08 October 2016

Report of the

Workshop on use of best available science in developing and promoting best practices for trawl fishing operations in Latin America

Cartagena, Colombia, 14-18 April 2016

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ABSTRACT

One of the most contentious issues in management of marine fisheries is the use of mobile bottom contact gears, trawls and dredges. There are growing concerns about the overall ecosystem impacts of bottom trawling. Some countries have banned bottom trawling and some major retailers refuse to stock fish caught using bottom trawl gears. However, such decisions are not always based on the best available scientific advice.

The initiative "Finding common ground on the scientific knowledge regarding best practices in trawling (TBP)" is an international collaboration of leaders in the scientific community to understand how trawling and other forms of towed bottom fishing gears interact with marine seabed habitats and their biota. An analysis of the datasets to which the project has had access has revealed an underrepresentation of fisheries from Latin America which is one of the most important areas of the world in terms of the amount of trawl fishing that occurs. These trawl fisheries contribute to the alleviation of poverty through the provision of food and livelihoods for many people. Therefore, it was considered important to attempt to address this data gap and to engage with stakeholders and science users in the Latin American region to raise awareness about potential best practice for trawling.

The TBP project, in close collaboration with FAO and the REBYC-II LAC project, conducted in April 2016 in Cartagena, Colombia, a workshop on use of best available science in developing and promoting best practices for trawl fishing operations in Latin America. Potential research institutions, universities, organizations and individual experts involved in the data collection and research work dealing with the assessment and/or management of ecosystem impacts of bottom trawl fishing in Latin America were invited to the workshop.

The workshop (i) summarized the progress done in the five phases of the project, (ii) identified what data are available on the spatial distribution of trawl fishing activities, where it is found, who are involved in generating these data as well as gaps in knowledge in Latin America region; (iii) evaluated the availability and applicability of data on habitats, bycatch and ecosystem impacts of bottom trawl fishing in the Latin America region; (iv) begin to assemble the data on trawl intensity in representative Latin American ecosystems; and (v) developed an arrangement for sharing expertise and data, and continuing the collaboration to develop best practices for trawling to enhance sustainability of food security and livelihoods and marine ecosystems in Latin American trawl fisheries.

The workshop served as an excellent first step in building collaboration with a network of global trawl fishing scientists. The collaborations identified should lead to a significant advance in our understanding of how to best manage Latin American trawl fisheries.

1. Background

One of the most contentious issues in management of marine fisheries is the use of mobile bottom contact gears, trawls and dredges. Some 25% of world fish catch comes from the use of these gears and catch from trawls is an important element in food security in much of the world. There are growing concerns about the overall ecosystem impacts of bottom trawling. Some countries have banned bottom trawling and some major retailers refuse to stock fish caught using bottom trawl gears. However, such decisions are not always based on the best available scientific advice.

Much of the scientific information available comes from fisheries in temperate waters whereas decisions on banning trawl fisheries in recent years have largely been associated with tropical coastal fisheries where there is a paucity of data. As a consequence, there is an urgent need for a global synthesis of the scientific knowledge related to the issue, including also tropical and sub-tropical trawl fisheries. The key questions are: (i) how does trawling affect the long-term sustainable yield of aquatic resources from an ecosystem, and (ii) how does trawling affect other ecosystem services.

The initiative "Finding common ground on the scientific knowledge regarding best practices in trawling (TBP)" is an international collaboration of leaders in the scientific community to understand how trawling and other forms of towed bottom fishing gears interact with marine seabed habitats and their biota. The initiative (later called the "project") is led by professors Ray Hilborn (University of Washington), Mike Kaiser (Bangor University) and Simon Jennings (University of East Anglia), and is currently funded with contributions from the Walton and Packard Foundations, fishing industries and FAO (project website: http://trawlingpractices.wordpress.com).

The project is bringing together global datasets on the spatial distribution of trawl fishing activities and the impact of trawling on marine ecosystems and productivity. The project uses this information to understand the extent and consequence of trawling at a global scale and on a region by region basis for those regions for which we can obtain data. The ultimate goal is to identify a range of suitable "best practices" for trawling and determine the consequences of adoption of these practices on biota, sustainable food production, ecosystems and ecosystem services.

2. Rationale for the workshop

An analysis of the datasets to which the project has had access reveals an underrepresentation of fisheries from Latin America, which is one of the most important areas of the world in terms of the amount of trawl fishing that occurs. These trawl fisheries contribute to the alleviation of poverty through the provision of food and livelihoods for many people. It was considered important to attempt to address this data gap and to engage with stakeholders and science users in the Latin American region to raise awareness about potential best practice for trawling.

To expand the representation of Latin American trawl fisheries in the global analysis, the TBP project conducted in close collaboration with FAO and the REBYC-II LAC Project a workshop with the following title: "**Workshop on use of best available science in developing and promoting best practices for trawl fishing operations in Latin America**". Potential research institutions, universities, organizations and individual experts involved in the data collection and research work dealing with the assessment and/or management of ecosystem impacts of bottom trawl fishing in Latin America were, when applicable, invited to the workshop.

3. The objectives of the workshop

The key objectives of the workshop were:

(i) Reviewing the progress in Phases I-V in TBP project and planning the meeting with the Latin American partners;

(ii) Identification of what data are available on the spatial distribution of trawl fishing activities, where it is found, who are involved in generating these data as well as gaps in knowledge in Latin America region;

(iii) Evaluation of the availability and applicability of data on habitats, bycatch and ecosystem impacts of bottom trawl fishing in the Latin America region;

(iv) Assemble the data on trawl intensity in representative Latin American ecosystems;

(v) Development of a collaborative arrangement for sharing expertise and data; and

(vi) Evaluation of best practices for trawling to enhance sustainability of food security and livelihoods and marine ecosystems in Latin American trawl fisheries.

4. Venue and workshop arrangements

The workshop was convened on 14 – 18 April 2016 at the Santa Clara Hotel in Cartagena, Colombia, ensuring adequate participation from the Latin American region. In total, 23 experts participated in the workshop. The workshop ran in two parts. The first two and half days (**Part I**) the project assessed the progress made in Phase I-V and planned the coming meeting with the Latin American experts. During the last two and half days (**Part II**) the focus was on Latin America trawl fisheries.

In the preparation of the workshop programme and in the identification of participants, the workshop organizers liaised closely with the FAO facilitated regional fisheries projects in the Latin America and in particular with the FAO-GEF REBYC-II LAC project (Sustainable management of bycatch in Latin America and Caribbean trawl fisheries).

Annex 1 of this report contains the summaries of the presentations of the Latin American experts.

PowerPoint Presentation are available at:
https://drive.google.com/folderview?id=0B7fh1E9kN63oel9fUzRZQlhpTFE&usp=sharing

The list of participants is provided in Annex 2.

5. Agenda and timeframe

Day 1: Thursday April 14 - Trawling Best Practices (TBP) Group

Welcome/ project update

Status Report TBP Phase I: footprint of trawling (Ricardo Amaroso, Simon Jennings)

Status Report TBP Phase II: impacts on biota (Mike Kaiser, Jan Hiddink)

Status Report TBP Phase III: risk analysis and update on habitat data collation (Roland Pitcher, Bob McConnaughey)

Status Report TBP Phase IV: food web effects of trawling (Adriaan Rijnsdorp)

Status Report TBP Phase V: best practices (Bob McConnaughey, Ray Hilborn)

Publication strategy and funding strategy for TBP

Day 2: Friday April 15 - Trawling Best Practices (TBP) Group

Plenary discussion of TBP Phase V and project summary paper

Small group meetings around each of the papers in draft

TBP Phase I: footprint of trawling (leads Ricardo Amaroso, Simon Jennings)

TBP Phase II: impacts on biota (leads Mike Kaiser, Jan Hiddink)

TBP Phase III: risk analysis (lead Roland Pitcher)

Day 3: Saturday April 16 - Trawling Best Practices (TBP) Group

AM: Wrap up TBP Group; next actions, responsibilities

PM: Beginning of meeting with Latin American Scientists and TBP Group

Welcome address from Mr. Francisco Arias, Director of Instituto de Investigaciones Marinas (INVEMAR)

Welcome address from AUNAP (Autoridad Nacional de Acuicultura y Pesca)

Welcome addresses and introductions of Latin American colleagues

Review TBP approach and key results (Ray Hilborn)

Day 4: Sunday April 17

Presentations of Latin American situation (see presentation abstracts in Annex 2 and table below).

- Each Latin American participant made a presentation about what is known regarding trawl fisheries and their impacts on benthic biota in their area of knowledge.

Day 5: Monday April 18

Define collaboration opportunities between TBP group and Latin American colleagues.

Identification of issues in Latin America.

Identification of programs and opportunities for collaboration.

Part I

Summary of the progress done in Phases I-V

Phase I: Trawl Footprint

The first phase is examining the distribution and intensity of trawling, compiling satellite Vessel Monitoring System (VMS) data and tow by tow position records.

Distributions of trawling effort were traditionally reported for regions of several hundred km^2 and larger; because similarly coarse scales were used for data collection and recording. Consequently, effort mapped at these scales provided a misleading picture of the small-scale spatial distribution, since frequently trawled areas were aggregated with unfished areas. Latterly, local and regional studies gave a higher resolution view of activity from positions in vessel logbooks, analyses of plotter data, and analyses of overflight data of VMS. The TBP project is focusing on the analysis of high resolution data because these provide a more accurate indication of the trawling footprint than data collected at coarser resolution.

An increasing number of regional analyses now describe trawling footprints based on VMS or high resolution tow by tow observer and logbook data. In regions where such analyses are available they often suggest that the footprint of trawling can be relatively small in relation to the potential fishing area and that effort is often highly concentrated in a few trawling hot spots. However, systematic comparisons among trawl fisheries in different regions will indicate the extent to which the aggregation of effort is a consistent feature of diverse trawl fisheries and how patterns and footprints of trawling are linked to overall catch and effort in the fisheries.

In the TBP project we have collated and analyzed VMS data for shelf seas in North and South America, Africa, Europe and Australasia to compare the high-resolution footprints and distribution of trawl and dredge fishing activity on an unprecedented scale. These data have allowed us to assess the effects of resolution on estimates of trawl footprint area and to describe trawling footprints expressed as the swept area ratio (area swept by gear per unit area per unit time). The descriptions of footprint will be linked to descriptions of the seabed habitat (collated in Phase 1) and the sensitivity of the habitats and associated fauna (from Phase 2) to conduct the risk assessment of trawling impacts (Phase 3). We have obtained habitat data from the University of Colorado, which maintains a global database of seabed samples. Areas for which trawling activity data are currently processed or available are shown in Figure 1 and an example of one high resolution map of trawling activity, expressed as swept area ratio, is provided in Figure 2.

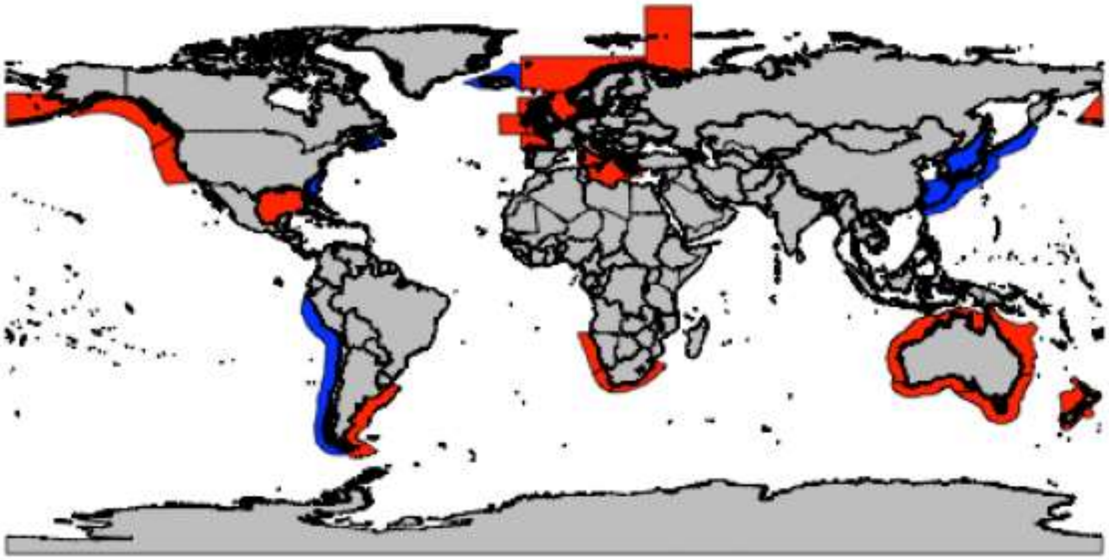

Figure 1. Trawling Best Practice regions where high-resolution trawling effort data are in hand (red) or being processed (blue).

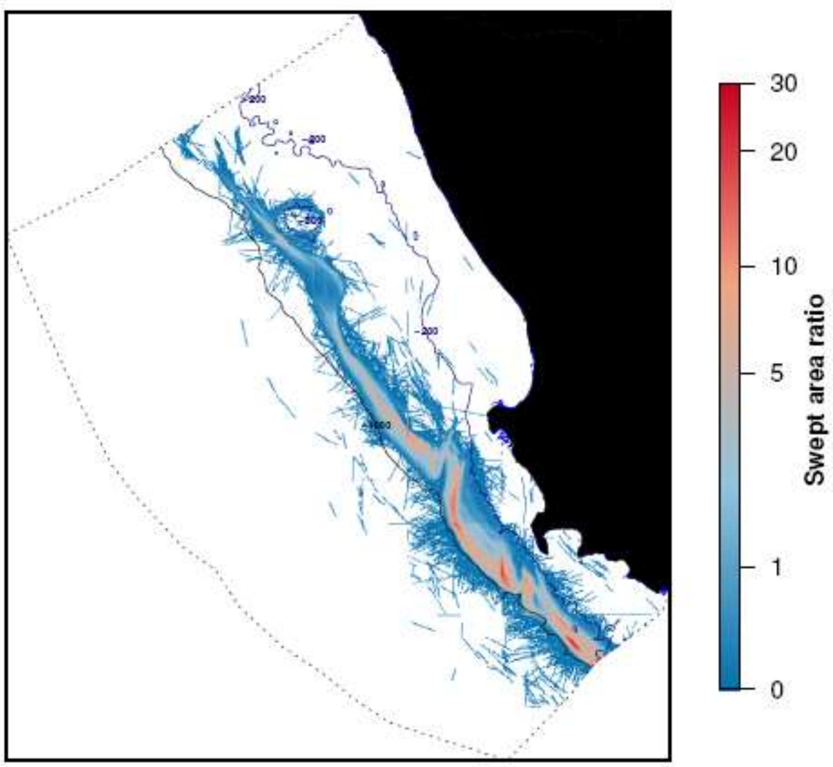

Figure 2. Distribution of bottom fishing activity in the South Benguela Current. Depth contours indicate 200 m and 1000 m.

It is essential to analyze data at a high resolution to provide an accurate representation of the trawling footprint. This is effectively illustrated when the TBP data are gridded at different scales (Figure 3). Most of the TBP analyses described hereafter were conducted using 1 km^2 grid cells, although slightly larger c-squares defined by equal increments of latitude were used in some analyses. These c-squares will reduce in area towards the poles.

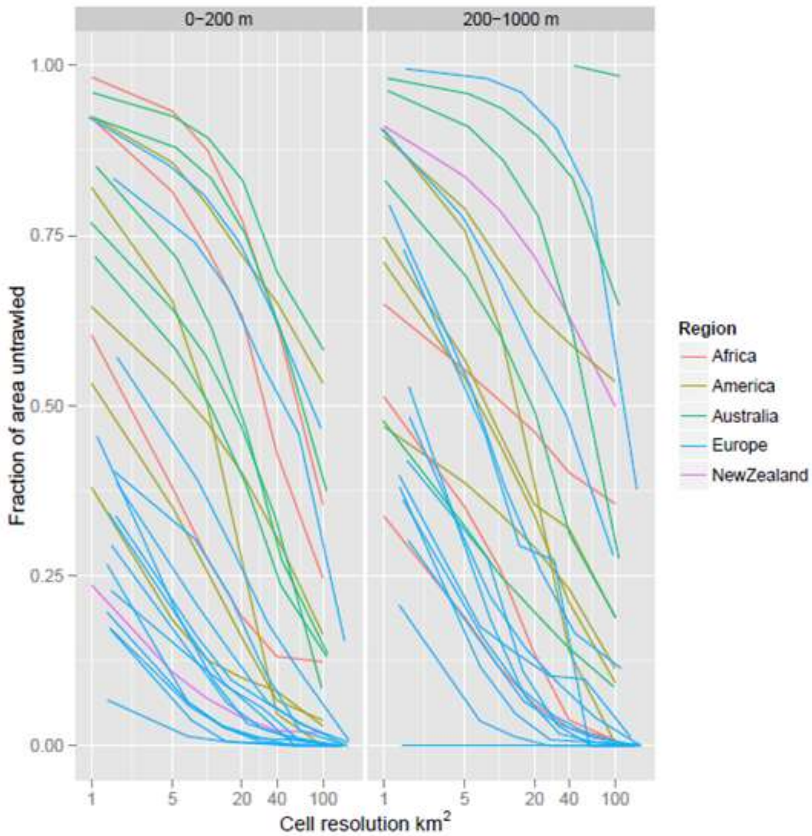

Figure 3. Estimates of the fraction of the 0-200m and 200-1000m depth bands that are untrawled as the resolution of analysis is increased. Untrawled area is estimated as the proportion of grid cells where no trawling was recorded.

The estimates of swept area ratio by grid cell can be used to estimate the proportion of a region that is untrawled and trawled with different frequencies. The untrawled area comprises grid cells that have never been trawled in the period of analysis (typically 2008-2010, with mean swept area ratios presented) as well as areas within the grid cells that are not trawled because trawling intensity is aggregated. In the TBP project, estimates of swept area have been made using both approaches, for example for the East Bering Sea (Figure 4). Similar plots have now been produced for many of the other TBP regions (Figure 5). Results show that in more than half the TBP regions over 60% of the seabed is unimpacted by direct trawl impacts. In northern Europe and the Mediterranean, however, unfished areas tend to be smaller and more than 10% of the area may be fished more than twice each year.

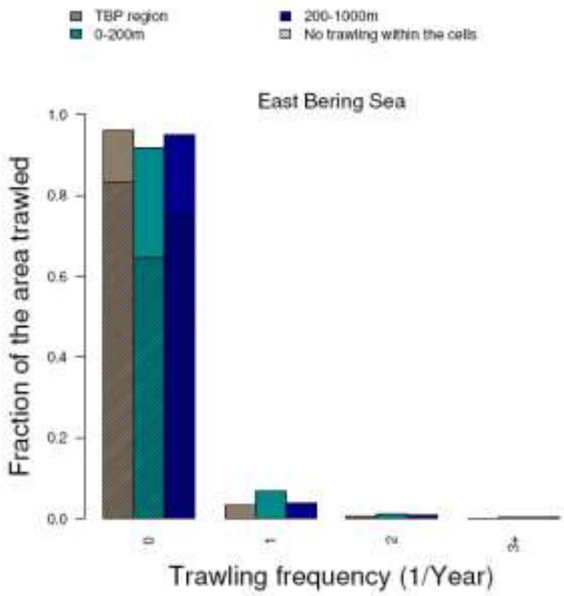

Figure 4. Fraction of the area untrawled and trawled at different frequencies within the entire TBP region and within depth ranges 0-200m and 200-1000m in the East Bering Sea. The shaded bars represent the untrawled areas comprising grid cells that are completely unfished in the study period.

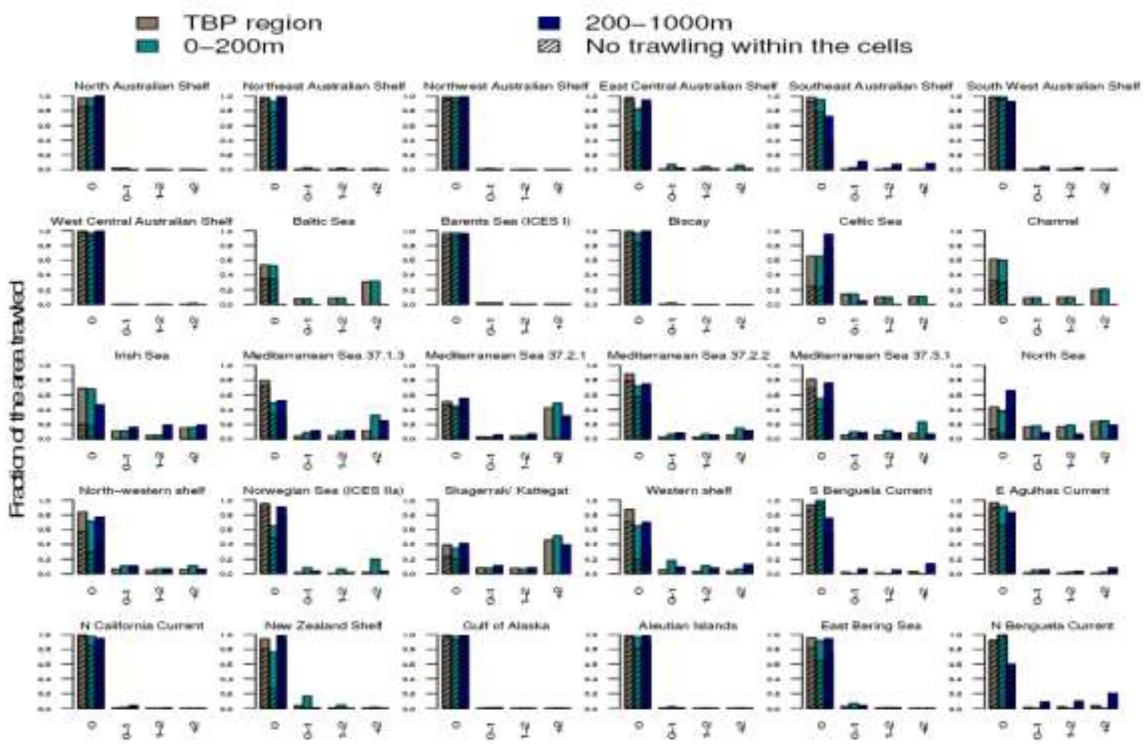

Figure 5. Fraction of the area untrawled and trawled at different frequencies within the entire TBP region and within depth ranges 0-200m and 200-1000m. The shaded bars represent the untrawled areas comprising grid cells that are completely unfished in the study period.

The project is currently estimating the coverage of trawling effort or catch that is accounted for in the VMS or tow by tow data, but initial analyses suggest that the TBP project has good coverage of the offshore trawl fleets in relation to total catch or effort in most regions. For instance: Bering Sea effort data represent 97.6%, 96.5%, 98.5% of total catch in 2008, 2009, 2010.

Phase II: Direct effects of commercial trawling on seabed communities

To understand the sustainability of fishing practices it is necessary to understand their wider ecosystem effects in addition to direct effects on target species. The overall effects of trawling result from the intensity of trawling, the mortality caused by each trawl pass, and the rate of recovery. The rate of recovery depends on the growth of surviving biota, the rate of recruitment of juveniles and the immigration of adults. Previous meta-analyses of fishing impacts on the seabed relied largely on the outcome of experimental studies (Collie *et al.* 2000; Kaiser *et al.*, 2006). While these studies have provided important insights into the instantaneous mortality of benthic biota in response to direct physical contact with fishing gear, the relatively small scale at which these experiments are undertaken most likely leads to an underestimate of the time taken for post-fishing recovery to occur because immigration from unfished areas is likely to be larger and quicker than in real fisheries.

The present study arose from an international collaboration that is the first attempt to quantify the effects of bottom trawling on abundance, biomass, species richness and diversity of benthic ecosystems using meta-analysis of data derived from large-scale comparative studies of commercial fishing activities. We employed systematic review methodology (Pullin & Stewart, 2006) to ensure appropriate rigour and to avoid selection bias when constructing our database. Our study is limited to studies on the continental shelf from which 90% of global fish landings are derived.

Methods

This study collated data from published bottom-trawling impact studies that were identified following a systematic review protocol (Hughes *et al.*, 2014) and analyzed the extracted data using a meta-analysis. ‘Bottom trawling’ is defined here to include any towed bottom gear, including otter trawls, beam trawls, scallop dredges and hydraulic dredges. It excludes gears like gill-nets, long-lines, pots and creels.

In this study we only report on the effects of real, large-scale commercial trawling activities (also called ‘comparative studies’ here). The effect of small-scale experimental studies, where scientists experimentally manipulate a small area of the seabed by trawling (usually $<<1km^2$) and examine the effect on the benthic community, will be reported elsewhere.

Fishing frequency for gradient studies

The analysis of gradient studies required the formulation of a common fishing effort scale to allow comparison between different studies, and here we use the trawling frequency (y^{-1}), which is the same as the swept area ratio ($km^2\ km^{-2}\ y^{-1}$). Trawling frequency expresses how often each m^2 is fished in a year, and is calculated by dividing the area fished in a year by the area of a defined area (cell). The area fished is usually calculated using logbook or vessel monitoring system (VMS) data, using the number of hours fishing multiplied by the fishing speed and the width of the fishing gear. About half the gradient studies reported trawling frequency in the paper, for the other gradient studies trawling frequency was calculated based on the reported fishing effort. Where trawling frequency could not be calculated, a study was not included in the analysis of gradient studies, but may have been included in the analysis of Control-Impact studies.

Classification of habitats and gears

The main gear types used in the trawled areas were extracted from the sources, and classified into four categories: otter trawls (OT), beam trawls (BT), towed dredges (TD) and hydraulic dredges (HD). In two study areas, fishing occurred by an even combination of two gears (BT/OT and TD/OT). In the case of these studies, the gear assigned was the gear that was assumed to have the strongest ecological effect based on previous work (BT and TD respectively, Kaiser *et al.*, 2006), but we note that this may potentially lead to an underestimate of the effect of those gears. The main habitat types in the trawled areas were extracted from the sources, and classified into five categories: biogenic habitats, gravel, sand, muddy sand/sandy mud, and mud. Biogenic habitats include mussel beds, seagrass beds and limestone reefs with a cover of sponges and gorgonians.

Results and Discussion

This is the first study to quantify the effects of real, large-scale, chronic bottom trawling activities on benthic ecosystems by synthesizing all available evidence. All studies were conducted on fishing grounds, and therefore the overall effects that we detected are representative of the typical effects of trawling in commercial fisheries. Commercially trawled areas on continental shelves are characterized by ‘hotspots’ of fishing in which the trawling frequency is in the range of 1 to 5 y^{-1} and extensive areas in which there is either no fishing or where the trawling frequency is below 0.25 y^{-1} (Jennings *et al.*, 2012). Overall, such intensities of trawling caused declines of up to 26% in abundance, biomass and species richness, while no effect of trawling on Shannon-Wiener diversity (H’) was found. Effects on total community abundance and biomass were stronger for gears such as dredges that penetrate the sediment more deeply, and weaker or absent in areas where a higher primary production results in a higher recovery potential and otter trawls were used.

The effects of the gradient studies and the control-impact studies were in broad agreement. The effects of trawling on total community abundance and biomass were stronger than the effects on the abundance and biomass of individual taxa. In a community, there will always be a variety of responses to trawling because the mortality and recovery rates will vary between species (Figure 6), and in addition to this some species may benefit from a release from competition when large long-lived animals are killed by a trawl. If the species that increase in abundance are smaller and/or less abundant that the species that decline (which is often the case as species that increase tend to be small, opportunistic and rare in undisturbed communities, Tillin *et al.*, 2006), the effect of trawling on whole communities will be larger than the mean effect on individual taxa.

Surprisingly, we did not find significant effects of gear type and habitats on the impact of trawling, although effects on biogenic habitats seemed stronger and effects of OT less. This is likely to be a combination of a lack of replicates once studies were divided into different factor levels, and a large remaining variation that is related to classifying gears and habitats into a few groups only while many other explanatory variables were not included.

Our expectation was that the recovery from large-scale commercial trawling activities would be slower than recovery from small-scale experimental trawling. Based on the results of the gradient studies, we estimate that recovery of community biomass to 95% of unfished levels takes between 2.2 years and 0.7 years for community abundance. This does not mean that the community has recovered to the same species, size and age composition that it had before trawling started, but it does mean that the ecosystem processes that are related to biomass or abundance such as secondary production will have largely recovered. These estimates are lower than empirical recovery estimates of community biomass from three areas were commercial trawling was stopped (4-5 years, Hiddink *et al.*, 2006a), but higher than estimates from experimental studies, which are in the order of 25-200 days (Kaiser *et al.*, 2006).

Conclusions and Implications

The effects of bottom trawling detected here are quite modest, unless areas are trawled at very high frequencies. This means that either the fraction of animals killed by a trawl is low or that the recovery from trawling is fast, or both. These results show that the impacts of trawling can be reduced by redirecting fishing to areas that recover more quickly and by developing or switching to gears that do not penetrate so far into the seabed where possible.

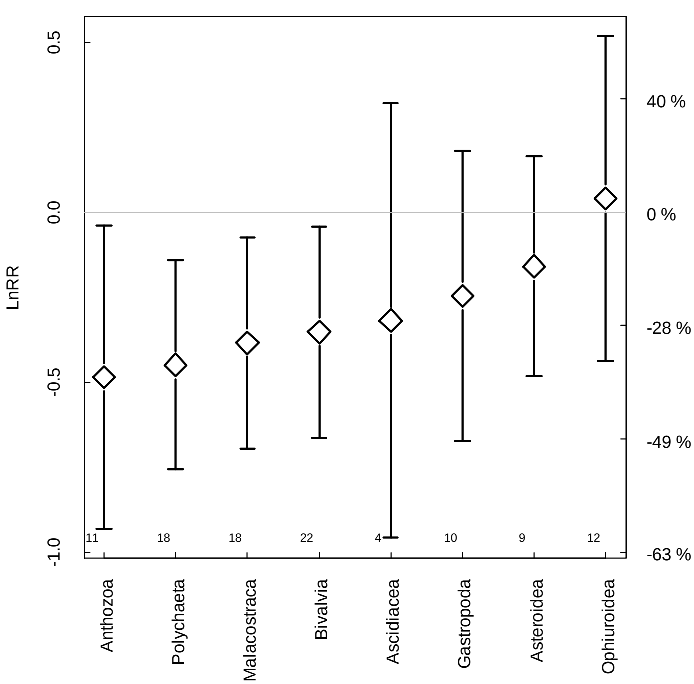

Figure 6. Effect on trawling on abundance and biomass of different classes of fauna. The number of studies reporting on each taxon (N) is given under each bar. (Analysis produced by Jan Geert Hiddink).

PHASE III: RISK ANALYSIS

Phase III will conduct a risk analysis of the impacts of trawling on sedimentary habitats, for regions and fisheries where adequate data are available from Phases I & II. The analysis will be a spatially explicit landscape-scale assessment of habitat status relative to an untrawled context. At the 2nd meeting in November 2013, a worked example was presented for a regional-scale trawl fishery in Australia. This example remains confidential, but another illustrative example for a large bay was prepared and provided as Appendix 2 in the November 2013 meeting report (http://trawlingpractices.files.wordpress.com/2014/01/trawl-second-meeting-report.pdf). This example is submitted for publication.

The Phase III risk analysis has critical inputs from Phases I & II, as follows:

Phase I:

1. The spatial maps of trawl effort intensity
2. The spatial maps of sedimentary habitats

Phase II:

3. The impact rates per trawl pass for different sedimentary habitats
4. The recovery rates after trawling for different sedimentary habitats

These data from Phases I and II will be combined in a simple model, based on a simplification of a type used for fisheries stock assessments, to estimate the expected long-term status of each sedimentary habitat type. This will be a relative assessment at the habitat level, essentially aggregating across all fauna that typify each habitat type, to be applied at the widest possible spatial scale. The relative status of habitats can be mapped or presented in a summarized form, e.g., in cases analyzed to date, sedimentary habitat status has typically been >90% at landscape scales, compared with status without fishing.

Phase III will be the major synthesis of the trawl footprint and impact on habitats and will let us calculate for each region (where we have data) how much each habitat has been reduced and what its current estimated status is (see example below). Phase III is critically dependent on Phases I and II, hence further progress is waiting on completion of outputs from these pre-requisite phases. To date, most work has been directed at contributing to the collation of necessary data and development of methods. Previous meetings of the Trawl Study Committee have reviewed examples of the risk analysis methods and agreed on methods of presenting the outputs that will avoid confidentiality issues associated with many trawl effort datasets.

The Project will now be able to extend the risk assessments down to the faunal level as we have been successful in obtaining funding from CSIRO for an Office of the Chief Executive Post-Doctoral Fellowship (OCE PDF), and recruitment of another post-doc was completed by September 2014. The OCE PDF will extend the risk analysis from sedimentary habitats to benthic invertebrate communities. To date, multiple datasets for benthic invertebrate surveys and of environmental predictor variables have been collated, and methods for predicting benthos distributions and conducting status assessments for invertebrate groups have been developed. This extension of the TBP Project will estimate the expected long-term absolute abundance status of benthic invertebrate groups, integrated across sediment types, at landscape scales. It is anticipated that this more detailed analysis will be possible only for regional case studies where suitable benthic invertebrate survey data are available. A key enabling activity of the TBP Project is identifying suitable and available benthic survey data sets for this extension of Phase III.

Example Faunal Level Status Assessment

This assessment extends the habitat level assessment, to understand the risks of trawling on invertebrate faunal groups. The taxonomic level of the assessment will depend on outputs from Phase II (class level is expected), and case study regions will depend on high resolution trawl effort and sediment data from Phase I — and both will depend on the availability of benthic invertebrate survey datasets.

Within any given taxonomic class of benthic invertebrates, it is likely that different types of species will have different habitat preferences and different distributions. Thus, different species within a given class may have different levels of exposure to trawl effort even if their depletion and recovery rates are similar. For this reason, statistical methods for grouping species have been developed, based on the similarity of their responses to environmental variables. Once grouped, methods for modelling and predicting the distribution of these groups have been developed using random forests. The methods enable inclusion of multiple gear types (e.g. sampling of benthic fauna from multiple devices e.g. trawl and sled), and data from multiple data sets that are disparate in space and time. The resulting invertebrate 'group' distribution model can aim to predict either the 'pristine' abundance of the group, by extracting out the effect of trawling, or predict the current distribution.

Following the method of the sedimentary habitat level assessment, the risk status of the group is calculated, which represents the estimated equilibrium population status assuming the current level of trawl intensity is applied indefinitely. Given that distributions are available, the faunal group status is an absolute estimate (unlike sedimentary habitats, which are relative). Figure 7 below is an illustration that highlights the importance of grouping species according to their habitat preference before estimating their risk status. The species distribution models evidently represent two types of bivalve species, an inshore group (Group 1) and offshore group (Group 2). Given their different distributions they encounter different exposure to trawling (higher inshore). Although, a relatively high status was estimated for both groups, Bivalves group 1 (status ~ 91%) has a ~50x higher impact due to trawling (~9% impact) than Bivalves group 2 (status > 99%; impact < 0.2%). The impact maps below represent the distribution of the absolute biomass of each faunal group that is depleted by trawling, clearly showing that Bivalves group 1 encounters more trawling activity (because most trawling activity is also inshore) than Bivalves group 2, and thus has a higher level of risk.

Currently, a comprehensive regional analysis for Australia is underway, using geographical areas including the Gulf of Carpentaria, the Great Barrier Reef region, South East Australia and parts of South and Western Australia. It is anticipated that faunal group level status assessments will be conducted for several case study regions around the globe. Other regions identified at the March

2015 meeting, where suitable available benthic survey data sets exist, included for example the Bering Sea, Gulf of Alaska, Isle of Man, North Sea, and East Coast USA.

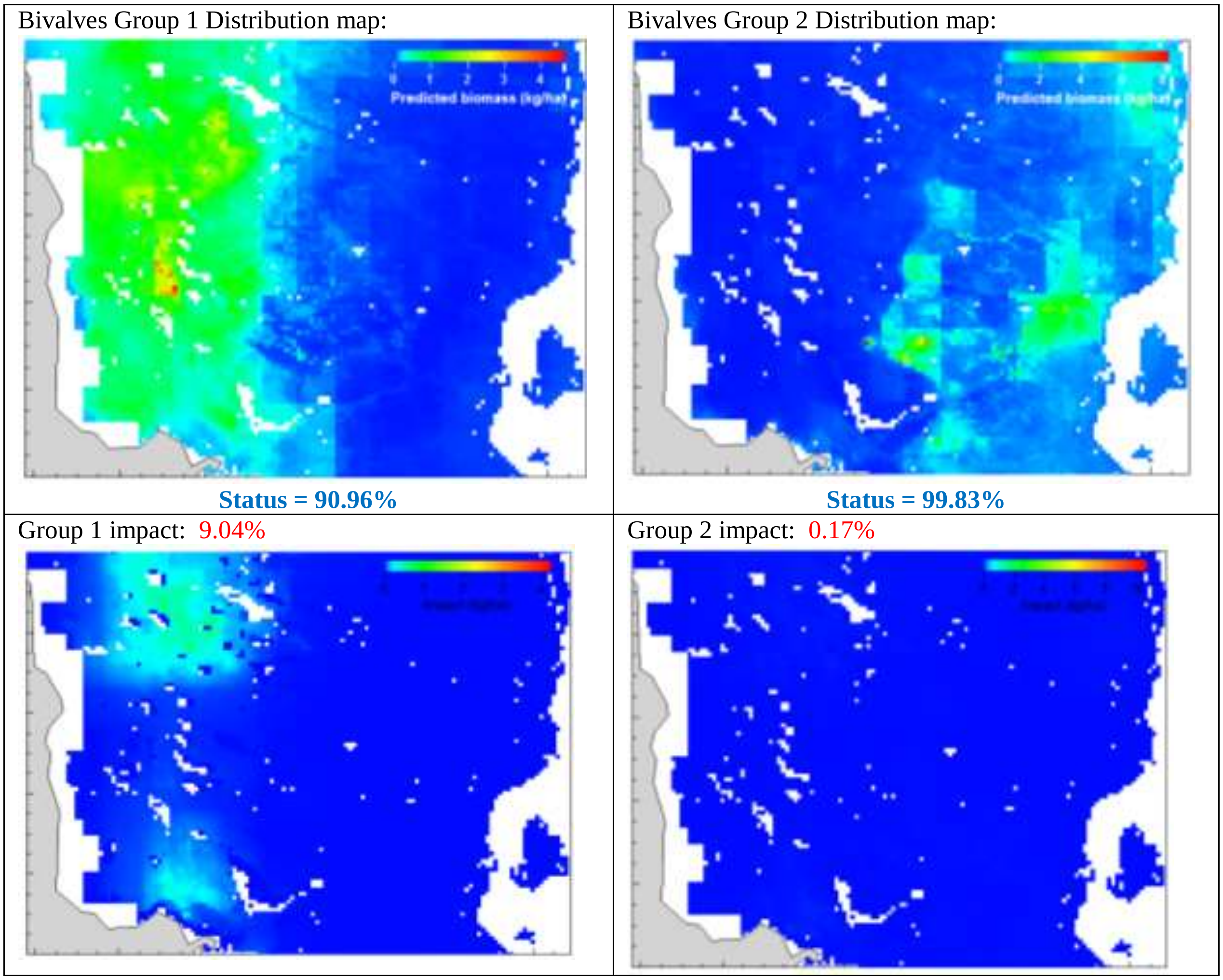

Figure 7: Maps of predicted distributions of two species-groups of bivalve molluscs, one with an inshore distribution and the other with an offshore distribution; together with maps of their estimated abundance impacted by shrimp trawling.

To date, the analysis of Australian data has predicted and mapped the distributions of species groups for the major classes of benthic invertebrates in regions where biological survey data are available. So far, the exposure of these faunal distributions to trawling, and their level of protection in areas closed to trawling, has been estimated (Figure 8). In most cases, the percentage of species-group abundance that is exposed to trawling is relatively low, and smaller than the percentage of abundance that is protected from trawling by various types of permanent spatial closures. In most regions, but not all, fishery closures typically protect a higher percentage of species-group abundance than do marine reserves. This exposure–protection assessment is currently being written up for publication and is expected to be submitted by mid-2016.

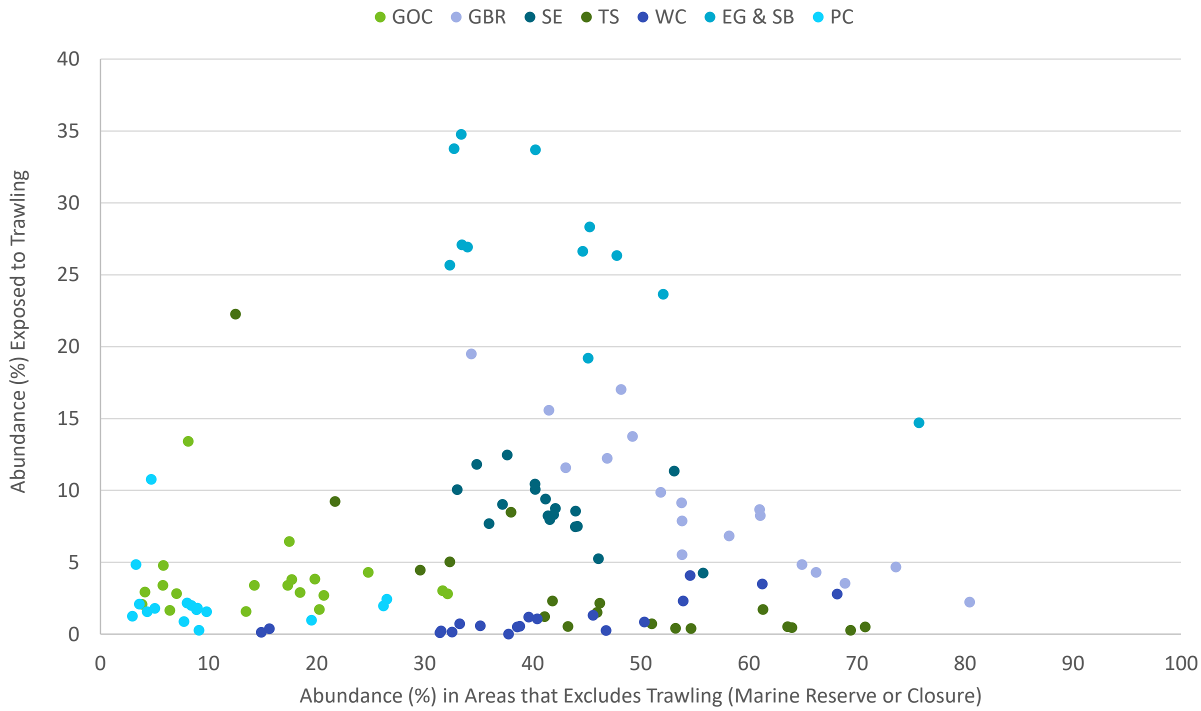

Figure 8. Plot of the percentages of predicted distributions of multiple species-groups of several classes of benthic invertebrates in seven Australian regions that are exposed to trawling and are protected in areas that exclude trawling.

Phase IV

One quarter of marine fish production is caught with bottom trawls and dredges on continental shelves around the world. Bottom-towed fishing gears kill between 20 and 50 percent of the benthic invertebrates in their path, depending on the gear type, substrate, and vulnerability of particular taxa. Emergent epifaunal species, which are particularly vulnerable to bottom fishing, stabilize the sediment and provide habitat for benthic invertebrates. We review evidence of the indirect effects of bottom fishing on fish production, to identify which habitats, fisheries, or target species are most likely to be affected. Recent studies have found differences in the diets of certain demersal species in relation to bottom-fishing intensity, thereby linking demersal fish to their benthic habitats at spatial scales of ~10km. Bottom fishing affects diet composition and prey quality rather than the amount of prey consumed; scavenging discarded bycatch makes only a small contribution to yearly food intake. Weight and length-at-age of plaice declined by up to 16% with increasing trawl disturbance on gravel and mud habitats, but not on sand. These observations, combined with modeling exercises, suggest that flatfish may benefit from light trawling levels on sandy seabeds, while higher intensity trawling on more vulnerable habitats has a negative effect. Models also suggest that reduction of the carrying capacity of habitats by bottom fishing could lead to lower equilibrium yield and a lower level of fishing effort to obtain maximum yield. The distribution of fishing effort is very patchy—small fractions of fishing grounds are heavily fished, while large fractions are lightly fished or unfished. This patchiness, coupled with the foraging behavior of demersal fish may mitigate the indirect effects of bottom fishing on fish productivity. Current research attempts to scale-up these localized effects to the population level.

Phase V: Evaluate alternative best practices

Phase V has identified a range of management and industry practices that will be used in an evidence-based analysis to identify best practices for minimizing the impacts of bottom trawling on benthic habitats. For each option or practice, the impact on benthic biota, sustainable food production and food security, and ecosystems and ecosystem services will be evaluated, along with changes in fuel consumption and other costs and impacts for the harvesting sectors.

Group discussions and research have identified a range of practices and options that are intended to promote sustainable harvesting with trawls (Table 1), including some management practices that are commonly used in the South and Southeast Asia (SSEA) and Latin America (LA) regions. Each practice has a primary objective, associated habitat benefits, and resource requirements that may or may not perform well depending on the local context. For example, trawling prohibitions in the nearshore and spatial zoning by vessel class are widely used in SSEA and LA, particularly when there are multiple scales of fishing operations and when monitoring, control and surveillance capabilities are limited. Similarly, freezing the footprint of trawl fisheries has been implemented as a practical precautionary measure in Alaska, because resources are available to monitor vessel positions (i.e., with onboard observers and VMS) and sustained high catches are obtained from the existing grounds.

Table 1. Management and industry practices being used in an evidence-based analysis to identify best practices for minimizing the impacts of bottom trawling.

Management Practice	**Description**
Freeze the fishing footprint	Future trawling is limited to previously trawled areas.
Prohibition by gear type	Trawls cannot be used in designated geographic areas, such as the nearshore zone. Closures may be permanent, seasonal, rotational, or bycatch-activated.
Gear modification	Specific configurations are required to reduce impacts on the seafloor.
Invertebrate by-catch quotas	The aggregate catch of designated benthic invertebrates is limited.[1]
Habitat impact quotas	A theoretical gear- and habitat-specific "cap-and-trade" system for effort control. The aggregate quota is intended to achieve specific habitat-conservation goals.[2, 3]
Broad-scale habitat management	Trawling is prohibited in designated areas (e.g., MPAs), as part of a multi-purpose habitat-conservation program.

[1] Wallace *et al.* (2015).

[2] Holland and Schneir (2006a).

[3] Holland and Schneir (2006b).

Management Practice	Description
Nearshore restrictions (coastal zoning)	Trawling is prohibited in sensitive nearshore habitats based on water depth or distance from shore.
Removal of effort	Fleet reductions through buybacks, licensing, etc. to reduce overall trawling effort and the trawling footprint.

A set of performance metrics has been developed to compare and contrast the efficacy of the different approaches, using an evidence-based analytical framework that links to outcomes from the preceding phases of the project (Table 2). For example, the Phase III risk analysis framework provides a basis for considering probable responses to trawl-gear modifications that are designed to minimize contact with the seafloor and reduce the removal of benthic biota, while Phase IV methodology supports interpretation of the corresponding changes in impacts on target fish. Similarly, the effects of closures that redirect effort to other habitat types can be considered based on understandings of habitat-specific impacts resulting from Phases 1 and 2.

Table 2. Impact metrics being used to evaluate the performance of the different management and industry practices to minimize trawling effects.

Performance Metric	Description
Benthic biota	Biomass, species diversity/richness, species composition, size spectra, and other ecological proxies for impacts on fish populations.
Sustainable food production and food security	Harvest levels and catch composition affecting domestic consumption and export markets.
Ecosystems and ecosystem services	Spatial extent and inclusion of representative habitats, especially those supporting vital ecological functions such as spawning, feeding and growth to maturity.
Fleet performance	Direct costs affecting operational efficiency, including those related to gear changes or modification, fuel usage, and catch rates.

Measures intended to reduce benthic impacts will generally reduce the total catch of a target species, such that a practical management goal is to optimize the target-species catch per unit of benthic impact. New work by the Committee is investigating this trade-off between catch and benthic impacts for the selected management measures, using a heuristic framework that combines a benthic impact and recovery model (Phase III[4])

$B_i/K_i = 1- F * d/r$

with a simple target-species catch model

Catch = F * q * fish biomass,

[4] Pitcher, R. *et al*. Estimating the sustainability of towed fishing-gear impacts on seabed habitats: a simple quantitative status assessment method applicable to data-poor fisheries. In prep.

where B_i is the abundance and K_i is the carrying capacity of benthic invertebrates, F is trawling effort, d is the depletion rate per trawl (impact), r is the population growth rate (recovery), and q is the catchability.

Clearly, the definition of best management practices will differ by location and the extant circumstances, such that useful guidelines and performance metrics must be flexible and account for a broad range of biological, technical, and socio-economic factors not the least of which are the local policy drivers for fishery management. To this end, the committee spent two days at this meeting conferring with trawl-fishery experts from Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, and Peru to gain a better understanding of management practices in the region. Our assessment is also considering the data requirements to implement, evaluate, and enforce the various measures, as well as the likely interactions with other input controls, output controls, and technical measures already in-place. Overall, we anticipate that the best practice for a particular region will fill gaps or adjust the emphasis of current practices, rather than overhaul the existing management system.

Continuing work will include stakeholder consultations on elements of the best-practice analytical framework, a global review of successful and unsuccessful applications of the different management options, and continuing collaborations with our SSEA and LA colleagues.

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Part II

Latin America – summary of the workshop outcomes

- Identification of fishing areas, fleets, fishing effort, catches and fisheries regulations related to bottom trawl fishing in Latin American countries (Summary Table 1 below).

- Data available in Latin America on the spatial distribution of trawl fishing activities (Summary Table 2 below).

- Potential management options to reduce trawling impacts on the benthos in Latin America (Summary Table 3 below).

- Identification of programs and opportunities for collaboration (Summary Table 4 below).

- Presentation Abstracts (Annex 1)

Summary Table 1. Identification of fishing areas, fleets, fishing effort, catches and fisheries regulations related to bottom trawl fishing in Latin American countries. (AP = Ana Parma, RA = Ricardo Amaroso, RC = Rodrigo Claudino, JA = Jose Aragão, PG = Patricio Gálvez, MZ = Maximiliano Zilleruelo, LM = Luis Manjarres, MR = Mario Rueda, LZ = Luis Zapata, IW = Ingo Wehrtmann, RM = Ricardo Meraz, RG = Renato Guevara).

Participant	**AP & RA**	**AP & RA**	**AP & RA**	**RC**	**JA**	**PG**	**MZ**	**LM & MR**	**MR & LZ**	**IW**	**RM**	**RG**
Country	**Argentina**	**Argentina**	**Argentina**	**Brazil**	**Brazil**	**Chile**	**Chile**	**Colombia**	**Colombia**	**Costa Rica**	**Mexico**	**Peru**
Area	Patagonean Shelf Scallop	Shrimp – Coastal Patagonian	Demersal Fish	South, South East	North/ North East	Centro sur y Sur Austral	Crustacean Central	Caribbean	Pacific	Pacific	Pacific	Pacific
Fleet description	Yes	Yes	Partial	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Effort information	Yes	Yes	Yes	Partial	Partial	Yes	Yes	Yes	Yes	Limited	Yes	Yes
Spatial distribution of effort	Yes (VMS)	Yes (VMS)	Yes (VMS)	Yes (VMS)	Yes (VMS)	Yes (Exist but only partial)	Yes (Onboard observers (sampling) & self report logbooks for industrial fleet, little info for artisanal fleet. VMS exists but data not available	Yes (Exist but only partial). Onboard observers (sampling). VMS exists but data not available.	Yes (Exist but partial) Onboard observers (sampling). VMS exists but data not available.	Yes (Exist but only partial)	Yes (VMS, on-board observer (sampling) 2009-2014	Yes since 2004 (VMS + observer data) (VMS only since 2000)
Catch/ landings quantity	Yes	Yes	Yes	Incompl .	Incompl .	Yes	Yes	Yes	Yes	Yes	Yes	Yes (only prelim. results)

Participant	AP & RA	AP & RA	AP & RA	RC	JA	PG	MZ	LM & MR	MR & LZ	IW	RM	RG
Country	**Argentina**	**Argentina**	**Argentina**	**Brazil**	**Brazil**	**Chile**	**Chile**	**Colombia**	**Colombia**	**Costa Rica**	**Mexico**	**Peru**
CPUE data	Partial	Yes	Partial	Catch/tri p	Catch/tri p (partial for previous years)	Yes	Yes (industrial)	Yes	Yes	Partial – catch/ trip	Partial	Yes (Catch/hour, tow by tow since 2004, all vessels).
Landing composition	Yes	Yes	Partial	Yes	Yes (Partial for previous years)	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bycatch	Yes	Yes	Partial	Partial	Partial	Partial	Yes (industrial)	Yes	Yes	Yes	Yes	Yes
Benthic invertebrate bycatch	Yes	No	No	Yes	No	No	Partial	Partial – survey information	Partial – survey information	Yes	Partial	Partial
Sediment data	Yes	Partial	Partial	Yes	Yes	Partial	No	Yes – survey information	Yes – survey information	Partial	No	YEs
Habitat mapping	No	No	No	Yes	Yes	No	No	Yes - broadscale	Yes - broadscale	Partial	No	Yes

Participant	AP & RA	AP & RA	AP & RA	RC	JA	PG	MZ	LM & MR	MR & LZ	IW	RM	RG
Country	**Argentina**	**Argentina**	**Argentina**	**Brazil**	**Brazil**	**Chile**	**Chile**	**Colombia**	**Colombia**	**Costa Rica**	**Mexico**	**Peru**
Regulations that could minimize seabed impacts		No	Large area closures	MPAs, zoning, closures	MPAs, zoning, closures	Yes (zoning)	Yes (zoning)	Spatial closures (zoning) (5 nm)	Spatial closures. ZEPA: Exclusive artisanal fishing zone in North Pacific. 2.5 nm closed to industrial fisheries. Zoning 1 nm. 3 MPAs (permanent trawl fishing closure) 1 MPA with spatial-temporal trawling fishing closure.	MPAs, spatio-temporal closures; AMPRs; 15m bathymetry closed to semi-industrial trawlers since 2016	MPAs, spatio-temporal closures	Indirect – forbidden areas, 5nm for industrial fleet, and 10nm for factory.

Summary Table 2. Data available in Latin America on the spatial distribution of trawl fishing activities.

Country / area	**Exist?**	**Available for project?**	**Who?**	**Data limitations**	**Groundgear description (Y or N)**	**Door-spread (Yes or No)**	**Gear-type**	**Other gear characteristics**
Argent.	VMS	TBD (under discussion)	Subsecretaria de Pesca	Under discussion	Yes (some sectors)	Estimate based on target sp. and size of boat	Bottom Trawl	Shrimp Trawl, Scallop Trawl, Hake Trawl (and others)
Brazil	VMS, Observer, and Logbooks	VMS 2009-2010 Available (published)	Ministry of Fisheries Database, Secretariat in the Ministry of Agriculture	Have to ask for permission, but optimistic outcome	Yes	Estimate based on target sp. and size of boat (actual measurements being recorded that could be applied to historical records)	Bottom Trawl (Double-rig, Pair-Trawl) & Semi-Pelagic	Trawlers for fish, squid, shrimp
Chile	VMS, Observer, and Logbooks	Observer + logbook 2009-2013, and maybe VMS	Subsecretaria de Pesca	In Progress, may be able to get more with permission (industry need to authorize use of VMS)	Yes	Not currently available Some estimates for wing end (trawl mouth) spread based on target sp. And size of boat (for crustaceans trawl fishery)	Bottom Otter Trawl	
Colombia	VMS, On-board observers	On-board observers (INVEMAR AUNAP, U Magdalena) is available; maybe VMS with permission	INVEMAR AUNAP, U Magdalena (fisheries monitoring); Maritime Authority of Colombia DIMAR (for VMS).	VMS data is currently restricted, but may be able to access with permission from DIMAR.	Yes	Yes (for each vessel; not each haul)	Caribbean: Bottom Trawl (Quad Gear). Pacific: Twin rig gear. Artisanal rig: Single	Shrimp Trawlers (Florida type)
Costa Rica	On-board Observers (2004-2011).	On-board observers yes. VMS	University of Costa Rica, INCOPESCA	For logbooks, need permission	Yes (1-type only)	Not estimated	Twin rig	Shrimp Trawlers (florida-type)

Country / area	**Exist?**	**Available for project?**	**Who?**	**Data limitations**	**Groundgear description (Y or N)**	**Door-spread (Yes or No)**	**Gear-type**	**Other gear characteristics**
	Captain logbook	no. Logbook maybe.						
Mexico	VMS (2012-current); On-board observers (2009-2014)	All available	VMS (CONAPESCA - Comision Nacional de Acuacultura y Pesca). On-board observers (INAPESCA - Instituto Nacional de Pesca)	Have to ask for permission (Pablo Arenas - Official letter from FAO)	Yes	Yes	Twin Rig	Shrimp Trawlers
Peru	VMS (2000+ - all industrial), On-board observers (2004), Captain logbooks (sporadic) Observer data, on-board factory vessels. Period 70's-90's (sparse)	Agreement of confidentiality may make VMS more complicated, but everything else is available	Ministry of Production, Instituto del Mar	VMS data may be available if name of the vessel is not mentioned. Shouldn't be impediment for the current project.	Yes	Yes (General estimate - by class of vessel, not tow by tow)	Single bottom otter trawl	The footrope and the doors are different among vessel class

Summary Table 3. Potential management options to reduce trawling impacts on the benthos in Latin America.

Management Option to Reduce Trawling Impacts on the Benthos	Explanation	Argentina	Brazil	Chile	Colombia	Costa Rica	Mexico	Peru	Notes
Prohibitions by gear type	Trawls cannot be used in designated geographic areas.	No	No	No	No, but trawl cannot be used in MPAs. Spatial-temporal fishing closures.	No, but semi-industrial fishing prohibited in interior gulf	No	No	Venezuela has a trawling ban for industrial trawling.
Modify gear or operations	Specific configurations are required to reduce impacts on the seafloor.	No	No	Yes - crustacean floating gears 2014 (Fish no)	No	No	No	Yes - vessel size limitation	
Removal of effort	Fleet reductions through buybacks, licensing, etc. to reduce overall trawling effort & footprint.	No	No (but freeze on fleet size)	Yes - fish trawlers (not crustaceans)	No - (but froze fleet size)	Yes, in the Gulf of Nicoya and Gulf Dulce	Yes - Gulf of Californi a	Yes - Within owners (Temporal fleet reduction along the fishing season	In Brazil this has been recommende d but no government decisions yet
Freeze fishing footprint	Limit future trawling to previously trawled areas.	No	No - but prohibited trawling beyond 1000m	No	Yes, in the Pacific (along the northern coast)	No	No	No	El Niño events prevent the application of this tool: demersal

Management Option to Reduce Trawling Impacts on the Benthos	Explanation	Argentina	Brazil	Chile	Colombia	Costa Rica	Mexico	Peru	Notes
									fish become less available during El Niño
Nearshore restrictions (coastal zoning)	Nearshore zone is closed to protect sensitive habitats.	Yes - limited areas	Yes - entire coast	Yes – 1 nm for artisanal, 5 nm for industrial	Yes – 1 nm Pacific, 5 nm Caribbean	Yes	Yes - 0-5 fathoms	Yes - first 5 miles for all industrial vessels; first 10nm for factory fleets	Yes - habitat protection and fleet conflict
Prohibitions by habitat type	Trawls cannot be used in designated habitats.	Yes - limited areas	Yes - coral reefs, lobster habitat	Yes - seamounts	Yes in coral reef and seagrass areas	No	No	Yes - nursery areas (south of 07º S	
Invertebrate bycatch quota	Limit aggregate catch of designated benthic invertebrate(s).	No	No	No	No	No	No	No	
Habitat impact quotas	Gear- and habitat-specific “cap-and-trade” system for effort (theoretical).	No	No	No	No	No	No	No	

Management Option to Reduce Trawling Impacts on the Benthos	Explanation	Argentina	Brazil	Chile	Colombia	Costa Rica	Mexico	Peru	Notes
Broad-scale habitat management	Multi-purpose habitat-conservation programs (e.g., MPA (Marine Protected Areas), EFH, HAPC).	Yes	Yes	Yes	Yes	Yes	Yes	Yes	

Summary Table 4: Collaboration arrangements.

Country / region	Collaborators	Collaboration topic / timetable	Regional Collaboration
Argentina	RA & AP	Data analysis of footprint	
Chile	RA & AP	Data analysis of footprint	
Colombia	MR	Use database to analyze footprint.	Collaborate with Chile and Costa Rica on collecting data, and possibly hosting a regional data analysis workshop. Design of experiments for impact assessment and risk assessment
Costa Rica	IW & REBYC-II LAC	Collect footprint data	
Brazil	RC & RA	Share data and look into analysis (analysis of data on fishing operations and catch obtained by on board scientific observers???)	
Mexico	RA	Planification to centralize all the spatial information	Mexico will prepare a plan about how to go forward
Peru	RG & RA	Look for funding for workshop	
All Countries		Impact and Risk Assessment (Methods)	To be discussed later

Annex 1

Presentation Abstracts

The Peruvian Sea and the Bottom Trawl Fishery

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The north system of the Peru (Humboldt) Current is one of the five major upwelling systems of the world with one of the highest productivities. It has a very high environmental variability (year-on-year, interdecadal and long term), but the most notable scale is the year-on-year ENSO. Upwelling determines the presence of cold/temperate surface temperatures in this system located at tropical latitudes. The continental shelf is narrow with a maximum width of around 60 miles, and has a very shallow OMZ. Living resources are well adapted to overcome this high variability, and also at the ecosystem level, there are some different equilibrium states as a response to the prevailing climate regime. The development of national fisheries has not escaped this uncertain dynamic that has left a footprint in the management strategy which is basically adaptive, since its origin.

The bottom trawl fishery began in the middle of the 1960's years, to capture hake (*Merluccius gayi peruanus*), the dominant demersal species whose distribution extends to all the Peruvian coast. The fleet consisted of small coastal trawling vessels (<500 HP) whose fishing ground was limited to the front of the main landing port (Paita - 05°S). In the 1970's years, hake fishing developed in a bigger extension of the continental shelf (north of 09°S) with a large fleet of factory trawling vessels (>1000 HP), fishing under agreements with Eastern Europe countries (former USSR, Poland) and Cuba. With the ending of those agreements, in 1980's years, a small national fleet of factory trawlers was raised to develop a fishery for local direct human consumption, but it failed towards the end of that decade.

The first years of 1990's were characterized by important changes in bottom oxygen content that drove to a northward contraction of the spatial distribution and concentration of hake (and associated fauna). The highest concentration in traditional fishing grounds (05°S) increased the catch rates and attracted the investment and creation of a new fleet of medium scale vessels (500-1000 HP). The initially successful measure developed a fishery with high catch rates, although with a high presence of juveniles, which finally led to overfishing levels in 2002, when all the fishery had to be banned for 20 months. The recovery of the hake stock has involved a drastic reduction (2/3) of the fleet, the establishment of a system of non-transferable individual quotas, and the presence of observers on board each fishing vessel, among others. At the present, hake biomass has notably recovered since the early years of 2000s.

Benthic community development on the Peruvian continental shelf is mostly related to the dynamics of the OMZ whose great variability, in great extent, seems to hide the potential effects of bottom trawling. The depth of OMZ determines a negative gradient north-south in bottom oxygen content, as well as in the macrobenthic abundance; while in contrast determines a positive gradient north-south in the abundance of sulfide bacteria. Most of the macrobenthic diversity is made up of small polychaetes, some gastropods and bivalves.

Pacific shrimp fishery in Mexico

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The shrimp is the most important fishery in Mexico. In the Pacific coast, Sonora and Sinaloa support the main part of the fishery in the Gulf of California (75% of the total catch), where the blue shrimp (*Litopenaeus stylirostris*), white shrimp (*L. vannamei*), and brown shrimp (*Farfantepenaeus californiensis*) are the three most important commercial species. The fishing area susceptible to the shrimp trawlers covers 35,000 km^2. During 2014 this fishery landed 53,403 metric tons (MT), valued at over $150 million (US). Industrial shrimp fleet is composed by 850 vessels (18 to 23 m in length), that can remain at sea for more than 15 days. The fleet can trawl from 3 to 60 fathoms with 220 to 620 hp; each vessel is equipped with navigational instruments, satellite, radar, compass and sonar; and can hold up to 100 tons of products.

The shrimp fishery has shown a boom– stability development pattern. The historical series of the catch including artisanal and industrial fleet, shows that this was increasing steadily until the 1980s, and then became oscillate around 50,000 MT. The number of vessels (effort) has decreased in recent years as a result of a government program for retirement of older and obsolete vessels, attempting to increase the efficiency of the fleet (Fig. 1).

Although shrimp trawl fisheries provide social and economic benefits, several other aspects need to be considered in their evaluation. The use of trawling gear has direct effects on benthic and demersal environments; shrimp trawling has the highest ratio of discarded biomass of any other fishing industry. In the Mexican Pacific bycatch is dominated by fish; however, are documented 537 species that include other taxa as crustacean, mollusk, echinoderm, cnidarian and algae. Assessing the magnitude of change in the ecosystem due to trawling is complicated by the lack of data characterizing trawler bycatch, benthic community structure and resilience and pre-trawling ecosystems.

The management regime implemented by the Mexican fisheries agency CONAPESCA includes seasonal closures, permit requirements, depth restrictions, area closures, fisheries reserve, and gear requirements as the use of excluder devices fish and turtles. These regulations are framed by the Mexican Fishing Law and established within the Norma Oficial Mexicana (NOM-002-PESC-1993). Seasonal closures are determined annually by the "Instituto Nacional de la Pesca" (INAPESCA) with the goal of protecting the growth, recruitment and reproductive period of commercial shrimp species, these closures generally extend from March through September. Trawlers are prohibited in bays and estuaries and must operate at depths greater than 5 fathoms. Satellite tracking systems have been installed on trawlers.

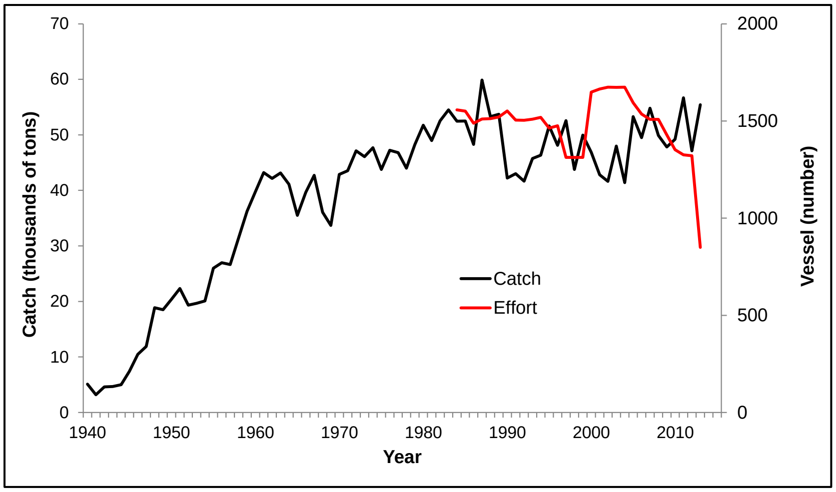

Figure1. Total Mexican shrimp catch in Pacific.

Bottom-trawl shrimp fishery in Costa Rica

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Costa Rica is a relative small country, but has a large marine territory (589.682 km^2; Fig. 1). The vast majority of the fishing activities take place along the Pacific site, and 97% of the landings are reported from this coast. Principal players in the research fishery sector are the universities (Research Unit for Fishery and Aquaculture (UNIP-CIMAR), Universidad de Costa Rica; Universidad Nacional)), the governmental fishery agency (Instituto Costarricense de Pesca y Acuicultura (INCOPESCA)), and different NGOs (e.g., MarViva, Conservation International, PRETOMA etc.). A total of seven shrimp species are targeted by the bottom trawl fishery (Table 1), and the historical records show that the landings of shrimps peaked in 1986-1987 (43.000 t yr-1) (Fig. 2). More recent data indicate an annual target catch of roughly 800 t yr-1 while the estimated annual bycatch (2010-2013) varied between 5000-6000 t yr-1 (Table 1). There is a clear tendency of decreasing catches of shallow-water shrimps, while deepwater catches constantly increased (Fig. 3). Publications about shrimp trawl fisheries started in the 1980s, focusing on the Golf of Nicoya area, followed by several years of scientific silence. In 2004 started a Public-Private-Partnership project about the deepwater shrimp fishery with the kolibri (*Solenocera agassizii*) and northern nylon shrimp (*Heterocarpus vicarius*) as target species, covering the entire Pacific coast of Costa Rica (Fig. 4). This project generated abundant information about the reproductive biology, catch trends, and bycatch composition, which has been published in international journals. Another important project ("The deepwater carcinofauna and its sustainable use along the Pacific of Central America: A regional initiative"; 2008-2011) covered the entire Pacific coast of Costa Rica (Fig. 5) and provided information about CPUE, bycatch composition, size frequency distribution of the target species S. agassizii and H. vicarius, among other related data. During the monitoring programs, which started in 2004, it became obvious that the catches of the target species decreased and that the bycatch increased, representing on average approximately 90% of the catches. Since sharks and rays formed an important part of this bycatch, the UNIP started studies regarding the distribution and abundance of elasmobranchs caught by the shrimp bottom trawl fishery as well as investigations about the reproductive and trophic biology of the most abundant species (e.g., maturity sizes, diet descriptions, and reproductive cycles). Additionally, the following aspects were studied: bio-accumulation of mercury in the most abundant species; collection of tissue samples for genetic analysis; synthesis and analysis of the generated information in order to recommend management strategies for shark and ray bycatch in the bottom trawl shrimp fishery. Currently, a PhD thesis about the sustainable management of shrimp trawl fisheries in Central America is in process at the University of British Columbia, Canada, and in collaboration with the UNIP-CIMAR of the Universidad de Costa Rica; the main objective of this thesis is to determine the optimal management strategies for the shrimp trawl fishery in Central America under climate change. Another important aspect related to the bottom-trawl fishery in Costa Rica is the fact that the constitutional court of the country prohibited in 2013 (Sentence No. 2013-10540) the renovation and reactivation of bottom trawl licenses as well as issuing new licenses considering the damage, which is generating this activity in the marine environment and its negative effects for the artisanal fisheries. All current licenses for this fishery are set to expire in 2018. However, the constitutional court indicated that a reactivation of these licenses would be possible, but only with scientific evidence for sustainable bottom trawl shrimp fishery. Considering this situation, the government of Costa Rica initiated a "Dialog table for a sustainable utilization of shrimp, job creation, and combating poverty". This inter-sectorial process started in mid-2014 with the participation of seven sectors, including Academy and NGOs (but pulled out later). The dialog table consists of five working groups: Research – Innovation – Communication – Wealth ("bienestar") – Funding – Legal regulation. Plenary meetings of this process are carried out only with the representatives of the participating sectors.

For cited figures, see: https://drive.google.com/drive/folders/0B7fh1E9kN63oWW5FY0JTbW9JWWc

Shrimp trawl fisheries and their impacts on benthic biota in Colombia

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The shrimp trawl fisheries in Colombia operates on both coasts Pacific and Caribbean since 1950 and 1971, respectively. On the Caribbean Sea the fishing grounds are aggregated at the south and north zones between 10 m and 60 m in depth (shallow-waters fleet: SWF), whereas on the Pacific the shrimp fisheries are distributed along the coast fishing in shallow and deep waters (DWF: 60 m to 250 m). Fishing technology is the same since 1950´s with vessels using 2 otter trawl nets by side in the Pacific: headline length of the nets are ranging between 60 to 80 ft, with mouth area of 60 m^2, and codend mesh size of 1.75 inches. Headline and mouth area in the trawl nets in the Caribbean are 42 ft and 28.6 m^2, while cod-end mesh size is as the

Pacific. Fisheries statistics (catch and catch per unit effort) of shrimp are available since the beginning of the fishery, however detailed performance of the fishery is gathered since 2010 by on board monitoring. Information to assess the status of the fishery and to test fishing impact includes: distribution of fishing effort (hauls position), hours trawling, water depth, trawling speed, species composition (of target catch, incidental catch and discards), individual weights/lengths and sex/maturity for the main species. In addition, spatial distribution of marine habitats (overlapped on shrimp fishing grounds) are available from the fishing surveys conducted on the both coast during the last 10 years. In the Caribbean, more than 85% of the target catch is Farfantepenaeus notialis. Other harvested species are *F. subtilis* and *Litopenaeus schmitti*. The status of the shrimp population is depleted with signs of recovery (exploitation rate of 17%). The impact on benthic biota (by-catch/shrimp ratio) is decreasing between 2010 (12) to 2015 (2.3); however such ratio varies between geographical zones. Incidental catch is about 27% and discards 65% of total catch, including rays, catfish, crabs, mojarras, croakers and crabs. On the Pacific, the main shrimp species is *Litopenaeus occidentalis* (>90%). Others less abundant species in shallow waters are *Xiphopenaeus riveti* and *Trachypenaeus* spp. The status of shrimp population is depleted with signs of recovery (exploitation rate of 12.5%). The bycatch/shrimp ratio is decreasing between 2010 (30) to 2015 (10), including fish species mostly (catfish, rays, croakers, mackerels). Deeb water shrimp fishery targeted species like *Farfantepenaeus californiensis*, *F. brevirostris* and *Solenocera agassizi,* which are fully exploited (exploitation rate of 45%). The fishing impact of this fishery is low: the bycatch/ratio is from 0.7 to 2.

Bottom Trawl Crustacean Fisheries in Central Chile

Maximiliano Zilleruelo
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The presentation shows target species of these fisheries (nailon shrimp, *Heterocarpus reedi*, red squat lobster *Pleuroncodes monodon*, yellow squat lobster *Cervimunida johni*, deep water shrimp *Haliporoides diomedeae*); the fleet that catch these species (industrial and artisanal), in number and main characteristics; fishing nets currently used and their changes; historic landings of this fisheries; geographical distribution of catch of target species.

For each of the main fisheries it is presented the distribution of the number of hauls per trip, haul duration (hour) and trip duration (days); catch quota and estimated effort; historical spatial distribution of catch/unit of effort (kg/h); proportion of bycatch composition (in weight); target and non-target species catch rate (kg/haul).

Hake (*Merluccius gayi*) is a target species of other fisheries, and frequently caught as bycatch in bottom trawl crustacean fisheries; catch rate (kg/h), estimated catch and official landing series for industrial fleet were shown.

Finally, observer coverage and number of fishing trips registered are shown.

Monitoreo pesquería demersal y aguas profundas en Chile

- Pesquería de arrastre de fondo -

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En Chile, la actividad pesquera sobre peces demersales y de aguas profundas es desarrollada tanto por flotas artesanales como industriales, sin embargo sólo estas últimas realizan actividades con redes de arrastre de fondo, cuyo monitoreo es realizado por el Instituto de Fomento Pesquero (IFOP), por encargo del Estado de Chile. Este programa tiene larga data y está basado en la observación directa mediante el embarque de personal científico a bordo de las naves comerciales, quienes recopilan información pesquera y biológica de los distintos recursos objetivo.

El área de operación de las flotas de arrastre cubre una extensión que abarca desde los 29°00' S a los 57°00'S. En esta se distinguen dos macro zonas, las que se diferencian por las características de las flotas y por los recursos objetivos en cada una ellas: la zona centro sur (29°00' S – 41°28'S) y la zona sur austral (41°28'S – 57°00'S).

En la actualidad en la zona centro sur operan dos flotas con arrastre de fondo cuyo objetivo principal es la merluza común (*Merluccius gayi gayi*). Esta actividad pesquera se inicia en la década de los años 40 y se pueden reconocer a lo menos tres fases durante su historia: una fase de crecimiento y primer colapso, la que abarcó desde 1946 y se extendió hasta 1973; una fase de baja productividad y recuperación (1974-1989) y; una tercera fase de crecimiento y segundo colapso (desde 1990 a la fecha). La última fase se destaca por un colapso caracterizado por un fuerte deterioro en la estructura poblacional, lo que ha obligado a la Autoridad Pesquera a tomar medidas con el objeto de recuperar el stock, siendo las principales, reducción de cuotas e implementación de vedas reproductivas.

Las dos flotas que operan en esta zona realizan sus actividades en profundidades entre los 100 y 500 m, por fuera de una zona de reserva artesanal que corresponde a las primeras 5 millas náuticas desde la costa. Estas flotas se diferencian por su poder de pesca y las estrategias de operación: la flota de menor tamaño (<1000 hp), se caracteriza por ser monoespecífica y participa del 12% de la cuota global de captura; la flota de mayor tamaño (>1000 hp) es una flota multiespecífica, y opera no sólo a merluza común (88% participación de la cuota), sino también sobre otros recursos como merluza de cola (*Macruronus magellanicus*) y calamar gigante (*Dosidicus gigas*), para lo cual emplea arrastre de media agua, arte que puede alternar en un mismo viaje de pesca.

Conforme a las medidas de regulación implementadas por la Autoridad Pesquera, ambas flotas han reducido drásticamente su tamaño en los últimos años, reducción que ha significado la salida del 75% de las naves desde el año 2000, lo que se ha traducido en una menor presión pesquera sobre los calderos tradicionales, sin embargo a pesar de esto no se han registrado señales claras de un inicio de proceso de recuperación de la actividad y del stock.

La pesquería demersal de la zona sur austral se inicia en 1977 con la operación de barcos arrastreros fábricas y se expandió a mediados de los 80 con el ingreso de buques palangreros fábricas, arrastreros y palangreros hieleros, además de actividades artesanales, generando un importante impulso (hasta la fecha) de una actividad económica en los puertos de la X, XI y XII Región, siendo de sus inicios sujeta a diversas regulaciones pesqueras con fines de conservación.

La pesquería industrial de arrastre es de carácter multi específica, desarrollándose esta actividad en aguas exteriores (por fuera de la zona de canales y fiordos australes), a partir del paralelo 41º28,6'LS hasta 57º00'LS. Los recursos más importantes explotados por el sector industrial han sido merluza austral (*Merluccius australis*), congrio dorado (*Genypterus blacodes*), merluza de cola (*Macruronus magellanicus*), y merluza de tres aletas (Micromesistius australis). El uso del arrastre de fondo se orienta principalmente hacia los recursos merluza austral y congrio dorado y en esta actividad destacan las flotas arrastre fábrica y arrastre hielera, cuyas participaciones en las cuotas globales de ambos recursos, es en torno al 50%.

En estas pesquerías, después de registrar un importante desarrollo industrial, en términos de volúmenes de desembarque, se registró una importante disminución de sus abundancias desde mediados de los noventa, condición que se mantiene hasta la actualidad, lo que se ha traducido en una reducción del tamaño de la flota que participa de las pesquerías, manteniéndose constante desde el año 2008, con 7 embarcaciones en operación permanente, 4 fábricas y 3 hieleras.

La condición deteriora de abundancia de los recursos demersales de esta zona obligó a la Autoridad Pesquera, entre otras cosas, a reducir drásticamente las cuotas de pesca a partir del año 2014, con el objeto de facilitar una recuperación de los stocks explotados. Esta reducción produjo cambios en las estrategias de pesca de las empresas, principalmente orientadas a la reducción del esfuerzo, en términos de días de operación al año y una mayor alternancia de recursos, orientando mayor número de lances a capturar merluza de cola, cuyo esfuerzo se realiza con redes arrastre de media agua. A pesar de esas medidas, aún no se visualizan efectos positivos de los indicadores pesqueros.

Es importante destacar que la mayoría de los recursos demersales de Chile se encuentran en niveles a lo menos de sobreexplotación e incluso algunos en condición de colapso, lo que sumado a la condición de muchos otros recursos (pelágicos y bentónicos), obligó al Estado a introducir fuertes modificaciones a la Ley de Pesca en el año 2013, en dónde destaca la definición de las cuotas de captura. Estas son establecidas por Comités Científicos, sin la intervención de los actores de las pesquerías, quienes participan en el manejo desde Comités independientes para el efecto, pero si, bajo el marco establecido, en términos de cuotas y status, por el ente científico. Esta ha significado un cambio de paradigma en la forma de administrar las pesquerías.

Trawl in fishing in Brazil

Rodrigo Claudino dos Santos
Brazil

Fishing ground: Brazil has a long coast line that extends up to 8000 km. In the north Brazil the continental shelf is wide (150-200 km), and long (1000 km), predominating flat bottom in shallow waters. The Brazilian Current carry warm tropical waters. The Amazon hydrographic basin fertilizes with nutrients the west part of this continental shelf generating a big primary production. That conditions support industrial shrimp and catfish fisheries.

In the northeast coast, the continental shelf is narrow (10-70km), and spread up to 2300 km, the bottom is irregular with presence of coral reefs. The warm water is poor in nutrients. The trawl fishery is located nearby rivers mouth and are mainly artisanal.

In southeast and south coast the continental shelf is wide (100-250 km) and longest (2700 km). There is a presence of two waters, in summer Brazilian Current carry tropical water to southward, and in the winter the Malvinas current carry cold and rich in nutrients water from Antartic, fertilizing this part of continental shelf.

Because this characteristics in Brazil the industrial trawling fisheries are concentrates in two sites north coast and southern-south coast, despite small scale trawling fisheries are spread for entire Brazilian coast, concentrated in river mouths and bays.

Fleet size: 5166 trawling vessels, 4561 (88%) small scale, 606 (12%) industrial

Fleet characteristics – small scale:

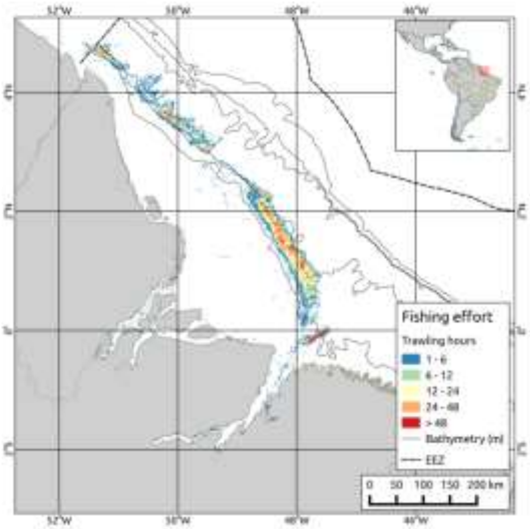
- LOA 8.64 m ± 1.72 m
- HP 39 ± 42.75
- GT 4.14 ± 3.93

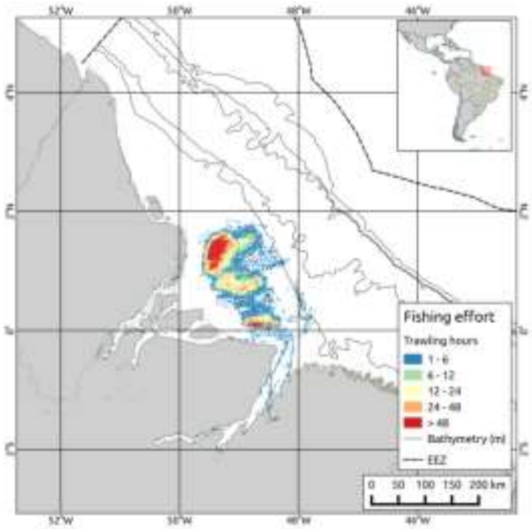
Fleet characteristics – industrial

- LOA 20.53 m ± 2.31 m
- HP 303.28 ± 78.28
- GT 70.01 ± 23.47

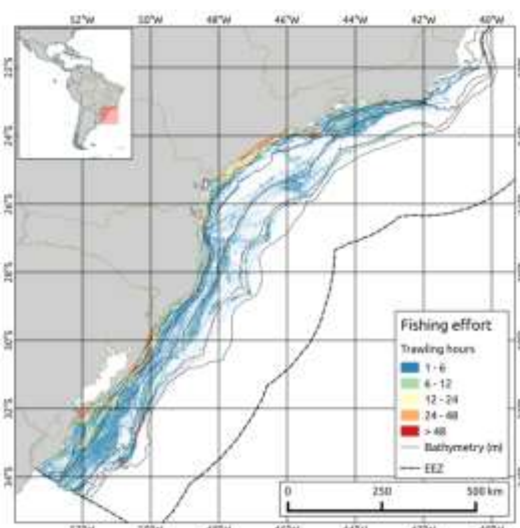
VMS data: In total 3000 fishing vessels are monitored by VMS, of this 606 are trawling fishing vessels. Brazil has a national VMS program, all fishing vessel bigger than 15 meters or bigger than 50 GT must be tracked. Are collect by hour, the vessel name, time stamp, latitude | longitude

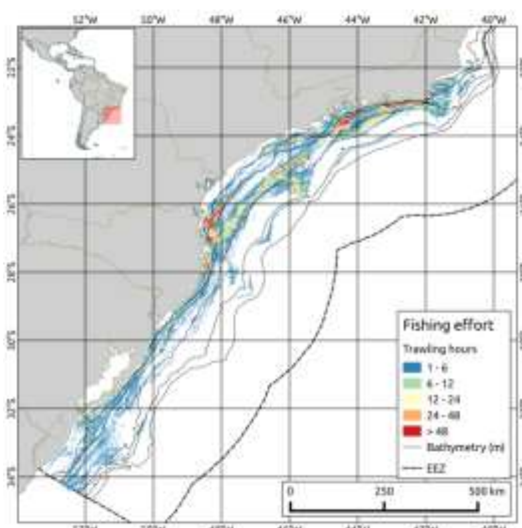
Effort distribution: There is two trawl fisheries in north Brazil, otter trawl for pink-shrimp (97 vessels) and pair trawl for catfish (48 vessels). Below two maps of effort distribution, left other trawl for pink-shrimp, and right pair trawl for catfish.





In the south and southeast, there is many trawl fisheries, like otter trawl for pink shrimp, simple trawl for finfishes, pair trawl for fishes, other trawl for squids, other trawl for flatfish. Below two maps of effort distribution, left other trawl, and right pair trawl.





<u>**Trawl Fisheries in the Amazon Continental Shelf and Northeast of Brazil**</u>

José Augusto Negreiros Aragão

Two main trawl fisheries are carried out in the Amazon continental shelf region of Brazil: double rig trawl for shrimp and pair trawl for catfish. The shrimp fishery is better studied but in both cases the knowledge on fisheries impact are limited. The available studies are focused mainly on the by catch composition and even detailed statistics on the activities are insufficient or not available. In the Northeast region the only shrimp trawl fishery is carried out by small and medium scale boats.

Shrimp Fishery in the North Region

The shrimp fishery occurs along the entire coast off the North region of Brazil. In the coastline, small scale fisheries are carried out in shallow waters by motorized wooden boats, ranging from 6 to 12 m in length. Main species caught are the *Litopenaeus schmitti* and the *Xiphopenaeus kroyeri.* In the open sea the offshore shrimp fishery is carried out by industrial boats, between the mouth of the Parnaíba River (02º53'S), in the state of Piauí, and the mouth of Oiapoque River (04º23'N), on the border of Brazil and French Guiana, comprising the coast of the states of Maranhão, Pará and Amapá. Catches are obtained mainly in deeps between 40 and 80 meters (Figure 1). Main species caught is the *Farfantepenaeus subtilis*, commercially called brown shrimp, with a small contribution of the *F. brasiliensis*. In both industrial and medium scale fisheries a great diversity of fish and other aquatic organisms caught as bycatch, also participate in the composition of the catches (Aragão; Cintra; Silva, 2004).

Figure 1 – Main shrimp fishing grounds in the North region coast of Brazil.

Information on the small and medium scale fishery is scarce but the industrial fishery is better known. The industrial boats are 17-24m in length and powered with 325-425hp motors (Figure 2). Journeys are 40 to 50 days long and the boats generally conduct four trawls a day.

Figure 2 – Typical industrial shrimp trawler operating in the Amazon continental shelf.

In 1980's the number of boats operating in the activity reached 250 but since then has decreased and today there are only 110 boats in operation. Landings have also decreased followed by an increase of the CPUE and now are comprise around two thousand tons per year (Figure 3). Belém, the capital city of the state of Pará, is the main landing port and the fishery is an important source of foreign income for the country.

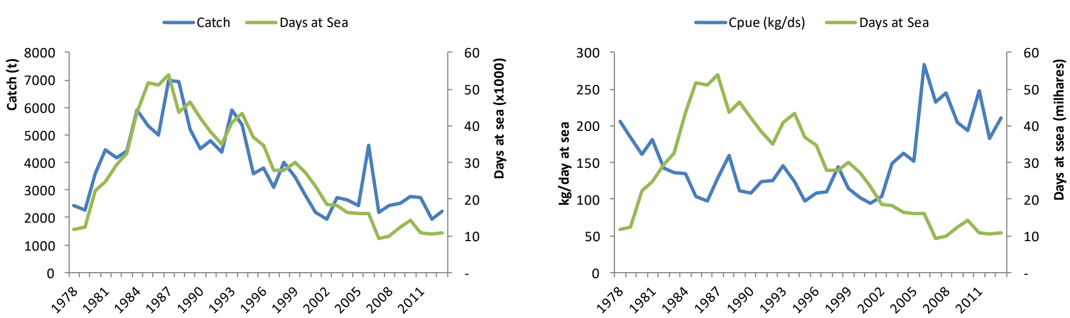


Figure 3 – Fishing effort, landing and Cpue in the industrial fisheries in the Amazon continental shelf.

The small and medium scale fisheries are carried out in the coastal zone by small and medium scale boats. There is little information on the activity and even reliable statistics on total landings are not available and the landings sites are disperse. The catch in these fisheries are composed mainly of seabob shrimp *Xiphopenaeus kroyeri*, white shrimp *Litopenaeus schmitti* and also by juvenile of brown shrimp *F. subtilis*, besides a number of other species fish and other organisms caught as bycatch (IBAMA, 1994).

Regulation Measures

The shrimp fishery in the North region is regulated by the following measures: number maximum of 180 boats; special license renewable on an annual basis required; mandatory presentation of logbooks; closed season from October to January; trawling not permitted in the coastal zone up to 10 miles in the states of Pará and Amapá; trawling not permitted in the coastal zone up to 3 miles in the states of Maranhão and Piauí; mandatory use of turtle exclude device (TED).

<u>Shrimp Bycatch</u>

Several species are caught as bycatch by artisanal and industrial fishery. Sciaenids are the main species in the catches of both fisheries: King weakfish / Pescada gó (*Macrodon ancylodon*); Silver croaker / Pescada branca (*Plagioscion squamosissimus*); Whitemouth croaker (*Micropogonias furnieri*). Red-sanpper (*Lutjanus pupureous*) is among other species caught in minor quantities by the industrial fleet. Proportion of by-catch in the industrial shrimp fishery was estimated between 4 and 7 kilograms for each kilogram of shrimp and in 2003 total by-catch was estimated a total catch of 17,2 thousand tons. Catches are composed of great diversity comprising some 150 species and the relative contribution of the main groups are: 43% of finfish, 5% of elasmobranches, 3% of crustaceans and 49% of a "mix" of small fishes, crustaceans and small shellfishes (Damasceno; Evangelista, 1991). Figure 4 gives an idea of the proportion of fish and other aquatic organisms in each half of the year (Paiva *et al.*, 2008) and Figure 5 is an illustration of the product of a trawl.

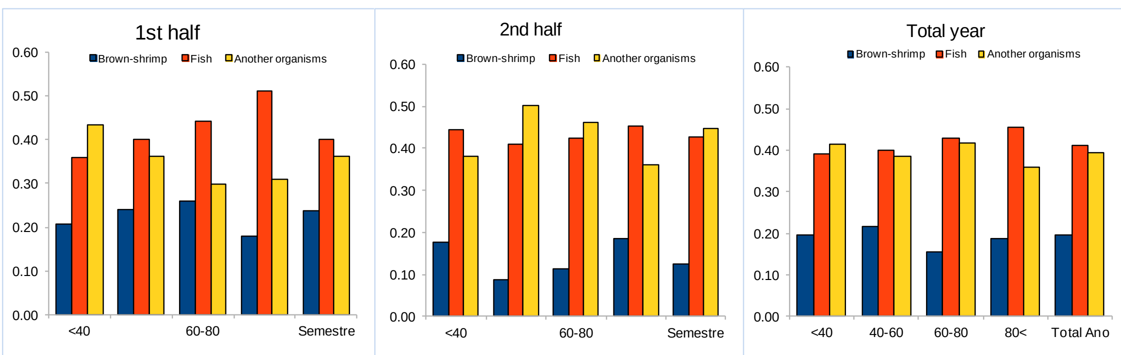


Figure 4 - Relative contribution of brown-shrimp, fish and other aquatic organisms in the catches of monitored trawls of industrial fisheries in the Amazon continental shelf in Brazil.

Figure 5 – Illustration of the product a shrimp trawl in the North region of Brazil

Other Impacts of the Industrial Shrimp Fisheries

Impacts of the shrimp fishery on biota and environment in the North region are not well known. The main studies targeted the by-catch composition as previously informed. But, at least it is evident the negative impact of the activity in a known nursery area, a called “lixeira” (“trash bin” in English), where an abundant presence of macrophitas and a high proportion of young forms of shrimp and of other aquatic organism in the trawl catches are reported, mainly from the third to the first semester of the year (CUTRIN, 2001).

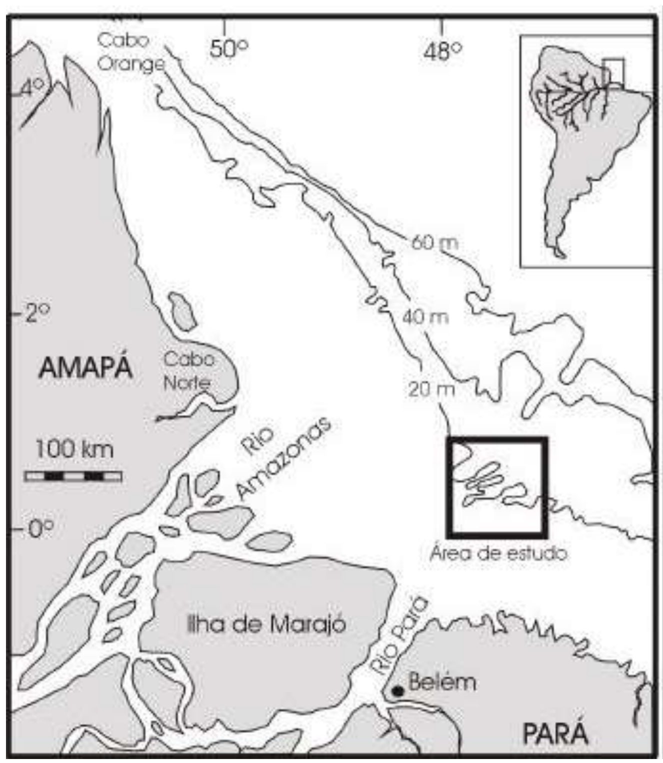


Figure 6 – Important nursery area (“lixeira” or “trash bin”) in the Amazon continental shelf.

Shrimp Fisheries in Northeast Region

Shrimp fisheries in northeast are the only trawl fishery in the region, carried out in the mouth of rivers, mainly the Parnaíba River and São Francisco River, and coastal muddy waters. Fleets are composed by over a thousand of small scale boats and the mains species caught are the *X. kroyeri*, *L. Schmitt* and, in some areas, *F. subtilis.* By-catches in these fisheries are composed by some 60 species, mainly finfishes, with the incidence of juveniles of several species, and the proportion of by-catch is 2 to 5 kilograms for each kilogram of shrimp. In its majority by-catch is landed and commercialized.

Figure 7 – A typical medium scale shrimp trawl boat that operates in the Northeast region of Brazil.

Bottom Trawl for Catfish in Amazon Mouth

Amanzon catfish (*Brachyplatystoma vaillantii)* is caught by industrial and artisanal fishery in front of the mouth of Amazon River, inside the estuary (Figure 8).

Figure 8 - Amazon catfish (*B. vaillantii)* fishing area (source: Ronaldo Barthen).

Industrial boats are between 17 and 29 meters in length and operate in bottom pair trawl system. There are 48 licensed boats and perhaps this is the only fishery carried out inside an estuary in the world. Total production fluctuates around 18 thousands ton annually. Nowadays the operations are carried out by even 3 or 4 boats together instead of the traditional pair (Figure 9). Artisanal fishery uses gillnet and longlines and operate inner the River.

Figure 10 – Industrial boats and fishery system for catfish in the mouth of the Amazon River.

Bycatch

At least 33 species make out the bycatch in the catfish fisheries in the mouth of Amazon River and most of them are of commercial interest. Main species are: dourada (*Brachyplatystoma rousseauxii*); gurijuba (*Hexanematichthys parkeri*); acoupa weakfish / pescada-amarela (*Cynoscion acoupa*). The proportion of bycatch is 0.7 kilograms for 1 kilogram of catfish. Besides this it is reported a high proportion (30%) of juveniles of catfish in the catches, with size between 6 and 41 cm and average of 24 cm.

Future Research

A comprehensive project dealing on shrimp and by-catch focusing the fisheries and ecosystem in the in Northern and Northeastern off Brazil was proposed by several universities under the coordination of the Federal University of Pará. The objective of the project is to promote multidisciplinary studies that support decision makers on the fisheries management and the conservation of shrimp stocks, allowing the proposal of measures that address the environmental, economic, and socio-cultural needs of both regions. But although the project was approved, funds were not allocated yet due to the present limitation of the government budget.

Brazil is also committed with REBYC-II LAC, a follow up project of the FAO/UNEP/GEF global REBYC-I project "Reduction of Bycatch in Tropical Shrimp trawling" (2002-2008). Several projects shall be carried out along coastal regions of the country. In the North and Northeast region projects to evaluate the spatial and seasonal distribution of the species that make up the by-catch of the shrimp fishery and development of environmentally friendly fishing technology aiming the reduction of by catch will be carried out. The first one is now being revised by the fisheries administration due to budget limitation and the second one is already under execution.

A fishery improvement project (FIP) for Red Snapper, a species that is part of shrimp by-catch, is now being carried out by the Federal University of Pará. The project is supported by private funds, allocated mainly by USA importers companies.

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