Improving fishing gears and operations in the shrimp and groundfish fisheries of Trinidad and Tobago, Suriname, Guyana and Brazil

For UNFAO's Strategic Action Programme for the Sustainable Management of Shared Living Marine Resources in the Caribbean and the North Brazil Shelf Large Marine Ecosystems (UNJP/RLA/217/OPS)

FINAL REPORT

Prof. Steve Kennelly

IC Independent Consulting

Australia

Contents

Executive Summary

This project provides guidance to fisheries stakeholders in Trinidad and Tobago, Suriname, Guyana and Brazil regarding best practices to reduce the impacts of fishing gears and operations on bycatch species and marine ecosystems in the North Brazil Shelf Large Marine Ecosystem. The Terms of Reference were to:

1. Carry out a desk-based review of background information on current fishing practices and gears used in the industrial and artisanal fisheries in the region, as well as the ecological impact of the fishing gears.
2. Review available information on modified gear (e.g. Bycatch Reduction Devices) trials conducted in the region and assess their ecological and economic implications.
3. Liaise with fisheries officers and other relevant stakeholders in the region to obtain information on current industrial and small-scale fishing practices and gears, as well as related plans and projects envisaged for the near future.
4. Liaise with REBYC II LAC project partners/coordinators in the region to obtain updated project results and ongoing activities.
5. Select relevant case studies (country/fishery/gear) in order to develop technical guidance on best practices fishing gears and fishing operations with particular emphasis on small scale non-trawl fisheries.
6. Assess the most adequate mechanism for introducing best practices into fisherfolk communities and consider capacity building needs; and
7. Prepare a final report providing guidance on best-practice fishing gears.

The methodology involved an examination of initial background material provided by FAO from the Caribbean Large Marine Ecosystem (CLME) Case Study on the Shrimp and Groundfish fisheries of the Guianas-Brazil shelf. In particular, the Shrimp and Groundfish Case Studies done in the four focus countries (Trinidad and Tobago, Guyana, Suriname and Brazil) provided key background information. We consolidated information from these reports by focussing on the various fisheries in each country, the various fishing methods used, the positive and negative issues that were identified for each, followed by potential solutions suggested from stakeholders.

Four country-specific documents were then provided to identified key stakeholders, including any REBYC II LAC project partners/coordinators, in the respective countries, to get feedback and any updates regarding the assembled information. After the feedback, we then assessed how the various identified problematic issues might be addressed (based on international best-practice standards for the fishing methods involved - as identified in the international literature). Finally, we identified potential ways forward for the future sustainable exploitation of fisheries resources in the region.

A draft final report was prepared and sent to FAO who then provided feedback and an additional unpublished draft report (Earys, in prep.). The latter summarized information regarding best practices in tropical shrimp trawl fisheries throughout the world, including those in the focus countries. This report was used to augment the information gathered regarding shrimp trawling into the final report for the project.

The synthesis of information about the fisheries in these four countries indicated that the three main fishing gears used (shrimp trawling, netting using gillnets and seines, and trapping) could be improved to approach world's best practice standards. The high discard rate in shrimp-trawl fisheries was by far the single most consistent and significant issue identified by stakeholders but these fisheries already have significant familiarity with TEDs and BRDs - most countries have TEDs mandated for use (although their actual level of use various considerably) and most have trialled (with some success) various square mesh panels as BRDs. In particular, the Suriname seabob fishery has achieved significant success in bycatch reduction to the extent that it has MSC certification.

So, at first glance, the Suriname seabob fishery appears to provide a logical and local solution to the most pressing fisheries issue in the region. That is, a solution where similar TED and BRD designs as that used in that fishery could be adopted and implemented in the other shrimp trawl fisheries in the region (as Guyana has done). If this was done successfully, and if the discards from shrimp trawling in the region really are to blame for low catches in other commercial and artisanal fisheries (as noted by stakeholders), then significant improvements in stocks and catches of finfish should become evident in those other fisheries in a relatively short period of time.

Fishing gears like gillnets, seines and traps were found to have less bycatch and discarding problems than shrimp trawls but, nevertheless, there exist a range of best-practice options available to ensure that such gears operate as selectively as possible. However, a necessary pre-requisite to these modifications (that involve such things as optimal mesh sizes, escape vents, etc.) is a thorough understanding of the optimal size at first capture for the target species.

The report concludes with several suggestions on mechanisms to introduce the identified best practices into the fishing communities in the four countries and priority capacity building needs.

Background

This project contributes to the Strategic Action Programme for the Sustainable Management of Shared Living Marine Resources in the Caribbean and the North Brazil Shelf Large Marine Ecosystems (CLME+ project) (UNJP/RLA/217/OPS). This Action Programme assists with ecosystem-based management/the ecosystem approach to fisheries (EBM/EAF) within the CLME+ region, and one of its main outcomes is to facilitate long-term benefits from the region's shrimp and groundfish fisheries, with special attention to livelihoods and social justice. In this regard, it is required that viability studies on best-practice fishing gears for the shrimp and groundfish fisheries are made available to fishers, potential investors and fisheries agencies in the countries in the CLME+ region.

This study focusses on four countries of the North Brazil Shelf Large Marine Ecosystem (NBSLME): Brazil, Guyana, Suriname and Trinidad and Tobago. This current project aims to provide technical guidance to these countries and fisheries stakeholders on best practices to reduce the impacts of fishing gears and operations on bycatch species and marine ecosystems in the NBSLME, while preserving the socio-economic benefits derived from fisheries.

The fisheries resources in the NBSLME region can be categorised as basically targeting penaeid shrimp and groundfish. The shrimp resources support important export-oriented fisheries while the groundfish resources support swim bladder exports as well as more locally focussed commercial and social uses. These fisheries are multigear, multispecies and multinational, using fishing methods that can be classified as industrial through to artisanal, depending on the level of mechanization, the type of labour force employed, financial investments and working regimes.

In general, it is well accepted that most of the shrimp species in the region (especially pink shrimp *Farfantepenaeus notalias*) show increasing trends in fishing mortality and fishing fleets are considered to be generally overcapitalized (FAO, 2103a). However, in the case of the seabob shrimp (*Xiphopenaeus kroyeri*) fisheries of Suriname and Guyana, there is no evidence from catch and effort data that the stock is overfished and/or that overfishing is occurring (FAO 2013b and c). With regard to groundfish, despite relatively stable catches, overexploitation is believed to be significant for some species. Information on trends in bycatch (organisms that are not targeted but incidentally caught – NB. All definitions in this report regarding bycatch follow those of the FAO report by Pérez Roda et al., 2019) is scarce but some information is available on discards (bycatch that is thrown away after capture) for some fisheries and there are indications that species considered as threatened under IUCN categories are caught (in particular turtles, sharks, rays and groupers).

Terms of Reference

The Terms of Reference for this project are to:

1. Carry out a desk-based review of background information on current fishing practices and gears used in the industrial and artisanal fisheries in the region, as well as the ecological impact of the fishing gears.
2. Review available information on modified gear (e.g. Bycatch Reduction Devices) trials conducted in the region and assess their ecological and economic implications.
3. Liaise with fisheries officers and other relevant stakeholders in the region to obtain information on current industrial and small-scale fishing practices and gears, as well as related plans and projects envisaged for the near future.
4. Liaise with REBYC II LAC project partners/coordinators in the region to obtain updated project results and ongoing activities.
5. Select relevant case studies (country/fishery/gear) in order to develop technical guidance on best practices fishing gears and fishing operations with particular emphasis on small scale non-trawl fisheries.
6. Assess the most adequate mechanism for introducing best practices into fisherfolk communities and consider capacity building needs; and

7. Prepare a final report providing guidance on best-practice fishing gears.

Methods

Initial background material for this project came from the Caribbean Large Marine Ecosystem (CLME) Case Study on the Shrimp and Groundfish fisheries of the Guianas-Brazil shelf. This was a four-year project (May 2009 to April 2013), involving 23 countries and funded by the Global Environment Fund (GEF), with the aim of facilitating management reforms to promote sustainable development and effective management of shared living marine resources, most of which are considered to be fully- or over-exploited. This project involved several background projects to obtain information about the marine resources and fisheries in the region followed by a series of workshops involving fisherfolk organizations, fishing industry, governments, nongovernmental organizations, academic institutions and regional or international organizations to discuss the work and identify ways forward. In particular, the Shrimp and Groundfish Case Studies done in six countries (Trinidad and Tobago, Guyana, Suriname, Brazil, Venezuela and French Guiana) provided key background information for this current project which focusses on the former four of these.

This project consolidated information from the reports from each of these country-specific case studies. This was done by focussing on the various fisheries in each of the four countries, the various fishing methods used, the positive and negative issues that have been identified for each, followed by potential solutions suggested from stakeholders in the above-mentioned workshops. Four country-specific documents were then provided to identified key stakeholders, including any REBYC II LAC project partners/coordinators in the respective country to get feedback and any updates regarding the assembled information. The feedback (mostly via email and zoom meetings) was then incorporated into this report. All countries provided feedback except Suriname. This stage of the project (ie ToRs 3 and 4) was the most difficult aspect of the project to achieve due to current travel restrictions as a result of the Covid 19 pandemic. In a project such as this, we would normally travel to each country and meet with stakeholders, fishers, and others in person for interviews and information exchange. As this was impossible in this case, we relied on email and zoom meetings to exchange information which is never as good nor immediate as personal interactions. Despite this forced limitation, however, we were able to glean sufficient information to satisfy the requirements of the project. After the feedback, we then conducted an assessment (based on international best-practice standards for the fishing methods involved - as identified in the international literature by, in particular, Broadhurst, 2000; Kennelly and Broadhurst, 2002; Uhlmann and Broadhurst, 2015; and McHugh et al., 2017) of how the various identified problematic issues might be addressed. Finally, we identified some potential ways forward for the future sustainable exploitation of fisheries resources in the region.

A draft final report was prepared and sent to FAO who then provided feedback and an additional unpublished draft report (Earys, in prep.) that summarized information regarding best practices in tropical shrimp trawl fisheries throughout the world, including the focus countries. This report was used to augment the information gathered regarding shrimp trawling into the final report for the project.

For each of the four countries, most of ToRs 1 and 2 are addressed in the four country-specific chapters. The non-bycatch, ecological and economic parts of ToRs 1 and 2 are addressed in the second last chapter. The third and fourth ToRs were addressed via the above-mentioned liaison with identified experts in each country. The case studies under ToR 5 are also provided in the four separate chapters, each covering one of the four countries. The seventh ToR is addressed in the second to last chapter of this report and ToR 6 regarding ways to introduce suggested changes is provided in the final chapter.

Country-specific findings

Trinidad and Tobago

The below is mostly derived from FAO (2013a), Ferreira and Soomai (2013) and Fisheries Division (2017a).

Overview of fisheries

Species caught

The demersal shrimp and groundfish fisheries of Trinidad and Tobago are conducted in the Gulf of Paria and Columbus Channel. While the higher-valued shrimp are the main target during the dry season (January to June), finfish are also targeted according to market demand or during the wet season when shrimp catches decline.

The shrimps mostly come from the family Penaeidae and include brown shrimp *(Farfantepenaeus subtilis)*, pink shrimp (*F. notialis*), pink-spotted shrimp, hoppers *(F. brasiliensis)*, white/cork shrimp (*Litopenaeus schmitti*), and honey/jinga or seabob shrimp (*Xiphopenaeus kroyeri*). Key groundfish are of the families Sciaenidae (e.g. *Cynoscion jamaicensis*, *C. acoupa*, *Macrodon ancylodon*, *Micropogonias furnieri*), Clupeidae, Engraulidae, Gerreidae (e.g. *Diapterus* spp.), Lutjanidae (e.g. *Lutjanus* sp., *Lutjanus synagris*, *Rhomboplites aurorubens*), Haemulidae (e.g. *Haemulon* spp., Ge*nyatremus luteus*, *Orthopristis* spp.) and Ariidae (*Bagre* spp., *Arius* spp.) (Kuruvilla, Ferreira & Soomai, 2001).

Fishing gear and areas

Shrimp are mainly caught by demersal trawlers, while groundfish are either targeted or caught as bycatch by these vessels but also by the artisanal multigear fleet that use gillnets, traps, demersal longlines and handlines. FAO (2013a) provides a summary of the gears used and it is repeated here as Table 1.

Table 1 – Fishing gears used in the demersal fisheries of Trinidad and Tobago (modified from Appendix 3 in FAO 2013a).

Fishery	**Fishing Gear**	**Fishing Vessel**			**Location and Timing**			**Fleet size**	
	Gear Type	**Type of Vessels**	**Onboard processing**	**Crew size**	**Fishing Season**	**Port(s)**	**Trip Duration (days)**	**No. of Vessels**	**No.of fishers**
Artisanal Trawl	Bottom Trawls: Minimum 3 cm codend mesh size. 10.6 m average headrope length	6.7-11.6 m stern trawlers, 90-150 hp inboard diesel or 2 x 45-75 hp outboards	Barrels with ice	2-3	Year round	Otaheite, San Fernando, Orange Valley, Cacandee, Bonasse, Fullerton, Icacos	1	Approx 95	190
Semi-industrial Trawl	Bottom Trawls: Minimum 3.5 cm codend mesh size. 11.6 m average headrope length	9.3-12.2 m stern trawlers, 165-275 hp inboard diesel with electronic and navigation aids	Ice holds and barrels with ice	2-3	Year round	Orange Valley	1-5	10	30
Industrial Trawl	Bottom Trawls: Two nets, minimum 3.5 cm codend mesh size. 15 m average headrope length	10.9-23.6 m otter trawlers, 325-425 hp inboard diesel with electronic and navigation aids	Ice holds and barrels with ice, some with freezers	4	Year round	San Fernando, Orange Valley, Port of Spain, Icacos	5-11	32	128
Artisanal Gillnet	Gillnets and entangling nets	Artisanal multi-purpose	Barrels with ice	2	Year round	Erin, Moruga, Port of Spain, Icacos	1	266	532
Artisanal Line	Hooks and Lines	Artisanal multi-purpose	Barrels with ice	2	Year round	Erin, Moruga, Port of Spain, Icacos, Brickfield	1	106	212

Trawl fleet

The Trinidad and Tobago trawl fleet is comprised of artisanal, semi-industrial and industrial trawlers.

Artisanal vessels are either small (termed Type I vessels) between 6.7 and 9.8 m long with two 45-75 hp outboard engines or medium sized (termed Type II) vessels 7.9 to 11.6 m long which are generally equipped with inboard diesel engines ranging from 90 to 150 hp. These are all single-rig stern trawlers operating as pair trawlers whose nets are manually retrieved. Recent data courtesy of the Fisheries Division shows that there are currently 24 Type I vessels and 76 Type II vessels operating off Trinidad and Tobago.

Semi-industrial vessels are larger in size (9.3 to 12.2 m) and are equipped with inboard diesel engines ranging from 165 to 275 hp. These are also single-rig stern trawlers with nets hauled using a hydraulic winch. There are presently eight semi-industrial vessels operating.

Industrial trawlers are the largest - between 10.9 and 23.6 m, with more powerful inboard diesel engines of 325 to 425 hp. Each industrial trawler carries two nets (double rig) each attached to outriggers and retrieved with hydraulic winches (Maharaj et al., 1993; Kuruvilla et al., 2001). There are presently 28 industrial vessels operating.

Artisanal vessels conduct one-day trips (8-20 hrs), while semi-industrial vessels make trips of one to five days, and industrial vessels five to eleven days (Fisheries Division catch and effort records 1992-2002). The average number of hauls per day for a small artisanal trawler is six with the average duration of a haul being 0.5-1 hrs, while a larger artisanal trawler would make an average of 4-5 hauls/day at about 1-2 hrs/haul. Semi-industrial trawlers also make an average of 4-5 hauls/day but with an average duration of 3-4 hrs/haul, while industrial trawlers make 3-4 hauls/day at 2-4 hrs/haul. The average towing speeds for artisanal, semi-industrial and industrial trawlers are one, two and three knots, respectively.

All trawlers operate in the Gulf of Paria on the west coast of Trinidad year round. The industrial trawlers, and to a much lesser extent the semi-industrial trawlers, also operate in the Columbus Channel on the south coast year round, and on the north coast. Since 1998, operations on the north coast have been restricted to the area west of Saut D'eau from 15 November to 15 January in daylight hours (06:00 to 18:00).

Based on measurements made in 2006 (Soomai and Seefoo, 2006), artisanal trawl nets are made of multifilament twine with a headrope length of around 10 m and stretched mesh size of 32 mm. Semi-industrial trawl nets have a headrope of around 10 m, footrope of ~12 m, tickler chain of 10.7 m, and otter boards made of wood and steel, 1.82 m long, 0.9 m high, at an angle of approximately 24 degrees. Bridles are 36 m long made of 11 mm diameter steel wire. The industrial trawl fishing gear and its rigging (otter boards, bridles, tickle chain) are slightly larger than those of the semi-industrial vessels but, as mentioned above, use two equal nets (average headrope length of 15 m) towed at each side of the vessel from outriggers.

The average stretched mesh size in the cod end of trawl nets is 35 mm for the semi-industrial and industrial trawlers, and 30 mm for the artisanal. The diagonal stretched mesh of the trawl net must not be less than 77 mm when trawling for fish, and not less than 38 mm when trawling for shrimp, and chafing gear must cover not less than 25 % of the codend. Semi-industrial and industrial trawlers are also required to use Turtle Excluder Devices (TEDs) in nets to prevent the capture of turtles. This conservation measure is subject to US inspection and certification to facilitate the trade of shrimp between Trinidad and Tobago and the United States.

Artisanal multi-gear fleet

The multi-gear fleet comprises pirogues which are wooden, fibreglass, or fibreglass-coated, open boats, 7-10 m in length, propelled by outboard engines ranging from 40 to 75 hp with two 60 hp engines being the fleet average (Chan A Shing, 1999a). A number of gear types are used by the fleet and fishers typically switch gears according to the seasonality or availability of resources with one gear type usually used per trip. Gillnets and line gear are mainly used to catch the above-listed groundfish. A 2003 census recorded 266 vessels using gillnets (133 monofilament and 133 multifilament), 106 vessels using demersal hook and line gears (65 handlines and 41 demersal longline), and 88 vessels using live bait lines in the Gulf of Paria and Columbus Channel.

The gillnets used are either monofilament or multifilament drift nets. The former are made of transparent nylon, while the latter are heavier and made of nylon and other synthetic twines. Monofilament nets are used in the day and night and are set below the surface whilst multifilament nets are generally fished at night at the surface. One or two net sets may be made per trip (Hodgkinson-Clarke, 1994). Soak times for monofilament nets range from 2 to 12 hrs and for multifilament nets 0.5 to 6 hrs (Hodgkinson-Clarke, 1994). Monofilament gillnets have a stretched mesh size ranging between 95 and 127 mm with net lengths ranging between 450 and 1,098 m. Multifilament gillnets use an average stretched mesh size of 102 mm with net length ranging between 732 and 1,190 m. (Hodgkinson-Clarke, 1994; Chan A. Shing, 1999a, 2002). Various styles of combination mono/multifilament gillnets were introduced during the early 1990s to strengthen/reinforce the net or to improve fishing power (Hodgkinson-Clarke, 1994). Gillnets target small pelagic species such as mackerels (*Scomberomorus brasiliensis* and *Scomberomorus cavalla*) and are fished year round on all coasts but more in the latter part of the year during the rainy season when *S. brasiliensis* landings are generally higher (Chan A Shing, 1999a, 2002; Hodgkinson-Clarke, 1994).

Regulations concerning the use of gillnets include:

- When not targeting mullet, there is a minimum stretched mesh of 4.25” (10.8 cm) for gillnets and a maximum net length of 900’ (275 m) and maximum width at centre of 15’ (4.5 m).
- When targeting mullet, a minimum stretched mesh of 3.5” (8.9 cm), with no species other than mullet may be landed in excess of 15 % of the weight of the catch. Maximum net length of 900’ (275 m) and maximum width at centre of 12’ (3.6 m).

- No carite (Spanish mackerel, *Scomberomorus brasiliensis*), kingfish (king mackerel, *Scomberomorus cavalla*), grouper (Serranidae), codfish (cobia, *Rachycentron canadum*), sorb (Mutton snapper, *Lutjanus analis*), pargue (snapper, Lutjanidae), or zeblan (*Palometa pompano*, *Trachinotus goodei*) less than 305 mm in length shall be taken, sold, or exposed for sale.
- No salmon (weakfish), redfish (vivanot, *Lutjanus vivanus*; walliacke, *L. synagris*), tête-ronde (Atlantic bigeye, *Priacanthus arenatus*), pomfano (Carangidae, *Selene* sp. or *Trachinotus* sp.), or cola (*L. purpureus*, *L. vivanus*, or *Ocyurus chrysurus*) under 8" (20.3 cm) in length shall be taken or sold or exposed for sale.
- No sardine shall be sold except to a bonafide fisher for the purposes of bait.
- Several areas are demarcated where the taking of fish and shellfish is prohibited.

The demersal line methods used by the artisanal fleet are locally termed banking and palangue. Banking gear (or drop lines, vertical lines) consists of one to several hooks attached to a weighted main handline which is set on banks mostly on the west and south coasts. The palangue is a demersal longline operated by both artisanal and industrial vessels on the west coast (Mohammed et al., 2011). Vessel size, trip duration, fishing depth, hook size and gauge of the main line are different for artisanal and industrial fleets. The gear consists of a mainline, which carries a number of branch lines with hooks. The number and size of hooks used vary depending on the species being targeted. There are two types: a "small palangue" (1,000 – 5,000 small hooks) used for small snappers and sharks and a "large palangue" (200-500 large hooks) generally for sharks.

Issues

Bycatch and discards

FAO (2013a) and Ferreira and Soomai (2013) show that by far the most commonly stated issue for the fisheries of Trinidad and Tobago concerns bycatch and associated discards from the trawl fishery. A study of the artisanal trawl fishery in 1986/87 identified 70 species of finfish from 40 families in the bycatch as well as several species of portunid crabs (Maharaj, 1989). The bycatch-to-shrimp ratio was estimated at 15:1 and the finfish to shrimp ratio was 9:1. It was estimated that approximately 94 % of the bycatch of artisanal trawlers was discarded. A study of the semi-industrial trawl fishery in 1989 identified 25 species of finfish in the bycatch from 14 families (Amos, 1990). Approximately 60 % of the finfish caught was discarded and the bycatch-to-shrimp ratio was estimated at 12:1 and the finfish to shrimp ratio was in the range of 5-10:1. Data for the industrial trawl fleet, available from logbook returns for November 1991 to April 1992, estimated a bycatch to shrimp ratio of 0.6:1 during the shrimping season, but also indicated that approximately 66 % of total bycatch was discarded and this was often comprised of commercially important groundfish species.

An at-sea sampling programme to update the above-mentioned studies on the artisanal (Maharaj, 1989) and semi-industrial fisheries (Amos, 1990) was conducted by the Fisheries Division between July 1999 and July 2000. Analyses of the catches by artisanal vessels identified 30 species of finfish from 20 families and several species of Portunid crabs (Kuruvilla et al., 2000). An estimated 90 % of the bycatch of artisanal vessels was discarded and the total bycatch-to-shrimp ratio was estimated at 12:1 and the bycatch landed to shrimp ratio was 1:1 (Kuruvilla et al., 2000). From analyses of the total catch of semi-industrial vessels, 26 species of finfish from 18 families were identified in the bycatch. For the semi-industrial fleet, the estimated total bycatch-to-shrimp ratio was 9:1 and the bycatch landed-to-shrimp ratio was approximately 3:1. Approximately 71 % of the bycatch of the semi-industrial fleet was discarded. The composition of the bycatch landed by artisanal and semi-industrial vessels in this study was similar to the findings for the 1980s (see above - Maharaj, 1989) with the most common families being Carangidae, Gerreidae, Lutjanidae, Sciaenidae, Triglidae and Portunidae (Kuruvilla et al., 2000).

A more recent study done in 2017 (Fisheries Division, 2017a) in the artisanal fleet revealed a discard to shrimp ratio of 7.5:1 and for the industrial fleet of 9.3 % shrimp, 9.2 % usable fish and 81.5 % discards (a ratio of for a discard:retained ratio of 4.4:1. In all cases, a great deal of the discarded fish from all trawl fleets were noted to be juveniles of other important coastal fisheries (Kuruvilla et al., 2001).

On another note, populations of portunid crabs are thought to have increased as a result of the discards from the trawl fishery (Kuruvilla et al. 2001). There may also be incidents of turtle capture by the fishery but the areas commonly trawled do not appear to be important routes for turtle migration and records do not indicate a high incidence of turtle capture (Kuruvilla & Chan-A-Shing, 2002).

Other Issues

The following other issues arose from the workshops described in FAO (2013a) and Ferreira and Soomai (2013).

- In addition to the above bycatch problems, many fishers were of the view that trawling for shrimp in inshore areas is responsible for a decrease in resources due to physical damage to fishing grounds.
- Another issue concerns loss of catch in trawls when TEDs are used. Specifically, debris and stingrays can block TEDs leading to the loss of catch.
- Juvenile (under 15 cm) salmon, croaker, blinch, cutlass fish, snapper being caught by gillnets.
- Transparent monofilament gillnets are thought to catch too large a volume of fish (e.g. Racando, Blinch) and a substantial proportion of the catch is discarded.
- Furthermore, ghost fishing due to lost monofilament (transparent) nets continuing to catch fish is thought to contribute to overexploitation.
- Some problems concerning non-compliance of the fishing industry to existing regulations are:
    - TEDs not being used by semi-industrial and industrial trawlers, or their escape flaps are sewn down and hence prevent the escape of turtles and other catch.
    - Turtles being landed.
    - Use of mesh size in gillnets and trawl nets which is less than the minimum mesh size.
    - Some artisanal trawler owners claim that the use of a mesh size in the codend of the trawl net which is greater than 1.25" (32 mm) or 1.125" (28.5 mm)(a minimum of

1.5" (38 mm) is required by law) results in no catch. They claim that white shrimp is caught only within one mile of the Gulf of Paria coastline - which is prohibited by law.

Potential solutions

Bycatch reduction

One of the most successful ways to reduce bycatches and discards in trawl nets is through the use of Bycatch Reduction Devices (BRDs) and TEDs which allow shrimp to be caught whilst releasing finfish and other problematic species like turtles. And during the period 2003-2008, Trinidad and Tobago participated in the FAO global Project EP/GLO/201/GEF "Reduction of Environmental Impact from Tropical Shrimp Trawling, through the Implementation of Bycatch Reduction Technologies and Change of Management". This project aimed to reduce the impact of tropical shrimp trawl fisheries on the environment through the removal of barriers to the introduction of environmentally friendly trawl gear and fishing practices. Under the project, a biological data collection system for groundfish was initiated and gear trials were done in the artisanal, semi-industrial and industrial fleets, overall covering an estimated 25 % of the national trawl fleet (Soomai, 2008a). Trawl fishers and vessel owners collaborated with government in this activity through their participation in a National Steering Committee. In this project, paired trawling (using two vessels) tested experimental gear against existing trawl gear. The gears examined were a fisheye BRD, a square mesh panel BRD, and a new monofilament artisanal trawl net (Soomai, 2007; Soomai and Seefoo, 2006).

The fisheye and the square mesh panel BRDs reduced discards in the existing multifilament net and in the experimental monofilament net. Unwanted bycatch was also reduced in the new monofilament net with a 13 % decrease in the ratio of discarded bycatch-to-retained bycatch and a 27 % decrease in the ratio of discarded bycatch to total catch. Larger shrimp catches were recorded overall, however smaller sizes of shrimp were caught in the monofilament net compared to the catch in the multifilament net. The monofilament net was able to operate efficiently in a variety of water conditions and at speeds of 2.5-3.0 knots. Trawling with the monofilament net was also noted to be more fuel efficient.

In the case of the semi-industrial and industrial nets, there was a 32 % reduction in the average weight of the total catch in the experimental net (fisheye or square mesh installed) and the shrimp to retained bycatch ratio was estimated at 1:1 (Soomai, 2008a).

A conclusion from this work was that the BRDs developed showed great promise but the period of gear testing was insufficient to determine the effectiveness of each BRD (fisheye and square mesh panel) in reducing discards in each of the trawl fleets (Soomai, 2008b). In addition, it was concluded that continued involvement of the trawl vessel owners in research is necessary both in terms of ensuring the success of these fisheries management initiatives and in reducing the negative perception of the trawl fishery by the public and environmental groups.

The Fisheries Division (courtesy of Bennett, pers. comm) advises that a follow-up project termed the 'Sustainable Management of Bycatch in Latin America and Caribbean Trawl Fisheries (REBYC - II LAC) is currently being conducted in Trinidad and Tobago. It started in 2015 and is scheduled to conclude in 2021. Bycatch Reduction Gear Trials were conducted on board industrial double-rigged trawlers in June and August 2017, July - August 2019 and in March 2020. The results are summarized in the table below.

Table 2: Summary of results from the most recent BRD trials in Trinidad and Tobago

Dates	**Specifications of BRD panel (mesh size, length x width)**	**Position of BRD panel**	**Percentage (%) reduction in discards by weight when using BRD (compared to control net)**
27-31 June, 2017 & 24-31 August, 2017	2" (51 mm) square mesh on a 24" x 10" (61 x 25 cm) panel	4' (1.2 m) in front of the bag tie	24.5 %
25 July - 6 August, 2019	2" (51 mm) square mesh on a 24" x 8" (61 x 20 cm) panel	7' (2.1 m) in front of the bag tie. BRD positioned topside of the cod end of the net	46.6 %
9-17 March, 2020	2" (51 mm) square mesh on a 17" x 8" (43 x 20 cm) panel	8'2" (2.5 m) in in front of the bag tie. BRD positioned topside of the cod end of the net	60.2 %

Potential solutions suggested by stakeholders

These solutions arose from the workshop described in FAO (2013a).

- Trawl gear technology:
    - All trawlers should use BRDs.
    - The Fisheries Division should continue testing the monofilament trawl net, fisheye and square mesh panel BRDs to determine their effectiveness in reducing discards.
    - Tests on the semi-industrial and industrial fleets using new experimental nets that are lighter in weight and made of Dyneema netting and new otter boards were recommended.
    - Trawling at slower speeds was suggested to catch more shrimp and allow smaller species and younger fish to swim out of the net.
    - If trawlers do not obey zoning rules (see below), and because engine power regulations can minimise damage to habitats and the resource, horsepower regulations for trawlers should be revised, restricted and enforced.
- Zoning:
    - Fishers were generally of the view that the Government should better police and/or introduce better controls in the form of zonation via restricted areas and times of operation for trawling for shrimp and fish, open/closed seasons for trawling in the Gulf of Paria.

    - In the absence of BRDs, restricting trawlers to deeper waters should reduce the catch of juveniles as it is believed that more juveniles exist in shallower waters.
    - Fishers also suggested limiting fishing effort through monitoring the entry of new trawlers into fisheries.
    - Protection of spawning zones (where there is often a high abundance of coral) rather than the 2 nm limit (i.e. zonal protection should be done based on depth).
    - A ban on night shrimp trawling was suggested to allow finfish fishermen to work effectively. However, shrimp are often mainly caught at night.
- Gillnets:
    - Ban monofilament gillnets and, in 5-10 years after fish have had a chance to grow, allow their use with larger mesh sizes. Middle-aged and elderly fishers who cannot be trained for alternative employment due to such a ban should be compensated by government.
    - Encourage the use of biodegradable materials and/or better materials for net anchorage to mitigate ghost fishing.
    - Oversee the quality of gears being sold to and used by fishermen especially in relation to monofilament mesh sizes.
    - Proper marking of gillnets should be enforced so as to avoid nets being cut by other vessels.
- Education:
    - The Fisheries Division should enhance its technical capabilities with regard to fishing gear technology.
    - Artisanal fishers also believe that educating younger fishers in resource management, and the impacts of fishing and land-based activities on the marine environment, will contribute to better management of marine resources in the long-term.
    - Educate consumers, fisherfolk and vendors on the biology and spawning habits of important species to increase awareness.
- Others:
    - Buy-back/compensation from Government for the re-tooling of trawlers.
    - Processing unwanted bycatch for fish meal would be an alternative to discarding, which also has the potential to increase income.
    - Support and subsidize local shrimp aquaculture and exports.
    - Ban boats from operating out of landing sites in rivers to decrease mangrove damage.
- Government policies as outlined in the Draft Policy Document (Fisheries Division, 2011a) include:
    - Move from an open access regime to one of a limited entry regime in order to alleviate overcapitalization and overexploitation across all fishing fleets.
    - Alleviate the negative impact of trawling through the introduction of more environmentally friendly trawl gear.

- Favour the introduction of BRDs that will reduce discards by up to 50 %.
- Ensure that fish trawling is conducted with an appropriate net.
- Phased introduction of an increased stretched mesh size for gillnets.
- Promotion of line fishing as a more sustainable fishing method over gillnetting.

Discussion

Shrimp trawling

The above summary of Trinidad and Tobago's fisheries indicates that the most significant issue regarding best-practice fishing gears for the country's coastal and oceanic fisheries concerns the selectivity of its shrimp trawl fisheries. Discard rates of 66-71 % were recorded, which was often comprised of commercially important groundfish targeted in other fisheries and particularly artisanal gillnet, trap and line fisheries. Such problems are typical of most tropical shrimp-trawl fisheries in the world (Pérez Roda et al., 2019).

Whilst Trinidad and Tobago have some regulations in place for their shrimp-trawl gear, the main bycatch-related regulations are limited to the mandatory use of TEDs to reduce the capture of turtles in order to comply with USA shrimp import requirements. Their proper use is regularly monitored by USA officials so one can assume that they are used appropriately and therefore significantly reduce the bycatch of not just turtles but other large megafauna such as sharks and large fish.

But the use of TEDs alone in shrimp-trawl fisheries is not the only technical modification required to ensure trawlers are operating at best-practice standards. Rather, in recent years it has become very common throughout the world for shrimp trawl nets to also include fish BRDs - sometimes based on grids with narrower bar spacings than TEDs (such as the Nordmore grid) or, more commonly, strategically located square mesh panels (Pérez Roda et al., 2019; for a review see Broadhurst, 2000). And, as noted by Earys (in prep.), while Trinidad and Tobago have been involved in several very significant (and quite successful) initiatives to trial such devices (in particular the REBYC I and REBYC II projects – see Table 2 above for the most recent results), they are yet to become mandatory in the shrimp trawl fisheries of the country. Regarding the use of BRDs in this country, Earys (in prep.) notes that "….an innate suspicion of fishers towards government officials has possibly hampered efforts to share information and encourage collaboration". Clearly, the implementation of a BRD based around the design(s) of the best performing square mesh panel trialled in the recent REBYC project would be the single most significant improvement in Trinidad and Tobago's fisheries to address its main issue of shrimp-trawl bycatch. If this was to occur, and the groundfish discards from shrimp trawling were reduced significantly as a consequence, the other commercial and artisanal fisheries targeting groundfish in the area should see increases in targeted catches in a relatively short period of time. The final chapter of this report contains a discussion of potential mechanisms to achieve such implementation.

Gillnetting

In addition to the use of square mesh panel BRDs in its shrimp-trawl fisheries discussed above, the second most obvious technical improvement to fishing gears for Trinidad and Tobago concerns the examination, testing and implementation of appropriate mesh sizes in the artisanal gillnet fishery. Whilst some may consider gillnetting to be a relatively non-selective fishing method (at least in comparison to line fishing – as recognised by Trinidad and Tobago's government policy – see above), this is not always the case (for a review see Uhlmann and Broadhurst, 2015). There exist very sound, sustainable fisheries that use gillnets to catch similar species and sizes as those caught by the artisanal fleets of Trinidad and Tobago. An example is the Australian Lakes and Coorong fishery which uses gillnets to target mullets and sciaenids. This fishery has had Marine Stewardship Council (MSC) certification for many years and uses appropriate mesh sizes for the given target species and size of fish for any given fishing trip (for details, see https://fisheries.msc.org/en/fisheries/lakes-and-coorong-south-australia/). To get to such a best-practice standard for the gillnet sector of Trinidad and Tobago's artisanal gillnet fishery, studies are needed to firstly determine optimal sizes at capture for key groundfish species (often taken to be the size at first maturity – Beverton and Holt, 1957) and then identify the best mesh sizes to achieve this. These then need to be introduced into the fishery and adequately complied with (see the final chapter of this report for a discussion of potential mechanisms to achieve this).

Another modification for gillnets that may be able to address their bycatch of turtles involves the more high-tech solution of light-emitting diodes (LEDs) on nets (Wang et al., 2010). An example from South America is the study by Ortiz et al. (2016) which observed that green LEDs attached every 10 m to the floatlines of Peruvian bottom-set gillnets reduced the bycatch of green turtles by 64 % without affecting target catches of fish. Such lights clearly have significant potential although one cannot say that they are routinely used throughout the world, and their cost and maintenance could prove challenging for artisanal fisheries.

Other issues

We consider that the above two changes (in particular, BRDs in shrimp trawls and secondly more appropriate mesh sizes for gillnets) are the key modifications required to begin to raise Trinidad and Tobago's fisheries gears and operations to best-practice standards. Several other management initiatives were also raised by stakeholders in the background information obtained during this project including, among others, establishing various zones for different fishing sectors (to protect areas and reduce conflicts), the use of bio-degradable materials to reduce ghost-fishing, banning gillnets and replacing them with hook-and-line methods, etc. But such initiatives involve quite long-term changes that require substantial investment and disruption to existing practices, markets and communities. And, in any case, they would unlikely have the more immediate and significant impacts on the sustainability of fisheries resources that the above suggested simple changes would have - especially the implementation of square-mesh panel BRDs in shrimp trawls.

Suriname

The below summaries are mostly derived from FAO (2013b) and Meeremans et al. (2017).

Overview of fisheries

The fishing fleet of Suriname consists of industrial, commercial small-scale and artisanal vessels. It is estimated that small-scale and artisanal vessels account for about 70 % of total landings, while the remaining 30 % is attributed to the larger industrial vessels. All industrial vessels operate in marine waters, while the commercial small-scale and artisanal fleets operate in both coastal and inland waters. The vessels involved include trawlers, snapper boats, open or decked wooden vessels and canoes. Most target multiple numbers of species and use several types of gear.

Trawlers target shrimp and a number of finfish species. Vessels are only permitted to operate outside the 10-fathom line over the entire Exclusive Economic Zone. Most vessels operate under license, but small-scale and artisanal vessels are more difficult to monitor and license due to their number (1000-1250 boats) and dispersion.

The Seabob fishery

The seabob shrimp-trawl fishery targets seabob (*Xiphopenaeus kroyeri*) but the smaller whitebelly shrimp *(Nematopalaemon schmitti*) may also be present in catches. The fleet consists of 26 licensed vessels, landing between 6,000 and 10,000 t annually, most of which is exported (LVV Fisheries Department, 2013).

The fleet uses 'Florida-type' outrigger trawlers, with an overall length of 20-23 m and maximum engine power of 500 hp (see Table 3 for details). The vessels are equipped for twin-rig bottom-trawling, and the use of TEDs and square-mesh panel BRDs is mandatory (LVV Fisheries Department, 2010). The minimum codend mesh size is 45 mm. Fishing trips typically last six to eight days and fishing takes place day and night (Southall et al., 2011). In November 2011, this fishery became the first tropical shrimp fishery in the world to be certified by the MSC.

Meeremans et al. (2017) indicated that 59 % of the catch in this fishery is the targeted seabob, with another 4 % of other retained bycatch and 37 % discards. It is important to note that these data suggest that this is one of the most selective tropical shrimp-trawl fisheries in the world.

The non-seabob shrimp trawl fishery

The non-seabob component of the shrimp trawl fishery targets large sea shrimp including brown shrimp *(Penaeus subtilis*), pink spotted shrimp or 'hopper' (*P. brasiliensis*), pink shrimp *(P. notialis*) and white shrimp *(P. schmitti*). The fishery consists of 22 licensed vessels and lands between 400 and 600 t annually (ca. 450 t in 2015). The shrimp are mainly exported to Europe and the USA (LVV Fisheries Department, 2013).

The vessels and trawling gear used are similar to the above seabob fishery. The minimum mesh size of the codend is 45 mm. The use of TEDs has been mandatory in this fishery since 1998 but the fishery is not required to use square-mesh panel BRDs as is the case for the seabob fishery (LVV Fisheries Department, 2013). Fishing trips typically last 30-50 days and trawling occurs mainly at night. See Table 3 for details.

Meeremans et al. (2017) indicated that 25 % of the catch in this fishery is the targeted shrimp, with another 16% of other retained bycatch and 59% discards.

Table 3 – Summary of fishing gears and areas for the main commercial fisheries of Suriname (modified from FAO, 2013b).

Fishery	**Deep-sea Shrimp Trawl**	**Atlantic Seabob**	**Groundfish Bottom Trawl**	**Large pelagic line**	**Red snapper**	**Mackerel**
Fishing area	From 15 fm (27m)	West: 10-15 fm (18-27m), East: 10-18 fm (18-33m)	From 15 fm (27m)	From 28 fm (51m)	From 15 fm (27m)	From 10 fm (18m)
Type of fishing	Florida twin rig otter trawl	Florida twin rig otter trawl	Bottom stern trawl	Longlines	Longlines and handlines	Longlines and handlines
Body mesh size (mm)	57	57	120			
Wings mesh size (mm)	57	57	160			
Corner mesh size (mm)	57	57	100			
Codend mesh size (mm)	45	45	80			
Bycatch device	Approved TED	Approved TED and BRD				
Max engine power (HP)	500	500	500	1000	400	400
Max vessel length (m)					30	30
Max allowed storage (ice and fish)(t)					40	40
Hook size				5	6, 7, 8	3, 4, 5, 6, 7
Harvest control rule		As per management plan	200 days at sea allowed	Max of 2000 hooks	Max. of 14 handlines	Max. of 14 handlines

Finfish trawl fishery

The finfish or multi-species bottom trawl fishery targets different demersal fishes like green weakfish/trout *(Cynoscion virescens*(), whitemouth croaker *(Micropogonias furnieri*), barracuda *(Sphyraena guachancho*), lane snapper *(Lutjanus synagris*), corocoro grunt/black snapper (*Orthopristis ruber*), largehead hairtail *(Trichiurus lepturus*), Jamaican and tonkin weakfish/witwitie *(Cynoscion jamaicensis/similis*) and poes/Thomas sea catfish (*Notarius grandicassis*). Between 6,000 and 8,000 t of fish are landed annually, most of which is exported to Europe, the USA and the Caribbean (LVV Fisheries Department, 2013). In 2015, 23 licenses were issued for this fishery.

The finfish trawl fleet consists predominantly of two types of vessels: converted shrimp trawlers and former 'kotters' from the Netherlands. Vessels are typically around 20 m with engines of 500 hp. Most vessels are rigged for stern trawling, in which a single otter trawl is towed along the sea floor, held open by one pair of steel otter boards. The minimum mesh size of the codend is 80 mm. Fishing trips typically last four to eight days and fishing takes place mostly during daytime (LVV Fisheries Department, 2013). See Table 3 for details.

Meeremans et al. (2017) indicated that 55 % of the catch in this fishery is the targeted finfish, with another 1% of jellyfish and other invertebrates and 44% discarded finfish.

Large pelagic line fishery

The large pelagic line fishery involves vessels with a maximum engine power of 1000 hp, operating from 28 fm (51 m) depth. They use horizontal longlines and vertical handlines with a maximum of 2000 hooks.

The Red Snapper Fishery involves up to 30 m long vessels with a maximum engine power of 400 hp, operating from 15 fm (27 m) depth. It uses up to 2000 hooks on horizontal longlines and up to 20 hooks on vertical handlines. Hook sizes are 6, 7 and 8. There is also a maximum allowable storage capacity of 40 t, including ice and catch. There is a requirement that all vessels have a Vessel Monitoring System.

The mackerel fishery is similar to the red snapper fishery and also involves 30 m long vessels with a maximum engine power of 400 hp, but operating from 10 fm (18 m) depth. Vessels deploy up to 2000 hooks on horizontal longlines and up to 20 hooks on a maximum of 14 vertical handlines. Hook sizes are 3 to 7. There is also a maximum allowable storage capacity of 40 t, including ice and catch. There is also a requirement that all vessels have a Vessel Monitoring System. See Table 3 for details.

Coast and sea fisheries

These fisheries use various types of traps and nets (the schutbank, fykenet and seine nets) and lines. Nets have a minimum stretched mesh size of 5 cm. The maximum allowable number of vertical hand lines is 14. Fishing is not permitted in river mouths nor during the turtle season of 1 March – 31 July in the Turtle area north of Galibi, 15 km west of Elanti out to 15 km.

Drift nets are also used and have a minimum stretched mesh size of 8" (200 mm), with 30 % can consist of 5-6" (127-152 mm) inches. The total length of the net is a maximum of 2000 m. Monofilament nets are not permitted.

Fishing for “Bangamary” (*Macrodon ancylodon*) uses drift nets with a minimum mesh size of 3” (76 mm) inches and a maximum length of 2000 m. The fishing area is between 3 and 5 fm (5.5-9 m) depth except in river mouths and in the above-mentioned turtle area during the turtle season.

Issues

These arose from the workshops described in FAO (2013b).

Bycatch and discarding

The main issue for Suriname’s fisheries concerns the bycatch from shrimp and finfish trawling. But as noted above, Meeremans et al. (2017) indicated that for the seabob fishery, 59 % of the catch is the targeted seabob, with another 4 % of other retained bycatch and 37 % discards. This makes this fishery one of the most selective tropical shrimp-trawl fisheries in the world. However, for the non-seabob shrimp fishery, 25 % of the catch is the targeted shrimp, with another 16 % of other retained bycatch and 59 % discards; and for the finfish fishery, 55 % of the catch is the targeted finfish, with another 1 % of jellyfish and other invertebrates and 44 % discarded finfish. This has resulted in artisanal fishermen complaining about lower catches due to fish and shrimp trawlers catching many juvenile groundfish including sciaenids which are discarded or sold as “Tri” or salted sun-dried small fishes. The shrimp industries are also thought to have a negative impact on sea turtles and dolphins

Other issues

- The juvenile stages of shrimp species harvested by artisanal fishermen in the near shore, estuaries and lagoon are said to affect recruitment of shrimp to the industrial fisheries.
- The interaction between the small pelagic trawl fishery and shrimp trawlers operating at the same depth from 15 fm (27 m) is said to affect each other’s stocks.
- Deep-sea shrimp trawlers believe that the poor catches of large shrimps are the result of the introduction of the seabob fishery.
- Bottom trawling can affect bottom habitats.
- Shrimp and fish trawlers can damage artisanal gillnets.
- Monofilament nets that are not particularly selective are commonly used and are thought to be particularly problematic in the Bigi Pan area that plays an important role in ecosystem maintenance.
- Sport fishers that can fish with nets conflict with the inland fisheries where native villages get their main source of income and protein.
- The trap (schutbank), fykenet / seine net fishery is in conflict with hatchery and nursery grounds due to mangrove trees being cut for their angle position in the river or river mouth.

Potential solutions

Bycatch reduction

Whilst bycatch and discarding from shrimp trawling is listed above as a major issue for Suriname, this country provides one of the world’s best examples of resolving such problems in a tropical shrimp trawling context. That is, and as summarized by Earys (in prep.), the work done in a variety of projects including the REBYCII LAC project has led to the successful development and implementation of TEDs and BRDs in the seabob fishery (see Fig. 1) to the point where the fishery is achieving a discard rate of just 37 % (a very low rate for tropical shrimp fisheries) and has been certified by the MSC - one of the best sustainability measures available for fisheries in the world (Cattani, et al., 2012; LVV and FAO, 2016; Polet et al., 2010)

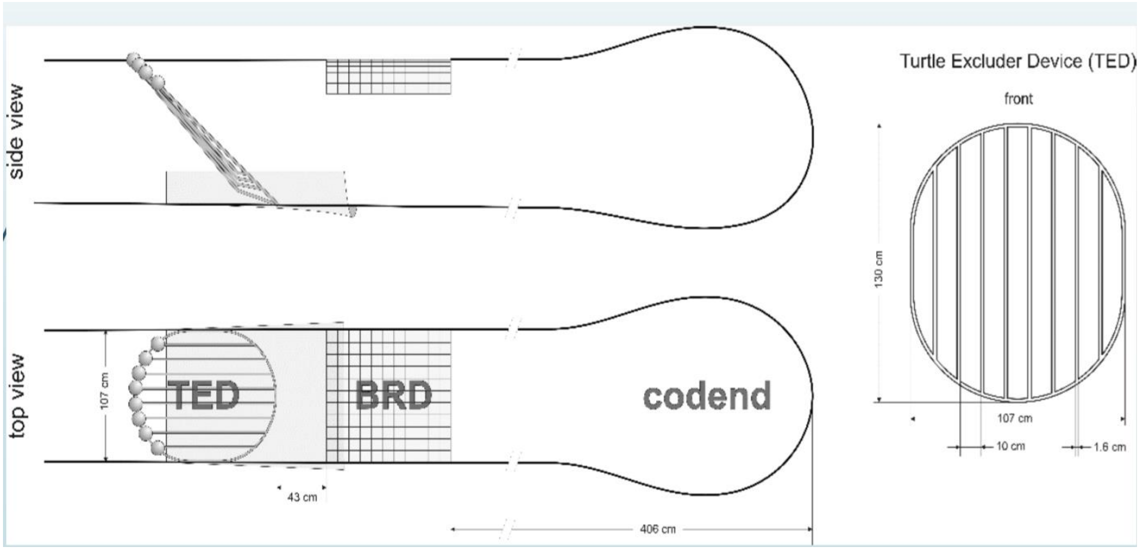

Fig. 1 BRD and TED developed in the REBYCII LAC project (LVV and FAO, 2016).

Potential solutions suggested by stakeholders

These solutions arose from the workshops described in FAO (2013b).

- The application of BRDs in the seabob fishery should be evaluated and possibly improved.
- Need to introduce appropriate technology (BRDs) in all shrimp trawl fleets (not just seabob) to reduce bycatch.
- Data should be collected on the types, numbers, and survival rates of the discarded bycatch from the seabob fishery.
- Determine the level of habitat destruction due to seabob trawling and reduce such impacts via lighter ground gear including modified otter boards.
- No trawling zones in red snapper areas should be established.
- Awareness training on bycatch.
- Do not allow monofilament nets, but instead fish with conventional nets.
- Scientific research regarding the interactions between deep-sea shrimp trawling and the seabob fishery is required.
- With the mandatory introduction of VMS, the Fisheries Department should take stringent measures against those not fishing or operating in accordance with the license conditions.

Discussion

Shrimp trawling

The above summary of the fisheries and fisheries issues of Suriname suggest that, as we saw in the previous chapter on Trinidad and Tobago, Suriname's key fishing gear issue also concerns bycatch from shrimp trawling. In particular, the discarding of juvenile sciaenids and other groundfish from shrimp trawlers that are not in the MSC-certified seabob fishery.

The data available suggest that Suriname's seabob fishery is one of the most selective tropical shrimp trawl fisheries in the world (see data in Pérez Roda et al., 2019) – to the point where it has attained MSC certification. A significant reason for this has been the successful implementation of TEDs and a square mesh panel BRD in the fishery (see Fig. 1). But for those shrimp trawlers not in this fishery, BRDs are not mandatory and therefore significant discarding of key groundfish occurs.

An obvious solution to this problem would be to implement a similar BRD as that used in the seabob fishery to the other shrimp trawlers in the country. Doing so should improve stocks for the other commercial and artisanal fisheries that target groundfish. In addition, as noted by stakeholders, additional refinement of the BRDs used in the seabob fishery could be made to further reduce bycatches in the fishery and any other shrimp trawlers that (eventually) use the technology.

However, it is important to note that, unlike for the seabob shrimp fishery (that mostly just targets shrimp), other shrimp trawl fisheries in the country will be more negatively impacted by BRDs due to a loss of saleable bycatch (termed "by-product" – sensu Pérez Roda et al., 2019). This is an issue facing shrimp-trawl fisheries globally that rely on significant sales of bycatch. That is, the technology exists to improve the selection of any shrimp trawl fishery to be similar to that of the seabob fishery, but in doing so, there will be a collateral impact on other retained catches. The seabob fishers of Suriname seemed to have been fortunate that their fishery developed with a focus on the targeted shrimps that apparently aggregate in large numbers, making it a relatively simple process to achieve sustainability to the level of MSC certification. To implement such BRDs in other fisheries - that rely on untargeted bycatches as a supplement to income and/or for consumption - must be done such that any new technology reduces unwanted organisms that are discarded and not all bycatches.

Other issues

The other issues and potential solutions identified by stakeholders for Suriname's fisheries are far less significant than the above shrimp trawl bycatch issue. Notwithstanding this, as was the case for Trinidad and Tobago in the previous chapter, ensuring appropriate mesh sizes for gillnets and indeed for demersal fish trawl nets, should also be a focus to ensure such fisheries approach best practice standards.

Guyana

The below summaries are mostly derived from FAO (2013c) and information obtained from country experts.

Overview of fisheries

The major fisheries of Guyana are for shrimp and groundfish. They operate in three areas: inshore, offshore and on the deep slope (Department of Fisheries, 2006b). The fisheries are categorised as: (i) Offshore Industrial Large Penaeid Shrimp Fishery; (ii) Industrial Seabob Fishery; (iii) Inshore Artisanal Fishery; (iv) Snapper and Grouper – Deep Slope Fishery; (v) Large Pelagic Fishery; (vi) Coastal Pelagic Fishery; and (vii) Small Pelagic Fishery. See Table 4 for a summary of the gears used.

Table 4 – Gears used in Guyana's marine fisheries (from FAO (2013c). * indicates that the gear is known for incidental catches of those fisheries' targets.

	Offshore Industrial Large Penaeid Fishery	**Industrial Seabob Fishery**	**Inshore Artisanal Fishery**	**Snapper and Grouper Deep Slope Fishery**	**Large Pelagic Fishery**	**Coastal Pelagic Fishery**	**Small Pelagic Fishery**
Jib Trawl Nets	yes	yes			yes *	yes *	yes *
Pin Seine			yes		yes	yes	yes
Chinese Seine		*	yes			yes *	yes *
Gillnet Polyethylene			yes		yes *	yes *	*
Gillnet Nylon			yes		yes		
Circle Seine			yes				
Handlines					yes	yes *	
Cadell			yes		yes	yes *	
Traps				yes			
Longlines				yes *			

Industrial fisheries

Guyana's shrimp trawl fleet are all foreign built vessels and operate for four to seven days at sea during each trip. They target large shrimp when fishing at between 18 and 91 m depth and in waters 40-145 km offshore, and seabob shrimp between 13 and 18 m depth and in water 15-30 km offshore. The fishing gear used are Jib trawl nets with 40-50 mm stretched mesh in the wings and 25-35 mm in the codend. Since 2018, the trawls in this sector have been required to be fitted with a TED and a square mesh panel BRD (see Fig. 2 - Fisheries Regulations, 2018). Using such devices, industry reported a 50 % decrease in bycatch. The main bycatch species in the large penaeid shrimp fishery include: grunts, red snapper, groupers, lobsters, crabs, squid, seabob and stingrays; whilst for the seabob fishery, the main bycatch species are butterfish, bangamary and small sea trout.

Fig. 2 – The BRD as specified in Guyana's Fisheries Regulations (2018).

SECOND SCHEDULE

(Regulation 41(2))

All trawler typed vessels rigged to fish in the fisheries waters are to be fitted with a bycatch reduction device confirming with the following specifications or other bycatch reduction device as approved by the Chief Fisheries Officer –

The Square-Mesh Window

Excluded Species

Figure 1

Description

The square-mesh window is designed to allow fish to voluntarily swim from the trawl (Figure 1). This BRD is simply a panel of large meshes hung on the bar so they remain open during the tow (Figure 2). This is in contrast to diamond meshes which tend to close under tension. The following details describe the construction of a 150 mm (75 mm bar length) square-mesh window measuring 6 bar lengths long by 6 bar lengths wide to fit a codend with a 45 mm (1¾") mesh size.

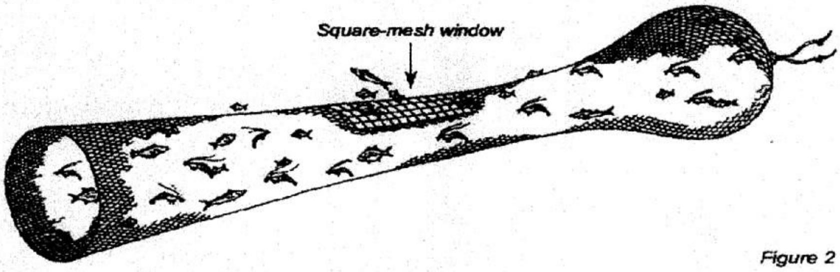

Figure 2

Construction

- Cut out a rectangular hole in the top of the codend measuring 40 meshes wide by 12 meshes long (Figure 3).
- Cut out the square-mesh window from 150 mm (6") netting measuring 6 bar lengths wide by 6 bar lengths long.
- Reinforce the edges of the window with 4mm rope.
- Secure the window to the codend at desired location ensuring codend meshes are distributed evenly between the bars.

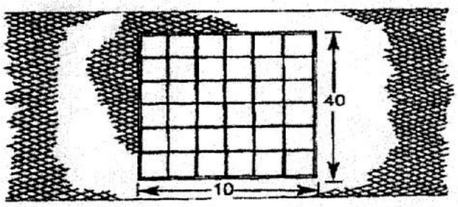

Figure 3

Trouble Shooting

Shrimp loss: This may be due to knot slippage, incorrect mesh or window size selection and poor window location. To prevent knot slippage the window may need to be replaced with knotless netting or netting made from thicker twine. Reducing mesh or window size will reduce shrimp loss, as will relocating the window further forward of the catch.

Poor exclusion rate: The mesh size may be too small, however, careful selection of a larger mesh size is required to prevent shrimp loss. Relocating the window closer to the accumulated catch may increase fish loss, but may increase the risk of shrimp loss particularly when large catches are taken.

Semi-industrial fisheries

The Red snapper and grouper fisheries are considered to be semi-industrial fisheries due to factors such as vessel design, the size and location of target species and the fishing gear used. The vessels are similar to artisanal vessels and are mostly large V-bottom vessels with inboard engines. They also usually have an extended shed over the deck for the storage of traps. The vessels have relatively small crews but can remain at sea for longer periods and hold a larger catch than artisanal vessels. The gears used are:

- Pots (also commonly called traps) to target snapper, groupers and grunts on the deep slope. These are baited and deployed for 2-3 days and tied to large buoys. Some fishers connect the traps together with a single line to avoid traps being easily stolen or lost.
- Handlines (called longlines locally) have several baited hooks in a line and target fish nearshore. A vessel ordinarily carries more than 8 polyethylene handlines, each with more than 16 hooks, which can hold a great load and are usually retrieved by mechanical winches.

Artisanal fisheries

There are three vessel types used in artisanal fisheries: (i) flat-bottom dories powered by sail, paddle or small outboard engines, that use Chinese seines, Pin Seines and Cadell lines; (ii) small V-bottom boats which are larger than flat-bottom dories, with an icebox but no cabin and powered by 25-55 hp outboard engines, that deploy small gillnets; and (iii) large V-bottom boats with both icebox and cabin and powered by inboard engines, that deploy large pin seines, drift seines, Cadell lines and handlines. Details about the above-mentioned gears are:

- Fixed gillnets (on stake) (called pin seines or beach seines) target a range of groundfish in the intertidal zone. They measure 2 m high and up to 2 km in length with a stretched mesh size of up to 90 mm, are set during the high tide and the catch is retrieved from mud flats after the ebb tide. The main species caught are mullet, queriman, snook, bangamary, croaker and catfish.
- Fyke nets (called Chinese seines locally) target groundfish and shrimp species on mud banks along the coast, in rivers and especially at river mouths where intertidal flows are greatest. They are funnel-shaped nets, 16 m long and 4-6 m wide at the mouth. Their mesh size gradually tapers from the mouth (80 mm) toward the bag end (10 mm). The net is attached to poles when set, and fish and shrimp are swept into the mouth by tidal currents and carried into the bag where they are trapped. The main species caught include whitebelly shrimp, seabob, bangamary, butterfish and catfishes. The main bycatch species include bangamary and Suriname mullet.
- There are three variations of the basic gillnet used in Guyana's artisanal fisheries:
    - Polyethylene nets (used as drift gillnets, called drift seines locally) target a range of medium to large-sized groundfish. These nets are 4 m deep and vary in length from 1 to 1.6 km, with a stretched mesh size of 200 mm. Recent information from fishermen indicate that these nets may now reach as long as 4.8 km in length. These nets are set out and hauled from boats. The main catch includes grey snapper, sea trout, cuffum, gillbacker, mackerel and sharks. The main bycatch species are: cuirass, catfish, cuffum, snook, mackerel, gill baker, cuvalli and sea conga.
    - Regular styled nylon nets are essentially a smaller version of the above polyethylene net but used to target smaller species closer inshore. The nets measure approximately 300 m in length with a stretched mesh size of 80 mm. Historically, the main catch is catfish (CIDA, 1994) but recent demand for bangamary on the export

market seems to have increased the use of these nets (called 'fine seine') to target this species. The main bycatch species are catfish, annafoke, basha and Kuma kuma.
    - The encircling gillnet (called circle seine locally) is unique to the artisanal fishery in the Corentyne River and targets smaller species. It is a nylon net, 300 m long with stretched mesh sizes less than 80 mm. The net is deployed into the water from the back of a vessel in such a way that it surrounds the fish school. The fish encircled will try to escape out of the net and become entangled and gilled. The main catch is lau lau, silver bashaw and highwater.
- The handlines have several baited hooks connected and target fish nearshore. A vessel ordinarily carries approximately 8 polyethylene handlines, each with 16 hooks. The hooks are baited with small species of fish caught inshore.
- Cadell lines are demersal set longlines and used to target fish in waters of approximately 9 m. The gear consists of a mainline (or called ground-line) anchored at either end with approximately 800 hooks connected to snood lines (or called gangions) at 2 m intervals. Hooks are baited with small fish from inshore. The catch mainly includes gillbacker, cuirass, catfishes and sharks.

Issues

These arose from the workshops described in FAO (2013c).

- As elsewhere in this region, a significant issue for Guyana's fisheries concerns bycatch from shrimp and finfish trawling.
- The use of fixed gillnets (pin seines), fyke nets (Chinese seines) and gillnets near the shore is considered to be possibly destructive to juveniles of many species. While there are regulations governing these gears, their use is said to continue to have negative impacts.
- There is also speculation among fishermen that the use of drift gillnets (drift seines) is having a destructive impact on the benthos.
- Fishermen on the Berbice River face the challenge of having their nets destroyed by large clumps of floating grass which are periodically discharged from the Canje River. These grasses also affect boat engines.

Potential solutions suggested by stakeholders

These solutions arose from the workshops described in FAO (2013c).

- Priority should be given to the identification, elimination and/or reduction of destructive gear like trawls while developing an effective gillnet (polyethylene) fleet.
- Assess the size of fish caught by various gears in relation to biological reference points like optimal size and size at maturity.
- The banning of fixed gillnets (pin Seines) has been suggested but available beach space is already a limiting factor and therefore the total impact of these nets on the resource may not warrant such a ban. Also, the pin seine activity is limited to high (spring) tides which restricts operations to about 26 weeks per year.

- Notwithstanding the above, regulation of mesh size, length and numbers of pin seines should be examined.
- The fyke net (Chinese seine) is the main gear in Guyana to harvest whitebelly shrimp so there is significant need for the continued use of the gear. Regulations should examine limiting the number of licences to those operators already in the fishery and placing limits on the number of nets per vessel. Operations could also be restricted to locations and seasons of high whitebelly shrimp abundance.
- Longlines (Cadell line) fishing should be encouraged but hook size regulations should be examined as a means of ensuring only larger sizes of the targeted species are caught.
- More in-depth study of the nearshore nylon gillnet is needed and, if found to be necessary, then regulations on mesh size and length of net could be put in place. Also, the number of licences issued should be restricted.
- The polyethylene gillnet/driftnet has been identified as one gear type to be encouraged because of good economic returns. However, regulations on mesh size should be addressed as a means of conserving the resource. Later, limitations on effort could be examined.

Discussion

The above summary of the fisheries and fisheries issues of Guyana indicates that, as we saw in previous chapters, an important issue concerns bycatch from shrimp trawling. However, the fact that Guyana has had TEDs mandated for several years and has had a BRD mandated for use in its shrimp trawl fisheries since 2018 (see Fig. 2) suggests that such fisheries are beginning to adhere to what most would consider best-practice standards in terms of the fishing gear used (see also Earys (in prep.).

Based on the information from stakeholders, of greater importance in Guyana concerns ensuring that the various types of seine and gillnets are modified to be as selective as possible for their targeted species and sizes of those species. This involves ensuring that appropriate mesh sizes are used for such nets as well as moderating the overall dimensions of such nets. To achieve this requires studies to firstly determine optimal sizes at capture for key species (usually the size at first maturity) and then identify the best mesh sizes required to achieve this for seines and gillnets. These then need to be introduced into the fishery and adequately complied with. In addition, some control over the size (particularly in terms of length) and numbers of such nets is required to minimise risks of overfishing.

Brazil

The below summaries are mostly derived from FAO (2013d) and emails / zoom discussions with government and academic experts.

Overview of fisheries

The main fisheries focusing on the shared resources of northern Brazil are industrial shrimp trawling, bottom gillnet fisheries targeting demersal fish, line/trap fisheries directed towards snapper and trap (covo or manzuá) fisheries for lobsters and snappers.

FAO (2013d) noted that Brazil has a total of 63,868 fishing vessels, of which 41,838 are propelled by rowing and/or sails (65.5 %), 20,287 are small motorized boats with a wooden hull (31.8 %) and 433 are medium and large-sized motorized boats with steel hulls. In 2013, Brazil's fisheries were therefore predominantly artisanal and small-scale whose fishers contribute seafood for direct consumption by the local population, with the industrial segment dedicated mostly to satisfying an export market. However, in more recent years, many of these former artisanal fisheries have developed to supply a growing export market – particularly for swim bladders of groundfish and other products.

Industrial shrimp fisheries

According to Aragão et al. (2001), the industrial shrimp fisheries of northeastern Brazil steel-hulled boats are about 24 m long and 6.5 m wide, and with engine power ranging from 365 to 425 hp. They are equipped with modern navigation equipment, communication systems and onboard freezing capability. They generally use double-rig trawl nets and usually undertake four hauls per day, lasting about 4-6 hrs during the period of higher productivity, and two slightly longer night hauls in the off season. Each vessel usually does between 4 and 6 trips during the year, lasting 30 to 60 days each trip. The average crew size is five. Industrial boats are mainly based in Belém (Icoaraci district), Pará but some are based in Ceará. The total fleet was historically over 250 boats, but in 2006 the fleet consisted of only 123 boats: 108 in Pará state and 15 in Ceará state. In 2013, 101 industrial fishing boats were licensed, but only 62 were in operation, probably due to economic circumstances.

There is also a significant trawl fishery that operates off the Amazon River mouth. These 48 vessels operate in shallow muddy waters as pair and even triple trawlers, towing long nets with codends of mesh size up to 100 mm to target Piramutaba (*Brachyplatystoma vaillantii*).

Groundfish fisheries

Groundfish fisheries are manly conducted by small and medium-sized boats, which may be sail or engine powered. The boats are typically 8-12 m in length, with an average crew size of four using bottom drift gillnets and longlines to target catfishes, croakers, mullet, snappers and groupers. The exception is the snapper vessels that range from 12 to 22 m and are powered by inboard diesel engines.

The commercial fishery targeting demersal fish species on the Brazil-Guianas shelf began using bottom longlines as the main fishing gear aimed at catching catfish species. Cotton gillnets were used in early times (Meschkat, 1960) but the use of nylon gillnets of monofilament or multifilament twines have been used throughout the region for decades and is the most commonly used gear in shallow areas (<20 m depth) off the coast. The drift gillnets used can reach lengths greater than 6 km and have a mesh size varying from 50 to 180 mm stretched mesh.

In recent years, and in conjunction with substantial Chinese investment, a very significant fishery has grown in importance in north-eastern Brazil using gillnets to target weakfish (*Pescada amarela*) and other finfish species (*Sciades* spp.) for their swim bladders which are exported mainly to China and, to a lesser extent, Vietnam. The gillnets used have gradually increased in length over time, whilst mesh size has decreased in order to catch greater quantities. Whilst the main export market is for swim bladders, the gutted and filleted fish also have good domestic markets.

Lobster fishery

The “caçoeira” net was formerly used to catch lobsters but is now banned and the fishery is currently only allowed to fish with pots (traps). However, the use of “caçoeira” is still frequently observed especially in fisheries carried out on the north coast. The Brazilian lobster fishery, with annual production around 5,500 tonnes, is mainly concentrated in the north-eastern coast of the country, from Bahia to Ceará, where up to 80% of the fishery occurs.

Artisanal fisheries

Information on artisanal and small-scale fisheries in the region is scarce and outdated. There are no reliable statistics on the landings or the number of boats in operation. Artisanal fisheries in the states of Maranhão and Pará are conducted in estuaries, bays and shallow waters near the coast. Fishing operations involve fixed gear called scoop nets, deployed depending on the tide, and small towed trawl nets (“puçá-de-arrasto” and “puçá-de-muruada”), operated manually, as well as larger trawl nets, also operated manually and aided by a small boat. Some villages operate large stationary fish traps made from galvanized chain link fence supported by mangrove posts with long wings that guide the fish into a series of central traps. This fishing system is widespread but the effort involved in terms of numbers of fishers is unknown.

Issues

These arose mostly from the workshops described in FAO (2013d) with additions from recent interviews with local experts.

- The over-expansion of the fishing industry in the face of relatively low abundances of marine fisheries resources, caused by reduced productivity of Brazilian waters due to environmental degradation of coastal environments due to urban, agricultural and industrial pollution.
- The overexploitation of coastal ecosystems has significantly decreased productivity and individual income per fisher/boat and pushed semi-industrial and industrial fishing fleets to expand their activities to more distant oceanic areas.
- A key issue is the use of inappropriate fishing methods, with a high incidence of catches of juveniles and inappropriate management measures. In the case of red snapper fisheries, a preference for small, plate-sized fish is also a driving force.
- The relatively high bycatch of the industrial shrimp trawl fishery is one of the main problems. Part of the catches is composed of species of commercial value, but only a small proportion is utilized - the majority is discarded. A 2009 study indicated that for every kilogram of shrimp, 6.93 kg of fauna are caught, comprising 61.1 % finfish, 29 % crustaceans, 2.9 % elasmobranchs and the reminder a "mixture" of small fishes, other crustaceans and molluscs (Paiva, et al., 2009).
- There is a lack of measures to deal with the above issue by improving selectivity in the shrimp trawling fishery such as by using BRDs.

- The sea turtles *Caretta caretta*, *Chelonia mydas*, *Eretmochelys imbricate* and *Lepidochelys olivacea* have been recorded in the bycatch of commercial fisheries. However, vessels which use bottom trawls and are more than 11 m in length are required to use TEDs throughout the Brazilian coast. But records of low catches of sea turtles in shrimp trawls, especially off the north coast, has been used to justify not using TEDs.
- *Chelonia mydas* are caught in fish traps on the beaches of Pará.
- Dolphins are also caught accidentally by groundfish commercial fishing, despite their catch being prohibited in Brazilian territory. Of the four species of dolphins that are found in the region, *Sotalia guianensis* is the most affected by fishing, due to its vulnerability to gillnets.
- There are indications that fish species considered as threatened under IUCN categories are also caught (sharks, rays and groupers).
- For the bottom gillnet fishery, there has been a diversification and reduction in the size of meshes in use from 80-100 mm in the past to 65-70 mm today.
- There is a lack of basic information on artisanal fisheries (in part due to the wide dispersion of landing sites), making it impossible to assess the level of exploitation of their target resources and any impacts of their activities on the environment.

Potential solutions

Solutions from stakeholders

These solutions arose mostly from the workshops described in FAO (2013d) with additions from recent interviews of local experts.

- Management of shrimp fisheries in Brazil has the following main objectives:
  - restoration and maintenance of ecologically sustainable levels of stock biomass;
  - minimizing the impacts of fishing operations on the ecosystem, with emphasis on the reduction of bycatch; and
  - ensuring optimal resource utilization and equitable distribution of economic benefits.
- Need appropriate BRDs to be implemented in the industrial shrimp trawl fishery.
- Better management measures are needed to ensure that species being fished are above the size at first maturation and not during reproductive aggregations.
- Appropriate gillnet lengths and mesh sizes are required when targeting catfishes.
- Better data are required regarding the nature and scale of artisanal fisheries.

Bycatch reduction work

A very significant body of research has occurred in Brazil to develop more selective fishing gears, particularly involving BRDs for shrimp trawls such as grids and especially square mesh panels tested in FAO's REBYC project (for a summary see Earys, in prep.). For example, Silva et al. (2011 and 2012) tested various Nordmøre grids for an artisanal canoe-based shrimp trawl fishery and found that such grids retained significantly less total bycatch than conventional gears without significantly affecting the weights or numbers of the targeted seabob (*Xiphopenaeus kroyeri*). In addition, Duarte et al. (2018) proposed a minimum diamond-shaped mesh size of at least 35 mm and a square-mesh window in the top of the codend comprising at least 48 mm mesh size for shrimp trawl fisheries.

Whilst this work was done in southern Brazil, its results are worth consideration in northern areas as it was noted that such a configuration would probably retain penaeids and larger teleosts, but allow many small teleosts to escape. The authors also concluded that anteriorly located grids (TEDs) are also required to reduce the bycatch of charismatic species like turtles, sharks and rays.

Despite this work, and the success of the MSC-certified seabob fishery in nearby Suriname, there is apparently little interest from the shrimp trawl industry of northern Brazil to use BRDs or even the mandated TEDs. Discussions with experts and the work of Duarte et al. (2019) revealed that reasons for this included the way in which the TEDs were originally implemented into the fishery over 25 years ago - with little notice and virtually no training in their installation and use. Such an experience has left a poor impression with the fishing industry in this region where, in any case, few turtles are apparently caught (although other ETP species such as dolphins and sharks do occur). With such a history, fishers are reluctant to even try the far easier-to-install BRDs like square mesh panels tested during the REBYC project and being used elsewhere. In addition, markets for by-product species from shrimp trawling exist and have increased in recent years (eg. for weakfish), further reducing the desire to exclude fish using BRDs.

In working towards a solution, Duarte et al. (2019) noted that TED use among Brazilian penaeid-trawl fisheries might be better promoted via a co-management strategy - facilitated by sustained education and technical expertise from researchers encouraging fishers to develop fishery-specific solutions. If industries can be encouraged to accept the concept of TEDs, they might then refine and develop ownership of the most appropriate configurations and begin to develop and accept appropriate BRDs like square mesh panels.

Discussion

Shrimp trawling

The above summary of the fisheries and fisheries issues of northern Brazil indicates that, as we saw for the other countries in previous chapters, an important issue concerns bycatch from shrimp trawling and this arises in two areas. Firstly, despite TEDs being mandatory in Brazil for 25 years, they are apparently rarely used in the northern region. Secondly, despite a significant amount of work having been done on developing BRDs in Brazil's shrimp trawl fisheries, BRDs are not yet mandatory for northern vessels. So, in terms of bycatch reduction, the main issue for this fishery is the proper testing and implementation and use of TEDs and BRDs.

Lobster fishing

There is also a concern regarding the fishing gears used to target lobsters in northern Brazil where the use of the caçoeira net, whilst formally banned, is still used. Best-practice fishing gears for lobsters is usually accepted to be pots (traps) made of appropriate mesh size and include escape vents that are designed to minimise the numbers of immature lobsters caught, so any use of more indiscriminate methods involving nets to catch lobsters should be discouraged, and current regulations to ban such nets should be enforced.

Gillnetting

Based on the information from stakeholders, of significant importance in northern Brazil is ensuring that the various types of gillnets and traps used are designed to be as selective as possible for their targeted species and sizes of those species. This involves ensuring that appropriate mesh sizes are used as well as moderating the overall dimensions of such nets and traps. To achieve this requires studies to firstly determine optimal sizes at capture for key species (usually the size at first maturity) and then identify the best mesh sizes and/or trap types (or design) required to achieve this. These then need to be introduced into the fishery and adequately complied with (see the final chapter of this report for a discussion of potential mechanisms to achieve this). In addition, some control over the size (particularly in terms of length) and numbers of these gears is required to minimise risks of overfishing. This is a particularly important issue now because, in recent years, there has been a significant expansion of fisheries targeting certain finfish for their swim bladders to support the growing Chinese markets for these exports. This has led to decreases in mesh sizes and increases in numbers of nets used, which has the potential to result in significant overfishing of these species and the eventual collapse of stocks, a situation seen all-too-frequently throughout the world when sudden new markets develop.

Guidance on best practice fishing gears for the region

The above synthesis of information about the fisheries of Trinidad and Tobago, Suriname, Guyana and Brazil operating in the Guianas-Brazil shelf region indicates that the three main fishing gears used (shrimp trawling, netting using gillnets and seines, and trapping) could be improved to approach world's best practice standards. And to identify what is meant by the term "world's best practice standards", we can consider several recent reviews of the international literature that have examined such gears (in particular, Broadhurst, 2000; Kennelly and Broadhurst, 2002; Uhlmann and Broadhurst, 2015; and McHugh et al., 2017). We examine each of these fishing methods below.

Shrimp trawling

Tropical shrimp trawling of the type that is common in the Guianas-Brazil shelf region is well-known as the most problematic fishing method in the world with respect to bycatch and discarding (Pérez Roda et al., 2019). In addition, because of the capture and subsequent discard (dead or alive) of large numbers of organisms, such gears are known to cause significant disruptions to natural ecosystems by killing and/or displacing large numbers of animals. Further, as is the case for most mobile fishing gears that involve bottom contact, otter trawling is known to have significant impacts on benthic habitats (McHugh et al., 2017). But as is the case in most regions of the world, such gears also represent one of the most lucrative fishing techniques in terms of financial gain because otter trawling is the most efficient way to catch valuable shrimp resources. So, as we have seen elsewhere for decades, the ecological impacts of shrimp otter trawling have been outweighed by the economic advantages that the gear represents.

In recent decades, however, numerous developments have occurred in the field of fishing technology that have led to improvements in the selectivity of shrimp trawls, consequent reductions in problematic bycatches and reductions in habitat and broader ecosystem impacts that have permitted such gears to still catch the valuable shrimp in an economically efficient way but with reduced ecosystem effects. These developments include:

- TEDs (devices with grids with large bar spacings) that exclude protected megafauna such as turtles, marine mammals, sharks and other large fish;
- Other grids with small bar spacings (such as the Nordmøre grid) that exclude smaller fish that are still larger than the targeted shrimp;
- Square mesh panels of various types but mostly placed on top of the anterior part of the codend to allow the escape of small fish via behavioural differences; and
- Modifications to anterior parts of the trawl to reduce habitat damage, drag and therefore fuel usage, whilst improving selectivity. For example, reducing the otter board angle of attack, minimising twine area and optimising horizontal-trawl openings.

For the countries examined in this project, the high discard rate in shrimp-trawl fisheries is by far the single most consistent and significant issue identified by stakeholders. It has caused concerns nationally (as a significant source of conflict between trawl fisheries and other coastal and artisanal fisheries) and internationally (as a potential source of trade-related action – especially concerning the bycatch of turtles). And, as for many other tropical trawl fisheries, these issues are caused by: (i) operating in tropical, richly diverse coastal areas using relatively unselective gear; and (ii) involving vessels with limited hold capacity that only supports the holding of the high value shrimp and a small portion of the bycatch (Kuruvilla et al., 2000).

In terms of the best-practice fishing gears mentioned above, the shrimp trawl fisheries operating in this region already have significant familiarity with TEDs and BRDs as most countries have TEDs mandated for use (although their actual level of use various considerably) and most have trialled (with some success) various square mesh panels as BRDs. Indeed, Guyana recently mandated a BRD (Fig. 2) and Suriname's seabob fishery has had a BRD in place for almost 10 years (Fig. 1).

The seabob fishery in Suriname is worth further discussion because it has, apparently to a large extent, largely resolved its bycatch and discarding issues. This fishery uses a well-designed TED in combination with a well-researched square mesh panel BRD (Fig. 1) to achieve quite low rates of bycatch reduction. Indeed, the 37 % discard rate for this fishery (Meeremans et al., 2017) is of the best recorded for tropical shrimp trawl fisheries in the world (Pérez Roda et al., 2019). And this was recognised by the MSC (one of the world's best assessment systems for sustainable fisheries) when the fishery achieved full certification almost 10 years ago. By way of comparison, a similar tropical penaeid trawl fishery which also has MSC certification is the Australian Northern Prawn Fishery which has much higher discard rates of 57.6% when targeting banana prawns and 79.7% when targeting tiger prawns (Kennelly, 2020).

Clearly the Suriname seabob fishery has achieved significant success in bycatch reduction compared to other shrimp trawl fisheries in the region: Trinidad and Tobago's artisanal and industrial fleets have discard rates of 88.2 % and 81.5 % respectively (Fisheries Division, 2017a); Suriname's non-seabob fishery has a discard rate of 59 % (Meeremans et al. 2017); and Brazil has a rate of 87.3 % (Paiva, et al., 2009). The exception to this is Guyana which recently mandated a similar BRD as that used in Suriname' seabob fishery for all its shrimp trawlers in 2018 (Fig. 2).

So, at first glance, the Suriname seabob fishery appears to provide a logical and local solution to the most pressing fisheries issue in the region. That is, a solution where the same (or similar) TED and BRD design as that used in that fishery could be adopted and implemented in the other shrimp trawl fisheries in the region (as Guyana has done). If this was done successfully, and if the discards from shrimp trawling in the region really are to blame for low catches in other commercial and artisanal fisheries (as noted by stakeholders in FAO, 2013a, b, c and d), then significant improvements in stocks and catches of finfish should become evident in those other fisheries in a relatively short period of time. However, as mentioned previously, unlike the Surname seabob fishery, the use of such a BRD in other shrimp trawl fisheries will have significant consequences for the large (and growing) landing of marketable by-product in such fisheries.

Netting and trapping

Ffishing gears like gillnets, seines and traps are recognised to have less bycatch and discarding problems than shrimp trawls. In addition, because such gears are stationary, interact with fewer organisms and have more localised and fewer impacts with bottom habitats, their ecological impacts on ecosystems and habitats can be expected to be far more benign than is the case for otter trawling (Uhlmann and Broadhurst, 2015; McHugh et al., 2017). In addition, whilst such gears tend to catch (in total) less seafood than trawling, they are recognised to be quite economically efficient as they require far less expense to establish and operate and yield quite high quality product.

As for trawling, there exist a range of best-practice technological options available to ensure that such gears operate as selectively as possible (see Uhlmann and Broadhurst, 2015 for a review). However, a necessary pre-requisite to these modifications is a thorough understanding of the optimal size at first capture for the target species (which is often identified as the size at sexual maturity). Once this is known, a variety of modifications can be considered:

- Simply regulating the size and/or shape of mesh throughout nets to match the target species and sizes can be sufficient to improve selectivity;
- Varying net length, hanging ratios, twine size and material, headline height and panel configuration can also influence the sizes and species caught in seines and gillnets;
- Pingers, reflective structures and LED lights on gillnets can be effective in mitigating the bycatch of marine mammals and turtles but their effectiveness is highly species-specific, they are costly and require tests in local fisheries, diligent application and maintenance;
- For pots (traps), the general design and/or shape, mesh configurations and materials, number of entrances and bait type all strongly affect species and size selectivity;
- Escape gaps for pots (traps) are very common and range from simple openings designed to match the size and shape of unwanted organisms to more novel designs that exploit

differences in behaviour. In many cases, escape gaps are cheap, simple to install and can be made from biodegradable materials to reduce ghost-fishing;
- Choosing less resilient materials in strategic locations/components in nets and pots (traps) can also reduce their ghost-fishing potential if lost; and
- Within-trap depredation can be minimized by choosing appropriate mesh sizes.

Irrespective of the type and extent of technical modifications for seines, gillnets and traps listed above, virtually none will result in 100 % selection for the targeted species and their sizes. That is, despite best efforts, at least some unwanted organisms will still enter nets and traps and be caught and discarded. Consequently, it may be beneficial to consider ways to maximize the chances of survival of organisms after capture via changes to operational and/or post-capture handling techniques (Broadhurst et al. 2006) including:

- Minimizing the deployment durations of nets and traps. In particular, this could be a relatively simple solution to minimize the mortality of turtles caught as bycatch in gillnets;
- Regulating the vertical distribution of gear in the water column to reduce habitat impacts and interactions with marine mammals and turtles whilst also improving species selectivity;
- Sorting catches in water, allowing for recovery prior to release and limiting air exposure should benefit most species;
- Appropriate release methods to minimize barotrauma (e.g. venting and release cages or weights) have been described for recreational hook-and-line fisheries and would have similar applications for net and trap fisheries.
- Also, using bird scarers or chutes to release discards back into the water can address predation mortality.
- Finally, it may be feasible to replace problematic nets and traps entirely with alternative gears such as hook-and-line gears which can result not only in less discarding and fewer habitat impacts, but more marketable catches.

The above list of best practices for gillnets, seines and traps are somewhat aspirational – even for the most developed, well-managed and well-resourced fisheries. Most would therefore probably not be feasible nor appropriate at this time for implementation into the artisanal gillnet, seine and trap fisheries operating in Trinidad and Tobago, Suriname, Guyana and Brazil. Instead, and as a starting point to work towards such best-practices, we suggest that, in this region, studies should be done to determine optimal sizes at capture for key groundfish species (usually the size at first maturity which, for many species, can be relatively easily obtained from FishBase.org). Then, once those critical sizes are determined, experiments are required to identify the best mesh sizes and configurations of nets and traps to achieve this. These then need to be introduced into the fishery and adequately complied with (see the next chapter for a discussion of potential mechanisms to achieve such implementation).

Other issues

In addition to the above issues concerning shrimp trawling, gillnetting, seining and trapping, during this project, a variety of other problems and potential solutions were identified by stakeholders in the four countries examined (listed in previous chapters). These included suggestions for spatial and temporal zoning for various fishing methods to avoid unwanted bycatches, work to reduce habitat damage by fishing gears, the protection of key areas such as nursery grounds for fish, replacing commonly used problematic gears with alternatives, etc. All such concepts have their uses and can lead to significant benefits in terms of resource sustainability. But many of these fall outside the scope of this current project which examines best-practice fishing gears and operations – not spatio/temporal closure strategies. But in any case, we consider that, at this time, such concepts would not achieve the more immediate and far-reaching ecosystem and economic benefits that the relatively simple suggestions made above regarding shrimp trawl BRDs and measures for better net and trap selectivity would realize.

Mechanisms to introduce best practices into fisherfolk communities and capacity building needs

Implementing best practices

Our examination of the available information regarding the fisheries issues in the Guianas-Brazil shelf region shows that a major limiting factor for the use of best-practice fishing techniques has been the rigorous adoption of new techniques followed by sufficient compliance monitoring. That is, as mentioned in the previous chapter, it is clear that most stakeholders in the four countries examined are quite familiar with best-practice modifications like TEDs, BRDs and appropriate mesh sizes, having been involved in many initiatives over the years to develop and trial such things. The main problem is that, except in a few very important cases (such as the Suriname seabob fishery and those shrimp fisheries exporting product to the USA), to a large extent such gears are not being used in routine fishing operations.

Key to getting modified gears routinely used in fisheries involves having sufficient incentive(s) for fishers to do so. That is, unless operators can realize benefits that encourage the use of modifications, they will not use them and the modifications, no matter how effective they are, will have no sustainability value. There exist several incentives that are useful in promoting sustainable fisheries, including approaches that illustrate benefits to local communities, individual harvests and ecosystem services. Such approaches, coupled with research involving fishers themselves, effective monitoring and oversight have been shown to be valuable in improving fishing practices. But one of the most important and commonly used incentives to achieve adoption of best-practice fishing techniques concern financial considerations – in various forms:

Conventional fisheries regulation and compliance

The most commonly used means to incentivize and motivate fishers to use modified fishing gears is via regulation and compliance. The former involves governments implementing laws; the latter involves fisheries officers/inspectors routinely monitoring fishing gear and operations to ensure fishers are obeying such laws. The incentives for fishers to comply are the fines issued for infringements and/or the risk of losing the licence to fish and therefore earn money. This incentive works in most jurisdictions that have sufficient legal and policing resources to ensure adequate levels of compliance. It works less effectively in artisanal fisheries in less-developed countries where such resources are less available, where licences to fish may not exist and where the fish caught are for personal, local and/or community consumption. In such cases, other incentives are required (see below).

Market-based incentives

In the last few decades, we have seen third party certification schemes such as the MSC initiative incentivize the use of best-practice fishing gears and operations. The relevant example in the Guianas-Brazil shelf region is the Suriname seabob fishery where the use of TEDs and BRDs are monitored by the MSC system. The financial incentive associated with such certification resides in having the MSC brand and the increased access to markets that it provides. A similar market-based incentive to incorporate best-practices is also seen in this region through the requirement for shrimp trawl fisheries that export shrimp to the USA to have TEDs installed – which is monitored by US officials regularly.

Operational incentives

Another incentive associated with using best-practice fishing gears that involve the reduction of unwanted bycatches concerns decreased sorting times and handling of catches that the gear (by its very nature) causes. That is, not having to sort fish to be retained versus discarded can lead to substantial cost-savings in labour for commercial fisheries – albeit less so for artisanal fisheries. In addition, and especially for BRDs in shrimp trawls, not having large quantities of fish and other species in codends during tows can lead to improvements in the quality of the target species that are landed and therefore improved prices and additional markets.

Artisanal fisheries

For artisanal fisheries however, where markets do not exist or are very local, money is not as significant a driver of fisheries production as occurs in more developed commercial fisheries. As a consequence, it is a far greater challenge to incentivize artisanal fishers to change methods that often have existed for decades or even centuries. In such cases, one must rely on much more community-based liaison, education, training and learning.

One framework to implement best-practice fishing gears and operations that can be applied in an artisanal context was outlined by Kennelly and Broadhurst (2002). This involves the following staged approach:

1. Identify and quantify the particular problem with existing fishing gears;
2. Identify (from work done elsewhere and from the fishers themselves) potential modifications that resolves the problem;
3. Fishing technologists then test these modifications onboard the fishery's own boats, with the fishers themselves making the solutions practical for their operations;
4. Implement successful modifications into the fishery via
    a. educators and fishing technologists doing talks, videos, articles etc. to the fishers not directly involved in the testing; and

    b. the fishers involved in the testing discussing and showing the modifications to other fishers;
5. Finally, publicize the resolution of the problem as widely as appropriate.

In addition to this implementation framework and of particular relevance to the Guianas-Brazil shelf region is the approach described by Silva et al. (2013) that addresses change in the Brazilian artisanal shrimp trawl fleet. This paper outlines an adaptive co-management framework that involves a learning-by-doing approach (adaptive management) by all stakeholders in the decision-making process (collaborative management). That is, once new best-practice gears and operations are identified, the results are promoted among fisher communities using contributions from experts, appropriate government organisations and fishers. This process includes a cycle comprised of: (1) preparing for learning, (2) learning and (3) evaluating learning. The implementation of changes is therefore continuously evaluated with a learning-by-doing approach, identifying gaps and priorities, creating and disseminating information and evaluating the outcomes.

An important consideration here is that the effective implementation of technological measures is likely to differ depending on whether they involve existing or completely new configurations, entail operational changes and/or whether the affected species is of commercial or charismatic value. That is, fishers may be motivated to conserve juveniles of their target species, but not to protect large predators that compete with their resource, damage their gear or simply are a nuisance. Simple changes within existing configurations, which possibly increase target catches, can be more readily adopted or accepted than unfamiliar configurations and/or changes that are costly to acquire and/or tedious to install and maintain. In addition, however, a critical factor in the medium to longer term is the education of fishers and communities regarding the importance of using sustainable fishing gears – in terms of not only improving access to markets via the conservation of threatened species and reduction of bycatches, but also in terms of the improvement in ecosystems that such practices engender which, ultimately, improves the populations (and catches) of target species.

Capacity building needs

In order to apply the above mechanisms for implementing best-practices in this region, there are a variety of areas where capacity could be improved. In particular:

- Develop appropriate management, legal and regulatory frameworks that facilitate the implementation of best-practice fishing gears;
- Develop effective co-management systems at local, country and regional scales;
- Develop effective Monitoring, Control and Surveillance systems;
- Develop adequate data collection, reporting and assessment systems for catches and bycatches;
- Gain access to, and train-up local, fishing gear technologists to provide expertise in gear development and technological transfer that ideally focusses on low-cost, low-tech measures to reduce bycatches;

- Finally, and most importantly, educators are needed to engage with artisanal fishing communities to provide awareness training in the following areas:
    - best-practice modifications to fishing gears and operations that are appropriate to their particular situations;
    - benefits in increased market access and better quality fish associated with adopting best-practices;
    - environmental benefits associated with new gears in term of habitats, ecosystems and therefore local fisheries production;
    - decreased operational costs associated with bycatch reduction in terms of reduced sorting times, reduced labour costs, better quality fish and improved markets; and
    - if appropriate for their situation, the potential advantages of MSC and/or export certifications.

References

Amos M. (1990). A study of Type III shrimp trawling in the Gulf of Paria. (Advanced Diploma in Resources Management and Environmental Studies). University of the West Indies: Cave Hill, Barbados.

Aragão, J.A.N.; Cintra, I.H.A.; Silva, K.C.A.; Vieira, I.J.A. (2001). A explotação camaroeira na costa Norte do Brasil. Bol. Téc. Cient. CEPNOR, Belém, v.1, n.1, p. 7-40.

Beverton, R. J. H., & Holt, S. J. (1957). On the Dynamics of Exploited Fish Populations. Fishery Investigations, Series II, Ministry of Agriculture and Fisheries. London, UK: Fishery Investigations, Series II, Ministry of Agriculture and Fisheries.

Broadhurst, M.K. (2000). Modifications to reduce by-catch in prawn trawls: A review and framework for development. Rev. Fish Biol. Fish. 10, 27–60. doi: 10.1023/A:1008936820089

Cattani, A.P., C. Bernardo, R.P. Medeiros, L.D. Santos, and H.L. Spach (2012). Bycatch Reduction Device Assessment in the Trawling Fishing from Sea-Bob Shrimp Fishery. Boletim do Instituto de Pesca 38:333-348.

Chan A. Shing C. (1999a). Report on 1998 census of fishing vessels (Trinidad). Fisheries Internal Report, 3. Chaguaramas, Trinidad and Tobago: Fisheries Division, Ministry of Agriculture, Land and Marine Resources

Chan A. Shing C. (2002). Atlas: Marine fisheries of Trinidad and Tobago. Part I: Trinidad Inshore Fisheries. Chaguaramas, Trinidad and Tobago. Fisheries Information Series, 10. Fisheries Division, Ministry of Agriculture, Land and Marine Resources.

CIDA (1994) – Fisheries Background Report (FBR) for the Guyana Fisheries Technical Assistance Project.

Department of Fisheries (2006b) – Fisheries Management Plan 2007-2011 (Draft). Ministry of Agriculture, Department of Fisheries.

Duarte, D.L.V., Broadhurst, M.K. and Dumont, L.F.C. (2019). Challenges in adopting turtle excluder devices (TEDs) in southern Brazil. Mar. Pol. 99, 374–381. doi: 10.1016/j.marpol.2018.10.048

Duarte, D.L.V., Broadhurst, M.K., Ortega, I., Pias, B.S. and Dumont, L.F.C. (2018). Quantifying the morphology of key species caught in the southern Brazilian penaeid fishery as a precursor to improving selection. Lat. Am. J. Fish. Sci. 46(4), 799–809. doi: 10.3856/vol46-issue4-fulltext-17

Eayrs, S. (in prep.) Best practices in bycatch reduction in tropical shrimp-trawl fisheries. FAO, 136pp.

FAO (2013a). Case Study on Shared Stocks of the Shrimp and Groundfish Fishery of the Guianas-Brazil Shelf, Report of the National Consultation in Trinidad and Tobago, Chaguanas, 12 September 2012. CLME Case Study on Shrimp and Groundfish - Report. No. 8, Rome, FAO. 2013. 207pp.

FAO (2013b). Case Study on Shared Stocks of the Shrimp and Groundfish Fishery of the Guianas-Brazil Shelf. Report of the National Consultation in Suriname, Paramaribo, 02-03 August 2012. CLME Case Study on Shrimp and Groundfish - Report. No. 5, Rome, FAO. 2013. 54pp.

FAO (2013c). Case Study on Shared Stocks of the Shrimp and Groundfish Fishery of the Guianas-Brazil Shelf. Report of the National Consultation in Guyana, Georgetown, 18 September 2012. CLME Case Study on Shrimp and Groundfish - Report. No. 7 -, Rome, FAO. 2013. 67pp.

FAO (2013d) Case Study on Shared Stocks of the Shrimp and Groundfish Fishery of the Guianas-Brazil Shelf. Report of the National Consultation in Brazil, Belem, 11-13 September 2012 CLME Case Study on Shrimp and Groundfish - Report. No. 6 -, Rome, FAO. 2013. 57pp.

Ferreira, L. & Soomai, S. (2013). Caribbean Large Marine Ecosystem (CLME) Project - Case Study for the Shared Stocks of the Shrimp and Groundfish Fishery of the Guianas-Brazil Shelf. Ecosystem Approach to Fisheries (EAF) Baseline Report for the Shrimp & Groundfish Fisheries of Trinidad and Tobago. 146pp.

Fisheries Division (2011a). A Draft Fisheries Management Policy for the Republic of Trinidad and Tobago. Port of Spain, Trinidad and Tobago: Fisheries Division, Ministry of Food Production, Land and Marine Affairs.

Fisheries Division (2017a). REBYC-II LAC Trinidad and Tobago REBYC-II Artisanal Trawlers (Type II) Baseline Data. Ministry of Agriculture, Land and Fisheries, Fisheries Division. September 2017. 9pp.

Fisheries Division (2017b). REBYC-II LAC Trinidad and Tobago REBYC-II Industrial Trawlers (Type IV). Baseline Data. Ministry of Agriculture, Land and Fisheries, Fisheries Division. September 2017, 12pp.

Fisheries Regulations (2018). Fisheries Regulations No. 3. The Official Gazette of Guyana (26th May 2018). Published by the Authority of the Government

Hodgkinson-Clarke, F.M. (1994). The construction and operation of artisanal gillnets in Trinidad. Occasional Paper Series No. 3. Chaguaramas, Trinidad and Tobago: Fisheries Division. Ministry of Agriculture, Land and Marine Resources.

Kennelly, S.J. and Broadhurst, M.K. (2002). Bycatch begone: changes in the philosophy of fishing technology. Fish and Fisheries, Vol. 3, 340-355.

Kennelly SJ (2020) Bycatch beknown: Methodology for jurisdictional reporting of fisheries discards - Using Australia as a case study. Fish Fish. 21:1046–1066. https://doi.org/10.1111/faf.12494

Kuruvilla S. & Chan A Shing. (2002). Globalization, international trade and marine fisheries: Case study of the trawl fishery in Trinidad and Tobago. Chaguaramas, Trinidad and Tobago: Fisheries Division, Ministry of Agriculture, Land and Marine Resources.

Kuruvilla, S, Ferreira, L. and Soomai. S. (2000). The Trawl Fishery of Trinidad and Tobago. Fisheries Information Series 9. Port-of Spain, Trinidad and Tobago: Fisheries Division: Ministry of Agriculture, Land and Marine Resources.

Kuruvilla, S., Ferreira, L. and Soomai, S. (2001). National Report of Trinidad and Tobago. In Tropical shrimp fisheries and their impact on living resources. Shrimp fisheries in Asia: Bangladesh, Indonesia and the Philippines; in the Near East: Bahrain and Iran; in Africa: Cameroon, Nigeria and the United Republic of Tanzania; in Latin America: Colombia, Costa Rica, Cuba, Trinidad and Tobago, and Venezuela. FAO Fisheries Circular, 94. Rome: FAO.

LVV and FAO (2016). Strategy for the reduction of unsustainable bycatch in Suriname's bottom trawl fisheries through the use of Turtle Excluder Devices (TEDs) and Bycatch Reduction Devices (BRDs). REBYC-II LAC – Suriname. 43pp.

LVV Fisheries Department (2010). Visserij management plan voor Suriname: de seabobgarnalen (*Xiphopenaeus kroyeri*) visserij. Ministerie van landbouw, veeteelt en visserij (LVV) Suriname, Onderdirectoraat Visserij, Februari 2010.

LVV Fisheries Department (2013). Visserij Management Plan voor Suriname 2014 - 2018. LVV Onderdirectoraat Visserij, 27 juni 2013.

Maharaj, V. (1989).The bycatch in the artisanal shrimp trawl fishery, Gulf of Paria, Trinidad. (Unpublished Master thesis): University of Rhode Island, Kingston, R.I., U.S.A.

Maharaj, L., Ferreira, L., & Lum Young, P. (1993). Description of the shrimp trawl fishery of Trinidad. Technical Report of FAO/UNDP: TRI/91/001/TR9 "Establishment of Data Collection Systems and Assessment of the Fisheries Resources". Port-of-Spain, Trinidad and Tobago: Ministry of Agriculture, Land and Marine Resources.

McHugh M.J., Broadhurst, M.K. and D.J. Sterling (2017). Choosing anterior-gear modifications to reduce the global environmental impacts of penaeid trawls. Rev Fish Biol Fisheries 27:111–134

Meeremans, P., Babb-Echteld, Y and T. Willems (2017). Sustainable Management of Bycatch in Latin America and Caribbean Trawl Fisheries. REBYC-II LAC – SURINAME. Bycatch and discards in Suriname trawl fisheries (2012 – 2017): a baseline study. December 2017, 64pp.

Meschkat, A. (1960). Report to the Government of Brazil on the Fisheries of the Amazon Region. Rome, FAO/TA Fisheries Officer- Report No. 1305. 94pp.

Mohammed, E., Ferreira, L., Soomai, S., Martin, L., & Chan A. Shing, C. (2011). Coastal fisheries of Trinidad and Tobago.In Salas, S., Chuenpagdee, R., Charles, A., and Seijo, J.C. (Eds). Coastal fisheries of Latin America and the Caribbean. FAO Fisheries and Aquaculture Technical Paper, 544, 315-356. Rome: FAO.

Ortiz, N., J.C. Mangel, Wang, J., Alfaro-Shigueto, J., Pingo, S., Jimenez, A., Suarez, T., Swimmer, Y., Carvalho, F. and B.J. Godley (2016). Reducing green turtle bycatch in small-scale fisheries using illuminated gillnets: the cost of saving a sea turtle. Mar Ecol Prog Ser, 545: 251–259, doi: 10.3354/meps11610.

Paiva, K. S.; Aragão, J. A. N.; Silva, K. C. A.; Cintra, I. H. A. (2009). Fauna acompanhante da pesca industrial do camarão-rosa na plataforma continental norte brasileira. Bol. Téc. Cient. CEPNOR, Belém, v. 9.

Pérez Roda MA, Gilman E, Huntington T, Kennelly SJ, Suuronen P, Chaloupka M., Medley P (2019) A third assessment of global marine fisheries discards. FAO Fisheries and Aquaculture Technical Paper No. 633, FAO, Rome, 78pp.

Polet, H., Delanghe, F., Depestele, J., Stouten, H., Van Craeynest, K., Vanderperren, E., Vanhee, J., Verhaeghe, D., and Verschueren, B. (2010). Evaluation of Bycatch Reduction Device (BRD) in Surinam Seabob fishery (*Xiphopenaeus kroyeri*). ILVO Instituut voor Landbouw- en Visserijonderzoek.

Silva, C.N.S., Broadhurst, M.K., Dias J.H., Cattani, A.P. and Spach, H.L. (2012). The effects of Nordmøre-grid bar spacings on catches in a Brazilian artisanal shrimp fishery. Fish. Res. 127–128: 188–193. doi: 10.1016/j.fishres.2012.01.004

Silva, C.N.S., Broadhurst, M.K., Schwingel, A., Dias J.H., Cattani, A.P. and Spach, H.L. (2011). Refining a Nordmøre-grid for a Brazilian artisanal penaied-trawl fishery. Fish. Res. 109: 168–178. doi: 10.1016/j.fishres.2011.01.035.

Silva, C.N.S., Broadhurst, M.K., Medeiros, R.P. and Dias, J.H. 2013. Resolving environmental issues in the southern Brazilian artisanal penaeid-trawl fishery through adaptive co-management. Mar. Policy 42: 133–141. doi: 10.1016/j.marpol.2013.02.002

Soomai, S. (2007). Report of Gear Trials conducted by the Fisheries Division, Ministry of Agriculture, Land and Marine Resources (MALMR) in collaboration with the National Fisheries Institute (INP), Mexico, May 21 – 31, 2007. Project EP/GLO/201/GEF "Reduction of Environmental Impact from Tropical Shrimp Trawling, through the Implementation of Bycatch Reduction Technologies and Change of Management". Port of Spain, Trinidad and Tobago: Fisheries Division, Ministry of Agriculture, Land and Marine Resources.

Soomai, S. (2008a). Report of Trawl Gear Trials, 4 October – 28 November, 2007. Project EP/GLO/201/GEF “Reduction of Environmental Impact from Tropical Shrimp Trawling, through the Implementation of Bycatch Reduction Technologies and Change of Management”. Port of Spain, Trinidad and Tobago: Fisheries Division, Ministry of Agriculture, Land and Marine Resources.

Soomai, S. (2008b). Trinidad and Tobago. National Coordinator’s Report. In Report of the ICES/FAO Working Group on Fish Technology and Fish Behaviour (WGFTFB), 21-25 April 2008, Tórshavn, Faroe Islands. ICES CM 2008/FTC:02

Soomai, S. & Seefoo, A. (2006). Report of gear trials conducted by the Fisheries Division, Ministry of Agriculture, Land and Marine Resources (MALMR) in collaboration with the National Fisheries Institute (INP), Mexico, November 12 – 25, 2006. Project EP/GLO/201/GEF “Reduction of Environmental Impact from Tropical Shrimp Trawling, through the Implementation of Bycatch Reduction Technologies and Change of Management”. Port of Spain, Trinidad and Tobago: Fisheries Division, Ministry of Agriculture, Land and Marine Resources.

Southall, T., Pfeiffer, N., and Sing-Renton S. (2011). MSC Sustainable Fisheries Certification of Suriname Atlantic Seabob shrimp: Public Certification Report. 2011. Food Certification International Ltd.

Uhlmann, S.S. and Broadhurst, M.K. (2015). Mitigating unaccounted fishing mortality from gillnets and Traps. Fish Fish, 16, 183–229

Wang, J.H., S. Fisler and Y. Swimmer (2010). Developing visual deterrents to reduce sea turtle bycatch in gill net fisheries. Mar. Ecol. Prog. Ser 408:241-250. DOI: https://doi.org/10.3354/meps08577