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Solving by-catch problems: Successes in developed countries and challenges for protein-poor countries

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Original Article

Abstract

One of the world's most serious and controversial fishing issues is the waste associated with the incidental capture, mortality and discarding of unwanted by-catch. In response to by-catch issues, developments in fishing technology changed focus towards more selective fishing gears under an objective to catch targeted species whilst avoiding unwanted by-catch. In more recent times, this field has expanded to address problems associated with fishing gears (especially dredges and trawls) impacting on habitats and ecosystems. Through a series of case studies, this paper describes the various categories of by-catch issues and how one can go about examining and resolving them. It also summarizes recent developments in the field, including the important development of FAO's International Guidelines on By-catch Management and Reduction of Discards. A relatively simple framework for ameliorating by-catch issues is described which is comprised of five key steps and has proven to be quite consistent across many examples. Using other case studies summarizing work in Nigeria, Cameroon, Madagascar and the Gaza Strip, this paper also describes some of the complexities associated with the implementation of by-catch reduction practices in protein-poor countries - as compared to the simpler situation in developed countries. It illustrates that the critical need for food security in poor countries goes hand-in-hand with the need for sustainable fisheries management - but the implementation of the latter in these circumstances is extremely complex and always country-specific. This paper marks a very successful period of achievement in ameliorating some of the most critical problems facing the world's fisheries. It also outlines how this work has broadened to address other emerging fisheries issues including ecosystem impacts. Finally this paper describes the enormous challenges faced by developing, protein-poor countries as they wrestle with by-catch issues whilst trying to feed the hungry.

Keywords: *Fishing technology, by-catch, discards, ecosystems, over-exploitation, buyemsellum sector, developing countries.*

Introduction

There have been many papers and reviews written about fisheries by-catch and discards. In Kennelly and Broadhurst (2002), we attempted to summarize the situation at that time. In this paper, I give a brief synopsis of that paper before providing an update of more recent issues and efforts to deal with by-catch, especially in developing countries.

Humans have been harvesting fish for at least 90,000 years using technologies that have developed from simple harpoons through to huge factory trawlers (Fig. 1a,b). For most of this history, under an assumption that the oceans, lakes and rivers

Fig. 1a. Early fishing technology from 90,000 years ago found in Zaire (from Yellen *et al.*, 1995).

Fig. 1b. The largest fishing vessel ever launched - the factory trawler Atlantic Dawn (from Fishing News International, March, 2000).

could not be exhausted, developments in fishing technology have focused on methods that caught ever-greater quantities of fish of an ever-increasing diversity.

It wasn't until the 14th Century that we began to see a problem with this unchecked development of fishing methods. For example, in 1376, in a petition to Edward III of England, an early form of beam trawl called the "*wondyrchoun*" was criticised for its impacts on small fish and benthic habitats. But the development of fishing technology continued unchecked, with little concern for overfishing or the small fish that were being discarded. From the early use of flaxen lines and cast nets, larger dragnets, fish traps, and pronged tridents (Nun, 1993) humans developed quite sophisticated fishing techniques and in the 19th Century, there was a dramatic increase in the use of most of the major methods used today. Around this time, longlines, drift nets, beam trawls, beach seines and trap nets were being used and new methods for catching very large quantities of fish were developed including purse seines, Danish seines and the modern-day otter trawl. The efficiency of these methods (and in particular, the trawl) in catching large quantities of fish established these techniques as the prime tools used up to the present day.

So, for most of history, humans have considered fishing technology as a major aid in providing a seemingly inexhaustible supply of seafood. With the benefit of archaeological evidence, however, we now know that such technological advances have led to major reductions in biodiversity and the progressive depletions of many fish populations (Pitcher, 2001).

Warnings during the 14th to 19th Centuries about the negative impacts that advances in fishing technology may be having on stocks and ecosystems were realized in the 20th Century, when major declines occurred in many of the world's stocks. The unchecked construction of bigger vessels (culminating in huge factory trawlers), combined with advances in electronic equipment, netting designs and materials all led to a strong test of the millennia-old assumption that seafood resources were inexhaustible. This is an assumption that we now know to be false.

The last few decades

This direction in the development of fishing technology changed dramatically during the last few decades in light of one of the world's most serious and controversial fishing issues - the waste associated with the incidental capture, mortality and discarding of unwanted by-catch (defined here simply as those organisms that are caught but not targeted). In response to such issues, developments in fishing technology changed focus to more selective fishing techniques, so that targeted species (and targeted sizes of those species) are caught whilst unwanted by-catch are not. In more recent times, this field has expanded to address broader problems of fishing gear (especially dredges and trawls) impacting on habitats and ecosystems.

This focus on by-catch reduction and ecosystem-effects of fishing has resulted in many successful changes in fishing practices which are estimated to be conserving millions of fish and other organisms in many parts of the world. These successes have occurred in many types of fisheries and have improved many of the world's most non-selective and problematic fishing techniques. Below, I describe some examples under various categories of by-catch.

By-catch of charismatic species

Despite centuries of concern over the discarding of small fish from nets (especially trawls), one of the first attempts to resolve by-catch issues did not address trawling but the more selective method of purse-seining (Hall 1994; 1998). Concern over the incidental mortality of dolphins in tuna purse-seines had been one of the most infamous by-catch issues since the 1960's with dramatic outcries from various environmental and conservation organisations. The most common way

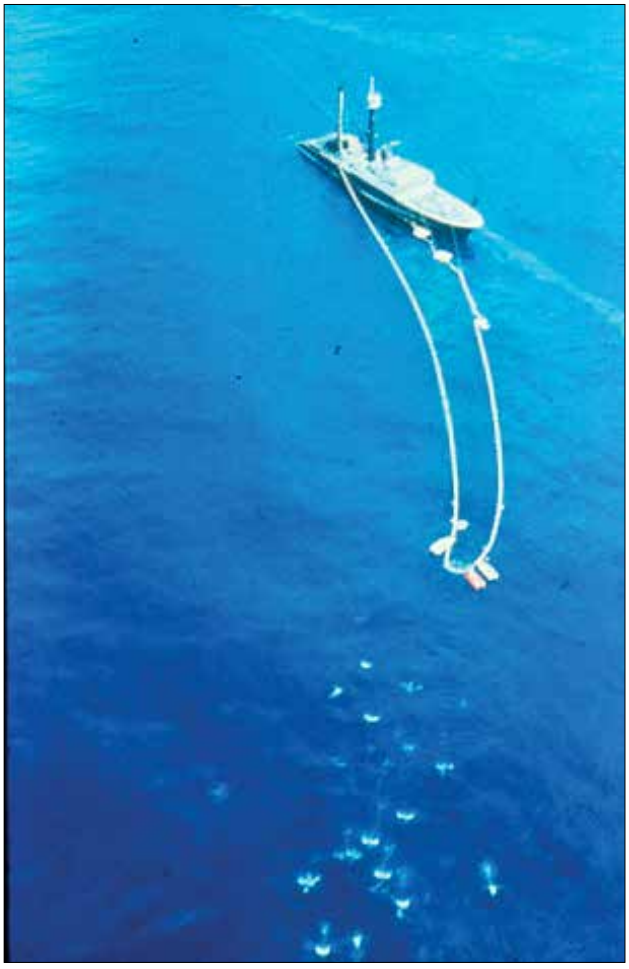

Fig. 2. The backdown manoeuvre used to release dolphins from tuna purse seines in the Eastern Pacific.

purse-seiners fish for tuna in the eastern Pacific Ocean is to encircle groups of dolphins to catch the tuna with which they associate. During the 1960's, the incidental mortality of dolphins using this method was approximately 350,000 dolphins/year which is believed to have caused significant declines in their populations. Through an extensive observer program (with 100% coverage) that provided detailed data on the interaction, coupled with the development of a series of technological innovations, dolphin mortalities were reduced in this fishery to negligible levels (Hall 1994, 1998). These modifications included changes in mesh sizes in a certain section of the net, modified methods for tying the cork line, a manoeuvre termed "backdown" after dolphins were encircled (Fig. 2; Medina, 1994), using speedboats to "herd" dolphins to the rear of the net and avoiding areas containing populations of particularly prone dolphins. Once these modifications were developed, a large-scale education programme trained skippers and crews in the new techniques. The success of the work done in this fishery showed that it was possible to save by-caught dolphins without closing a major fishery.

By-catch of other species, especially juveniles

Another, near-global example of how fishing technology contributed to minimizing by-catch is the success that various types of by-catch reduction devices (BRDs) have had in decreasing the unwanted by-catch of large numbers of juvenile fish from shrimp trawls (Broadhurst 2000). Much of this work began in the Gulf of Mexico and Europe more than 30 years ago but the example below comes from work done in New South Wales (NSW), Australia.

In NSW, high-profile by-catch problems in shrimp fisheries started in the late 19th century (Dannevig, 1904; Kennelly 1995) but reached a maximum in the late 1980's with threats to close certain fisheries to stop the by-catch of juvenile fish. Firstly, an observer programme estimated large by-catches of juvenile fish in these fisheries (Liggins and Kennelly, 1996; Kennelly *et al.*, 1998). Then, after a series of field experiments using commercial vessels (Broadhurst, 2000), two gear modifications proved successful at reducing by-catch while maintaining and sometimes even enhancing catches of shrimp. Because the targeted shrimp in the estuarine fishery were smaller than the by-catch to be excluded, a modified Nordmøre-grid (Isaksen *et al.,* 1992) was found to be most effective (Fig. 3a, b). For the oceanic fishery, a composite square-mesh panel anterior to the cod end (Fig. 4a, b) was developed that allowed small fish to swim out of the cod end, while commercially important shrimp, slipper lobsters, squid and octopus were retained. The sizes of fish excluded could be selected by adjusting the mesh size in the square-mesh panel. Both these modifications are now among the BRDs that are used in NSW's shrimp fisheries.

By-catch - conspecifics, especially juveniles

The size selectivity of all fishing gears means that most methods will catch undersized, unwanted individuals of the

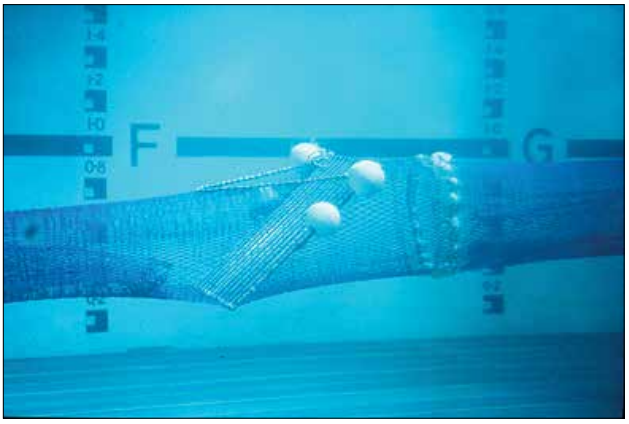

Fig. 3a. The Nordmore grid used to reduce the by-catch from NSW estuarine prawn trawls.

Fig. 3b. The difference in catches and by-catches when using the grid (right side of the tray) compared to a conventional control codend (left side of the tray).

target species, which is another form of by-catch. For trawl codends, a variety of studies have examined ways to improve selectivity. This starts with surveys to properly quantify and describe the particular selectivity issue (in terms of species and sizes), followed by experiments that test the effectiveness of alterations. Examples of this are mesh size changes in codends, changing the orientation of the meshes and/or using devices such as grids or panels. For example, codends made entirely of square-shaped meshes (which stay open better when towed) have been shown to be very efficient in increasing the selectivity for desired sizes of prawns in the Gulf St. Vincent prawn fishery (Broadhurst *et al.*, 1999).

By-catch - perceived, but not real, problems

Because of their controversial nature, by-catch issues may arise that, upon close inspection, are simply the result of inaccurate perceptions. In such cases, often an observer program will quantify and identify if any issue exists and if, in fact, any amelioration work is necessary. An example comes again from Australia when poor local publicity concerning the use of a small prawn hauling net led to significant outcry and calls for the method to be banned in the rivers where it was used. The particular concern was that it was thought that this fishing method (like trawls) caught and killed large numbers of juvenile fish. The technique involved a simple Danish seine, set in known holes in certain rivers for 4-5 minutes where school prawns were known to aggregate. The highly selective

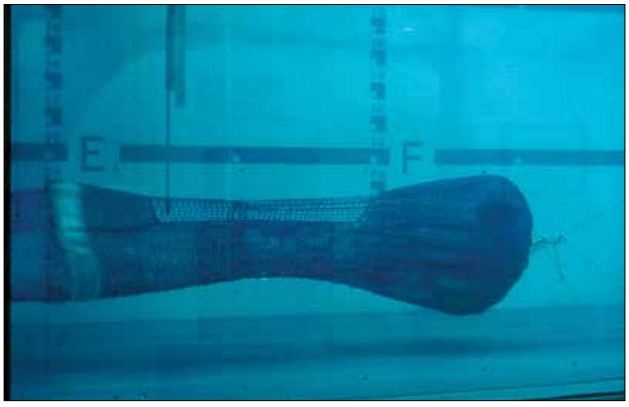

Fig. 4a. The square mesh panel used to reduce the by-catch from NSW oceanic prawn trawls.

Fig. 4b. The difference in catches and by-catches when using the panel (right side of the tray) compared to a conventional control codend (left side of the tray).

gear used and its rapid deployment and retrieval meant that actually very few fish were caught in this fishery and, those that were caught, were released in good condition within seconds. A simple observer program followed by the public display of the results led to a marked decline in controversy surrounding the method in those rivers, where the method continues to this day (for details see Gray *et al.*, 2003).

Ecosystem impacts

During recent years, public concern about the effects of fishing on the environment has broadened from relatively simple by-catch and discarding issues, to encompass a much wider context involving the impacts of fishing methods on whole ecosystems (Pitcher, 2001). One of the main issues facing the

world's fisheries today concerns the impacts of fishing on all species affected - not just those that are caught, retained or discarded, but also the ecological implications of disrupting habitats and the many uncaught species affected (Kaiser *et al.,* 1998; Watling and Norse, 1998; Freese *et al.,* 1999; Lindegarth *et al.,* 2000). While the species that comprise the biodiversity of these systems (sponges, ascidians, byrozoans, polychaetes, microscopic organisms, juveniles of commercially exploited species, etc.) often have little charisma, public appeal or commercial priority, their role is seen as critical because they underpin much of the local ecosystem. Since fisheries rely on the continued normal functioning of these ecosystems, it becomes obvious that the fishing industry itself should be very concerned about these issues.

This broadening of our perceptions of fishing has led to major initiatives throughout the world to adopt an "Ecosystem Approach" to fisheries management. Issues concerning biodiversity and ecosystem-wide effects of fishing are now central to most management plans where there are policies to manage in an ecologically sustainable manner. A corollary is that there are now significant demands for more scientific information on the ecological impacts of fishing and finding solutions that will minimize them.

In recent years, there has been a substantial effort by scientists to increase our knowledge of these issues but, because of the scales and complexities involved, such studies are usually difficult, expensive and of a long duration. Nevertheless, as was the case above, substantial work has been occurring to firstly quantify and identify particular issues, species and methods of concern - through observer programs augmented with SCUBA-based and remote underwater video and photographic sampling. For example, such work identified problems associated with mobile gears like trawls disrupting natural ecosystem function via direct contact with benthic habitats. And subsequent to this characterization work has been experiments to test alternative ways of towing trawls using modified otter boards and ground gear (Fig. 5a, b).

UN FAO International guidelines on by-catch management and discarding COFi, February, 2011

In 2009, the United Nations Committee on Fisheries (COFI) decided that it was timely to take stock of what had been achieved over recent decades in resolving by-catch issues and tasked FAO to develop International guidelines on by-catch management and reduction of discards. These were approved by COFI in 2011 (FAO, 2011). The guidelines discuss by-catch management planning, data collection techniques and ways to do by-catch assessments, research and development.

Critically, the guidelines summarise the various measures available to manage by-catch and reduce discards including: input and output controls; improving the design and use of fishing gear and by-catch mitigation devices; spatial and temporal measures; by-catch limits and/or quotas; economic incentives; and others. The guidelines also provide information on the consequences of by-catch and discarding issues for monitoring, control and surveillance (MCS) activities in addition to awareness, communication and capacity-building measures. Finally the guidelines provide guidance on their implementation, special considerations for Regional Fisheries Management Organizations (RFMOs) and special requirements of developing countries.

Among the emerging issues identified in the guidelines that deserve mention here are recommendations about less obvious, cryptic interactions of fishing gears with ecosystems: the unobserved mortality of species due to pre-catch losses, ghost fishing and post-release mortality (Gilman *et al.*, 2013

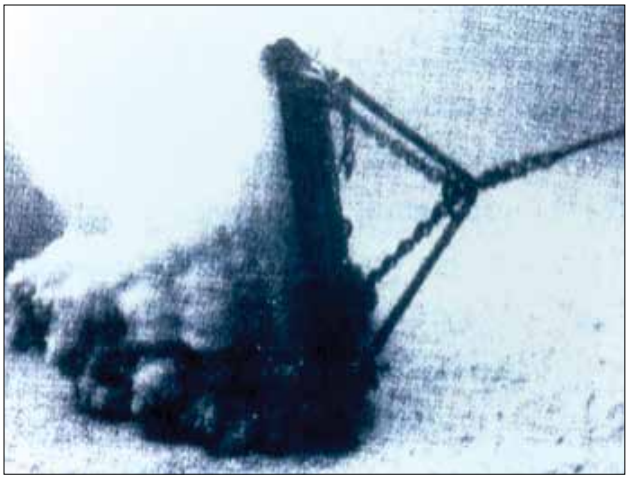

Fig. 5a. Trawl otter boards can cause significant habitat damage and consequent effects on the ecosystem.

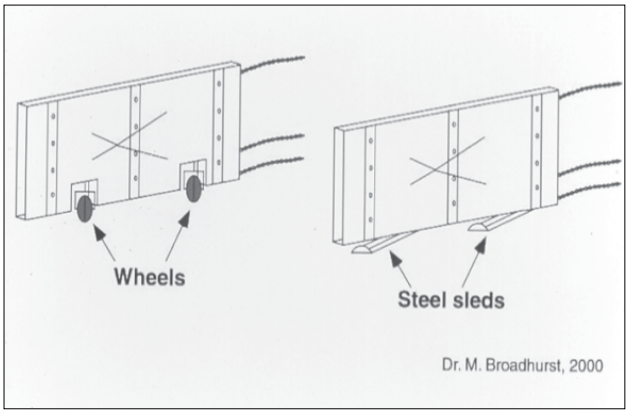

Fig. 5b. Adding wheels or sleds can greatly reduce such impacts (as well as improve fuel efficiency).

for a review). Examples include when organisms are caught (or collide with the vessel or gear) and die but are not landed onboard. This can occur when species are impacted by mobile gear but not get caught, or when the crew may intentionally release some or the entire catch prior to landing onboard (slipping). Another set of examples concerns organisms that escape from fishing gear alive but die later - such as when small fish escaping through a trawl cod end may later die due to stress or injury, or when demersal dredges damage scallop shells which leads to subsequent disease. Further, significant losses can occur through predation of the catch from the gear - such as when sharks and cetaceans feed on catches from pelagic longlines or escapees from trawl codends and BRDs, or when crabs, octopus, etc. feed on catches in traps and nets.

As was the case for work on by-catch and discard reduction, the guidelines recommended that member states identify, quantify and reduce impacts of unobserved mortality of species due to these emerging issues concerning pre-catch losses, ghost fishing and post-release mortality.

Common framework used to resolve by-catch issues

Success stories in reducing by-catch involve many different species, using a diversity of fishing methods in a variety of fisheries and locations. One might expect that this diversity of approaches, gear types, species and fisheries would make it difficult to identify any overarching summary of how one might go about solving by-catch problems in a given fishery. However, the opposite is true - there is actually a relatively simple framework that describes how by-catch problems get resolved that has proven to be quite consistent across many examples (Fig. 6).

This framework involves industry and researchers each applying their respective expertise to the particular problem. It comprises five key steps: (1) quantifying by-catch (mostly via industry-based observer programs) to identify the main species and their sizes, (2) developing alterations to existing fishing gears and practices that minimize the mortality of these species/sizes, (3) testing these alternatives in appropriately-designed field experiments onboard commercial vessels, (4) gaining acceptance of the new technology throughout the particular fishery and, most importantly, (5) communication of the solution to the interested stakeholders who first raised the issue as a concern via videos, photographs, etc.

At all stages of this framework, but most importantly at its beginning and end, it is crucial that ALL interested parties: fishers, environmental groups, government officials and scientists, engage positively to identify, resolve and then communicate the by-catch problem and its solution.

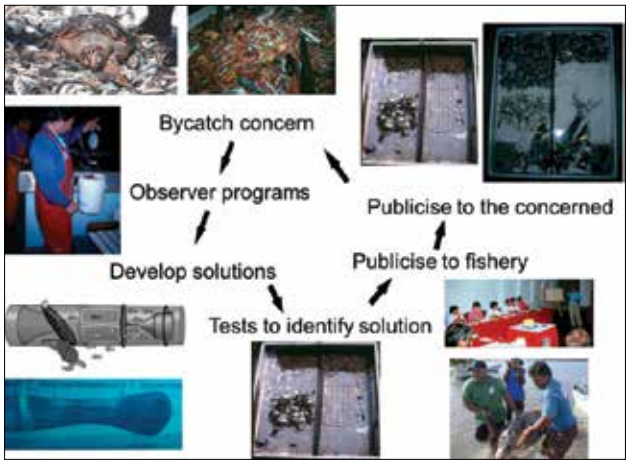

Fig. 6. The By-catch Reduction Framework.

By-catch challenges in developing countries - Improving food security by the introduction of sustainable fishing practices

Whilst the above discussion outlines how by-catch and discarding issues have evolved and been addressed in many parts of the world, it is vital to consider how by-catch issues affect developing countries. That is, whilst developed countries followed a framework of identifying and quantifying issues, then developing what were often technological solutions, developing countries often have very different by-catch issues and generally lack the resources needed to adhere to such a model. Yet, there is a need for sustainable fishing practices to be implemented in developing countries where food security is a major, long-term problem. Using the term "vital" in this context is literal - the lack of sustainable fishing practices is impacting food security and livelihoods in many parts of the world.

Recent data from FAO indicates that approximately one-third of world fisheries production occurs in low-income, food-deficient countries - where seafood is a major source of protein. Unfortunately, however, many of the fishing methods used in such countries lack the improvements that have been implemented in developed countries which make fishing gears more selective. For example, the use of trawl nets in developing countries has, to a large extent, not incorporated the use of by-catch reduction technologies that reduce the wastage associated with the capture and discard (or, in many cases, retention) of undersize fish. This leads to the sub-optimal use of the resource, with significant consequences for the population's food security. Below, I use four case studies from Nigeria, Cameroon, Madagascar and the Gaza

Strip to describe some of the complexities associated with the implementation of sustainable fishing practices in these countries - as compared to the simpler situation in developed countries. This discussion illustrates that the critical need for food security in poor countries goes hand-in-hand with the need for sustainable fisheries management - but the implementation of the latter is extremely complex and always country-specific.

Nigeria

Currently, Nigerian shrimp trawl fisheries have extensive implementation of by-catch reduction technologies, which are mostly driven by European Union requirements for shrimp imports (a major market for the Nigerian trawl industry). Virtually all trawlers use Turtle Exclusion Devices (TEDs) and quite well-designed square mesh panel BRDs that effectively reduce the by-catch of large quantities of juvenile fish (Fig. 7a, b)

Fig. 7a. The Turtle Exclusion Devices currently used in Nigeria.

However, this finfish by-catch has a very well-established market where it is retained and on-sold at sea from trawlers to smaller-scale canoe operators who then on-sell this by-catch onto onshore buyers (mostly women) who dry and smoke the fish for on-sale at local and regional markets (Fig. 8a, b).

This multilayered sector (termed the "*buyemsellum*" sector) provides significant seafood protein to a large number of people who would otherwise simply lack it. Introducing BRDs to these fisheries thus causes a problem as it effectively reduces the by-catch available for on-selling. The current fisheries challenge in Nigeria, therefore, is to examine and resolve this *buyemsellum* issue. Work has begun via significant socio-economic surveys of the sector in an attempt to identify alternative sources of seafood for the sector, different employment options, etc.

Also noted to be important in Nigeria is the need for a general "awareness and enlightenment" campaign to educate the general population and key stakeholders about the need for sustainable fisheries management, conservation of resources

Fig. 7b. Square mesh panel BRDs currently used in Nigeria.

and how changes to fishing practices can assist in such areas. Particular groups to target in such work are the captains, crews and consumers so that they can be sufficiently informed to begin to contribute to the process.

Madagascar

Madagascar currently has a very well managed shrimp trawl fishery, with no *buyemsellum* sector and a significant uptake

Fig. 8a. The Nigerian "buyemsellum" sector at Lagos. Large canoes buy by-catch from trawlers at sea and then on-sell it to local women who dry and smoke the fish for further on-selling.

Fig. 8b. Dried and smoked fish products in the "buyemsellum" sector.

of by-catch reduction technologies, under drivers that include the shrimp import requirements of Europe and a desire by the industry to eventually achieve Marine Stewardship Council certification. Without the complexity arising from a *buyemsellum* sector, the main issues for Madagascar's trawlers are to improve the performance of the BRDs currently used so that they release more discards whilst increasing the retention of shrimp. Quite straightforward modifications (that have been developed elsewhere) to the gears currently used should be able to assist with these priorities.

Cameroon

The Cameroon trawl sector is characterised by having very little formal fisheries management, no implementation of sustainable fishing practices, and no pressing drive to improve fishing methods due to export requirements (most of the targeted shrimp is not exported to Europe). There is also a significant *buyemsellum* sector that, as in Nigeria, complicates the need to reduce by-catch with the need to provide fish for undernourished people. The current challenges for this fishery therefore concerns most aspects of fisheries management - especially a better functioning Monitoring, Control and Surveillance (MCS) system, a program to quantify and then ameliorate by-catch issues, as well as identifying ways to manage the *buyemsellum* sector. But first, Cameroon needs a general "awareness and enlightenment" campaign to educate the general population and key stakeholders about the need for sustainable fisheries management, conservation of resources and how changes to fishing practices can assist in such areas.

Gaza Strip

The Gaza Strip area of Palestine is the most densely populated part of the world with approx. 10,000 people per square kilometre. It is an occupied territory with a very small fishing ground that is policed by Israeli armed forces.

In 2005, the Palestinian Authority were quite well advanced in their knowledge and acceptance of sustainable fishing management. Further, the region attracted significant humanitarian attention and funding with several projects and initiatives underway or being developed by a variety of governments and organisations to improve fisheries management practices in the region. A key driver was the need to make Gazan wild fisheries management more sustainable as it formed a vital source of protein for the huge population.

However, in 2006, following a general election, major military actions occurred in the region, effectively sidelining the above initiatives for more urgent priorities such as basic security and emergency access to food.

Lessons learned in developing countries

In Nigeria, and Madagascar, we see that the implementation of sustainable fishing practices is well underway, with the use of BRDs and TEDs now routine. In Cameroon, however, we see a country that is just beginning its journey to modern fisheries management, compliance and research. Whilst in Gaza, we see that other, higher priority issues have thwarted attempts to introduce sustainable fishing practices. However, it is well accepted that, in each case, there is a recognised, critical need for initiatives that will reduce by-catch and discarding, improve selectivity and therefore lead to better managed fisheries.

One of the key lessons learned from these case studies is that each developing country has its own unique mix of socio-economic and/or political circumstances that either encourage or discourage the uptake of sustainable fishing practices. As a consequence, solutions to by-catch issues in the developing world will always be country- and fishery-specific and will often require quite different approaches to those taken in developed countries where resources for research, management and compliance activities are more plentiful. That is, for developing countries, it is very important to consider and wherever possible, transfer and/or adapt the knowledge gained in developed countries over the past few decades in designing and implementing sustainable fishing practices.

Conclusion

This paper has attempted to summarize a very successful period of achievement by the world's by-catch reduction specialists, gear technologists and fishers in ameliorating some of the most critical problems facing the world's fisheries. It also outlines how to continue this work and broaden the lessons learned to address other emerging fisheries issues through a relatively simple framework involving fishers and

scientists applying their respective expertise. But it doesn't end there. This paper has also tried to highlight the complex and varying challenges faced by developing, protein-poor countries as they wrestle with by-catch issues and sustainable fisheries management practices - whilst trying to feed their hungry. But one can conclude from the recent history of this field that, even though solutions to such issues are currently not obvious, they do exist and will be found - as long as all stakeholders work together to find them.

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