1.3 Redear herring (Harengula humeralis, Cuvier 1829)

During the spawning season the species migrates inshore where it becomes very vulnerable to overfishing using beach seines. Beets and LaPlace (1987) and Pena-Alvarado et al. (2008) suggest that restrictions on the use of beach seines may be needed to preserve this species and other baitfish stocks in Puerto Rico. In Trinidad fishery landings peak during January-August (Manickchand-Heileman and Hubbard, 1992).

3.1.4 Scads

FAO Fishstat has reports from four countries landing scads: Grenada, Saint Vincent/Grenadines, Saint Kitts and Nevis and Venezuela. Additionally Trinidad and Tobago reports Tobago to have a targeted scad fishery, on both round- and bigeye scad. Figure 7 presents combined catches of scad species.
Bigeye scad is mainly targeted by Venezuela. The fishery shows largely fluctuating annual landings but with a general downward trend, especially in recent years, with lowest landings recorded so far. In general a year of relatively high landings is followed by a year of far lower landings, building up again towards a peak after approximately 5 years. Still even these maxima show a strong trend towards lower numbers (Figure 8).

Figure 6. School of scads (Photo by Martin de Graaf)

The scads fishery in Grenada is one of the major fisheries of the country, targeting both round and bigeye scads, mainly using beach seines. In general scads are seen as a high quality, low-cost protein source for the local community, but in recent years there has been an increasing demand for scads as bait.

Saint Kitts and Nevis reported low catches of bigeye scad since 2007 (maximum 41 tons in 2001). Scads fall under the so called TURF management – Territorial User Rights in the Fisheries. Fishing opportunities are allocated to specific seines through a common agreement.

St. Vincent/Grenadines has only started a targeted scad fishery in recent years (since 2004), with maximum annual landings of 202 tons (in 2007) for bigeye scad and 236 tons (in 2009) for unidentified scads. It is the second most important of the 6 species that comprise the small pelagics fishery which accounts for 45% of the annual fish catch. Mackerel scad, (*Decapterus macarellus*) and bigeye scad together account for 70% of the total small pelagics fishery.

In Guadeloupe bigeye scad species is the 11th largest fishery compared to other species (groups) and amounted to an estimated catch of 117 metric tons in 2008 (Guyader et al., 2012). Murray (1996) listed it as important for St. Lucia and suggests that the fishing effort for the beach seine and gillnet fisheries which target this and other small coastal pelagics likely exceed the Maximum Sustainable Yield (MSY).

It has been found to be strongly attracted by *Fish Aggregation Devices* FAD's where it may be an important part of the catch (Soria et al., 2009) and it may have potential for aquaculture (Iwai et al., 1996). In St. Vincent and the Grenadines the species is harvested all year but peak harvest occur from May-August (Singh-Renton et al., 2012). There it is a preferred species because it keeps better than most other baitfish species (Singh-Renton et al., 2012). In St. Croix the bigeye scad is in high demand but lightly exploited (Tobias, 1987). He describes a novel and very successful fishing method using jigs in water depths of 15-50m and light to attract zooplankton. In a 12-month St. Croix study, highest catch rates (and abundance) were observed January-March and monthly mean fish fork lengths ranging between 199 mm and 227 mm.

To protect and manage this valuable resource in St. Croix, Tobias (1987) recommended a) restrictions on seine nets to a minimum stretch of 3.8 cm and the prohibition on netting bigeye scad of less than 17.8 cm around islands.

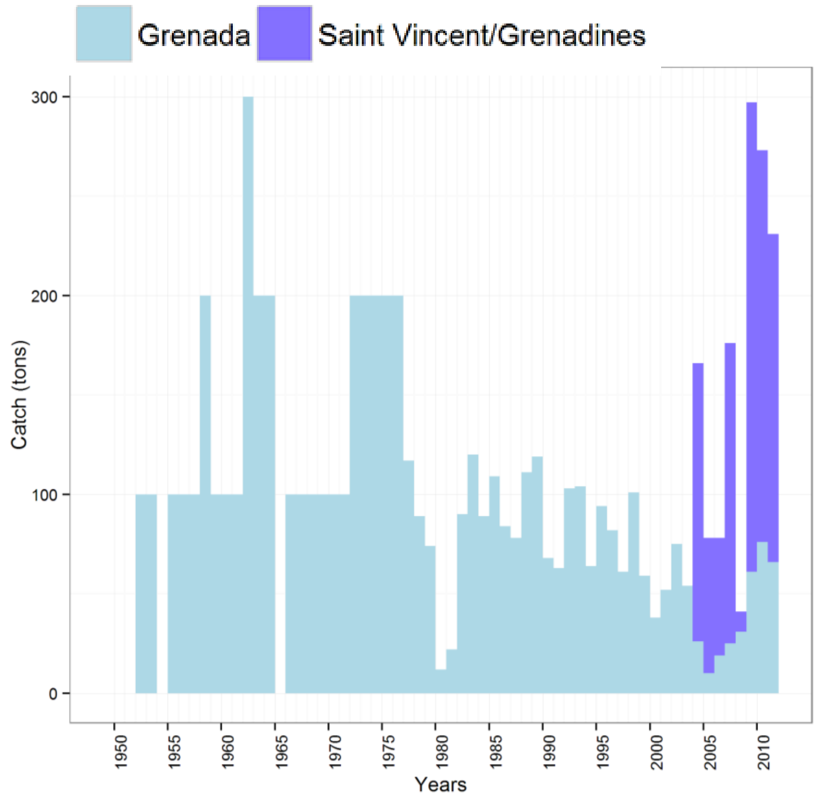

Figure 7. Catches of unidentified scad in the study area. Source: FAO Fishstat.

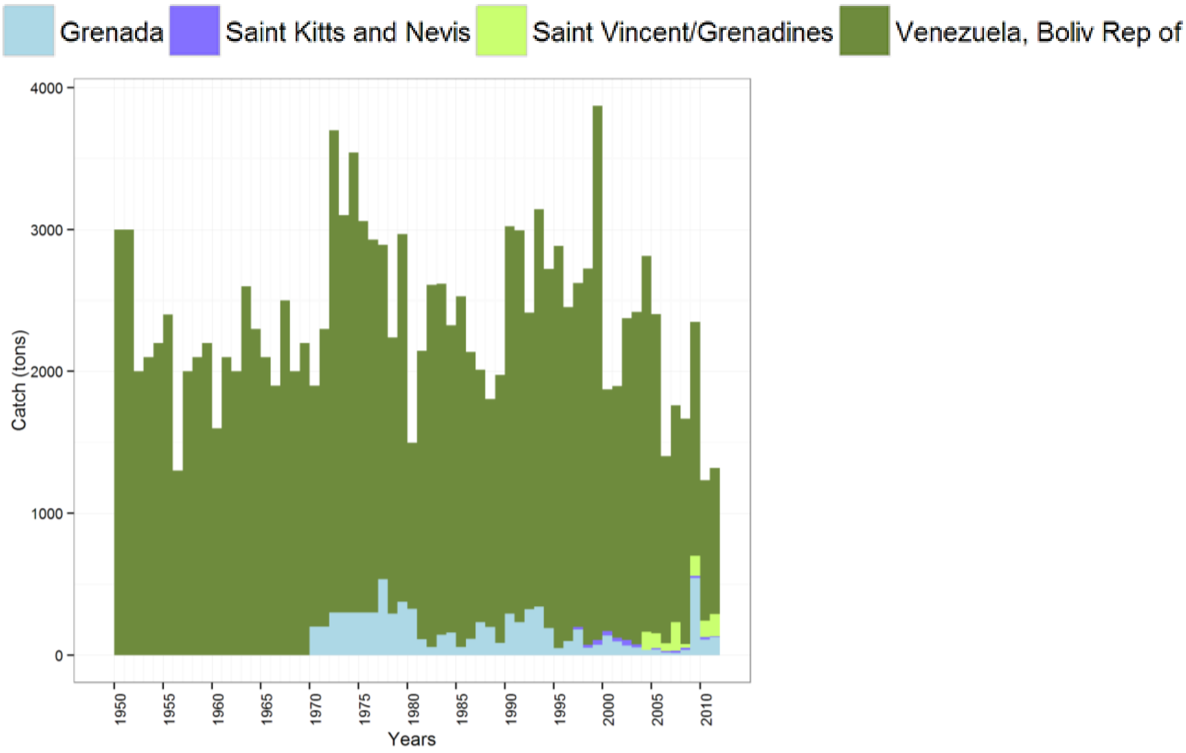

Figure 8. Catches of bigeye scad in the study area. Source: FAO Fishstat.

Highest catches for Mackerel scad, (*Decapterus macarellus*) in St. Vincent and the Grenadines are recorded February to June (Singh-Renton et al., 2012) and the major part of the catch consists of juvenile fish (Singh-Renton et al., 2012). Tobias (1987) reported the species as a minor component of the nocturnal baitfish catch for St. Croix. The species has been listed for the Dutch Caribbean (van Buurt, 2001) and corresponds to the species referred to locally as "moulo banana", a species which appears to have become rare in recent years around the ABC islands. Stobberup and Erzini (2006) did a stock assessment at Cape Verde. However, no assessments could be found for this species in the Caribbean.

Throughout its range, Round scad (*Decapturus punctatus)* is caught commercially and principally used as bait. It is one of the three most important species exploited in a small pelagics fishery off the Caribbean coast of Colombia (Páramo and Roa, 2003), the fourth most important species in the coastal baitfish fishery of St. Vincent and the Grenadines (Singh-Renton et al., 2012) and listed by Murray (1996) as important for St. Lucia. Murray (1996) further suggests that the fishing effort for the beach seine and gillnet fisheries which target this and other small coastal pelagics in St. Lucia likely exceed MSY. As with other *Decapturus* scads, this species keeps much less well than *Selar* (Singh-Renton et al., 2012). In the ABC islands the species is fished on a daily basis by most fishermen in the first half of the morning using chumming and hook and line for use as bait for trolling purposes. There it is the favourite bait for trolling for wahoo, *Acanthocybium solandri*.

The species is not listed as important for either Puerto Rico (Kimmel, 1987) or the US Virgin Islands (Beets and LaPlace, 1987). Falfan et al. (2007) did not mention this species for the baitfish fishery off the Mexican Yucatan and De Sturm (1991) did not list *Decapturus* as a key fishery resource for the region. Hence, while the species occurs widely throughout the region, it appears to be of only local importance as a fishery resource.

Round scad is principally marketed fresh as a food fish but with expanding longline fisheries in the region buying up these species as bait St. Vincent and the Grenadines found it necessary to ban such sales for a one year period in 2008 (Singh-Renton et al., 2012). The stock status of these species there remains unknown (Soomai, 2005).

3.1.5 Flyingfishes

Flyingfish, especially the fourwing flyingfish (*Hirundichthys affifinis*), are the most important small pelagic species in the Eastern Caribbean as an important economic, cultural and food resource (CRFM, 2013). FAO Fishstat reports flyingfish landings from five countries, clearly dominated by Barbados and with lower landings reported from Grenada, Martinique, Saint Kitts and Nevis and Saint Lucia (Figure 10).
Landings show large fluctuations, mainly influenced by catches from Barbados. Flyingfish are caught with gillnets, hand lines and dip nets in waters off the island shelf. Flyingfish are the main pillar of the Barbadian fishing industry (Mahon, 2008).

Although it remains difficult to assess the reasons for the fluctuations occurring in the fisheries, or the proportion of biomass which is taken from the total stock some major changes in the fishery of Barbados can be identified. During the first half of the 20th century, flyingfish were either captured on handlines, most often made of a small hook, or with shallow dipnets (Brown, 1942; Hall and Britain, 1956). In 1950/1, the gillnet was introduced to the fishing fleet. Motorization of the fishing fleet was the second major development in the flyingfish fishery. Motorised pelagic vessels became bigger, more powerful and more efficient (Berkes and Shaw, 1986; Oxenford, 1985), generally fishing within 30 nautical miles from shore (FAO/IC, 1982).

The next major development was the introduction of on-board ice holds, "ice boats" available since the 1970s, allowing the vessel to stay at sea for longer periods (up to around two weeks) and to fish further from Barbados in areas of potentially higher fish densities without fear of the catch spoiling.

During the same period, the marketing and distribution was optimised as well. Even though the number of landing sites did not increase dramatically, the available facilities did improve significantly. Unfortunately the marketing policy and distribution did not keep up to date with the developments which resulted in an oversaturation of the market in the 1980s, forcing fishermen to sell their products far under value. Further the price of fish was fixed by the government until 1972, a measure which often left fishermen without a chance to make appreciable profits. Improvements on this topic have been achieved in more recent years, with the development of processing companies.

FAO Fishstat reports flyingfish landings from five countries clearly dominated by Barbados and with lower landigns reported by Grenada, Martinique, Saint Kitts and Nevis and Saint Lucia. Landings show large fluctuations, mainly influenced by catches of Barbados.

The Sailfin flyingfish (*Parexocoetus brachypterus*) is apparently abundant in the eastern Caribbean as the second-most abundant adult flyingfish (Oxenford et al., 1995b) and may account for 50% of the numerical catch of juvenile flyingfish caught at night in April and May (Oxenford et al., 1995c).

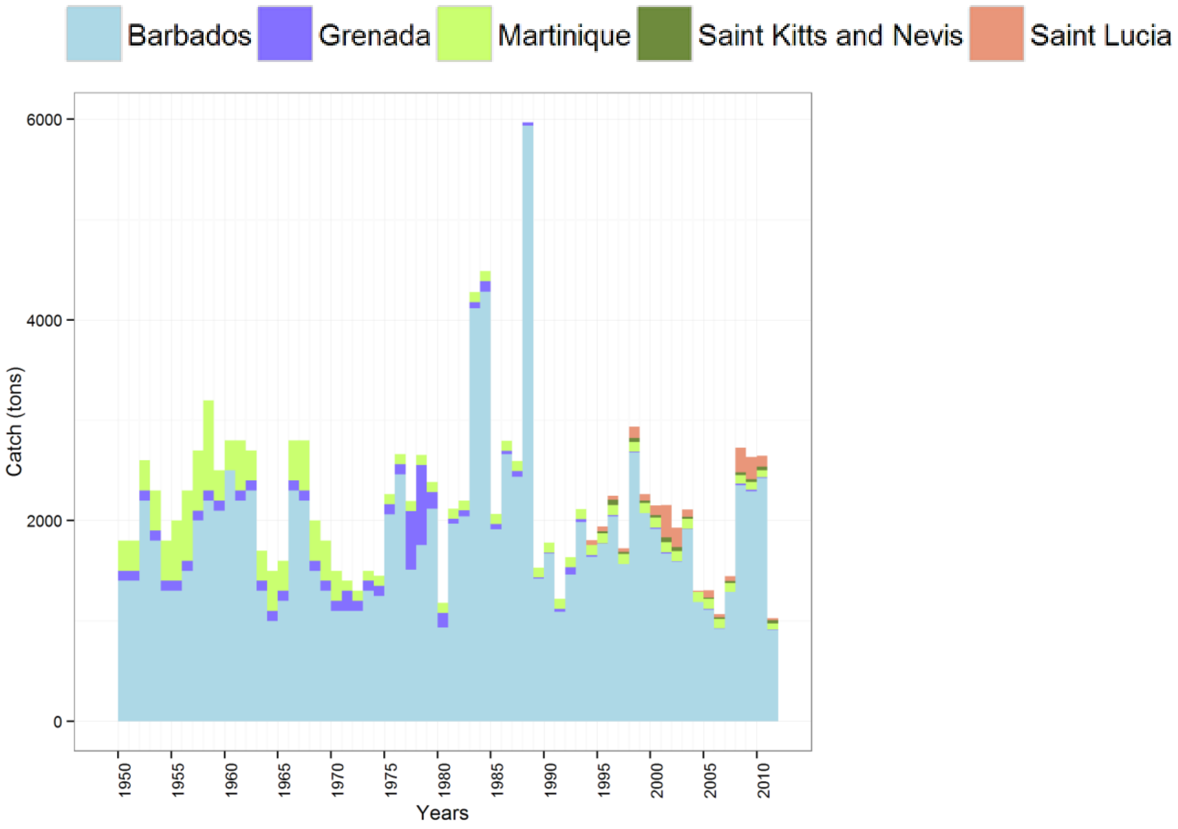

Figure 9. Catches of flyingfish - all species – in the study area. Source: FAO Fishstat.

Figure 10. Mirror wing flyingfish (Photos by Martin de Graaf)

3.1.6 Sardinellas

For Venezuela, in terms of landings, the sardine fishery (mainly round sardinella) forms the major part of the fishery industry. The fishery for sardines in Venezuela took off in the 1950s - 1960s with the building of canneries and the availability of outboard engines, which allowed local fishermen to become independent producers (Novoa et al., 1998). From the 1960s until 1983 reported catches of sardines remained very stable and the exploitation rate was estimated to be low. After the economic crisis of 1983 with the consequent increase of unemployment a shift towards a stronger exploitation of natural resources was observed with indications of unsustainable catches (Rodŕiguez, 2000). The fishery exploded in the mid–1990s before collapsing in 1999 – 2000, with a strong increase once more during the early 2000s. After 2005 a dramatic decrease was observed and catches are nowadays back to the same levels as in the 1980s (Figure 11 and 12; decrease in catches are partly compensated by St. Vincent). As a response to these dramatic developments, in 2009 a hydro acoustic survey has been carried along the Venezuelan eastern coast, which indicated a considerable decrease in stock size, probably related to a combined effect of natural and fishing mortality coupled with unfavourable environmental conditions that hampered recruitment (FAO, 2006). The stock currently shows signs of overexploitation, if not depletion (López, personal communication in FAO (2006)).

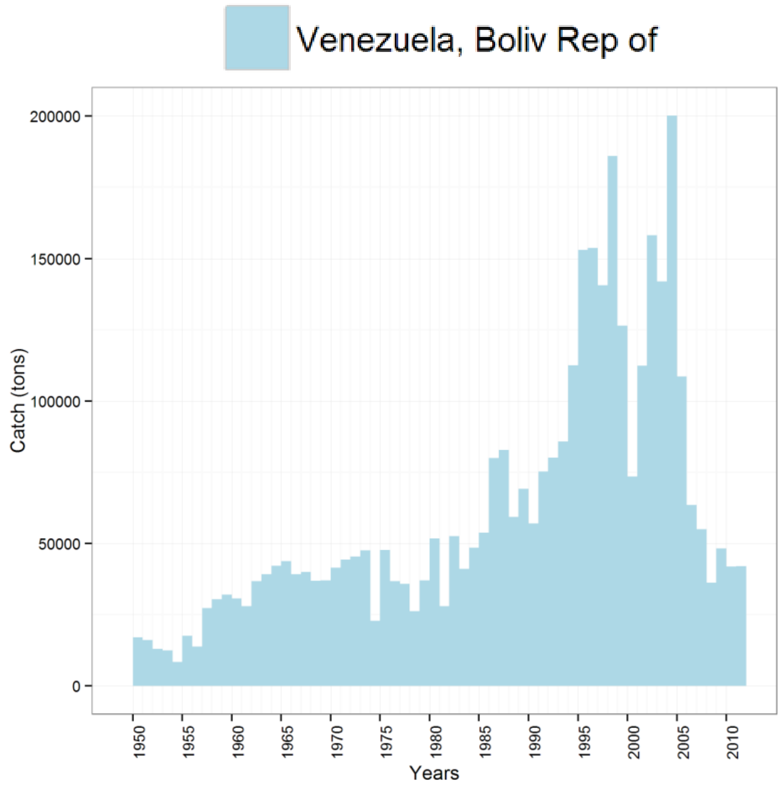

Figure 11. Catches of round sardinella in the study area. Source: FAO Fishstat.

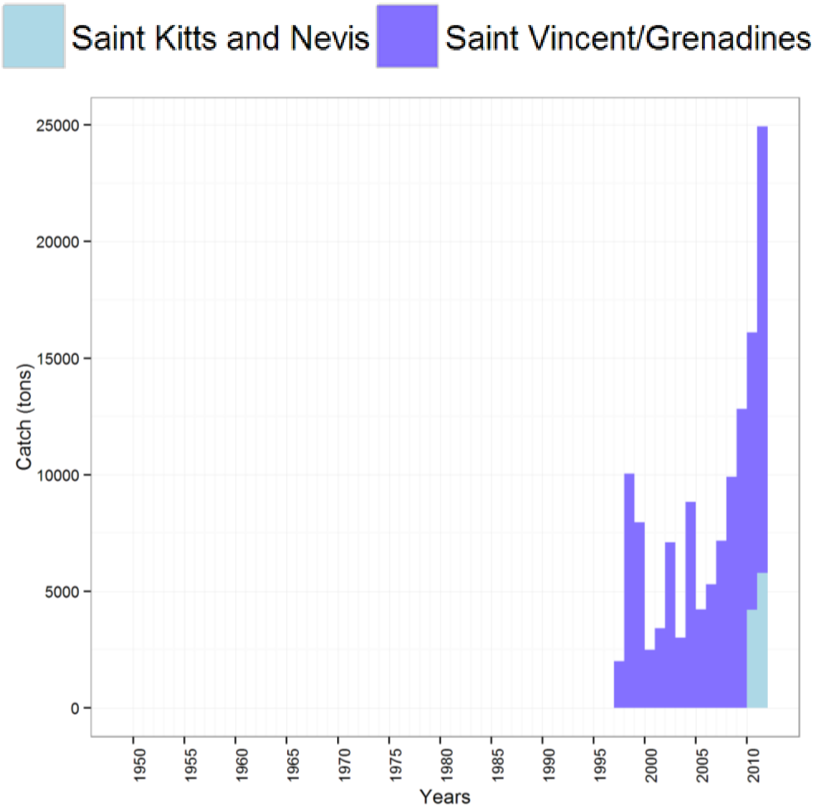

Figure 12. Catches of Sardinella sp. in the study area. Source: FAO Fishstat.

3.2 Biology of selected species

3.2.1 Sardinella aurita

Distribution and migration
Eastern Atlantic: Mediterranean, North African coast southwards down to Saldanha bay, South Africa. Western Atlantic: Cape Cod to Argentina. Prefers clear saline water with temperatures below 24 degrees in the Mediterranean and approximately 24 – 28 °C in the Caribbean (Whitehead, 1985) (Rueda-Roa, 2012) (Paramo and Roa, 2003)The species is distributed mainly at the surface, but may occur as deep as 350m (Whitehead, 1985). The main distribution is strongly correlated with the Guajira and the Margarita upwelling area.

Spawning
Spawning may take place more than once per year. In the Caribbean, off the coast of Venezuela the spawning period is related with the upwelling period. Spawning seems to take place during the whole year with two peaks in the first and the last quarter, effectively in the period November- March. Southern area: short, peak in December. Northern area, reproduction is more protracted with two peaks in November and February (Freon et al., 1997). The authors found a delay in reproduction of 5 months after the planktonic production which results from the upwelling. Meanwhile the energy necessary for reproduction is stored as lipids. This strategy seems to give priority to optimizing food availability for the larvae.

Behaviour
Strongly migratory and schooling behaviour.

3.2.2 Bigeye scad

The bigeye scad is a small schooling carangid that is common in tropical and subtropical oceans worldwide. The fish reaches a maximum size of about 30 cm and is found from the surface to depths of about 170 m. Common names in the region include: masbangu, jackfish and ojón. It is typically the most important schooling small pelagic around islands that lack a continental shelf and large populations of clupeids (Roux and Conand 2000). In other areas such as Puerto Rico, which possesses estuaries and a significant island shelf, the baitfish fishery is totally dominated by clupeids (Kimmel, 1987) and in the Virgin Islands the species only forms a very small portion of the baitfish resource (Beets and LaPlace, 1987). Its biology has been studied in several countries in the Pacific and Indian oceans (Clarke and Privitera, 1995; Dalzell and Penaflor, 1989) but no major studies are available for the Caribbean (Roux and Conand, 2000). There, the information available typically amounts to simple and typically incomplete catch statistics.

Distribution and migration
This species has a worldwide circumtropical distribution. According to sources referring to the Pacific, adults prefer clear oceanic waters around islands to neritic waters (Cervigón et al., 1992). It is only occasionally found in turbid waters (Smith-Vaniz, 1995).
(Dalzell and Penaflor, 1989) found in the fisheries at the Philippines that catch rates of bigeye scad are highly seasonal, reflecting not only changes in biomass but also behaviour associated with life history stages.

Spawning
Sex ratios were roughly 1:1 and ripe females were most abundant March–September in St. Croix (Tobias, 1987). At Reunion Island, in the southwest Indian ocean, most (pre)spawning specimens are found in October and November.

Size at first maturity was 215 mm and maximum size observed was 255 mm (Roos et al., 2007). Clarke and Privitera (1995) report a spawning period from April through September or October in Hawaii. Eggs are deposited pelagically (Iwai et al., 1996). Richards (1984) finds larval bigeye scad to be one of the most common species in ichtyoplankton tows throughout the Caribbean, while off the Yucatan it is the second-most common species following *Sardinella aurita* (Falfan et al., 2007).

Behaviour
The bigeye scad is believed to inhabit deep waters coming up to the surface at night to feed (Goodbody and Harvey, 1986; Roux and Conand, 2000) but regularly comes nearshore at the surface during daytime. Pelagic individuals travel in compact groups of hundreds of thousands of fish (Mundy, 2005). Mainly nocturnal in habit, they disperse at night to feed on small shrimps, benthic invertebrates, and forams when inshore, and zooplankton and fish larvae when offshore (Smith-Vaniz, 1995; Allen and Erdmann, 2012). Roux and Conand (2000) studied diet in various sizes of fish. All food of this species was pelagic. The smaller size classes consumed mostly crustaceans (zooplanktivorous) while large specimens consumed mostly fish (piscivorous). This contrasts with most clupeids which also importantly feed on phytoplankton.

In Reunion, growth was found to be highest during summer and least during winter. Recruitment to the fishery occurs at the beginning of summer at sizes of 65-90 mm FL and coincides with the disappearance and mass mortality of large individuals after reproduction peaks (Roos et al., 2007).

3.2.3 Mackerel scad, Decapterus macarellus (Cuvier, 1833)

Figure 13. Mackerel scads(?) , Bonaire (Photo by Martin de Graaf)

Distribution and migration
The Mackerel scad is small tropical and subtropical shoaling coastal carangid with a circumglobal distribution. It is common to sizes of up to 30 cm TL but maximum size is reported to be up to 46 cm.

Biology
It typically occurs at depths of 40-200 m. Preferring clear oceanic waters, it feeds principally on zooplankton and often aggregates. Carvalho (1993) studied growth and mortality, Carvalho and Caramelo (1999) assessed the fisheries, Almada (1997) studied its life history. Arnaud and Bonhomme (1998) evaluated gene flow in *D. macarellus* and found evidence of gene flow across large areas of the South China Sea.

3.2.4 Round scad, Decapturus punctatus (Cuvier, 1829)

Distribution and migration
This species is found in the temperate and tropical coastal waters of both the Eastern and Western Atlantic. In the Western Atlantic it is found from Nova Scotia to Brazil. It is most common at sizes of about 18 cm TL but reported to a maximum of 30 cm.

Spawning
McBride et al. (2002) have examined reproductive periodicity in this species and found spawning periodicity to be every 5 days. Spawning was diurnal and batch fecundity between 5-34 thousand eggs per spawn. However, in general, very little has been published about the biology of this species.

Biology
This species forms large schools at times, but in Curacao and Bonaire occurs typically scattered in small schools all along the fore-reef slope of the island. It inhabits shelf waters and its known depth range is down to about 100 m deep. It tends to aggregate consistently at lee side of coastal promontories and fishermen use such sites to fish them for bait every morning before going trolling. According to Berry and Smith-Vaniz (1978) the species feeds primarily on planktonic invertebrates.

3.2.5 Flyingfishes

Flyingfishes are common in the waters of the Caribbean and twelve different species have been identified from the eastern Caribbean (Hunte et al., 1995). Van Buurt (1979) has identified 10 species of flyingfish for the Dutch Caribbean waters of Curaçao and Bonaire. In these islands, the small, clearwinged species are typically referred to as Fleerchi while the larger dark winged species are referred to as Buladó. One species on the list, the Bluntnose flyingfish, *Prognichtys gibbifrons*, once considered to be widely distributed in the Atlantic has been found to currently be limited to the waters off the west coast of tropical Africa (Parin, 1996).

3.2.6 Four-winged flyingfish, Bulado, Hyrundichtys affinis (Gunther, 1866)

Distribution and migration

This species is limited to the temperate and tropical waters of the western and eastern Atlantic (Shakhovskoy and Parin, 2013) Shakhovskoy and Parin (2013) describe consistent differences between fish from the eastern and western Atlantic. Maximum length in the Western Atlantic is no more than 22.4 cm. This species has been the best studied flyingfish in the Caribbean with several studies available for the waters around Barbados (Oxenford et al., 1995b).

Spawning

Reproduction likely takes place year-round even though localized spawning occurs in shorter periods. Maximum spawning intensity around Barbados occurs in the season of low rainfall and low water temperatures (Khokiattiwong et al., 2000) whereas at Rio Grande do Norte, Brazil, this occurs at the beginning of the rainy season with a sex ratio of 1:1 (De Araujo et al., 2001; De Araujo and Chellappa, 2002). At 210 mm 90% of the fish are mature (Shakhovskoy and Parin, 2013). Spawning can occur near the surface, in the water column or at the bottom, apparently with sticky eggs and during daytime (Hunte et al., 1995). Females lay about 30 thousand non-bouyant eggs during a season in about four spawning events. Larvae and eggs are rare in plankton tows, even in the presence of spawning adults.

Biology

Studies on the genetics of the species have revealed significant genetic differences even between closely separated migratory populations (Gomes et al., 1998; Gomes et al., 1999; Oxenford, 1994). The results suggest a complicated population structure possibly due to homing behaviour. Campana et al. (1993) used Th/Ra dating methods to study longevity in the species and found that most adult flyingfish were one year old. Only few adult animals were 2 years old.

3.2.7 Sailfin flyingfish, Parexocoetus brachypterus (Richardson, 1846)

Distribution and migration

This flyingfish is common in tropical and subtropical seas worldwide, including the Caribbean and Lesser Antilles.

Spawning

Maximum length is about 20 cm, common lengths are up to 16 cm. Size of maturation is 11-13 cm (TL) (Parin, 1996). Larvae were more abundant at coastal than at oceanic locations, indicating coastal spawning in this species (Hunte et al., 1995). Stevens et al. (2003) describe a spawning aggregation of this species in the north-eastern Gulf of Mexico involving upwards of 1 million fish. This took place two days after full moon in May 2001 with a sex ratio of 1 female for every 3 males. Spawning occurred in small aggregations of 3-4 fish, presumably each female being pursued by several males. Spawning occurred in absence of flotsam but the eggs are non-buoyant (Hunte et al., 1995).

Biology

As has been suggested of *H. affinis*, and other flyingfish, mass mortality after spawning may take place.

3.2.8 Halfbeaks, Hemiramphidae

In Guadeloupe *Hemiramphidae* amounted to an estimated catch of 204 metric tons in 2008 (Guyader et al., 2012). There are two species of importance and these are *Hemiramphus balao* and *H. brasiliensis*. In Puerto Rico, *Hemiramphus* amounts to 14% of the small pelagics catches whereas in SVG it is the third most important fishery resource (*H. balao*) (Singh-Renton et al., 2012).

The two species are very similar in size and shape but differ greatly in life history characteristics but typically intermingle in reef habitats and are rarely distinguished amongst each other in catch statistics. This compromises the utility of much of the catch statistics from the Caribbean for this species group.

In Florida the fishery for these species is conducted by means of nocturnal lampera-net fishing (McBride and Styer, 2002). Catch rates increased yearly until about 2003 (Anonymous, 2010) and stabilized since then. Combined Florida catches amount to about annual catch of about 600 metric tons, all of which is sold for use as bait. Based on the most recent stock assessment (Mahmoudi and McBride, 2002) the fishery was considered overfished. The Florida Fish and Wildlife Conservation Commission in 2003 had to implement catch restrictions on the fishery including closure during August and a 5 year moratorium on lampera-net endorsements (Anonymous, 2010).

3.2.9 Ballyhoo halfbeak, Hemiramphus brasiliensis (Linnaeus, 1758)

Distribution and migration
This species is largely a shallow coastal species, found only inshore, above reefs and shoreward over seagrass beds (McBride and Thurman, 2003). It is slightly larger than *H. balao*. The species have been best studied in the USA because of their commercial importance there. Recent studies are now also available from Venezuela and Brazil. *H. brasiliensis* is the species for which most information can be found.

Spawning
In Florida reproduction peaks during late spring and early summer and reproduces more than once in a lifetime (iteroparous) with all females spawning daily for about a month (Mahmoudi and McBride, 2002). The eggs attach to floating seagrass. This species has a lower batch fecundity than *H. balao*, but life time fecundity is similar. Spawning occurs at dusk (McBride and Thurman, 2003) and over shallow reef waters over wide areas. Size of maturation in Venezuela is at about 240 mm Standard Length (SL) and multiple spawnings take place each year. Sex ratios showed about 3 times more females than males. (Longart et al., 2011b).

Biology
This species feeds principally on seagrass and zooplankton (Berkeley and Houde, 1978). (Longart et al., 2011a, c) provide some data on food habits and biometrics for the species while Rosas et al. (2008) have described its embryonic development, all for Venezuelan waters. In Venezuelan shallow coastal waters the species may represent up to 13% of the fauna in certain areas (Ruiz et al., 2007).

3.2.10 Balao halfbeak, Hemiramphus balao (Lesueur, 1821)

Distribution and migration
This species is largely deeper water coastal species, found only above reefs and offshore in deep waters (McBride and Thurman, 2003). It is slightly smaller than *H. brasiliensis*.

Spawning
Spawning occurs at dusk (McBride and Thurman, 2003) and off-shore of the reefs over wide areas.

Biology
Longevity is up to only 2 years and annual survival is about 7.5% (McBride and Thurman 2003). This species feeds on phytoplankton (Berkeley and Houde, 1978). The large contrast in survival and fecundity between the two species suggests a large difference in trade-offs between survival and reproduction (McBride and Thurman, 2003).

3.2.11 Redear herring (Harengula humeralis (Cuvier 1829)

Distribution and migration

This pelagic clupeid is typical of seagrass and shallow reef areas near coral reefs. They feed principally at night on copepods, larval decapods, fish and stomatopods (Ortaz et al., 1996; Pena-Alvarado et al., 2008). It is found throughout the West Indies and is easy to distinguish from other sardines due to its yellow/orange spot at the opercula and orange stripes on the upper half of the body. The species attains a maximum of 22 cm but is common to sizes of about 12 cm (Pena-Alvarado et al., 2008). The species is often a carrier of clupeid poisoning and is considered inedible in the Leeward Dutch Caribbean and also in Venezuela.

In Trinidad length-frequency data indicate three year-classes in the population.

Spawning

Sex ratios often show a predominance of females in the mature size-classes (1♂:1.6♀) (Pena-Alvarado et al., 2008). Mean length of maturity for males and females is similar and roughly 95 mm (Alvarado et al., 2008). In Puerto Rico reproduction is year-round but most intense January-August. Spawning probably takes place at night, close to shore. In Trinidad spawning takes place in the wet season July-December and fishery landings also peak during this period (Manickchand-Heileman and Hubbard, 1992).

Biology

Natural mortality in Los Roques, Venezuela was 0.90 yr-1 while fishing mortality was 2.74 yr-1 yielding a high exploitation rate (Posada, 1999).

3.2.12 Atlantic thread herring (Opisthonema oglinum)

Distribution and migration

This tropical and subtropical species is found in the Western Atlantic from Maine to Argentina and estuarine river mouths are used as nursery habitat (Pena-Alvarado et al., 2008). It is a shallow-water species with a maximum size to 38 cm but common to 20 cm (Pena-Alvarado et al., 2008). Characteristic are the two dark spots above and behind the opercula and 6-7 stripes on the upper body. Inhabit harbours and shallow coastal areas (Klima, 1971; Lieske and Myers, 1994). Form schools (but solitary individuals reported), probably not entering water of low salinity. The species seems to be rather stationary, but (Klima, 1971) report seasonal north-south migrations in the eastern Gulf of Mexico. Western Atlantic: Gulf of Maine (USA), Bermuda, throughout the Gulf of Mexico, Caribbean and West Indies southward to Santa Catarina, Brazil.

Spawning

Sex ratios often show a predominance of females in the mature size-classes (1♂ :2.1♀) (Pena-Alvarado et al., 2008). Mean length of maturity for males and females is similar and roughly 125 mm (Pena-Alvarado et al., 2008). The spawning period varies throughout the Caribbean and the Gulf, but mostly within the period February – September. (Vega-Cendejas et al., 1997b) found a markedly different period at Campeche Bank, Gulf of Mexico: July – December. This species has a 6-month spawning season in Puerto Rico with ripe females being found only April-September (Pena-Alvarado et al., 2008).

Table 2 Spawning season for Atlantic thread herring.

Period	Peak	Area	References
April-September	June-July	Puerto Rico	(Pena-Alvarado et al., 2008)
May-October	May & August	Southern Gulf of Mexico	(Garcia-Abad et al., 1998)
February-September	April-August	Eastern Gulf of Mexico	(Houde, 1977)
March-August	June	Florida	(Fuss et al., 1969)
March-August	June	Northern Gulf of Mexico	(Kemmerer, 1977)
(May & June)		North Carolina	(Hildebrand, 1963)
(June)		North Carolina	(Smith, 1994)
(April-July)		Florida	(Prest, 1971)
(August & September)		South Texas	(Finuncane et al., 1978)
(February-May&August)		Florida	(Herrema et al., 1985)
(March – July)		Venezuela	(Whitehead, 1985)
(May - June)			(Bigelow et al., 1963)
July - December		Southern Gulf of Mexico	(Vega-Cendejas et al., 1997b)

(Prest, 1971) reported that *O. oglinum* spawns in near shore shelf waters at depths of 10 – 30m. The species scatters its eggs in open water and on substratum, and does not guard its eggs (Legore, 2007); although it is not clear on what studies or information this is based).

Behaviour
The fish commonly form dense schools in the upper 3m of the water column, but in some seasons they may also occur close to the bottom, in particular larger specimens (Cervigón et al., 1992). The species feeds on both phyto- and zooplankton but large specimens will also take large prey like fishes. Páramo and Roa (2003) found strong geographic segregation based on size in this species with smaller fish found in warmer waters and larger fish strongly associated with cooler upwelling waters.

3.2.13 Atlantic anchoveta

Distribution and migration
Western Atlantic: in the Antilles, from Cuba southward; Costa Rica south and east to Colombia and Venezuela, Trinidad south to Itapema, Santa Catarina, Brazil.
Occurs inshore and forms quite large schools. Enters brackish waters of lagoons and estuaries and can tolerate salinities of 10-31 ppt (Santa Cruz Canal, Pernambuco, Brazil). A filter-feeder presumably on both phytoplankton and zooplankton. Spawns off the Araya Peninsula, Venezuela from October to January, with a distinct peak in mid-November. Eggs are oval, spawned at 0230-0500 hours along shoreline out to about 1.5 km and hatching about 20-24 hours later (Whitehead et al., 1988).

3.2.14 Anchovy

This group consists of a number species: *Anchoa colonensis*, *A. hepsetus*, *A. filifera*, *Anchoviella perfasciata*, *Engraulis eurystole, Anchoa lamprotaenia*. Species in this group have all coastal distributions. They form dense schools. Engraulis eurystole is reported to spawn in July/August (Whitehead et al., 1988).

The distribution of *A. colonensis*, *A. filifera* and *Anchoviella perfasciata* are restricted to the Gulf and Caribbean. *Anchoa. hepsetus* has is more wide spread in the western Atlantic: 44°N - 36°S According to Fishbase, in the West Indies A. hepsetus is replaced be *A. colonensis*. *E. eurystole* is distributed in the western Atlantic from the US coast.

4. Fishery independent surveys in the area

Fisheries surveys targeting small pelagic fish are scarce and incidental in the area (Table 3). The majority of historic surveys investigated the round sardinella stock off Venezuela. In recent years only 2 surveys targeting small pelagic species have been done. Namely one targeting small pelagics in general, organised within the FAO LAPE (Lesser Antilles Pelagic Ecosystem) project. The second survey was a locally organised acoustic survey executed by Venezuela (pers. Communication Juan José Cárdenas), as a response to the dramatic drop in the round sardinella population, but a routine execution of the survey, as it used to be done in the 1990s, is not possible (given the financial and political situation of the country). Pelagic research initiatives are nowadays generally coordinated by the French fisheries research institute (IFREMER) or the Institute de Recherche pour le Developpement (IRD).

Other noteworthy surveys include those executed around Barbados during the 1980s monitoring of flyingfish, using different techniques (larvae, visual observations, gill nets or dip nets). Table 3 illustrates the incidental character of small pelagic surveying in the Caribbean.

Table 3 Surveys targeting small pelagic fish

year	main target species	area	method	reference
1971-74	Thread herring	southeastern GoM	Larvae surveys	(Houde, 1977)
1985	Atlantic thread herring scaled herring round sardinella round scad	Off coast Columbia 11°16N-74°14W; 12°24N-71°49W	Hydro acoustics	(Blanco, 1986)
1988	Several species	Off coast Columbia 11°16N-74°14W; 12°24N-71°49W	Hydro acoustics	(Anonymous, 1989)
1987-88	Flyingfish species	southeast off the coast of Barbados	Gill net (study)	(Khokiattiwong et al., 2000)
1988	Flyingfish species	Barbados, Martinique Tobago, Grenada 9°30N - 16°N; 58° - 62°30N	Dipnets (study)	(Oxenford et al., 1995c)
1988	Flyingfish species	Barbados, Martinique Tobago, Grenada 9°30N - 16°N; 58° - 62°30N	Larvae surveys (study)	(Hunte et al., 1995)
1988	Flyingfish species	Barbados, Martinique Tobago, Grenada 9°30N - 16°N; 58° - 62°30N	Visual survey (study)	(Oxenford et al., 1995b)
1988	Several species, incl. demersal and crustaceans	4 surveys covering Suriname, Guyana, Venezuela, Trinidad and Colombia	Hydro acoustics, trawl	(Strømme, 1989b) (Strømme, 1989a) http://www.fao.org/docrep/004/x3950e/x3950e13.htm
1995	round sardinella	off coast Venezuela 10°W - 11°30W; 63°30N - 64°30N	Hydro acoustics	(Cárdenas and Achury, 2000)
1996	round sardinella	off coast Venezuela 10°W - 11°30W; 63°30N - 64°30N	Hydro acoustics	(Cárdenas and Achury, 2000)
1996	round sardinella	off coast Venezuela 10°W - 11°30W; 63°30N - 64°30N	Hydro acoustics	(Cárdenas and Achury, 2000)
1996	round sardinella	off coast Venezuela 10°W - 11°30W; 63°30N - 64°30N	Hydro acoustics	(Cárdenas and Achury, 2000)
1997	round sardinella	off coast Venezuela 10°W - 11°30W; 63°30N - 64°30N	Hydro acoustics	(Cárdenas and Achury, 2000)
1997	Several species	Off coast Columbia 11°16N-74°14W; 12°24N-71°49W	Hydro acoustics	(Paramo et al., 2003) (Páramo and Roa, 2003)
1997	round sardinella	off coast Venezuela 10°W - 11°30W; 63°30N - 64°30N	Hydro acoustics	(Cárdenas and Achury, 2000)
1997	round sardinella	off coast Venezuela 10°W - 11°30W; 63°30N - 64°30N	Hydro acoustics	(Cárdenas and Achury, 2000)
1998	round sardinella	off coast Venezuela 10°W - 11°30W; 63°30N - 64°30N	Hydro acoustics	(Cárdenas and Achury, 2000)
2004	Severel species	Lesser Antilles 63°0W-56°0W; 9.50°N-21°00 N	Hydro acoustics	(FAO, 2006)
2009	round sardinella	off coast Venezuela 10°W - 11°30W; 63°30N - 64°30N	Hydro acoustics	(López et al., 2010)

5. Conclusions and recommendations

5.1 Available fisheries dependent data

It has to be recognised that at least parts of the artisanal fisheries are largely underrepresented in official – FAO - landing numbers. In some areas or for some periods it is estimated that true catches might be as much as 200-500% higher than estimated (Mendoza et al., 2003). Further, correct identification of species and aggregation of data remains an issue, for example landings from 1950-1960 for St. Vincent and the Grenadines contained only 13 species in FAO Fishstat, although disaggregated reconstructed catch information identified more than 90 species for each year (Mohammed et al., 2003). Mendoza et al. (2003) reports that tonnage reports in FAO Fishstat are generally good, but taxonomic information is transferred with a considerably loss. Another challenge when it comes to the monitoring of small pelagic species in the Caribbean using landing information lies in the nature of the fisheries. The vast majority of small pelagic fish are used as bait fish and hence remain unregistered most of the time. Keeping in mind all the above mentioned restrictions estimates provided by FAO Fishstat are most probably underestimating the true catches of small pelagics quite dramatically and trends, at least in some cases might be blurred out or masked due to the nature of the fishery, because of misidentification or because of over-aggregation of the species information.

5.2 The pelagic community of the Wider Caribbean Region

Small pelagic fish in the Wider Caribbean Region can be divided into:

1) Coastal Pelagic. Species with pelagic behaviour, but coastally bound. 10-20 species, wide spread in the region, locally abundant and targeted as bait fish. This group consists of *Carangidae*, *Clupeidae*, *Engraulidae* and *Hemiramphidae*. It is often not clear what species are involved and what their status is.
2) Oceanic pelagics ; all flying fishes; wide spread in the region. Heavily targeted as bait fish, locally for human consumption (Barbados).
3) *Sardinella aurita*, off shore distribution, limited to an area of upwelling off the coast of Venezuela.

The first group can be surveyed in local, fishery independent, sea going surveys because the species are more or less coastal. Depending on the area and the species involved, local information could inform on the aggregations and spawning time/location. As a start, one may choose for either an acoustic survey or larvae survey. From a logistic point of view this the surveying of this group should not give problems, provided a vessel, crew and scientific staff are available. An abundance estimate in a larger area, consisting of more i islands or countries, may be calculated from extrapolation.

The second group, flying fishes, is clearly crossing boundaries of EEZ's in the region. The species involved are wide spread. They may aggregate closer to the coast, depending on the region and species. Their status is unclear. However, (mass) spawning aggregations, sometimes close to the coast, makes this group potentially vulnerable.

Flying fish do not form dense schools and stay typically high up in the water column. There it seems unlikely that they can be successfully surveyed by means of echo integration. On the other hand, densities of eggs and larvae are very low in the studies that have been carried out, which indicates that ichthyoplankton surveys are not suitable either. Flyingfish could be surveyed within ecosystem focussed surveys, running multiple methodologies like visual observations of birds and mammals, biological sampling of fish and hydrographical observations.

Adult flyingfish can be surveyed for example within the line transect methodology for sea mammals (Buckland et al., 1993; Fréon, 1988). The execution of these type of visual observation techniques can be combined with egg and larvae surveys

The third group, Sardinella, is located in a limited area, mainly inside the Venezuelan EEZ. The stock has been surveyed briefly in the eighties in Columbian waters, in 1995-1997 and 2009 in Venezuelan waters by means of hydro acoustics, indicating a significant decrease of the stock from the nineties to 2009. The monitoring of the stock is a Venezuelan appointment, although at the margins, some EEZ? boundaries are crossed (Columbian, Dutch). Given the importance of this stock, economically and ecologically, is should be surveyed by means of hydro acoustics every year by Venezuela.

For the second and the third group, the organisation of routine surveys does not require international coordination unless the objective is to make abundance estimates in larger areas. But even in that case, available data can be combined or extrapolated at a later stage and on a higher aggregation level. Annex A gives a description of possible hydro acoustic methods.

5.3 Small pelagic fishery potential in the Dutch Caribbean

Is there potential for a fishery targeting small pelagic species in the Dutch Caribbean? The most obvious condition for such fishery is the presence of small pelagic fish in the vicinity of the islands. This provisional study has shown that there are no obvious "hidden" resources – although flying fish may have some potential (see Barbados) - somewhere in the Dutch EEZ. There are small pelagic fish resources, often close to the coast, but these are in the same order of magnitude as elsewhere in the Caribbean. However, these resources are poorly recorded and not managed. Modern trawlers, equipped with sonar, may find fishable concentrations in the vicinity (ten of miles) of their home port.

The second condition is the availability of appropriate vessels. Part of the vessels that operate from Caribbean islands, including the Dutch Caribbean, are in general seaworthy and therefore able to operate tens of miles from the coast. Simple hydro acoustic equipment (sonar and echosounders), is not expensive. Therefore vessels may certainly be able to detect fish concentrations. However, in order to catch small pelagic fish, in general a vessel needs equipment to operate pelagic trawl or purse seine with exception of flying fish driftnet fishery. This requires investments of tens of thousands euros. In addition this equipment needs to be maintained, which requires local knowledge and additional investments.

Investments in boats, equipment and maintenance need to be earned back, which brings forward the third condition: the presence of a market for small pelagic fish. The obvious answer is: no, there is no demand for small pelagic fish on a large scale, other than for bait fish. Traditionally on the Dutch Caribbean islands, there is a small local market for scads for human consumption. Markets of small pelagic fish are usually global. Worldwide small pelagic fish account for 30% of global landings, mainly for the use in intensive food production (pigs and poultry) and aquaculture. Only between 10 and 20% of these is used directly for human consumption (Alder et al., 2008). With lack of a highly productive area in the region, such as for example the upwelling area off Venezuela which is related to Sardinella abundance, it is unlikely that the Dutch Caribbean islands would be able to add to this global trade. On a local scale however, small pelagic fish can be important as a cheap food source.

It is therefore important to address the question: What is the trade-off is between targeting large pelagic species versus their prey? Direct consumption of small pelagic fish, rather than using it in the reduction sector, is more efficient from a biological and an economical point of view. Headley (2009) addresses the question of whether direct harvest of flyingfish or indirect harvest through converted predator biomass is more profitable in a case study for flyingfish and dolphin fish (*Coryphaena hippurus*) and concludes that direct harvest of flyingfish is the better management strategy.

In the eastern Caribbean, Barbados is an example which shows that this concept is possible. Barbados is the only state in the wider Caribbean where small pelagic – more specifically flying fish – is directly used for human consumption (Fanning and Oxenford, 2011). Fishing may also affect ecological processes worldwide and in the Caribbean (Pauly and Christensen, 1995). By targeting and reducing the abundance of high-value predators, the trophic chain and the flows of biomass is deeply modified across the ecosystem (Pauly, 2005).

As a first step a (bio-)economic study into the potential of the development of a sustainable fishery for small pelagic fish in the Dutch EEZ could be initiated. The flyingfish fishery in Barbados (http://www.agriculture.gov.bb/agri/index.php?option=com_content&view=article&id=67%3Afisheries-division&Itemid=82) could be used as an example or a reference. Depending on the presence of local pelagic resources, such a study should not merely focus on flying fish but should include all small pelagic fish.
The Barbados flying fish fishery could also be used as an example for a local experimental fisheries project.

5.4 Recommendations and future research

Ongoing small pelagic fish and/or fisheries surveys are rare, and sporadic in the Wider Caribbean, including the Dutch EEZ Given the uncertainty about the health of the stocks, but also because of the potential to fish for small pelagic fish for the local market, it is recommended that the Netherlands puts increased effort into research in this field, covering at least the Dutch EEZ. Involvement and cooperation with local institutes should be seen as crucial. From a Dutch perspective, the main focus should be given to the area to the pelagic area's adjacent to coastal reef zones around the archipelagos.

Acoustic surveys targeting small pelagics have been executed in the past (LAPE project, Norwegian survey) proving the potential of this technique to monitor small pelagic resources in the Eastern Caribbean. For flyingfishes, acoustics are most probably not the best available monitoring tool and other techniques such as visual surveys or egg/larvae surveys are more appropriate and should be considered.

As with most scientific challenges, the Dutch Caribbean could be seen as a problematic area or an area of opportunity. Opting for the second option we stress that this could be an opportunity to develop innovative methodologies towards an ecosystem approach in fish stock monitoring. The ecosystem approach to fisheries management is being pushed worldwide. The biggest obstacle is a lack of appropriate ecosystem data of pelagic environment adjacent to the coastal reef zones. Starting on the right foot by going straight to an ecosystem survey probably makes more sense than starting single species surveys and then trying to adapt those to ecosystem surveys later (because of time series concerns etc.). A holistic approach, incorporating observations of multiple trophic levels, using different strategies within a single survey would be highly preferable.

As such any acoustic survey, given that the needed equipment and knowledge is available could be turned into such an ecosystem survey, using CTD measurements to monitor hydrographical conditions, WP2 samplers to collect plankton information, acoustics to gain an insight into the pelagic part of the ecosystem. Trawling should be applied to groundtruth acoustic findings, collect biological samples and data on species which cannot be observed acoustically. In addition visual observations should be carried out for large predators, birds and flying fish. Hence obtaining the possibility of monitoring over a broad range of trophic levels and making in-situ measurements of species interactions, and of the influence of environmental changes onto the distribution and behaviour of given species.

The other way round, sea going surveys on cetaceans and seabirds in the Dutch EEZ, could be combined with fish surveys. At present only some pilot surveys have been carried out as yearly sea going surveys are relatively expensive (Geelhoed and Verdaat, 2012; Geelhoed et at., 2014; Scheidat et al., 2013). However by combining different targets/disciplines costs could be kept relatively low. A yearly ecosystem survey of this type would be clearly different from other research in the wider Caribbean, which is currently dominated by local, reef based - often scuba diving – studies. On the short term, seagoing ecosystem surveys would lead to new data and hence a better understanding of the Caribbean pelagic ecosystem en on the long term to invaluable long time series necessary for proper management of natural resources in the Dutch EEZ and the Wider Caribbean.

Besides the development of novel survey techniques, it would be crucial to continue the recently implemented fisheries monitoring programmes for fish species. The current programme does include all species (personal communication Martin de Graaf), but more emphasis on small pelagic fish is desirable At present this group is missed – like in almost everywhere in the Wider Caribbean because surveys normally focus on the target species, rather than the bait.

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Justification

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The scientific quality of this report has been peer reviewed by the a colleague scientist and the head of the department of IMARES.

Approved: Dr. M. de Graaf
Reseacher

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Date: 6 May 2015

Approved: Drs. J.H.M. Schobben
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Signature:

Date: 6 May 2015

Appendix A. monitoring survey methods for stock assessment of small pelagicfish in the Dutch Caribbean

In order to manage exploitation of stocks of small pelagic fish, these populations need to be assessed before appropriate actions can be taken. However, the choice of how to assess a population is an important decision because managers aim to maximise the knowledge about health of a fish population while minimising the time and money expended to gain that knowledge. A fish population is defined as a group of individuals of the same species or subspecies that are spatially, genetically, or demographically separated from other groups. A population will have a unique set of dynamics (e.g., recruitment, growth, and mortality) that influence its current and future status. Due to limits determined by funding and time available, biologists almost never examine all the fish in a population, but instead base inferences on a sample of individuals from a population. How, where, and when those samples are drawn has a tremendous influence on the quality of data and validity of subsequent stock size estimates.

The first step in designing a monitoring survey is to clearly define its objectives. For fisheries surveys, the objective is most often to estimate the relative or total fish abundance. Both of these objectives involve defining the area to be sampled, so that the population will be fully represented. The trade-off between ideal design of the survey and time/resources available may ultimately influence statistical confidence in the estimate. Important information on survey needs can be gained by clearly identifying the target of interest, such as a specific species or age-group. Identifying survey targets ahead of time will aid in identifying data limitations that may result from the survey design. For example, a survey designed to quantify open-water pelagic species will not provide valid estimates for species or age-groups that are commonly found in near-shore shallow waters. Such restrictions will be critical for other researchers or managers who may use the survey data. Consequently, different survey types will need to be used in order to be able to get knowledge about stock size levels at different life stages of the species. Then, selection of survey timing is important to minimize bias and maximize species or age-group separation by taking into account seasonal, diel, or lunar patterns in fish behaviour.

A seasonal consideration for survey timing is for example schooling associated with spawning migrations. The different life stage characteristics of the main small pelagic fish species groups of the Dutch Caribbean and potentially valid survey methods (ichthyoplankton [ITY] or acoustic [ACU]) are presented in the following table:

Species (groups)	Spawning period	Egg type	Egg size [mm]	Early-feeding larvae size [mm]	Suitable for surveys?	
					ITY	ACU
Sardinella aurita	Nov-Feb	pelagic	1.1	4	Yes	Yes
Scads (Carangidae)	April-Oct	Pelagic	0.7	8	No	Yes
Anchovies (*Engraulidae*)	?	pelagic	0.5-1.4	6	Yes	Yes
Flyingfishes	?	benthic	1.7	6	Yes	No

Two standard survey methods are commonly used to monitor different life stages of pelagic fish. These are: (1) ichthyoplankton surveys that give an indication about the amount of egg/larvae and therefore potential recruitment and spawning stock size; and (2) acoustic surveys to monitor the size of the juvenile/adult component of the fish population.

1) ichthyoplankton surveys to monitor pelagic fish stock recruitment

Ichthyoplankton sampling sites should cover the waters at and adjacent to spawning areas. Sampling stations for surveys should be distributed at appropriate intervals in order to cover the area. A zigzag pattern crossing both sides of bays and inlets is sometimes necessary. A grid pattern is usually chosen to cover larger bodies of open water. A relatively large survey area may be required since larvae may be well dispersed. Fixed distance sampling intervals can simplify area extrapolation procedures that may be used to calculate indices of abundance.

a. Sampling procedures

Ichthyoplankton samples can be collected using for example larger 60 cm diameter bongo nets or smaller 20 cm diameter bongo nets. The net designs should have a bag length-to-mouth ratio of 5:1 for both sizes of bongo nets and contain a 0.35 mm aperture black, nylon mesh. Plankton net mesh apertures smaller than 0.35 mm or larger than 0.5 mm in size are not recommended for egg and larval surveys of selected main small pelagic species in the Dutch Caribbean. Anchovy eggs eggs for example are 0.5 to 1.4 mm in diameter and the heads of newly hatched larvae are a few mm in size. Another point is that although all flyingfish species are pelagic, the eggs of most are not buoyant but have filaments for attachment to substrata. They are therefore not suitable for sampling by ichthyoplankton surveys. Net mesh apertures larger than 0.5 mm may extrude some eggs and larvae of thementioned small pelagic fish species. At the lower end of the mesh size range, a plankton net's water filtering performance can be reduced if apertures are less than 0.35 mm in size, as meshes can become rapidly. A pressure wave can develop in front of a plankton net under tow and deflect fish larvae away from the net opening. Continuous net washing becomes necessary to clear obstructed meshes. Furthermore, fine-mesh plankton nets with mesh apertures less than 0.35 mm in size require a finer monofilament fibre in their construction and do not withstand the rigors of intensive field use to the same extent as coarser nets.

Flow meters may be used to measure the volume of water filtered through the nets. They are tied into the centre opening of the nets and positioned in the direction of flow so that the flow meter rotor can rotate freely and the number of revolutions can easily be recorded after each net tow. As indication: the chosen tow duration should be standardised for all stations and provide a density measuring resolution limit of ± 0.01 to 0.05 larvae/m3. The cable is slowly paid out from the vessel at a rate of approximately 0.15-0.33 m/sec and immediately recovered at the same rate. This type of plankton net deployment is known as a standard oblique tow. A slow descent and ascent rate facilitates intensive sampling of the top metres of the water column where most fish larvae are captured. The maximum vertical net depth is dependent on the tow wire angle and the amount of weight. The weight is shackled immediately below the bongo frame as net drag can increase the wire angle making it difficult to keep the gear at the required towing depth especially when the nets are towed against strong currents.

b. Survey timing and design

It is important to time ichthyoplankton surveys a few weeks after completion of major spawning activity. If plankton net samples are to be collected and compared annually, it is equally important to time surveys consistently. Larvae should be sampled at a similar stage of ocean dispersal or during a time period when most larvae are approximately the same size (6 to 10 mm). Series of discrete depth tows at selected locations can be conducted (e.g. 0 to 50 m vertical depth at 5 m intervals) to examine larval depth distribution over a 24 hour period. Densities of larvae are sometimes greater in near-surface waters during night than during daytime. Continuous advection of waves of larvae through the survey areas, however, can often obscure vertical or diurnal distribution patterns. Net avoidance of larger larvae is a significant factor and ichthyoplankton surveys should therefore be conducted early in the season when larvae are relatively small (< 15 mm) and sampled with oblique tows (covering the upper water depth) so that deflection and capture avoidance by large larvae in the surface waters is minimized. Consistent survey timing between years is therefore important to avoid annaul effects due to sampling bias.

Additionally, other planktonic material present in the water can quickly obstruct a plankton net's filtering ability, creating a pressure wave in front of a net and dramatically reduce a net's effectiveness. Considerable net washing is therefore required after each tow in order to clear obstructed net meshes. It is best to avoid such circumstances by careful survey design and timing to avoid times of increased occurrence of other planktonic organisms in the water.

The recovered nets from each plankton net tow should be thoroughly washed down with salt water and the contents of cod-end buckets preserved in 10-50 ml 5% formalin. Jars can then be topped up with water after the plankton net samples have been collected. The cod-end buckets should be easily uncoupled and can be constructed from standard PVC pipe and clamped to the nets with stainless steel hose clamps.

c. Sample processing

Plankton samples are transferred from field jars to glass petri dishes where counts of eggs, larvae and other larval fish species can be conducted. A grid marked on the bottom of the petri dish facilitates systematic inspection of each grid quadrat. Direct counts of fish larvae are conducted with fine forceps under a dissecting microscope adjusted to low magnification. A transfer micro-pipette can be useful for counting eggs. A dissecting microscope is required to inspect samples because eggs (0.5 mm in diameter) and newly hatched larvae (a few mm in length) are often difficult to see by eye. Standard sub-sampling is required for any sample that exceeds approximately 1000 larvae. It is best to avoid excessive counts of 1000 or more larvae. Survey design adjustments such as the seasonal timing of the survey, the duration of the plankton net tows, or the size of the plankton net openings can facilitate in lowering excessive counts. After counting is completed, eggs and larvae can be placed in sample vials and preserved for subsequent measuring, drying and weighing.

d. Density measurements and abundance estimation

Larval density (D) measurements (number/m^3) can be determined for each sampling station from the laboratory count (N) and the corresponding volume (V) of seawater (m^3) filtered through the plankton net:

$$D = N/V$$

The volume of water filtered through the net is determined from the area of the net opening (A), a rotor efficiency factor (E), the number of rotor evolutions (F), and a rotor constant (A):

$$V = \frac{(A \times E \times F)}{K}$$

A simple area expansion method can be used to approximate the total number of eggs or larvae that are present in the area at the time of the survey. The surface area (m^2) represented by each sampling station can be determined by dividing the total estimated survey area (m^2) by the total number of equally distributed sampling stations. An estimate of the total numbers of fish larvae (N) can be determined from the sum of the product of each of the n stations (i) represented area (A, in m^2), the oblique sampling tow depth (d, in m) and the corresponding larval density measurement (D, in number/m^3):

$$N = \sum_{i=1}^{n} A_i \times d_i \times D_i$$

Reliable measures of total spawner abundance, however, cannot be obtained from ocean ichthyoplankton surveys because of sampling deficiencies (amount of effort required to cover large areas in short periods of time), capture avoidance by large (growing) fish larvae and difficulties incorporating daily larval fish mortality rates. Larval fish surveys, nevertheless, can provide indications of abundance as long as survey timing and sampling protocols are consistent from year to year. At the very least, ocean ichthyoplankton surveys can provide evidence of presence or absence.

2) acoustic surveys to monitor the adult component of pelagic fish stocks

Acoustics is a remote sensing technique with advantages over traditional fish and zooplankton "point sampling" methods as they can sample nearly the entire pelagic zone quickly (sound speed in salt water ~ 1500 m/sec), to provide continuous areal sampling along a transect, and to provide high data resolution (less than a meter vertically and tens of meters horizontally). Limitations specific to acoustics include difficulty in determining identity of detected fish, variability in acoustic properties of fish, the inability to sample very close to the transducer and to the sea bed, and the inability to acquire biological data, such as fish length, age, and sex. Therefore, fisheries acoustic surveys typically have to be integrated with other sampling methods, such as net catch and environmental data. Trawling will confirm target identity and obtain biological data. However, taking trawl samples may take a significant amount of time during a survey, so it is essential that trawl time be considered during the survey design phase. If the variances in trawl catches and acoustic surveys are known, Simmonds and MacLennan (2005) provide recommendations on balancing the trawling and survey components to minimize the variance in stock size estimate. Environmental data are needed for the calculation of data-analysis parameters and may be useful in characterizing the location of targets of interest. Temperature is required for the calculation of sound speed and the acoustic absorption coefficient. As temperature may vary across the survey area, measurements should be taken regularly. Depending on survey objectives, other environmental data, such as dissolved oxygen or fluorescence, may be useful for classifying analytic regions based on target-species preferences.

a. designing the acoustic survey

An elementary sampling unit (ESU) is a unique object or area from which survey data are drawn. In the case of acoustic estimates, this ESU may correspond to non-overlapping whole transects or transect segments. The sampling frame is defined as the total number of ESUs that exist within the area to be surveyed. The survey area should be accurately defined with the survey objectives in mind. Examples of defined survey areas might be the open water beyond a certain depth or bays and near shore waters between certain depth contours. When creating the sampling frame and defining transects one has to think about the issue of selection probability. Random sampling methods assume that each sampling unit has an equal probability of selection and, therefore, no one sampling unit should have a higher probability of being sampled than any other. For example, zigzag transects may over-sample certain areas and under-sample others, even if random starting positions are used. Defining the sampling frame is required when choosing to extrapolate density estimates to absolute fish abundance and decisions must be made, such as:

- Should bays or deep-water areas be included?
- What is the horizontal distribution of target species? How close to shore should we reasonably expect some of the small pelagic offshore fish to be?
- What is the bathymetric distribution of the target species?

All of these issues affect how the total survey area is defined and how well total-abundance is estimates.

The quality of acoustic-survey estimates is typically evaluated by the variance of the estimate. We can control quality by reducing variance through selecting the appropriate sampling design (transect design) and sample size (transect length/spacing) within the survey area. The choice of these will depend on how and by how much the population size and distribution varies.

However, initial acoustic surveys cannot be adequately designed without prior knowledge of population variance. Estimates of variance for the initial design of an acoustic survey may be obtained from a pilot or exploratory survey or from similar surveys conducted elsewhere.

In designing a pilot or exploratory survey, a preliminary calculation of necessary sampling effort is the degree of coverage (Aglen 1983). Degree of coverage (Λ) is defined as:

$$\Lambda=\frac{D}{\sqrt{A}}$$

where D is the transect length sampled, and A is the size of the survey area. Errors associated with abundance estimates decrease as Λ increases. Aglen (1983) presents an empirical relationship between the CV (SE/mean) and Λ as:

$$\mathrm{CV}=\frac{0.5}{\sqrt{\Lambda}}$$

Population distribution within the survey area should be considered when choosing among survey designs. For potential fisheries acoustic surveys in the Dutch Caribbean, the most appropriate design candidates are:

- Stratified systematic with parallel transects
- Zigzag with parallel zigs and parallel zags

Stratified systematic

Parallel transects are placed systematically within the sampling frame based on expected variability or where the means may be different (Fig. 1). Stratification can be based on bathymetric criteria (e.g., shallower and deeper than a given depth contour) or regionally (e.g., east versus west or bays versus open water). Number of transects (sampling effort) is determined based on variance calculations, time constraints, or information from pilot studies. This design will reduce overall variance by stratifying the sampling frame into more-homogenous areas.

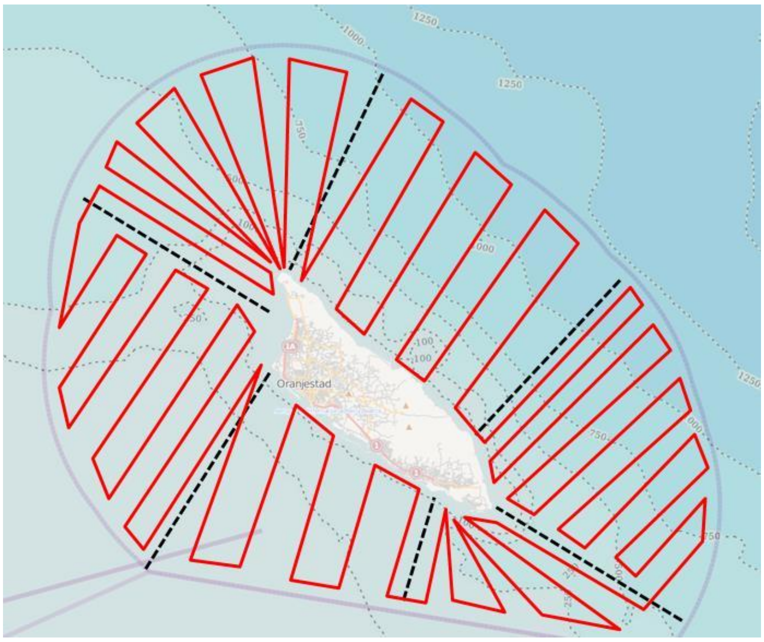

Figure 1. *An example of a stratified transect design (red lines) with systematic samples nested within arbitrary strata (divided by black dashed lines) in the territorial waters of Aruba. Note that in some strata (NW & SE off the island), parallel transects were not practical.*

Zigzag

Parallel zigs and parallel zags are distributed throughout the sampling frame (Fig. 2). Placement is generally systematic (evenly spaced) with a fixed or random transect start. This survey design maximises the amount of transect sampling time relative to transit time, but if you are planning to use the classical analysis approach (analysis assuming random sampling), then you will only be able to utilise every other transect, thus decreasing the effectiveness of the survey by half. The reason for this difference in how the data may be used is that the zigzag design results in sections of one transect being highly correlated to that of the adjacent transect at the intersecting vertices. Leaving out every other transect diminishes the effect of this small-scale correlation and makes classical analysis possible.

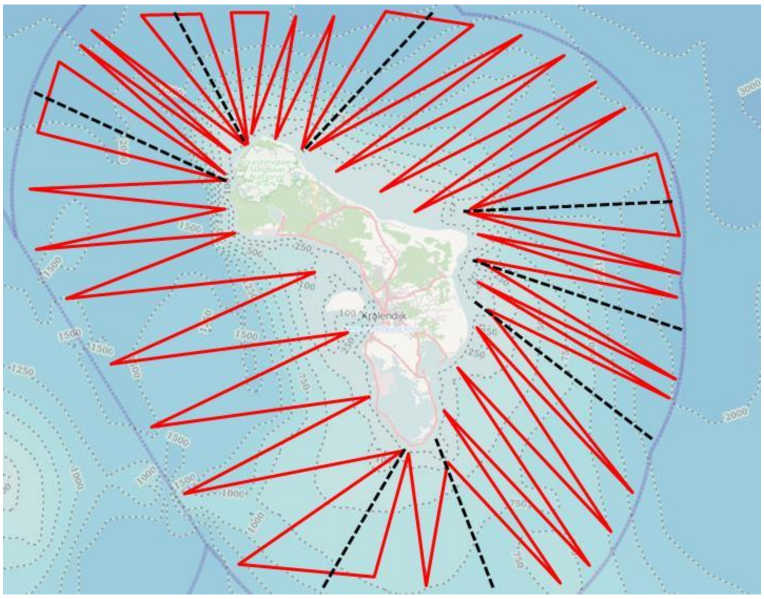

Figure 2. *An example of a stratified zigzag design with parallel zigs and parallel zags (red lines) with samples nested within arbitrary strata (divided by black dashed lines) in the territorial waters of Bonaire.*

If the person conducting the survey is not the person who designed the survey, it is helpful to have the designer on board for at least the first part of the survey, especially if this is the first time the survey is to be conducted or if a major change in the survey is planned. With the survey designer on board, unforeseen complications can be dealt with immediately without loss or decreased integrity of the data.

b. echosounder calibrations

Calibrations are conducted to verify that the echosounder and transducer are operating properly and to ensure system stability over time. Calibrations characterize system parameters relative to expected standard values. Calibration data should be documented as meticulously as survey data. Echosounder calibrations should use the standard-target method (Foote et al. 1987), which relates acoustical energy to an absolute standard. The standard-target method calibrates the overall acoustic system (echosounder, transducer, and cable) and consists of two parts: on-axis sensitivity and beam-pattern measurements. On-axis target strength (TS) and area backscattering coefficient (s_A) measurements calibrate gain parameters, and beam-pattern measurements supply beam width and angle-offset values. They are not independent. The echosounder manufacturer Simrad provides a calibration software program with their scientific system to calibrate and measure echosounder beam patterns. The calibration sphere TS is dependent on the water temperature and salinity, and common values are given in Simmonds and MacLennan (2005).

Before conducting a calibration, important issues to consider are:

- The calibration should be conducted in the same environmental conditions (water temperature and salinity) as experienced during the survey
- Water depths must be sufficient to exceed near-field limitations and/or system limitations for the echosounder frequencies to be calibrated
- Calibrations must be conducted before the survey begins to establish proper echosounder operation, and after or near the end of the survey to ensure no significant changes have occurred; additional calibrations during the survey are valuable for maintaining system performance and ensuring high-quality data

- Calibrations must be conducted with the same pulse durations, transmit powers, and bandwidths used during the survey; a relatively fast ping rate, such as 5 pings per second, is often used to increase the number of sphere observations
- If multiple frequencies will be operating simultaneously during collection, run all frequencies while calibrating each single frequency to include any effects from the other units and to determine if there is acoustical interference between systems; some manufacturers however recommend calibrating each frequency separately

The calibrations reflect an integration of the echosounder, transducer, and shipboard electrical system. If changes to any component of this system occur (e.g., the shipboard electrical system or transducer cable length) during the survey, the echosounder must be calibrated again. Foote et al. (1987) describe the calibration method in detail.

c. Data collection

It is essential to document all initial echosounder parameter settings and any changes made to them during data collection in a survey log. Record the old and new value, date, and time of modification so that the data collected prior to the modification can be reprocessed using a data analysis software package. The survey log should also include identification of personnel involved and environmental (weather and sea) conditions.

Choice of the pulse duration, sometimes referred to as pulse length, is dependent on the objectives and conditions of the survey. A shorter pulse duration is necessary for higher resolution of individual targets, whereas a longer pulse duration is desirable for greater water depths because of a higher signal-to-noise ratio. Most of the standard surveys on European shelf seas (<200m depth) are done with 1.024 msec.

Ping interval (*i*, sec, the time delay between sequential pings) and ping rate (pings/sec) are related (ping rate = 1/(ping interval)). In choosing a ping interval, the goal is to select the smallest interval that will not cause shadow bottoms in the data and is within the processing speed of the echosounder. To avoid a shadow bottom originating from the "third" bottom return, the minimum ping interval (*i*, sec) is:

$$i = \frac{3 \times 2 \times \mathrm{BD}}{c}$$

where BD is the expected maximum bottom depth (m) in the area, and c is the speed of sound in water (m/sec). The factor "3" is related to the third bottom signal, and the factor "2" is related to the sound traveling from the transducer to the bottom and back to the transducer.

The collection of raw data is essential. Unless better information is available, set the raw-data depth to the maximum depth in the survey. Raw-data depth is a collection value, and data will not be collected beyond that point. Reasonable acoustic-survey file sizes are 10-20 MB or 10-15 min. Large file size causes some data-analysis software packages to run slowly. More importantly, if there is a file corruption, less data are lost when using a number of smaller–sized files rather than one large file. Global positioning system (GPS) data are critical for acoustic estimates of population size. GPS data should be sent to the echosounder and stored with the acoustic data string.

The transducer gain is a measure of amplification related to the receiver sensitivity of the echosounder. Transducer gain is calculated from calibration data relative to a known standard. Simrad units come with factory default values, but these are not adequate for data processing, so transducer gain must be determined from a calibration. The S_a correction (dB) in Simrad units is needed to account for differences in TS and S_v calibrations. This value is calculated from calibration data relative to a known standard. S_a correction can be modified in data-analysis software. For 38, 120 and 200 kHz transducers, maximum output power should be limited to 2000W (38 kHz), 300 W (120 kHz) and 100 W (200 kHz) to avoid harmonic distortion (Simrad 2002, Tichy et al. 2003). Harmonic distortion results in two errors. First, the sound level does not increase proportionally with increasing input power.

Second, the transducer beam pattern shifts toward a flatter, wider main lobe and increased side lobes. The combination of these two errors results in incorrect TS and integration values and therefore wrong fish density estimates!
It is important to remember which system and data-collection settings may be changed in data analysis.

The following table is a summary of system settings, collection settings, and which settings can be modified in data analysis:

Settings	Entered at data collection (Simrad EK60)	Modifiable in analysis post-processing software
Transducer gain	X	X
Pulse duration	X	
Ping rate	X	
Raw data depth	X	
File size	X	
Transducer depth	X	X
Collection threshold	X	
Sound speed	X	X
Absorption	X	X
Power setting	X	
S_a correction	X	X
Equivalent beam angle	X	X
3dB angle	X	X

Acoustic data collected in high wind or poor sea conditions may suffer from bubble entrainment and/or noise from waves. Little can be done to reduce this problem other than to conduct surveys under the best conditions possible. It is possible to minimize this problem by deploying transducers at deeper depths (either on a towed body or a drop keel). Transducer motion results in a change in the orientation of the transducer beam, relative to the insonified targets, between transmission and echo return. Targets insonified on-axis may be received off-axis or vice versa. Similarly, the return signal from targets insonified at the edge of the beam may be lost.

d. Target identification

Fisheries acoustic surveys are designed to provide fish-density and abundance estimates, usually age- or length-based, for one or more target species. Identification of the target species can be done based on prior knowledge of echogram characteristics (depth distribution, shape of schools, and layer structure). TS distribution and its change with depth is a good indication of changes in species or age composition. However, the main method of identifying the species, age, and size composition of organisms in the echogram is by direct sampling, primarily with midwater trawls. Vertical gillnets have also been used and underwater video is another potential source of validation.

e. Data processing and analysis

If echsounder settings have changed during the survey, make sure to change these in the data-analysis file. Make separate files for sections with different settings. Decisions about keeping sound speed and absorption values consistent for the survey or to vary with location (if sampling over a large area or one with very different values) are necessary at this stage of the analysis. A surface exclusion zone will remove unreliable data while maintaining information about the survey targets.

In the case of surface conditions, it is advisable to apply noise removal and/or biological thresholds before selecting a surface exclusion zone, as these thresholds may remove or reduce the effect of bubbles present near the water surface on the data. Echosounders and data-analysis software use algorithms to detect the seabed. Depending on bottom type and topography, performance of these algorithms varies. The algorithms perform well on hard, flat substrate, but their ability to detect the bottom degrades on soft substrate or rugged topography. Echo strength from the seabed is typically orders of magnitude greater than the echo strength from biological organisms, thus, eliminating seabed echoes from the water-column data is imperative. Improper bottom detections are found and corrected manually through inspection of the echograms or through automated algorithms. Failure to verify bottom detection could result in increased S_v values due to bottom inclusion. Bottom detection can also exclude echoes from dense fish schools. A detailed pixel-by-pixel check of the bottom definition is possible in the software. The bottom-exclusion zone is selected to remove data within the near-bottom dead zone. However, targets of interest within this exclusion zone are also removed from analysis. Areas of an echogram with discrete spikes, diagonal lines, or horizontal lines resulting from acoustic, electrical, or trawl noise may be manually excluded as "bad-data regions," but data associated with the noise will also be removed from analyses.

Note that the assumption about fish density in bad-data regions is important if these regions are large.

Uncertainty in classifying and separating acoustic backscatter by target species from non-target species or background noise is a potential source of error in acoustic estimates of density and abundance. The simplest way to separate target from non-target species or scattering objects is to conduct a survey during a time (seasonal or diel) when they are separated. When individual fish can be resolved, in situ TS values can be obtained and used for calculating average backscattering cross sections, which can then be used to scale volume or area backscattering coefficients to fish density. When using *in situ* TS, it is important to analyse the data in depth regions with homogeneous fish groups, because the sampling volume increases with depth, and fish in deeper water will, therefore, be overrepresented in the data relative to their contribution to overall density. If larger fish are found in deeper water, they will thereby be overrepresented in a TS distribution derived from the whole water column. TS-length and TS-weight relationships have been developed for several fish species. Relationships for similar species from the literature are frequently used for surveyed species for which no TS relationship is available. Given the variability observed among different studies, even for similar fish, it is however doubtful if the different species-specific equations represent any improvement over standard multi-species equations.

Existing candidate TS relationships of similar or identical main small pelagic species or species groups found in the Dutch Caribbean are given below:

Species (group)	Relationship	Frequency	Source
Sardniella aurita and Anchovies (*Engraulidae*)	$TS = 20 \log_{10}(L) - 71.9$	38 kHz	Foote (1987)
bigeye scad (*Selar crumenophthalmus*)	$TS = 20 \log_{10}(L) - 69.0$	120 kHz	Cotel and Petit (1996)
oxeye scad (*Selar boops*)	$TS = 20 \log_{10}(L) - 70.9$	38 kHz	Sunardi *et al.* (2009)
	$TS = 20 \log_{10}(L) - 70.4$	120 kHz	Sunardi *et al.* (2009)

Recorded backscatter levels per species are presented as per unit area (NASC $\equiv s_A$) based on individual horizontal sampling bins along transects. When converting volume backscattering coefficients (s_v) to numeric densities (numbers/m^3), s_v is scaled by the species- and size-dependent scattering value σ_{bs} (backscattering cross section). For that, TS values per species and fish size (in dB) need to be transformed:

$$\sigma_{bs}=10^{(TS/10)}$$

For the calculation of stock size, a density estimate based on area is most useful. NASC (≡ s_A) may be used to calculate total density (ρ_a, in numbers/m^2 or /nmi^2) within the sampling area:

$$\rho_a=\frac{s_A}{4\pi\times\sigma_{bs}}$$

Simple random analysis is appropriate for data collected with systematic surveys with parallel transects. Each transect provides a single local estimate of fish density. Calculations of means and variance follow the standard methodology and assume that the randomly selected observations are independent and identically distributed. We can compute the average density (ρ) and variance (s^2) from the average density for each transect i (ρ_i) over all n transects:

$$\rho=\frac{1}{n}\sum_{i=1}^{n}\rho_i$$

$$s^2=\frac{1}{n-1}\sum_{i-1}^{n}(\rho_i-\rho)^2$$

Assuming the transects are representative of the whole area (A) and that this area is known absolutely (has no variance), the expansion to total fish numbers (N) in the survey area is straightforward:

$$\mathrm{N}=\mathrm{A}\times\rho$$

where A is in units of total area, and ρ is in units of density per area. The final step is to convert fish abundance to species-specific abundance and biomass, which requires separation of densities by species or age-groups. Biomass is then calculated from these densities and observed weights or from a length to weight regression.

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Appendix B. Longlist of small pelagic fish in the Dutch Caribbean

	Species	Common name	Local name CN	Common length in centimeter (male/ unsexed)	Habitat	Depth range in meter	C = Caribbean Sea A = Atlantic Ocean P = Pacific Ocean I = Indian Ocean M = Mediteranian Sea Spatial range	Prey/diet													Predators																												
								Plankton											Nek-ton		Coryphaenidae (Dolphinfish)	Scombridae (Mackerel, tuna, bonito)					Istiophoridae (Marlin, sailfish)			Xiphiidae (Swordfish)	Serranidae (Grouper)	Carangidae (Jacks)		Belonidae (Needlefish)	Merlucciidae (Hake)	Pomatomidae (Bluefish)	Sparidae (Sea bream,porgy)	Lobotidae	Trichiuridae (Cutlassfish)	Ariidae (Sea catfish)		Carcharhinidae (Sharks, rays)	Triakidae (Hound shark)	Botidae (Flounders)	Delphinidae (Dolphins)			Sternidae (Terns)	
								Invertebrate					Other			Benthos																																			
								Copepods	Pteropods	Ostracods	Gastropod larvae	Invertebrates unspecified	Zooplankton unspecified	Phytoplankton unspecified	Fish larvae	Foraminafera	Small shrimps and/or crabs	Zoobenthos unspecified	Small fish	Nekton unspecified	*Coryphaena hippurus* (Common dolphinfish)	*Thunnus albacares* (Yellowfin tuna)	*Scomberomorus regalis* (Cero)	*Acanthocybium solandri* (Wahoo)	*Scomberomorus brasiliensis* (Serra Spanish mackerel)	*Scomberomorus cavalla* (King mackerel)	*Istriophorus albicans* (Atlantic sailfish)	*Makaira nigrican* (Atlantic blue marlin)	*Tetrapturus albidus* (Atlantic white marlin)	*Xiphias gladius* (swordfish)	*Epinephelus striatus* (Nassau grouper)	*Caranx ruber* (Bar jack)	*Seriola dumerili* (Greater amberjack)	*Tylosurus crocodilus crocodilus* (Hound needlefish)	*Merluccius albidus* (Offshore silver hake)	*Pomatomus saltatrix* (Bluefish)	*Calamus leucosteus* (Whitebone porgie)	*Lobotes surniamensis* (Atlantic tripletail)	*Trichiurus lepturus* (Largehead hairtail)	*Arius felis* (Hardhead sea catfish)	*Arius melanopus* (Dark sea catfish)	*Carcharhinus porosus* (Smalltail shark)	*Mustelus canis* (Dusky smooth-hound)	*Bothus lunatus* (Plate fish)	*Delphinus delphis* (Short-beaked common dolphin)	*Stenella frontalis* (Atlantic spotted dolphin)		*Onychoprion fuscatus* (Sooty tern)	*Anous stolidus* (Brown noddy)
	Carangidae																																																
1	*Decapterus punctatus*	*Round scad*	*Moulo*	18.0 TL[1]	Reef-associated: neritic waters, often near sandy beaches[1], shoaling near bottom[2]	0-100[3]	46°N-23°S C/A/M	**x**[4]	x[4]	x[4]	x[4]										x[5]			x[6]			x[7]	x[7]	x[7]								x[8]											x[9]	x[9]
2	*Decapterus macarellus*	*Mackerel scad*	*Moulo*	30.0TL[10]	Pelagic-oceanic: clear oceanic waters, often around islands[1], shoaling along reef edge near deep water	0-400[11] usually 40-200[12]	54°N-46°S 180°W-180°E C/A/M/P/I						**x**[12]																																						
3	*Decapterus tabl*	*Roughear scad*	*Moulo di baranka*	25.0TL[1]	Reef-associated: mid-water or near bottom also near surface[1]	7-400[13] usually 150 - 220[1]	37°N-16°S C/A/P/I	**x**[1]				x[1]																																					

	Species	Common name	Local name CN	Common length in centimeter (male/ unsexed)	Habitat	Depth range in meter	C = Caribbean Sea A = Atlantic Ocean P = Pacific Ocean I = Indian Ocean M = Mediterranian Sea Spatial range	Prey/diet													Predators																												
								Plankton											Nek-ton		Coryphaenidae (Dolphinfish)	Scombridae (Mackerel, tuna, bonito)					Istiophoridae (Marlin, sailfish)			Xiphiidae (Swordfish)	Serranidae (Grouper)	Carangidae (Jacks)		Belonidae (Needlefish)	Merlucciidae (Hake)	Pomatomidae (Bluefish)	Sparidae (Sea bream,porgy)	Lobotidae	Trichiuridae (Cutlassfish)	Ariidae (Sea catfish)		Carcharhinidae (Sharks, rays)	Triakidae (Hound shark)	Botidae (Flounders)	Delphinidae (Dolphins)			Sternidae (Terns)	
								Invertebrate					Other			Benthos																																	
								Copepods	Pteropods	Ostracods	Gastropod larvae	Invertebrates unspecified	Zooplankton unspecified	Phytoplankton unspecified	Fish larvae	Foraminafera	Small shrimps and/or crabs	Zoobenthos unspecified	Small fish	Nekton unspecified	*Coryphaena hippurus* (Common dolphinfish)	*Thunnus albacares* (Yellowfin tuna)	*Scomberomorus regalis* (Cero)	*Acanthocybium solandri* (Wahoo)	*Scomberomorus brasiliensis* (Serra Spanish mackerel)	*Scomberomorus cavalla* (King mackerel)	*Istriophorus albicans* (Atlantic sailfish)	*Makaira nigrican* (Atlantic blue marlin)	*Tetrapturus albidus* (Atlantic white marlin)	*Xiphias gladius* (swordfish)	*Epinephelus striatus* (Nassau grouper)	*Caranx ruber* (Bar jack)	*Seriola dumerili* (Greater amberjack)	*Tylosurus crocodilus crocodilus* (Hound needlefish)	*Merluccius albidus* (Offshore silver hake)	*Pomatomus saltatrix* (Bluefish)	*Calamus leucosteus* (Whitebone porgie)	*Loboes surinamensis* (Atlantic tripletail)	*Trichiurus lepturus* (Largehead hairtail)	*Arius felis* (Hardhead sea catfish)	*Arius melanopus* (Dark sea catfish)	*Carcharhinus porosus* (Smalltail shark)	*Mustelus canis* (Dusky smooth-hound)	*Bothus lunatus* (Plate fish)	*Delphinus delphis* (Short-beaked common dolphin)	*Stenella frontalis* (Atlantic spotted dolphin)		*Onychoprion fuscatus* (Sooty tern)	*Anous stolidus* (Brown noddy)
4	*Selar crumenophthalmus*	*Bigeye scad*	*Masbangu*	30.0 max TL[14]	Reef-associated: clear oceanic waters around islands to neritic water[1], pelagic[11]	0-170[12]	47°N-24°S 180°W-180°E C/A/M/P/I						x[12]		x[12]	x[12]	x[12]	x[12]			x[5]	x[15]	x[16]							x[17]								x[18]	x[19]					x[16]				x[9]	x[9]
5	*Trachurus lathami*	*Rough scad*	*Masbangu*	30.0TL[1]	Reef-associated: coastal pelagic and demersal over continental shelve, rare in oceanic insular areas[1]	30-200[20]	45°N-37°S C/Brasil					x									x[21]	x[21]													x[22]	x[23]			x[19]				x[24]		x[25]	x[25]			
	Clupeidae																																																
6	*Ophistonema oglinum*	*Atlantic thread*		20.0 SL[26]	Reef-associated: shallow coastal area and harbors	5 - ?	41°N-37°S 98°W-33°W[26] C/Brasil	x[27]					x[16]				x[27]		x[27]				x[16]		X[28]	X[16]														x[29]	x[29]	x[30]							
7	*Jenkinsia lamprotaenia*	*Dwarf round*		7.5max TL	Reef-associated: usually inshore	0-50	34°N - 8°N 100°W-60°W[26] C						x																			x	x																
8	*Harengula jaguana*	*Scaled herring*		12.0SL[26]	Reef-associated: coastal waters, over mud sand bottoms[1]	0-22[31]	43°N-37°S 99°W-33°W[26] C/Brasil						x[32]							x[29]																				x[29]	x[29]							x[9]	x[9]

	Species	Common name	Local name CN	Common length in centimeter (male/ unsexed)	Habitat	Depth range in meter	C = Caribbean Sea A = Atlantic Ocean P = Pacific Ocean I = Indian Ocean M = Mediterranian Sea Spatial range	Prey/diet													Predators																												
								Plankton											Nek-ton		Coryphaenidae (Dolphinfish)	Scombridae (Mackerel, tuna, bonito)					Istiophoridae (Marlin, sailfish)			Xiphiidae (Swordfish)	Serranidae (Grouper)	Carangidae (Jacks)		Belonidae (Needlefish)	Merlucciidae (Hake)	Pomatomidae (Bluefish)	Sparidae (Sea bream,porgy)	Lobotidae	Trichiuridae (Cutlassfish)	Ariidae (Sea catfish)		Carcharhinidae (Sharks, rays)	Triakidae (Hound shark)	Botidae (Flounders)	Delphinidae (Dolphins)			Sternidae (Terns)	
								Invertebrate					Other			Benthos																																	
								Copepods	Pteropods	Ostracods	Gastropod larvae	Invertebrates unspecified	Zooplankton unspecified	Phytoplankton unspecified	Fish larvae	Foraminafera	Small shrimps and/or crabs	Zoobenthos unspecified	Small fish	Nekton unspecified	*Coryphaena hippurus* (Common dolphinfish)	*Thunnus albacares* (Yellowfin tuna)	*Scomberomorus regalis* (Cero)	*Acanthocybium solandri* (Wahoo)	*Scomberomorus brasiliensis* (Serra Spanish mackerel)	*Scomberomorus cavalla* (King mackerel)	*Istriophorus albicans* (Atlantic sailfish)	*Makaira nigrican* (Atlantic blue marlin)	*Tetrapturus albidus* (Atlantic white marlin)	*Xiphias gladius* (swordfish)	*Epinephelus striatus* (Nassau grouper)	*Caranx ruber* (Bar jack)	*Seriola dumerili* (Greater amberjack)	*Tylosurus crocodilus crocodilus* (Hound needlefish)	*Merluccius albidus* (Offshore silver hake)	*Pomatomus saltatrix* (Bluefish)	*Calamus leucosteus* (Whitebone porgie)	*Lobotes surniamensis* (Atlantic tripletail)	*Trichiurus lepturus* (Largehead hairtail)	*Arius felis* (Hardhead sea catfish)	*Arius melanopus* (Dark sea catfish)	*Carcharhinus porosus* (Smalltail shark)	*Mustelus canis* (Dusky smooth-hound)	*Bothus lunatus* (Plate fish)	*Delphinus delphis* (Short-beaked common dolphin)	*Stenella frontalis* (Atlantic spotted dolphin)		*Onychoprion fuscatus* (Sooty tern)	*Anous stolidus* (Brown noddy)
9	*Harengula humeralis*	*Redear herring*	*Sardinchi*	15.0TL[1]	Reef-associated: coastal waters, often along shoreline and over clear coral reefs, shoaling in beaches[1]	0-50[26]	34°N-15°N 90°W-53°W[26] C						x													x[16]					x[33]			x[16]															
10	*Sardinella aurita*	*Round sardinella*		25.0SL[26]	Reef-associated: oceanodromous[2] coastal waters inshore to edge shelf, strongly migratory	0-350	47°N-40°S 98°W-43°E C/A/M	**x**					x	x[37]							x[34]			x[6]						x[35]			x[36]															x[9]	x[9]
	Engraulidae																																																
11	*Cetengraulise dentulus*	*Atlantic anchovetta*	*Anchok*	15.0 TL[1]	Pelagic-neritic: inshore, enter brackish water	10-?	23°N-28°S 85°W-32°W[38] C/Brasil						x	x																				x[16]															
12	*Anchoa colonensis*	*Narrow-striped anchovy*	*Anchok*	10.0 TL[1]	Pelagic-neritic: Often shallow waters close to shore	0-50[38]	23°N-7°N 90°W-61°W[38] C	x[38]		x[38]	x[38]					x[38]																																	

	Species	**Common name**	**Local name CN**	**Common length in centimeter (male/ unsexed)**	**Habitat**	**Depth range in meter**	**C = Caribbean Sea A = Atlantic Ocean P = Pacific Ocean I = Indian Ocean M = Mediterranian Sea**	**Prey/diet**													**Predators**																													
								Plankton											Nek-ton		Coryphaenidae (Dolphinfish)	Scombridae (Mackerel, tuna, bonito)					Istiophoridae (Marlin, sailfish)			Xiphiidae (Swordfish)	Serranidae (Grouper)	Carangidae (Jacks)		Belonidae (Needlefish)	Merlucciidae (Hake)	Pomatomidae (Bluefish)	Sparidae (Sea bream,porgy)	Lobotidae	Trichiuridae (Cutlassfish)	Ariidae (Sea catfish)		Carcharhinidae (Sharks, rays)	Triakidae (Hound shark)	Botidae (Flounders)	Delphinidae (Dolphins)			Sternidae (Terns)	
								Invertebrate					Other			Benthos																																	
							Spatial range	Copepods	Pteropods	Ostracods	Gastropod larvae	Invertebrates unspecified	Zoopplankton unspecified	Phytoplankton unspecified	Fish larvae	Foraminafera	Small shrimps and/or crabs	Zoobenthos unspecified	Small fish	Nekton unspecified	*Coryphaena hippurus* (Common dolphinfish)	*Thunnus albacares* (Yellowfin tuna)	*Scomberomorus regalis* (Cero)	*Acanthocybium solandri* (Wahoo)	*Scomberomorus brasiliensis* (Serra Spanish mackerel)	*Scomberomorus cavalla* (King mackerel)	*Istriophorus albicans* (Atlantic sailfish)	*Makaira nigrican* (Atlantic blue marlin)	*Tetrapturus albidus* (Atlantic white marlin)	*Xiphias gladius* (swordfish)	*Epinephelus striatus* (Nassau grouper)	*Caranx ruber* (Bar jack)	*Seriola dumerili* (Greater amberjack)	*Tylosurus crocodilus crocodilus* (Hound needlefish)	*Merluccius albidus* (Offshore silver hake)	*Pomatomus saltatrix* (Bluefish)	*Calamus leucosteus* (Whitebone porgie)	*Lobotes surniamensis* (Atlantic tripletail)	*Trichiurus lepturus* (Largehead hairtail)	*Arius felis* (Hardhead sea catfish)	*Arius melanopus* (Dark sea catfish)	*Carcharhinus porosus* (Smalltail shark)	*Mustelus canis* (Dusky smooth-hound)	*Bothus lunatus* (Plate fish)	*Delphinus delphis* (Short-beaked common dolphin)	*Stenella frontalis* (Atlantic spotted dolphin)		*Onychoprion fuscatus* (Sooty tern)	*Anous stolidus* (Brown noddy)
13	*Anchoa hepsetus*	*Broad-striped anchovy*	*Anchok*	11.0TL[1]	Pelagic-neritic: Often shallow waters close to shore[38]	1-70[38]	44°N-36°S 98°W - 32°W[38] C/Brasil	x[38]		x[38]	x[38]					x[38]																x[16]								x[29]	x[29]	x[24]*							
14	*Anchoa filifera*	*Longfinger anchovy*	*Anchok*	10.0TL[1]	Pelagic-neritic: Coastal waters[38]	?-35	23°N-27°S 85°W - 32°W[38] C																																										
15	*Anchoviella perfasciata*	*Poey's anchovy*	*Anchok*	9.0 TL[1]	Pelagic-neritic: Coastal waters[38]	0-50[38]	32°N-10°N 94°W- 60°W[38] C																																									x[9]	x[9]
16	*Engraulis eurystole*	*Silver anchovy*	*Anchok*	8.0 TL[1]	Pelagic-neritic: Shallow sheltered waters, harbors[38]	124-282[20]	45°N - 0° 91°W-46°W[38] C/Brasil																																										
	Exocoetidae																																																
17	*Hirundichthys affinis*	*Fourwing flyingfish*	*Bulado Fleerchi*	24.0TL[1]	Pelagic-neritic: oceanodromous[37], far and near coast in surface waters[1]	100-?[1]	41°N-13°S C/A														x[39]	xunsp[39]		x[39]			xunsp[39]																						

								Prey/diet													**Predators**																												
								Plankton											Nek-ton		Coryphaenidae (Dolphinfish)	Scombridae (Mackerel, tuna, bonito)					Istiophoridae (Marlin, sailfish)			Xiphiidae (Swordfish)	Serranidae (Grouper)	Carangidae (Jacks)		Belonidae (Needlefish)	Merlucciidae (Hake)	Pomatomidae (Bluefish)	Sparidae (Sea bream,porgy)	Lobotidae	Trichiuridae (Cutlassfish)	Ariidae (Sea catfish)		Carcharhinidae (Sharks, rays)	Triakidae (Hound shark)	Botidae (Flounders)	Delphinidae (Dolphins)			Sternidae (Terns)	
								Invertebrate					Other			Benthos																																	
	Species	**Common name**	**Local name CN**	**Common length in centimeter (male/ unsexed)**	**Habitat**	**Depth range in meter**	**C = Caribbean Sea A = Atlantic Ocean P = Pacific Ocean I = Indian Ocean M = Mediteranian Sea Spatial range**	Copepods	Pteropods	Ostracods	Gastropod larvae	Invertebrates unspecified	Zoopplankton unspecified	Phytoplankton unspecified	Fish larvae	Foraminafera	Small shrimps and/or crabs	Zoobenthos unspecified	Small fish	Nekton unspecified	*Coryphaena hippurus* (Common dolphinfish)	*Thunnus albacares* (Yellowfin tuna)	*Scomberomorus regalis* (Cero)	*Acanthocybium solandri* (Wahoo)	*Scomberomorus brasiliensis* (Serra Spanish mackerel)	*Scomberomorus cavalla* (King mackerel)	*Istriophorus albicans* (Atlantic sailfish)	*Makaira nigrican* (Atlantic blue marlin)	*Tetrapturus albidus* (Atlantic white marlin)	*Xiphias gladius* (swordfish)	*Epinephelus striatus* (Nassau grouper)	*Caranx ruber* (Bar jack)	*Seriola dumerili* (Greater amberjack)	*Tylosurus crocodilus crocodilus* (Hound needlefish)	*Merluccius albidus* (Offshore silver hake)	*Pomatomus saltatrix* (Bluefish)	*Calamus leucosteus* (Whitebone porgie)	*Loboes surinamensis* (Atlantic tripletail)	*Trichiurus lepturus* (Largehead hairtail)	*Arius felis* (Hardhead sea catfish)	*Arius melanopus* (Dark sea catfish)	*Carcharhinus porosus* (Smalltail shark)	*Mustelus canis* (Dusky smooth-hound)	*Bothus lunatus* (Plate fish)	*Delphinus delphis* (Short-beaked common dolphin)	*Stenella frontalis* (Atlantic spotted dolphin)		*Onychoprion fuscatus* (Sooty tern)	*Anous stolidus* (Brown noddy)
18	*Hirundichthys speculiger*	*Mirrorwing flyingfish*	*Bulado Fleerchi*	30.0maxTL [1]	Pelagic-oceanic: Oceanodromous [37], in oceanic surface waters see map: open ocean	0-20	C/A/M/P/I														n	o		d	a	t	a		i	n		f	i	s	h	b	a	s	e										
19	*Exocoetus obtusirostris*	*Oceanic two-wing flyingfish*	*Bulado Fleerchi*	20.0TL [1]	Pelagic-neritic: oceanodromous [37], far and near coast in surface waters[1]	0-20	60°N-40°S C/A/M/P/I											x [40]				x [15]																										x [9]	x [9]
20	*Exocoetus volitans*	*Tropical two-wing flyingfish*	*Bulado Fleerchi*	20.0TL [1]	Pelagic-neritic: oceanodromous [37], far and near coast in surface waters[1]	0-20	C/A/P/I	x					x [40]								x [21]	x [41]						x [21]		x																		x [9]	x [9]
21	*Cheilopogon cyanopterus*	*Margined flyingfish*	*Bulado Fleerchi*	25.0 TL [1]	Pelagic-oceanic: Oceanodromous[37], in oceanic surface waters see map: open ocean	0-20	40°N-25°S C/A/M/P/I	x					x								x [39]																											x [9]	x [9]

	Species	Common name	Local name CN	Common length in centimeter (male/ unsexed)	Habitat	Depth range in meter	C = Caribbean Sea A = Atlantic Ocean P = Pacific Ocean I = Indian Ocean M = Mediteranian Sea	Prey/diet													Predators																												
								Plankton											Nek-ton		Coryphaenidae (Dolphinfish)	Scombridae (Mackerel, tuna, bonito)					Istiophoridae (Marlin, sailfish)			Xiphiidae (Swordfish)	Serranidae (Grouper)	Carangidae (Jacks)		Belonidae (Needlefish)	Merlucciidae (Hake)	Pomatomidae (Bluefish)	Sparidae (Sea bream,porgy)	Lobotidae	Trichiuridae (Cutlassfish)	Ariidae (Sea catfish)		Carcharhinidae (Sharks, rays)	Triakidae (Hound shark)	Botidae (Flounders)	Delphinidae (Dolphins)			Sternidae (Terns)	
								Invertebrate					Other			Benthos																																	
							Spatial range	Copepods	Pteropods	Ostracods	Gastropod larvae	Invertebrates unspecified	Zoopplankton unspecified	Phytoplankton unspecified	Fish larvae	Foraminafera	Small shrimps and/or crabs	Zoobenthos unspecified	Small fish	Nekton unspecified	*Coryphaena hippurus* (Common dolphinfish)	*Thunnus albacares* (Yellowfin tuna)	*Scomberomorus regalis* (Cero)	*Acanthocybium solandri* (Wahoo)	*Scomberomorus brasiliensis* (Serra Spanish mackerel)	*Scomberomorus cavalla* (King mackerel)	*Istriophorus albicans* (Atlantic sailfish)	*Makaira nigrican* (Atlantic blue marlin)	*Tetrapturus albidus* (Atlantic white marlin)	*Xiphias gladius* (swordfish)	*Epinephelus striatus* (Nassau grouper)	*Caranx ruber* (Bar jack)	*Seriola dumerili* (Greater amberjack)	*Tylosurus crocodilus crocodilus* (Hound needlefish)	*Merluccius albidus* (Offshore silver hake)	*Pomatomus saltatrix* (Bluefish)	*Calamus leucosteus* (Whitebone porgie)	*Lobotes surniamensis* (Atlantic tripletail)	*Trichiurus lepturus* (Largehead hairtail)	*Arius felis* (Hardhead sea catfish)	*Arius melanopus* (Dark sea catfish)	*Carcharhinus porosus* (Smalltail shark)	*Mustelus canis* (Dusky smooth-hound)	*Bothus lunatus* (Plate fish)	*Delphinus delphis* (Short-beaked common dolphin)	*Stenella frontalis* (Atlantic spotted dolphin)		*Onychoprion fuscatus* (Sooty tern)	*Anous stolidus* (Brown noddy)
22	*Parexocoetus brachypterus*	*Sailfin flyingfish*	*Bulado Fleerchi*	16.0 TL[1]	Pelagic-neritic: oceanodromous[37], in coastal waters, rare in open ocean	0-20	C/A/P/I																			x[16]																						x[9]	x[9]
	Hemiramphidae																																																
23	*Hemiramphus brasiliensis*	*Ballyhoo halfbeak*	*Boka largu*	35.0 TL[44]	Reef-associated: inshore, surface-dwelling[42]	0-5[42] usually 0-2[43]	43°N-13°S C/A												x[42]				x[16]																										x[9]	x[9]
24	*Hemiramphus balao*	*Balao halfbeak*	*Boka largu*	35.0TL[44]	Reef-associated: inshore, surface-dwelling[42]	5- ?[42]	42°N-13°S C/A						x[42]	x[42]					x[42]																														x[9]	x[9]

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[1] (Cervigón et al., 1992)
[2] (Bianchi et al., 1999)
[3] (Schneider, 1990)
[4] (Berry and Smith-Vaniz, 1978)
[5] (Gibbs and Collette, 1959)
[6] (Manooch and Hogarth, 1981)
[7] (Junior et al., 2004)
[8] (Sedberry, 1989)
[9] (Hensley and Hensley, 1995)
[10] (Jimenez Prado and Bearez, 2004)
[11] (Mundy, 2005)
[12] (Fischer et al., 1995)
[13] (Figueiredo J.L. et al., 2002 in Fishbase)
[14] (Sanches J.G., 1991 in Fishbase)
[15] (Matthews et al., 1977)
[16] (Randall, 1967)
[17] (Scott and Tibbo, 1968)
[18] (Franks et al., 2003)
[19] (Muto E.Y. et al., 2005 in Fishbase)
[20] (Scott and Scott, 1988)
[21] (Pimenta et al., 2001)
[22] (Rohr and Gutherz, 1977)
[23] (Lucena et al., 2000)
[24] (Bowman et al., 2000)
[25] (Melo et al., 2010)
[26] (Whitehead, 1985)
[27] (Smith, 1997)
[28] (Collette and Nauen, 1983)
[29] (Vega-Cendejas et al., 1994)
[30] (Lessa and Almeida, 1997)
[31] (Gines, H. and F. Cervigon, 1967 in Fishbase)
[32] (Gomez-Canchong, P.L. et al. 2004 in Fishbase)
[33] (Silva Lee, A.S. 1974 in Fishbase)
[34] (Palko et al., 1982)
[35] (Cavaliere, A. 1963 in Fishbase)
[36] (Pipitone and Andaloro, 1995)
[37] (Riede, 2004)
[38] (Whitehead et al., 1988)
[39] (Oxenford, 1986)
[40] (Lipskaya, 1987)
[41] (Borodulina, 1981)
[42] (Collette, 1978)
[43] (Gasparini and Floeter, 2001)
[44] (Collette, 1981)

*Additional predator species for Anchoa hepsetus: Shark and ray species predating on *Anchoa hepsetus*: *Carcharhinus altimus* (bignose shark), *Carcharhinus obscurus* (dusky shark), *Rhizoprionodon terraenovae* (Atlantic sharpnose shark), *Rhinoptera bonasus* (cownose ray) Myliobatidae, *Squatina dumeril* (sand devil) Squatinidae [24] (Bowman et al., 2000). Other species predating on *Anchoa hepsetus*: rachycentron canadum (Cobia) rachycentridae (Franks et al., 1996); Harengula jaguana (scaled herring) Clupeidae [29](Vega-Cendejas et al., 1994); *Menticirrhus americanus* (Southern Kingcroaker) Sciaenidae [24] (Bowman et al., 2000).

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