2 Reconciling Fisheries with Conservation Through Programs to Develop Improved Fishing Technologies in the United States

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2.1 Introduction

Technological advancements have revolutionised fishing vessels and fishing gear allowing effective harvesting of target species, but these have also placed harvest pressure on many fish stocks including by-catch. Discarded by-catch can adversely affect the population size and structure of impacted stocks, and reduce the availability of by-catch species that are targeted by other users. The discarding of unwanted and regulated by-catch and the inadvertent capture and mortality of protected species by commercial and recreational fisheries has become an increasingly significant problem in the worldwide effort to conserve and manage marine fisheries resources. By-catch in fisheries worldwide was estimated to be approximately 27 million mt by Alverson et al. (1994). As better estimates of the magnitude of by-catch in fisheries have been made available through fishery observer programs, concern over the impact of by-catch has increased.

Since the mid-1970's, concern over by-catch in the United States has intensified among state and federal fisheries managers, conservationists, fishers and the general public. The incidental capture of endangered and threatened species was the first problem to be addressed and substantial progress has been made to reduce the impacts of fishing gears on their populations (NMFS 2006). More recently, as in other countries, concern over by-catch in the United States has broadened to include the incidental capture of finfish and other living marine resources. Increased world demand for protein has focused attention on the need to minimise waste in all fisheries. In 1996, the United States Congress passed legislation amending the

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Magnuson-Stevens Act of 1976 which required fishery managers to improve limits on by-catch in fishery management plans. The above history has resulted in United States programs to develop more selective harvesting gears, and examples of these programs are presented in this chapter. The common feature of these programs is that they are all designed to reconcile fisheries with conservation through improved fishing technologies.

2.2 Development of the Turtle Excluder Device (TED)

The inadvertent capture of sea turtles and marine mammals (most of which are protected species) is problematic for many fisheries in the United States. In 1978, all species of marine turtles which occur in United States waters were listed as either threatened or endangered under the Endangered Species Act of 1976. A report by the United States National Academy of Sciences, National Research Council (1990) determined that the penaeid shrimp fishery was the single largest cause of sea turtle mortality. The implications of the listing of sea turtle species under the Endangered Species Act and these findings of the National Academy of Sciences represented severe implications for the valuable penaeid shrimp fishery of the United States – especially in the Gulf of Mexico (the world's largest shrimp fishery) unless mitigation measures could be developed to allow continued fishing without jeopardising the recovery of sea turtles.

In response to the mandates of the United States Endangered Species Act, the United States National Marine Fisheries Service initiated a research program to investigate methods to reduce the incidental capture and mortality of sea turtles in the shrimp trawl fishery. Alternatives considered included: spatial and seasonal closures, restricted tow times, and modifications to fishing gear. It was felt that closures would be only minimally effective due to the widespread distribution of sea turtles and also they would be economically detrimental to the industry. Further, it was considered that restrictions on tow times would not be enforceable. An intensive gear development program was therefore conducted by the National Marine Fisheries Service between 1978 and 1980 which resulted in the development of a metal grid device (turtle excluder device or TED, Fig. 2.1) that was placed in the codend extension of the trawl (Watson and Seidel 1980). The grid mechanically separates and excludes sea turtles and other large objects and organisms while shrimp pass through the grid bars into the codend. The prototype design was developed based on behavioural observations of sea turtles encountering shrimp trawls (Ogren et al. 1977) and was similar to a device developed by shrimp fishers to exclude jellyfish (Seidel and McVea 1982). The original TED demonstrated a 97% reduction in sea turtle captures with less than a 3% reduction in shrimp

Catch Per Unit of Effort (CPUE) (Watson and Seidel 1980). In 1981, a program was initiated to encourage the voluntary use of TEDs by United States shrimp fishers. The United States government sponsored industry workshops and technical demonstrations of the device to encourage voluntary adoption. However, fishers who tested the device were concerned that it was too large, cumbersome and complicated to use.

The government continued research and development of the TED design between 1980 and 1984 in an effort to improve its handling characteristics. Additional modifications were made to reduce fish by-catch as an incentive to encourage adoption (Watson et al. 1986) and in 1985 and 1986, additional workshops and demonstrations were conducted to encourage voluntary acceptance of the gear. After an intensive technology transfer and demonstration effort, it became clear the industry would not voluntarily use the technology. In 1986, several non-governmental organisations (NGOs) filed intents to sue the federal government if it did not enforce the protection of sea turtles as required under the Endangered Species Act. In response, the federal government called for mediation between representatives of the shrimp industry and NGOs which resulted in regulations requiring mandatory use of the grid device by the industry.

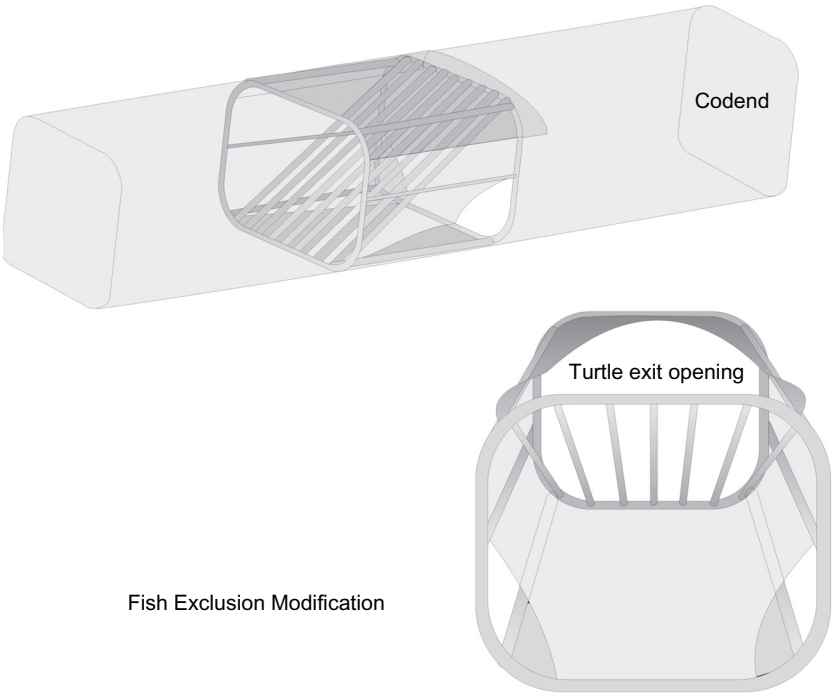

Fig. 2.1. The original Turtle Excluder Device (TED) design

In response to this, segments of the United States shrimp industry began a campaign to resist the requirement of mandatory use of the gear. Others began independent research to develop alternative designs when it became apparent that mandatory regulations would be enacted and enforced anyway. The new designs that were developed by the industry were cheaper, less complicated and easier to use than the design developed by the government researchers. These designs were certified by the government as effective in reducing sea turtle capture, but were less effective than the original design in retaining shrimp catch. Resistance from the industry to mandatory regulations was intense and included political pressure, litigation, adversarial confrontation, and civil and criminal disobedience. The intensity of the industry resistance resulted from fear of reduced revenue and economic hardship, denial and disbelief of the magnitude of the sea turtle problem, general opposition to regulations, distrust of federal regulators precipitated by an effective campaign by some segments of the industry, and ineffective communication between industry and government.

In 1989, after three years of litigation and opposition, mandatory regulations requiring TEDs were fully implemented. This implementation required intensive enforcement efforts and prosecution. The widespread use of certified industry designs resulted in the identification of operational and technical problems resulting from poor construction and installation. As segments of the industry began to accept the inevitability of the technology, however, communication and cooperation began to improve between government gear specialists and fishers. In 1989 and 1990, fishers, net shops and gear technicians began working together to solve operational and technical problems and to develop more efficient designs (Fig. 2.2). The effective transfer of technological improvements resulted from intensive technical training of law enforcement officers and at-sea enforcement assistance from government gear technicians who were able to advise fishers on technical problems. In addition, effective technical manuals, summary placards, and an intensive program of technical training workshops for fishers (including effective multimedia training presentations and hands-on demonstrations) were initiated. Cooperation between fishers and gear technologists resulted in efficient and effective technological improvements, better communication, a more effective technology-transfer program and better compliance with mandatory regulations. This program continues today and is a major component in sea turtle recovery efforts that are resulting in increasing populations of sea turtles in United States waters and the continued promulgation of the valuable United States penaeid shrimp fishery. The TED technology developed in the United States has also been successfully exported to 21 other countries around the world whose shrimp fisheries affect sea turtle populations through a foreign technology transfer program (Epperly 2003).

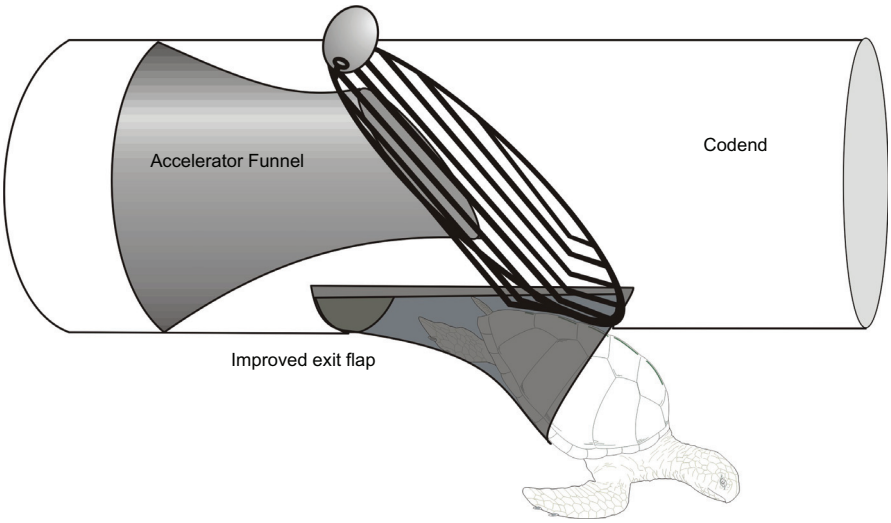

Fig. 2.2. An improved industry design (Super Shooter TED)

2.3 Development of By-catch Reduction Devices (BRDs)

In 1990, amendments to the Magnuson Fishery and Management Act (Public Law 101-27) required the United States Secretary of Commerce to conduct a 3 year research program to determine the impacts of shrimp-trawl by-catch on federally managed fishery resources. This legislation addressed the effect of by-catch mortality on fishery resources in addition to the protection of threatened and endangered species under the endangered species and marine mammal protection acts. The amendments required the secretary to establish a cooperative program to design and evaluate approaches for reducing the mortality of incidentally harvested fishery resources in shrimp fisheries.

A comprehensive approach was adopted to plan and implement a regional by-catch research program which had the advantage of the experience gained from the development and implementation of TEDs. In 1991, the National Marine Fisheries Service's Southeast Regional Office and Fisheries Science Centre developed and published a document entitled 'Shrimp Trawl By-catch Research Requirements' (NMFS 1991). This document established research protocols based on proven scientific methods which were subjected to peer review by an industry-organised panel of researchers and statisticians. To ensure effective communication and participation of all affected parties, the NMFS established cooperative agreements with

the Gulf and South Atlantic Fisheries Development Foundation, a non-profit industry organisation, to organise a Finfish By-catch Steering Committee to guide the development and implementation of the by-catch research plan. The steering committee included representatives of the commercial and sport-fishing industries, conservation organisations, state fishery management agencies, fishery commissions, management councils, universities, and state and federal fishery research agencies. A Technical Review Panel and Gear Review Panel were also established to advise the Steering committee. Working together they developed a research plan addressing finfish by-catch in the Gulf of Mexico and South Atlantic shrimp fisheries (Hoar et al. 1992). Key components of the plan included: cooperative efforts between the shrimp fishery, states, universities, conservation groups and the federal government, strict adherence to stringent scientific protocols, and concurrent studies on social and economic impacts. One of the objectives of the by-catch research program was to identify, develop and evaluate gear options for reducing by-catch in the Gulf and South Atlantic shrimp fisheries. The gear review panel was responsible for selecting the best prototype of gear modifications for commercial evaluations, monitoring tests of the gears in different shrimping areas and prioritising options of gear modifications for consideration by management. The goal of the gear development project was to develop gear modifications to shrimp trawls and/or fishing practices that were capable of reducing the by-catch of finfish with minimal loss of shrimp catches. The research plan identified a 4-phase gear development plan:

1. **Initial Design and Prototype Development** – The full range of technical approaches to the modification of trawl designs was identified. Industry-based techniques, ideas solicited from fishers, designs from net shops and studies conducted by various research groups were evaluated. Studies of fish behaviour, gear instrumentation and gear performance were done on each design using SCUBA, remote video cameras and other techniques. This work evaluated fish behaviour and the feasibility of various prototypes. The results of this phase were subjectively evaluated based on the experience and expertise of the gear designer and research team. Operational data were taken on modified gears, and preliminary data on catching performance were obtained from comparative gear trials. One hundred and forty five gear modifications were evaluated by commercial fishers, universities and state and federal research agencies under this program between 1992 and 1996. The next phase of development was initiated once a design was determined to offer potential for by-catch reduction. This next phase involved integrating the design into the construction of nets.

2. **Proof-of-Concept** – Objectives during this phase were to evaluate effects of prototype modifications on key species, determine total rates of finfish reduction and establish catch rates of shrimp. Proof-of-concept testing was designed to evaluate the adequacy of the design for its safety features and any problems with the operational use of the design. Proof-of-concept testing was conducted under a specific scientific protocol developed under the 'Shrimp Trawl By-catch Research Requirements' (NMFS 1991). The most successful designs were prioritised based on the proportion of by-catch reduction and shrimp retention and were reviewed by a technical review panel for their progression to Phase 3 – operational evaluation by the commercial shrimp industry throughout the Southeast United States.
3. **Operational Evaluation** – The objective in this phase was to test each BRD-equipped net against a standard net under conditions encountered during commercial shrimping operations. Trained observers were placed onboard co-operating commercial vessels to collect data on both shrimp and finfish catch rates as well as species composition. Testing was conducted over a wide range of geographic areas, seasons and conditions.
4. **Industry Evaluation** – This phase involved widespread commercial evaluations of BRD designs. The research program was successful in developing and testing gear modifications to shrimp trawls that were capable of producing significant reductions in finfish by-catch with minimal reduction in shrimp catch rates. The most effective designs included the 'fisheye' BRD (Fig. 2.3) which is a simple metal, cone-shaped device inserted into the trawl codend to create an escape opening, the extended funnel BRD (Fig. 2.4) which consists of a large square-mesh section with a small mesh funnel inside of the square-mesh, and the Jone/Davis BRD (Fig. 2.5) which is a modification the expanded mesh BRD. The expanded mesh and Jones/Davis BRDs are installed between the TED and the codend. Approved BRD designs were made mandatory using management regulations in all state and federal waters in the southeastern United States in 1998 and 1999 (Watson et al. 1999).

The effectiveness of these technologies was monitored by fishery observers between 1998 and 2003. In 1998, under the Red Snapper Initiative Project, research was done to provide data on the effectiveness of the mandatory use of by-catch reduction devices by the commercial shrimp fishery in the north central and western Gulf of Mexico. The 1998 results for the Jones-Davis BRD were similar to results obtained during the development

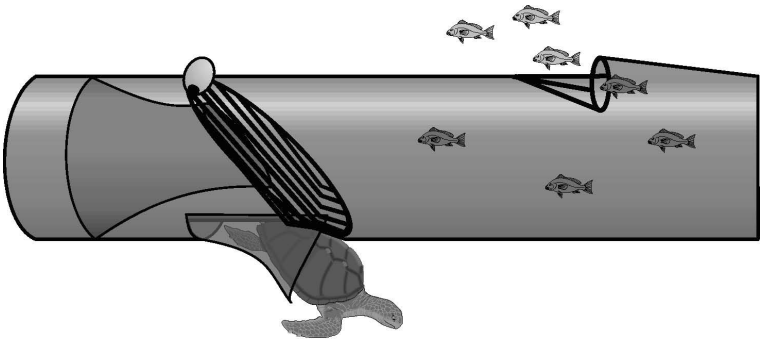

Fig. 2.3. The Fisheye BRD

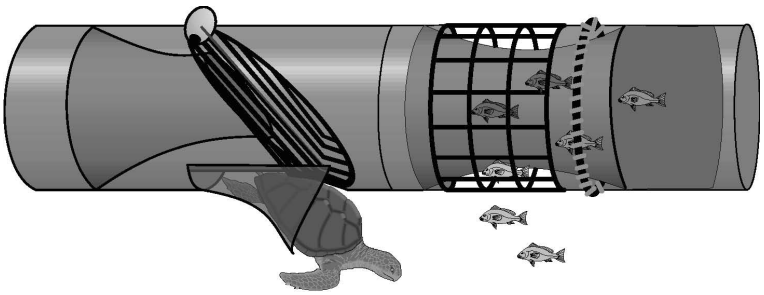

Fig. 2.4. The Extended Funnel BRD

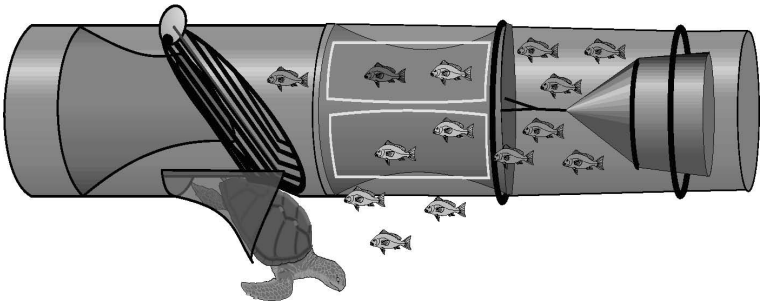

Fig. 2.5. The Jones/Davis BRD

and certification of the device, but the results for the Fisheye BRD showed a lower finfish reduction rate. Regulations were modified to restrict the placement of the fisheye BRD in an attempt to improve its performance and continued monitoring of the fishery indicated that these changes to the regulations had little effect on the performance of the fisheye BRD. It is not clear what factors may have caused these results but video observations of fish behaviour associated with fisheyes indicated a large portion of fish escape through the device occurs at the surface when the net is hauled

back. Observations also indicated that this escape at the surface is lowest when the fisheye is installed in the anterior section of the codend. When the fisheye is installed farther back in the codend, more fish escape through the device during the tow. Video observations of shrimp behaviour and fisheyes obtained by Texas A&M University and Georgia Sea Grant specialists indicate that the majority of shrimp loss through the device also occurs at the surface during haulback – when the fisheye is placed farther back in the codend. This information suggests that any operational efforts to reduce shrimp loss with fisheyes during haulback may have an adverse impact on reducing fish by-catch. In this case, the potential negative impact on fish reduction would be greatest for the fisheye installed in the forward position. Observations of the Jones-Davis BRD and other BRD designs using funnels indicated that the majority of fish escape occurs during the tow and is not subject to the above problems associated with haulback procedures.

Other variables identified by gear technologists during this work that could affect fisheye BRD performance included: the length of the codend, the location of tie-off rings in codends, the location and length of the lifting lines (triangular sections of webbing attached to the codend to which the codend haulback line is attached), the circumference of the codend and orientation of knots in the codend. Fishing practices that may affect the performance of fisheyes include: towing speed, winch retrieval speed, codend hauling procedures, hauling direction and frequent turning. Research is continuing in attempts to develop more effective technologies to reduce the by-catch associated with the shrimp trawl fishery while maintaining effective and efficient harvesting gear.

2.4 Development of Sea Turtle Mitigation Technologies in the Pelagic Longline Fishery

Pelagic longline gear is used throughout the world to catch widely dispersed species. The gear is very efficient at catching large pelagic fishes, such as bluefin, bigeye *Thunnus obesus*, yellowfin *T. albacares* and albacore *T. alalunga* tunas, broadbill swordfish *Xiphus gladius*, and the istiophorid billfishes. There are many possible variations in the configurations of this gear, but in general, when compared with such gears as trawls or pelagic gillnetting, pelagic longlines are considered highly selective for large target species (Yamaguchi 1989). However, the by-catch of protected species including sea birds, sea turtles and marine mammals by pelagic longline gear is considered a global problem. Loggerhead *Caretta caretta*, leatherback *Dermochelys coriacea* and Olive ridley *Lepidochelys olivacea*

sea turtles are captured in longline fisheries, and although recorded mortalities are very low, the injuries sustained during interactions with hooks and lines are of concern as little data are available regarding post-release mortality (Watson and Kerstetter – in press).

Estimates of catches of turtles in the United States pelagic longline fishery have raised concerns that this fishery may be affecting the potential recovery of loggerhead and leatherback sea turtle populations in the Atlantic Ocean. In 2001, the NOAA Fisheries Service closed a large portion of the North Atlantic to longline fishing by United States fishers and initiated a cooperative research effort between fishers, universities and the federal government to investigate potential gear modifications and/or fishing practices to reduce sea turtle catch rates. Components of the project included the active participation of fishers in the design and implementation of the research, adherence to stringent scientific protocols and significant input from fishers on experimental designs. During initial meetings between industry and other partners, various problems were identified in relation to the need for stringent scientific protocols and the practical aspects of fishing practices.

A concerted effort was made to improve communications and trust among the various groups involved in this project, and to reach acceptable compromises on disagreements. The result was that fishers were able to educate scientists with their knowledge of the fishery, turtle interactions, and potential practical solutions while scientists were able to educate fishers on scientific research methodology and protocols. This cooperation, trust and effective communication resulted in an extremely effective and successful research project. The program tested potential sea turtle mitigation measures developed by an informal steering committee of fishers, research biologists, and fishery management personnel. Mitigation measures were evaluated on commercial longline fishing vessels in the Western Atlantic Ocean using appropriate experimental designs. Between 2001 and 2003, this program developed sea turtle mitigation techniques utilising circle hooks and fish bait that demonstrated reductions in interactions of between 58% and 94% for loggerhead turtles and 44% and 86% for leatherback turtles, without significantly affecting catch rates of the target species (Watson et al. 2005). Results from Western Atlantic studies determined that the use of circle hooks instead of traditional J hooks reduced the proportion of hard-shelled turtles swallowing hooks from 68.8 to 27.3% (Watson et al. 2005). Turtles that were hooked by circle hooks tended to be hooked in the mouth, where hooks could be safely removed, reducing the potential for post-hooking mortality. These studies determined that the use of large circle hooks 4.9 cm or larger in width significantly reduced turtle captures compared to 4.0 cm or smaller J and tuna hooks. Furthermore, large circle hooks were determined to be commercially viable

for some target species. The catch rate for swordfish was increased by 30% when circle hooks were used with large (300 – 500 gram) mackerel bait and reduced by 33% when used with squid bait. Catch rates for bigeye tuna were increased by 26% when circle hooks were used with squid bait but reduced by 81% when used with large mackerel bait (Watson et al. 2005).

Laboratory studies with captive 45 – 65cm length loggerhead turtles indicated that the proportion of turtles that attempted to swallow circle hooks varied according to circle hook size, bait type and baiting technique (Watson et al. 2003). As circle hook size increased from 14/0 to 18/0, a smaller proportion of turtles tested attempted to swallow the hooks regardless of bait type or baiting technique. Fewer turtles attempted to swallow single hooked, sardine baits compared to threaded sardine baits, single hooked squid baits or threaded squid baits (Stokes et al. 2006). Threaded baits using both squid and sardine had a higher proportion of turtles attempt to swallow the hooks than single hooked baits.

In this project, gear technicians and fishers also developed effective tools and techniques to safely remove hooks from sea turtles and other pelagic by-catch species which has the potential to improve post-release survival (Watson et al. 2005). This pelagic longline sea turtle mitigation technology has been implemented in the pelagic longline swordfish and tuna fishery in the Atlantic and Gulf of Mexico and in the Pacific swordfish fishery, and is being evaluated in other fisheries around the world (Watson and Kerstetter – in press; Gilman 2006).

2.5 Discussion

The above examples of cooperative fishing gear research projects in the United States indicate some general characteristics of successful projects to reduce by-catch in commercial fisheries. Although the TED development project was ultimately successful, it was a very difficult, lengthy and expensive process and was not successful until a truly cooperative effort between government and the fishing industry was attained. These experiences identified several factors that are important to successful fishing gear research projects. First and foremost, the affected industry or constituents should be active participants in every aspect of research planning, technology development and evaluation. Secondly, planning for the development and implementation of new technologies needs to include a major long-term commitment for technology transfer and assistance to industry. Thirdly, voluntary acceptance of new technologies may also require financial or other incentives. New technologies which result in increased costs and/or loss of revenue will tend to be resisted. Fourthly, mandatory requirements for new technologies must include effective enforcement but regulations

should be as flexible and as easily modified as possible to allow successful implementation and improvement of new technologies as they are developed. Fifthly, and most importantly, successful cooperative research programs require effective communication and trust between all partners.

Effective leadership is also a vital component of successful cooperative research programs. The most effective programs include leadership that is effective in communicating among partners and the development of advisory groups with the right mix of expertise and skill to be effective. Leadership must be receptive and proficient in developing compromise solutions when partners have divergent points of view, or be firm and resolute when compromises are not an option. A representative industry organisation that can effectively communicate industry concerns, needs and opinions in negotiations, and that can form a technical advisory group, is especially beneficial in a successful cooperative by-catch reduction program.

Challenges that are commonly encountered in such programs include a lack of trust and understanding between program partners, and misinformation. Other significant problems in developing cooperative research projects include securing adequate funding, requirements for permits, environmental impact statements, and other regulatory requirements that can significantly delay and, in some cases, prevent such programs.

Cooperative research programs have proven to be highly effective in developing solutions to critical fisheries problems like by-catch issues. To be successful, they must have common goals and sincere commitment from all partners. Partners must be effective communicators and negotiators who are willing to compromise to move processes forward. Programs need effective and expert advisory personnel to assist with regulatory and permit requirements, ensure that local knowledge is integrated into the scientific process, maintain acceptable scientific standards and effectively develop and execute successful research.

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