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Hard Bycatch Reduction Devices for Bottom Trawls: A Review

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The term bycatch commonly refers to that part of a fisher's catch which is not targeted. The importance of reducing bycatch and minimizing ecological impacts of fishing operations has been emphasized by scientists and fishery managers, and recognized by fishermen. FAO Code of Conduct for Responsible Fisheries has given priority status to development and improvement of fishing technology that eliminates bycatch and selectively target fish in a way that promotes sustainability and conservation. Any device that can be used to reduce or exclude bycatch is generally known as bycatch reduction device (BRD). BRDs that have rigid structures in their construction are designated as hard BRDs. In this paper, significance of hard BRDs in bycatch reduction in trawls and different hard BRDs in vogue in world fisheries, are reviewed. Flat grid, bent grid, slotted grid, oval grid, hooped and fixed angle grid BRDs, BRDs with rigid escape slots, semi-flexible BRDs and combination BRDs are discussed.

Keywords : Trawl bycatch, bycatch reduction devices, hard BRDs, trawling

Bycatch and discards are common problems faced by all fisheries globally. It is recognized as unavoidable in any kind of fishing but the quantity varies according to the gear operated (McCaughran, 1992; Riedel & DeAlteris, 1995; Pillai, 1998; Fonseca *et al.*, 2005a; Madsen & Hanson, 2001). The target catch is the catch of a species or species assemblage, which is primarily sought in a fishery and the bycatch is the incidental catch of non-targeted species that is either retained or discarded due to economic, legal or personal considerations.

Global bycatch by the world's marine fishing fleets was estimated at 28.7 million tonnes in 1994, of which 27.0 million tonnes (range : 17.9-39.5 million t) were discarded annually and shrimp trawling alone accounted for 9.5 million t (35 %) of discards annually (Alverson *et al.*, 1994). In 1998, FAO estimated a global discard level of 20 million tonnes (FAO, 1999). Average annual global discards, has been re-estimated to be 7.3 million tonnes, based on a weighted discard rate of 8%, during 1992-2001 period (Kelleher, 2005). Trawl fisheries for shrimps and demersal finfishes account for over 50% of the total estimated global discards. Tropical shrimp trawl fisheries have the highest discard rate and accounts for over 27% of total estimated discards (Kelleher, 2005). In tropical countries like India, bycatch issue is more complex due to the multi-species nature of the fisheries. The bycatch in Indian shrimp trawling is a serious problem accounting for 70-90% of the total catch. However, with the decline of shrimp catch, bycatch began to contribute significantly to the overall income of the shrimp trawlers. Among the bycatch, about 40% consisted of juveniles and sub-adults

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that are invariably discarded leading to the depletion of the resources (Pillai, 1998; Pillai *et al.*, 2004).

Fish are discarded when the fish is of wrong species, wrong size or sex, poisonous, damaged and when the fish is incompatible with rest of the catch. Other aspects like lack of space onboard and high grading also result in discards. Prohibited aquatic species incidentally caught are also discarded (Clucas, 1996). During the last two decades fishery scientists, resource managers, fishermen, conservation and environmental groups have been actively working towards addressing bycatch issues. Development and implementation of selective fishing methods in order to minimize ecological and environmental impacts of fishing have been recognized as one of the greatest challenges in fisheries management, in recent times (Andrew & Pepperell, 1992; FAO, 1995; 1996; 1997; 2009; Prado, 1997; Hameed & Boopendranath, 2000; Boopendranath *et al.*, 2003; 2008; Eayrs, 2005; Gibinkumar *et al.*, 2005; Boopendranath, 2007, 2009; Boopendranath & Pravin, 2009).

Incorporation of BRDs is considered as one of the simplest and efficient ways of increasing the selectivity of fishing gears. BRD can be defined as any device that can be incorporated in a fishing gear in order to exclude or reduce non targeted and unwanted catch in a fishing system and thereby making it more selective. BRDs are also known as trawl efficiency devices or trash excluder devices. Incidental turtle mortality during commercial shrimp trawling in coastal waters of Orissa has been reported by Gopi *et al.* (2002). Turtle Excluder Devices (TED) are a specific type of BRD designed to exclude sea turtles. Development of TED for Indian fisheries has been reviewed by Boopendranath *et al.* (2010a). Details of CIFT-TED have been described by Dawson & Boopendranath (2003) and its implementation in Andhra Pradesh has been reported by Sankar & Raju (2003).

Significance of BRDs

According to Brewer *et al.* (1998) and Salini *et al.* (2000) there are four main advantages in reducing the amount of unwanted bycatch in shrimp trawls: (i) it reduces the impact of trawling on the marine community, including vulnerable or endangered species; (ii) fishers could benefit economically from higher catch values, reduction in capture of large bycatch species which damages the shrimp caught, shorter sorting time, lower fuel costs (due to reduced net drag), and longer tow times (the codend would fill more slowly); (iii) fishers would face less criticism from conservation groups; and (iv) recreational and non-shrimp commercial fisheries would benefit from a reduced impact on species of their concern.

Principles of BRDs

BRDs have been developed taking into consideration the differential behaviour patterns such as differences in swimming speed and vertical distribution and size selectivity of targeted and non-targeted organisms. The fish generally are active and are capable of swimming against the water flow inside the net and could escape if an opportunity is provided while the shrimps are carried by the flow of water into the codend (Pillai, 1998; Broadhurst, 2000; Hameed & Boopendranath, 2000; Dawson, 2000; Matsushita & Yoshiki, 2000; Boopendranath *et al.*, 2003). A schematic diagram of typical BRDs is given in Fig. 1.

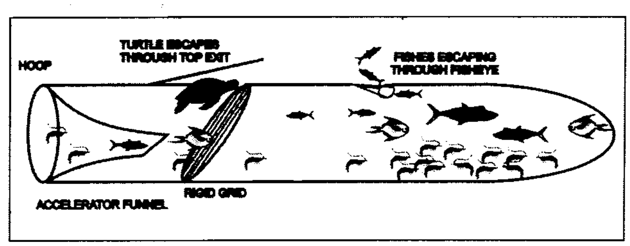

Fig. 1. Schematic diagram of BRDs

Classification of BRDs

Most of the BRDs have been developed through intensive research, taking into consideration the characteristics of the fishery and geographical peculiarities of the region. There is no standard classification for BRDs in the literature except a generalized categorization (Talavera, 1997; Mitchell *et al.*, 1995; Pillai, 1998; Broadhurst, 2000). A classification of BRDs based on the structure, materials used and principles of operation is given in Fig. 2.

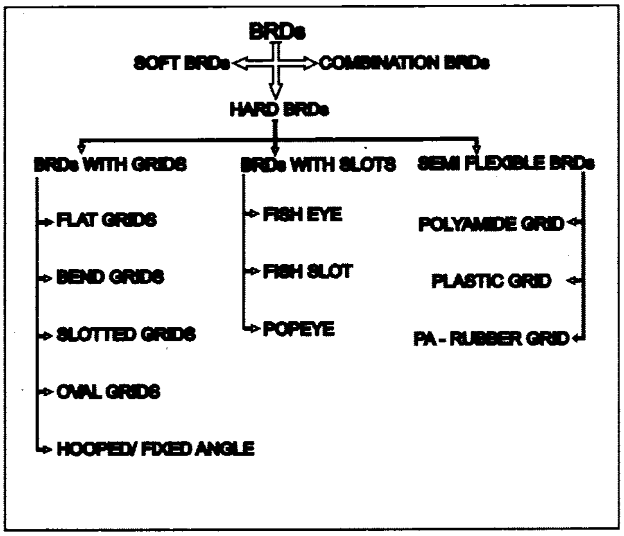

Fig. 2. Classification of BRDs

BRDs can be broadly classified into three categories based on the type of materials used for their construction, as hard BRDs, soft BRDs and combination BRDs. Hard BRDs are those, which use hard / semi flexible grids as separating devices in their construction. Soft BRDs make use of large meshed netting panels or large openings made in the netting to facilitate the escape of bycatch (Boopendranath *et al.*, 2010b). In combination BRDs more than one BRDs are used in a single system. Hard BRDs can be broadly classified into BRDs with grids, BRDs with slots and semi-flexible BRDs. BRDs with grids can be further classified into flat grid BRDs, bent grid BRDs, oval grid BRDs, slotted grid BRDs, hooped and fixed angle BRDs. The materials used for making hard BRDs include solid steel rods, aluminium rods, steel or aluminium tubing, fibreglass rods, polyamide grids etc. Over 30 different hard BRD designs have been developed for different resource groups and fishing areas.

Flat grid BRDs

Flat grid BRDs are mostly rectangular in shape without any bend in the grid bars (Fig. 3). This type of design was developed in Norway originally to exclude jelly fish (Isaksen *et al.*, 1992). The grid made of either aluminium or steel, is usually mounted in the throat section at an angle of 45 – 50° from the horizontal. The grid is usually associated with an accelerator funnel for guiding the catch to the grid. Escape openings are provided either on top or bottom and are either kept open or covered with a flap of netting. Examples for flat grid BRDs are Nordmore grid (Isaksen *et al.*, 1992; Prado, 1993; Riedel & DeAlteris, 1995; Brewer *et al.*, 1998; Halliday & Cooper, 1999; Hannah & Jones, 2000; Hannah *et al.*, 2003; Valdemarsen & Suuronen, 2003; Fonseca *et al.*, 2005a; Fonseca *et al.*, 2005b), Wicks TED (Robins *et al.*,1999), Kelly / Girourard grid (Morris, 2001), and Sort-V grid (Maartens *et al.*, 2002).

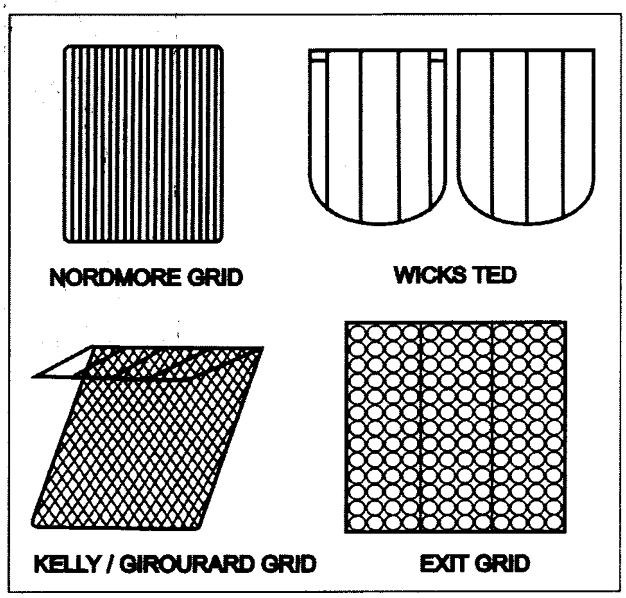

Fig. 3. Flat grid BRDs

Bent grid BRDs

Bent grid BRDs are either rectangular or elliptical in shape. In this group of BRDs, the grid bars and, in some cases, grid frame are bent at one end near the exit opening (Fig. 4). This is to facilitate the easy ejection of the debris, seaweeds, and bycatch components and prevent clogging of the grid. Exit holes are guarded with flap of netting. The grid is mounted in the aft section of the trawl just in front of the codend at an angle between 45° and 55° from horizontal. Material used for its construction is steel or aluminium. Super Shooter TED (Mitchell *et al.*, 1995; Brewer *et al.*, 1998; Kirubakaran *et al.*, 2002; Steele *et al.*, 2002), Seymour TED (Robins *et al.*, 1999), Juvenile and Trash Excluder Device (JTED) (Chokesanguan *et al.*, 2000) NAFTED (Brewer *et al.*, 1998; Eayrs, 2004) are BRDs coming under this category.

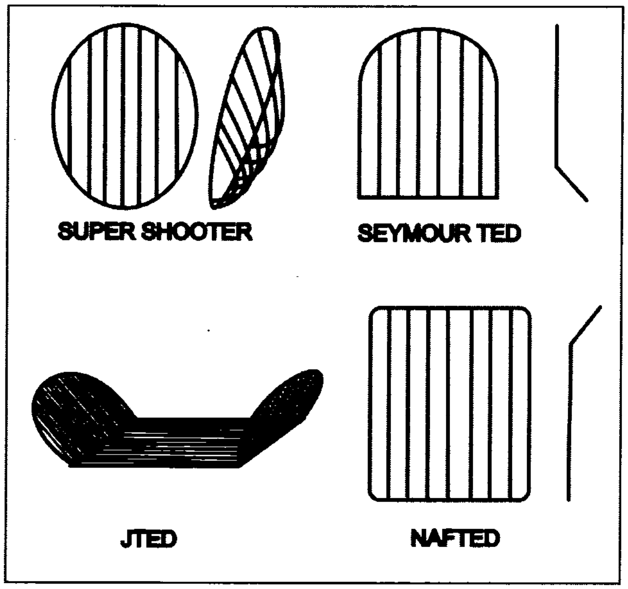

Fig. 4. Bent grid BRDs

Oval grid BRDs

Oval grid BRDs are flat grids, which are either oval or circular in shape (Fig. 5). The grids are made of steel and are mounted in a netting section between throat and codend of the trawl net. Grid angle varies from 45° to 55° from horizontal. Exit openings are either at the top or the bottom of the section. Various grid designs of this type are used worldwide, which include Georgia-Jumper (Anon, 1990; Mitchell *et al.*, 1995; CIFT, 2003), Saunders grid (Talavera, 1997), Thai Turtle Free Device (TTFD) (Talavera, 1997, Chokesanguan, 1996); Oregon grate (Hannah *et al.*, 2003), CIFT-TED (Dawson & Boopendranath, 2001; Boopendranath *et al.*, 2003) and Halibut Excluder Grate (Rose & Gauvin, 2000).

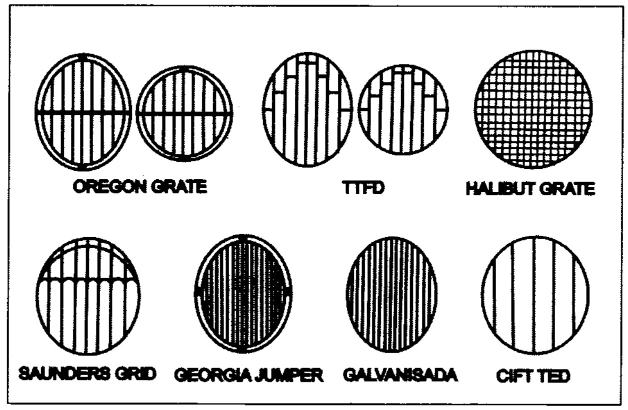

Fig. 5. Oval grid BRDs

Slotted grid BRDs

These are flat grids mostly rectangular in shape made of either aluminium or steel (Fig. 6). Slotted grid BRD is inserted in the aft section of the trawl just in front of the codend. The main characteristic of this category of BRDs is that they are provided with slots for allowing the passage of targeted species other than shrimp. The slots may be either at top or at bottom, made by

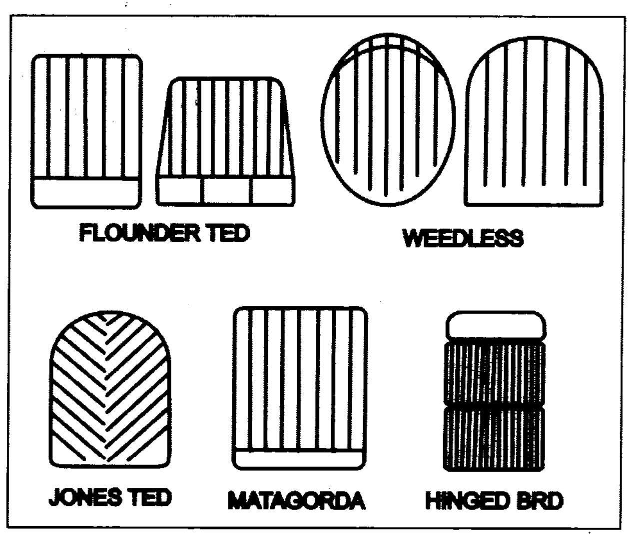

Fig. 6. Slotted grid BRDs

welding cross bars or by leaving one end of the bars without joining to the frame. Steel, aluminium and polyamide are used to construct the grids. The important grids under this category are Flounder TED, Jones TED, Matagorda, Hinged grid and Anthony Weedless (Anon, 1990; Talavera, 1997; Mitchell *et al.*, 1995; Dawson, 2000; Dawson & Boopendranath, 2001; Belcher *et al.*, 2001; Boopendranath *et al.*, 2003; CIFT, 2003; Eigaard & Holst, 2004; CFR, 2005; Boopendranath *et al.*, 2008).

Hooped and Fixed angle BRDs

Hooped and Fixed angle BRDs have circular, oval or rectangular hoops in front and rear of the deflecting grid, which is rigidly fixed in a framework at the desired angle (Fig. 7). Materials used for construction are steel or aluminium. The main advantage of hooped TEDS are (i) sturdier construction for fishing in rugged conditions and (ii) constant angle of the deflector bars unaffected by changes in the eleongation of netting. However, these designs are relatively cumbersome in terms of onboard handling and hence is not in popular use. The NMFS Hooped BRD, Cameron shooter BRD and Fixed angle BRD comes under this category (Oravetz & Grant, 1986; Prado, 1993; Mitchell *et al.*, 1995; Talavera, 1997, Rogers *et al.*, 1997; Dawson, 2000; Hameed & Boopendranath, 2000; Boopendranath, 2003).

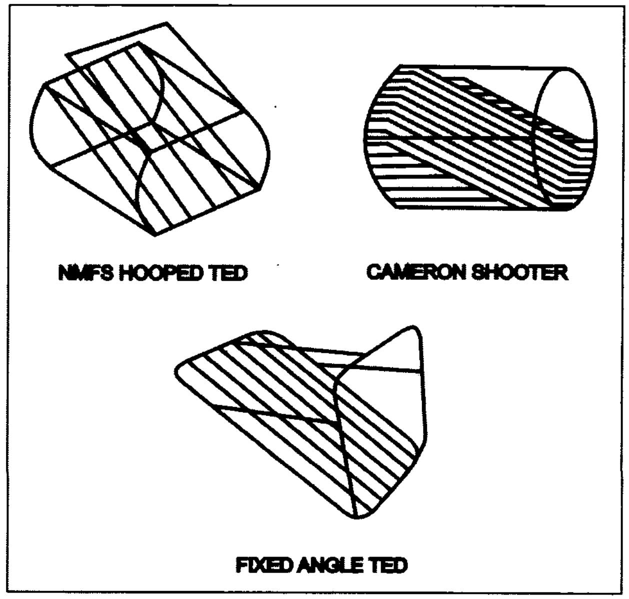

Fig. 7. Hooped and Fixed angle BRDs

BRDs with rigid escape slots

BRDs with rigid escape slots are designed to facilitate the escapement of fish from the codend (Fig. 8). Fisheye is the most important BRD coming under this category. It consists of an oval shaped rigid structure with 8 - 15 cm height and 30 - 40 cm width, with supporting frames made of stainless steel rods. Fishes swim backward from the codend and escape through the fisheye (Pillai, 1998; Brewer *et al.*, 1998; Hannah *et al.*, 2003; Burrage, 2004). There are several design variations of fisheye such as Florida Fish Eye (FFE) used in the Southeast US

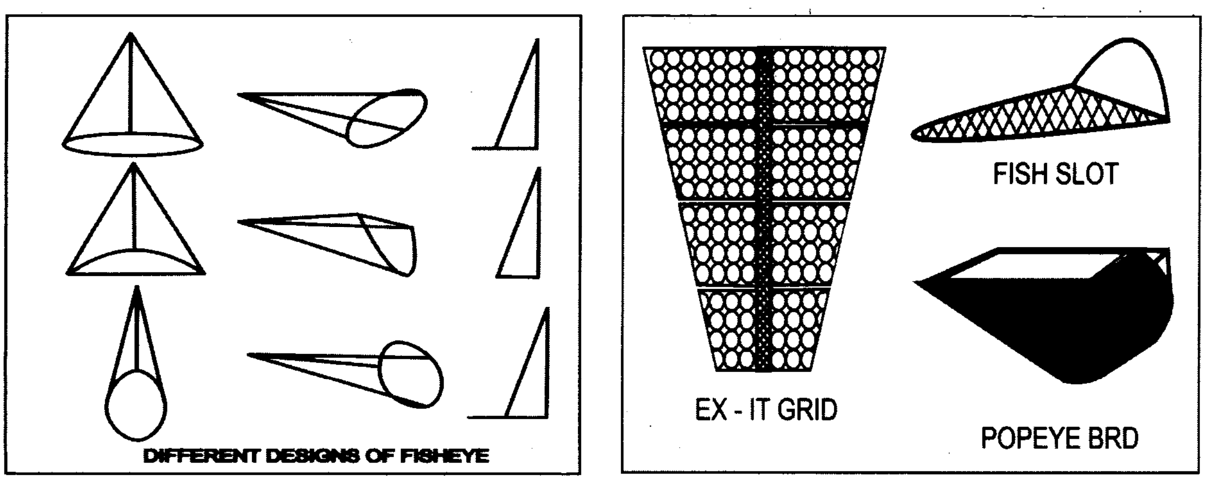

Fig. 8. BRDs with rigid escape opening

Atlantic and in the Gulf of Mexico (Steele, *et al.*, 2002), Florida Fish Excluder (FFE), (Anon, 1997) and Snake eye BRD used in North Carolina Bay (Fuls & McEachron, 1997). Fisheyes of different size and shape are used in south Atlantic and in the Gulf of Mexico (Anon, 2002). Fish slot (Morris, 2001), Sea eagle BRD (Anon, 1997) Popeye Fish excluder or Fishbox BRD (Anon, 2004), EX-it and Sort-V grids (Maartens *et al.*, 2002) are other designs in this category.

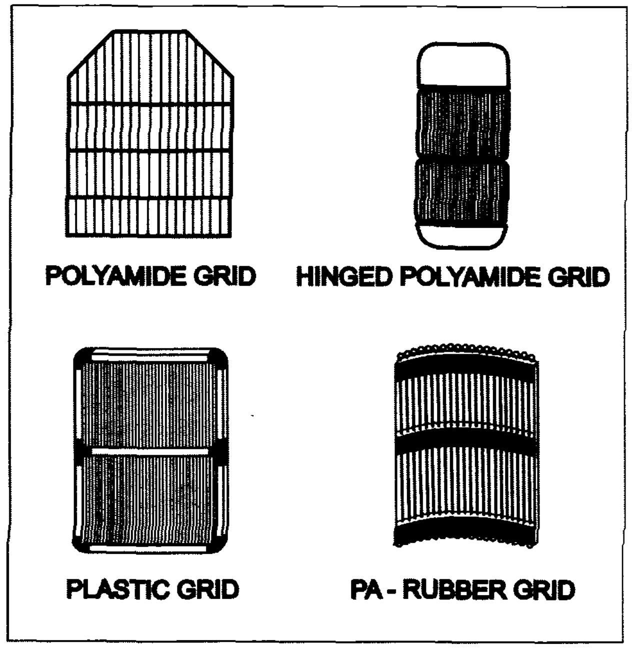

Fig. 9. Semi flexible BRDs

Semi-flexible BRDs

Semi-flexible BRDs are constructed out of semi flexible or flexible materials like plastic, polyamide, FRP and rubber, (Fig. 9). These include (i) flexible plastic grid made of polyethylene and the grid frame consisted of plastic tubes used in the North Sea brown shrimp fishery (Polet, 2002), (ii) Polyamide grid with hinges for operation from net drums used in the Danish experiments in the North Sea shrimp fishery (Madsen & Hanson, 2001; Anon, 2003) and (iii) Polyamide-rubber grid design from Denmark (Anon, 2002).

Combination BRDs

Sometimes, two or more BRDs are combined in a single gear to enhance the efficiency (Fig. 10). Researchers proposed different combinations of grids, slotted BRDs such as fisheye and soft BRDs such as square mesh window, bigeye BRD and similar ones to obtain optimum results (Mounsey *et al.*, 1995; Robins-Troeger *et al.*, 1995; Brewer *et al.*, 1998; McGilvray *et al.*, 1999; Robins *et al.*, 1999; Robins & McGilvray, 1999; Ramirez, 2001; Steele *et al.*, 2002; Eayrs, 2004).

Thirty-three hard BRD designs described have been operated either experimentally or commercially in different fishing areas with promising results. Super shooter TED operations indicated shrimp loss between 2 and 12% in Australian waters (Brewer *et al.*, 1998). The Super shooter TED

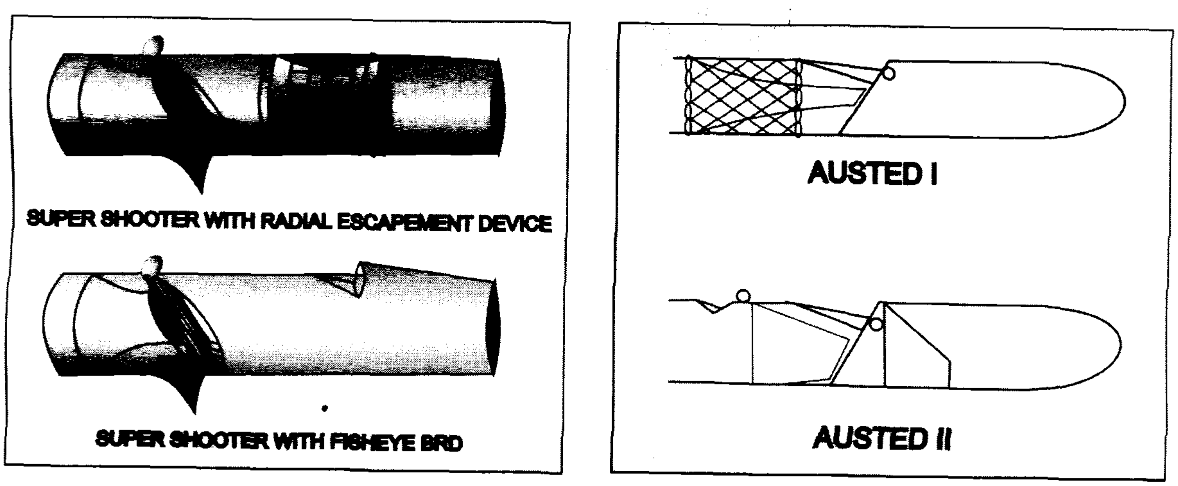

Fig. 10. Combination BRDs

also performed well in areas where the other inclined grid BRDs tended to clog due to accumulation of sponges and seaweeds and worked well when used in combination with other BRDs such as fisheye.

As 40% of the bycatch in India is contributed by juveniles (Pillai, 1998) a Juvenile Fish Excluder cum Shrimp Sorting Device (JFE-SSD) has been developed for bringing down the bycatch of juveniles and small sized non-targeted species in commercial shrimp trawl (Boopendranath *et al.*, 2008; WWF, 2009). The JFE-SSD operations off Cochin, India have realised bycatch reduction up to 43 % with a shrimp retention of 96-97% (Boopendranath, 2009). Super shooter TED operations off Visakhapatnam, India, indicated higher exclusion of fish when the exit was on the lower side (43.4%) and 13.7% when the exit was on the upper side. In both cases, 100% escapement of turtles was observed (Kirubakaran *et al.*, 2002). The NAFTED operations in Australian waters in combination with square mesh window during the commercial trials indicated shrimp loss of 3.3% in the catch of a standard trawl (Brewer *et al.*, 1998). CIFT-TED operations in Arabian Sea and Bay of Bengal indicated 100% exclusion of sea turtles with a mean catch loss in the range of 0.52 to 0.97% for shrimp and 2.44 to 3.27% for non shrimp resources (CIFT, 2003; Boopendranath *et al.*, 2003). It is substantially less than the loss incurred during the operations with imported TED devices (Boopendranath *et al.*, 2003; Anon, 2011). The CIFT-TED was also reported as a simple BRD which can be fabricated easily and installed with minimum training, using net making skills and workshop facilities available locally (Anon, 2011).

Experiments with Nordmore grid, in Norwegian waters, have shown a low and fairly constant shrimp loss of 2-5% (Isaksen, *et al.*, 1992) while fishes above 200 mm size were observed to escape. Experiments using Nordmore grid in Nova Scotia, Canada showed target catch loss of 2-5% and bycatch reduction of 48-98% (Halliday & Cooper, 1999). Experiments with Nordmore grid in Portuguese continental waters showed up to 78.5% exclusion of large bycatch species with negligible loss of target catch (Fonseca *et al.*, 2005b). Experiments using modified versions of Nordmore grids made of plastic, in the North sea reduced >70% fish and 65% benthos with a target catch loss of 15% (Polet, 2002). Maartens *et al.* (2002) observed the escapement of juveniles up to 95%, during experiments with two different rigid sorting grids *viz* ., Sort-V grid and EX-it grid, in coastal waters off Namibia.

Performance of fisheye depends on the shape, size, position, light and water current. Fisheye experiments conducted in Florida and in coastal Australian waters showed enhanced bycatch reduction when used in combination with other BRDs (Brewer *et al.*, 1998; Steele *et al.*, 2002). During experiments using Fish slot in North Carolina, USA an average reduction of weakfish was about 30% and shrimp loss was about 55%. This model is prone to hang on the bumper rails of the vessels sides and can damage the tail bag or BRD (Morris, 2001). Experiments using Popeye fish excluder or fish box BRD in Queensland waters showed 29-60% reduction in bycatch (Anon, 2004) Flexible polyamide grid experimented in North Sea has been shown to be efficient in fish and lobster exclusion, and also has flexibility to be wound into the net drum (Madsen & Hanson, 2001).

Combination BRDs are used to increase the efficiency of the BRD in terms of bycatch reduction and retention of target catch. Experiments with flat gird and square mesh conducted at the Fladen Ground in the North Sea showed negligible shrimp loss and 42-56% reduction of under-sized fishes (Madsen & Hanson, 2001). Experiments with flat hinged grid in combination with square mesh window conducted in North Sea showed bycatch reduction in the range 37-57% (Eigaard & Holst, 2004). Super shooter TED operations in combination with fisheye in Australian Northern shrimp trawl fishery showed more than 25% exclusion of bycatch and less than 5% loss in target catch (Brewer *et al.*, 1998). Experiments with AusTED-I and its modified version AusTED-II conducted in Australian waters showed promising results in terms of bycatch reduction, shrimp retention and exclusion of turtles and large animals (McGilvray *et al.*, 1999, Robins *et al.*, 1999, Mounsey *et al.*, 1995, Robins-Troeger *et al.*, 1995, Brewer *et al.*, 1998, Robins & McGilvray, 1999). Average bycatch reduction ranged between 18 and 55% for AusTED-I and between 15% and 49% for AusTED-II depending on fishery conditions.

Conclusion

A variety of BRDs have been developed and used either on commercial or experimental basis, in order to mitigate regional bycatch issues and to increase the selectivity of trawl nets. Some BRDs have been developed through intensive research, taking into consideration the characteristics of the fishery and the geographical peculiarities. There has been significant reduction in world bycatch levels during the past two decades. Increased use of BRDs in trawling could be an important reason contributing to the reduction in bycatches, in recent years. Experimental fishing trials alone could never encompass the range of commercial fishing conditions and the environment in which the fishery operates (Robins *et al.*, 1999). Cooperation between fishing industry, scientists and other stakeholders is fundamental for the success of bycatch management efforts. Ease of construction and operation of the BRDs, cost-effectiveness of the technology and the economic benefits influence the adoption of bycatch reduction technologies. BRDs most appropriate to the regional fishing conditions should be adopted and enforced legally, after careful scientific evaluation and commercial trials, to ensure long-term sustainability and to protect the biodiversity of fishery resources.

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References

Alverson, D.L., Freeberg, M.H., Murawski, S.A. and Pope, J.G. (1994) A global assessment of fisheries bycatch and discards. 233 p, FAO *Fish. Tech. Pap. No. 339*, Rome, FAO

Andrew, N.L. and Pepperell, J.G. (1992) The bycatch of shrimp trawl fisheries. In: *Oceanography and marine biology* (Ansell, A.D. and Gibson, R.N., Eds), pp 527-565, Annual Review, **30**

Anon (1990) Decline of the sea turtles: causes and prevention, Commission on Life Sciences (CLS), http://books.nap.edu/ openbook/030904247X/ html/index.html (Accessed on 12 March 1991)

Anon (1997) Shrimp trawling, Proclamation SH-3-2001, Division of Marine fisheries, www.ncfisheries. net/content/brd (Accessed on 27 June 2011)

Anon (2002) Flexigrid beats problems, tough grid fold on to net drum, *Fish News Int.* **41** (12), pp 1 & 12

Anon (2003) Fleet to sort small hake with grids, *Fish News Int.* **42** (4), pp 8

Anon (2004) Popeye fish excluder, Queensland Government Department of Primary Industries and fisheries, *Trawl fishery newsletter*, #5, http://www2. dpi.qld. gov. au/trawlfishery /16505.html (Accessed on 20 March 2005)

Anon (2011) Turtles and TEDs : Outcome of the trials conducted off Dhamra, Orissa, WWF- India, New Delhi, 23 p

Belcher, C., Vendetti, R., Gaddis, G., and Parker, L. (2001) Results of gear testing to reduce turtle capture in the whelk trawl fishery, Georgia seagrant college program, The University of Georgia Marine Extension service, Bulletin No. **23**, 28 pp

Boopendranath, M.R. (2007) Possibilities for bycatch reduction from trawlers in

India, In: *Indian fisheries – A progressive outlook* (Vijayan, K.K., Jayasankar, P. & Vijayagopal, P., Eds), pp 12-29, Central Marine Fisheries Research Institute, Cochin

Boopendranath, M.R. (2009) Responsible fishing operations, In: *Handbook of fishing technology* (Meenakumari, B., Boopendranath, M.R., Pravin, P., Thomas, S.N. and Edwin, L., Eds), Central Institute of Fisheries Technology, Cochin, 380 p

Boopendranath, M.R. and Pravin, P. (2009) *Technologies for responsible fishing - bycatch reduction devices and turtle excluder devices.* Paper presented in the International Symposium on Marine Ecosystems-Challenges and Strategies (MECOS 2009), 9-12 February 2009, Marine Biological Association of India, Cochin

Boopendranath, M.R., Percy Dawson., Pravin, P., Remesan, M.P., Raghu Prakash, R., Vijayan, V., Mathai, P.G., Pillai, N.S., Varghese, M.D. and Ramarao, S.V.S. (2003) Design and development of turtle excluder devices for Indian fisheries, In: *Marine turtles of the Indian sub-continent* (Shanker, K. & Choudhury, B.C., Eds), pp 244-267, Universities Press (India) Pvt. Ltd., Hyderabad

Boopendranath, M.R., Pravin, P., Gibinkumar, T.R. and Sabu, S. (2006) *Development of bycatch reduction devices and turtle excluder devices in the context of sustainable seafood production.* Paper presented at National Seminar on Seafood Production: Reflections, Alternatives and Environmental Control, 23-24 February 2006, Goa

Boopendranath, M.R., Pravin, P., Gibinkumar, T.R. and Sabu, S. (2008) *Bycatch reduction devices for selective shrimp trawling* - Final report on ICAR Ad-hoc Project, Central Institute of Fisheries Technology, Cochin, 220 p

Boopendranath, M.R., Reghu Prakash and Pravin, P. (2010a) A review of the development of TED for Indian Fisheries, IOSEA Marine turtle MOU website. www.ioseaturtles.org/pom_detail.php?id=96 (Accessed on 15 January 2011)

Boopendranath, M.R., Pravin, P., Gibinkumar, T.R. and Sabu, S. (2010b) Soft bycatch reduction devices for bottom trawls: A review, *Fish. Technol.* **47** (2), pp 99-110

Brewer, D., Rawlnison, N., Eayrs, S. and Burridge, C. (1998) An assessment of bycatch reduction devices in tropical Australian prawn trawl fishery, *Fish. Res.* **36**, pp 196-215

Broadhurst, M.K. (2000) Modifications to reduce bycatch in prawn trawls: A review and framework for development, *Rev. in Fish Biol. Fish.* **10**(1), pp 27-60

Burrage, D.D. (2004) Evaluation of the "Gulf Fisheye" bycatch reduction device in the Northern Gulf inshore shrimp fishery, *Gulf Mex. Sci.* **22**(1), pp 85-95

CFR, (2005) 50 CFR 223.207, Approved TEDs. www.uscg.mil/d8/grftc/ New%20TED%20Regs.doc (Accessed on 11 December 2006)

Chokesanguan, B. (1996) The experiment on turtle excluder devices (TEDs) for shrimp trawl nets in Thailand, SEAFDEC Training Department, Samut Prakan, Thailand, 43 p

Chokesanguan, B., Ananpongsuk, S., Siriraksophon, S. and Podapol, L. (2000) Study on juvenile and trash excluder devices (JTEDs) in Thailand. SEAFDEC Training Department, Samut Prakan, Thailand, TD/RES/47, 8 p

CIFT (2003) CIFT-TED for Turtle-safe trawl fisheries, *CIFT Special Bulletin No.* **12**, 40 p

Clucas, I. A. (1996) Study of the options for utilization of bycatch and discards from marine capture fisheries, *FAO Fisheries Circular No.* 928, Rome, FAO, 59 p

Dawson, P. (2000) Use of BRDs and TEDs in shrimp trawling, In: *Advances in harvest technology*. pp 424-433, ICAR Winter School Manual, CIFT, Cochin

Dawson, P. and Boopendranath, M.R. (2001) CIFT-TED construction, installation and operation, *CIFT Technology Advisory Series* - 5, CIFT, Cochin, 16 p

Dawson, P. and Boopendranath, M.R. (2003) CIFT-TED Construction, installation and operation, *Kachappa* **8**, pp 5-7

Eayrs, S. (2004) *Reducing turtle mortality in shrimp-trawl fisheries in Australia, Kuwait and Iran.* Paper presented at the Expert Consultation on Interactions between Sea Turtles and Fisheries within an Ecosystem Context, 9-12 March, 2004, FAO *Fisheries Report No. 728*, FAO, Rome, 238 p

Eayrs, S. (2005) A guide to bycatch reduction in tropical shrimp trawl fisheries, FAO, Rome: 110 p

Eigaard, O.R. and Holst, R. (2004) The effective selectivity of a composite gear for industrial fishing: a sorting grid in combination with a square mesh window, *Fish. Res.* **68**, pp 99-112

FAO (1995) *Code of conduct for responsible fisheries,* FAO, Rome, 41 p

FAO (1996) *Fishing operations,* FAO technical guidelines for responsible fisheries 1, 26 p

FAO (1997) Report of the technical consultation on reduction of wastage in fisheries, Tokyo, Japan, 28 October- 1 November 1996, *FAO Fisheries Report No. 547*, Rome, FAO, 27 p

FAO (1999) *The state of world fisheries and aquaculture,* 1998, FAO, Rome

FAO (2009) Guidlines to reduce sea turtle mortality in fishing operations, FAO Fisheries Department, FAO, Rome, 128 p

Fonseca, P., Campos, A., Larsen, R.B., Borges, T.C. and Erzini, K. (2005a) Using a modified Nordmore grid for by-catch reduction in the Portuguese crustacean trawl fishery, *Fish. Res.* **71**, pp 223-239

Fonseca, P., Campos, A., Mendes, B. and Larsen, R.B. (2005b) Potential use of a Nordmore grid for bycatch reduction in a Portuguese bottom trawl multi-species fishery, *Fish. Res.* **73**, pp 49-66

Fuls, B.E. and McEachron, L.W. (1997) Evaluation of three bycatch reduction devices in Aransas Bay during the 1997 Spring and Fall commercial bay-shrimp seasons, *Fish. Bull.* 22 p

Gibinkumar, T.R., Sabu, S., Pravin, P. and Boopendranath, M.R. (2005) *Hard bycatch reduction devices for trawls.* Paper presented at the 7th Indian Fisheries Forum, 8-12 November 2005, Bangalore

Gopi, G.V., Pandav, B. and Choudhary, B.C. (2002) A quantitative analysis of incidental turtle mortalities during commercial shrimp trawling in the coastal waters of Orissa, Wild life Institute of India, Dehradoon, 40 p

Halliday, R.G. and Cooper, C.G. (1999) Evaluation of separator grates for reduction of bycatch in the silver hake (*Merluccius bilinearis*) otter trawl fishery off Nova Scotia, Canada, *Fish. Res.* **40**, pp 237-249

Hameed, M.S. and Boopendranath, M.R. (2000) *Modern fishing gear technology,* Daya publishing house, Delhi, 186 p

Hannah, R.W. and Jones, S.A. (2000) Bycatch reduction in an ocean shrimp trawl from a simple modification of the trawl footrope, *J. North W. Atl. Fish. Sci.* **27**, pp 227-233

Hannah, R.W., Jones, S.A. and Matteson, K.M. (2003) Observations of fish and shrimp behaviour in ocean shrimp (*Pandalus jordani*) trawls. Oregon Department of Fish and Wildlife Marine Recourses Program 2040 S.E. Marine Science Drive Newport, Oregon 97365, 28p

Isaksen, B., Valdemarsen, J.W., Larson, R.B. and Karlsen, L. (1992) Reduction of fish bycatch in shrimp trawls using a rigid separator grid in the aft belly, *Fish.* Res. 13, pp 335-352

Kelleher, K. (2005) *Discards in the world's fisheries marine - an update,* FAO Fisheries Technical Paper No. 470, FAO, Rome: 131 p.

Kirubakaran, P., Neelakandan, M., Shaji, S., Rao, D.V., Venkateswarulu, N. and Varghese, C.P. (2002) Preliminary observations on the operation of TED in bottom trawl, *Fishing Chimes* **21**(12), pp 31-33

Maartens, L., Gamst, K.A. and Schneider, P.M. (2002) Size selection and release of juvenile monkfish *Lophius vomerinus* using rigid sorting grids, *Fish. Res.* **57**, pp 75-88

Madsen, N. and Hanson, K.E. (2001) Danish Experiments with a grid system tested in the North Sea shrimp fishery, *Fish. Res.* **52**, pp 203-216

Matsushita. and Yoshiki. (2000) Bycatch reduction technologies for towed fishing gears, *Bull. Jap. Soci. Sci. Fish.* Nippon Suisan Gakkaishi **66**(2), pp 261-268

McCaughran, D.A. (1992) Standardized nomenclature and methods of defining bycatch levels and implications. In: *Proceedings of the National industry bycatch Workshop* (Schoning, R.W., Jacobson, R.W., Alverson, D.L., Gentle, T.G. and Auyong, J., Eds), pp 200–201, Newport, Oregon, Natural Resources Consultants Inc, Seattle, Washington

McGilvray, J.G., Mounsey, R.P. and MacCartie, J. (1999) The AusTED-II, An improved trawl efficiency device 1, Design theories, *Fish. Res.* **40**, pp 17-27

Mitchell, J.F., John, W. Watson., Daniel, G. Foster and Robert E.Taylor (1995) The Turtle Excluder Device (TED): A guide to better performance, *NOAA Technical Memorandum NMFS-SEFSC- 3-6*, 35p

Morris, B. (2001) *Certification of bycatch reduction devices in North Carolina* - Report to North Carolina Sea Grant, November 2001, Grant 99-FEG-33

Mounsey, R.P., Baulch, G.A. and Backworth, R.C. (1995) Development of a trawl efficiency device (TED) for Australia's Northern prawn fisheries I, The Aus-TED design, *Fish. Res.* **22**, pp 99-105

Oravetz, C.A. and Grant, C.J. (1986) Trawl efficiency device shows promise, *Aust. Fish.* **45**, pp 37-40

Pillai, N.S. (1998) Bycatch reduction devices in shrimp trawling, *Fishing Chimes*, **18** (7), pp 5-47

Pillai, N.S., Varghese, M.D. and Mathai, T.J. (2004) Performance evaluation of different selective devices for the reduction of by-catch in shrimp trawls. In: *Large Marine Ecosystems: Exploration and Exploitation for Sustainable Development and Conservation of Fish Stocks* (Somvanshi, V.S., Ed), pp 569-576, Fishery Survey of India, Mumbai

Polet, H. (2002) Selectivity experiments with sorting grids in the North Sea brown shrimp (*Crangon crangon*) fishery, *Fish. Res.* **54**, pp 217-233

Prado, J. (1993) Selective shrimp catching devices: a review. *INFOFISH Int. 1/93*, pp 54-60

Prado, J. (1997) *Technical measures for bycatch reduction*. Paper presented at the Technical Consultation on Reduction of Wastage in Fisheries, Tokyo, Japan, 28 October-1 November 1996, *FAO Fish. Rep. 547*, pp 25-44

Ramirez, D.A. (2001) Modified trawl net for selective capture of shrimp using small boats in Baja California Sur, Mexico, *INFOFISH Int. 6/2001*, pp 60-62

Riedel, R. and DeAlteris, J. (1995) Factors affecting hydrodynamic performance of the Nordmore Grate System: a bycatch reduction device used in the Gulf of Maine shrimp fishery, *Fish. Res.* **24**, pp181-198

Robins, J.B. and McGilvray, J.G. (1999) The Aus-TED-II, An improved trawl efficiency device II Commercial performance, *Fish. Res.* **40**, pp 29-41

Robins, J.B., Campbell, M.J. and McGilvray, J.G. (1999) Reducing prawn trawl bycatch in Australia: An overview and an example from Queensland, *Mar. Fish. Rev.* **61**(3), pp 46-55

Robins-Troeger, J.B., Buckworth, R.C. and Dredge, M.C.L. (1995) Development of a trawl efficiency device (TED) for Australian prawn fisheries II, Field evaluations of the Aus TED, *Fish. Res.* **22**, pp 107-117

Rogers, D.R., Rogers, B.D., De Silva, J.A. and Wright, V.L. (1997) Effectiveness of four industry-developed bycatch reduction devices in Louisiana's inshore waters, *Fish. Bull.* **95**(3), pp 552-565

Rose, C.S. and Gauvin, J.R. (2000) Effectiveness of a rigid grate for excluding Pacific Halibut, *Hippoglossus stenolepis*, from ground fish trawl catches, *Mar. Fish. Rev.* **62**(2), pp 61-66

Sankar, O.B. and Raju, M.A. (2003) Implementation of the turtle excluder device in Andhra Pradesh, *Kachappa* 8, pp 2-5

Salini, J., Brewer, D., Farmer, M. and Rawlinson, N. (2000) Assessment and benefits of damage reduction in prawns due to use of different bycatch reduction devices in the Gulf of Carpentaria, Australia, *Fish. Res.* **45**, pp 1-8

Steele, P., Bert, T.M., Johnston, K.H. and Levett, S. (2002) Efficiency of bycatch reduction devices in small otter trawls used in the Florida shrimp fishery, *Fish. Bull.* **100**, pp 338-350.

Talavera, R.V. (1997) Dispositivos excluidores de tortugas marinas, *FAO Documento Technico de Pesca, No. 372*, Rome, FAO, 116 p

Valdemarsen, J.W. and Suuronen, P. (2003) Modifying fishing gear to achieve ecosystem objectives. In: *Reykjavik conference on responsible fisheries in the marine ecosystem* (Sinclair, M. and Valdemarsson, G., Eds), pp 321-341, FAO, Rome

WWF (2009) Modifying shrimp trawls to prevent bycatch of non-target species in the Indian Ocean, www.smartgear.org/smartgearwinners/smartgearwinner2005/smartgearwinner 2005 (Accessed on 20 May 2010)