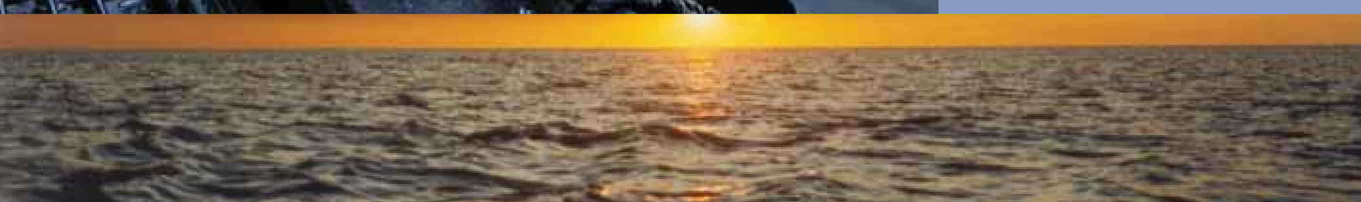
A Guide to Bycatch Reduction in Tropical Shrimp-Trawl Fisheries

Revised edition



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A Guide to Bycatch Reduction in Tropical Shrimp-Trawl Fisheries

Revised edition

by

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Foreword

Bycatch is the unwanted or non-target part of the catch taken by fishermen. It is either discarded at sea or used for human or animal consumption. The capture of bycatch may pose a threat to species diversity and ecosystem health because this part of the catch is usually unregulated. In tropical shrimp-trawl fisheries, bycatch often consists of juvenile food-fish species and is therefore a threat to food security and sustainable fisheries production. Bycatch is a global problem that must be addressed.

The Food and Agriculture Organization of the United Nations (FAO) is addressing this problem through the technical project, 'Reduction of discards and environmental impact from fisheries'. Under this project FAO is executing a five-year global project funded by the Global Environmental Facility (GEF) titled, *'Reduction of environmental impacts from tropical shrimp trawling, through the introduction of bycatch reduction technologies and change of management'*. Twelve countries[1] from Latin America, the Caribbean, West Africa, Southeast Asia and the Gulf region, and one inter-governmental organization[2] are also participating in this project.

A Guide to Bycatch Reduction in Tropical Shrimp-Trawl Fisheries is a result of this project. It is designed for fishermen, net makers, fishing technologists and others interested in a practical guide to the design, use and operation of effective bycatch reduction devices. Fishery managers, policy-makers and legislators will find this guide useful to help develop specifications governing the design and application of these devices in a shrimp-trawl fishery.

The issue of bycatch is not going away and scrutiny of fishing activity is increasing. All fishermen are strongly urged to use appropriate bycatch reduction measures to help maintain the productivity of the fishery and the long term prosperity of the fishing industry. By responding appropriately, fishermen can help to protect the marine environment and assist global food security both now and in the future.

Eayrs, S.
A Guide to Bycatch Reduction in Tropical Shrimp-Trawl Fisheries.
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[1] Bahrain, Cameroon, Colombia, Costa Rica, Cuba, Iran, Indonesia, Mexico, Nigeria, Philippines, Trinidad and Tobago, and Venezuela

[2] Southeast Asian Fisheries Development Center (SEAFDEC)

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First and foremost I would like to acknowledge the efforts of Garry Day a.k.a 'TED'. Garry spent many years working at sea in Australia and overseas testing and developing TEDs and BRDs, often in bad weather, sometimes with reluctant fishermen. His contribution to the development of these devices has been enormous, and much of TED and BRD performance and efficiency information used in this guidebook is based on his efforts at sea. He has no doubt accelerated the uptake of TEDs and BRDs by fishermen and saved them financial hardship by identifying sources of shrimp loss and solving their gear problems. Garry also spent many hours producing illustrations for this guidebook that are accurate and geometrically correct.

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Finally, but by no means least, I want to acknowledge the efforts of all fishermen that have tested a TED or BRD. Without your efforts much of the operational knowledge of these devices would not have been obtained in such a timely nor cost-effective manner. By risking a catch reduction and loss of income to contribute to this knowledge, sometimes while other fishermen do little or nothing, is a generous contribution and greatly appreciated.

Introduction

A global problem

Most commercial fisheries have to deal with bycatch, which can be broadly defined as anything that a fisherman does not mean to catch, including fish, turtles, pieces of coral, sponges, other animals and non-living material. The Food and Agriculture Organization of the United Nations (FAO) has recently estimated that nearly 7 million tonnes of fish bycatch is discarded globally by commercial fishermen every year. This is equivalent to about 8% of the global catch from marine capture fisheries. Industrial shrimp trawling in tropical waters is a leading offender in the capture of bycatch and accounts for about 27% of all global discards. Shrimp trawling is generally regarded as one of the least selective fishing methods because the bycatch may consist of over several hundred teleost species and outweigh the shrimp catch by 20 to 1 or more. No other fishing method comes close to matching such discarding and wastage of marine resources.

Bycatch from shrimp trawling is dominated by large volumes of fish.

Threatened and endangered species

Shrimp trawling is also having a serious impact on sea turtles. In some shrimp-trawl fisheries several thousand turtles are caught and drowned each year. This impact, combined with other human activity such as long line fishing, hunting and coastal development, has resulted in six of the world's seven species of sea turtle being listed in the 2003 IUCN World Conservation Union Red List of Threatened Species. Five of these species are listed as critically endangered (high risk of extinction in the wild in the immediate future) and one species is listed as endangered (very high risk of extinction in the wild in the immediate future). The threat of these animals becoming extinct has also led to the listing of all sea turtle species in Appendix 1 of the Convention on International Trade in Endangered Species (CITES). This means that the international commercial trade of sea turtles is prohibited, including trade in turtle meat, eggs and shell. Many countries have also responded to threats posed to these animals by requiring specific protection within waters under their jurisdiction. This has led to a range of protective measures including restricted local trade and consumption of turtle products, protection of nesting sites and the mandatory use of turtle excluder devices (TEDs) in shrimp-trawl fisheries.

Other bycatch species that are under threat from shrimp trawling include sharks, dugongs, sea snakes, sea horses, coral and some fish species. In some instances these animals are protected by law and their capture is illegal. In others, their capture is a waste of a resource.

Global response to reduce bycatch

In response to concerns over the capture of turtles and other bycatch in shrimp trawls, fishermen in many countries have taken steps to modify the trawl net and use bycatch reduction devices[3]. The most common modifications are TEDs to prevent the

[3]In this guide the term 'bycatch reduction device' refers to any device or modification made to the trawl net to reduce bycatch. Many countries have developed regulations that define a TED as a device to exclude sea turtles from the trawl and a BRD (which is the acronym for bycatch reduction device) as a device to exclude fish and other small bycatch from the trawl. In this guide, use of the acronyms TED and BRD is based on these definitions, and the term bycatch reduction device includes both TEDs and BRDs and any other modification to the trawl to reduce bycatch.

capture of turtles and other large animals and BRDs to prevent the capture of fish bycatch.

The United States (US) has played a leading role in these efforts by developing and testing a large range of TEDs and BRDs. These efforts have been ongoing since the mid-1980's and the use of these devices is now a mandatory requirement in most shrimping grounds in the Gulf of Mexico and South-western Atlantic shrimp fisheries. Based on their proven ability to exclude at least 97% of turtles that enter a shrimp trawl, several TED designs have been approved for use in these waters. Two types of BRD, the Jones-Davis BRD and the fisheye, are currently approved for these waters based on their ability to reduce fish bycatch, and in particular red snapper. The US has also been responsible for accelerating the global development of TEDs in tropical shrimp-trawl fisheries. This has been achieved through the introduction of an embargo on wild-caught shrimp from countries that do not have in place an effective sea turtle conservation program. This has forced many countries to respond appropriately by requiring the mandatory use of approved TEDs by local shrimp fishermen.

In Mexico, TED development and research also has a long history and these devices are now a mandatory requirement in the industrial shrimp-trawl fleets in the Pacific Ocean and Gulf of Mexico. BRDs such as the fisheye are also being used, and there is ongoing development of a prototype trawl system that not only reduces bycatch and seabed impact, but has the potential to reduce fuel consumption.

In Australia, TED and BRD development has been ongoing for well over a decade. In all tropical Australian shrimp fisheries TEDs are required to protect turtles and most require the use of BRDs to reduce the capture of unwanted fish and other bycatch. In nearly all Australian temperate water shrimp fisheries, BRDs such as inclined grids, composite square-mesh windows and fisheyes are required to reduce fish bycatch. Australia is also one of only two countries (Brazil being the other) where the US embargo has been lifted from individual fisheries following the introduction of an effective turtle protection program.

In Southeast Asia, attempts are being made to reduce the capture of turtles and other bycatch, particularly the catch of juvenile fish of commercial importance. The Southeast Asian Fisheries Development Centre (SEAFDEC) is an inter-governmental organization that has been leading the way in this region and has developed and tested several TED and BRD designs. SEAFDEC has developed a Juvenile and Trash Excluder Device (JTED) and has tested it widely throughout the region with good success. They have also developed a specialized TED to better suit local fishing conditions called a Thai Turtle Free Device (TTFD). Several countries in Southeast Asia, including Thailand, Indonesia, Malaysia and the Philippines, have been working toward the mandatory introduction of TEDs into their shrimp-trawl fisheries to reduce turtle capture and seek removal of the US embargo.

In the Arabian Gulf several countries are also currently testing and developing bycatch reduction devices, partly due to concerns over the capture of

The catch on the right includes large animals because a TED was not fitted to the trawl. The catch on the left is the result of using a TED.

In many countries TEDs are being used to exclude turtles and other large animals from the trawl.

turtles and the discard of large numbers of small fish and other bycatch, and partly in response to the US embargo. In Iran the testing of bycatch reduction devices has been ongoing for several years, and the Northern Australian Fisheries TED (NAFTED) and fisheye has proven to be an effective combination to reduce bycatch. Recently the performance of several bycatch reduction devices was assessed in Kuwait on both industrial and artisanal trawlers (dhows), including TEDs, the fisheye, a radial escape section (RES), and a square-mesh codend. The performance of these devices was encouraging and their development is continuing. In Bahrain there have also been efforts to reduce small fish bycatch.

Many other countries in Latin America, the Caribbean, Asia and Africa are also working toward the development of effective bycatch reduction devices. In Nigeria the fisheye has been effective in reducing catches of juvenile fish and TED development is ongoing, while Mozambique has recently made TEDs a mandatory requirement in their shrimp-trawl fishery. Research into bycatch reduction is ongoing in Colombia, Costa Rica, Ecuador, Guatemala, India, Pakistan, Trinidad and Tobago, and Venezuela.

FAO response to reduce bycatch

The FAO is at the forefront of TED and BRD research in developing countries. Since 2002 FAO has executed a five-year global project called 'Reduction of discards and environmental impact from fisheries'. This project concentrates on four tropical regions of the world, namely Latin America including the Caribbean, West Africa, the Gulf Region and Southeast Asia. It is funded by the Global Environment Facility (GEF) and is implemented by the United Nations Environmental Programme (UNEP). Key objectives of the project include minimising the capture of bycatch, such as turtles, fish and other animals, and the impact of

A BRD is a trawl modification designed primarily to reduce fish bycatch.

shrimp trawling on the seabed. The project aims to achieve these objectives through the introduction of more appropriate fishing gear, and improved fishery legislation and management frameworks.

The *FAO Guide to Bycatch Reduction in Tropical Shrimp-Trawl Fisheries* is a result of this project. It is written primarily for fishermen and others interested in the practical aspects of bycatch reduction devices, including their design, installation and operation. The Guide includes technical information and construction details for many devices that have proven to reduce bycatch in tropical shrimp-trawl fisheries, and provides technical details about their selection, placement and maintenance. Flow charts enable fishermen to assess a TED or BRD and provide a framework to assist with testing and implementing these devices to suit their specific needs. Fishery managers, policy-makers and others will find this guide useful to help understand the design, use and application of bycatch reduction devices in a shrimp-trawl fishery. This information will aid the smooth introduction of these devices into a fishery and their rapid adoption by fishermen. It will help the development of regulations and specifications that are not only effective in reducing bycatch, but that also encourage fishermen to further develop these devices and optimize their performance. Importantly this information will also encourage high levels of compliance by fishermen.

A glossary of terms may be found on page 100 and an abbreviations list on page 110.

Shrimp fishermen all over the world are acting responsibly to reduce the capture of turtles and other bycatch by using TEDs and BRDs. Note the TED on the middle trawler.

What is Bycatch?

In its broadest sense, bycatch includes all non-target animals and non-living material (debris) which are caught while fishing. In shrimp-trawl fisheries bycatch may be defined as anything the fisherman does not intend to catch and may include turtles, fish, crabs, sharks, stingrays, pieces of coral, weed and seabed debris. Sometimes this is called incidental or accidental catch.

Bycatch also includes animals and non-living material that interact with the fishing gear but do not reach the deck of the fishing boat. This includes coral and weed that are contacted by the passing ground gear and small fish that are selected out of the net. These interactions are often brief, lasting no more than a split-second, and could be a major source of unaccounted mortality. This part of the bycatch has not been well researched, but failure to account for this mortality is counter to the notion of sustainable fisheries and may threaten the health of the ecosystem.

Shrimp trawling is a relatively unselective fishing method because large volumes of bycatch are typically retained in the codend comprising several hundred species. In large industrial fisheries this bycatch is usually discarded overboard, but in small-scale fisheries it has commercial value and is used either for human or animal consumption. In Southeast Asia and West Africa this part of the bycatch is called trash fish. In Australia any part of the catch that is retained for sale is called byproduct.

Bycatch from shrimp trawling includes fish and other animals of all sizes.

What are discards?

Discards are that part of the bycatch that are released or returned to the sea either dead or alive. It also includes all animals and non-living material that interact with the fishing gear but do not reach the deck of the boat. The discarded catch may consist of species of low commercial value, under-sized commercially important species, juveniles and seabed debris. Fishermen usually discard this part of the catch because it is not economical to retain it onboard or regulations forbid it from being landed.

Sometimes catches of commercial species exceed the processing or preservation capacity of the fishing boat and the excess catch has to be discarded. This might occur if the crew are unable to sort through the catch before the onset of spoilage, if ice supplies are insufficient to cool the catch or if storage space is inadequate. Discarding might also be the result of a practice known as high-grading. This practice is where fishermen dump catch previously landed to make room for a more valuable or fresher catch. For example, in some small-scale shrimp fisheries, catches landed in the early part of a fishing trip may be discarded to make space for a similar-sized catch taken at the end of the trip.

Baskets of trash fish ready for sale. Trash fish is a threat to sustainable fisheries and food security because it includes juvenile fish.

What is trash fish?

This term usually applies to small, undersized fish and other animals that were traditionally discarded overboard because they had no economic value. However, in recent years this part of the catch has become a substantial source of income for many small-scale fishermen because it can be sold as fish meal or food for cultured fish or shrimp. For some fishermen, trash fish may generate over one-third of their income from the catch. In fisheries where trash fish are landed, codend mesh size may be as small as 15mm and few animals escape. This practice poses a threat to sustainable fishing in the region because juvenile fish are also included as trash fish.

The term trash fish is misleading because it suggests this part of the catch has no ecological or commercial value. Clearly this is not the case.

Why Reduce Bycatch?

The FAO has recently estimated that over 7 million tonnes of fish bycatch are discarded every year by commercial fishermen around the world. Shrimp trawling is a major contributor to this total, and not surprisingly, there is a call to reduce this bycatch or to find ways of using more of it. There are also calls to eliminate catches of other bycatch from shrimp trawling including sharks, stingrays, and sponges, as well as catches of endangered or protected species, such as turtles, sea snakes and some fish.

The FAO Code of Conduct for Responsible Fisheries requires fishermen worldwide to reduce bycatch and the environmental impacts of fishing. The code establishes principles and standards applicable for responsible fishing activities. It specifically requires that countries take steps to ensure that fishing operations reduce bycatch and waste, and that the environmental impacts of fishing are minimized. The code is voluntary in nature, but it does reflect global concerns regarding the need to reduce bycatch. Similar codes of conduct have been produced by other countries or inter-governmental organizations such as SEAFDEC. These codes require similar outcomes and are usually localized to suit regional or local needs. In addition to codes of conduct, many countries have introduced environmental policies requiring fisheries to be managed under the principle of ecologically sustainable development (ESD) and that bycatch be reduced as much as practicable.

In many countries, fishermen have been acting responsibly to these calls by testing or adopting TEDs and BRDs to reduce bycatch. The use of TEDs is now mandatory in many countries and the capture of turtles (and other large animals) is increasingly an issue of the past. There is now clear evidence that TEDs have contributed positively to the recovery of turtle populations. In the United States, for example, there is documented evidence that numbers of Olive Ridley turtles has increased dramatically since the introduction of these devices to the region. This is an excellent outcome.

Bycatch from shrimp trawling usually consists of many fish species and occasionally large animals.

Bycatch also includes sponges and rocks and may reduce the quality of the shrimp catch.

Shrimp fishermen are also increasingly using BRDs to reduce the capture of fish and other bycatch. In many countries fishermen have been using these devices for some time and there has been a substantial reduction in fish bycatch. However, there is still much work to be done. Bycatch levels are still too high and fishermen are still struggling to optimise the performance of these devices to exclude the many species that are caught in a shrimp trawl.

A common perception by other stakeholders is that shrimp trawls sweep large expanses of the ocean, catching all animals in the path of the trawl. Sure, shrimp trawling is a relatively unselective fishing method compared to many other methods, however not all animals in the path of the trawl are caught. Some animals pass under the ground gear while others escape around the side or over the headline of the trawl. In fact, shrimp fishermen have been using fishing methods designed to reduce the capture of many of these animals, including:

- trawls with a low headline height to minimise fish catches,
- ground chain arrangements that reduce the amount of seabed animals, rocks and debris taken,
- avoidance of fishing grounds where bycatch is known to be high, including grounds where coral, sponges and rocks are present,
- using mesh sizes big enough to allow some small animals to escape, and
- using TEDs and BRDs.

While misconceptions exist and some fishermen still catch large volumes of bycatch, there will be continued pressure to further reduce bycatch. Moreover, as other animals are listed for protection from human impacts, fishermen will be required to reduce their threat to these animals. If the bycatch issue is not tackled appropriately it could lead to eventual closure of sections of productive fishing grounds, or worse, closure of whole fisheries. This has already occurred in the United States and Australia.

To successfully reduce bycatch fishermen must be part of the research process. This will result in rapid development of effective TEDs and BRDs and higher compliance with the rules and regulations. In addition, understanding the concerns of fishermen, such as the costs of these devices and fears of shrimp loss, are matters that must be accommodated as they influence their uptake rate and adoption of these devices.

A key to the successful involvement of fishermen is to explore how they may benefit from reducing

In some fisheries large TEDs are now being used to rapidly exclude turtles and other large animals from the trawl with little shrimp loss.

bycatch. These benefits may include:

- improved trawling and processing efficiency,
- better product quality and marketing opportunities, and
- protecting the marine environment and extending the life of the fishery.

Trawl and processing efficiency

Reducing bycatch may improve trawl and processing efficiency because:

- trawl duration can be longer, thus decreasing the time lost to repeatedly haul and deploy the trawl,
- wingend spread may be maintained for longer periods because the drag of the catch is less,
- damage to the codend caused by large animals and rocks can be reduced,
- processing (sorting) time should be quicker, and
- injuries to crew from dangerous animals will be reduced.

Product quality and marketing opportunities

Keeping heavy animals such as sharks and stingrays out of the trawl means fewer damaged shrimp in the codend and a more valuable shrimp catch. Reducing the numbers of unwanted fish can make sorting and processing a lot quicker, contributing to better shrimp quality, particularly during the heat of the day. These shrimp may attract a higher price and lead to higher income for the fishermen.

In some instances fishermen may gain new marketing opportunities through the sale of shrimp caught using trawls fitted TEDs and BRDs. As consumers become more environmentally aware they are increasingly redirecting their seafood purchases toward products that have been caught using environmentally-friendly fishing methods. This is increasingly obvious in developed countries and there are signs of this occurring in developing countries.

Food security

Shrimp trawling can pose a threat to food security, particularly in developing countries. This is because many shrimp fishermen use very small meshes in the trawl and codend so that the escape of small, juvenile fish and other animals (trash fish) is difficult. The addition of a small mesh cover surrounding the codend ensures that almost no animals escape from the trawl.

The capture and discarding of these animals is a waste of a source of food. These animals are usually dead or dying when landed, and therefore do not have the opportunity to reproduce or grow to a size more suitable for human consumption. Given an opportunity to grow and become adults these fish would better contribute to overcoming the

Large catches take a long time to sort and are demanding on the crew.

Clean catches of shrimp with little bycatch means rapid sorting and a good quality product.

problem of food security in developing countries. In addition, the capture of these animals is clearly a threat to reproductive capacity of each species and the health of the ecosystem. Retaining this part of the catch for sale may increase this threat because fishermen will deliberately target these animals, particularly if shrimp catches are poor. They are also less likely to be willing to use a bycatch reduction device and forgo valuable income.

Protecting the marine environment

There is growing global concern that shrimp trawling is affecting the marine environment by catching bycatch and damaging the seabed. Studies suggest that shrimp trawling can have a detrimental effect on some marine ecosystems and may even damage the shrimp fishery itself. This is because the environment that supports the shrimp fishery consists of many linked parts, and damage to one part may lead to changes in other parts of the system. This can be a particular problem in fisheries where fishermen rely heavily on the bycatch, including juvenile fish, to supplement their income.

By reducing bycatch, shrimp fishermen will help to:

- ensure the health, diversity and integrity of the environment,
- enhance shrimp stocks in some fisheries by catching fewer juvenile shrimp, and
- protect fish stocks by keeping juvenile and adult fishes out of the catch.

By using bycatch reduction devices and adopting a positive, pro-active attitude fishermen can reduce or deflect criticisms by other stakeholders. This criticism is largely undermined when fishermen are behaving responsibly to reduce bycatch and the impacts of fishing.

By excluding bycatch fishermen can reduce the impact of shrimp trawling on the marine environment.

The ABC of TED and BRD Design

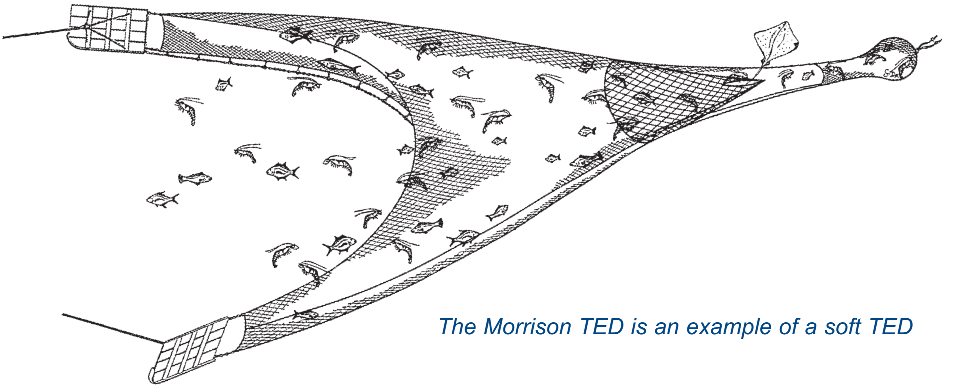
This section answers some of the questions fishermen frequently ask about the design of TEDs BRDs. It describes the major types of devices currently available to reduce bycatch. The advantages and disadvantages of each device is also provided based on the assumption that excluding all bycatch - both living and non-living - from the trawl is a desirable outcome. In the subsequent section details are provided about choosing and testing a TED or BRD.

What is a TED?

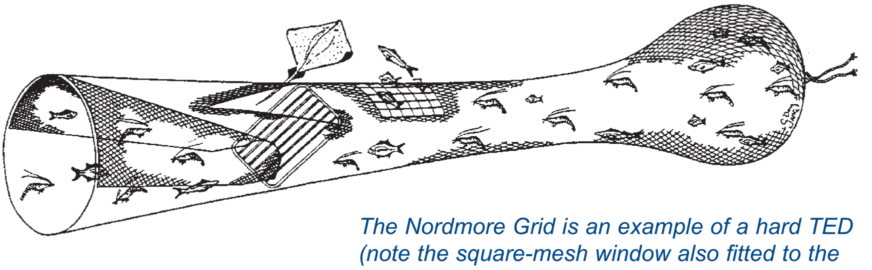
In the context of this Guide, a TED or 'turtle excluder device' is any modification to a shrimp trawl designed to reduce the capture of turtles. These devices are sometimes called a 'trawl efficiency device' because they can also prevent the capture of other large animals including sharks, stingrays, jellyfish and some large fish.

The most common TED designs use an inclined grid to prevent large animals from entering the codend. A panel or funnel of netting immediately in front of the grid may be used to direct animals away from the escape opening and to maximise the length of grid available to separate large animals from the shrimp and small bycatch. Large animals are then guided by the grid toward an escape opening located either in the top or bottom of the codend. Small animals (including shrimp) pass through the bars of the grid and enter the codend. The escape opening is a hole cut in the codend and is usually covered with a flap of netting or other material to prevent the escape of shrimp.

A less common TED design uses an inclined netting panel instead of a grid. The netting guides large animals toward an escape opening in the top panel of the trawl while small animals pass through the meshes and enters the codend.



The Morrison TED is an example of a soft TED



The Nordmore Grid is an example of a hard TED (note the square-mesh window also fitted to the codend)

What is the difference between a 'hard' and a 'soft' TED?

Depending on the material used to construct the inclined grid or netting panel, TEDs are either 'hard' or 'soft. A hard TED typically uses a rigid grid made of aluminium, steel or plastic, for example, the Nordmore grid and Super Shooter. These are the most common types of TED currently used worldwide. Hard TEDs have been criticised as a possible safety hazard to crews, particularly in rough weather, but these fears are largely unfounded.

Soft TEDs use a non-rigid inclined panel of netting to guide bycatch towards the escape opening in the top of the trawl. Examples of this TED include the Morrison TED, the Parker TED and the 'blubber' chute. Soft TEDs have been found to be less effective in excluding heavy sponges and other seabed animals because these foul the netting. The Parker TED is now the only soft TED approved for use in the Gulf of Mexico and South-western Atlantic shrimp fisheries.

Hard TEDs

Advantages:

- Very large escape opening may allow large leatherback turtles and other large animals to be rapidly excluded
- Exclude some seabed animals (sponges, corals etc.) and rocks (downward-excluding TEDs only)
- May increase shrimp catch due to longer towing time (less drag and fewer hauls)
- May reduce sorting time
- May improve shrimp quality by reducing contact with large animals
- Reduce hazard to crews from large, dangerous animals

Disadvantages:

- Damage, fouling or clogging of the guiding panel or funnel by large animals and debris could lead to shrimp loss
- Fouling of escape opening by large animals and debris could lead to shrimp loss (a.k.a TEDed)
- A little more difficult to handle than a standard codend
- Rigid grid may be a safety hazard to crew (depends on location in codend)

Soft TEDs

Advantages:

- Very large escape opening may allow large leatherback turtles and other large animals to be rapidly excluded
- May increase shrimp catch due to longer towing time (less drag and fewer hauls)
- May reduce sorting time
- May improve shrimp quality by reducing contact with large animals
- Reduce hazard to crews from large dangerous animals

Disadvantages:

- Poor installation may affect trawl performance
- Damage, fouling or clogging of the guiding panel by large animals and debris could lead to shrimp loss
- Effectiveness depends on trawl spread
- More difficult to repair than a standard trawl
- Less effective than hard TEDs at excluding heavy items such as rocks and sponges

What are BRDs?

In the context of this booklet, a BRD is any modification designed principally to exclude fish bycatch from a shrimp trawl. These devices may also exclude other animals and non-living material (debris), but because fish usually dominate the bycatch most BRD research has attempted to exclude these animals from the trawl. Most BRDs are located in the codend of the trawl as this is where the catch is accumulated and the opportunity to escape is high.

The JTED is a BRD that filters small fish including trash fish from the catch but not the larger shrimp.

How do BRDs work?

There are two categories of BRD depending on the principle method used to exclude bycatch from the trawl. The first category are BRDs that separate the catch by size. These devices use inclined grids or panels of netting to physically block the passage of bycatch into the codend and guide it toward an escape opening. Depending on their design, these devices exclude bycatch either larger or smaller than shrimp from the trawl. The grid-style JTED and square-mesh codend are examples of BRDs that exclude small animals from the trawl. TEDs can also be included in this category because they exclude large bycatch animals from the trawl.

The second category of BRDs are those that exploit behavioural differences between shrimp and bycatch. Most fish can swim in a moving net, orientate to the direction of tow, and swim out through an escape opening. This behaviour is principally the result of fish responding to the visual stimulus of the trawl and the generation of water turbulence as the trawl is towed through the water. Shrimp, on the other hand, generally exhibit little directional swimming and passively enter the codend. They respond principally to tactile stimuli (touch) and have limited capability to swim in a moving trawl and through an escape opening. Examples of this type of BRD are the fisheye, square-mesh window, Jones-Davis BRD and RES.

The design of the RES allows fish to swim forward in the codend and escape through the large escape openings.

What is a JTED?

JTED stands for 'juvenile and trash excluder device'. This device is designed to exclude small fish - usually juvenile or trash fish - from the trawl and maintain the catch of shrimp and large fish. The JTED consists of three sections hinged together; the first two sections are metal grids and the third section is a metal frame supporting a panel of fine-mesh netting. Small fish swim between the bars of the grids and escape. The netting panel in the third section helps maintain the orientation of the device, prevents shrimp surging forward in the codend and escaping, and prevents small fish from re-entering the codend. The JTED was designed by SEAFDEC and has been tested in shrimp fisheries in several countries including Vietnam, Thailand, Malaysia, Myanmar, Philippines, Brunei Durrussalam and Indonesia.

The SEAFDEC has also developed two rope JTEDs. One design is a rectangular stainless steel frame fitted with tightly strung parallel ropes. The frame is inserted into the top of the codend with the ropes oriented lengthways along the codend. Small fish escape from the trawl by rising upward between the ropes of the JTED. An alternative version of this device is a cylinder of codend netting with a stainless steel hoop fitted to both ends. The entire cylindrical section is then inserted in the trawl ahead of the codend. Similarly to the first rope JTED, a row of parallel ropes is used to provide escape openings for the fish.

The rope JTED is designed to allow fish escape between the parallel ropes.

JTED

Advantages:

- Exclude small fish and trash fish
- May increase towing time (less drag and fewer hauls)
- May reduce sorting time
- Bar spacing can be reduced if grid is attached to an outer frame
- Rope spacing can be easily adjusted (rope JTED only)
- Relatively simple design and easy to use (rope JTED only)
- May increase shrimp catch due to longer towing time

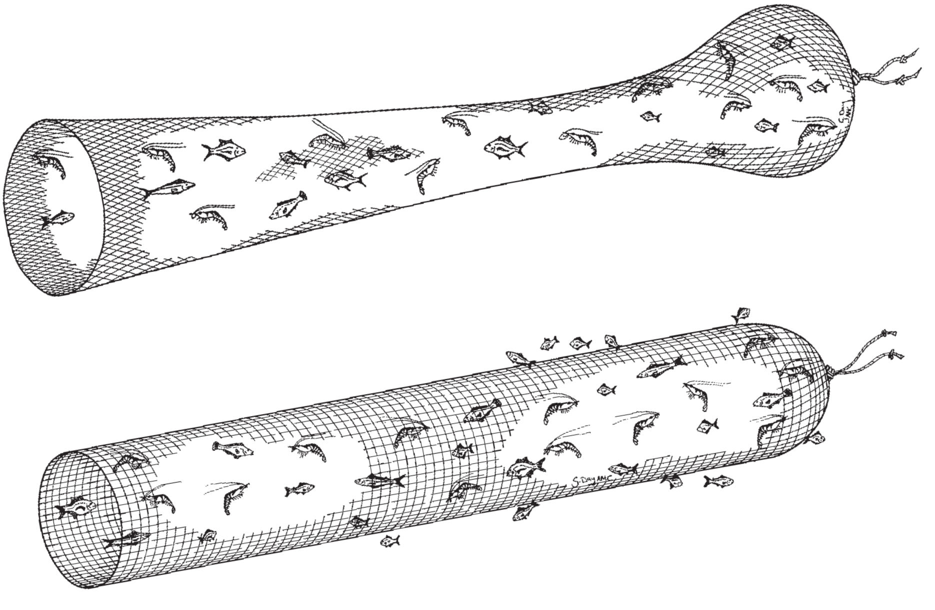
Disadvantages:

- Complex design compared to other devices (grid-style JTED only)
- High construction cost (grid-style JTED only)
- Hinges may become clogged with mud and other debris and affect grid orientation (grid-style JTED only)
- Relies on small fish having the ability to swim forward and upward through the escape openings (rope JTED only)
- May allow large, valuable fish to push ropes aside and escape (rope JTED only)
- Ropes may stretch and become slack (rope JTED only)

Can square-mesh codends help reduce bycatch?

A codend constructed entirely from square-mesh netting can allow a substantial amount of small fish and other bycatch to escape. This is because square-mesh netting stays open for the duration of the tow, unlike diamond-mesh netting that closes under the weight of the catch. The selection of mesh size is very important and trial and error is needed to find the mesh size that maximises fish exclusion and prevents shrimp loss. Typically, this mesh size will be 60 - 90% of the diamond mesh size. Square-mesh codends can also be constructed from knotted diamond-mesh material and oriented sideways. However, this is a wasteful use of netting material and the knots will eventually slip and distort mesh geometry (unless ropes are hung along the length of the codend to support the netting under load).

The last section of this square-mesh codend is replaced with diamond-mesh to prevent shrimp escape.



The mesh openings of a traditional diamond-mesh codend collapse as it fills with catch and prevents the escape of small fish. In contrast, the mesh openings of a square-mesh codend retain their shape as it fills with catch and are available for fish to escape.

Square-mesh codends

Advantages:

- Small fish bycatch may escape
- May reduce sorting times
- May increase towing time (less drag and fewer hauls)
- May increase shrimp catch due to longer towing time
- Less reliant on behaviour and swimming ability to exclude small fish and animals
- May exclude small seabed animals and debris

Disadvantages

- Shape of fish affects escape rates, so some species are more likely to escape than others
- Relatively difficult to construct, particularly a combined diamond- and square-mesh codend
- Square-meshes may distort if not correctly attached to a diamond-mesh netting
- More difficult to repair than traditional diamond-mesh
- Material wastage and knot slippage, if constructed from diamond-mesh

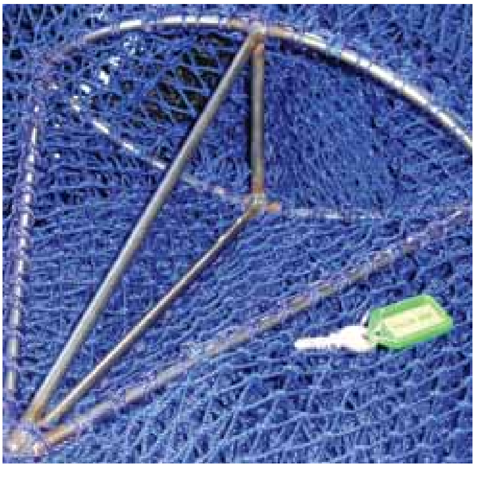
Some fishermen are more comfortable using a codend constructed from both square- and diamond-mesh because this may prevent the escape of small shrimp. One option is to replace the top panel of a diamond-mesh codend with square-mesh. Another option is to replace the entire middle section of the codend with a cylinder of square-mesh netting. In this way the last part of the codend is constructed from diamond-mesh netting so that it closes under load and prevents small shrimp from escaping. Presumably these BRDs are less effective in reducing the catch of small fish and other bycatch because there are fewer openings for these animals to escape and they may become blocked by gilled fish, seaweed or debris. There is also considerable work attaching the square-meshes uniformly to the diamond-meshes.

What are fisheyes and how can they help to reduce bycatch?

A fisheye is an elliptical steel or aluminium frame fitted to the codend through which fish swim to escape. Fisheyes are usually placed in the top or sides of the codend so that strong swimming fish can escape, while shrimp passively enter the codend.

Fisheyes must be inserted in the codend so that fish swim forward to pass through the escape opening. The location of the fisheye is important. If it is too close to the accumulated catch shrimp loss can occur during haul-back, particularly during rough weather. On the other hand, it should not be located too far forward as fish swimming ahead of the accumulated catch are unlikely to reach the escape opening. The optimal position of the fisheye is difficult to predict given that performance is influenced by fish behaviour, catch composition and volume.

The fisheye is designed to allow strong swimming fish to escape from the trawl.



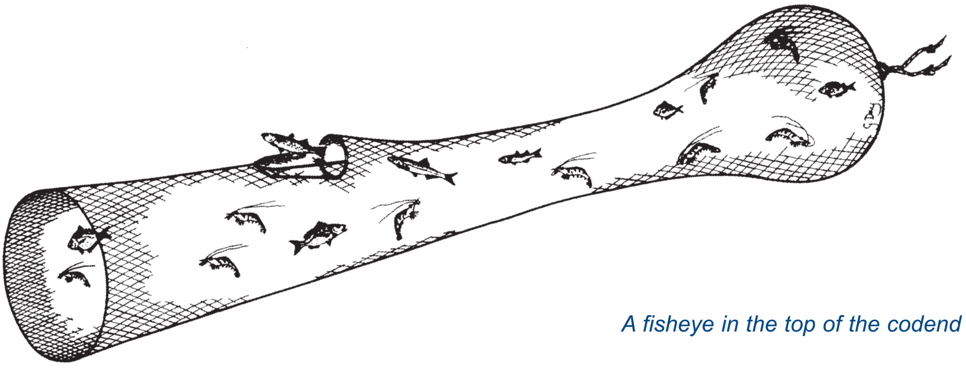
Fisheyes

Advantages:

- Simpler design and cheaper than many other BRDs
- Lower maintenance than other BRDs
- Easily moved to different positions in the codend
- May increase shrimp catch due to longer towing time (less drag and fewer hauls)
- May reduce sorting times
- Easy to handle

Disadvantages:

- Will not exclude seabed animals and debris
- Poor escape for species that behave in the same way as shrimp
- Optimal position difficult to determine
- May foul on the side of the vessel during hauling



A fisheye in the top of the codend

What is an RES and a Jones-Davis BRD?

The RES was developed to exclude large fish bycatch. It consists of a tapered netting funnel attached to the codend surrounded by large escape openings that extend radially around the codend circumference. All animals in the trawl pass through the funnel and are directed toward the middle of the codend. As fish exit the funnel, some turn and swim forward, and escape through the escape openings. Water turbulence around the outside of the funnel helps fish to swim forward and escape. The escape openings are usually constructed from large square-mesh material, although they may simply be large openings cut into the codend. In the USA this BRD is known as the 'expanded mesh design' or the 'extended funnel design' if the tapered funnel has an overhanging upper section at the trailing end.

The Jones-Davis BRD is similar to the RES but the escape openings are simply large holes cut into the codend netting. A cone fish stimulator (deflector) or a float located behind the tapered funnel may be used to promote fish escape.

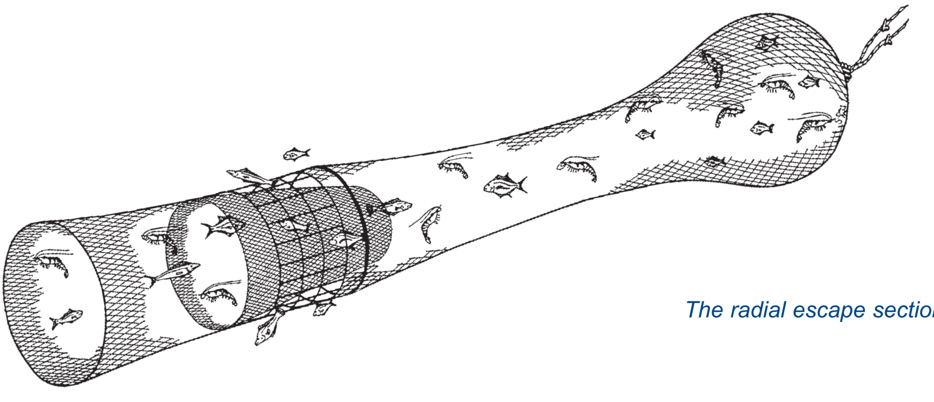
RES and Jones-Davis BRD

Advantages:

- Large escape openings allow large fish to escape
- May increase shrimp catch due to longer towing time (less drag and fewer hauls)
- May reduce sorting time

Disadvantages:

- Will not exclude seabed animals and debris
- Funnel may become clogged
- More complicated design than most other fish excluders
- May foul on the side of the vessel during hauling
- More difficult to handle than a standard codend



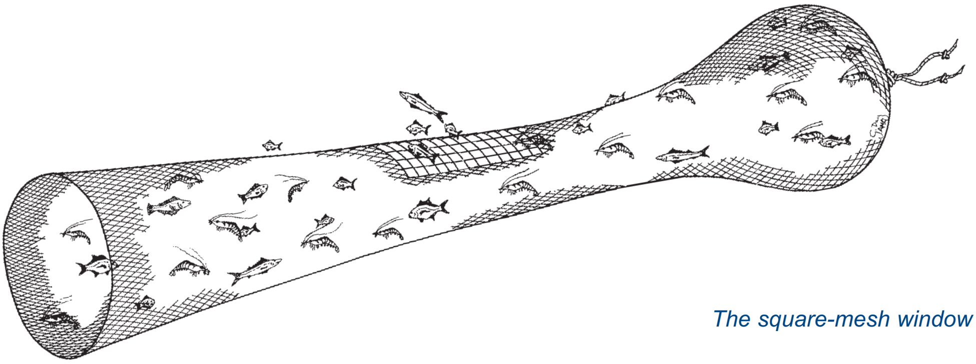
The radial escape section

What is a square-mesh window and how might it reduce bycatch?

A square-mesh window is usually a panel of square-mesh netting located in the top panel of the codend or trawl body. As fish pass through the trawl they orientate directionally toward the device and swim through the square escape openings. The selection of mesh size is very important and trial and error is needed to find the mesh size that maximises fish exclusion and prevents shrimp loss. Like the fisheye the size and location of the square-mesh window is also important. The top of the codend is the favoured position, as this reduces shrimp loss, and it should not be too close to the catch in the codend or shrimp will be lost. Conversely, if the square-mesh window is located too far forward in the codend, fish swimming ahead of the accumulated catch will be unable to swim forward and reach the escape openings.

Large square-mesh windows have also been tested in the top panel of the trawl in the tapered section of the trawl body immediately ahead of the codend or behind the headline. The success of these windows has generally been limited because shrimp loss can be very high, particularly if large volumes of shrimp enter the trawl simultaneously.

These fishermen are using a very large square-mesh window to exclude fish bycatch from the trawl.



The square-mesh window

Square-mesh windows

Advantages:

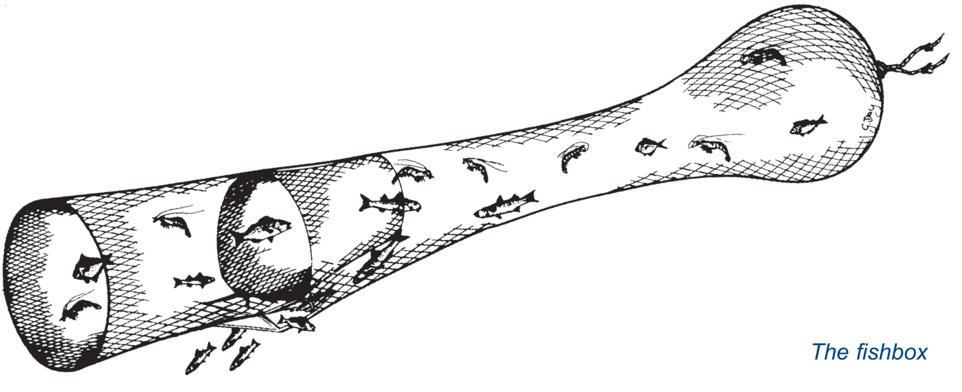
- Small fish bycatch may escape
- Relatively simple design and easy to use
- May reduce sorting times
- May increase towing time (less drag and fewer hauls)
- May increase shrimp catch due to longer towing time

Disadvantages:

- Shape of fish affects escape rates, so some species are more likely to escape than others
- Square-meshes may distort if not correctly fitted
- Performance (if located in the codend) linked to catch volume
- More difficult to repair than traditional diamond mesh
- Will not exclude seabed animals and debris

What is a Fishbox?

A fishbox is designed to alter the movement of water in the codend. It is a box-like device fitted to the top or bottom of the codend with an opening through which fish can swim and escape. A plastic or metal plate (foil) is installed to the front of fishbox frame and another to the top of the frame. These plates generate water turbulence adjacent the escape openings in the bottom and sides of the device as the trawl is towed through the water. The bulk movement of this water is forward into the fishbox and inclined through the escape opening in the bottom of the device. Many fish species actively seek regions of water turbulence because swimming is easier and it is thought that the inclined movement of water helps direct fish out of the trawl. This is a relatively new BRD that has been successfully tested in the United States and Australia.



The fishbox

Fishbox

Advantages:

- Easily installed
- Large opening allows large fish to escape
- May increase shrimp catch due to longer towing time (less drag and fewer hauls)
- May reduce sorting time

Disadvantages:

- Poor escape for species that behave in the same way as shrimp
- Limited knowledge of fish behaviour and influence of foil design and orientation on fish exclusion rates
- May foul on the side of the boat during hauling
- Will not exclude seabed animals and debris

What other modifications can be used to reduce bycatch?

A range of simple rigging modifications to the trawl may be used to reduce the capture of bycatch. These modifications may not be suitable for all fisheries, and many have not been widely tested, but they may serve to stimulate new ideas. They are:

- A triangular or diamond-shaped cut into the top of the codend. This is a very simple modification that can reduce the capture of strong swimming fish.
- Changes to ground chain settings. This modification may reduce the capture of large sponges and seabed debris. For example, releasing the centre dropper chains of a 'texas drop' ground chain system may allow this bycatch to escape underneath the trawl footrope.
- Longer sweeps between the otter board and trawl. This can be used to reduce the capture of small sea urchins such as 'sea eggs', other benthic animals and seabed debris, although sometimes this may increase fish catches.
- Headline height reduction. By reducing headline height some fish will escape capture by swimming over the headline of the trawl. This modification could reduce catches of schooling or large swimming fish. By reducing headline height, the wingend spread of the trawl may increase and potentially increase catches of bottom dwelling shrimp (and offset any loss of swimming shrimp).
- A length of twine stretched between the otter boards to frighten fish away from the trawl. The twine will vibrate as it is towed through the water, warning fish of the approaching trawl and giving them time to escape.
- A horizontal separator panel. This is a panel of net that divides the trawl into two compartments, each leading to separate codends. This panel allows rocks, shell, crabs and other bottom-dwelling animals to be kept separate from the remainder of the catch. Either codend can be left open if desired or made of larger mesh so that small animals can escape.

The use of long sweeps and headline floats will increase the amount of bycatch that enters a trawl.

- Large mesh barrier across the trawl mouth. The barrier is fitted between the headline and footrope of the trawl to prevent large animals from entering the codend. Fouling by large animals or debris is likely to reduce wingend spread and catching performance.
- Large cuts in the top panel of the net ahead of the codend. This modification has successfully reduced bycatch in daylight fisheries but been less successful during the night. In Australia this modification is known as the Bigeye.
- Square-mesh netting adjacent the footrope of the trawl. This modification has been successfully used in some fish-trawl fisheries to reduce the capture of less mobile seabed animals such as sea urchins and starfish. It has some potential for use in shrimp-trawl fisheries, but has not been widely tested. The success of this modification relies on shrimp passing over the square-mesh panel following ground chain contact.

- Reducing the size of codend covers and chaffing gear. This modification will allow more codend meshes to be available for small animals to escape.
- Increased codend mesh size. This will allow more small animals to escape. It is one of the simplest BRDs to implement but interestingly one of the least favoured options, particularly where small fish are retained for sale. A good starting point for bycatch reduction research.
- Lastridge ropes 'hung' along the length of the codend. This can allow codend meshes to remain open and small fish to escape. Usually at least four ropes are required, and they must be about 5% shorter than the stretched length of the codend. This modification is used mainly for diamond-mesh codends and prevents meshes closing under load from the catch, although it can also be useful in square-mesh codends, particularly if knotted material is used. The effectiveness of this modification is likely to be limited if long codends are used.
- Altering the joining (hanging) ratio of codend meshes to trawl meshes. By reducing the joining ratio the codend meshes are unable to close under load. This may allow more small fish to escape near the front of the codend, but may have limited effectiveness near the accumulated catch.

The mesh size above is small and unselective and few animals will be able to escape from the codend.

These fishermen are using a TED to exclude large animals from the trawl. However the small mesh codend and codend cover will allow few (if any) small animals to escape.

Choosing and Testing a TED or BRD

This section provides information on how to choose and construct a TED or BRD that will suit particular operating conditions. Details on methods of testing a device through collaboration with recognised research organizations are also provided. The subsequent section answers frequently asked questions related to the installation of these devices.

How do I choose a TED or BRD?

The flow diagram on page 24 describes the main steps for choosing and testing a TED or BRD for your particular needs.

The initial choice of a TED or BRD depends on what type of bycatch is going to be excluded. The choice is influenced by:

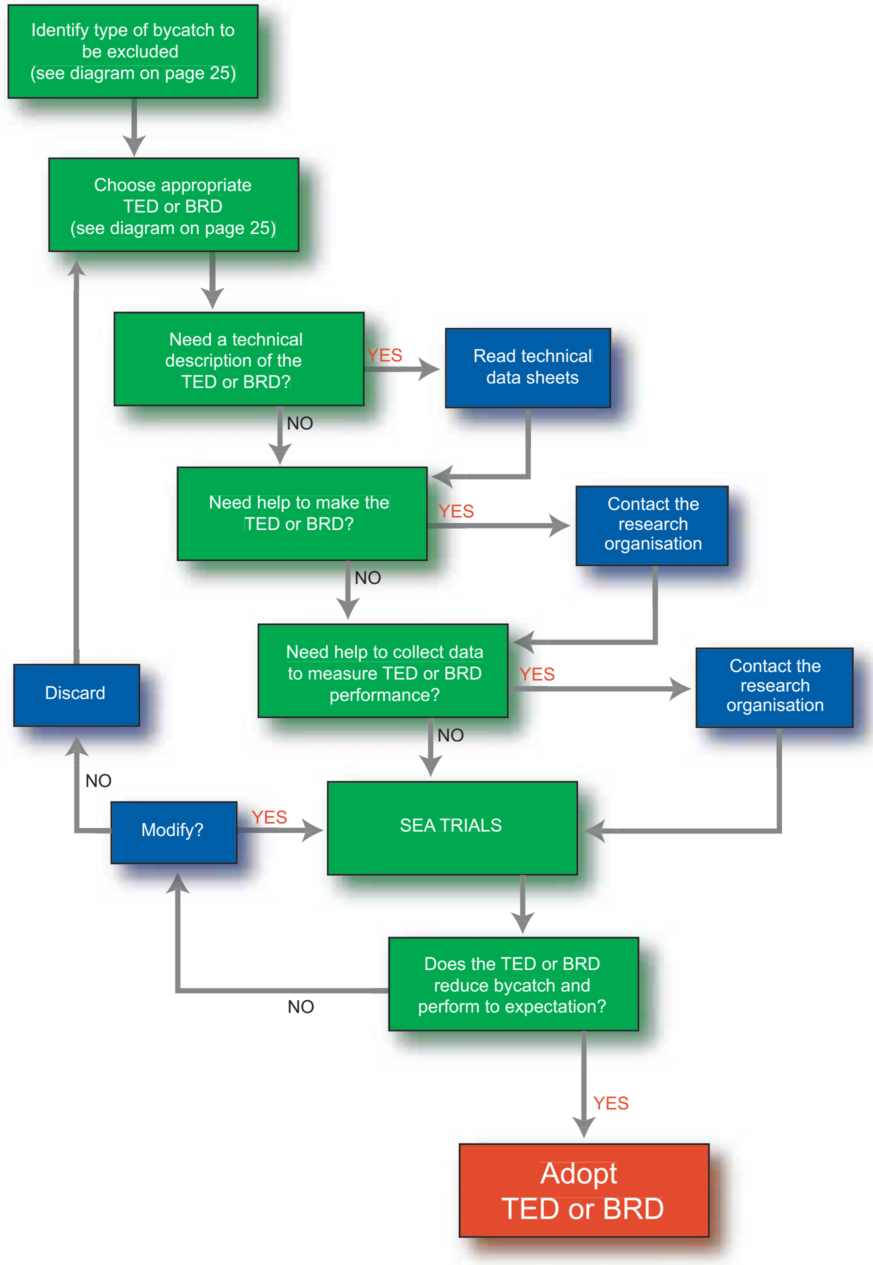
- the need to protect endangered or threatened species,
- the size and behaviour of shrimp being caught,
- the size and behaviour of bycatch,
- variations in catch composition,
- the desire to retain valuable bycatch,
- variations in the amount of bycatch caught through the season and between fishing grounds, and
- the cost of the device.

Clearly, the need to protect endangered or threatened species is a high priority, and it is essential that fishermen choose the correct TED or BRD to exclude these animals from the trawl. However, in some instances this choice may be predetermined by legislation designed to protect these animals. Knowledge of catch composition in all areas of the fishery and throughout the fishing season is also required to choose an effective TED or BRD. This choice may be influenced by a desire to maintain valuable bycatch, and this should not be discouraged providing regulations allow this bycatch to be retained and catch rates are ecologically sustainable. Given the variable size, behaviour and composition of the bycatch it may be necessary to use several different devices simultaneously to maximise bycatch reduction.

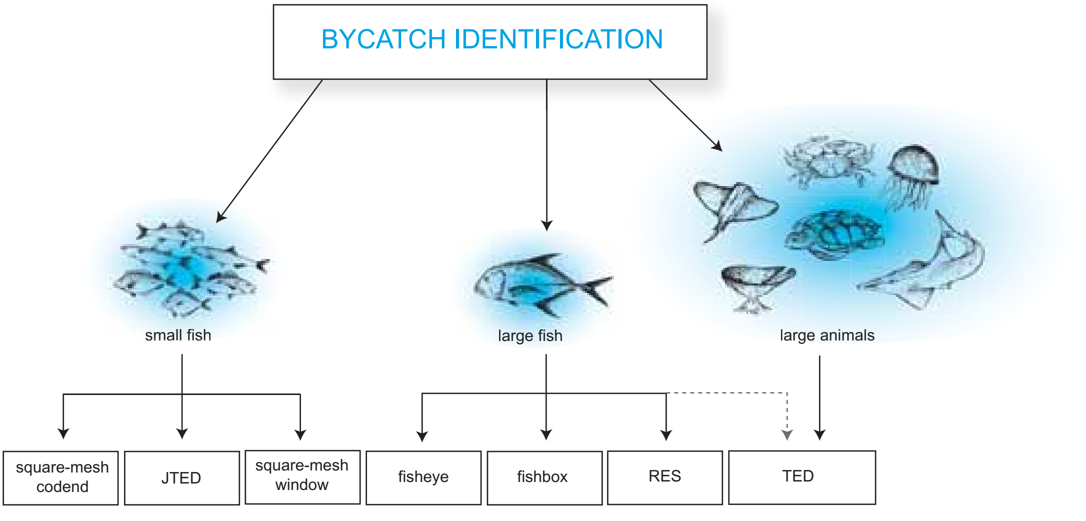
Getting hold of a TED or BRD to test is the next step. The technical data sheets at the back of this guide provide construction details of the most common types of devices available today. At this stage it might also be useful to contact other fishermen, net makers or fishing technologists experienced in the construction and use of these devices. They can provide advice on the TED or BRD best suited for a particular fishery. It is important that the device does not contravene any existing regulations, particularly those related to the design, size or type of the device, and it must not jeopardize the survival of endangered or threatened animals.

By using an upward-excluding TED and a square-mesh window, large animals and fish bycatch can be excluded from the trawl.

How to choose and test a TED or BRD



Choosing a TED or BRD



The first steps toward reducing bycatch is to identify the type of bycatch to be excluded. This is followed by selection of an appropriate bycatch reduction device. In this figure the bycatch that can be excluded by the most common types of bycatch reduction device are shown. The dashed line indicates the less common option used to reduce a particular type of bycatch.

What is the cost of a TED or BRD?

The cost of purchasing or constructing a TED or BRD varies considerably between devices. It is influenced mainly by material availability, cost, and labour rates. A simple device will require less material and time to construct so will be relatively cheap. For example, a square-mesh window can be constructed from scraps of netting and may cost no more than a few dollars at most. It can also be easily made by the fisherman. In south east Asia the cost of a small steel TED may be less than US$100. In contrast, a large stainless steel or aluminium TED in Australia or the United States may cost more than ten times that amount.

Given little experience in the use and operation of these devices it may be wise to select a cheap and simple device, such as a fisheye or square-mesh window. This is a good choice because it is a relatively inexpensive way to get started and will help fishermen gain confidence and experience in their use. It might also be useful to select a device that is currently being used by other fishermen to exclude similar bycatch species. In this way fishermen can be reasonably assured that the device will reduce bycatch and shrimp loss will (hopefully) not be too high.

When fishermen first use a TED or BRD it is possible that shrimp loss occurs relatively frequently and is initially high. It is important not be discouraged. Experience and knowledge are the keys to efficient bycatch reduction.

Collaboration between researchers and fishermen is a key requirement for the successful introduction of a TED or BRD into a fishery.

Who can help with the development and testing of these devices?

To fully assess a TED or BRD it is important to ask:

- is it working? (less or no bycatch),
- is it affecting the size of the shrimp catch? (more or less shrimp),
- is it affecting the quality of the shrimp? (fewer damaged shrimp),
- is it easily handled onboard? and
- is there any change in trawl spread and drag? (longer towing time and greater efficiency)

These are often difficult questions to answer so it might be a good idea to work with a fisheries research organization. Many of them have experience in developing and testing a TED or BRD and can assist with the selection, installation, testing and assessment of the device. While collaboration is not essential, it could save considerable time, effort and money.

It is important to realise that the results of a collaboration are usually more favourably accepted by other stakeholders because the testing program is usually more rigorous (thorough) and involves an independent party. An example of benefits gained by collaboration is provided by SEAFDEC working with researchers and fishermen in Southeast Asia to introduce the JTED. This has resulted in the JTED being tested onboard commercial shrimp trawlers in many countries in the region, including training of fishermen in the installation and operation of the device. The development of an effective turtle protection program and lifting of the US embargo requires all shrimp fishermen in a country to use approved TED designs. This will not happen if there is no collaboration with other fishermen and fishery managers.

Testing TEDs and BRDs

To fully assess the performance of a TED or BRD a detailed testing program is recommended. This will need to be a rigorous process, with performance targets in place to ensure that the device performs as claimed and satisfies the concerns of other stakeholders. In Australia's Northern Prawn Fishery, a testing protocol has been established to help fishermen test their own TED and BRDs and to identify new devices suitable for approval in the fishery. The protocol has three assessment phases:

- an initial assessment phase;
- a visual assessment phase; and
- an at-sea testing phase.

The initial assessment phase involves the fisherman providing members of a special committee brief notes of the TED or BRD to be tested, including a description of the device, its operation and claimed performance. The committee - consisting of a fishing technologist, an independent fisherman and the fishery manager - determines if the device has potential to perform as claimed. The committee will then either request a visual assessment of the device or recommend commencement of the at-sea phase.

The visual assessment phase involves the committee viewing the device or testing it in a flume tank. This phase is required only if some doubt about the claimed ability of the device exists or further clarification is required. It also provides a mechanism to assess complex or unusual TED or BRD designs.

The at-sea testing phase involves the fisherman being provided a permit to test the new device under normal fishing conditions. The committee provides instruction to the fisherman regarding testing conditions, duration and data collection - these instructions are designed to minimize any disturbance to the normal fishing operation and recognize that fishermen usually have limited ability to collect catch data. If the new device performs as claimed then a trained observer may board the boat for several weeks to enable an independent assessment of the device.

Currently a new TED is deemed to have performed satisfactorily if no turtles are caught during the entire at-sea testing phase. This ensures that any new TED design performs as well as those currently approved for the fishery. In the case of a BRD there is no bycatch target at present; the codend with the new device simply needs to retain less bycatch than a standard codend. It has been suggested that new BRD designs should be tested against a currently approved device. The new device would need to exclude the same amount of bycatch or more to gain acceptance as an approved BRD. The new device could also be the benchmark to compare the performance of future devices, and in this way the bycatch target would continue to increase. Once the at-sea testing is completed the results are provided to the committee for recommendation or otherwise as an approved bycatch reduction device.

The benefits of the protocol include:

- a method of demonstrating the achievement of reduced bycatch, while accommodating the difficulties of testing under commercial fishing conditions;

By working together information is exchanged between researchers and fishermen.

- providing fishermen a quick, simple and inexpensive means of assessing TED or BRD performance onboard their fishing boat (they pay only for the device and feed the observer);
- empowering fishermen to take greater control of TED and BRD development (this improves compliance with TED and BRD regulations);
- providing a rigorous testing process that satisfies the concerns of other stakeholders;
- promoting the ongoing development of more efficient TED or BRDs; and
- enhanced bycatch reduction.

To test a specific TED or BRD, obtain more information, discuss issues or to share results, any of the research organizations listed under 'Contacts' on page 108 can be contacted.

TED and BRD Installation
Frequently Asked Questions

Once a TED or BRD has been chosen, there are a number of factors to consider that could affect its performance. The first consideration will be where to install the device in the trawl for optimal performance and how it might influence trawl deployment and hauling. This section attempts to answer these questions.

Choker lifts can prevent the catch from reaching the codend and may drown turtles if located ahead of the TED.

Where should the TED or BRD be installed in the codend?

The location of the TED or BRD is influenced by codend size and rigging, catch volume, fish and shrimp behaviour and towing speed. Large codends usually allow greater flexibility in the location of these devices, particularly if a small codend cover is used. These codends also allow larger TEDs or BRDs to be used with larger and/or more escape openings.

A TED or BRD needs to be positioned so that shrimp are retained in the codend and unable to swim through the escape openings of the device. For BRDs designed to exploit differences in swimming performance between fish and shrimp, the device will need to be located in a position that allows fish to escape but not the shrimp. If located too far ahead of the accumulated catch, fish will struggle to escape but shrimp retention will be good. If located too close to the catch shrimp loss will be high. There is no simple rule for determining the optimal position of these devices because catch volume is seldom consistent. This makes determining the precise location of a BRD difficult. However, as a starting point the BRD should be located about 1 - 2 m ahead of the accumulated catch when the codend is hauled onboard. If shrimp loss is high then the device can be moved further away from the catch. Consideration of weather conditions will also be required in determining the optimum position; in bad weather shrimp loss may be high due to surging of the catch in the coded. Rapid hauling of the codend and maintaining 'way' or forward motion should reduce this problem.

If the lifting gear is placed between the TED and codend the removal of sponges and debris from the trawl is a simple task.

How important is the position and design of the lifting gear?

Poorly positioned or designed lifting gear are a common cause of shrimp loss from trawls equipped

Locating the lifting gear between the TED and codend ensures that the TED remains outboard as the catch is retrieved and minimizes the risk of injuring the crew.

with a TED or BRD. A choker lift is not recommended because it may constrict the codend and interfere with the performance of the device. If placed ahead of the device the constriction may restrict the passage of large animals into the codend and toward the TED or BRD. This may drown turtles and prevent the exclusion of other bycatch from the trawl. The orientation of a device may also be affected by a choker lift in this location. If the choker lift is placed aft of the device, the constriction may impede the passage of shrimp into the codend and they may move forward during haul-back and escape through the TED or BRD.

Lifting ropes or 'elephant ears' have been tested both ahead and behind TEDs and BRDs. Lifting ropes located ahead of the device may restrict bycatch from escaping if water pressure drags the rope over the escape openings. Moreover, hauling and lifting of heavy codends may place considerable strain on rigid devices, such as a TED or JTED, and cause them to become bent or damaged. It is better to position the lifting rope a short distance behind these devices so it cannot block the escape openings and the risk of damage is reduced. The device will also remain out-board as the codend is hauled and emptied, minimising the risk of animals and debris falling out the escape opening and injuring crew. In this position the removal of debris, sponges and other animals fouled by the bars of the grid is also a simple and safe operation. As BRDs such as a fisheye or square-mesh window need to be close to the accumulated catch, the lifting rope may need to be located well ahead of these devices to ensure the hauling rope (lazy-line) does not block the escape openings. Care is also required that the hauling rope does not become twisted. This will twist the 'elephant ears' and block the passage of animals into the codend.

To prevent shrimp loss the hauling rope needs to be long enough to stop the codend and bycatch reduction device from twisting sideways under tow. As a guide, the first 6m (approximately 18 feet) of the hauling rope should hang directly behind the lifting position at the codend when the gear is streamed at the surface.

Will trawl deployment be affected by a TED or BRD?

In most cases, trawl deployment will not be affected by a TED or BRD and the time taken to shoot the trawl away should not change. However, fishermen must be careful to ensure that the codend is not twisted when the trawl is deployed. This may prevent the passage of shrimp through the codend and they may be lost through the escape openings of the device. By watching the device and visible floats as the trawl is being deployed, a fisherman can see if the codend is twisted and rectify the problem without wasting a tow. Increasing vessel speed before deployment may cause the device to sit up higher in the water and better indicate if the codend is twisted. It may also flop to one side but will usually correct itself once the trawl has been deployed. Care must be taken to ensure that turbulent wash generated by the trawler at higher speeds does not cause the TED or BRD to flip over.

Optimizing TED Performance

A well-designed and maintained TED should ensure that large animals and objects are rapidly excluded from the trawl and shrimp loss is minimal or non-existent. This is influenced by the design, construction and rigging of the various TED components under the full range of conditions experienced in the fishery. The maintenance of these components is also important to optimize performance.

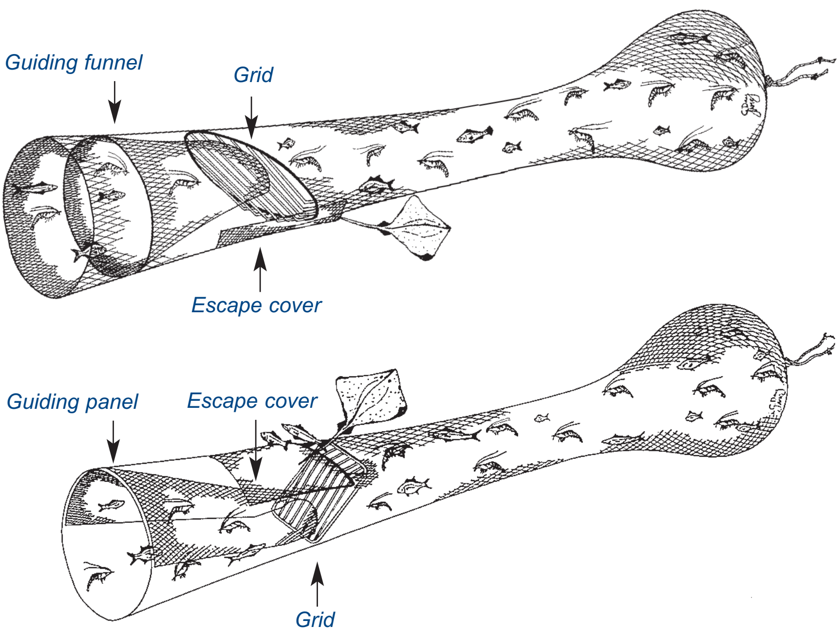
The diagram on page 32 highlights the various design and construction parameters that influence TED performance.

However, research has found that TED performance is not consistent in all areas of a fishery and that performance can deteriorate with time. This has made the task of optimizing TED performance difficult, and highlights the need to seek expert assistance until experience and knowledge is gained.

A summary of the important tips to optimize TED performance is provided on page 42.

Grid size (grid height and width)

Grid size influences the area of the grid that is available to exclude turtles and other large animals from the trawl. Both large and small grids are similarly effective in excluding these animals providing they can quickly pass through the escape opening of the TED. Large grids are usually recommended because they allow larger escape openings to be used. In turn, this allows larger animals to be excluded from the trawl. Large grids also reduce the risk of shrimp loss because they are further from the escape opening as they pass through the grid (particularly if a guiding panel or funnel is used ahead of the grid). Furthermore,



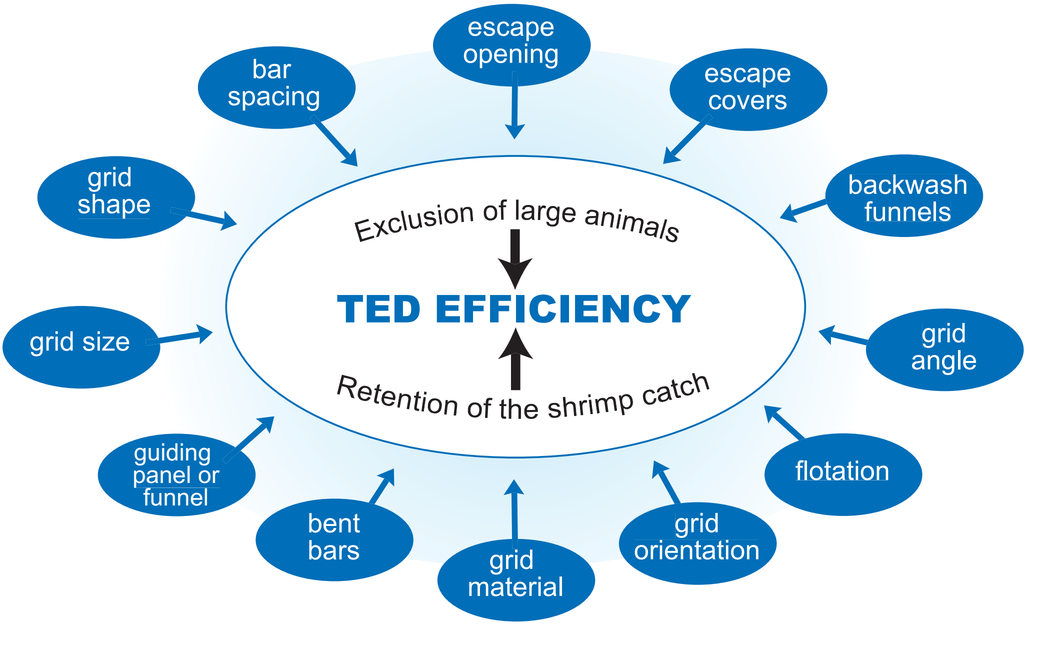
The various components typically incorporated into the design of a downward-excluding TED (top) and an upward-excluding TED (bottom).

when large grids are used the passage of shrimp into the codend is less likely to be hampered by partial blockage of the grid by animals or debris. If shrimp cannot pass through the grid there is a risk they may pass through the escape opening of the TED and escape.

Grid size also affects grid angle and the ability of the escape cover (or flap) to seal tightly over the escape opening. The correct grid size slightly distorts or enlarges the circumference of the codend immediately around the grid. This will allow the escape cover to be tightly held over the escape opening and against the grid by water pressure. The risk of shrimp loss will be low. If the grid is too small, the escape cover may flounder over the escape opening and not seal tightly. The risk of shrimp loss will be high. The height of a rectangular grid is the vertical distance between the top and bottom of the outer frame of the grid when the codend is horizontal. In contrast, the height of a bent-bar grid is usually the vertical distance from the bends in the bars to the outer frame of the grid when the codend is horizontal. For example, if a bottom excluding TED is used this height is measured from the top of the outer frame of the grid to the bends in the bars. This slightly underestimates the true grid height but helps ensure the escape cover seals snugly against the grid.

If a small codend is being used and a large grid is required it may be necessary to increase the circumference of the codend. Some distortion of the codend is necessary but it should not be excessive. It should not be necessary to alter the extension or body of the trawl to fit the new codend.

The various design and construction parameters that influence TED performance and efficiency. Note that a failure to exclude large animals is likely to cause shrimp loss.



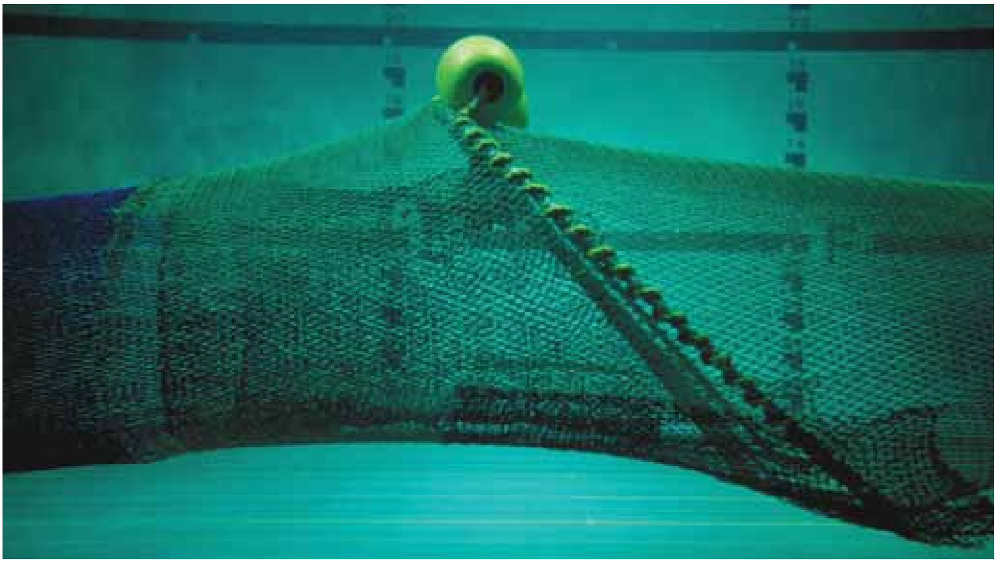
Grid shape

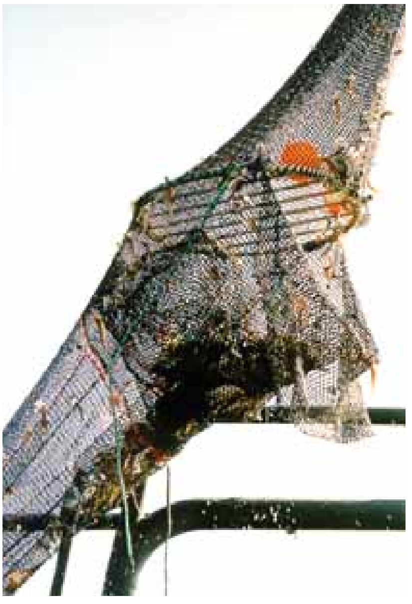
The shape of a grid usually fits into one of three categories; rectangular, oval, or a hybrid rectangular and oval grid (often referred to as a 'tombstone' grid). Rectangular grids are the simplest to construct. They have a relatively large escape opening because it is similar in width to the grid. A disadvantage of this shape is the risk of netting abrasion at the corners of the grid. This can result in broken meshes, loss of grid angle and reduced TED efficiency. A rectangular grid will also distort and stretch the codend meshes adjacent the corners of the grid. With time this will reduce grid angle and compromise TED efficiency.

Oval or rounded grids better conform to the cylindrical shape of the codend and the problem of net abrasion is reduced - any abrasion is spread over a greater area of the grid. Oval grids may also increase the ability of an escape cover to seal tightly over the escape opening and prevent shrimp loss. This is because the escape opening is attached to the sides of the grid. The upper-most section of the grid now protrudes above the escape opening and the escape cover is held by water pressure tightly over the escape opening and against the grid. The risk of shrimp loss is now reduced. A disadvantage of an oval grid is that the escape opening is usually not as wide as that for a similar-sized rectangular grid of similar width. Attempts to increase this width require the escape opening to be cut further around the sides of the codend. As fewer codend meshes now support the grid, the risk of the remaining meshes stretching and loss of grid angle is high. Increasing the overall size of the grid is one way to overcome this risk and enable a larger escape opening to be used.

Tombstone-shaped grids can be used so that the square end of the grid provides for a wide escape

A Super shooter TED tested in the flume tank at the Australian Maritime College (AMC). The working height of the grid is sufficient to distort the circumference of the codend and the escape cover seals tightly over the escape opening and against the grid. Note that grid height is measured from the bends in the bars of the grid.





Oval grids conform well to the cylindrical shape of the codend. Note the escape opening extends part way round the sides of the grid.

A tombstone-shaped grid is a compromise between a rectangular - and an oval-shaped grids. The canvas sheet in front of the grid is used to assist the rapid exclusion of animals from the trawl.

opening while the opposing rounded end of the grid better conforms to the shape of the codend. In this way, the grid provides a good compromise between rectangular and oval grids. These grids can also be used inverted with the rounded end of the grid adjacent to the escape opening.

Bar spacing

A grid is usually constructed with an outer frame to which parallel bars are welded. These bars are spaced at an interval that allows large bycatch to be separated from the catch and excluded from the trawl. Bar spacing is typically between 100 - 120 mm, but 15 - 80 mm spacing has been successfully used in some fisheries. A grid with a narrow bar spacing will usually exclude smaller-sized bycatch such as sponges, jellyfish and fish, and may reduce the risk of these animals lodging between the bars of a grid. However, a narrow bar spacing may hamper the passage of shrimp into the codend and increase the risk of escape.

Straight- or Bent-bar grid

The bars of a grid can be either straight or bent. Straight-bar grids (sometimes called flat-bar grids) are the simplest to construct, but sponges and other heavy objects may lodge against the grid adjacent the escape opening where the bars meet the outer frame of the grid. This can block the passage of shrimp into the codend and push the escape cover away from the escape opening. The risk of shrimp loss will be high.

Bent-bar grids overcome the problem of grid blockage because the bycatch is unable to lodge against the outer frame of the grid. The bars are typically bent about 10 - 20° at a distance approximately 100 - 200 mm from the outer frame of the grid. Both rectangular and oval-shaped bent-bar grids may also protrude above the escape opening (where the bars meet the outer frame of the grid), and the escape cover should seal tightly and prevent shrimp loss.

The AMC designed NAFTED is an example of a rectangular bent-bar grid. Note that the width of the escape opening is equivalent to the width of the grid. This version of the NAFTED has no escape cover and was designed with a bar spacing of 60 mm to exclude large jellyfish.

Grid orientation

The orientation of a grid refers to the direction large animals and objects are excluded from the trawl. Two options for grid orientation are usually available; either upward (top) or downward (bottom) exclusion. A downward excluding grid is usually best suited to exclude heavy sponges, rocks and other debris because the escape opening is located in the bottom of the codend. An upward excluding grid is best suited for fishing grounds where this bycatch is seldom encountered. These grids can be used without an escape cover to allow more fish to be excluded, but a guiding panel is required to minimise shrimp loss. There is no evidence that either orientation is less effective in excluding turtles and other large animals from the trawl and retaining the shrimp catch.

In some fisheries upward excluding grids have been used with horizontal bars near the base of the grid. This modification is designed to allow flatfish easy passage into the codend. Care is required that this does not impede the rapid exclusion of turtles, sponges or other heavy objects.

Grid angle

When the codend is horizontal, grid angle is measured upward from a line parallel to the codend toward the bars of the grid. This measurement applies to both bent-bar and straight-bar grids. Grid angle has a strong relationship with grid size and is one of the most critical factors influencing TED efficiency. Typically grid angle is between 45 and 60°.

If a low grid angle is desired then a large grid is needed to sufficiently distort the circumference of the codend and ensure the escape cover fits tightly over the escape opening. If the grid is too short - irrespective of grid orientation - shrimp can be lost because the escape cover will not seal tightly against the escape opening. If a high grid angle is desired then a smaller grid can be used but large animals or objects may lodge against the bars of the

The grid on the left lost substantial amounts of shrimp due to a low grid angle (25°) and loose fitting escape cover (brown netting). The same grid (right) was re-hung at a greater angle (45 - 50°) and caught more shrimp than a standard net. Note how the grid on the right expands the circumference of the codend netting; this indicates an appropriate grid height for the selected grid

grid and block the passage of shrimp into the codend.

Because netting adjacent to the grid can become stretched and distorted over time, it is important to regularly check that grid angle has not changed. The rope used to support and bind the grid to the codend may also become loose, allowing the meshes to stretch and slide down the outer frame of the grid, and contribute to loss of grid angle. It will need to be tightened on a regular basis. To maintain grid angle, short 'belly' ropes can be attached to the TED and codend netting either side of the escape opening. These ropes extend for about 1 metre ahead and behind the grid. If netting near the grid stretches or the rope bindings become loose, these ropes will support the grid and prevent loss of grid angle.

Escape opening

An escape opening is a hole cut into the codend directly ahead of the grid through which large animals and objects are excluded from the trawl. As a general rule, the larger the escape opening the better a TED performs because large bycatch is quickly excluded from the trawl. If a small escape opening is used, the exclusion of this bycatch may be delayed. This may cause grid blockage and shrimp loss through the escape opening. All things being equal, larger or wider grids allow larger escape openings to be used.

Escape cover

An escape cover (or flap) is a piece of netting fitted over the escape opening to help prevent shrimp loss. It is usually sewn to the codend ahead of the escape opening and partially down each side while the trailing edge of the cover remains free. In this way it operates much like a trap door, allowing large animals to move the cover aside and escape. An escape cover works best if it does not extend further than 6 - 10 meshes past the grid, with no weight or flotation added.

The knot orientation of an escape cover is crucial to

The pyramid TED was designed to exclude large animals through escape openings in the top and bottom of the codend. Shrimp loss was high probably because the grid is too small and the escape covers were attached too tightly to the codend.

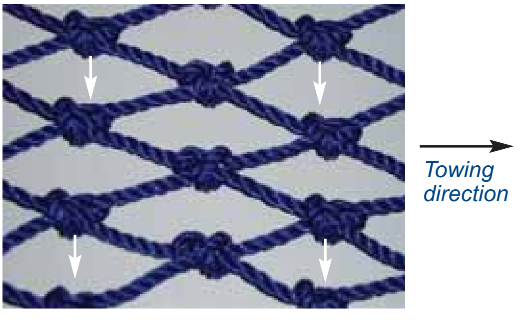
Small escape openings can block the grid and result in shrimp loss.

The TED on the left has a new escape cover and the TED on the right has an old stretched escape cover (and reduced grid angle). Note the large, gaping escape opening and how attachment of the escape cover has slipped down the sides of the grid. This TED was loosing a substantial amount of shrimp. The canvas sheet was used to assist the rapid exclusion of large animals from the trawl.

ensuring a snug fit and reduced shrimp loss, particularly if a small grid is used or grid angle is low. The knots should be oriented so that water pressure forces the cover to sit tightly over the escape opening when the net is towed through the water. If an oval or bent-bar grid is used, water pressure will hold the escape cover in contact with the part of the grid that protrudes beyond the escape opening. If a rectangular or straight-bar grid is used this pressure may not be sufficient to ensure the escape cover seals tightly over the escape opening and contacts the grid. This explains why rectangular grids should be larger than oval grids for the same sized codend.

The repeated exclusion of large animals will stretch an escape cover width-wise over time and reduce its elasticity. This can be a source of shrimp loss because the cover can no longer return to its original shape and seal tightly over the escape opening. The length of the escape cover is also reduced and it may no longer cover the entire escape opening. To overcome these problems it is best to use depth-stretched knotted polyethylene netting. This material is very elastic and the knots are usually heat-set for greater stability. Depth-stretched netting better conforms to the shape of the codend and TED to seal tightly over the escape opening. If a wider escape cover is used (more netting) over the same sized escape opening, less stretching of the meshes will occur as animals are excluded from the trawl. There will also be a greater number of knots pushed down by water pressure and the cover will sit tightly over the escape opening.

An alternative to a large single escape cover is to use two sections of netting that overlap along their length over the escape opening. This is called a double cover flap design. It is designed to allow rapid exclusion of very large animals such as leatherback turtles from the trawl. The benefits of two escape covers include greater coverage of the escape opening and protection against shrimp loss as animals escape from the trawl. There is also less stretching and distortion of the netting in each panel due to repeated exclusion of large animals. This should maintain the performance of the TED and reduce the need to regularly replace the escape cover.



As this netting panel is towed through the water, water pressure acting on the raised section of the knots forces the panel downwards.

A poorly fitting escape cover may allow shrimp to escape because it does not sit snugly against the grid.

Guiding panel or funnel

Guiding panels are sections of netting sewn into the codend ahead of the TED to direct the catch away from the escape opening. As the name implies, funnels are tapered tubes of netting that perform the same task as guiding panels. They are critical in preventing shrimp loss from TEDs that use no escape cover. When an effective escape cover is used, the panel or funnel has been removed from the TED with no loss of shrimp catch.

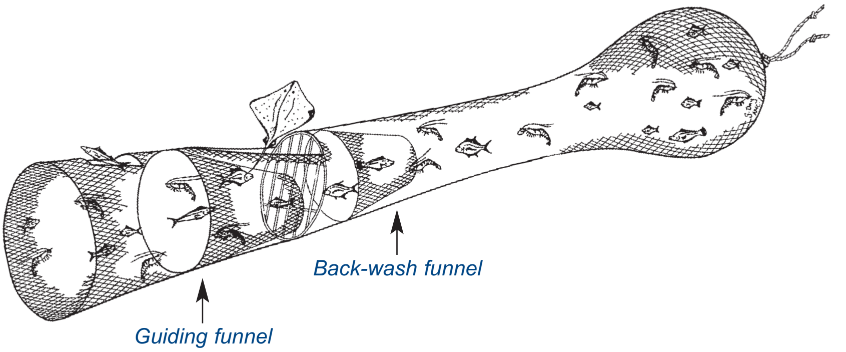
Poorly designed or fitted panels and funnels may fail to direct the shrimp away from the escape opening. The greater the distance between the funnel exit and the inclined grid, the greater the likelihood of this happening. A quick and simple solution is to extend the length of the funnel so it contacts the bars of the grid. Over time the panel will become stretched as large animals distort the netting. In the case of a downward-excluding TED the netting will need to be replaced. In the case of an upward excluding TED, weight (such as chain or lead core rope) can be added to the end of the funnel. This will allow the shrimp to exit the funnel at the bottom of the codend further from the escape opening. The weight should be uniformly distributed along the end of the funnel to prevent distortion. Care is required to ensure this does not impede the passage of sea turtles and large animals through the TED. A better option is to replace the funnel with new netting. It is worth noting that guiding funnels or panels may not be required if the TED is fitted with an escape cover.

The selection of mesh size in the construction of a guiding panel or funnel is critical, particularly where there is a high risk of encountering large starfish, sponges or other fouling animals. These may block the passage of shrimp into the codend or even delay the exclusion of large animals from the trawl. Trial and error will be required to determine the optimum mesh size. The use of heat-set polyethylene netting is recommended to construct a guiding panel or funnel because of its elastic properties. The netting should also be depth-stretched so that it will expand laterally and allow rapid passage of large animals toward the grid. Heavy canvas has proven to be a successful replacement for netting material as it eliminates the problem of animals fouling the netting material. However, because canvas does not stretch it can tear away from the codend if an extremely large animal enters the net. This material can also be used ahead of the grid (on the bottom of the codend) to prevent fouling and help the passage of these animals toward the grid.

Flotation

Floats are sometimes used to compensate for the weight of the TED or BRD, to stabilise the device, maintain the geometry of the codend and prevent chafing of netting on the seabed. They are particularly important if downward-excluding TEDs are used to ensure there is adequate clearance for turtles and other animals to escape from the trawl. This could be a serious problem if a trawl is constructed from polyamide (nylon) because this material sinks and the codend may be very close to the seabed. As polyethylene netting floats trawls constructed from this material are less likely pose such a risk.

This TED is designed with a guiding funnel in front of the grid and a back-wash funnel behind the grid. The guiding funnel helps prevent shrimp loss as they enter the codend. The back-wash funnel prevents the catch from surging forward and being lost through the escape opening.



The required amount of flotation differs between devices and construction material. For example, a fisheye constructed from steel or aluminium rod is usually light enough that only a small float is required to maintain codend geometry. A grid constructed from lightweight aluminium tubing may not require flotation if fitted to a codend of buoyant polyethylene netting. In contrast, a stainless steel grid will require flotation to help counter its additional weight.

Floats should be attached to the upper half of a grid and inside the codend. This will prevent tangling with the lazy-line or fouling on rigging as the codend is hauled onboard. They must not interfere with the escape cover, the passage of large animals from the trawl or the passage of shrimp into the codend. Hard plastic floats are preferred over foam or polystyrene floats as they are more resistant to crushing and do nor lose buoyancy in deeper waters (greater than 25 - 30 m). Brightly coloured floats can help with visual location of the TED when the trawl is at the surface and help check for twists in the codend.

Back-wash funnels

Back-wash is a term that describes the forward movement (surging) of the catch. This occurs when towing speed is reduced and the trawl is hauled to the surface, particularly in bad weather. This can cause shrimp to surge forward and be lost through the escape opening of the TED (or BRD).

Back-wash funnels are conical-shaped sections of netting fitted inside the codend aft of the TED. They are attached by their leading edge to the codend, while the trailing edge remains free or is attached by a few meshes to the bottom of the codend. They remain open under tow to allow the catch entry into the codend, but collapse when the trawl slows or is hauled. This prevents forward movement of the catch in the codend. It is important that the trailing edge of the funnel cannot surge forward and become fouled around the bars of the grid. It is also important that the funnel does not block trail behind the TED and block the escape openings of a BRD

Back-wash can also be a problem when the boat makes a sharp turn with the trawl at the surface, particularly if the codend contains a large volume of shrimp. This problem typically occurs when target-fishing schools of shrimp and the boat turns sharply for a second shot.

Grid material

Most grids are constructed from aluminium or stainless steel to avoid problems of corrosion. Because stainless steel grids are heavy they are often constructed from smaller diameter rod or pipe than that used in an aluminium grid. Additional flotation may also be required to provide adequate buoyancy.

Plastic and steel wire rope (SWR) has also been used to construct a grid. In some temperate water shrimp fisheries plastic grids are used so that the net can be wound around a net drum without damaging the grid. There is little evidence of these grids being used in tropical shrimp fisheries. The use of SWR to construct a grid has been attempted in Australia. This grid was known as the AusTED and it performed well. The SWR was encased in plastic to avoid problems with corrosion and crew injury due to broken strands of wire. When located in the codend, the grid formed a concave shape and grid angle was not consistent, although this did not seem to affect performance. However, in fisheries where grid angle is legislated this will be problematic.

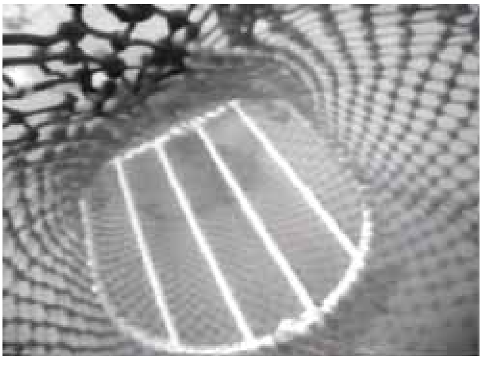
TED maintenance program

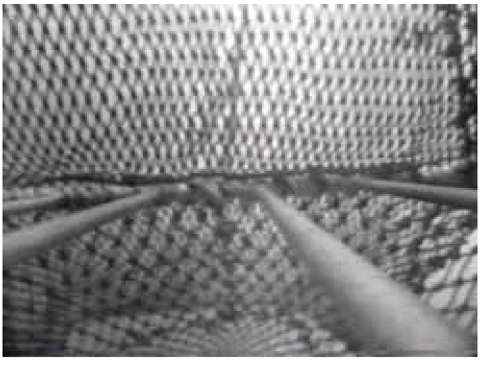
It is clearly important that a TED is well maintained to ensure peak performance. There are a number of TED components that must be checked and maintained on a regular basis. The following table (overleaf) provides inspection details of these components and the frequency of inspection. Damage to these components will occur more often if fishing in a region where large animals are frequently encountered. If a TED is well maintained there is no reason why it will not last for several fishing seasons.

The broken bar of this TED may allow turtles and other large animals to enter the codend and be caught. Alternatively these animals may become jammed in the grid.

COMPONENT	INSPECTION DETAILS	INSPECTION FREQUENCY	SUGGESTED ACTION
Guiding panel or funnel	Check for mesh stretch or damage and detachment from codend meshes	Daily	Replace if necessary or re-attach to codend
Grid bars	Bent or damaged bars, bar spacing	Daily	Straighten if possible or replace
Grid angle	Loss of angle	In the first week, daily for new grid then weekly	Re-attach grid to codend at correct angle
Grid bindings	Check for abrasion, frayed rope strands and loose bindings	Weekly	Replace or retighten if necessary
Escape opening	Damaged meshes adjacent the opening; mesh slippage around frame of grid	Daily	Repair or reattach adjacent meshes to grid frame
Escape cover	Stretched meshes and attachment to codend	Daily	Replace or reattach to codend
Backwash funnel	As for guiding panel or funnel	Daily	As for guiding panel or funnel
Floats	Check strong attachment to grid or codend	Weekly	Reattach to grid or codend

This TED is well maintained and should rapidly exclude turtles and other large animals and maintain the shrimp catch. The meshes around the grid (left photo) are evenly distributed and grid angle is about 50°. The bars are straight and evenly spread. The escape cover (right photo) sits tightly over the escape opening and is in contact with the bars of the grid. It also extends a short distance past the escape opening.





Tips for optimizing TED performance

The following table provides a summary of the important tips to optimise TED performance.

TED COMPONENT	TED TIP
Grid size	The size of a grid influences the size of the escape opening and the ability of the escape cover to sit tightly over the escape opening. Grid size should be as large as possible. A small grid will need to be fitted at a higher angle to distort the codend ensure good escape cover performance.
Grid shape	The shape of a grid can affect the size of the escape opening, the exclusion of large animals, shrimp retention and wear and tear on the codend.
Bar spacing	A small bar spacing allows exclusion of more bycatch species, although unfounded concerns over increased shrimp loss has prevented most fishermen from using less than 100 mm bar spacing.
Bent bars	Bent-bar grids can improve the speed of large animal exclusion and consequently reduce shrimp loss.
Grid orientation	This can be altered to target the exclusion of particular species groups. For example downward-excluding grids are thought to be best suited to excluding heavy, negatively buoyant items such as large sponges or rocks.
Grid angle	Incorrect grid angle can result in shrimp loss or poor bycatch reduction. The relationship between grid angle and size is important to ensure efficient operation. Grid angle should be 45 - 60º.
Escape opening	Larger escape openings improve the exclusion speed of large animals and reduce shrimp loss, although there are issues with maintaining the shape and strength of the codend for larger openings.
Escape cover	There are many misconceptions about these devices and they are a major cause of over-tuning. They should be made of depth-stretched or heat set netting; not be too narrow or too long, and not have weight or flotation added. They need to be replaced regularly.
Guiding panel or funnel	They are easily blocked and are best used for fishing on 'clean' grounds or when no escape cover is used. Canvas may also be considered as an alternative to netting.
Flotation	Floats assist grid stability and orientation, and help overcome the weight of the grid.
Backwash funnel	These prevent shrimp loss in bad weather. Care is required they do not block the escape openings of a BRD.
Grid material	Aluminium and stainless steel are the most common grid materials as they do not corrode and they resist damage.

TED Performance & Operation
Frequently Asked Questions

This section answers many frequently asked questions about the design and operation of a TED.

How large should my TED be?

The TED will need to be large enough to satisfy the fishery regulations and/or sea turtle protection program. In many countries the size of a TED refers to the height and/or width of the grid. In the United States, however TED measurement refers to the size of the escape opening as this dimension reflects the size of turtles that are excluded from the trawl. For those countries seeking to introduce an effective sea turtle conservation program, a good starting point would be to ensure that a TED meets the US regulations and then adapt it to suit the fishing operation and conditions of the fishing ground. A TED can always be made larger if the conditions of the fishery warrant it.

As a guide, a TED with a large grid is better because it has a larger filtering area and shrimp have further distance to swim to escape. Larger grids are usually fitted with larger escape openings so turtles and other large animals can be excluded more quickly. If the grid is large enough to distort (enlarge) the circumference of the codend, the escape cover will seal tightly over the escape opening and prevent shrimp loss.

The exclusion of sawfish from a TED is difficult irrespective of grid orientation. Note this TED does not have a guiding panel or funnel.

There is no precise rule to determine optimum grid size. However, as an approximate guide, the circumference of a grid should be about 60% of the stretched-mesh circumference of the codend. This will ensure the grid distorts the codend and the escape cover seals tightly over the escape opening. TEDs have been used effectively measuring between 52 - 75% of codend circumference. At lower grid angles a higher percentage will be required to distort the codend.

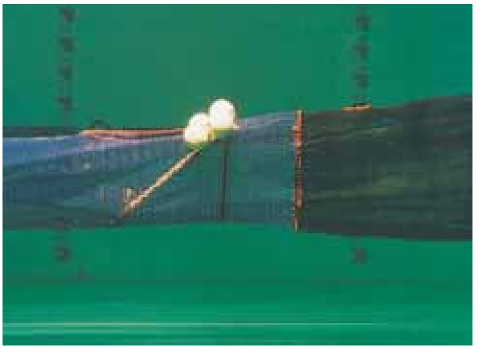
This TED has a large filtering area to reduce the risk of shrimp loss. It will also have a large escape opening to exclude large animals.

Is an upward-excluding TED better to exclude turtles and other animals?

Providing a TED is well designed and maintained, there is no evidence that an upward-excluding TED is more efficient than a downward-excluding TED to exclude turtles and other large animals. There is also no evidence that these animals cannot escape from a downward-excluding TED because the escape opening is too close to the seabed. The use of adequate flotation will help ensure there is sufficient clearance under a TED for these animals to escape.

If fishing in a location where the catch includes large sponges, rocks and other debris a downward-excluding TED is generally a better option. This is because it is difficult to guide heavy objects up the bars of an upward-excluding grid and through the escape opening. To exclude fish or jellyfish from the trawl an upward-excluding TED may be desirable because the escape cover can be removed to allow rapid escape with minimal shrimp loss.

A protractor is a simple method of measuring grid angle during construction of the TED. It should also be frequently used at sea to check that grid angle has not changed.



This TED is used in estuarine fisheries in eastern Australia. The grid angle is about 45°.

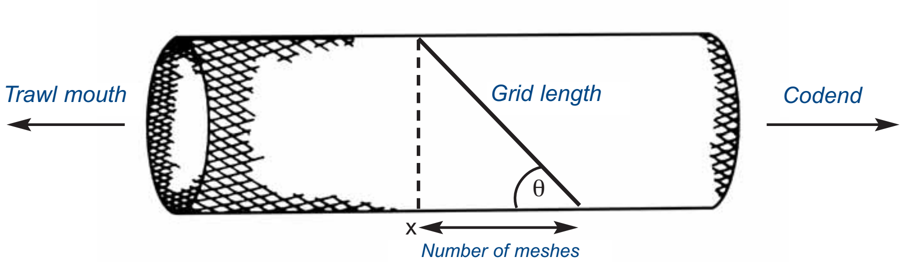
What grid angle do I use?

Research has shown that the best grid angle is 45° - 60° for both upward- and downward-excluding TEDs. At higher angles, the grid may become clogged with debris, sponges and other animals and prevent shrimp from entering the codend. At lower angles, more shrimp might escape because the escape cover is unable to seal tightly over the escape opening and against the grid. A longer guiding panel or funnel may solve this problem. As a last resort the size of the grid may need to be enlarged or replaced with a larger one.

How do I install a grid at the correct angle?

There are two simple techniques that can be used to install a grid at the desired angle. The simplest technique is to insert the grid into the tubular codend or extension piece, hang it up and adjust the grid until the desired angle is reached. A protractor or bevel gauge can be used to measure this angle. Care must be taken as the angle of the grid may decrease by 5° or more after the escape opening is cut into the codend. If required reposition the grid to the desired angle.

A second technique involves counting the codend meshes and using a calculator. This technique is



slightly more complicated but provides a useful estimate of grid angle if a protractor or bevel gauge is not available. The top of the grid is first attached to the seam joining the codend netting (the seam should be located along the top of the codend). From this position count halfway around the circumference of the codend and mark this position (position X).

Then determine the number of meshes from this position that the bottom of the grid needs to be attached to provide the desired grid angle. The following formula can be used to estimate the number of meshes required to produce this angle:

$$\text{No. of meshes} = \frac{\text{Grid length x Cos angle } (\theta) \text{ x } 0.6}{\text{Mesh size}}$$

For example, if a grid measuring 100 cm was to be inserted at 55° into a codend with a mesh size of 35mm the number of meshes required would be:

$$\text{No. of meshes} = \frac{100 \text{ cm x Cos } 55 \text{ x } 0.6}{3.5 \text{ cm}}$$

$$= \frac{100 \text{ cm x } 0.573 \text{ x } 0.6}{3.5 \text{ cm}}$$

$$= 10 \text{ meshes}$$

The bottom of the grid would be attached 10 meshes along the length of the codend to produce an angle of 55°. It should be noted that in this example the meshes are assumed to be stretched to 60% of their total stretched length when the trawl is in the water. The amount of assumed stretch will be largely determined by the size of the grid compared to the stretched mesh circumference of the codend. Failure to account for this will result in inadequate grid angle and poor TED performance.

The following table is provided for those unfamiliar with the cosine (Cos) function. By inserting the appropriate number for a given grid angle it is simply a matter of completing the above formula.

Angle (θ)	Cos Angle (θ)
30	0.866
35	0.819
40	0.766
45	0.707
50	0.642
55	0.573
60	0.500

How do I check grid angle?

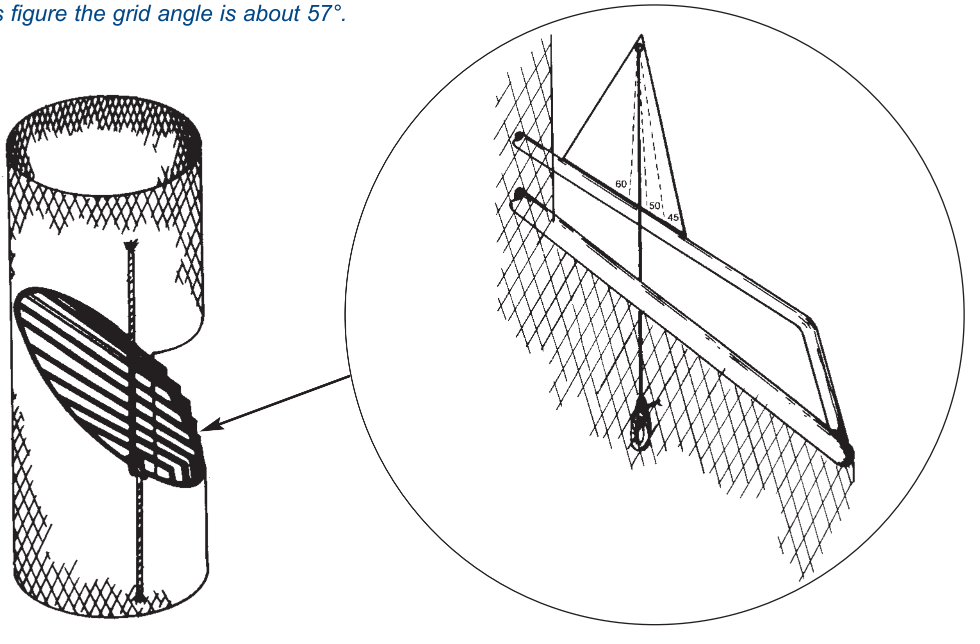
Grid angle is measured from the horizontal to the bars of the grid. An easy method of checking grid angle is to suspend the codend vertically, free of twists, with the grid at eye level. A large protractor or bevel gauge is then inserted through the escape opening to measure the grid angle (in this position the angle is measured from the vertical). If a protractor is not available then a simple option is to use a thin, triangular-shaped sheet of timber measuring 8 cm, 8 cm, and 11.2 cm respectively. The angle between the two short sides of the triangle will measure 90° and the remaining two angles will each be 45°. From one corner (between a short and long side of the triangle) measure 4 cm, 5.6 cm and 6.4 cm along one side of the triangle and mark the triangle. Draw lines from these points to the opposite corner of the triangle (repeat this on the other side of the triangle). Make a small notch or hole in this corner and attach a short length of string with a small weight attached. The angle between the 4 cm side and a line to the opposite corner of the triangle is 60°. The angles between the 5.6 cm and 6.4 cm sides and a line to the opposite corner are 55° and 50° respectively. By resting the marked side of the triangle against a bar of the grid the weighed string will hang vertically. The position of the string at the marked side of the triangle is the grid angle.

A weighted string and a triangular-shaped piece of timber can be used to make a simple, inexpensive and effective grid angle gauge. In this figure the grid angle is about 57°.

Can grid angle change during a tow?

The angle of a grid should be checked regularly, as the bindings securing the grid to the net may become loose or new netting may become stretched. Failure to do this will result in loss of grid angle and poor TED efficiency. In the worse case grid angle may reduce to 30° or less and shrimp loss will be high. Fishermen will blame the TED for this loss but poor maintenance is the real culprit.

A technique to prevent or delay loss of grid angle is to use 'belly ropes'. These ropes are attached to the grid and the codend netting for a distance of 1 m forward and aft of the grid. Usually two ropes are used, one either side of the grid. If the ropes are attached to a newly constructed TED they will take up the strain as the codend netting stretches. Braided rope is best for this purpose because it does not stretch, although twisted rope will work fine. Rope diameter is typically 8 - 14 mm.



Belly ropes (lastridge ropes) are a simple option to prevent loss of grid angle, particularly as the meshes supporting the grid become worn and stretched.

During a tow, large animals, rocks and other debris blocking the grid may reduce grid angle and prevent the escape cover from sealing tightly over the escape opening. This will lead to shrimp loss. A well designed and maintained TED can reduce this risk, however this problem is sometimes unavoidable. There may be no sign of a problem until the trawl is hauled - the cause of the blockage may remain fouled in the grid and the shrimp catch will be poor. A simple technique that can be applied to clear the grid requires boat speed to be reduced suddenly for several seconds whilst trawling. This may allow fish and other animals that are blocking the grid to float free as the trawl slows. It may even allow heavy objects to fall through the escape opening of a bottom-excluding TED. Boat speed may have to be reduced to near zero to be effective but care is required to prevent the otter boards from collapsing or sinking into the mud or sand. Unless the trawl is fitted with sophisticated acoustic or video equipment it is not possible to determine when the grid becomes blocked or if this method successfully clears the grid until the trawl is hauled. The application of this clearance technique therefore relies solely on the judgement of the fisherman.

What bar spacing should be used?

Clearly there is a need to ensure that bar spacing is effective in preventing the capture of turtles and other large animals while allowing shrimp to enter the codend. A narrow spacing will result in more animals being excluded from the trawl but it could also result in shrimp loss. The US regulations prevent the use of a bar spacing greater than 102 mm to protect turtles but in other countries a spacing between 100 - 120 mm is common. For example, in Nigeria bar spacing is 102 mm but in Australia it is typically 120 mm, including those fisheries where the US embargo has been lifted.

Can I rapidly change bar spacing?

There are two techniques available to rapidly change bar spacing. The first involves the attachment of a second grid to the main grid. The bars of the second grid reduce the overall bar spacing available for bycatch to pass through. This may improve bycatch reduction although care is required to ensure an equal distance between adjacent bars. Failure to do this may increase shrimp loss and fouling of turtles and other large animals between the bars of the grid. It is for this reason that this modification is not recommended for countries seeking to lift the US embargo.

The second technique involves attaching the grid to an outer frame of the same material. The frame is attached to the codend at the desired angle and the grid is simply inserted into the codend and attached to the frame using cable ties or twine. This technique allows a damaged grid to be exchanged within minutes (as opposed to an hour or more for a grid to be attached to a codend and bound with rope) and the option of using a different bar spacing to suit different locations of the fishery. The grid will also be inserted at the correct angle because the outer frame is still in place. This 'cassette-style' approach requires the grids to closely fit the outer frame and ensure turtles and other animals cannot foul the grid. The US TED regulations do not permit this modification as turtle flippers may become fouled in the space between the frame and grid.

Why use a guiding panel or funnel?

Although not used with all TEDs (or BRDs), guiding panels or funnels of netting can be fitted immediately ahead of the device to guide the catch away from the escape opening and prevent shrimp loss. They are either conical in shape or simply a tapered panel of netting sewn at an angle into the codend.

It was originally thought that a netting funnel would increase the speed of water passing through the TED and assist the passage of shrimp into the codend. For this reason it was called an "accelerator funnel". However, flume tank tests and sea trials have since found that when the funnel is made from shrimp netting there is little acceleration of the water. These tests also found an area of turbulent water outside the perimeter of the funnel. Fish seek these turbulent regions to conserve energy, so if escape openings are placed near them, more fish escape.

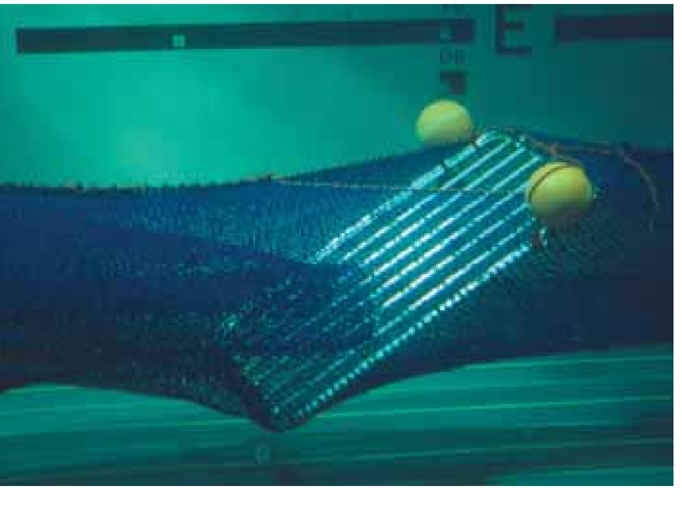
The use of smaller mesh or canvas in the funnel may help to reduce 'meshing' or entanglement of fish, starfish and other debris. Partial or complete blockage can also occur and the funnel will need to be modified to permit the passage of large animals. Funnels and panels of netting must be checked regularly for damage.

How can escape covers help?

An escape cover may be placed over the escape opening of a TED to prevent shrimp loss but allow large animals and other debris to be excluded from the trawl. Escape covers are usually made from netting or solid material such as plastic sheeting and should be large enough to overlap the escape opening. They may be held tightly over the escape opening by water pressure or, in the case of burst panels, until a large animal breaks the holding twine. They must be easily pushed aside by large animals escaping from the trawl and readily return to their original position immediately after escape.

What does "being TEDed" mean?

When fishermen use TEDs and tow several trawls at the same time, the shrimp catch in one trawl is sometimes substantially less than that in the other trawl. In the worse case the shrimp catch may be less than half that in another trawl! Understandably this is very frustrating and a major cause for concern. In Australia, fishermen call this "being TEDed" because the TED is blamed for the reduction in the shrimp catch. In some instances the cause of this loss is the inability to exclude large animals and debris, such as fish traps or tree



A guiding panel or funnel is useful to guide shrimp through the grid and into the codend. However, they may not be required if an escape cover is used over the escape opening.

trunks, from the trawl. However, in the majority of instances the real cause of this loss is poor TED selection or operation in a specific area of the fishery. Examples of this include the use of a small TED in a region where very large animals are frequently encountered, use of an upward excluding TED in a location where large rocks and heavy sponges are caught, and poor TED maintenance.

What is meant by "over-tuning a TED"?

Over-tuning refers to excessive TED modifications made by fishermen in an attempt to reduce or prevent shrimp loss and being TEDed. Examples of these modifications include heavy weights attached to the escape cover of an upward excluding TED, an excessively long escape cover, excessive grid angle, and excessive amount of cover that is sewn to the codend netting. All of these modifications are designed to help the escape cover seal more tightly over the escape opening. They achieve this aim, but they also serve to delay the escape of large animals from the trawl. The TED is now over-tuned. Large animals now struggle to escape from the trawl and the escape cover is pushed aside for longer periods. During this time the escape cover is unable to effectively prevent shrimp escape and shrimp loss is high. The fisherman has now been TEDed. The modifications that were initially used to prevent shrimp loss are now the major cause of shrimp loss!

Careful selection of a TED to suit operating conditions and good maintenance is essential to prevent

This TED has been over-tuned. Note that the escape cover has been lengthened (attached to the original escape cover using blue twine) and chain and lead weights added (left photo). These modifications were made by the fisherman in the mistaken belief they would solve his problem of shrimp loss. Instead, they only served to increase grid blockage, delay the exclusion of large animals from the trawl and further increase his problem. The initial problem with this TED was not related to poor escape cover performance, but was the result of using an under-sized grid and low grid angle (right photo). The grid was reinstalled at a higher angle and an escape cover without any weights was used extending only 6 meshes past the grid frame. Shrimp loss was eliminated and the incidence of grid blockage significantly reduced.

being TEDed. The need to over-tune a TED is a signal that this has not been achieved and usually an indication that there is a problem elsewhere with the TED. The TED must be carefully inspected and all components checked and replaced if necessary. In particular the escape cover must be designed to readily move aside as a large animal is being excluded and return quickly to its original position over the escape opening. If a bottom excluding TED is used a canvas sheet attached to the bottom of the codend may prevent fouling animals such as sponges and starfish from blocking the escape opening of the TED. In the worse case these animals could foul the escape cover and prevent it from sealing tightly over the escape opening. A canvas sheet in this position may also assist the rapid progress of large animals through the TED.

It is important to note that over-tuning a TED may in fact solve the problem of shrimp loss at locations where few large bycatch animals are encountered, particularly if the escape cover is stretched or grid angle is too low. However, when used at locations where large numbers of these animals are encountered, the risk of being 'TEDed' is high.

The problem of over-tuning clearly highlights the difficulties fishermen face trying to optimise TED performance across an entire fishery. An option not widely practiced at present, but which may go a long way to avoiding the problem of shrimp loss, is for fishermen to use different TED designs at different locations of the fishery. For example, a downward-excluding TED might be used where sponges are commonly encountered and an upward-excluding TED for locations where they are less common. In this way, a TED suited to specific conditions in the fishery is used and optimal TED performance and efficiency can be maintained.

What are the common causes of shrimp loss from a TED?

The most common causes of shrimp loss are grid blockage and delayed exclusion of large animals from the trawl. These are linked to poor selection, installation, operation and maintenance of the device. Over-tuning of the TED to account for poor escape cover performance is also a common cause of shrimp loss.

Do nets fitted with a TED still catch turtles?

An efficient, well designed and operated TED should exclude all turtles that enter a trawl. However, occasionally a turtle may enter a trawl a few minutes before hauling commences and have insufficient time to escape through the TED. The turtle is likely to be active and can be released alive.

On rare occasions small turtles may pass through the bars of the grid and be caught. This will require bar spacing to be reduced. This can either be achieved by replacing the grid with one that has smaller bar spacing or inserting a second grid with bars offset to the first grid.

What do I do if I catch a turtle?

Unless regulations prevent otherwise, all turtles, either dead or alive, must be released to the water. The release of live turtles from the trawl can be achieved using one of two methods. The first method is to slowly haul the trawl out of the water so that the turtle gently slides down the netting toward the trawl mouth and into the water. Care is required that the turtle does not become fouled in the netting or is injured. The boat should be stationary and the propeller not moving as this procedure is attempted. The second option is to gently remove the turtle through the escape opening of the TED. This will probably require a rope strop to choke the trawl off ahead of the turtle. The strop can then be tied against the side of the boat and the codend lowered onto the deck. Caution will need to be taken to ensure the turtle does not fall onto the deck and suffer injury. If the turtle is active it should be gently returned to the water as previously described. If a turtle is not active or appears dead it should not immediately be thrown overboard. The turtle could be comatose and simply require some time (several

This turtle entered the trawl immediately before haul-back and there was insufficient time for it to be excluded by the TED. The trawl was hauled onboard and the turtle escaped alive through the trawl mouth.

hours or more) to recover. Appendix 3 provides instruction on the resuscitation and release of turtles that are comatose when hauled onboard.

How does TED performance differ between fishing grounds?

As fishermen gain experience in the use of these devices they may find it necessary to regularly adjust or replace the TED to suit the various conditions of the fishery. As previously mentioned an upward-excluding TED is best suited to regions where heavy animals and debris is not encountered. These TEDs can also be used with the escape cover removed or shortened to allow the escape of fish from the trawl. A downward-excluding TED is best for regions where heavy debris and large animals are frequently encountered. The TED will need to have a large escape opening so that this bycatch can be readily excluded from the trawl. Grid angle will need to be low to reduce the risk of grid blockage without affecting the ability of the escape cover to seal tightly over the escape opening.

Will a TED increase codend drag?

The overall effect of the TED on codend drag has not been quantified and remains a subject of further research. However, the addition of a TED to a codend is unlikely to have any noticeable impact on codend drag and it should not make the trawl more difficult to tow through the water. Even the smallest shrimp trawler should be able to tow a TED. The drag increase associated with towing the TED and having a distorted codend may in fact be more than offset by a drag decrease associated with reduced high pressure (and associated water turbulence)

If a turtle is caught it should be elevated so that water can drain from its lungs. This may take several hours.

ahead of the catch, reduced capture of large animals, and reduced catch-induced distortion of codend geometry.

To better understand why a TED may not increase codend drag we need to understand the type and amount of drag that is experienced by the components of a trawl (including otter boards, wires, net, codend and ground gear). Drag is best thought of as a resistance force generated by movement of the trawl components as they are towed through the water. It is a force that must be overcome by the thrust of the fishing boat to enable the trawl to be towed at the desired speed.

As a trawl is towed along two types of drag are present, pressure drag and friction drag. Pressure drag is caused by variation in water pressure acting on the trawl, and is the result of forced displacement of water through and around the components of the trawl. In the case of a codend, the accumulated catch displaces water forward and sideways through the meshes of the codend. This generates high pressure immediately ahead of the catch while lower pressure exists adjacent and behind the codend - the codend is now experiencing pressure drag. Friction drag is caused by the viscosity of water, and it occurs when water slides over the surface of the trawl components. As friction drag acting on a codend (including the catch) is much smaller than pressure drag it is usually not considered important and is ignored.

The pressure drag acting on a codend can be found by the following expression, which shows the factors that can cause it to change:

Drag = $^1/_2$ x sea water density x codend profile area x speed^2 x Cd

where sea water density = 1 025 (kg/m^3); codend profile area = area of a circle; speed = towing speed (m/s); Cd = a dimensionless drag coefficient that accounts for flow characteristics around the codend, codend size and shape, and viscosity of the water. Note that the expression makes no mention of catch weight. This is because catch weight has no impact on codend drag unless it results in the codend sliding along the seabed to produce associated contact friction, alters the profile of the codend or the flow characteristics of the codend.

The addition of a TED will increase the profile (circumference) of the codend, and based on the above expression this will increase the pressure drag acting on the codend. Furthermore, the components of the TED, such as the grid, funnel, floats and escape cover, will displace water as they are towed along and also generate pressure drag forces. Clearly it seems that the addition of a TED serves to increase the overall pressure drag acting on the codend. However, the effect of the TED is not as simple as it seems, and there are several secondary effects that may compensate for a presumed increase in pressure drag. Firstly, an increase in the profile area of an object will increase the drag force only if the object is solid or maintains water flow characteristics around the object. The codend is obviously not solid, and because the TED enlarges the circumference of the codend, the meshes adjacent the TED are stretched open wider. This may improve the escape of water from the codend and reduce the high pressure region that exists in front of the accumulated catch. In turn, this will reduce pressure drag and make the codend easier to tow through the water. A further reduction in high pressure may be provided by water turbulence trailing behind the components of the TED. This turbulence is the result of displaced water around these components and it will further reduce the high pressure region ahead of the accumulated catch. Finally, the exclusion of large animals by the TED may also reduce pressure drag by minimizing catch-induced increases in codend profile area.

How heavy is a grid in water?

All objects placed in water will either float (positively buoyant), sink (negatively buoyant) or remain at the same depth (neutrally buoyant). The following expression is used to determine the buoyancy (weight) of a grid in water:

Grid buoyancy (kg) =

$$\left(\frac{\text{Seawater density}}{\text{Grid density}} - 1\right) \times \text{TED weight in air}$$

where seawater density = 1025 kg/m^3; grid density = 7400 kg/m^3 (stainless steel) or 2500 kg/m^3 (aluminium). For example, a stainless steel grid that weighs 20 kg in air has a buoyancy of -17.2 kg in water (the negative sign in the calculation indicates that the grid sinks) while a 20 kg aluminium grid has a buoyancy of -11.8 kg. All metal grids will sink, but it is important to realise that they may weigh up to 40 % less in sea water. This should be remembered when confronted with the spectre of using large grids, for example, to meet the US regulations and protect large turtles.

If the grid is fitted into a section of polyethylene netting then the above expression can be used to calculate the buoyancy of the netting, provided its weight is known and a density of 950 kg/m^3 is used. The difference between the buoyancy of the grid and codend netting (and floats if used) is the overall buoyancy of the entire codend. Note the weight of the grid calculated above will be reduced even further when fitted to polyethylene material. If fitted to polyamide (nylon) netting the weight of the grid will be greater because the density of polyamide is about 1 140 kg/m^3.

Why are floats used?

Many bycatch reduction devices are made of heavy materials such as steel or aluminium. Some flotation is needed to stabilise the device, maintain the geometry of the codend and prevent chafing of netting on the seabed. With downward-excluding TEDs, floats may help with the exclusion of large animals by increasing the distance between the seabed and the escape opening. The floats must be placed so they do not block the opening. They can also be used to indicate the orientation of a TED or BRD prior to deployment, particularly at night.

Does the buoyancy of a float change with depth?

It is a common belief that the buoyancy of a float changes with depth due to changes in water pressure. To see if this is true, we must first understand that the buoyancy force acting on a float is the difference between the lift force provided by the water and the weight of the object:

Float buoyancy (kg)

= float lift - float weight (in air)

= (float volume x seawater density) - float weight

= $(4/3 \times \pi \times \text{float radius}^3 \times 1025)$ - float weight

= $(4/3 \times 3.14 \times \text{float radius}^3 \times 1025)$ - float weight

Note that the above expression makes no mention of water pressure. This is because water pressure has no impact on buoyancy unless it reduces the radius of the float or causes it to implode and allow water to enter. A hard plastic float at 100 m will therefore have the same amount of buoyancy as it does at 2 m providing it remains watertight. A polystyrene float on the other hand, will have its radius reduced by water pressure in deep water and its buoyancy dramatically reduced. Note also the cubic relationship between float radius and float buoyancy; a twofold increase in radius will result in an eightfold increase in buoyancy.

Are TEDs a safety hazard to crew?

In many fisheries, concerns have been raised about the potential safety hazard of using TEDs. These hazards include injury caused by TEDs striking crew when codends are hauled aloft (particularly in bad weather), and rocks, fish and other bycatch falling onto the crew below. Such hazards can be minimized by careful handling of the TED and awareness of the potential for objects to fall from the TED. Careful location of the TED in the codend will ensure it remains outboard as the codend is hauled onboard, thus further minimizing the risk of injury. It is interesting to note that in many fisheries that require the use of these devices few injuries have occurred. In fact, these devices can actually improve crew safety because they do not have to manhandle large animals overboard. Rigged correctly, TEDs should not be a hazard to crew.

Can TEDs improve catch quality and value?

The exclusion of turtles, other large animals such as sharks, stingrays, fish, sponges, rocks and other debris from the trawl can reduce damage to the shrimp catch. Shrimp can be damaged by crushing in the codend or on the sorting tray or deck, or by penetration by spikes or teeth.

The time required to sort the catch and discard bycatch overboard can delay shrimp processing and impair shrimp quality, particularly in the heat of the day. Therefore, bycatch reduction has the potential to substantially improve the value of the shrimp catch.

Careful location of the TED ensures it remains clear of the boat and minimizes risk of injury to crew.

Do TEDs weaken my codend?

Some fishermen have raised concerns that a TED can weaken the codend, particularly when large catches are being hauled onboard. There is no evidence that such a problem exists and it is difficult to understand how this might occur. If the TED is correctly attached to the codend, any tension in the codend meshes is evenly distributed throughout the netting. Moreover, if the lifting strops are located between the TED and codend, the TED is unlikely to hamper the safe hauling of large catches onboard. In contrast, the hauling of large catches may cause the grid of the TED to be bent and damaged, particularly if the frame and bars of the grid are constructed from small diameter rod or pipe. If large catches are expected the grid should be reinforced or constructed from stronger material.

Does hauling speed affect shrimp catches?

It is important that the codend is hauled to the surface and onboard as quickly as possible. Failure to do this may allow shrimp (and other valuable animals) to move forward in the codend and through the escape openings of the TED (or BRD). Generally the longer it takes to haul the net onboard the greater the risk of shrimp loss.

Shrimp loss can also be prevented during the hauling process by ensuring the net maintains forward movement through the water. This is important when the codend is full and the accumulated catch is close to the escape openings of the device. It is particularly important in bad weather when surging of the catch in the codend can result in large numbers of shrimp escaping from the device. A suggested option to reduce this problem is to haul the trawl while heading into the sea. When the otter boards have reached the trawl blocks, a short burst of speed will help flush the catch into the codend. Rapid retrieval of the hauling rope immediately afterwards will obstruct the forward passage of shrimp toward the escape opening of the TED. A back-wash funnel or panel can help prevent the

Over 14,000 kg of shrimp were caught in one day and the TED and codend remained in perfect condition.

catch from surging toward the escape opening, particularly in bad weather or if hauling is slow.

How can a back-wash funnel or panel prevent shrimp loss?

A back-wash funnel is a conical section of netting located aft of a grid (or BRD) and is designed to act as a one-way valve. Shrimp and other animals freely pass through the funnel but the tapered exit-opening prevents these animals from passing back the other way. The end of the funnel may be attached by a few meshes to the bottom of the codend to prevent it from surging forward when hauling the trawl or in bad weather. The funnel may also be weighted at its trailing end to collapse when tow speed slows.

A back-wash panel performs a similar role to a funnel, except it is usually a rectangular- or trapezoidal-shaped sheet of netting. It is attached along its leading edge and sides to the codend in such a way that it guides the catch toward the bottom of the codend. There is only a small opening between the panel and the codend so the catch cannot easily surge forward and escape. Care is required to ensure that the panel does not trail back and block the escape openings of a BRD.

Can TEDs exclude fish and other bycatch?

TEDs are primarily designed to exclude turtles and other large animals from the trawl but it is possible to exclude smaller bycatch. For example, an upward excluding TED without an escape cover will allow some fish to swim upward and through the escape opening. This TED should also allow sea snakes to escape; an important outcome given several species around the world are threatened by fishing activity. A grid with a smaller bar spacing should help exclude a high proportion of fish and jellyfish as they attempt to avoid contact with the grid, and a bottom excluding TED will minimise the capture of rocks, sponges and other debris.

Although normally in combination with a BRD, additional modifications that can exclude fish through the escape opening of a TED includes the use of 'hummer bars', 'cones' or floats. These devices are located immediately behind the grid and are designed to deter fish from entering the codend. The hummer bar is a wire grid strung between a circular aluminium hoop. It is fitted vertically to the codend and the wires vibrate or 'hum' as it is towed through the water. This is thought to stimulate fish to stay ahead of the wires and seek the escape openings of the TED. Problems with 'hummer bars' include fouling or damage by sponges, starfish, weed and fish.

The 'cone' consists of a small wire hoop encased in plastic surrounding a cone-shaped section of netting. This device is held in place behind the grid by several lengths of twine attached to the codend. Visual and physical contact with the cone stimulates fish to swim forward and through the escape openings. A simpler option to stimulate fish is to replace the cone with a single float. As the trawl is towed through the water the float bobs about around and deters fish from entering the codend.

In some fisheries seaweed may foul the bars of the grid and stimulate shrimp escape. Bent-bar grids and so-called weedless grids are designed to overcome this problem. As the seaweed contacts the grid it slides down the inclined bars toward the escape opening of the TED. When the seaweed reaches the bend in the bars the change in bar direction causes the weed to fall off and (hopefully) be lost through the escape opening.

How will using a TED affect shrimp catching performance?

The use of a TED has the potential to provide fishermen with gains in catching performance because the negative impact of large animals on catching performance are reduced. For example, the capture of these animals has the potential to distort the geometry of the trawl and adversely affect seabed contact, particularly if a small trawl is used. Clearly this will reduce the catch rate of shrimp. There are also some reports that large catches in a codend can reduce the wingend spread of a trawl. This is probably due to catch-induced drag forces reducing the ability of the otter boards to maintain high wingend spread. By excluding bycatch from the trawl, codend drag will increase at a slower rate and wingend spread may be maintained. In instances where towing times are limited by the time it takes to fill a codend, excluding the bycatch may allow tow times to be increased. Therefore, shrimp catches should also be increased.

The exclusion of large animals from the trawl has the potential to minimize damage to the codend. If a TED is not used these animals may bite or break holes in the netting as they actively try to escape, and shrimp may be lost through these holes.

A TED can also impair the catching performance of a trawl, particularly if becomes blocked for an extended period. The capture of large animals, tree trunks, 44 gallon drums, lost fish traps and other debris has been responsible for catch loss in trawls fitted with a TED (although some of these items would damage the trawl and cause shrimp loss even if a TED was not used).

How will using a TED affect economic performance?

All things equal, an increase in catching performance should also increase economic performance because more shrimp will be landed. Moreover, TEDs have the potential to increase catch quality and reduce fuel consumption through reduced drag. This will put more money into the pockets of fishermen. The initial outlay for a TED could be several hundred dollars or more, and while several will need to be purchased to ensure adequate spares are available, gains in economic performance could more than offset this outlay. Ignoring unforeseen mishaps, a TED should last several seasons depending on maintenance regime, quality of construction and care of operation.

How will using a TED affect the way I manage my business?

The use of a TED has the potential to empower fishermen with greater control over their fishing operation, particularly through improved control over tow duration, catch volume and quality. Moreover, the use of these devices demonstrates a positive, pro-active attitude towards conservation of the marine environment and reduces associated concerns and threats from other stakeholders. In some instances this may pave the way towards the eco-labelling of the shrimp catch, and allow operators to maintain or even increase market share.

Optimizing BRD Performance

A well-designed and maintained BRD should ensure that fish and other bycatch is rapidly excluded from the trawl and that shrimp loss is minimal or non-existent.

Traditionally, most effort to reduce bycatch in tropical shrimp-trawl fisheries has focussed on the development of TEDs, but attention is increasingly being directed toward reducing catches of small fish and other bycatch.

Factors influencing BRD efficiency

The efficiency of a BRD is a function of the ease with which it can exclude fish and other bycatch from the trawl and retain the shrimp catch. This is achieved either by filtering the catch by size (so-called mechanical or physical separation) or exploiting behavioural differences between the shrimp and bycatch (so-called behavioural separation). The ability of a BRD to perform these functions is influenced by the design and operation of the device under the full range of operating conditions experienced in the fishery.

The diagram on page 58 highlights the various parameters that influence BRD performance. A summary of the important tips to optimize BRD performance is provided on page 63.

BRD location

Most BRDs are fitted to the codend because this is where the catch is accumulated and a higher proportion of the bycatch will encounter the device. The location of a BRD in the codend is important. If it is located close to the accumulated catch, bycatch reduction will be good because relatively little effort is required for the bycatch to swim through the escape openings of the device. however, if the BRD is too close to the accumulated catch shrimp loss will be high, particularly when the trawl is hauled or used in bad weather. If the BRD is located too far forward of the catch, bycatch reduction will be poor because it will struggle to swim forward and reach the escape openings of the device. For the same reason, shrimp loss will be low. Clearly the ideal location of a BRD is difficult to predict, given that catch volume can differ widely between fishing grounds and consecutive tows. For this reason trial and error is the only way to identify the optimum location of a BRD.

Knowledge of bycatch behaviour can also influence the location of the BRD. The most common example of this fish behaviour is the use of BRDs located in the top or sides of the codend. These devices rely on strong swimming fish turning ahead of the accumulated catch, swimming forward and though the escape openings of the BRD. A fisheye is an example of this type of BRD.

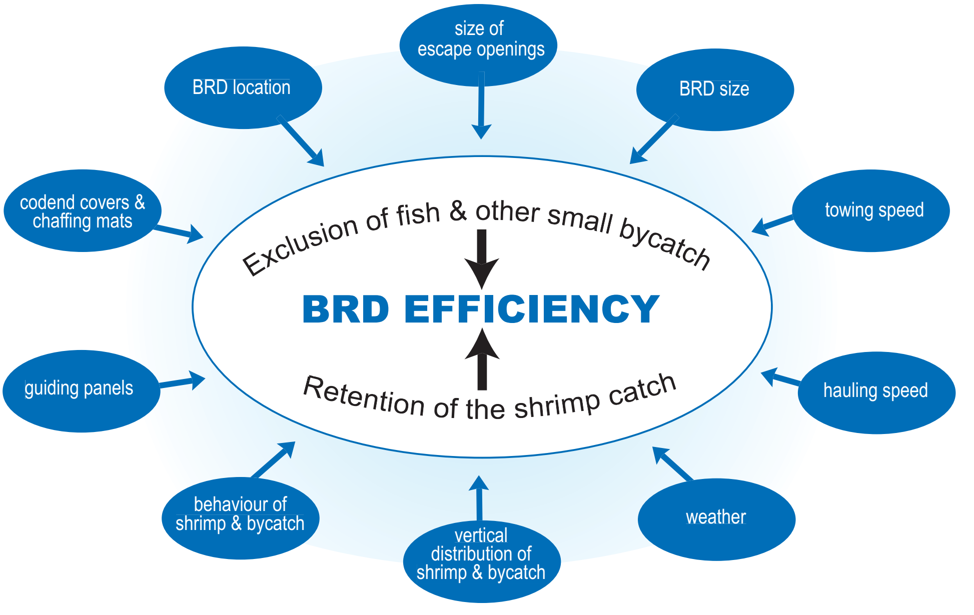
Other examples of BRDs that exploit knowledge of bycatch behaviour include ground chain modifications to avoid the capture of crabs or sponges and a reduction in headline height to allow fish to escape over the trawl.

Size of BRD

The size of a BRD is important because it influences the number and size of escape openings available for bycatch to escape. In turn, this influences the volume and size of bycatch that can escape from the trawl. For example, a large square-mesh window will provide a greater number of escape openings to be available for fish to escape. Clearly, the size (length and circumference) of a codend will play a role in determining the size of a BRD that can be located in this part of the trawl.

Size of escape openings

The size of a BRD escape opening is important because it influences the size of the animals that can escape. The mesh openings of a square-mesh codend must be small enough to prevent shrimp from escaping but large enough for small bycatch to escape. On the other hand, the large escape openings of the fisheye and RES will allow larger fish and other bycatch to escape from the trawl.



The various parameters that influence BRD performance and efficiency.

Determining the optimum size of escape openings is difficult, particularly if the size and composition of the bycatch changes between fishing grounds and throughout the fishing season. An estimate of the required size of an escape opening is possible based on knowledge of catch composition, but at-sea testing using a trial-and-error approach will be required to accurately determine the optimum size of these openings.

Hauling speed

If the trawl is hauled slowly to the sea surface and onboard, fish and other bycatch may swim forward and escape through the BRD. There is some evidence that for some devices, such as the fisheye and RES, a high proportion of the bycatch escapes from the trawl during the hauling process. While slow hauling is good for bycatch reduction, it can be a major cause of shrimp loss as they also swim forward and escape. It is therefore recommended that the trawl is hauled as quickly as possible.

Hauling a shrimp trawl by hand is a laborious process that may allow large numbers of fish and shrimp to escape from the trawl.

The frayed lengths of rope attached to the codend cover help protect the codend from damage. However, as they also block the codend meshes the escape of small bycatch is impossible.

Weather conditions

In bad weather the catch may surge forward in the codend and escape. This may improve bycatch reduction but it can also increase shrimp loss. This problem occurs mainly when the trawl is being hauled to the surface and onboard the boat. Hauling the trawl with the boat heading into the sea or swell may go some way to minimising catch surging and shrimp loss. Hauling the codend with the sea abeam would further reduce this problem but in bad weather crew safety may be threatened.

Codend covers and chaffing mats

These modifications are designed to prevent codend damage due to seabed contact or attack by sharks and other animals. Codend covers are typically a cylinder of old netting that surrounds the codend. It is common for an old, worn codend to be used, and sometimes frayed lengths of rope are attached to further prevent codend damage. In some fisheries codend covers surround the entire codend. The use of these covers is an irresponsible practice because they prevent the escape of small, juvenile fish and other bycatch. If possible codend covers should be eliminated or reduced in overall size. This will allow a greater number of small fish to escape and also increase the amount of codend available for locating the BRD.

Chaffing mats are typically a thin sheet of rubber that extends along the length of the codend. They are usually attached only to the bottom of the codend to protect it from seabed contact and abrasion. Chaffing mats also reduce the number of codend meshes available for fish to escape, but are preferred because they block fewer codend meshes. The size of chaffing mats should also be reduced if possible.

Vertical distribution of shrimp and bycatch

Most shrimp are distributed on or near the seabed and low-opening trawls are used to capture these animals. The height of these trawls is generally between 1 to 1.5 m, and is equal to otter board height because the headline is attached directly to the top of the otter board. Many fish escape from these trawls by simply swimming over the headline. However, in other fisheries, the trawl is separated from the otter boards by sweep wires that may measure 10m or more in length. Floats are also attached to the headline and the height of the trawl may now approach 3m or more. While this configuration is designed to catch schooling species of shrimp, or those with a more pelagic lifestyle, these trawls are likely to catch greater amounts of bycatch. The sweeps are likely to herd fish toward the trawl mouth and fewer fish will now be able to escape over the headline. Clearly this is undesirable, and a reduction in headline height and removal of the sweeps should be considered to

The catch in the basket on the right was excluded by a JTED and consists mainly of small fish. The swimming performance of these fish is poor and so they must be filtered from the trawl using a grid or small mesh.

reduce this bycatch. Although this may not be possible when schooling shrimp are being sought, the trawl should be modified when catch rates decrease or other shrimp species are targeted.

When targeting shrimp that are scattered over the seabed, there is some potential to reduce headline height to less than 1 m. This can be achieved simply by re-attaching the headline to a lower position on the otter board. A lower attachment height may cause the otter boards to stand upright and the towing chains may need adjusting to increase otter board heel. This modification has the potential to increase shrimp catches because wingend spread may increase in response to reduced trawl height.

There is little difference in the vertical distribution of bycatch and shrimp in the codend. Underwater video footage indicates that these animals enter the codend at various heights. Shrimp are usually still swimming although a few may be close to the bottom panel of the codend. The most obvious difference in distribution is the presence of sponges, coral and bottom-dwelling fish entering the codend near the bottom panel of the trawl.

Behaviour of bycatch and shrimp in the trawl

Most attempts to reduce bycatch have involved placing a TED or BRD in the codend of the trawl. However, based on knowledge of bycatch and shrimp behaviour it is possible to reduce some bycatch before they enter the codend. For example, modifying the ground gear or providing escape openings in the bottom panel of a trawl can reduce catches of crabs, starfish and sponges. Some species of fish, including many pelagic species, swim in the trawl mouth for a period and then rise upwards to seek escape through the top panel of the trawl (sometimes large numbers of these fish can be seen caught in the meshes of this panel). A larger mesh size or even a square-mesh window strategically placed in this location may be effective in allowing these animals to escape from the trawl. Many fish species can have their schooling behaviour disrupted if they are herded or confined into a small area, such as the tapered section of netting immediately ahead of the codend. In this location fish may respond by suddenly 'exploding' in all directions and a square-mesh window or cylinder may allow these fish to escape.

Efficient bycatch reduction devices can also be developed to exploit differences in the swimming behavior of bycatch and shrimp as they pass through the codend. These differences are currently exploited by the fisheye, fishbox, and RES. The escape openings of these devices are located in the top or upper sides of the codend ahead of the accumulated catch. Strong swimming fish are able to swim faster than the towing speed and they can swim forward and out through the escape openings of the BRD. On the other hand, small fish are less likely to escape because they do not have the swimming capability to reach the BRD. Other BRDs are required to exclude these animals, such as the JTED or square-mesh codend.

The design and shape of some BRDs produces a region of turbulent water flow (eddies) immediately adjacent the escape openings of the device. Within the region of turbulence some water is carried forward and fish actively seek these regions because swimming is easier (fish have also been observed actively seeking these regions behind the bars of a grid, behind floats and even behind a codend where water turbulence can carry them forward). The fisheye, fishbox and RES are BRDs that produce water turbulence to assist fish escape. The shape of the fisheye is designed to distort the codend meshes ahead of the escape opening, and these meshes generate turbulent flow as the trawl is towed forward. Fish are 'attracted' to this region by the turbulence and only need to swim forward to escape. The funnel of an RES has a similar role. Not only does it concentrate the catch to the middle of the codend but it also serves to generate turbulence near the escape openings of the device. Fish then swim forward and out through the escape openings.The fishbox is designed with foils to produce water turbulence as the trawl is towed through the water. Similarly to the other devices, fish are attracted to this region and can escape from the trawl.

In contrast, shrimp have poor directional swimming capability and they passively enter the codend. They typically enter the codend at any height above the seabed swimming horizontally in a random direction. If they make contact with other animals or codend netting they usually respond with rapid flexing of the tail (tail-flicks) to propel themselves backwards and away. This response has limited directional capability.

The fisheye BRD relies on strong swimming fish being able to swim forward and through the escape opening of the device.

Knowledge of this behaviour is used in the design of BRDs that allow the escape of strong swimming fish. For example, the funnel of an RES extends past the escape openings to guide shrimp toward the codend. Unlike most fish, shrimp are unable to swim forward and through the escape openings of the device.

Towing speed

The effect of towing speed on BRD performance is unclear and requires further study. In the first instance, it might be expected that BRDs that exploit differences in swimming performance between bycatch and shrimp will be less effective at higher speed because fewer fish will be able to reach the escape openings of the device. The average size of fish that are caught may also decrease as fewer small fish escape from the trawl. However, there is some evidence that the effect of increased towing speed on bycatch may not be so straightforward. Some studies have found little or no difference in rates of bycatch reduction with increased speed, and this is thought to be due to increased water turbulence and velocity in the codend at higher speed. This in turn increases the lateral movement of water out of the codend and helps fish swim toward the escape openings of the device. Clearly there is a need to research the relationship between bycatch reduction and towing speed in greater detail.

Guiding panels

These are panels of netting located ahead of a BRD to guide shrimp away from the escape openings of the device. They are typically used in front of fisheyes and square-mesh windows. The leading edge of these panels is attached to the top of the codend several meshes ahead of the BRD. The sides of the panel are generally sewn to the sides of the codend at an angle (for example, along a row of bars). Care is required that they are attached well forward of the BRD to ensure they do not cover the escape openings of the device.

A criticism of these panels is that they also guide bycatch away from the escape openings of the device. Bycatch near the top of the codend is guided away from the BRD and can only escape if it can swim forward and reach the device. This may reduce the escape of small fish and other bycatch. However, it is possible that this criticism is unwarranted and in fact these panels actually increase bycatch reduction. This is because water turbulence is generated as these panels are towed through the water making it easier for fish to reach the BRD. All things held equal, a higher proportion of smaller fish could therefore be expected to escape. The effect of these panels has not been rigorously tested and their actual impact remains unclear.

If a TED is not used these panels may suffer damage by large animals as they enter the codend.

BRD maintenance program

It is clearly important that a BRD is well maintained to ensure peak performance. The following table provides inspection details of the various BRD components, the frequency of inspection and suggested action.

COMPONENT	INSPECTION DETAILS	INSPECTION FREQUENCY	SUGGESTED ACTION
Escape openings	Damaged meshes; mesh distortion (square-mesh); mesh slippage/detachment around frame of BRD	Daily	Repair or replace meshes; re-attach to BRD
Guiding panel or funnel	Check for mesh stretch or damage; detachment from codend meshes	Daily	Replace if necessary; reattach to codend
Floats	Check attachment to BRD or codend netting	Weekly	Re-attach to BRD or codend
Backwash funnel	As for guiding panel or funnel	Daily	Replace
Grid (JTED only)	Bent or damaged bars, bar spacing	Daily	Straighten if possible or replace
Grid angle (JTED only)	Loss of angle	In the first week, daily for new grid; weekly	Re-attach grid to codend at correct angle
Grid bindings (JTED only)	Check for abrasion, frayed rope strands, loose bindings	Weekly	Replace/retighten if necessary

Tips for optimizing BRD performance

The following table provides a summary of the important tips to optimize BRD performance.

BRD COMPONENT	BRD TIP
BRD size	A large BRD will allow large escape openings to be used. The number of escape openings may also be increased.
BRD location and attachment	If located in the codend, the BRD must be close enough to the accumulated catch for fish to escape, but not too close that shrimp loss is high. The BRD should be securely attached to the trawl and correctly orientated.
Escape opening	The size of the escape opening(s) determines the size of the bycatch that can escape.
Guiding panel or funnel	They are used to guide shrimp away from the escape openings as they pass through the codend. They must not block the escape openings of the BRD.
Flotation	Floats assist BRD stability and orientation. They must not block the escape openings of the BRD.
Backwash funnel	These funnels prevent shrimp loss as the trawl is hauled, particularly in bad weather. They must not be located in a position where they can block the escape openings of a BRD.

The attachment of this fisheye to the codend is poor (uneven and loose bindings) and may reduce its performance.

BRD Performance & Operation
Frequently Asked Questions

This section answers many frequently asked questions about the design and operation of a BRD.

Can several BRDs be used together?

There is no reason why several BRDs cannot be used simultaneously (in addition to the TED). For example, a square-mesh codend could be used with a fisheye so that both small and large fish are excluded from the trawl. The handling and operation of the codend would be little different to that of a standard diamond-mesh codend and would exclude fish of a wider size-range. Other possible BRD combinations to exclude both large and small fish include a JTED with a square-mesh window or an RES with a codend constructed from larger diamond-mesh.

In many fisheries the use of both a TED and BRD is mandatory. This ensures that large animals such as turtles and sharks are excluded as well as smaller fish and other animals.

What is the simplest BRD to use?

Possibly the simplest modification to reduce bycatch is to adjust the ground gear of the trawl. If a so-called texas-drop ground chain system is used, increasing ground chain length by one or two links will reduce the amount of benthic fish, shell and debris that is caught. Increasing the length of the dropper chains will also reduce this catch because it can easily pass under the footrope of the trawl. Other examples of simple BRDs include larger codend mesh size, the use of flappers or large holes cut into the codend, shorter sweep wires, or codend rigging such as lastridge ropes.

While not classed as a BRD a simple way to prevent bycatch is to avoid regions where bycatch levels are known to be high. These areas include inshore and estuarine regions where small fish are often abundant. Avoiding known fish and shrimp nursery grounds, including seagrass beds, is another option to reduce bycatch. There are many fisheries where these regions are closed to fishing but there are also many fisheries where they are not.

Does BRD performance differ between day and night?

In many fisheries, BRDs exclude a higher proportion of fish bycatch during the day time. This is thought to be linked to differences in fish behaviour and their improved ability to observe the BRD. It is therefore important to measure the performance of these devices during night and day for a full assessment of their capability.

Can I use a back-wash funnel to prevent shrimp loss?

There is no reason why a back-wash funnel cannot be used to prevent shrimp loss. The funnel would be located aft of the BRD and ahead of the accumulated catch. When the trawl is hauled to the surface the tapered end of the funnel would collapse and prevent surging of the catch toward the BRD. This is particularly important if hauling is slow or the weather is bad. If the funnel is located in this position there is no need to have a second funnel aft of the TED.

How do I join diamond mesh to square-mesh netting?

To do this is quite simple but requires a few simple calculations to determine the joining ratio of diamond mesh to square mesh. Using the square-mesh window described in page 90 the first step is to determine the number of diamond meshes required to be attached to the window. Note that is important that all diamond and square meshes are attached evenly and not distorted, and the window is fully open.

When the trawl is towed the width or opening of a codend mesh (ahead of the accumulated catch) is typically 20 - 30% of its mesh size. As the exact mesh opening is difficult to measure an assumed opening is used; in this example a mesh width of

25% (0.25) is assumed. The expression to calculate the number of diamond meshes is;

$$\text{No. diamond meshes} = \frac{\text{no. square mesh bars x square mesh bar length (mm)}}{\text{diamond mesh size (mm) x mesh opening}}$$

$$\text{No. diamond meshes} = \frac{6 \times 75}{45 \times 0.25} = 40$$

So, 40 diamond meshes are to be joined to the 6 square-mesh bars across the width of the window. Now, the next step is to determine the number of diamond meshes required to be attached to the sides of the window. As we have assumed the codend mesh has a stretched width of 25%, the length of the mesh must be reduced accordingly. In this example, the mesh length is reduced to 97% of initial length (if a mesh width of 20% is assumed the length is reduced to 98%, and if 30% is assumed the length is reduced to 95%). The expression to calculate the number of diamond meshes now becomes;

$$\text{No. diamond meshes} = \frac{6 \times 75}{45 \times 0.97} = 10$$

So, we need to attach 10 diamond meshes to the 6 square-mesh bars along the length of the window. The above example is based on fitting a square-mesh window of known dimensions to a diamond mesh codend. However, if the number of diamond meshes is known but the number of square meshes is not, for example, when determining the circumference of a square-mesh codend to join to a diamond mesh extension piece, the expression can be transposed thus;

$$\text{No. of square mesh bars} = \frac{\text{no. diamond meshes x diamond mesh size (mm) x mesh opening}}{\text{square mesh bar length (mm)}}$$

Using the square-mesh codend on page 92 as an example, the expression becomes;

$$\text{No. of square mesh bars} = \frac{150 \times 45 \times 0.3}{19} = 107 \text{ bars}$$

So, 107 bars are attached to the 150 mesh extension piece at a ratio of 3 diamond meshes to 2 square mesh bars (and to account for the 7 bars, picking up an extra bar every 20 diamond meshes). Note that in this example a mesh opening of 30% (0.3) was assumed. This was simply to enlarge the square-mesh codend to accommodate large animals or catches and to provide additional mesh openings for small fish to escape.

How do fish behave in a shrimp trawl?

As a trawl approaches, fish will be aware of the sounds made by the trawl as it is towed through the water and over the seabed. Despite this awareness they seem unable or unprepared to respond to these sounds by swimming away (a fortunate behaviour when fish are the target species). This is confirmed by observations of fish under ultra low-light conditions being run over by approaching trawl ground gear. The reasons for this behaviour are unclear, but may be linked to the noisy underwater environment and the speed of sound through water (about three times the speed of sound in air). In this environment responding to sounds, even that of an approaching trawl, uses valuable energy and increases the risk of predation from more immediate threats. This means that fish mainly respond to the visual and physical stimuli of an approaching trawl.

Fish in the water column may escape over or around the approaching trawl or enter the trawl mouth. Those fish in the trawl mouth may attempt to swim with the trawl for a period of time. This is linked to a desire to swim with an object that has a strong visual contrast with the background. It is called an optomotor reaction. If towing speed is higher than sustained fish swimming (cruising) speed, they attempt to maintain position with the trawl repeatedly using short bursts of acceleration followed by a gliding movement. This is a so-called kick-and-glide response, and it is used by fish to conserve energy and avoid predation. The fish in the trawl mouth eventually tire and either attempt escape around or through the meshes of the trawl, or they enter the trawl. Many small fish will also be swimming with the trawl in the same direction. As they are weak swimmers they do not have the luxury of using a kick-and-glide response. To keep up with the trawl they must swim at a speed that rapidly leads to exhaustion, and they are soon overrun by the trawl and enter the codend.

Other fish do not respond by swimming with the trawl. Instead they will enter the trawl mouth either passively or with burst-speed swimming manoeuvres in random directions. Those that enter the trawl passively are quickly overrun and are retained in the codend. Fish that are burst-speed swimming typically contact the trawl netting at high speed. Some become gilled in the netting and some may escape through the meshes. Others will rebound off the netting and swim in another direction. This may continue until they make their way into the codend. Many schooling pelagic fish may attempt an upward escape by swimming through the meshes in the top panel of the trawl as they become tired.

Fish on the seabed usually remain motionless until contact is imminent or made. They react with a kick-and-glide response to keep ahead of the approaching trawl, and may even settle back on the seabed before contacted by the trawl. This may be repeated several times before they either escape

Shrimp trawls catch fish of many different sizes and swimming capability. Knowledge of fish behaviour including swimming performance is important to develop effective bycatch reduction devices.

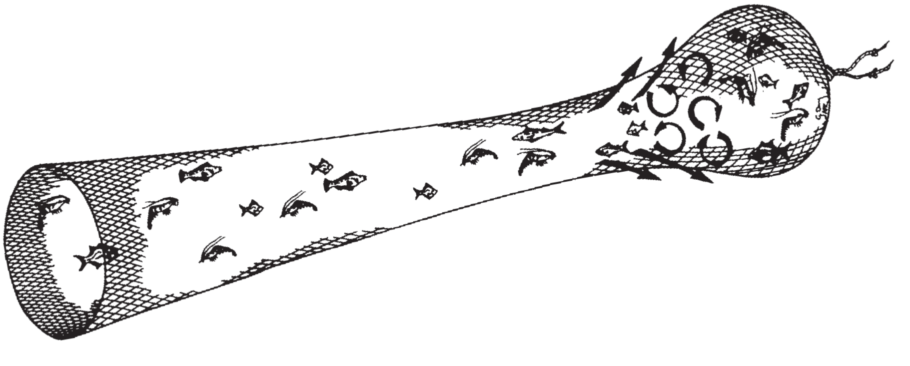
(usually over the lower sweep or under the footrope) or enter the trawl.

As fish swim through the trawl and approach the codend, some will attempt escape through the trawl meshes. It is possible that crowding in the narrow part of the trawl elicits this response. Other fish will continue burst-speed swimming in random directions, haphazardly bumping into codend netting and other fish. Fish sensitive to the optomotor reaction may respond to the visual contrast of codend netting against the background. They will orientate and swim with the netting for a while before tiring and being overrun by the codend. They may even attempt to burst-swim through the trawl meshes. Fish that live on the seabed may rest on the bottom panel of the trawl for several minutes before reaching the codend.

Upon reaching the codend weak swimming fish will simply be overrun and join the accumulated catch. In contrast, stronger swimming fish may seek out regions of water turbulence. These regions are attractive because some of the turbulent water moves forward and it is easier for fish to swim and maintain station with the trawl. Examples of this behaviour include small fish swimming immediately behind the bars of a grid or behind a trawl float. Sometimes the turbulence is sufficient to allow fish to briefly remain motionless while being carried forward with the trawl. Knowledge of this behaviour is useful because it allows the development of BRDs that deliberately generate water turbulence near the escape openings. The fisheye, fishbox and RES are three BRDs that deliberately generate water turbulence to assist bycatch reduction.

While water turbulence can attract fish toward the escape openings of a BRD, stimulating them to escape can be difficult, particularly for species strongly responsive to the optomotor reaction. Many fish prefer to remain in this location swimming easily with the trawl. Overcoming this problem is difficult and success has not yet been widely achieved. What is required is some way of temporarily disrupting the effects of the optomotor reaction. The use of plastic cable ties attached to the fisheye adjacent the escape opening has been one attempt at overcoming this problem but with limited success. One option to consider might be to temporarily slow the towing speed. It has been observed that many fish escape during the hauling process - presumably because the forward motion of the trawl is less and the altered trawl geometry upsets the optomotor reaction. A sudden reduction in towing

The accumulated catch generates water turbulence as the trawl is towed through the water. Some of this water is directed sideways through the codend meshes. A BRD located in this region may be effective because the water movement helps fish reach the escape opening of the device.



speed could potentially achieve the same result and stimulate these fish to escape. Care would be required to prevent bogging of the otter boards and trawl in soft mud or sand. Fortunately not all fish are as difficult to remove from the trawl and many do escape through the openings of the BRD.

A BRD can be strategically located to take advantage of water turbulence generated by the trawl or the catch. For example, as the catch accumulates in the codend water is pushed forward by the forward movement of the trawl. This generates a region of water turbulence ahead of the catch and some water is directed laterally (sideways) out through the meshes of the codend. This is attractive to fish because it allows them to swim easily with the trawl for a period and avoid joining the accumulated catch. These fish are able to save energy and can take advantage of the lateral water movement to swim out through the escape openings of a nearby BRD. As this method is partially reliant on catch volume, identifying the ideal location for the BRD is not always possible because catch volume varies during the tow and between fishing grounds. Clearly, the location of the BRD should not be immediately adjacent of the catch or shrimp loss may be high. Locating the BRD too far from the catch (several meters) is unlikely to help bycatch reduction - although it will protect the shrimp catch. The final location of the BRD must be based on knowledge of expected catch volume followed by a trial and error approach to determining its most effective position.

How do shrimp behave in a shrimp trawl?

As the trawl approaches, shrimp are located either on the seabed or swimming in the water column. Shrimp on the seabed generally respond to the approaching trawl by remaining motionless. This behaviour is thought be used to avoid detection by predators. Shrimp that are swimming do not respond to the trawl until contact is imminent or made. Their escape response is rapid swimming or contraction of their abdomen and rapid propulsion (tail-flicks) away from the trawl. As this response is not sustained they are eventually overrun by the trawl and enter the codend. There is no herding of shrimp into the trawl.

Shrimp that are on the seabed respond to ground chain contact with rapid tail-flicks backwards and upwards. This response may be repeated several times to a height of several meters. The combined influence of towing speed, head line height and cover (lead-ahead) ensures that many of these shrimp are unable to escape from the trawl. They are not responsive to the optomotor reaction. Shrimp that do escape the approaching trawl may swim in the water column for several minutes before returning to the seabed.

Shrimp that enter the trawl mouth have limited swimming capability, particularly if they have responded several times to trawl contact. They usually enter the codend passively, although some shrimp may first be impinged on the netting for a period of time. If shrimp are then contacted by other animals, the trawl or bycatch reduction device, they may take evasive action and tail-flick several times. This may result in shrimp unintentionally escaping through the TED or BRD. There is little evidence that they are capable of deliberately swimming through the escape openings of a device. Shrimp enter the codend at any height but are usually exhausted and do not have the ability to swim with the trawl.

How can I prevent bycatch from entering a shrimp trawl?

This is a worthwhile notion because it avoids trawl-induced damage to fish and other bycatch, improves the catching performance of the trawl and improves the quality of the shrimp catch. Reducing the amount of bycatch that enters a trawl will compliment the performance of BRDs in the codend.

There are several options to preventing bycatch from entering a trawl. The simplest is to avoid areas of high bycatch density. This is not always possible, particularly if shrimp catches are high. Another option is to stop fishing when catch rates are low and bycatch levels are high. An example of this is daylight closures. Modifying the ground gear is a simple option to avoid sponges, rocks and coral from entering the trawl providing it does not impact on the shrimp catch. In at least one instance a large mesh panel has been tested extended across the entire trawl mouth to prevent the entry of large animals into the trawl. The meshes of the panel were large enough to allow the entry of shrimp and small bycatch, but this idea was not successful due to fouling and damage to the panel by bycatch. An option that has not been widely tested is a reduction in headline height so that fish can escape over the headline of the trawl. This modification has some potential in fisheries that target bottom dwelling shrimp and can be easily introduced to existing trawl gear.

Do fish that escape survive?

It is important that the survival of fish is evaluated to fully assess the effectiveness of a BRD. Clearly if fish escaping from a BRD suffer high mortality rates then it needs to replaced by another device. One option to assess fish survival is to use underwater cameras to observe how they escape from the trawl. Survival rates are likely to be high if fish swim rapidly through the escape openings of a BRD without having contacted the trawl, other fish or the device. However, if they heavily contact the device or squeeze through the escape openings they are likely to suffer serious damage and internal injury, and the mortality of these fish is a high possibility. A more difficult but effective option is to collect the escaped fish and place them into a recirculating water tank for several days. The survival rate of tank-held fish can then be used to indicate the potential survival rate of fish that escape through the BRD. A third option to assess fish survival is to physically inspect escaped fish for signs of damage, including scale loss, fin damage or bruising or swelling of the body. Badly damaged fish are likely to suffer higher mortality rates, so this is also a useful indicator of fish survival. The latter two options are difficult to achieve because they require the collection of animals that have escaped from the BRD, usually in a secondary codend located around the escape openings of the device or the main codend. It is also important that escaped fish are not further damaged by the collection process.

With few exceptions there has been little work in tropical shrimp-trawl fisheries assessing the survival of fish that have escaped from a BRD. This is because studying the survival rate of fish is difficult and expensive. Many countries are still struggling with the introduction of effective BRDs

Most fish and other bycatch that are landed on deck are either dead or dying. With the exception of crustaceans and a few other animals the survival of animals returned to the sea is unlikely.

(and TEDs) and it is perhaps premature to conduct this work until greater experience in the use of these devices has been obtained.

How will using a BRD affect shrimp catching performance?

In the same way that a TED can improve the catching performance of a trawl, a BRD can also provide fishermen with gains in catching performance. This is achieved by overcoming the negative effects of bycatch on trawl efficiency, such as reduced wingend spread and towing times. By using a BRD the area swept by the trawl per unit of time is increased and all things held equal the shrimp catch should increase. Moreover, towing times are now less influenced by catch volume, meaning that time lost due to repeated hauling of the trawl is reduced and additional time is available for fishing.

How will using a BRD affect the economic performance of my fishing operation?

By improving the catching performance of the trawl and increasing the shrimp catch a BRD should put more money into the pockets of the fisherman. In addition, the exclusion of fish with spikes or sharp teeth has the potential to improve the quality of the shrimp catch, thus improving catch value. Overall, using a BRD could improve the economic performance of a fishing operation.

How will using a BRD affect the way I manage my business?

By reducing bycatch fishermen have greater control over their fishing operation, including the option of increased towing times and increased control over catch volume and quality of the shrimp catch. The use of BRDs is a responsible move that may allow eco-labelling of the shrimp catch and associated opportunities to expand market share or open new markets.

Overcoming the US Embargo
TED Regulations & Other Details

This section briefly describes the US embargo on shrimp imports and the requirements for an effective sea turtle protection program[4]. A summary of the US TED regulations is provided in Appendix 1. It is essential that countries seeking to lift the embargo have regulations in place governing the design and size of TEDs that are comparable to the US regulations.

What is the US embargo on shrimp imports?

In 1989 the US Government passed Section 609 of the US Public Law 101 - 162 restricting the import of shrimp to countries with shrimp fisheries that did not have an adverse impact on sea turtles. Initially, this embargo was introduced to protect local sea turtle populations and applied only to countries in South America and the Caribbean Sea. In 1996 the embargo was extended to include all countries worldwide that export shrimp to the US. In effect this embargo means that the US will not import shrimp from any country that does not have in place a sea turtle protection program of comparable effectiveness to the US program. The responsible agencies for the implementation of this law are the US Department of State and the US National Marine Fisheries Service (NMFS).

What is a program of comparable effectiveness?

A program of comparable effectiveness is one that has laws and regulations requiring mandatory turtle protection measures and achieves a comparable level of turtle protection to that required in the US. In tropical shrimp-trawl fisheries, such a program will usually require the mandatory introduction and use of TEDs by all fishermen. This will need to be supported by appropriate regulations governing TED design, rigging and operation. An effective monitoring and enforcement program will need to be developed and evidence that fishermen are using these devices must be provided. Documented evidence will need to be provided demonstrating that the approved TEDs are excluding sea turtles. The NMFS has found that effective TED designs are capable of excluding 97% of sea turtles that enter a shrimp trawl (usually within 5-minutes of entering the trawl mouth), and TEDs used in other countries will normally be required to provide evidence that they are achieving a similar rate of exclusion. However, in some cases the NMFS may assume a country is achieving a similar rate of turtle exclusion if they have adopted the US dimensions for grid size and escape opening and they may not request documented evidence that 97% of turtles are being excluded from the trawl.

There are also likely to be additional reporting requirements to compliment the introduction of TEDs and demonstrate that a comparable level of turtle protection is being achieved, for example, uptake levels by fishermen and compliance rates. These requirements may vary between countries due to variations in fishery location, fishing method and operation, and it is therefore advisable before commencing a turtle protection program to confirm these requirements with the US Department of State and the NMFS.

What are the US TED Regulations

A summary of the regulations is provided in Appendix I. These regulations describe the main design details for the use of TEDs in the Gulf of Mexico and southeast Atlantic shrimp-trawl fisheries. Countries attempting to develop an effective turtle protection program and seeking removal of the embargo should consider these regulations as a foundation upon which to build their

[4]The detailed description of the US TED regulations in this guidebook in no way implies that the FAO, its staff, nor the author support the use of trade embargoes to restrict trade and meet national environmental criteria. The regulations are included here because they serve as a useful foundation to develop effective TED designs given their demonstrable success in preventing turtle capture in shrimp-trawl fisheries worldwide.

own fishery-specific regulations of comparable effectiveness. The regulations are designed to provide sufficient protection for large turtles such as loggerhead and leatherback turtles.

As these regulations are subject to change in response to renewed concerns about turtles it is advisable to check for recent amendments or changes prior to developing a turtle protection program.

Who does the embargo apply to?

The embargo applies to all countries that export wild-caught shrimp to the US. It does not apply to cultured or farmed shrimp. In 2004 Bangladesh, Haiti, India, Indonesia, Nigeria, Thailand and Venezuela did not have an effective turtle protection program in place and were unable to export shrimp to the United States.

The use of TEDs is an essential component of a sea turtle protection program and removal of the US embargo on shrimp imports.

What countries are currently exempt from the embargo?

Since 1989 many countries have been exempted from the US embargo. This includes countries with cold water fisheries not frequently inhabited by turtles. In 2004 there were 14 certified countries on the basis that their turtle protection programs were comparable to the US program. These countries were: Belize, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Guyana, Honduras, Mexico, Nicaragua, Pakistan, Panama, Surinam, and Trinidad and Tobago. There was an additional 16 shrimp catching countries with fishing grounds located in cold waters not frequented by turtles. They were: Argentina, Belgium, Canada, Chile, Denmark, Finland, Germany, Iceland, Ireland, the Netherlands, New Zealand, Norway, Russia, Sweden, the United Kingdom and Uruguay. The Bahamas, China, the Dominican Republic, Fiji, Hong Kong, Jamaica, Oman, Peru and Sri Lanka are also exempt from the embargo on the basis that they either catch shrimp using small boats with less than five crew and no mechanical means of hauling the nets, or they use fishing methods not deemed to threaten turtles.

Who makes the assessment of a turtle protection program?

A delegation of staff from the US Department of State and the NMFS will assess a turtle protection program for comparable effectiveness. These staff are experienced in the design, use and regulation of TEDs and therefore well qualified to assess the program. The assessment usually involves the delegation making an initial visit to a country seeking approval in order to inspect the fishery and help prepare the protection program. This will then be followed by periodic inspections by the delegation to provide ongoing technical assistance and ensure that the program continues to protect turtles.

When did the latest regulations come into effect?

The latest revision of the regulations came into effect in August, 2004. This means that all countries currently certified and those seeking certification must incorporate these new regulations into their protection program in order to provide a comparable level of turtle protection. These regulations must also be incorporated into the laws and regulations of each country and their use made mandatory.

How might I benefit from the new regulations?

The NMFS also determined that these changes may in fact allow large animals and debris to be released from the trawl more rapidly. TEDs must now be fitted with a larger escape opening and modified escape cover, which allows easier passage of these animals from the trawl. The escape cover can then quickly return to its original position and seal tightly over the escape opening. This should reduce or minimise shrimp loss.

Can a country seek an exemption from the new TED regulations?

Yes. However, any request for such an exemption must demonstrate that the commercial shrimp fishery does not interact with turtles including large loggerhead and leatherback turtles. Evidence that there is no interaction must be based on scientifically sound data, preferably provided by independent observer based studies that represent a sizeable sample of the fishing fleet and overall fishing effort over the fishing season.

The US Department of State and the NMFS can be contacted to provide information and details describing how such a study might be pursued. It should be noted that countries are still required to introduce and use these new regulations until an exemption is granted.

Are there alternatives to using TEDs?

In some instances it may be possible to catch shrimp for import to the US without the need to use a TED, but only in exceptional circumstances. The use of short towing times is one option available to some fisheries. In the US, for example, towing times less than 75 minutes can be used providing the fishing boat has no hydraulic or mechanical-advantage hauling system (ie. no blocks or pulleys), is a so-called bait shrimper that retains all live shrimp onboard (no dead shrimp onboard for human consumption) or uses a push net, skimmer trawl or wing net. Towing time is measured from the time the otter boards enter the water until they are hauled above the water. For a trawl that is attached to the otter board via sweeps or ropes the tow time is measured from the time the codend enters the water until it is removed. It is unclear how other countries might apply towing-time restrictions but presumably they would need to demonstrate that such a restriction was comparable to TEDs in protecting sea turtles. Under special circumstances it may also be possible to apply towing-time restrictions where the presence of sea weed, sponges or other environmental conditions makes trawling with TEDs impracticable.

Does a test-net or try-net need to be fitted with a TED?

If a single net with a headline length measuring 3.6 m or less and a footrope length measuring 4.6 m or less is used then in does not have to be fitted with a TED. However, this net must not be attached to another net and there must only be one try-net used at any one time. It must also not be towed as a primary net. This clearly assumes the try net will be used only to provide a sample of shrimp density and that towing times will be short and not threaten turtles. Tow time restrictions do apply to the use of try-nets.

Can individual fisheries seek exemption from the embargo?

Where a country has more than one shrimp fishery, approval to export shrimp to the US can be granted to individual fisheries providing it has been demonstrated that the fishery has an effective turtle protection program. Currently this situation only exists in fisheries in Australia and Brazil. The TED regulations in Australia's Northern Prawn Fishery are provided in Appendix 2. An exemption can also be granted to an individual fishery if the US Department of State and the NMFS are satisfied that turtles do not inhabit the region.

Are shipments of shrimp into the US checked?

Every shipment of shrimp imported into the US must be accompanied by a form confirming that the shrimp was caught under circumstances that are not harmful to sea turtles. The form must be completed and signed by both the exporter and importer. If the shrimp was caught by a country certified by the US Department of State under Section 609, it is assumed that the shrimp satisfies this standard.

Interestingly, Section 609 allows the import of shrimp caught in an uncertified country, but only if a government official in the uncertified country also signs the form and affirms that the shrimp was caught under specific conditions that do not pose a threat to turtles.

Where can I obtain more information about the TED regulations?

There are several possible options for obtaining information about the US TED regulations and the development of programs to reduce turtle capture and lift the embargo, including:

- The US Embassy in each country.
- Foreign Affairs Officer. Office of Marine Conservation, US Department of State, 2201 C.St. NW, Room 5806, Washington DC 20520
- National Marine Fisheries Service. TED Technology Transfer Program. P.O. Box 1207, Pascagoula, Mississippi. 39568-1207. http://www.nmfs.noaa.gov or http://www.mslabs.noaa.gov/teds.html
- Fisheries research institutes or management authorities in each country.
- Copies of the Federal Register, Code of Federal Regulations, Title 50 Part 223.206 and 223.207 (50 CFR 223.206, 50 CFR 223.207) located on the internet.

The Future of Bycatch Reduction
in Shrimp-Trawl Fisheries

The issue of bycatch is not going away and fishermen will always be under pressure to reduce catches of non-target animals and non-living material. However, in many countries fishermen have already come a long way and bycatch has been dramatically reduced. TEDs are now used in most tropical shrimp-trawl fisheries and the capture of turtles and other large animals is increasingly a rare occurrence. In many fisheries fishermen are also using BRDs to reduce fish capture and other bycatch. While the overall performance of these devices is not spectacular, at least some bycatch is being excluded from the trawl.

In some fisheries, the problem of bycatch may increase in the near future as shrimp stocks continue to be overfished and fishermen increasingly rely on income derived from the sale of bycatch species. Here, the distinction is blurred between a shrimp-trawl fishery and a multi-species fishery that also targets fish and other animals, and the ability to introduce BRDs into these fisheries will be hampered by fears for catch loss and reduce income.

The future of bycatch reduction probably lies in better management of fishing activity and the development of effective BRDs. The management of fishing activity can be improved by introducing area or seasonal closures, particularly in locations that are nursery grounds for juvenile fish and other animals. In many countries this is already a commonly used option because it is immediately effective. Once the closure is in place and fishing is prohibited no bycatch will be (legally) caught. Closures also afford total protection to all bycatch while they remain within closed areas; it is unlikely that BRDs will ever achieve a comparable level of protection. Given the effectiveness of closures in protecting bycatch, their use as a management tool will be increasingly common. Better management of fishing activity also requires effective Monitoring, Control and Surveillance (MCS). In some countries, particularly those in developing regions, this capability is inadequately resourced. This means that fishing activity may be unregulated and the management of a fishing closure an unattainable goal. Failure to redress this problem threatens the long-term health of the fishery and ecosystem, and must be overcome. The enforcement of fishing regulations, including those related to the design and use of TEDs and BRDs, is also clearly required. The introduction of these devices into a fishery is meaningless if an effective MCS program is not implemented.

The development of effective BRDs is also required to further reduce bycatch. In the near future improvements will be made as fishermen gain more experience in the use and operation of current BRD designs. This will include better selection of a device to suit the fishing ground and improved positioning in the codend. The selection of appropriately sized escape openings and good maintenance will also go a long way to optimizing the performance of these devices. Fishermen may also begin to use several BRDs at the same time to more effectively exploit the size and behavioural differences between shrimp and bycatch. This will require greater knowledge of fish and shrimp behaviour. There is also a need to evaluate the design of existing shrimp trawls. In many fisheries trawl design has changed little over recent decades, from a time when there was little concern for the capture of bycatch. It is now time to re-evaluate trawl design, particularly the impact of sweeps, ground gear, head line height and mesh size on bycatch.

Greater focus on preventing bycatch from entering a trawl could also help. Clearly, allowing bycatch to freely enter a trawl and then make efforts to exclude them is a clumsy way to deal with the problem. Innovative options that may have some potential to prevent the entry of bycatch include the use of sound barriers, glow-netting, light beams, air bubble curtains and electrical fields. All of these options have been tested in other fisheries, some with limited application and others with limited success, and it is perhaps timely that consideration be given to testing them in a shrimp trawl.

The bycatch that interacts with the trawl but is not landed on deck also needs to be researched. The magnitude of this impact is presently unknown but it could be sizeable, particularly if the escaped animals do not survive contact with the trawl. Measuring the survival of bycatch is extremely difficult but an attempt to do so is a responsible move. While the conduct of survival experiments has been done in several fish-trawl fisheries, it has not been widely attempted in tropical shrimp fisheries.

The development of new, more effective BRD designs is likely to take considerable time, effort and money. However, collaboration is the key to success and it should not be expected that fishermen can do this alone. Fishing technologists, scientists, fishery managers and others should be encouraged to work with fishermen to overcome the bycatch problem. This collaboration will need to be wide-ranging, and includes training in the design, use, operation and maintenance of these devices, the development of testing protocols and specifications governing the design and operation of these devices, and the development of effective monitoring and surveillance programs. Such efforts will clearly require adequate financing and commitment by all stakeholders.

The future of bycatch reduction may also include the identification of bycatch-reduction targets. This may be a pro-rata reduction in catch volume or a specific species or group. At-risk species (such as long-living, slow-growing species) will need to be identified and indicators developed to demonstrate if their numbers are responding to the use of bycatch reduction devices. In developing countries, the use of observers can be used to monitor the performance of these devices and the realisation of bycatch targets. In developing countries this is not an option, and alternatives will need to be found including education and landing inspections.

All fishermen are encouraged to join the bycatch-reduction journey. Only with a commitment to reduced environmental impact and improved trawl selectivity can they protect the viability of the fishery and ecosystem. To do so now will go a long way toward protecting their livelihood and ensuring the fishery remains productive for future generations.

The bycatch reduction journey requires a commitment from fishermen and other stakeholders to work together to improve trawl selectivity and reduce environmental impact.

Technical Data Sheets

This section of the guide contains technical data sheets showing how to construct commonly used TEDs and BRDs. Not all TED designs currently used in shrimp-trawl fisheries around the world are included. This is not only beyond the scope of this guide but unnecessary given that general construction details of these devices is similar. Therefore, this section provides generic construction details for one TED as well as details for two TED designs from the United States; these are included because their design provides an insight into the minimum requirements to avoid the capture of leatherback turtles and overcome the US embargo. The major BRDs used today are also included in this section.

Each data sheet also indicates the major bycatch groups that can be excluded with each device, a brief description of the device and a trouble-shooting section that outlines solutions to problems that may be commonly encountered.

Note that all dimensions are in millimetres unless otherwise indicated. It is very important that the entire data sheet is read before commencing construction of a device. This may save costly errors.

The Turtle Excluder Device (TED)

Excluded Species

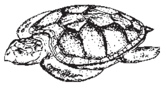


Figure 1

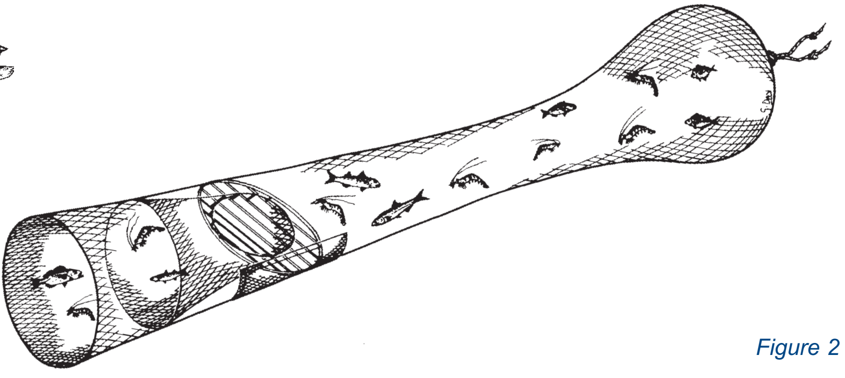


Figure 2

Description

The TED is primarily designed to exclude turtles and other large animals from the trawl although smaller animals may also be excluded (Figure 1). The TED described here features an oval shaped grid secured to the trawl at an angle of about 55 degrees, with a bar spacing of 110 mm (4 1/3"). A funnel of netting guides all animals toward the top of the grid and prevents shrimp loss through the escape opening in the bottom of the codend. Large animals are then guided by the grid through the escape opening while shrimp and other small animals pass between the bars and enter the codend (Figure 2). A cover of buoyant polyethylene netting is fitted over the escape opening to further prevent shrimp loss. The guiding funnel described here is optional and may not be required provided the escape cover works effectively. The TED is fitted to a 48 mm ($1^{7}/_{8}$") mesh codend measuring 200 meshes in circumference. The TED and codend are designed to be fitted to a large trawl net; smaller versions of this TED can be designed for smaller nets, however care is required to ensure that the escape opening allows large turtles and other animals to escape.

Construction

1. Grid placement

- Construct grid as shown (Figure 3). The outer frame of the grid is constructed from 40 mm aluminium pipe and measures 4 750 mm in diameter. The outer height and width of the grid measures 1 670 mm and 1 140 mm respectively. The bars of the grid are constructed from rectangular-section aluminium bars measuring 40 mm by 25 mm (the narrow side of the 25 mm bar faces the towing direction). The grid consists of seven bars; the largest measures 1 680 mm and is bent (cut and welded) 330mm from the bottom of the grid (these measurement are taken from the inside of the grid frame). The length of the remaining bars are reduced to fit the inside of the frame; their length depends on the shape of the outer frame.

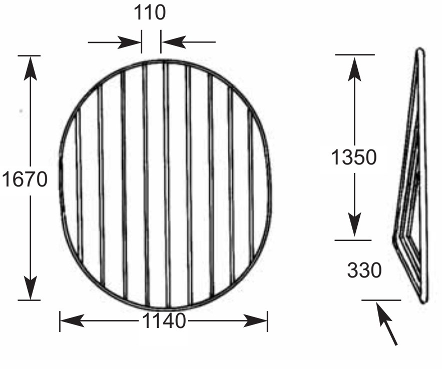


Figure 3

- Hang codend vertically and identify the desired location of the grid (alternatively the codend can be stretched vertically between two points). Insert grid into the codend. Locate the top of the codend (with the codend vertical this is the position of the uppermost mesh;it is easier to construct the TED if the seam joining the sides of the codend are uppermost) and attach the top of the grid frame to this mesh with twine or a cable tie.
- Locate the bottom of the codend and mark this mesh. From this mesh follow the line of meshes (toward the drawstring) for a total of 19 meshes. Attach the bottom of the grid frame to this mesh.
- Attach the sides of the grid frame to the codend in 2 or 3 locations on either side of the frame. Check grid angle.
- As the grid angle will decrease by about 5 degrees after the escape opening is cut into the codend the remaining steps are followed after the completion of the escape opening and cover (see next section below).
- Check grid angle. To adjust the grid remove twine or cable ties except that fixing the top of the grid frame to the codend. Reposition the grid to desired angle and re-attach using twine or cable ties. Re-check grid angle.
- Thread a 30 m length of rope tightly around the circumference of the grid frame and adjacent meshes. Ensure that the meshes are not distorted or under strain. The ends of the rope can be tied together or knotted around one of the bars before securely attaching the ends to a few rows of codend meshes (in case adjustment of the grid is required 200 - 300 mm of this rope should be attached to the codend).

2. The escape opening and cover

- Cut escape opening in the codend as shown (Figure 4) starting full mesh ahead of the grid frame. The width of the escape opening (adjacent to the grid) should be 60 meshes wide. Reinforce this opening with heavy twine or small-diameter rope.
- Cut out the escape cover. The escape cover measures 65 meshes wide by 40 meshes long.
- On the leading edge of the escape opening mark the middle (14th) mesh. Count forward (toward the trawl mouth) a total of 3 meshes. The leading edge of the escape cover will be attached to the this row of meshes.
- On one of the 65 mesh-long sides of the escape cover mark the 33rd mesh. Attach this mesh to the 3rd mesh previously marked. Attach the remainder of this side of the escape cover to the codend following a mesh-to-mesh joining ratio. Then attach the shorter sides of the escape cover to the codend until 10 meshes past the grid. The escape cover should extend 2½ meshes either side of the escape opening at the base of the grid. The remaining 10 meshes of the cover should be left unattached.

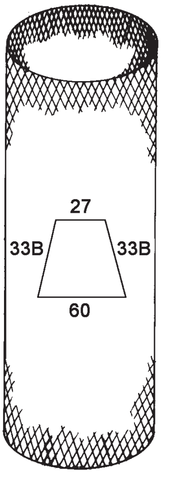
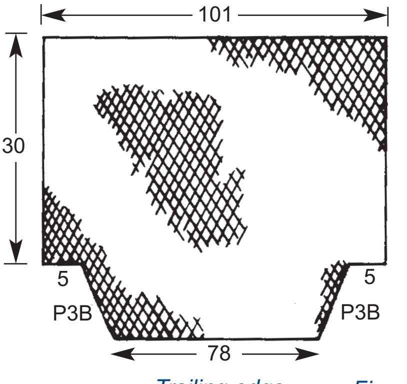


Figure 4



Trailing edge

Figure 5

3. Guiding funnel attachment

- Construct guiding funnel as shown (Figure 5) using 48 mm codend netting (or smaller mesh-netting if available). Join the 30 mesh sides of the funnel together.

- From the top of the grid frame count 30 meshes forward (toward the trawl mouth) and mark the mesh. Secure the 51st mesh on the leading edge of the panel to the marked mesh. Check that the 30th mesh of the funnel contacts the bars of the grid. Attach the leading edge of the guiding panel to the 30th row of codend meshes using a mesh-to-mesh joining rate. Ensure that the seam joining the sides of the panel together is attached to the uppermost mesh in the codend.
- If desired, 5 - 10 meshes of the funnel can be attached to the codend immediately ahead of the top of the grid frame. In this way the start of the tapered section is attached to the grid. The remainder of the funnel stays free.

4. Belly-ropes and flotation

- Attach one 2 m length of small diameter (8 - 14 mm) rope to either side of the grid and codend. The middle of each rope should be securely attached to the grid as shown (Figure 6) and the remainder along the length of the codend. The meshes should be pulled reasonably tight as the rope is attached; in this way the rope will take up the strain as the meshes become stretched over time.
- Attach float to the grid frame near the top of the codend. Ensure they do not impede the passage of animals through the escape opening (Figure 7).

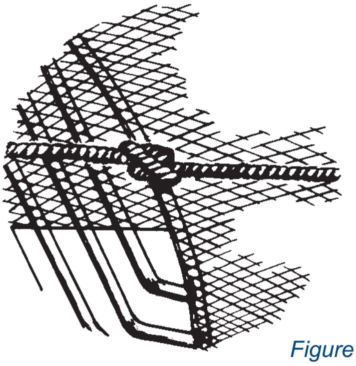


Figure 6

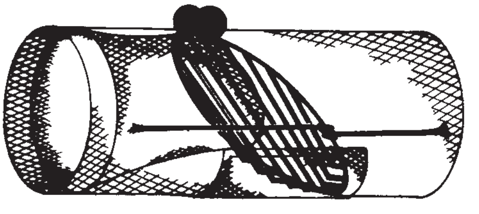


Figure 7

Trouble Shooting

Shrimp loss: This may be due to incorrect grid angle, grid blockage, stretched funnel netting, stretched escape cover or a large animal caught in the escape opening.

Clogged guiding funnel: This may be caused by starfish, coral, crabs, sponges or large animals fouling the meshes of the funnel. A smaller mesh size or canvas material may prevent clogging. Increasing funnel diameter may allow larger animals to pass more freely through the funnel but may also cause shrimp loss through the escape opening.

Poor exclusion rate: This may be due to inadequate bar spacing or inadequate grid size. Increasing bar spacing or grid length may improve fish escape. If the bars are fitted to a second, inner frame, the inner frame can simply be quickly replaced with another of different bar spacing. In this way the outer frame does not have to be detached from the extension piece and grid angle is maintained.

Clogged grid: A clogged grid may be caused by large animals, sponges and other debris. Reducing grid angle may overcome this problem.

Twisted codend: This may be due to poor codend deployment (prior to shooting away) and may result shrimp loss through the escape opening. Careful observation of the grid floats will assist checking for a twisted codend. Meshes unevenly secured to the grid or an excessively short lazy line may also cause twisting of the codend.

Hauling: When hauling the codend care must be taken to ensure the grid does not foul on the lazy line guides or 'bull horns'

The Double-Cover Offshore Turtle Escape Opening

Excluded Species

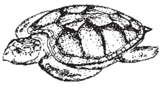


Figure 1

Description

This technical data sheet describes the construction details for the double-cover turtle escape opening for a single-grid hard TED. The double-cover escape opening is a recent innovation from the US that has proven effective in allowing the escape of large turtles (Figure 1), including loggerhead turtles, while retaining the shrimp catch. In the US, a so-called double-cover escape flap can only be used if the escape opening measures at least 142 cm (56") wide when stretched and 51 cm (20") long when stretched. All measurements are stretched mesh measurements. Note that many US shrimp fishermen have voluntarily increased the size of the escape opening to meet the requirements of the 181 cm offshore turtle escape opening (see following data sheet for details).

Construction

1. Grid

- Construct grid to required size and design. Attach to the codend in desired location.

2. Cutting the escape opening

- In the codend ahead of the grid cut an escape opening with a stretched mesh measurement of 51 cm (20") forward on each side of the grid and 142 cm (56 inches) across at the leading edge (Figure 2). When making the cut leave ½ mesh immediately forward of the grid frame. If the codend mesh size is 38 mm (1½") the cut will be approximately 14 meshes long by 41 meshes wide. If the codend mesh size is 25 mm (1") the cut will be approximately 20 meshes long by 56 meshes wide.

3. Escape covers

- Cut 2 rectangular pieces of netting (preferably depth stretched and heat set). The stretched width of each panel must measure at least 147 cm (58") and the approximate length of each escape cover should be 145 cm (57") (Figure 2). The mesh size should be no larger than 41 mm ($1\frac{5}{8}$") to prevent turtles from fouling the meshes and delayed escape.

4. Escape cover attachment

- The escape covers are attached to the leading edge of the escape opening (Figure 2). Mark the center mesh of the leading edge of the escape opening. Determine the number of meshes to the left and right of the center mesh needed to obtain a stretched mesh measurement no greater than 38 cm. Mark these meshes (points A and B in Figure 2).
- Attach the right hand escape cover to position A and sew two escape cover meshes to one escape opening mesh. Repeat this joining rate until point B is reached (this joining rate helps ensure both escape covers overlap along their entire length). Continue sewing the escape cover using a joining rate of one cover mesh to one escape opening mesh for a distance of two or three meshes past the edge of the escape opening.
- Repeat this procedure for the left hand escape cover.
- Attach the outer side of the right hand escape cover along a straight row of meshes adjacent the escape opening (Figure 2). The trailing edge of the cover must not extend more than 61 cm (24") past the posterior edge of the grid frame.
- Repeat this procedure for the left hand escape cover. Note: if an accelerator funnel is used with this TED the funnel must have an inside horizontal opening in a straight line measuring at least 28 cm (71"). No more than $^{1}/_{3}$ of the accelerator funnel can be attached to the grid.

5. Edge lines

- These are optional but serve to strengthen the escape covers and prevent stretching of meshes (Figure 2). They must be made from polyethylene line (rope) with a diameter not exceeding 0.95 cm. The line can only be attached to the inside and trailing edges of each cover. If edge lines are used the outside edge of each cover must be attached to the codend along its entire length.

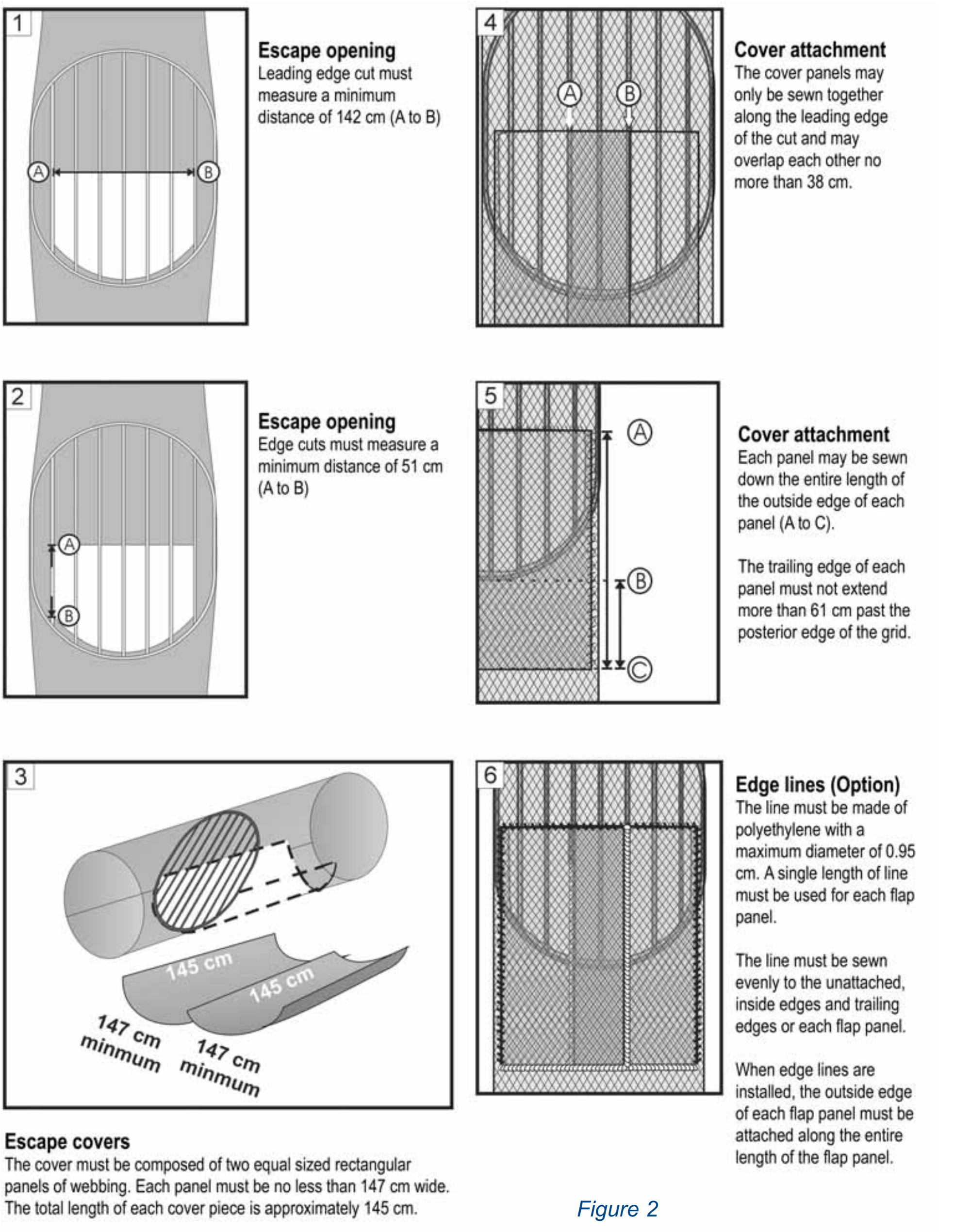


Figure 2

Details of the Double Cover Opening were provided by John Mitchell, NOAA.

The 181 cm (71-inch) Offshore Turtle Escape Opening

Excluded Species

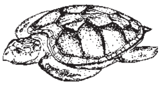


Figure 1

Description

This technical data sheet describes the construction details for the 181 cm (71") escape opening for a single-grid hard TED in offshore US waters. The size of the escape opening has proven to be effective in allowing the escape of large turtles (Figure 1), including loggerhead turtles, while retaining the shrimp catch. In the US, an escape opening measuring 181 cm (71") in width must be accompanied by a length measuring 66 cm (26"). Note all measurements are stretched mesh measurements.

Construction

1. Grid

- Construct grid to required size and design. Attach to the codend in desired location.

2. Cutting the escape opening

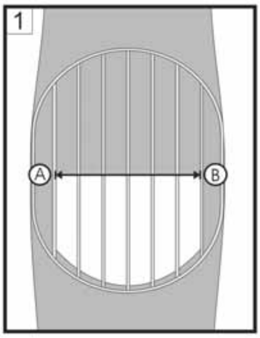
- In the codend ahead of the grid cut an escape opening with a stretched mesh measurement of 66 cm (26") forward of the grid and 181 cm (71") across (Figure 2). When making the cut leave ½ mesh immediately forward of the grid frame. If the codend mesh size is 38 mm (1½ ") the cut will be approximately 18 meshes long by 48 meshes wide. If the codend mesh size is 25 mm (1") the cut will be approximately 27 meshes long by 73 meshes wide.

3. Escape covers

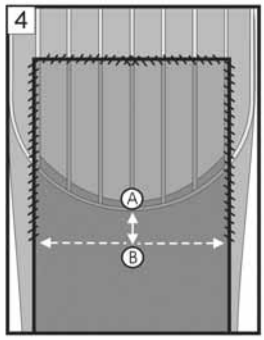
- Cut a rectangular piece of netting (preferably depth stretched and heat set) with a stretched mesh measurement of 338 cm (133") wide by 132 cm (58") long (Figure 2). The mesh size should be no larger than 41 mm (1 $^{5}/_{8}$") to prevent turtles from fouling the meshes and delayed escape.

4. Escape cover attachment

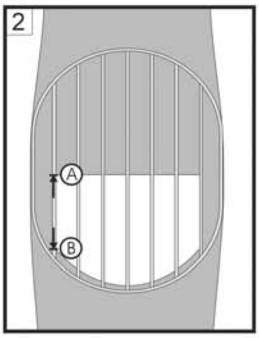
- Attach the escape cover to the leading edge of the escape opening (Figure 2). Depending on the mesh size of the codend and escape cover, a joining ratio of escape cover meshes to escape opening meshes will be required, e.g. 2:1 or 3:2. The escape cover may extend past the sides of the escape opening by a distance no more than 13 cm (5") on each side.
- Attach the outer sides of the escape cover along a straight row of meshes down the sides of the escape opening for a distance no more than 15 cm (6") past the posterior edge of the grid (Figure 2). The trailing edge of the cover must not extend more than 61 cm past the posterior edge of the grid frame. Up to 46 cm (18") of the cover may trail behind the grid unattached.
- Check that the aft edge of the escape opening measured at least 181 cm (71") when stretched. Note: if an accelerator funnel is used with this TED the funnel must have an inside horizontal opening in a straight line measuring at least 28 cm (71"). No more than 1/3 of the accelerator funnel can be attached to the grid.



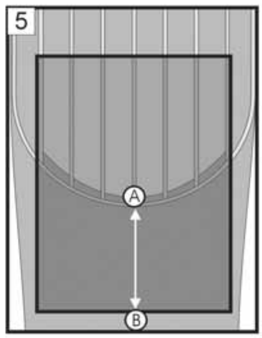
Escape opening
Leading edge cut must measure a minimum distance of 181 cm (A to B).



Cover attachment
The cover may be attached no more than 15 cm beyond the posterior edge of the TED frame (A to B). This measurement must be taken from the center of the frame when hanging.

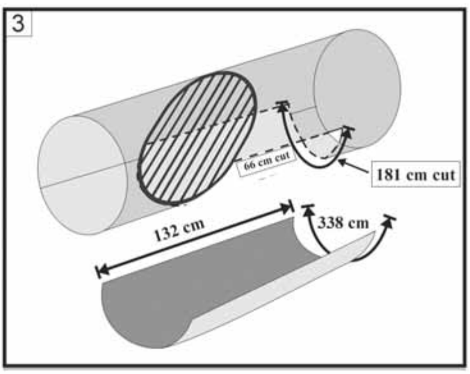


Escape opening
Edge cuts must measure a minimum distance of 66 cm (A to B).

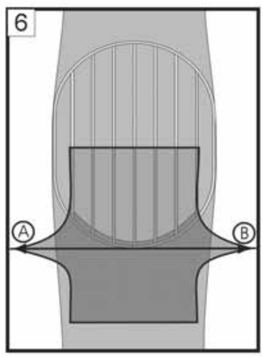


Cover length
The length of the cover may not exceed 61 cm measured from the posterior edge of the TED frame to the trailing edge of the flap (A to B).

This measurement must be taken from the center of the frame when hanging.



Escape cover
The cover must be a 338 cm by 132 cm piece of webbing. The 338 cm edge of the cover is attached to the forward edge of the opening (180 cm edge).



Escape opening measurement
This measurement must be greater than or equal to 181 cm when stretched in a horizontal straight line (A to B).

Measured at the aft edge of the exit hole cut.

Figure 2

Details of the 181 cm Offshore Turtle Escape Opening were provided by John Mitchell, NOAA.

The NSW Nordmore Grid

Excluded Species

Figure 1

Description

The NSW Nordmore grid is primarily designed to reduce unwanted bycatch from estuarine shrimp trawls such as jellyfish and finfish while maintaining catches of shrimp (Figure 1). The Nordmore grid is made up of an aluminium grid with 20 mm ($^3/_4$") bar spaces, an escape exit and a guiding panel, all of which are inserted into a tube section of 40 mm ($1^1/_2$") netting 60 meshes in length. The guiding panel directs the entire catch to the base of the grid where the separating process begins. Shrimp pass through the bar spaces while other, larger organisms are directed along the grid and out through the escape exit. The Nordmore grid has also been tested without a guiding panel and a netting cover over the escape exit.

Construction

1. Assembling the grid and netting

- Construct aluminium grid as shown (Figure 2). A bar spacing of 20 mm ($^3/_4$") will require a total of 12 bars.
- Cut a 100 mesh by 100 mesh panel of codend netting into five panels as shown (Figure 3). Panel 1 will become the tube, panels 2 & 3 the guiding panel and panels 4 & 5 will be left over to make a spare guiding panel.
- Cut out the triangular escape exit shown in panel 1.
- Sew the top edges of panels 2 and 3 together as shown. This will ensure the correct knot direction for the guiding panel.
- Lay the guiding panel on top of panel 1 and sew or lace (mesh for mesh) the top edge of the guiding panel to the centre of the top edge of panel 1.
- Mark out the dotted line shown in panel 1. The line should start 12 meshes from the centre of the panel, making a 1P2B 'path' down the netting and finish 13 meshes from the outside edge. Sew or lace the sides of the guiding panel row for row to the marked line (the guiding panel will tend to pull quite tightly as the two bodies of net are sewn together).
- Turn up the two outside edges of panel 1 and sew them together. This will form a seam that will correspond to the bottom centre line of the net.

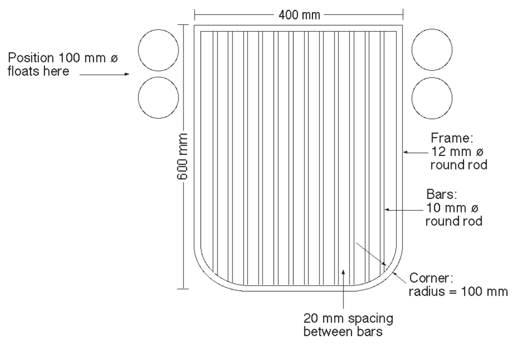


Figure 2

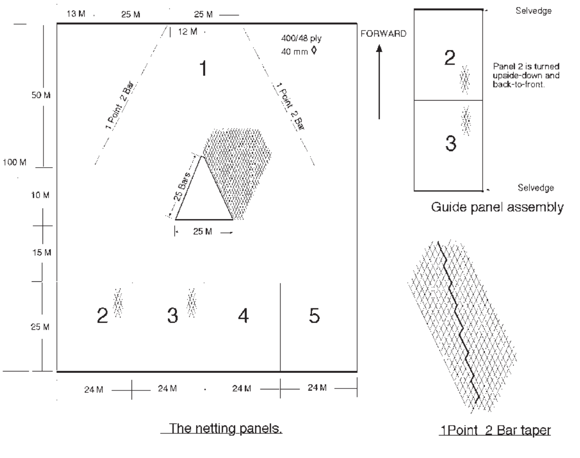


Figure 3

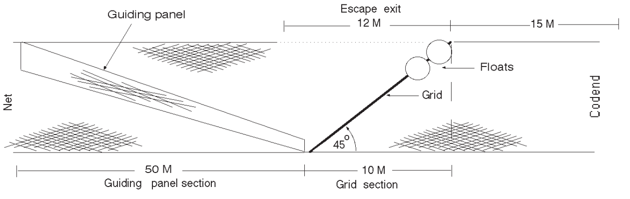


Figure 4

2. Inserting the grid

- Insert the grid into the tube and lace the top edge of the grid to the 25 meshes that form the base of the triangular escape exit (Figure 4). Where the row of meshes meets the seam (at the bottom), count forward 10 meshes and lace the bottom of the grid to at least 15 meshes along this row. The grid should then sit inside the netting an an angle of approximately 45 degrees. If the netting you are using has a mesh size greater than 40 mm (1 $^{1}/_{2}$") you should only count forward 9 to 9 $^{1}/_{2}$ meshes (Figure 5).
- The remaining netting, between the top and bottom of the grid, should be laced to the grid by equally spacing the rows down each side and across the bottom. This will require some care to avoid distorting the net.
- The edges of the escape exit should be reinforced by 'picking up' two bars and tightly selvaging to 8mm rope. The ends of the rope can be spliced to the corners of the grid. This will help to support and maintain correct grid angle.
- A few links of light chain can be added to the aft end of the guiding panel. This will reduce any lifting caused by water pressure and minimise the risk of shrimp escape.
- Four 100 mm (4") diameter polystyrene floats should be attached to the top of the sides of the grid.
- The entire tube section, made up of guiding panel, grid and escape exit can then be inserted between the codend and the main body of the net.

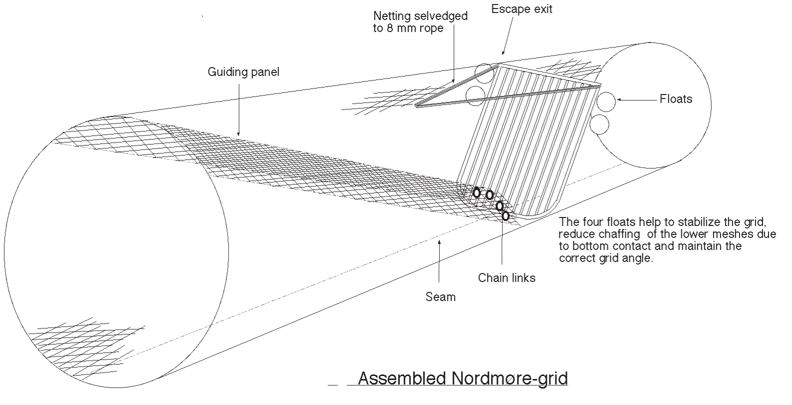


Figure 5

Assembled Nordmøre-grid

Trouble Shooting

Shrimp Loss: Shrimp loss may be due to incorrect grid angle, grid blockage (see below), stretched funnel netting, a stretched escape cover or a large animal caught in the escape opening.

Twisted codend: this may be due to poor codend deployment (prior to shooting away) and may result in shrimp loss through the escape opening. Careful observation of the grid floats will assist checking for a twisted codend. Meshes unevenly secured to the grid may also cause twisting of the codend.

Clogged grid: A clogged grid may be caused by large animals, sponges and other debris. Reducing grid angle may prevent this problem.

Composite Square Mesh Panel construction details provided by Matt Broadhurst of the NSW Department of Primary Industries.

The Fisheye

Excluded Species

Figure 1

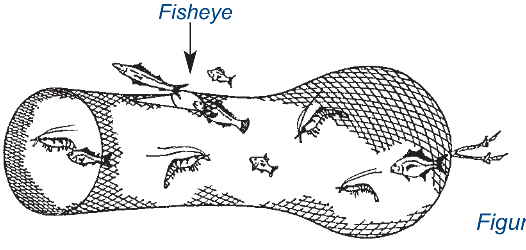


Figure 2

Description

The fisheye is designed to allow fish to voluntarily swim from the trawl (Figure 1). This BRD features a steel or aluminium frame secured to the top or side of the codend (Figure 2). The frame provides a rigid elliptical or "eye shaped" escape opening through which fish can swim while shrimp passively enter the codend. The orientation of the fisheye is variable, however, to prevent shrimp loss it must cause fish to swim forward through the escape opening. The fisheye can be placed anywhere in the codend and more than one may be fitted to the trawl to increase fish loss. The following details describe the construction of a fisheye to fit a codend with a 45 mm (1 3/4") mesh size.

Construction

- Construct fisheye from 8-12 mm diameter steel or aluminium rod as shown (Figure 3). The internal opening of the ellipse measures 400 mm and the circumference measures 1 040 mm
- Make a 46 mesh cut across the codend (Figure 4).
- Insert fisheye into the codend. Secure the leading edge of the cut to the bottom of the ellipse ensuring the meshes are distributed evenly.
- Secure the top of the ellipse to the top meshes of the cut.
- Secure the sides and middle brace to the codend meshes.
- Secure a 100 mm (4") float 5 meshes behind the ellipse to counter the weight of the steel and hold the BRD upright and level.

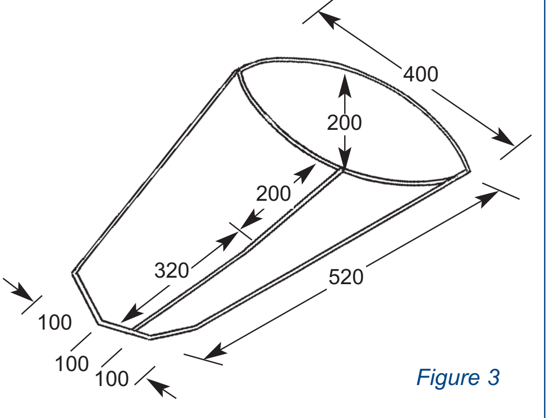


Figure 3

Trouble Shooting

Shrimp Loss: Shrimp loss may be due to poor positioning of the fisheye and relocating the fisheye further forward of the catch will reduce this problem. Shrimp loss may also occur during haulback and during rough weather when the catch surges forward in the codend.

Poor exclusion rate: This may be due to poor fisheye location. Relocating the fisheye closer to the accumulated catch may increase fish loss, but may also increase the risk of shrimp loss particularly when large catches are taken.

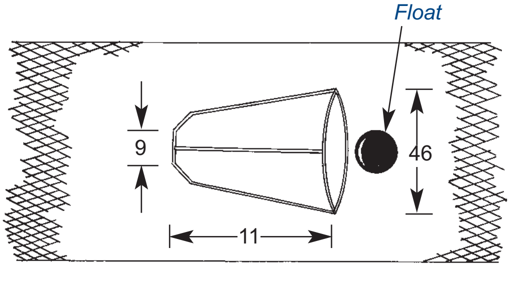


Figure 4

The Square-Mesh Window

Excluded Species

Figure 1

Description

The square-mesh window is designed to allow fish to voluntarily swim from the trawl (Figure 1). This BRD is simply a panel of large meshes hung on the bar so they remain open during the tow (Figure 2). This is in contrast to diamond meshes which tend to close under tension. The following details describe the construction of a 150 mm (75 mm bar length) square-mesh window measuring 6 bar lengths long by 6 bar lengths wide to fit a codend with a 45 mm (1 3/4") mesh size.

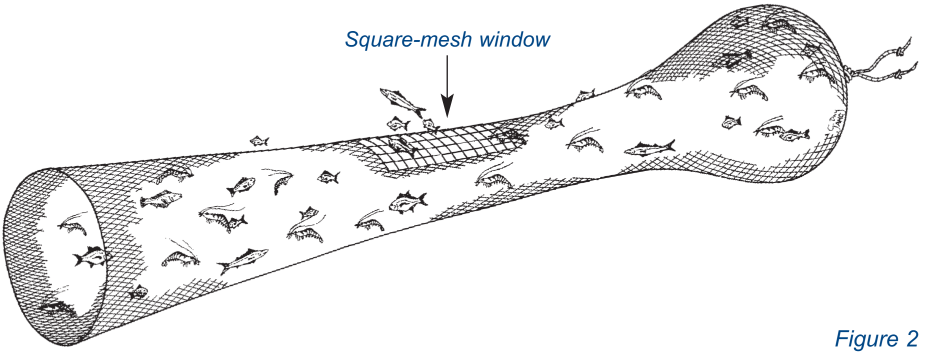


Figure 2

Construction

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

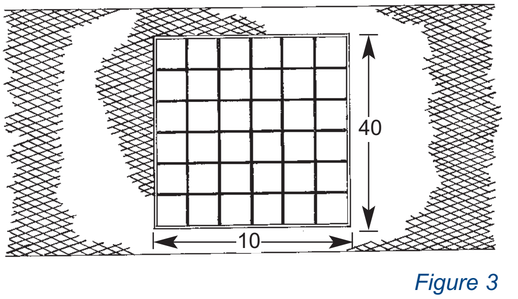


Figure 3

Trouble Shooting

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

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

The Composite Square-Mesh Panel

Excluded Species

Figure 1

Description

The Composite Square-Mesh Panel has been found to be effective in excluding large quantities of bycatch while maintaining catches of shrimp and byproduct (Figure 1). This BRD is simply a number of netting panels joined together and orientated so they remain open during the tow (Figure 2). The Composite Square-Mesh Panel is designed so that the load is distributed forward and lateral to the main escape panel allowing it to remain open. The following details describe the construction of a Composite Square-Mesh Panel using 45 mm and 60 mm mesh.

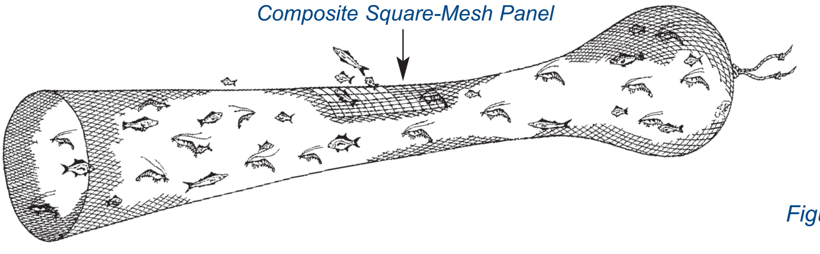


Figure 2

Construction

- Cut panels, A, B, and C from 45 mm mesh (22.5 mm bar) as shown (Figure 3). This will make it easy to match and sew the panel to the meshes in the top of the codend (ie. 2 meshes to each bar).
- Cut panel D from 60 mm mesh as shown. It is important that the stretched length of panels A, B and D are equal.
- The width of panel D is equal to the width of 11 meshes of panel C.
- Because panel D is usually made from lighter ply, it may be necessary to include an extra row of meshes across the top and bottom and along each of the sides. These can be 'picked up' (ie as a selvedge) where panel D is sewn to panels A, B and C.
- After each of the square mesh panels have been cut out, attach panels A and B to D. It is best to sew panels A and B so that the square meshes pull in opposite directions (ie simply flip either panel A or panel B over before sewing).
- To complete the Composite Square-Mesh Panel evenly sew panel C to A, D and B.

Installation

- On top of the codend, cut out a piece of netting measuring 48 meshes across by 21 meshes forward at the desired location.
- Evenly lace the panel into the codend, starting across the bottom and then along each of the sides and finally across the top.

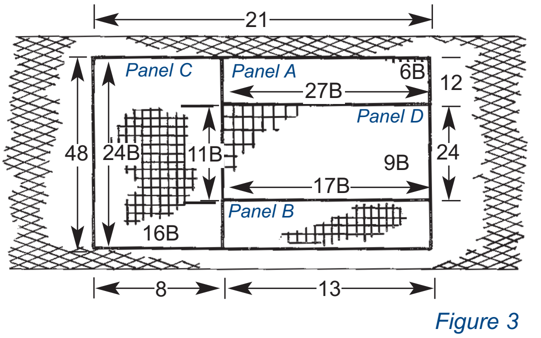


Figure 3

Composite Square Mesh Panel construction details provided by Matt Broadhurst of the NSW Department of Primary Industries.

The Square-Mesh Codend

Excluded Species

Figure 1

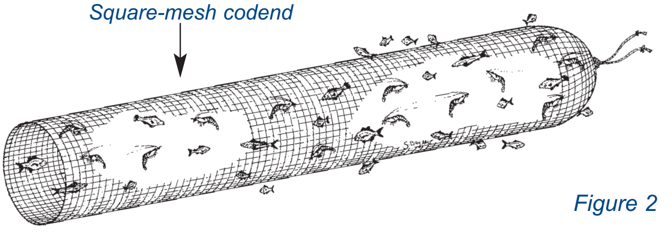


Figure 2

Description

The square-mesh codend is designed to exclude small fish from a shrimp trawl (Figure 1). Unlike most other BRDs which modify a diamond mesh codend, this BRD replaces the entire codend (Figure 2). By hanging diamond mesh netting on the bars, square-meshes are created which remain open during the tow. Knotless netting is sometimes preferred to avoid problems with knot slippage. The size of the mesh will determine the size of the animals that escape, however, careful selection is required to prevent shrimp loss. The following details describe the construction of a square-mesh codend made from 38 mm (1 $^{1}/_{2}$") diamond mesh netting designed to replace a 45 mm codend measuring 150 meshes around by 100 mesh deep (Figure 3). The square-mesh codend is then joined to a 50 mesh long cylinder of diamond mesh netting - called the extension piece - with the lifting strop attached (Figure 4). The diamond meshes of the extension piece are assumed to have a horizontal mesh opening of 30% (0.3).

Construction

- Cut out the square-mesh panel as shown (Figure 3).
- Join the longer sides of the panel together to form the codend.
- Secure the square-mesh codend to the diamond mesh netting using a joining rate of 2 square-meshes to 3 diamond meshes and pick up an extra bar every 20 diamond meshes (Figure 4).

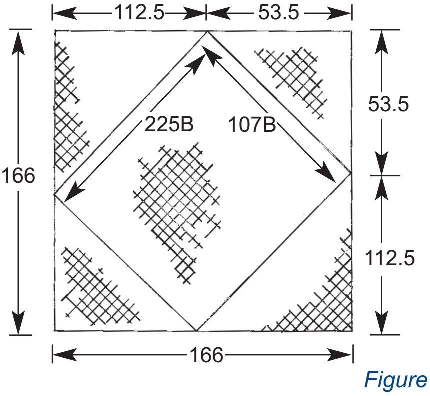


Figure 3

Trouble Shooting

Shrimp Loss: This may be due to knot slippage or poor mesh size selection, and in both cases replacing the codend is recommended. Hanging ropes along the length of the codend (so they take the load of the catch) may prevent knot slippage or alternatively the codend may be replaced with knotless netting.

Poor exclusion rates: The mesh size may be too small, however, careful selection of a larger mesh size is required to prevent shrimp loss.

Twisted codend: This problem may be due to uneven hanging of the codend to the diamond mesh extension.

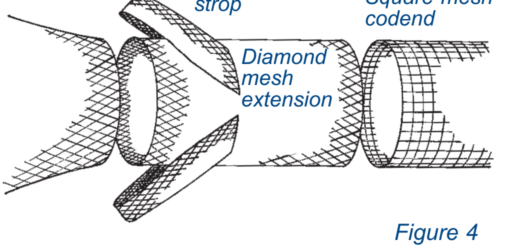


Figure 4

The Radial Escape Section

Excluded Species

Figure 1

Description

The Radial Escape Section (RES) is designed to allow fish to voluntarily swim from the trawl (Figure 1). This BRD features a guiding funnel to concentrate all animals into the middle of the codend. As fish exit the funnel, some swim forward and through a panel of large square-meshes that extend radially around the codend (Figure 2). In contrast, shrimp do not have this swimming ability and they passively enter the codend. A plastic encased wire hoop can be fitted behind the square meshes to help the RES maintain shape and resist deformation. The following details describe the construction of a RES fitted to a 45 mm (1 $^3/_4$") mesh cylinder of codend netting measuring 120 meshes in circumference. The square-mesh escape openings are constructed from 200 mm netting (100 mm bar length). Larger escape openings can be used if desired.

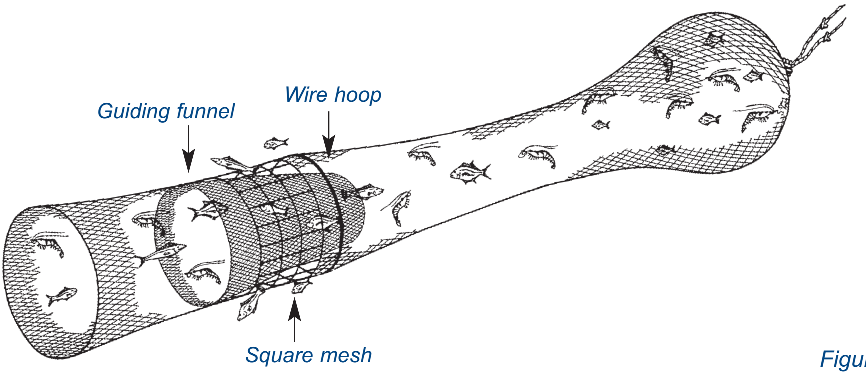


Figure 2

Construction

- Cut panels A and C from 45 mm (1 $^3/_4$") netting and panel B from 200 mm (100 mm bar length) netting as shown (Figure 3).
- With the seams of each panel uppermost attach all panels together using a joining rate of six 45 mm meshes to one 100 mm bar.
- Construct an 18 mm wire hoop measuring 2.5 m in length and swage the ends together. Attach the hoop 5 meshes from the leading edge of panel C.
- Cut out netting panels as shown (Figure 4). Join the outer edges of each panel to form a funnel.
- Secure the leading edge of the funnel to the 2nd row of meshes from the leading edge of panel A using a mesh to mesh joining rate.
- Attach the completed RES to the standard codend using a joining rate of 5 codend meshes to 4 RES meshes.
- Thread a length of 12 mm rope around the hoop and adjacent meshes to prevent chafing.

Trouble Shooting

Clogged guiding funnel: This may be caused by starfish, sponges or large animals fouling the funnel meshes. A smaller mesh size or canvas material may prevent clogging. Increasing funnel diameter may allow larger animals to pass more freely through the funnel.

Poor exclusion rate: This may be due to excessive funnel length or inadequate mesh size. Shortening the length of the funnel or increasing the size of the mesh openings may improve fish escape.

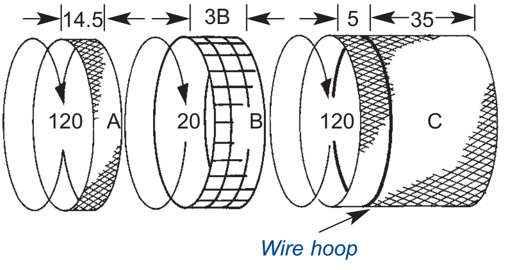


Figure 3

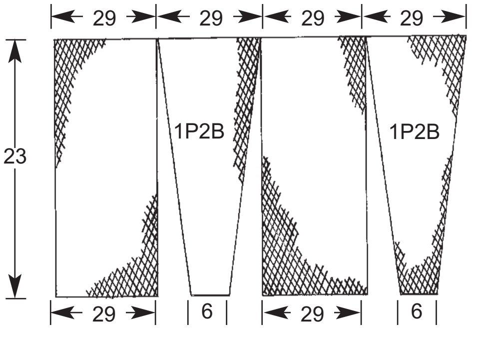


Figure 4

The semi-curved rigid Juvenile and Trash Excluder Device (JTED)

Excluded Species

Figure 1

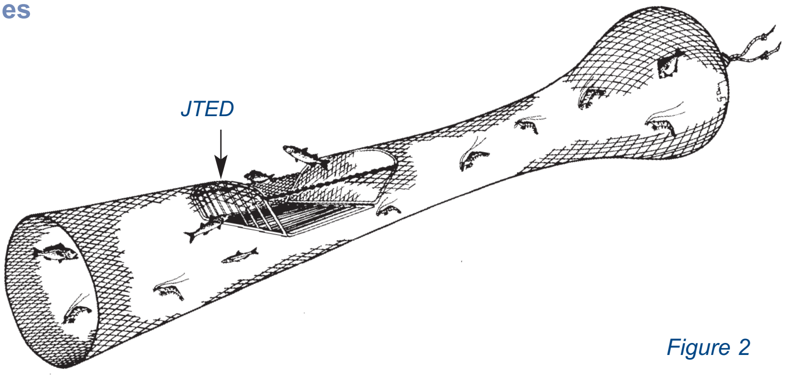


Figure 2

Description

As the name implies the Juvenile and Trash Excluder Device (JTED) is designed to exclude small fish - usually juvenile or trash fish - and other trash from the trawl (Figure 1). This BRD features three rigid metal sections hinged together; the first two sections are metal girds and the third section is a metal frame supporting a panel of fine-mesh netting (Figure 2). The JTED is located in the top of the codend, and between the lifting ropes and the accumulated catch in the codend. The dimensions provided here are for the construction of a JTED to fit a 25 mm (1") mesh codend measuring 300 meshes in circumference.

Construction

1. Extension piece and escape opening

- Construct a codend extension piece from PE 380D/15 netting material with a mesh size of 25 mm. The length of the extension piece should be 300 meshes wide and measure about 350 cm long. Sew the sides of the netting together to form a cylinder 300 meshes in circumference.
- Form a 250 cm metal rod into a circular hoop with a diameter of 80 cm. Attach one end of the extension piece uniformly to the hoop. Construct a second identical hoop and attach to the other end of the extension piece. Attach several lengths of rope to each hoop and pull tightly so the extension piece is stretched horizontally - this makes attachment of the JTED easy. Alternatively, the extension piece can be hung vertically from one hoop at the leading end.
- With the seam joining the sides of the extension piece uppermost, count 40 meshes from the leading edge of the extension piece toward the trailing edge of the extension piece. Mark this mesh and then count a further 60 meshes in the same direction. Mark this mesh. Cut the escape opening in the extension as shown (Figure 3) between the two marked meshes. Secure a thin rope to the escape opening ensuring the meshes are uniformly attached to the rope (this is optional but provides support to the meshes and additional strength).

2. Metal frames

- Construct outer frames as shown (Figure 4). Each outer frame is constructed from a 260 cm length of 12 mm metal rod bent into the desired shape. The ends of the rod are welded together.
- The bars of each grid are constructed from 6 mm rod and welded into place at the desired bar spacing. Care is required to ensure all bars are parallel and bar spacing is uniform. Bar spacing is typically 10 - 40 mm.
- Weld a chain link to the shoulder of each semi-curved frame 40 cm from the base of the frame.
- To the long side of each frame weld short lengths (~75 mm) of steel pipe. One end of each pipe should

contact the end of the pipe welded to the adjacent frame. Insert a steel bolt through both lengths of pipe and fix with a bolt. A second bolt can be used for added security. Alternatively, small hammer locks can be used to connect each frame or even cable ties. Prime and paint all metal surfaces to prevent rusting.

- Cut the netting panel as shown (Figure 5) from PE 380D/12 netting with a mesh size of 15 mm. Attach this panel to the semi-curved frame ensuring the meshes are attached evenly.
- Using small shackles, attach two 1 060 mm lengths of chain to the welded chain links on each semi-curved frame.
- Fit completed JTED frames to the extension piece ensuring the meshes are attached evenly.
- Remove the metal hoops from the extension piece and attach the competed JTED to the codend. The final location of the JTED should be about 10 m from the trailing end of the codend.
- Attach sufficient flotation to counter the weight of the JTED. At least one 150 mm (6") float should be attached to the top of the leading semi-curved frame and two floats to the aft semi-curved frame.

Trouble Shooting

Shrimp loss: This may be due to excessive bar spacing or damaged bars. This can be overcome by reducing bar spacing or repairing/replacing the bars. Damaged bars may be caused by large animals striking the device. A TED located ahead of the JTED will overcome this problem.

Poor exclusion rate: This may be due to inadequate bar spacing or inadequate grid size. Increasing bar spacing or grid length may improve fish escape. If the bars are fitted to a second, inner frame, the inner frame can simply be quickly replaced with another of different bar spacing. In this way the outer frame does not have to be detached from the extension piece and grid angle is maintained.

Clogged grid: This may be caused by large animals, sponges and other debris. Reducing grid angle may overcome this problem. A TED located ahead of the JTED will overcome this problem.

Incorrect grid angle: This may be caused by sand, mud or other debris fouling the hinges and preventing the correct grid angles from being obtained. The hinges should be flushed out regularly and checked that they are free to move. At the same time the tightness of the attachment bolts should be checked as the loss of these bolts will also result in incorrect grid angle and poor performance.

Twisted codend: this may be due to poor codend deployment (prior to shooting away) and may result in shrimp loss through the escape opening. Careful observation of the grid floats will assist checking for a twisted codend. Meshes unevenly secured to the grid may also cause twisting of the codend.

Clogged grid: A clogged grid may be caused by large animals, sponges and other debris. Reducing grid angle may prevent this problem.

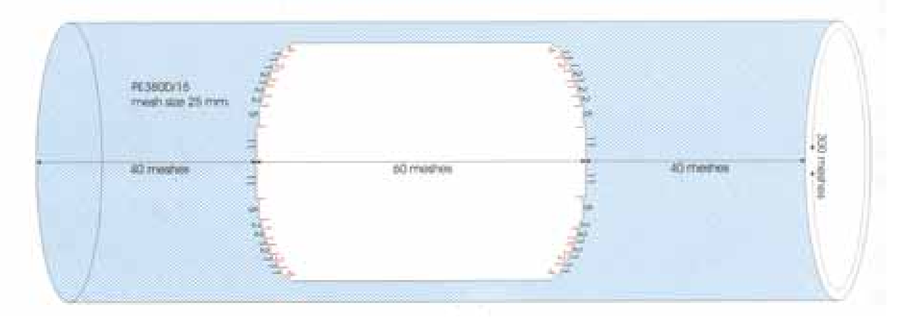


Figure 3

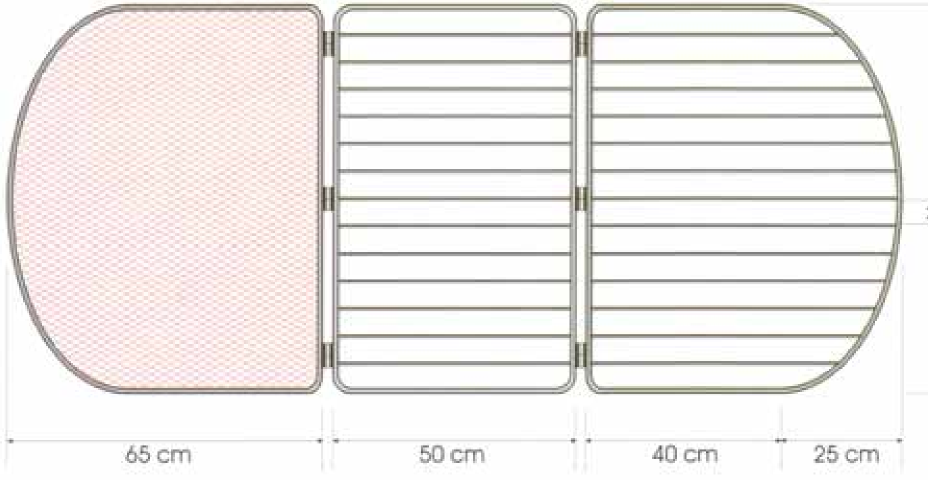


Figure 4

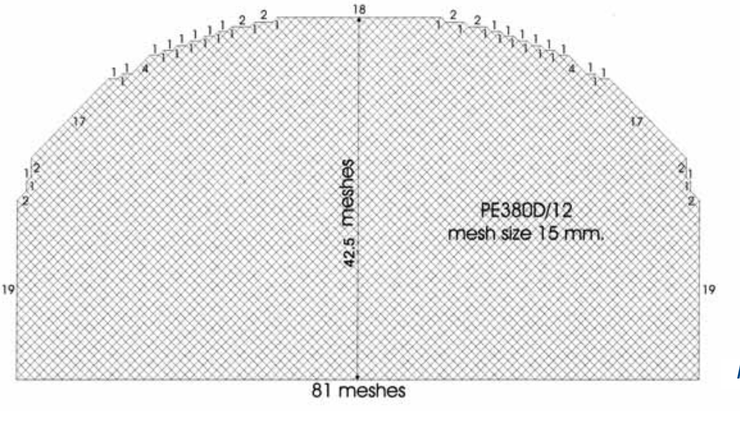


Figure 5

The details outlining the construction of the JTED were provided by the SEAFDEC Training Department, Samut Prakan, Thailand.

The Cone

Excluded Species

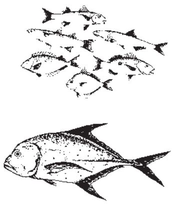


Figure 1

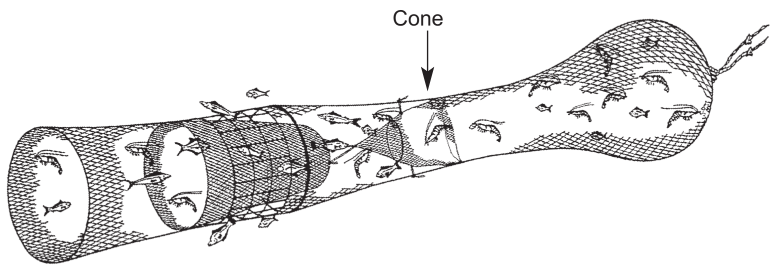


Figure 2

Description

The cone is not a BRD but has been designed to increase the efficiency of BRDs to exclude fish from the trawl (Figure 1). It is simply two panels of netting attached to a small wire hoop and inserted behind a BRD such as a fisheye, square-mesh window or RES (Figure 2). The cone impedes the passage of fish into the codend and 'stimulates' them to swim forward and through the escape openings. The following details describe the construction of a cone made from 45 mm (1 3/4") codend material. A simple alternative to the cone is to insert a 200 mm float in the same location and tethered to the sides of the codend. The float will bob about and stimulate fish to swim forward.

Construction

- Cut out two triangular panels of netting. The sides of each panel measure 40 bars and the base measures 40 meshes. Secure the sides of the panels together to form a cone (Figure 3).
- Construct the hoop from 10 mm wire measuring 1 m in length. Encase the wire in plastic to prevent corrosion.
- Locate one seam and count 16 bars from the point of the cone. Secure the hoop to the 16th bar of the seam. Repeat for the other seam and then secure the remainder of the hoop to the netting. Ensure the meshes are distributed evenly around the hoop.
- Cut out a 1 500 mm length of 4 mm rope. Secure the middle of the rope to the point of the cone.
- Count 23 bars from the point of the cone and secure a 300 mm length of 4 mm rope to this bar. Repeat for the opposite side of the cone.

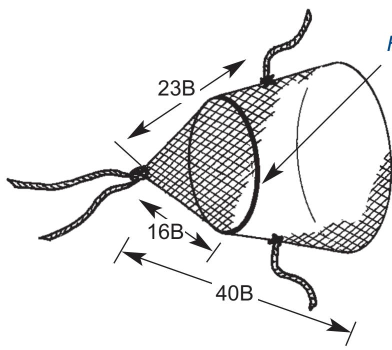


Figure 3

Installation

- Secure the rope (attached to the point of the cone) to the sides of the codend. The point of the cone should be approximately 300 mm from the escape opening of the fisheye or square-mesh window, or the trailing edge of the RES funnel.
- The two remaining ropes are secured to the top and bottom of the codend. Ensure there is approximately 125 mm of rope between the codend and the cone.

The Flapper

Excluded Species

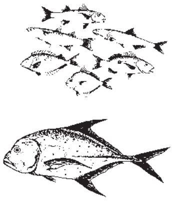


Figure 1

Description

The flapper or 'fish escape cut' is designed to allow fish to voluntarily swim from the trawl (Figure 1). This BRD is simply a hole located in the top of the codend through which fish can swim and the size of the hole will determine the size of fish that can escape (Figure 2). More than one flapper may be used to increase fish loss. This BRD has the advantage that it is easy to close, enlarge or reposition if required. The following details describe the construction of a flapper suitable for all codend mesh sizes. The orientation of the triangular escape opening is optional, however, the flap folded back as shown below may generate water turbulence as the trawl is towed that aids the escape of fish.

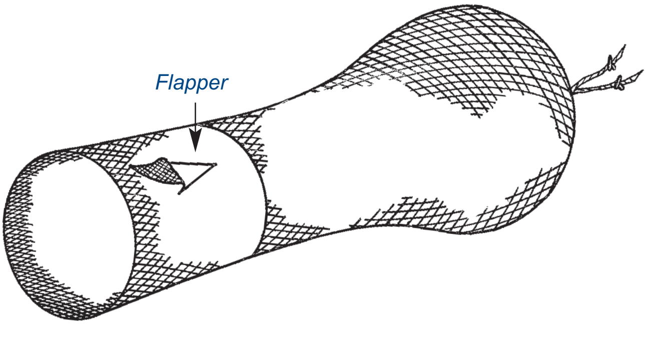


Figure 2

Construction

- Make two 20 bar cuts to form a triangular flap of netting.
- Reinforce the edges of the flapper with twine to prevent damage to the netting.
- Fold the flap back and attach the apex of the triangular flap to the codend 8 meshes ahead of the escape opening.

Trouble Shooting

Shrimp loss: Shrimp loss may be due to poor positioning of the flapper. The distance between the catch and the flapper reduces as the catch accumulates, making it easier for shrimp to swim through the escape opening. Shrimp loss may also occur during haulback and during rough weather when the catch surges forward in the codend. As a rule of thumb the larger the escape opening the greater the chance of shrimp loss.

Poor fish loss: This may be due to poor flapper location or inadequate escape opening. Relocating the flapper closer to the accumulated catch may increase fish loss, but may increase the risk of shrimp loss particularly when large catches are taken. Increasing the size of the escape opening may allow more or larger fish to escape.

Glossary of Terms

Accidental catch

A reference to non-target animals and non-living material captured by the fishing gear. This term is synonymous with bycatch.

Bycatch

Part of the catch taken incidentally to the target species toward which fishing effort is directed. It includes all non-target animals and non-living material, including those that escape from the fishing gear during the fishing operation and are not landed onboard. Some or all of the landed bycatch may be returned to the sea as discards, usually dead or dying.

Bycatch excluder device (BED)

See bycatch reduction device. In Indonesia this term is synonymous with TED.

Bycatch reduction device

Any modification to a trawl designed to reduce the capture of bycatch. Strictly speaking a TED is a type of bycatch reduction device that excludes turtles and other large animals from the trawl. The acronym BRD stands for 'bycatch reduction device' but usually refers to devices that are specifically designed to reduce the capture of fish bycatch and other small animals and debris. Other modifications that may reduce bycatch include larger meshes in the main body of the trawl, ground gear modifications or headline height adjustment.

Byproduct

Any part of the catch which is kept or sold by the fisherman but which is not the target species.

Catchability

In a broad sense, catchability is the extent to which a fish or shrimp is susceptible to capture by fishing gear. In stock assessment it is the proportion of the stock removed by one unit of fishing effort.

Discard

That part of the catch released or returned to the sea, dead or alive, whether or not such fish are brought fully on board a fishing vessel.

Fish Excluder Device (FED)

In some parts of the world this term is used to describe a device that reduces the catch of fish bycatch. This term is synonymous with bycatch reduction device.

Incidental catch

Has the same meaning as accidental or non-target catch.

Industrial fishery

A fishery involving commercial companies using relatively large amounts of capital and energy, relatively large fishing vessels and fishing gear, making long fishing trips, usually offshore, usually for export.

Monitoring Control and Surveillance

Activities undertaken by the fishery enforcement system to ensure compliance with fishery regulations.

Non-target species

Species for which the fishing gear is not specifically deployed or set, but may have immediate commercial value and be a desirable component of the catch. Includes bycatch and byproduct.

Responsible Fishing

Fishing activities that are not only sustainable but also provides consumers with high quality, nutritious seafood that meets appropriate food safety standards.

Selective fishing gear

A fishing gear allowing fishermen to capture few (if any) species other than the target species.

Selectivity

Ability to target and capture fish by size and species during the fishing operation while allowing bycatch to escape unharmed. In shrimp fishing this can be influenced by the timing and location of the fishing operation, the size, design and operation of the fishing gear and onboard processing practices.

Small-scale fishery

A traditional fishery involving fishing households (as opposed to commercial companies), using relatively small amount of capital and energy, relatively small fishing vessels (if any), making short fishing trips, close to shore, mainly for local consumption. This term is synonymous with artisanal fishery.

Stakeholder

An individual, company or organization with an interest in a fishery. In the broadest sense everyone is a stakeholder because fishery resources are a community asset.

Subsistence fishery

A fishery where the catch is shared and consumed directly by the families and relatives of the fishermen rather than being bought by a middleman and sold at the next larger market.

Sustainable Fishing

Fishing activities that do not cause or lead to undesirable changes in biological and economic productivity, biological diversity, or ecosystem structure and functioning from one human generation to the next. Fishing is sustainable when it can be conducted over the long-term at an acceptable level of biological and economic productivity without leading to ecological changes that foreclose options for future generations.

Target species

Those species that are primarily sought by fishermen in a particular fishery. The subject of directed fishing effort in a fishery.

TED

A term that initially meant turtle excluder device, but sometimes means trawl efficiency device. It is an inclined grid or net panel that prevents large animals from entering the codend. TEDs not only exclude turtles but also sharks, stingrays, jellyfish, sponges and large fish.

TEDed

A colloquial term used by fishermen when the shrimp catch from a net is considerably less than expected. Implies that the TED is responsible for the reduced catch.

Trash fish

Usually part of the bycatch with little or no commercial value. In some countries, trash fish are used in fish or shrimp culture. It can also be used for fishmeal production. In many developing countries (e.g. China, India) it is used extensively for human consumption.

Undersized

Fish (caught) at a size smaller than the minimum size limit established by regulation.

APPENDIX 1: A Summary of US TED Regulations

This section is a summarised account of the US TED regulations for the Gulf of Mexico and South Atlantic shrimp-trawl fisheries. These regulations provide countries seeking to remove the US embargo a useful guide about important TED design details and regulations. However, it is unnecessary for these countries to exactly follow the US regulations provided that they establish a sea turtle protection program that provides a comparable level of turtle protection. This means that countries have the flexibility to develop their own national regulations that accommodate for differences between shrimp fisheries (see Appendix 2 for an example). Such countries should therefore consider the US regulations as a foundation upon which to build their own national or fishery specific regulations. It is advisable that these countries review the complete US regulations before embarking on a TED development program. These details can be obtained from the Federal Register, Code of Federal Regulations, Title 50 Part 223.206 and 223.207 (50 CFR 223.206, 50 CFR 223.207). Copies of these regulations are available on the Internet.

The US TED regulations are contained within four key categories: (a) Hard TEDs; (b) Special hard TEDs; (c) Soft TEDs, and; (d) Revision of design criteria and allowable modifications. Hard TEDs are constructed with rigid bars and are either categorised as 'hooped hard TEDs' such as the NMFS, Coulon and Cameron TEDs or 'single-grid hard TEDs' such as the Matagorda, Georgia and Super Shooter TED. The specifications cited below for the Hooped hard TED and the single-grid hard TED are based on the requirements for fishing operations in offshore waters where leatherback turtles may be encountered (these dimensions are reduced where these turtles are not encountered, ie. inshore waters). The so-called special hard TEDs are those that do not meet all the design and construction criteria of hard TEDs. This includes TEDs used in the Atlantic summer bottom trawl fishery to target flounder (that are not approved for use on shrimp trawlers) and the Weedless TED. Soft TEDs are defined as those that use netting to guide turtles toward an escape opening located in the top of the codend. The Parker TED is the only approved example of a soft TED. The regulations cited below for this TED are based on the requirements for fishing in offshore waters and inshore waters in Georgia and South Carolina.

Construction material

(a) Hard TEDs are constructed from solid steel, aluminium or fibreglass rod, or steel or aluminium tubing. The minimum outside diameter of steel rod is 6.4 mm and 12.7 mm for aluminium or fibreglass rod. If tubing is used the minimum outside diameter is 12.7 mm with a minimum wall thickness of 3.2 mm. The bars of the grid must be permanently attached to the outer frame of the grid.

(b) The Weedless TED must be constructed from aluminium or steel pipe with a minimum outside diameter of 32 mm ($1\frac{1}{4}$") and a minimum wall thickness of 3 mm ($\frac{1}{8}$"). The bars of the grid opposite the escape opening must be permanently attached to the outer frame of the grid. The ends of the bars nearest the escape opening must be angled forward of the leading edge of the outer frame adjacent the escape opening.

(c) The Parker TED must be constructed from polyethylene or polypropylene netting material.

Grid or netting shape

(a) Hard TEDs can be either oval, round or tombstone in shape.

(b) The Weedless TED must have a tombstone shaped grid.

(c) The Parker TED must be constructed from a triangular-shaped panel of netting that forms a complete barrier inside the trawl.

Grid angle

(a) In a Hard TED the angle of the grid must be between 30° and 55° from the horizontal when the trawl is in operation.

(b) In a Weedless TED the angle of the grid must be between 30° and 55° from the horizontal when the trawl is in operation.

Bar spacing or mesh size

(a) In a Hard TED the spacing between bars of the grid must not exceed 102 mm (4").

The bars of the grid must run from top to bottom (vertically) when the TED is positioned in the net. If a so-called Flounder TED is used then up to four of the bottom bars and two of the top bars (including the frame) may run from side to side (horizontally) when the TED is positioned in the net.

(b) In a Weedless TED the bars of the grid must also run from top to bottom when the TED is positioned in the net. The space between the ends of the bars and the bottom frame of the TED must be no more than 102 mm (4"). A horizontal brace bar must be permanently attached to the outer frame of the TED and each bar of the grid. This brace must be attached to the rear side of each bar and outer frame and constructed from the same material. It must be located to the lower-most half of the grid and frame, and may be offset behind the grid using spacers not exceeding 127 mm (5").

(c) The Parker TED must be constructed from a triangular-shaped panel of netting with a mesh size of 203 mm (8") and two trapezoidal panels of netting with a mesh size of 102 mm (4"). All mesh sizes are stretched-mesh measurements.

Hoop or grid size

(a) In a hooped hard TED the front hoop must have an inside horizontal measurement of at least 1 016 mm (40") and an inside vertical measurement of at least 762 mm (30"). The bars of the grid must be at least 590 mm (23⅕") from the top of the front hoop.

The grid size of a single-grid hard TED must have inside horizontal and vertical measurements of at least 813 mm (32"). The required inside measurements must be taken at the mid-point of the deflector grid.

(b) In a Weedless TED the size of the grid is the same as that for a single-grid hard TED.

Flotation

(a) & (b) Floats can be attached either inside or outside the codend using heavy twine or rope, but not to the escape cover or flap. They must either be constructed of aluminium, hard plastic, expanded polyvinyl chloride or expanded ethylene vinyl acetate. If floats are attached inside the net they must be located behind the rear surface of the TED so they do not impede the passage of sea turtles toward the escape opening. The combined buoyancy of the floats must be at least be 6.4 kg (14 lb) and sufficient to overcome the weight of the grid. If a downward excluding hard TED is used all floats must be attached to the upper half of the grid.

Float dimension requirements

(a) & (b) For all hard TEDs and the Weedless TED at least one aluminium or hard plastic float no smaller than 250 mm (10") in diameter, or two expanded polyvinyl chloride or expanded ethylene vinyl acetate floats, each no smaller than 172 mm (6¾") in diameter by 222 mm (8¾") in length, must be attached.

Location and size of escape opening

(a) In a hard TED the escape opening must be centred on and immediately forward of the grid frame. If a upward excluding TED is used the escape opening must be located in the top of the codend and if a downward excluding grid is used the escape opening must be located in the bottom of the codend. The escape opening must be made by removing a rectangular-shaped piece of netting from the codend.

The required size of the escape opening depends on the type of TED used and location fished. The escape opening that can be used on an offshore hooped hard TED is 1 016 mm (40") wide by 889 mm (35") long with each measurement taken simultaneously. On a single-grid hard TED used in all offshore waters, the cut across the width of the codend cannot be less than 1 803 mm (71") when stretched. The forward cuts of escape opening must also have a stretched length of at least 660 mm (26"). The total circumference of the escape opening should be at least 3 610 mm (142"). The maximum width of the escape opening in a single-grid hard TED cannot be narrower than the outside width of the grid minus 102 mm (4") on both sides of the grid.

If a so-called double-cover flap (overlapping escape cover) is used the size of the escape opening must at least measure 1 420 mm (56") wide when stretched and the forward cuts must measure 508 mm (20") long when stretched.

(b) In a Weedless TED the location and shape of the escape opening must be the same as for a hard TED. The required size of the escape opening is identical to that required for a single-grid hard TED.

(c) In a Parker TED the escape opening must measure at least 2 438 mm (96") directly forward of the apex of the excluder panel. This measurement is made with the meshes taut.

Other details

(a) A hard TED must be sewn into the trawl around the entire circumference of the grid frame with heavy twine.

(b) The Weedless TED must also be sewn into the trawl around the entire circumference of the grid frame.

(c) The Parker TED must be designed to guide turtles toward an escape opening located in the top of the codend.

The leading edge of the excluder panel must be attached to the inside of the bottom of the trawl across a straight row of meshes. Every mesh of the leading edge of the excluder panel must be attached evenly to the row of meshes in the bottom of the trawl. The apex of the excluder panel must be attached to the inside of the top of the trawl at the centreline of the trawl. The distance, measured along the centreline of the top panel of the trawl, from the row of meshes to which the leading edge of the excluder panel is sewn to the apex attachment point must be 78 - 83 meshes if trawl mesh size is 57 mm (2¼"). If a smaller mesh size is used the number of meshes is increased.

Accelerator funnel

(a) & (b) An accelerator funnel can be used if it is made of netting with a stretched mesh size not greater than 41 mm (1⅝"). It must be inserted into the codend immediately ahead of the TED and its trailing (rear) edge must not extend past the bars of the grid. In offshore areas where leatherback turtles may be encountered the horizontal opening of the inside of the funnel must measure at least 1 803 mm (71") when the meshes are stretched. Only one-third of the circumference of the funnel can be attached to the codend irrespective of grid orientation. The trailing edge of the funnel can be attached to the bars of the grid on the side opposite the escape opening.

Escape cover

(a) & (b) An escape cover may be fitted over the escape opening providing no device or restriction prevents it from being moved aside and sea turtles can escape. The escape cover must be constructed from netting material. A hinged escape cover framed with steel or aluminium rod or tubing (a so-called door frame) cannot be used. The mesh size of the escape cover can be no larger than 41 mm (1 ¾") stretched mesh and it must be attached along its entire forward edge to the outside of the codend forward of the escape opening. The sides of the escape cover must be attached to the same row of meshes (measured in the fore and aft direction) for a distance not exceeding 150 mm (6") behind the posterior edge of the grid. The sides of the cover must not overlap the sides of the escape opening by more than 127 mm (5") on each side. In offshore waters the cover must measure 3 378 mm (133") wide by 1 321 mm (52") long. The trailing edge of the panel must not extend more than 610 mm (24") beyond the posterior edge of the grid.

If a double cover flap is used it must be constructed from two panels of netting of equal size. Each panel must measure at least 1 473 mm (58") wide and overlap each other by no more than 381 mm (15"). The panels can be attached together at the leading edge of the escape opening. The trailing edge of the panels must not extend more than 152 mm (6") beyond the posterior edge of the grid. No chaffing gear can be used with this escape cover.

Chafing gear and rollers

(a) & (b) A single piece of nylon netting with a twine diameter no smaller than 2 $^{1}/_{2}$ mm may be attached to the outside of the escape cover to prevent chafing on bottom opening TEDs. This netting may be attached along its leading edge only and may not extend beyond the trailing edge or sides of the existing escape cover. It must not negatively impact on the ability of the TED to exclude turtles. A chafing flap cannot be used with the double cover flap modification

Roller gear may be attached to the bottom of a TED to prevent chafing on the bottom of the grid frame and the trawl net. Roller gear basically consists of a hard plastic roller or tube mounted on a steel or aluminium axle rod. The maximum diameter of the roller shall be 152 mm (6") and the maximum width of the axle rod shall be 304 mm (12"). The escape cover must be designed and attached to the trawl so it cannot come into contact with any part of the roller gear. Currently, few US fishermen use roller gear to protect the TED.

APPENDIX 2: TED Regulations in Australia's Northern Prawn Fishery

In 2000 the US embargo was lifted from the Northern Prawn Fishery (NPF) because a turtle protection program was in place that satisfactorily minimised the impact of shrimp trawling on turtles and was comparable in effectiveness to the US program.

The regulations for this fishery are much simpler than the US regulations. There are several reasons for this simplicity. The bulk of shrimp caught in this fishery are destined for overseas markets, particularly those in Asia. The catch is processed quickly, finger packed into small (1.5 - 3.0 kg) boxes and placed into freezers usually within minutes of landing. The high value of shrimp provides a strong economic incentive for fishermen to optimise shrimp quality and minimise damage caused by turtles and other heavy animals in the codend. Fishermen understand that a poorly performing TED can impact negatively on their income and therefore strive to optimise the ability of the TED to rapidly exclude these animals from the trawl. This fishery also has a wide-spread monitoring program with enforcement officers boarding approximately 70% of the fishing fleet each year to check that TEDs (and other fishing gear) comply with fishery regulations. Independent observers are also sometimes used to monitor the effectiveness of TEDs by spending time at sea recording fishing practices and collecting catch data. High TED compliance rates are also linked to effective extension programs that keep fishermen well informed about TED developments. In this way fishermen are provided up to date information about TED regulations and operational details of TED performance, and are able to make informed decisions about their fishing operation. This extension has been in the form of videos, newsletters, booklets, port workshops, and loans of various TED designs. It has also included at-sea assistance to test TEDs under normal commercial fishing conditions.

NPF Regulations

A TED is defined as any device fitted to a net or modification that allows turtles to escape immediately after capture in the net. NPF fishermen can use any TED design provided it meets this criteria and meets the following requirements:

1. The TED must have a rigid or semi-rigid grid of inclined bars to guide turtles to an escape opening immediately forward of the grid.

2. The TED must be attached to the entire circumference of the net.

3. The TED must be fitted with one or more escape openings that measure at least 780 mm across the width of the net (when the netting is pulled taut) and at the same time measures 380 mm in a perpendicular direction from the midpoint of the width measurement.

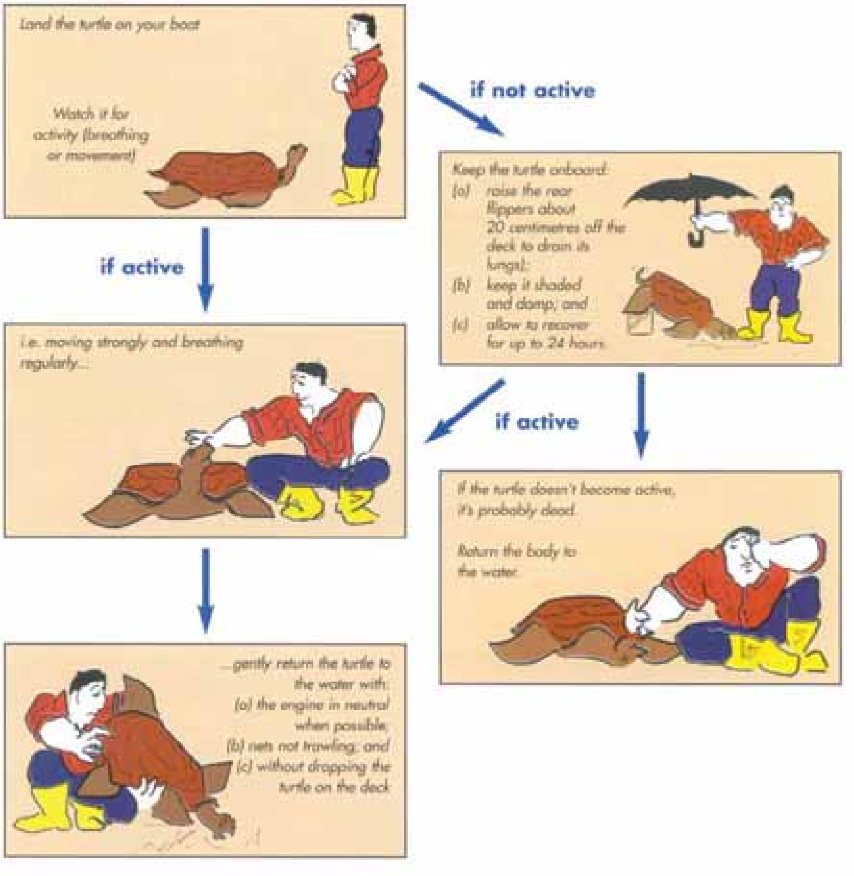
4. The distance between the bars of the TED must not exceed 120 mm. If the TED is made from wire or other semi-rigid material then the TED must be braced or designed so that this distance cannot be exceeded.

Note that the orientation of the grid, the design of the escape opening, accelerator funnel or guiding panel, the required flotation and grid angle are not specified in these regulations. This provides fishermen the freedom to develop TED designs that suit their fishing operation and fishing ground, and therefore optimise TED performance. A failure to achieve this result will fail to protect turtles and risks reducing the shrimp catch; hence the design and operation of these TED components are effectively self-regulating.

Appendix 3: Turtle Recovery Procedures

Turtle Recovery Procedures

Sea turtles caught in trawl nets may be stressed. Most are conscious and able to swim away after removal from the net, but some may be tired or appear lifeless. Turtles that appear lifeless are not necessarily dead. They may be comatose. Turtles returned to the water before they recover from a coma will drown. A turtle may recover on board your boat once its lungs have drained of water. This could take up to 24 hours. By following these steps you can help to prevent unnecessary turtle deaths:



Additional information

All records of turtle catches and deaths are important. If you catch a sea turtle record when, where, what species and what condition it was in when released. Record any tag numbers that may be on the front flippers of the turtle. This information should be recorded on your compulsory fishing log book or passed on to the Southern Fisheries Centre, telephone: (07) 3817 9500.

Turtle recovery procedures provided by Julie Robins of the QLD Department of Primary Industries and Fisheries.

Contacts

Further information on bycatch reduction can be obtained from the following organizations:

The Food and Agriculture Organization of the United Nations (FAO) Fishing Technology Service	Viale delle Terme di Caracalla 00153 Rome ITALY Ph +39 06 57051 Fax +39 06 5705 5188 www.fao.org
Australian Maritime College	PO Box 21 Beaconsfield Tasmania 7270 AUSTRALIA Ph +61 (0)3 6335 4404 Fax +61 (0)3 6335 4459
Southeast Asian Fisheries Development Centre (SEAFDEC) Training Department	PO Box 97 Phrasamutchedi Samut Prakan 10290 THAILAND Ph +662 425 6100 Fax +662 425 6110
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NSW Department of Primary Industries Conservation Technology Unit National Marine Science Centre	PO Box J321 Coffs Harbour New South Wales 2450 AUSTRALIA Ph +61 (0)2 6648 3905 Fax +61 (0)2 6651 6580
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National Fisheries Institute	Pitagoras 1320 Col. Santa Cruz Atoyac CP 03310 Mexico DF
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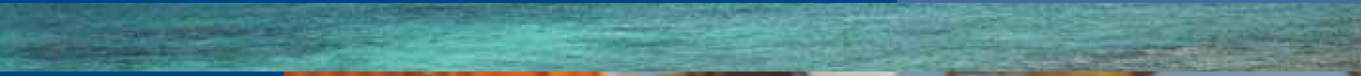
Abbreviations

AFMA	Australian Fisheries Management Authority
AMC	Australian Maritime College
BED	Bycatch Excluder Device
BRD	Bycatch Reduction Device
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
FAO	Food and Agriculture Organization of the United Nations
FED	Fish Excluder Device
FSD	Fish Separator Device
IUCN	International Union for Conservation of Nature and Natural Resources
JTED	Juvenile and Trash Fish Excluder Device
NMFS	National Marine Fisheries Service
MCS	Monitoring Control and Surveillance
RES	Radial Escape Section
SEAFDEC	Southeast Asian Fisheries Development Centre
TED	Turtle Excluder Device or Trawl Efficiency Device
TTED	Thai Turtle Excluder Device



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