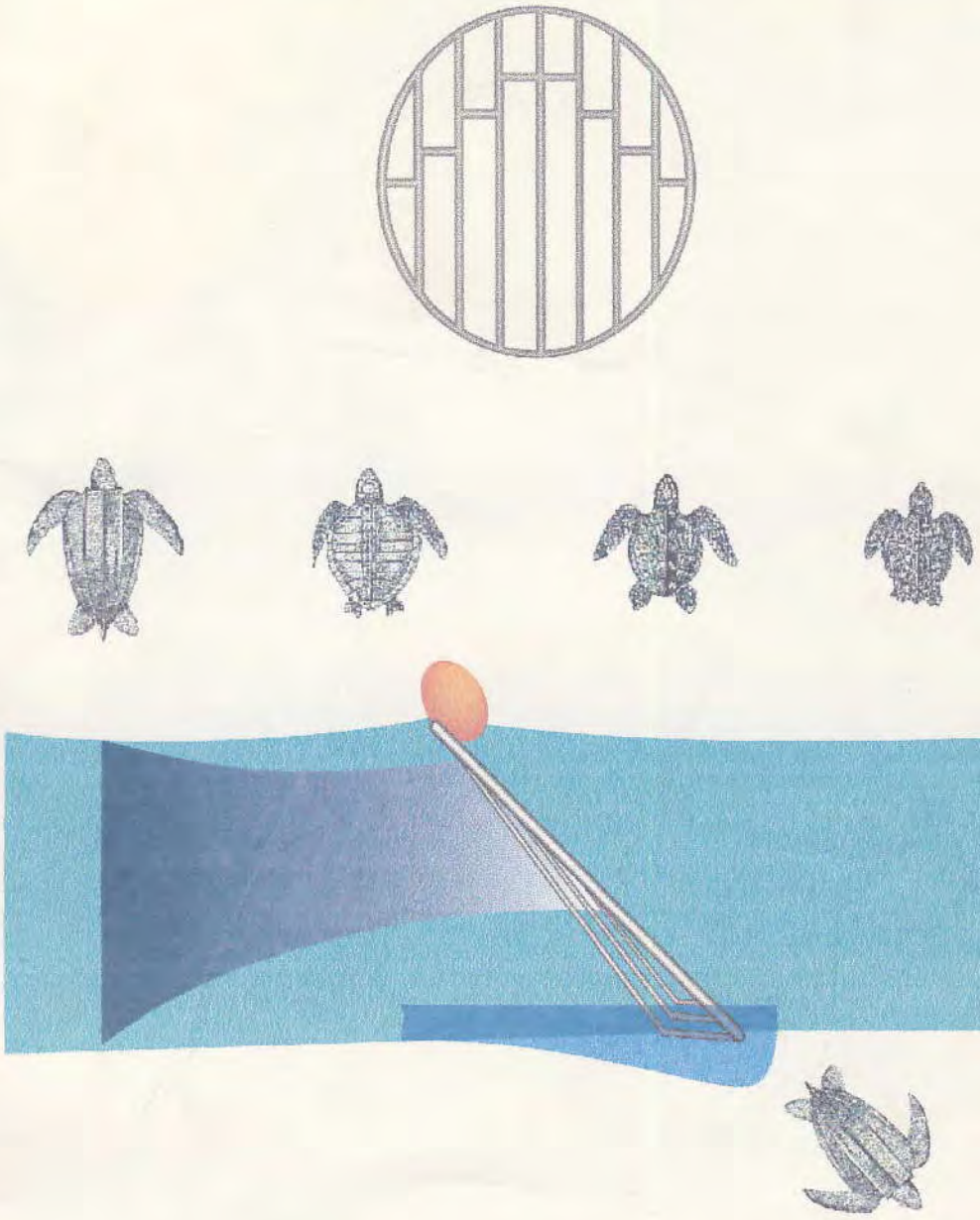
INTRODUCTION OF TEDs IN ASIA



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ABSTRACT

The U.S. shrimp import embargo that went into effect on 1st May, 1996, stipulates that fishing methods used in shrimp capture in harvesting countries should inflict no harm on marine turtles. To comply with these conditions the Training Department and the Marine Fisheries Resources Development and Management Department, both departments of SEAFDEC, together with SEAFDEC member countries, conducted a series of experiments and trials to develop a suitable Turtle Excluder Device (TED) for use in shrimp trawls in Southeast Asian countries. To find a regionally acceptable turtle protector, a study tour was made to observe the various devices in use in both the U.S. and Mexico.

Experiments were completed in three phases, the first being carried out in the Gulf of Thailand with the objective of determining a design of TED suitable for local fishing conditions. Three devices (the Supershooter, the Anthony Weedless, and the Bent Pipe) were imported from the U.S. Two other devices, the Georgia Jumper and the Mexican were imported from Mexico. During this phase of the experiments the Thai Turtle Free Device (TTFD) design was found to offer the most convenient and efficient characteristics for use by Thai fishermen; namely a low escape rate of the target species, ease of operation and a low construction cost. To disseminate information on the RED and to inform fishermen that this met the requirement of the U.S. import embargo, a workshop was conducted in the South of Thailand that was attended by 80 fishermen. At this time, 100 TTFDs were distributed for voluntary use. Several further trials and demonstrations were conducted for both concerned authorities and fishermen. Subsequently, 2,900 TTFDs have been manufactured and distributed.

The second and third phases of experiments were carried out in Malaysia and the Philippines respectively with the objective of determining the suitability of the TTFD for use in Southeast Asian waters. These trials would also be used to determine the impact of using the TED on the shrimp catch. The results of these trials showed that the catch was not affected. Thus it was determined that the TTFD was a suitable device for use in Southeast Asian waters. Similar workshops and demonstrations were conducted both in Malaysia and the Philippines. Additionally, demonstrations and sea trials were made in Brunei, Darussalam, and in Australia. Further introductions of the use of TEDs to more member countries of SEAFDEC and other Southeast Asian countries were achieved by distributing the research papers and actual TTFDs. Participants taking part in the SEAFDEC fishing technology training courses were also introduced to the TTFD use and operation.

The introduction of TEDs in Asia seems to be very successful. The use of these devices was accepted by fishermen, because they also achieved lower escape rates and a cleaner catch while achieving the necessary release of turtles. The U.S. import ban has been lifted in Thailand and there is now a national law enacted that ensures that shrimp trawls must be equipped with TEDs. This project is a good example of regional co-operation in Responsible Fishing implementation.

1. Introduction

Sea turtles are ancient animals which have co-existed with the earth for over 150 million years. Six of the seven species of living marine turtles recognised in the world are confirmed to nest in Southeast Asia. These are the leatherback (*Demochelys coriacea*), the green turtle (*Chelonia mydas*), the Olive ridley (*Lepidochelys olevacea*), the hawksbill (*Eretmochelys imbricata*), the loggerhead (*Caretta caretta*) and the flatback (*Chelonia deprssa*) (Kamarruddin, 1993; Soehartono, 1993; Palma, 1993; Chantrapornyl, 1993; Sukarno et al., 1993, Chantrapornyl, 1996; Kamarruddin et al., 1996). All six species are commonly found in ASEAN waters except the flatback which is restricted primarily to Eastern Indonesia. All are highly migratory, often passing through territorial and international waters from feeding to nesting ground and back again. The turtles are likely to come from an area with a radius of 2,500 kilometres around the nesting area (Limpus, 1993).

Four species of sea turtles have been recorded in Thai waters, namely, the leatherback turtle (*Demochelys coriacea*), the green turtle (*Chelonia mydas*), the hawksbill turtle (*Eretmochelys imbricata*) and the olive ridley turtle *(Lepidochelys olivacea*) (Fig.1). The green and hawksbill turtles are common in the Gulf of Thailand while the olive ridley turtle is the most abundant species along the Andaman Sea coast of Thailand. Only a small number of leatherback turtles have been found in the vicinity of the Andaman Sea coast, whereas green and hawksbill turtles are rarely found. The distribution of sea turtles in Thai waters are along the fine sand and calm beaches of the coastline and islands in the Gulf and the Andaman Sea coast of Thailand. Khram Island located in the inner Gulf of Thailand, Chonburi Province, is an important nesting area for green and hawksbill turtles (Fig.2).

Previously, sea turtle eggs were commercially harvested by many beach side communities where nesting beaches are declared to be concessional areas. According to the concessional regulation, 30% of the harvested eggs were reincubated by the concessionaires and the young sea turtles released to the sea. Since 1968, awareness of a decline in the sea turtle population in Thailand has been raised and serious attempts to conserve sea turtles have been initiated. A sea turtle conservation project has been conducted at Phuket Marine Biological Center since 1971, this was the pilot project for the Queen's Project on sea turtle conservation at Man-Nai Island in the Gulf of Thailand. Since then, the biology of sea turtles has been studied and many nesting beaches declared as National Parks in order to protect the wild life and their habitat. The relevant laws and regulations have been enacted, as well as the promotion of education and campaign programs that have been distributed to the public.

Thai people have their traditional belief that sea turtles are long living animals and it is sinful to kill them. In practice, the Royal Thai Government has applied legislation to protect and conserve the sea turtle from any fishing implement. Nevertheless, the U.S. Shrimp import embargo that went into effect on 1 May, 1996, stipulates a condition that methods such as trawling used in shrimp capture by harvesting countries should inflict no harm on the marine turtle.

Public law 101-162 section 609, enacted by Congress in 1989, requires nations who wish to export shrimp to the United States to "adopt regulations governing the incidental taking of sea turtles comparable to those of the U.S., and that the average rate of incidental taking be comparable to the incidental rate of capture by U.S. vessels. The clear intent of this law is to encourage nations to adopt regulations requiring TEDs on all shrimp trawling vessel fishing in waters shared with five sea turtle species (Keep's ridley, hawksbill, loggerhead, green and leatherback).

To comply with the conditions set by the U.S. Shrimp import embargo, the SEAFDEC Council asked the Training Department (TD) and Marine Fisheries Resource Development and Management Department (MFRDMD) of SEAFDEC in co-operation with the Department of Fisheries (DOF), Thailand and SEAFDEC's member countries to conduct a series of experiments to develop a suitable device called a Turtle Excluder Device (TED) for use with shrimp trawls in Thailand and Southeast Asian countries.

2. Methodology for introducing TED technology in Thailand

In Thailand the trawl fishing technique was introduced more than 30 years ago, but the development of the trawl gear has been toward ways to increase catch efficiency. The knowledge of by-catch reduction devices and TEDs were very limited. Since solving the problem of the imposed shrimp embargo was very urgent, the most effective method was to see what had been done in the USA where the original TEDs were designed. Mexico was one of the countries that was subjected to the shrimp embargo previously. The Method of introducing an answer to the embargo problem was devised that first there should be a study on TED design and construction, with the experiments following. A study tour to the USA and Mexico was undertaken in July, 1996 in order to gain knowledge of the TEDs regulations and the type of TED used in USA.

Five types of TEDs were imported for Testing : Three being imported form the USA, namely, the Anthony Weedless, the Super Shooter and the Bent Pipe these three types were recommended by NMFS NOAA and the two from Mexico, namely, the Georgia Jumper (Sauder Grid) and the Mexican these two being presently used in Mexico.

After the five type of TEDs were received the sea trials were conducted. Because the import price was very high, the author and the team decided to modify the TEDs to make them more suitable for use in the region. The SEAFDEC/TD in co-operation with the Department of Fisheries of Thailand studied the design and construction of various of TEDs and then modified the super shooter and Georgia Jumper into what has become known as the Thai Turtle Free Device (TTFD).

In conjunction with this work the faculty of Engineering at Kasetsart University then modified the Super shooter and Hooped TED into the Thai-KU. This design was more complex as far as the hydrodynamics and water resistance were concerned.

2.1 The Experiments

2.1.1 Experimental methods

The experiments were carried out in September and October 1996 using two research vessels namely M.V. Pramong 4 and M.V. Pramong 1 in the coastal waters off Chumphon and Songkhla provinces (see Fig. 3) where the depths of water ranged from 10 to 20m.

Two shrimp trawl nets (two seam type, see Fig. 4) employed in the experiments were designed for the 250 horse power fishing vessels. The nets were 39.5 m long and were complete with a 21 m long head rope and 24 m ground rope.

The seven types of TEDs employed in the experiments were three from the U.S. , namely, the Anthony Weedless, the Super Shooter and the Bent Pipe TEDs (Fig. 5a), and two from Mexico, namely, the Georgia Jumper and the Mexican TEDs (Fig. 5b). The other two TEDs were the Thai-KU and the Thai Turtle Free Device (TTFD) designed by the Faculty of Engineering, Kasetsert University and the Training Department of SEAFDEC Thailand, in Cooperation with the DOF, respectively (Fig.5c).

2.1.2 Experimental procedure

The TED was attached to the cod end extension part of shrimp trawl net. Experiments were started from the early morning until late at night. For each type of TED experiment a total of 8 trawls were carried out, these comprised (4 hauls) of each for two periods, during the day-and night-time. An extra trawl without a TED, as a control, was made before trawling with TEDs was started in each of the periods. During this series of experiments, all the TEDs were tested with an operational time for each haul of one hour. In the experiments the exit part of the TEDs were covered with pieces of net as a cover net or second codend, in order to measure both the amount and species of escaped fishes. The fuel consumption of the vessels with and without TEDs was also recorded. The experiments were made in two parts as first and second experiments .

The first experiment was carried out in the waters off Chumporn province during September of 1996. A total of 60 hauls comprising 12 hauls without TEDs and 48 hauls using six types of TED, namely, the Anthony Weedless, the Super Shooter, the Bent Pipe, the Georgia Jumper, the Mexican, and the Thai-KU were made by the M.V. Pramong 4.

The second experiment was carried out in the waters off Songkhla province during October of 1996. Using six types of TED; 5 TEDs from the first experiment, namely, the Super Shooter, the Bent Pipe, the Georgia Jumper, the Mexican and the Thai-KU, and the TTFD TED which replaced the Anthony Weedless. These were tested on board M.V. Pramong 1. A total of 60 hauls comprising 12 hauls without TEDs and 48 hauls using the six types of TED.

2.1.3 Data Analysis

The catch data by weight in kg collected both from the codend and the cover net in each haul were analysed for the rate of escape in percent as the following equation:

$$Rate\ of\ escape = (100A) / (A+B)$$

where A is the catch by weight in the cover net, and B is the catch by weight in the codend.

The mean value of the escape rate of each type of TED were computed and compared to that of the control net (without TED). The composition by species, of the rate of escape in the cover net was also recorded. The rate of escape for shrimp was considered in comparison to that of the day and night operations.

Comparisons of the fuel consumption of the vessels between the trawling operations with TEDs and without TEDs were made.

2.2 Results and discussion

The species composition of by catch from 120 hauls indicated that no turtles were caught in the codend or the cover net of the shrimp trawl net.

2.2.1 The first experiment

Table 1 exhibits the total catch by weight in the codend and cover net and the rate of escape in percent for each type of TED during day and night-time operations. The results indicate that there were no differences in terms of the escape rate between the day and night operation for all type of TEDs except that of the Bent Pipe TED. This indicates that the Bent Pipe TED is highly efficient in that the results showed a low escape of small fish and invertebrates during daylight hours but showed poor results at night. In the case of the Anthony Weedless TED, the escape rates were higher than 35.94% for both day and night operations and showed the lowest efficiency in catching fish and shellfish. Figure 6 shows the rate of escape relative to the type of TED for day- and night-time operations. The ratio of escape between the economic species groups and the trash fish was different during day and night. In addition, three types of TEDs, namely, the Super Shooter, Georgia Jumper and the Thai-KU showed quite good results based on the low rate of escape, for both the day- and night-time, which were found to be lower than 11%. The escape rate of the different species/group for both periods for the Super Shooter, Georgia Jumper and the Thai-KU TEDs are shown in Table 2 and Figure 7. Consideration of the escape rate for shrimp between the day and night found that no shrimp escaped through the TEDs during day-time operation.

The escape rate for shrimp was considered as the index for the possibility of installing TEDs, but in tropical fisheries all catch both economic and trash fish can be sold in the market. For this reason the rate of escape for the total catch must be considered, and it

can be said that among the six types of TEDs in the first experiment, the Thai-KU TED showed a high efficiency. However, in view of the structure, operation and installation of the Thai-KU TED it was found that there were some operational weight problems.

2.2.2 The second experiment

Following the success of the first trials the second series of experiments, five types of TED from the first experiments, namely, the Super Shooter, the Bent Pipe, the Georgia Jumper, the Mexican and the Thai-KU were tested in the same manner and were compared with the TTFD. The results of the total catch by weight in the codend and cover net and the rate of escape in percent for each type of TED during day and night-time operations are exhibited in Table 3. This indicates that there was not much difference in terms of escape rate for both day and night-time operation for the Super Shooter, Thai-KU and TTFD. Two types of TEDs, namely, Super Shooter and TTFD were the most efficient in terms of the low rate of escape which were found to be 2.67% and 1.80% for day-time operation and 1.91% and 1.04% at night, respectively. Figure 8 shows the rate of escape by total weight relative to type of TED for day- and night-operations. The figures also show that the main escaping fish for both day- and night-time operations were trash fish compared to economic fish in terms of the rate of escape. The escape rate of each group of species for all types of TEDs used in the experiment are shown in Table 4 and Figure 9. The escape rate for shrimp in this experiment showed the same result that was found in the first experiment; i.e., that no shrimp escaped during day-time operation.

2.2.3 Fuel consumption

The fuel consumption for a one hour trawling operation with different types of TED were compared to the control net operation in Figure 10. The figure shows there was not much difference in fuel consumption for the six types of TED and the control net. The fuel consumption for the Super Shooter and TTFD were 23.66 and 24.31 litre per haul, respectively. In addition, the trawls installed with the Super Shooter and TTFD used less fuel than operating without a TED (control net).

2.3 The workshop on the use of TEDs in Thailand

These experiments in the use of TEDs in Thailand had the aim of solving the problem of the U.S. shrimp embargo that became effective on 1 May, 1996. The experiments had to be carried out within a time limit and the results had to be distributed for the fishermen to encourage them to use the TED. Another aim was to promote selective fishing gear and responsible fishing that is vitally important both now and in the future.

The Department of Fisheries in co-operation with the Export Department and with the technical assistance of NOAA, SEAFDEC/TD and Kasetsart University organised a workshop on the use of TEDs for shrimp trawls from 7-10 October, 1996. The participants were the representatives of the fishermen from 22 coastal provinces in

Thailand (4 fishermen from each province) and the 2 extension fishery officers from each province.

The workshop was divided into two parts. The first was an outline of the history of TEDs and type of TEDs; regulation and use was explained by a NOAA expert, the preliminary results of the experiment on TEDs in the Gulf of Thailand by SEAFDEC/TD and the Department of Fisheries and other experiments in Australia and Asian countries were presented by an Australian researcher and researchers from SEAFDEC member countries. The second part of the workshop concerned the installation of TED into the shrimp trawls and then the TEDs (TTFD) were demonstrated onboard the research vessel, M.V. Pramong 4 and Pramong 9 together with 4 local shrimp trawlers in Songkhla province. The fishermen and participants were divided into 6 groups to observe and practice the use of TEDs onboard the vessels.

On the last day of the workshop, there was an evaluation session. The fishermen had a positive reaction to the use of TEDs. They readily accepted the reasons for the introduction of TEDs and the results of the fishing trials gave them confidence in the low escape rate levels and cleaner shrimp caught. The first 100 TTFDs were distributed for voluntary use.

For the further use of TEDs, several trials and demonstrations both to concerned authorities and fishermen were undertaken. Some 2,900 have been manufactured and distributed to fishermen there being a complement of 3,000 shrimp trawlers registered in the Thai shrimp fisheries. In November, 1996, the American shrimp embargo was lifted in respect to Thailand.

3. The experiments and workshop on TEDs in Malaysia

To implement the use of TTFDs in Southeast Asia the second phase of the project was conducted in Malaysia at the beginning of 1997 with the objective of determining the suitability of the TTFD in Malaysian waters. Two sizes of TTFD were tested 80 x 80 cm and 80 x 100 cm. These are the small and medium of the three available TED sizes. A research vessel and commercial fishing boat were used for the tests. The results showed that the TTFD prevented entrapment of marine turtles without affecting the fish and shrimp catch. The escape rate for the research vessel using the two TTFD sizes measured at 2.3% and 5.25% for day time operation and 0.01% and 4.67% during the night time operation respectively. The escape rate for the fishing vessel were 6.53% and 4.05% during the day and 3.34% and 7.7% at night respectively for the two sizes. The results indicated that the shrimp catch rate was not affected.

The demonstration and workshop were carried out in March, 1997 at Pantai Remis, Perak by SEAFDEC in co-operation with the Department of Fisheries of Malaysia. The exercise had two main components. The first was an exhibition of and introduction to TEDs on shore. Secondly, the demonstration of the use of TEDs onboard shrimp trawlers was carried out at sea.

The exhibition and presentation on TEDs were given to 100 participants composed of fishermen, fishery officers, students and observers from Thailand and the Philippines. There was also an intensive practice session in the installation and equipping of a shrimp trawl net with a TED.

Twenty modified TTFDs were presented to the fishermen at the end of this session. A demonstration of the actual use of TEDs onboard a commercial shrimp trawler was given after the activities on shore were completed. The demonstration was quite successful, most of the fishermen were interested in the device and indicated no resistance to its use because the escape of fish and shrimp were very low during the demonstration.

4. The sea trials and experiments on TEDs in the Philippines

Further implementation extension was undertaken by sea trials and demonstrations on TEDs in Philippines waters which were conducted by SEAFDEC/TD in co-operation with the Bureau of Fisheries and Aquatic Resources (BFAR) of the Philippines in April, 1997. The trials and demonstrations had two main components, the first being the sea trails for three types of TED, namely, the hooped TED, the Super Shooter and the TTFD. Secondly the discussions and demonstration of the installation and fixing the angle of the TED in the codend of the shrimp trawl.

To complete the promotion of the use of TEDs, a special lecture and practice session were also given to 10 instructors and 50 trainees of the National Commercial Fisheries Development Center (NCFDC).

The third phase of the experiment was carried out in Manila Bay in the Philippines using three types of TED, namely, TTFD, Super Shooter and the Hooped TED. A series of 32 hauls were made being eight hauls for each type and a control haul without a TED. The average retained catch for all units was 538.3 kg with an escape rate of 14.62%. The lowest escape rate was for the TTFD at 11.55%, also having the highest total of retained shrimp. Initial results indicate that the TTFD has the highest shrimp catch efficiency with the least total escape rate.

5. The sea trials and experiments of TEDs in Brunei Darussalam

In response to a request made by the Council Director of SEAFDEC for Brunei Darussalam for technical assistance from the Training Department (TD) to conduct trials and demonstrations of the TTFD. The missions sent from the TD rendered assistance in conducting the trials for the Brunei officers from 2nd to 9th September 1997.

The trials and demonstrations were divided into two parts, the first being conducted on the Fisheries Research Vessel, K.P. TENGGIRI, the second being conducted aboard the commercial trawlers, SRI MEGA BERANGKAT and SERI MAA MOOR.

On the first day, a lecture and explanation of TEDs, TTFD, and by-catch reduction devices was given to 10 fisheries officers and 20 fishermen at the fish handling complex.

A demonstration of TTFD installation was held on board K.P. TENGGIRI which was followed by two and a half days of sea trials. Eleven TTFD equipped hauls were conducted, seven with a bottom opening and four with a top opening TTFD. The escape rate at 15% was rather high because there were a lot of big fish in the area which could not pass through the TTFD. Also, there were a lot of big logs and garbage which were retained on the TTFD. However, the sea trials were smooth and successful from the point of view of excluding sting rays and garbage.

Six hauls were made on aboard the SRI MEGA BERANGKAT, three using a bottom and three using a top opening TTFD. The escape rate in this series was 10%. Four hauls were carried out aboard the SERI MAA MOOR, two hauls with bottom opening and two with a top opening TTFD. The escape rate for this series was 5% with one turtle being caught in the cover net over the opening (second codend).

The overview of the result is that the trials and demonstrations were successful, but the escape rate was rather high due to the fishing conditions in Brunei Darussalam waters, big fish, logs of wood and garbage. More sea trials are necessary to obtain more reliable data for analysis. It may be necessary to modify the TTFD to suit these waters. The introduction of a Bycatch Reduction Device (BRD) design is another idea to be pursued in these waters, since the area is still viable in terms of fisheries resources.

6. Introduction of TEDs in Indonesia

The demonstrations on the use of TEDs in Indonesia was a part of the Turtle Excluder Devices project carried out by SEAFDEC/TD. The objective was to introduce TEDs based on experience in Southeast Asian countries. The demonstration was composed of an review of TEDs, TTFD and BRD and their installation in the trawl codend.

62 participants attended the demonstration. 52 were students from the Fisheries College and 10 were fishery officers from the Department of Fisheries, Indonesia. The participants were very active in their participation in both lectures and practises. The hooped TED made from rattan wood was introduced in Indonesia over ten years ago and is out of date. So the newly designed TTFD is very interesting for them. At the end of the demonstration, two TTFD sets were presented to the fishermen.

7. Introduction of TEDs in other countries in Asia

For further the introduction of TEDs in other countries, the demonstrations of TTFDs were also conducted in Darwin, Australia, in conjunction with an FAO Workshop on Selective Shrimp Trawl Devices from 2nd to 26th July 1997. Further introductions of the use of TEDs in Asia has been carried out by distributing the papers of the experiments and actual TTFD devices. Participants taking part in the SEAFDEC/TD fishing technology training courses are also introduced to the TTFD use and operation.

8. Conclusion

The introduction of TEDs in Thailand, Malaysia and the Philippines, Brunei Darussalam and other regional countries seems to be very successful. After actual demonstration and the dissemination of results of the experiments the fishermen do not resist its use and fully understand the necessity for its implementation.

The modification of the TEDs is one of the keys for the success because the TTFD is locally made and the cost of construction is less; furthermore there is a psychological incentive as fishermen like to use a locally designed and made device instead of imported technology.

To gain the fishermens' acceptance, emphasis has been placed on how they will benefit from their use so the low escape rates and the cleaner catch have been emphasized rather than to the release of the turtles which nonetheless must be achieved. In Thailand, a law that nets for shrimp trawling must be equipped with TEDs is already enacted. This project is a good and successful example of regional cooperation in Responsible Fishing implementation.

A study on BRDs will be the aim of a follow up project, to be implement in future in Southeast Asian Countries.

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Table 1 The results of total catch in the codend and cover net and the rate of escape for each type of TEDs in the first experiment

Type of TEDs	Day-time Operation			Night-time Operation		
	Cod End (kg)	Cover Net (kg)	Rate of Escape (%)	Cod End (kg)	Cover Net (kg)	Rate of Escape (%)
Super Shooter	32.79	2.99	8.36	25.81	1.46	5.34
Anthony Weedless	18.35	17.34	49.00	20.48	11.49	35.94
Bent Pipe	194.20	8.16	4.03	32.07	6.97	17.85
Mexican	27.83	6.90	19.88	43.30	4.68	9.57
Georgia Jumper	59.51	3.76	5.94	32.97	4.08	11.00
Thai-KU	29.42	2.57	8.02	36.87	1.04	2.75

Table 2 Escape rate of each group of species for three types of TEDs in the first experiment.

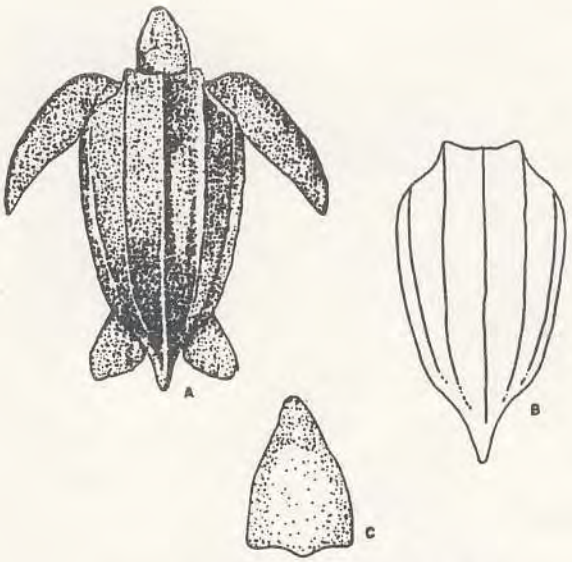
Group of Fishes	Thai-KU		Super Shooter		Georgia Jumper	
	Day	Night	Day	Night	Day	Night
Pelagic fish	3.23	1.90	1.46	0.00	0.00	1.89
Demersal fish	13.89	6.25	8.17	0.20	0.87	5.71
Cephalopod	11.64	1.43	1.94	17.72	0.00	0.00
Shrimp	0.00	10.74	0.00	1.92	0.00	7.95
Crab	11.11	0.00	42.00	6.85	56.25	0.00
Others	5.95	1.35	16.01	23.46	18.30	35.57
Trash	1.99	1.05	2.61	0.00	3.55	1.21

Table 3 The results of total catch in the codend and cover net and the rate of escape for each type of TEDs in the second experiment

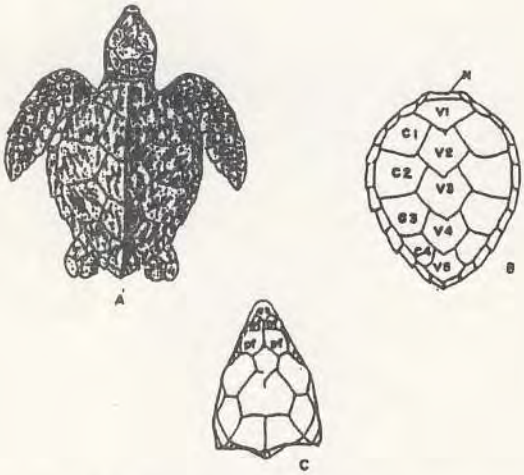
Type of TEDs	Day-time Operation			Night-time Operation		
	Cod End (kg)	Cover Net (kg)	Rate of Escape (%)	Cod End (kg)	Cover Net (kg)	Rate of Escape (%)
Super Shooter	26.21	0.72	2.67	10.09	0.2	1.91
TTFD	7.40	0.14	1.8	9.52	0.1	1.04
Bent Pipe	26.21	0.58	2.17	40.72	6.36	13.52
Mexican	16.17	0.31	1.89	23.3	3.04	11.53
Georgia Jumper	11.62	0.76	6.15	101.7	0.88	0.85
Thai-KU	87.21	8.37	8.76	11.68	1.46	11.12

Table 4 Escape rate of each group of species for three types of TEDs in the second experiment.

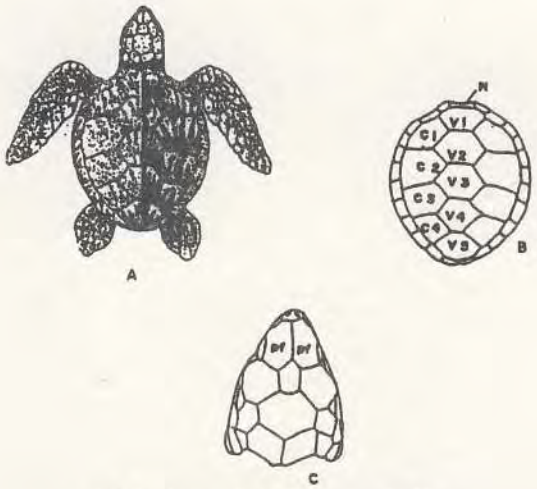
Group of Fishes	TTFD		Super Shooter		Georgia Jumper	
	Day	Night	Day	Night	Day	Night
Pelagic fish	3.46	0.99	3.23	3.26	0.00	0.00
Demersal fish	0.72	0.49	4.24	1.59	3.62	0.08
Cephalopod	1.10	4.94	2.11	0.00	0.00	0.00
Shrimp	0.00	1.02	0.00	0.00	0.00	0.14
Crab	0.00	0.00	4.04	9.33	11.21	36.22
Others	0.00	0.00	0.00	0.00	0.00	0.00
Trash	2.63	0.37	0.38	1.55	15.10	0.19



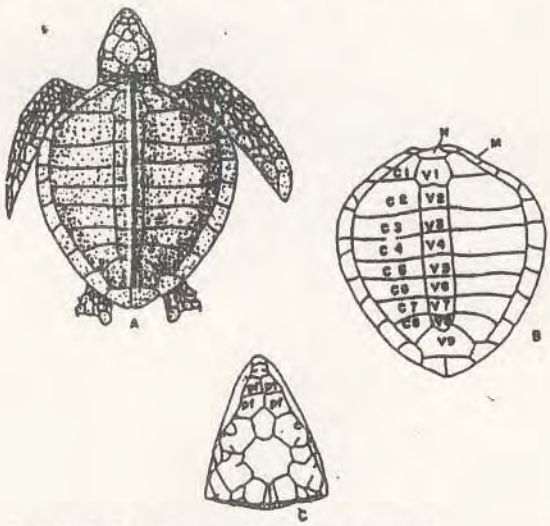
Dermochelys coriacea (Linnaeus 1766)
(Leatherback turtle) A : Dorsal view;
B : Dorsal carapace; C : Head view



Eretmochelys imbricata (Linnaeus 1766)
(Hawksbill turtle) A : Dorsal view;
B : Dorsal carapace; C : Head view



Chelonia mydas (Linnaeus 1758)
(Green turtle) A : Dorsal view;
B : Dorsal carapace; C : Head view



Lepidochelys olivacea (Eschscholtz 1829)
(Olive Ridley turtle) A : Dorsal view;
B : Dorsal carapace; C : Head view

Figure 1. Four species of sea turtle found in Thai waters

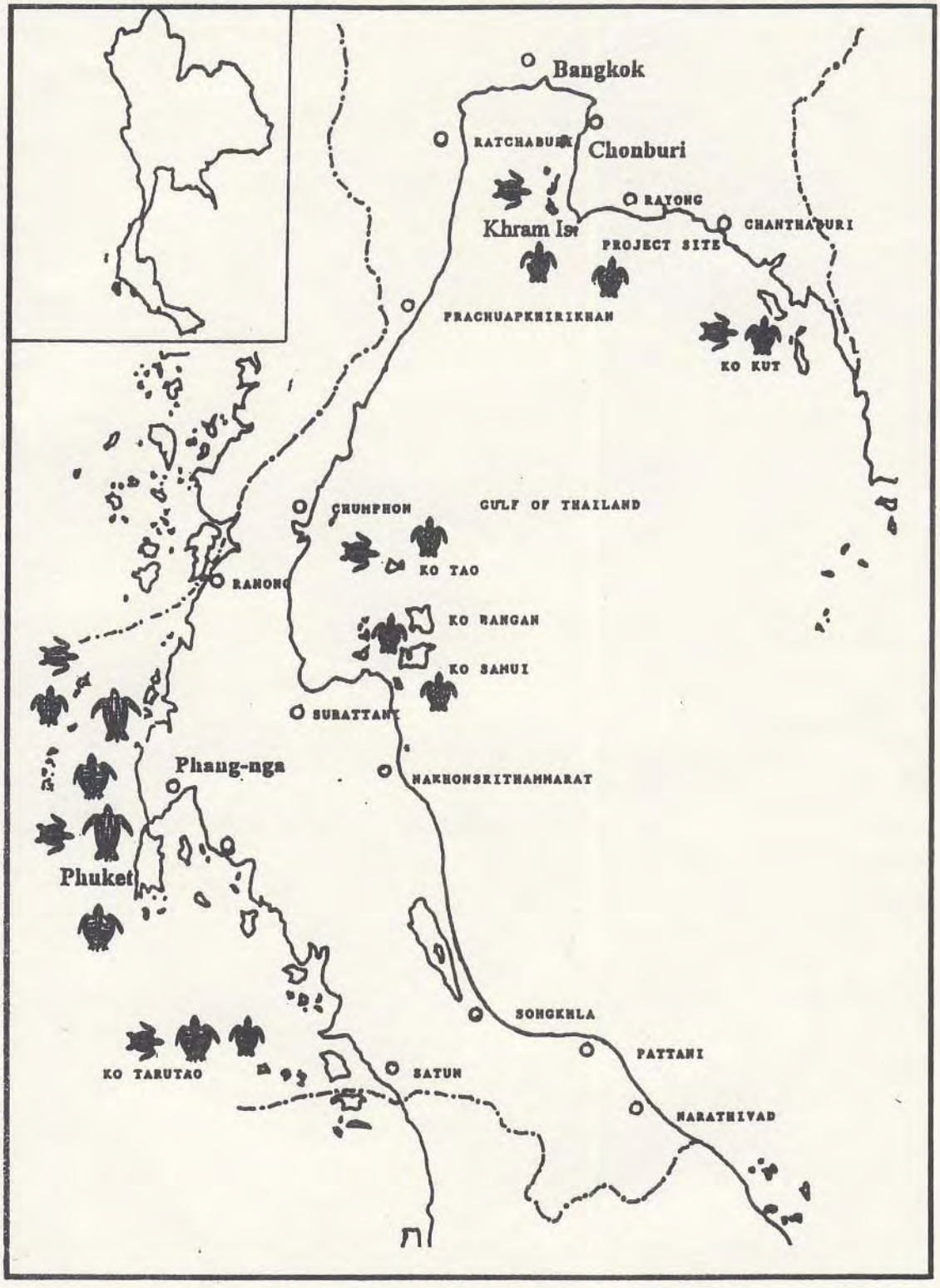


Figure 2. Map of the east and west coasts of Thailand showing the nesting areas of sea turtles and Queen's project site.

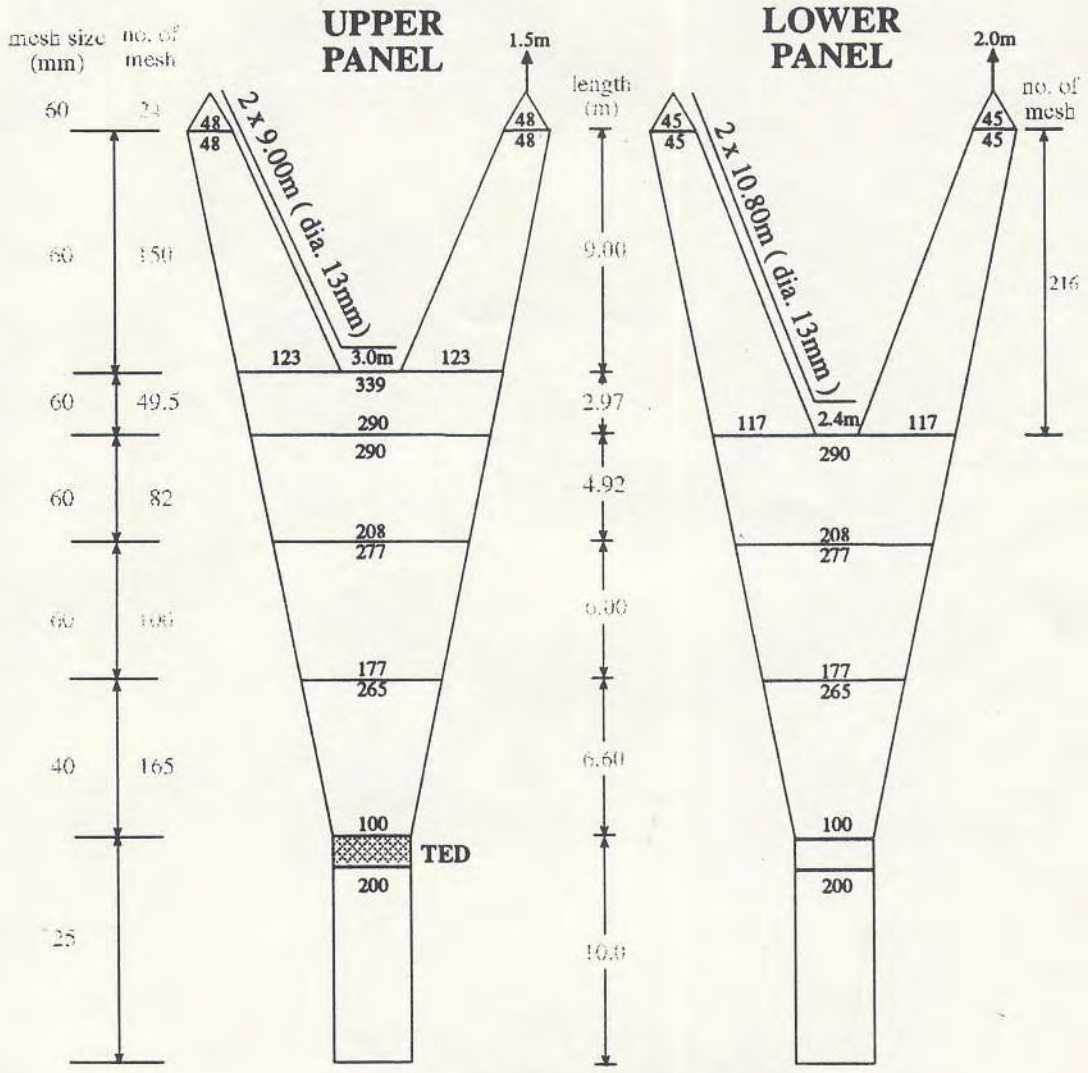
= Green turtle

= Hawksbill turtle

= Olive ridley turtle

= Leatherback turtle

FIG. 3 Fishing areas for shrimp trawl experiments with TEDs



Total length 39.49m

FIG. 4 The diagram of the shrimp trawl net.

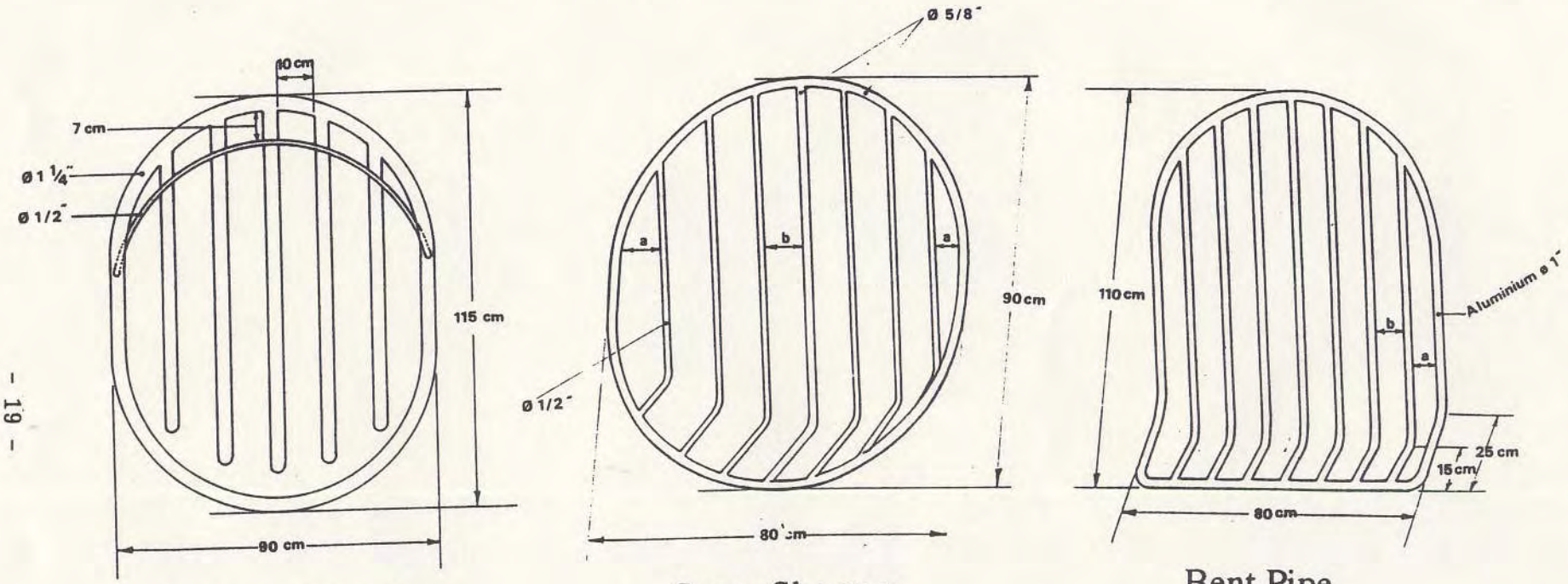
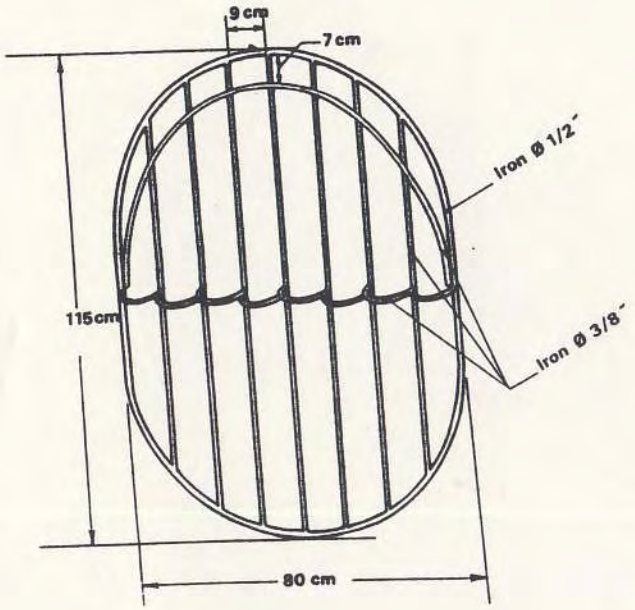
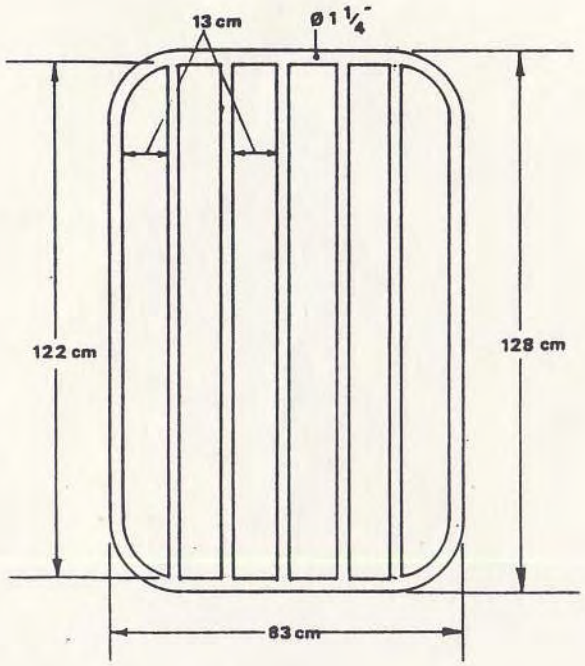


FIG. 5a. Three types of TED from U.S.A

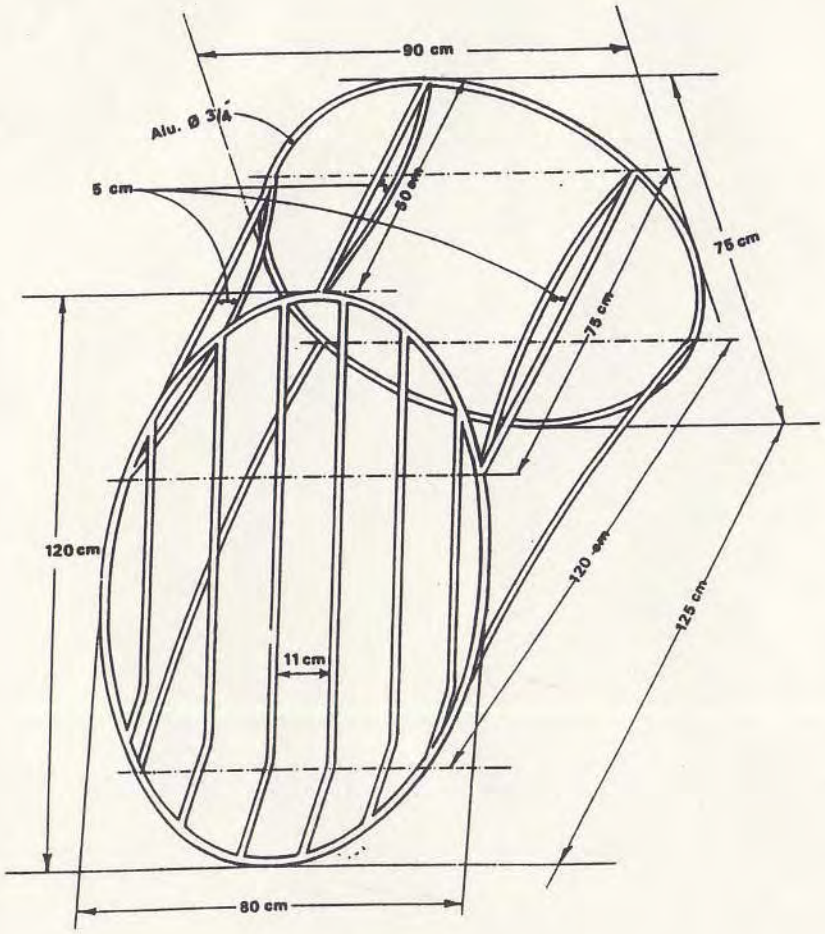


Georgia Jumper

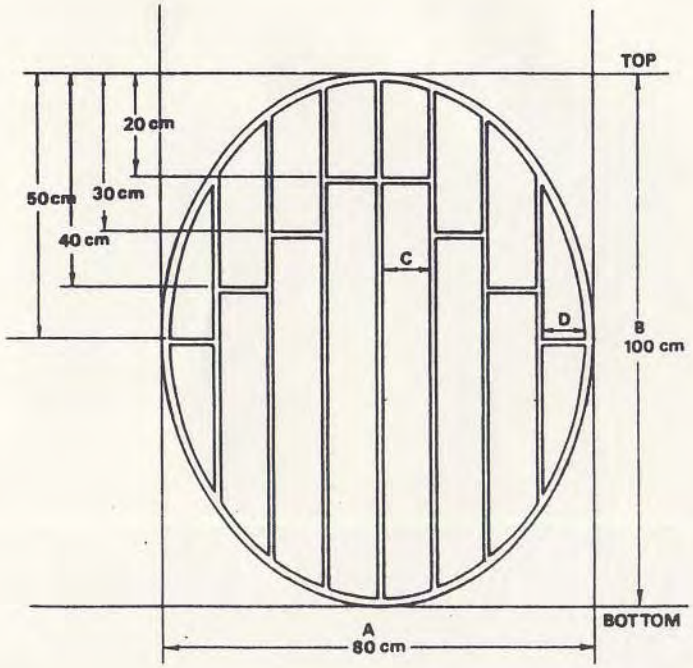


Mexican

FIG. 5b. Two types of TED from Mexico



Thai-KU



Thai Turtle Free Device (TTFD)

FIG. 5c. Two types of TED from Thailand

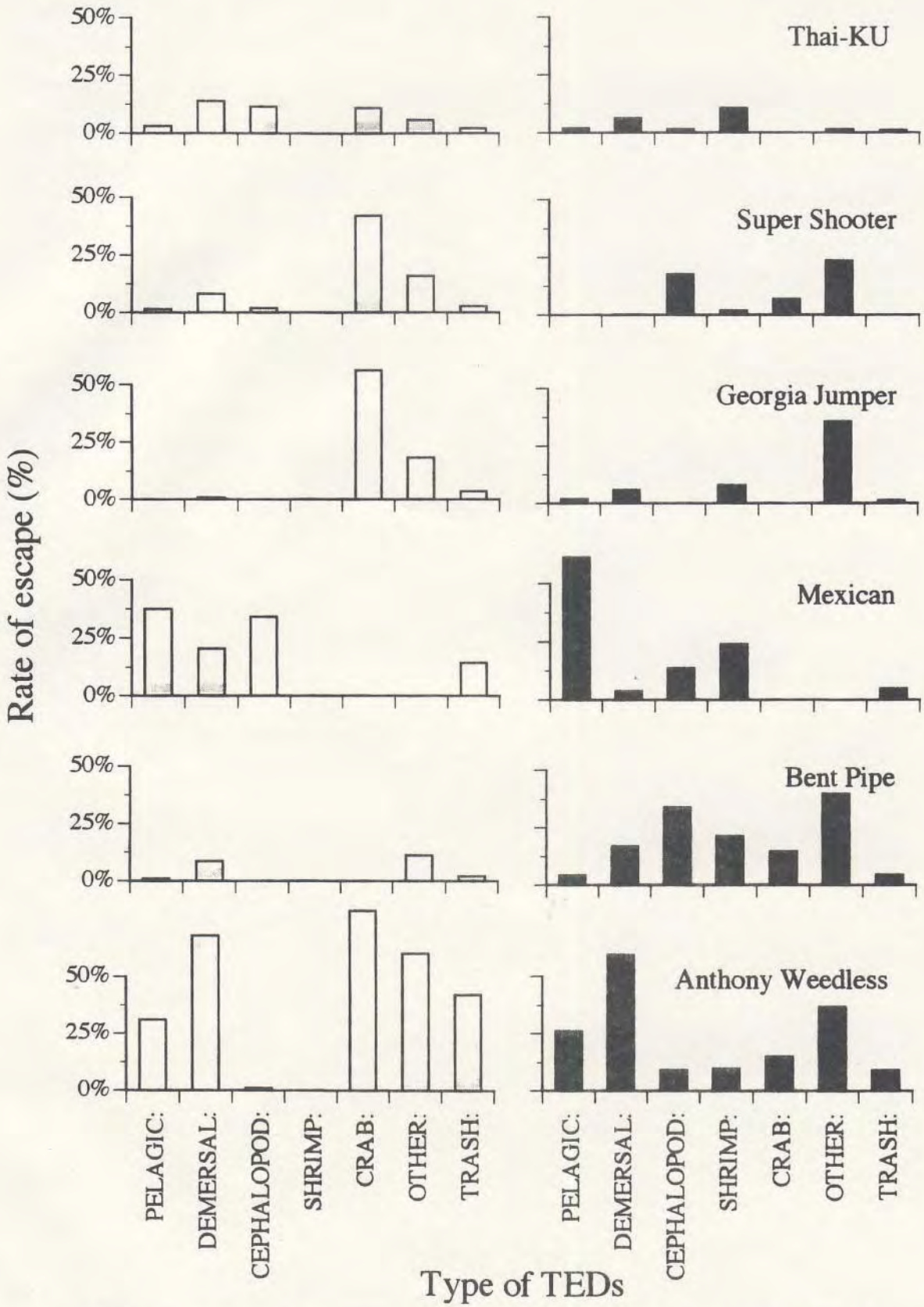


FIG. 6. Rate of escape by total weight of the economic fish for different types of TEDs in the first experiment.

Day-time operation

Night-timeoperation

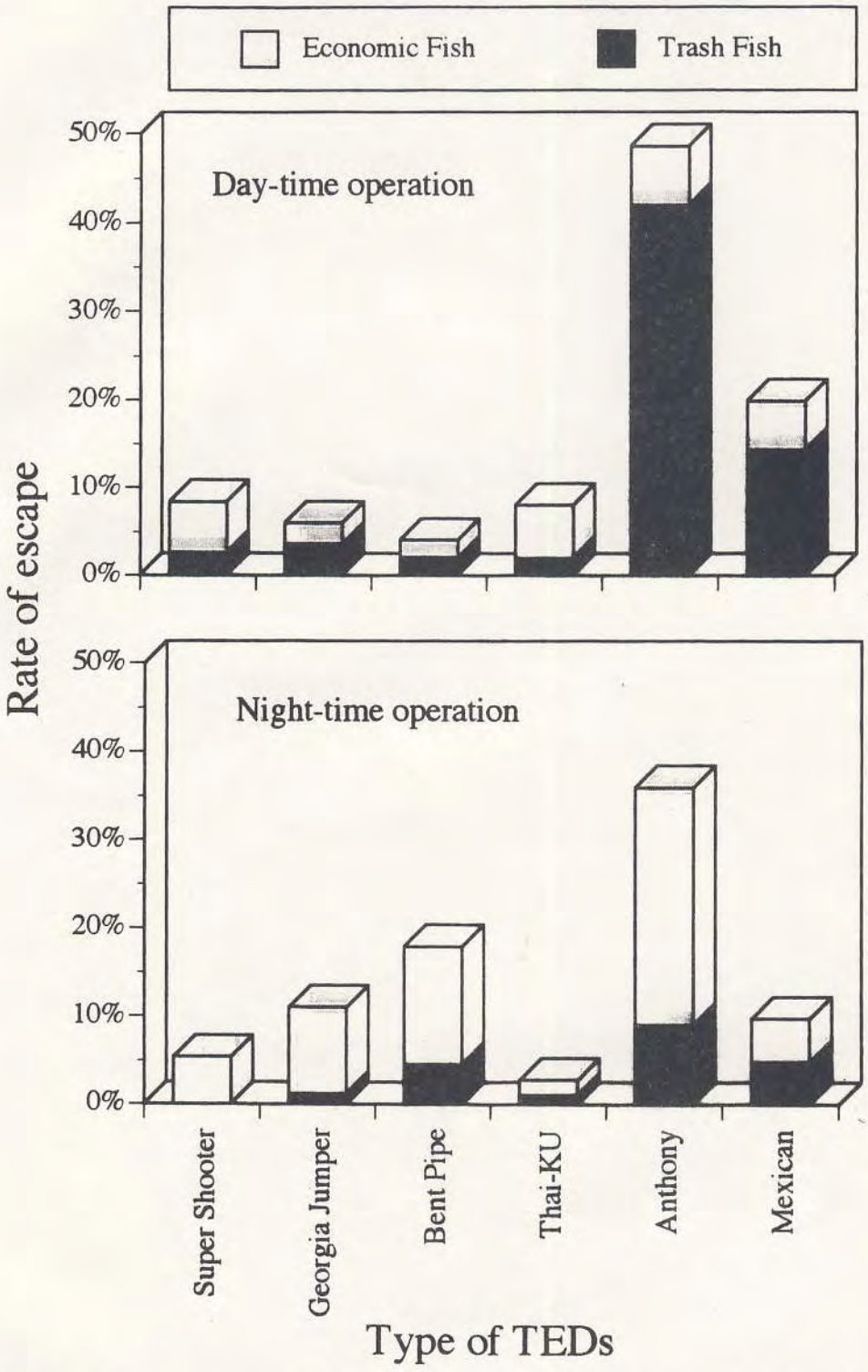


FIG. 7. The escape rate relatives to type of TEDs used for the day- and night-time operation in the first experiment.

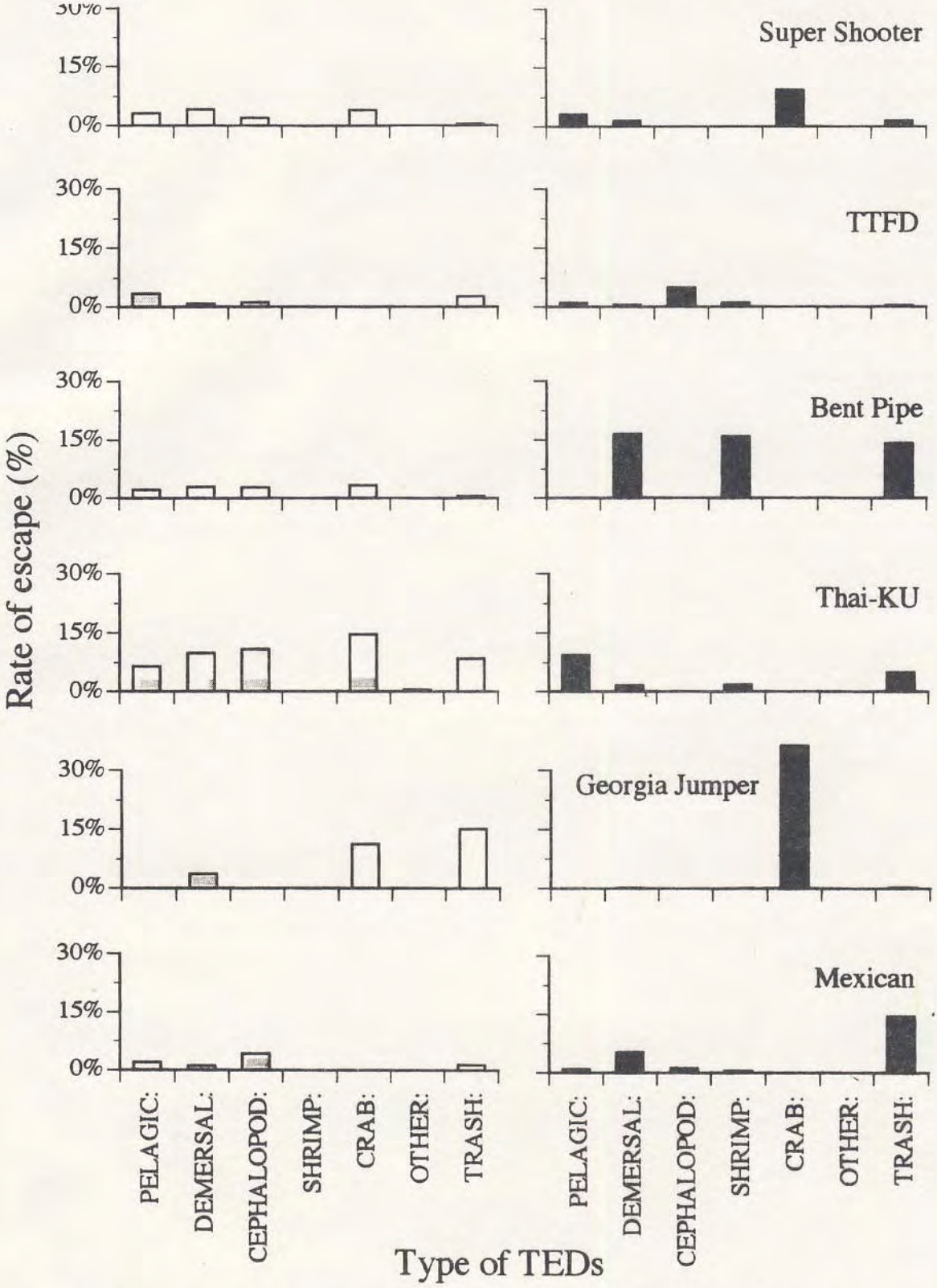


FIG. 8. Rate of escape by total weight of the economic fish for different types of TEDs in the second experiment.

Day-time operation

Night-time operation

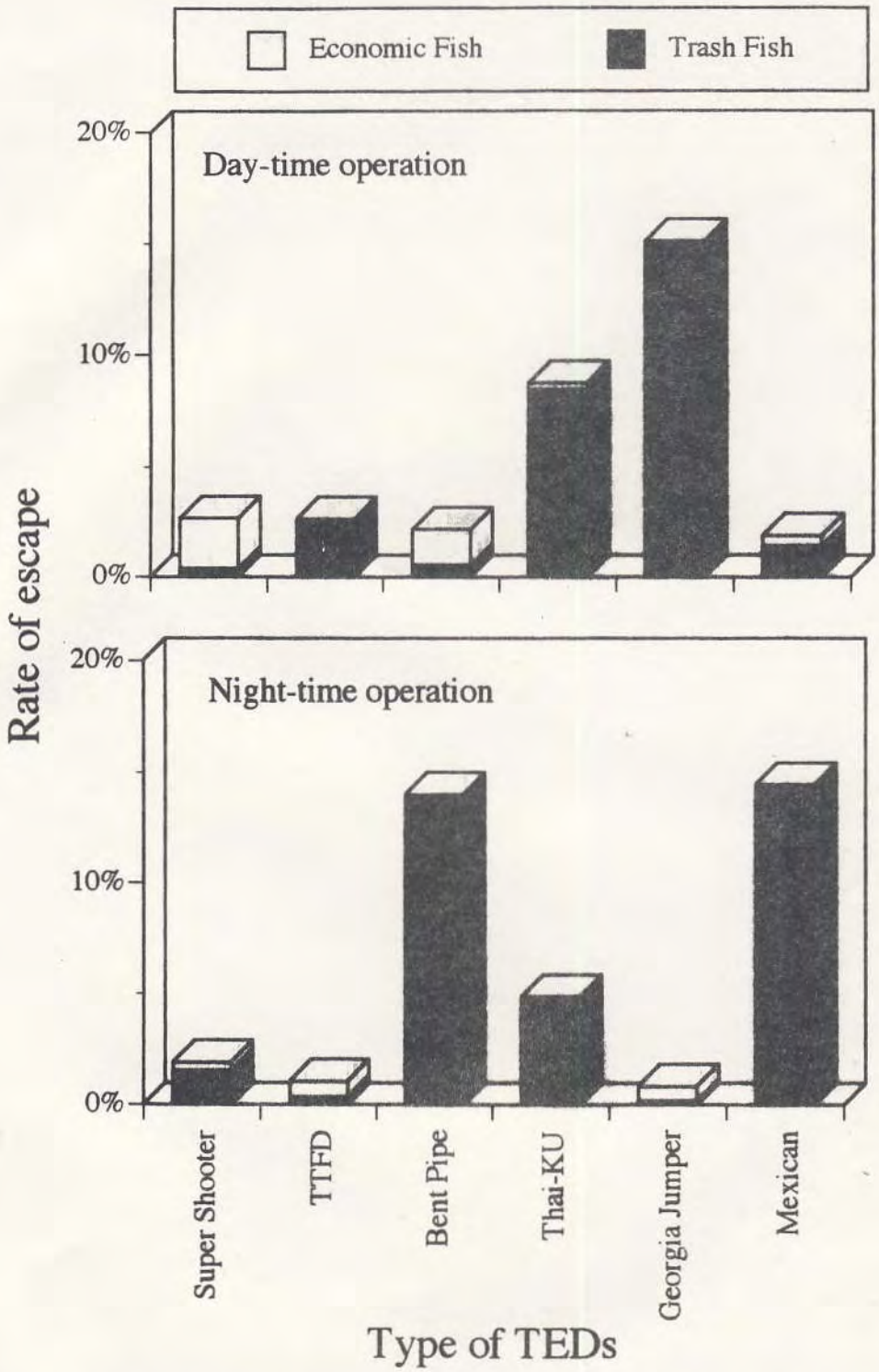


FIG. 9. The escape rate relatives to type of TEDs used for the day- and night-time operation in the second experiment.

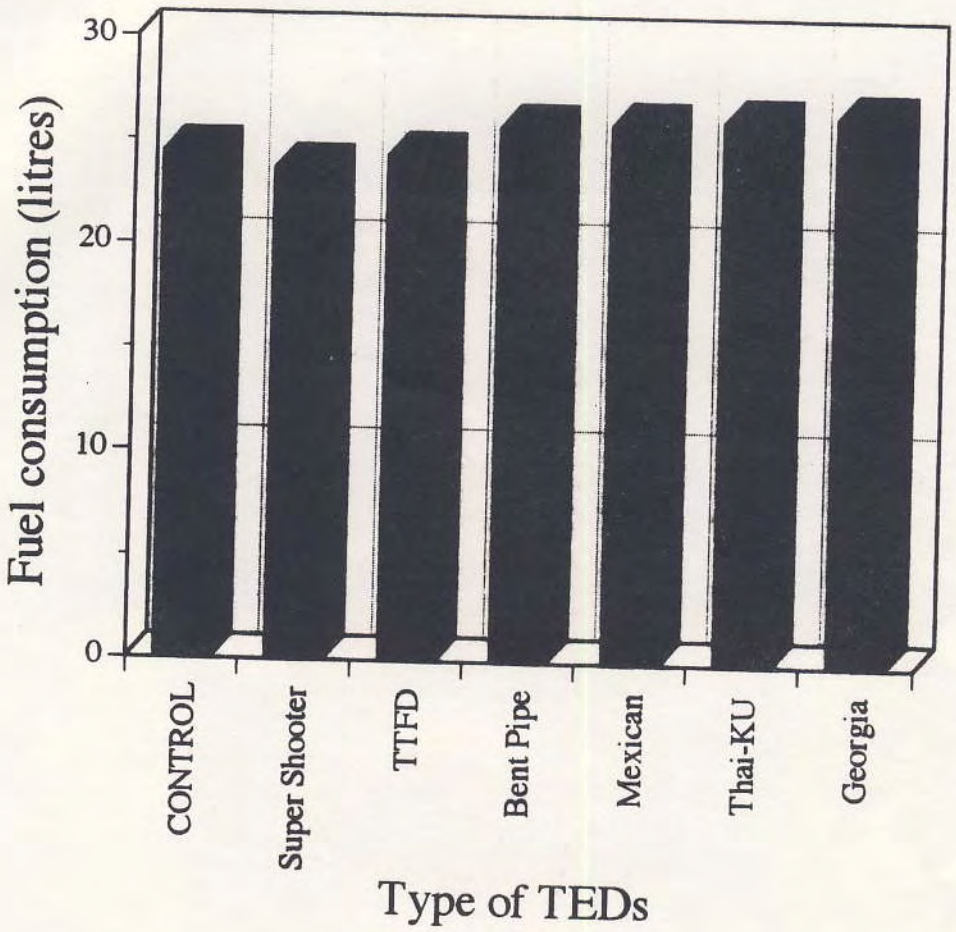


FIG. 10. Fuel consumption relatives to type of TEDs.