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Bycatch in the Soviet purse seine tuna fisheries on FAD-associated schools in North Equatorial Area of the western Indian Ocean

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Abstract

The bycatches taken by the Soviet/Russian/Liberian tuna purse seiners from the North Equatorial Area (0-10°N, 45-70°E) of the Indian Ocean during FAD (fish aggregation devices) fishing season (August-November) and discards resulted from this fishery were estimated. Data were collected by scientific observers aboard Soviet/Russian/Liberian-flag purse seiners in the western Indian Ocean (WIO) during 1986-1992. A total of 108 sets on FAD-associated schools were analysed. More than 40 fish species and other marine animals were recorded, of which only two species, yellowfin and skipjack tunas, are target species. Average levels of bycatch were 1.923 metric tons (t) per set (non-tuna bycatch 0.915 t), or 96.8 t (46.1 t) per 1,000 t of target species. Principal species in the bycatch were bigeye (0.995 t per set), pelagic oceanic sharks (0.246 t), rainbow runner (0.215 t), triggerfishes (0.199 t), and dolphinfishes (0.169 t). One turtle was recorded in the bycatch. Estimated discards are equal to 0.891 t per set or 44.9 t per 1000 t of target species. Potential discards (which included small skipjack, yellowfin, bigeye, and all frigate and bullet tunas) were estimated on the level 0.162 t per set or 8.3 t per 1000 of target species.

Introduction

Two tunas, yellowfin *Thunnus albacares* (Bonnaterre, 1788) and skipjack *Katsuwonus pelamis* (Linnaeus, 1758), are the target species of western Indian Ocean purse-seine tuna fisheries. More than 40 species of fish and other marine animals regularly or occasionally occur in the catches together with this two tunas forming bycatch.

In this paper bycatch is defined as the fraction of the catch that consists of non-target species (including other species of tuna), which are encircled by the fishing gear and are unable to escape by themselves. Bycatches may be retained on board or discarded. Bycatches of associated and non-associated species during purse-seine fishing for tropical tunas may be rather high, and

generally depend on fishing tactics (i.e. number of set on different types of surface tuna schools: free-swimming, associated with marine mammals, log- (or FAD-) associated, etc.).

The FAD fishing technique (sets on natural logs, anthropogenic flotsam, man-made FAD) were introduced in different purse seine tuna fisheries for different reasons: to improve catch rates, minimize fishery expenses, to comply with "dolphin-safe" policy etc. Such fishing tactics may produce relatively high bycatch rates (Joseph, 1994; Bailey et al., 1996; Hall, 1996, 1998; Anon., 1997).

In the Indian Ocean the purse seine tuna FAD fishing technique was used from the early years of the fishery and expanded extensively in recent years (starting from 1995). Purse seiners make FAD sets in the WIO throughout the year but the principal season of FAD fisheries occurs in the summer-autumn season in the North Equatorial area (0-10°N, 45-70°E).

No comprehensive bycatch estimates were published for the fishery up to the present[1]. Some information on bycatch levels and species composition was presented by Stretta et al. 1998 and Santana et al., 1998.

This paper is an attempt to estimate bycatch and discards by Soviet/Russian/Liberian tuna purse seiners of in the WIO, during the principal season of FAD fisheries in the North Equatorial area, based on information collected by scientific observers.

MATERIALS AND METHODS

Sampling methodology and the methods of analysis were described in Romanov, 2000 in press. Extract from "Materials and methods" from Romanov, 2000 (in press) is attached in Appendix I.

FAD in this paper means any type of floating object used for tuna fishing (natural logs, palm branches, anthropogenic flotsam (table desk, freezers, wire rope bobbins, longline floats, etc.), specially constructed fish aggregation devices, etc.).

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[1] Paper "Bycatch in the tuna purse-seine fisheries of the western Indian Ocean" (Romanov, 2000 in press) is under revision for publishing in the Fishery Bulletin.

The majority of the sampled data does not consist of any information on discards. Recorded discards discussed in the "Discards" chapter. In order to obtain additional information on discards I made questioning of several observers and one member of the tuna vessel crew (fish processing officer) for their estimates of discards. Results are presented in the "Discards" section below.

Size frequencies of principal tuna species were raised to total sampled catch. In the raising procedure for estimates of total weight of tuna measured (if sample not weighed aboard) the following L-W relationships were used (calculated by the author basing on YugNIRO database):

Yellowfin $W=3.111907*10^{-5}*L^{2.859513}$ (n=16240)

Skipjack $W=5.173059*10^{-6}*L^{3.339043}$ (n=6990)

Bigeye $W=1.882289*10^{-5}*L^{2.980910}$ (n=1374).

For albacore, frigate and bullet tunas no representative size frequencies sampling coverage were recorded.

RESULTS AND DISCUSSION

Total catch and sampled catch distribution

Detailed total catch and catch composition data for Soviet/Russian/Liberian purse seine tuna vessels by small-scale strata are available for 1985-1994. These figures are based on daily radioreports on fishing activity of the vessels. The catch reporting rate according to my estimates varied in the range 96-99% during 1985-1991, decreasing to 71% in 1992-1994 (Romanov, 2000 in press).

Total catches of the Soviet fleet in 1985-1994, sampled catch and sampled FAD catch (two latter is grouped for the same 10-years time span) by one-degree stratum are presented at Fig. 1. The same pictures of catch distribution during August-November given at Fig. 2.

For the purpose of analysis of sampling representativeness, cumulative (August-November) catches in 1985-1994 in the North Equatorial area 0-10°N, 45-75°E were grouped by five-degree squares. Catch was recorded in 9 of the 10 five-degree squares (Fig. 3). Every 5-degree substratum with catch was numbered from 1 to 9 respectively (Fig. 3). Total Soviet catch varied considerable within this area. Highest catch was recorded in strata 6, 7, and 8 representing in total 91% of total catch. Fig. 3 shows total catch by 5-degree square, the share of sampled catch in 1986-1992 to cumulative catch by stratum and the percentage of FAD sets in the sampled catch. Areas with highest fishing activity: 6, 7, 8 were sampled at the rate from 6% to 24% (in weight). Non-sampled areas: 1, 2, 4, 5 correspond to areas with minor fishing activity (about 5% of total catch). Proceeding from this I believe that sampled data adequately represent catch and fishery activity in the area/season.

A total of 108 purse-seine FAD sets were sampled and 101 positive sets were analysed in the North Equatorial Area, which correspond to 87% of total number of sampled sets in the area/strata. The total catch in the FAD sets that were sampled amounted to 2,200 t.

Species composition

The species composition of catches in FAD sets included 44 species (or higher taxa)(Table 1). Total catch per positive set in the area is equal 21.8±4.74 t. Percentage of principal species in FAD schools was 70% for skipjack, and 22% for yellowfin (catch per set is equal 15.2±3.95 and 4.6±1.05 t respectively).

The majority of FAD sets produced bycatch. Bycatch was not recorded in one case of successive set during the day on the same FAD. On average, bycatch consisted of 8% of the catch in the area. Total bycatch per positive set was equal to 1.923±0.516 t and per 1000 t of target species: 96.8±48.0 t (Table 2).

Tuna bycatch consisted of bigeye, albacore, frigate and bullet tunas (Table 1, 2). Total tuna bycatch was equal to 1.008±0.432 t per positive set and 50.7±43.8 t per 1000 t of target species (Table 2).

Non-tuna bycatch was 0.915±0.225 t per positive set or 46.064±21.796 t per 1000 t of target species (Table 2). The bulk of the non-tuna bycatch in sets on FADs-associated schools is made up of carcharhinid and hammerhead sharks (0.246 t/12.4 t), rainbow runner *E. bipinnulata* (0.215 t/10.8 t), triggerfish of the genus *Canthidermis* (0.199 t/10.0 t), dolphinfish *C. hippurus* (0.169 t/8.5 t), wahoo *A. solandri* (0.041 t/2.0 t), billfishes of the genera *Makaira* and *Tetrapturus* (rarely swordfish *X. gladius*) (0.023 t/1.2 t), and mackerel scad *D. macarellus* (0.011 t/0.6 t). Capture of a sea turtle (unknown species) was recorded only once (Table 1, 2).

Tuna size frequencies

Size frequencies in numbers and in weight of the target tuna species (yellowfin and skipjack) and one of the principal bycatch tuna species (bigeye) from sampled catches are presented in Fig. 4-6. Size frequencies were used for estimates of potential discards (see "Discards" section below).

Discards

Recorded discards.

A high level of discarding by Soviet vessels of the "Rodina" type in the WIO was recorded, generally with peak catches higher than such vessels can process within a reasonable period of time (catches more than 70-80 t in single set). In such cases the vessel's crew was unable to load and freeze the catch within short period of time which the result that the tuna would deteriorate. Such peak catches usually occurs in sets on free-swimming yellowfin schools south of the equator. Discards resulting from such "slipping" of the catch were not recorded in the time/area stratum analyzed.

Non-recorded discards

Interviews of the observers and some members of crew were made during 2000 by the author in order to obtain additional information on non-recorded discards. These confirmed information obtained earlier that Soviet vessels generally did not discard small-sized yellowfin, skipjack, kawakawa, frigate and bullet tunas, at least up until 1991, but rather retained them for sale as "small mixed" tuna. Description of preferences for utilization or discarding of the other species presented in Table 3:

Basing on data presented in the Table 3 the formula for discards calculation could be as follows: **Discards = total bycatch - (tuna bycatch + billfishes bycatch + weight of sharks fins + bycatch of blue sea chub + bycatch of irregularly retained species).**

However, I have made no attempts to estimate neither weight of retained sharks fins nor weight of discarded carcasses without fins. Nor have I attempted to assess the weight of blue sea chub retained by crews.

Total discards were assessed as:

Discards = total bycatch - (tuna bycatch + billfishes bycatch)

Based on this formula, estimated discards per positive set is equal to 0.892 t, or 44.9 t per 1000 t of target species (Table 4).

Although all the observers questioned stated that Soviet/Russian/Liberian vessels did not discard small tunas, I assumed that small species such as frigate and bullet tunas and also small specimens (less than 1 kg) of bigeye, and target species potentially could be discarded due to non-marketable size. Applying this assumption and size frequencies of three tuna species in the catches, I estimated potential discards of target species and tuna bycatch.

A length-weight relationship shows that yellowfin of 37 cm FL and less had weight less than 1 kg. For skipjack and bigeye specimens of 38 cm FL weights are below 1 kg. No reliable size frequencies were obtained for albacore. I assumed that albacore was not discarded. I considered all frigate and bullet tunas as potential discards.

Skipjack with FL 38 cm and smaller account for 0.894% of this species' catch in weight. For yellowfin and bigeye these proportion are 0.502% and 0.152% respectively, i.e. 0.136 t of skipjack, 0.023 t of yellowfin, 0.002 of bigeye, and 0.001 t of frigate and bullet tunas discarded per positive set.

Skipjack/yellowfin ratio in the sampled catch is 3.292 for every 1000 t of this species catch. So potential discards per 1000 t of target species is as follows: skipjack 6.9 t, yellowfin 1.2 t. Potential discard rates of other tuna are estimated as: bigeye 0.1 t, and 0.1 t of aggregated frigate and bullet tunas.

The remainder of the estimated total discards accounted for by other species to 0.162 t per set or 8.3 t per 1000 t of target species. Total estimated discards are presented in Table 4.

CONCLUSION

The species composition of catch in FAD sets included 44 species (or higher taxa). Total catch per positive set in the area is equal 21.8±4.74 t. Tuna bycatch consisted of bigeye, albacore, frigate and bullet tunas. Total tuna bycatch was equal to 1.008±0.432 t per positive set and 50.7±43.8 t per 1000 t of target species. Non-tuna bycatch was 0.915±0.225 t per positive set or 46.064±21.796 t per 1000 t of target species (Table 2). The bulk of the non-tuna bycatch in sets on FADs-associated schools is made up of carcharhinid and hammerhead sharks, rainbow runner, triggerfish, dolphinfish, wahoo, billfishes (rarely swordfish), and mackerel scad. In the analysed time/area strata discards were not recorded in the logbooks. For this reason discards were estimated based on common principals of retaining/discarding species for tuna purse seiners obtained by questioning observers and crew. Discards are equal to 0.892 t per positive set, or 44.9 t per 1000 t of target species. Additional potential discards are equal 0.162 t per set or 8.3 t per 1000 t of target species. Total estimated discards are 1.053 t per positive set or 53.2 t per 1000 t of target species.

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Table 1. Species composition of tuna purse-seine catches in the North Equatorial area of the western Indian Ocean

Family, species	Log-associated
PISCES	
Dasyatidae	
Dasyatis spp.	+
Mobulidae	
Manta birostris (Donndorff, 1798)	+
Mobula spp.	+
Carcharhinidae	
Carcharhinus falciformis (Bibron, 1839)	+
C. longimanus (Poey, 1861)	+
?C. obscurus (LeSueur, 1818)[2]	+?
Carcharhinus spp.	?
Sphyrnidae	
Sphyrna lewini (Griffith & Smith, 1834)	+
Sphyrna spp.	+
***Belonidae* sp.**	+
Lampidae	
Lampris guttatus (Brünnich, 1788)	+
Sphyraenidae	
Sphyraena barracuda (Walbaum, 1792)	+
Sphyraena spp.	+
Carangidae	
Caranx spp.	+
Decapterus macarellus Cuvier, 1833	+
Decapterus spp.	+
Elagatis bipinnulata (Quoy & Gaimard, 1824)	+
Seriola spp.	+
Naucrates ductor (Linnaeus, 1758)	+
Coryphaenidae	
Coryphaena hippurus Linnaeus, 1758	+
Coryphaena spp.	+
Kyphosidae	
Kyphosus cinerascens (Forsskål, 1775)	+
Echeneidae	
Echeneis naucrates (Linnaeus, 1758)	+
Gempylidae	
Ruvettus pretiosus Cocco, 1829	+
Ephippididae	
Platax spp.	+
Scomberomoridae	
Scomberomorus commerson (Lacépède, 1800)	+
Scomberomorus spp.	+
Scombridae	
Acanthocybium solandri (Cuvier, 1831)	+
Auxis rochei (Risso, 1810)	+
Auxis thazard (Lacepede, 1800)	+
Katsuwonus pelamis (Linnaeus, 1758)	+
Thunnus alalunga (Bonnaterre, 1788)	+
Thunnus albacares (Bonnaterre, 1788)	+
Thunnus obesus (Lowe, 1839)	+
Istiophoridae	
Makaira indica (Cuvier, 1832)	+
M. mazara (Jordan et Snyder, 1901)	+
Makaira spp.	+

[2] *The sign (?) denotes doubtful, in the author's opinion, species identification by observer.*

Family, species	Log-associated
Tetrapturus audax (Philippi, 1887)	+
Xiphiidae	
Xiphias gladius (Linnaeus, 1758)	+
Balistidae	
Canthidermis maculatus (Bloch, 1786)	+
Monacanthidae	
Aluterus monoceros (Linnaeus, 1758)	+
Aluterus spp.	+
Diodontidae	
Diodon spp.	+?
CHELONIDEA	+
Number of species (taxa)	44

Table 2. Estimates of the bycatch (t) of various species (groups) of marine animals in FAD school sets.

Species, a group of species	FAD schools	
	Per positive set	Per 1000 t of target species
Bigeye (*T. obesus)*	0.995±0.433	50.1±33.2
Albacore (*T. alalunga*)	0.011±0.010	0.6±0.6
Frigate and bullet tunas (*A. thazard, A. rochei*)	0.001±0.001	0.1±0.1
Tuna bycatch	1.008±0.432	50.7±43.8
Silky shark (*C. falciformis*)	Not estimated	Not estimated
Oceanic whitetip shark (*C. longimanus*)	Not estimated	Not estimated
?Dusky shark (*C. obscurus*)	Not estimated	Not estimated
Unidentified carcharhinid sharks (*Carcharhinus spp.*)	Not estimated	Not estimated
Scalloped hammerhead (*S. lewini*)	Not estimated	Not estimated
Unidentified hammerheads (*Sphyrna spp.*)	Not estimated	Not estimated
Shark bycatch	0.246±0.056	12.4±5.6
Black marlin (*M. indica*)	Not estimated	Not estimated
Blue marlin (*M. mazara*)	Not estimated	Not estimated
Striped marlin (*T. audax*)	Not estimated	Not estimated
Swordfish (*X. gladius*)	Not estimated	Not estimated
Billfish bycatch	0.023±0.011	1.2±0.8
Wahoo (*A. solandri*)	0.041±0.023	2.0±1.6
Rainbow runner (*E. bipinnulata*)	0.215±0.105	10.8±7.8
Dolphinfish (*C. hippurus*)	0.169±0.076	8.5±5.7
Barracuda (*S. barracuda*)	0.003±0.003	0.1±0.2
Triggerfish (*C. maculatus*)	0.199±0.067	10.0±5.6
Unicorn leatherjacket (*Aluterus spp.*)	+	+
Triggerfishes	0.199±0.067	10.0±5.6
Mackerel scad (*D. macarellus*)	0.011±0.011	0.6±0.7
Mantas, mobulas (Mobulidae)	0.002±0.004	0.1±0.2
Sea turtles	+	0.1±0.1
Other bycatch	0.005±0.003	0.3±0.2
Non-tuna bycatch total	0.915±0.225	46.1±21.8
Total bycatch	1.923±0.516	96.8±48.0

Table 3. Utilization/Discarding bycatch by Soviet purse seine vessels crew

Group of species	Utilization	Discards
Sharks	Fins for selling	Carcass always discarded
Mantas, mobulas	Not utilized	Always discarded
Billfishes	For crew consumption	Never discarded
Wahoo	Rarely utilized	Mostly discarded
Dolphinfish	Rarely utilized	Mostly discarded
Rainbow runner	Not utilized	Always discarded
Barracuda	Not utilized	Always discarded
Flotsam community (generally triggerfishes, mackerel scad, other small fishes)	Blue sea chub (*Kyphosus cinerascens*) often used for crew consumption	Other species always discarded
Sea turtles	Not utilized	Always discarded

Table 4. Estimates of nominal discards, potential discards and total discards in Soviet purse seine FAD tuna fisheries in North Equatorial area (t)

Group of species	Per set			Per 1000 t of target species		
	Nominal discards	Potential discards	Total discards	Nominal discards	Potential discards	Total discards
Skipjack	-	0.136	0.136	-	6.9	6.9
Yellowfin	-	0.023	0.023	-	1.2	1.2
Bigeye	-	0.002	0.002	-	0.1	0.1
Frigate and bullet tunas	-	0.001	0.001	-	0.1	0.1
Sharks	0.246	-	0.246	12.4		12.4
Mantas, mobulas	0.002	-	0.002	0.1		0.1
Billfishes	-	-	-	-	-	-
Wahoo	0.041	-	0.041	2.0		2.0
Rainbow runner	0.215	-	0.215	10.8		10.8
Dolphinfish	0.169	-	0.169	8.5		8.5
Barracuda	0.003	-	0.003	0.1		0.1
Flotsam community (generally triggerfishes, mackerel scad, other small fishes)	0.215	-	0.215	10.9		10.9
Sea turtles	+	-	+	0.1		0.1
Total	0.891	0.162	1.053	44.9	8.3	53.2

Appendix I

Extracts from "Materials and methods" (Romanov, 2000 in press)

Bycatch assessments were based on data collected by YugNIRO scientific observers aboard Soviet (since 1992 – Russian) tuna purse seiners in the WIO, during 1990-1991. The vessels were the "Rodina" type[3]. In addition, observer data collected in the same area aboard sister-ships by AtlantNIRO[4] and "Rybprognoz"[5] during 1986-1990 and data by TINRO[6] and TURNIF[7] during 1990 and 1992 were used. The fishing vessels all used purse seines of 1800 m in length, 250-280 m in depth, and 90-100-mm mesh size in the bunt.

The observers were placed on board opportunistically, without a sampling scheme and without preference to any vessel type. Thus, the sampling could be considered as random. Two other types of Soviet fishing vessels, "Tibiya"[8] and "Kauri",[9] which took part in the Indian Ocean fisheries during 1985-1987 and since 1991 (under Liberian flag), respectively, were not sampled. In this paper coverage rate was estimated as percentage of sampled catch to total catch.

The observers recorded the results of each set. The type of school, according to Scott (1969) and Petit and Stretta (1989), of each set was recorded. I consider sets in which an

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[3] Length overall – 85 m, GRT – 2634, carrying capacity ~ 1600 m^3.

[4] AtlantNIRO – The Atlantic Scientific Research Institute of Marine Fisheries and Oceanography. 5 Dmitry Donskoi St., 236000 Kaliningrad, Russia.

[5] The Joint Stock Company "Rybprognoz", formely until 1993 The Department of Searching and Scientific Research Fleet of the Western Basin "Zaprybpromrazvedka". 5[a] Dmitry Donskoi St., 236000 Kaliningrad, Russia.

[6] TINRO – The Pacific Scientific Research Institute of Marine Fisheries and Oceanography. 1, Shevchenko Alley, 690600 Vladivostok, Russia.

[7] TURNIF – The Pacific Department of Fish Searching and Scientific Research Fleet. 2, Pervogo Maya St., 690600 Vladivostok, Russia.

[8] Length overall – 55.5 m, GRT – 736, carrying capacity ~ 361 m^3.

[9] Length overall – 79.8 m, GRT – 2100, carrying capacity ~ 1200 m^3.

observer recorded catch in any quantity, as positive sets. The average bycatch level was estimated for all positive sets.

For the positive sets, species composition, total weights, and numbers of each species in the catch were recorded. In the vessels of the "Rodina" type the retained catch was frozen and stored separately. The retained catch was weighed after freezing while being moved to the holds. In nine cases, the weight of some of the catch was estimated by the ship masters because the holds were overloaded and some catch was stored in the freezers till landing. So estimates of retained catch are presented here as frozen weights rather than wet weights. The bycatch was estimated as wet weight. Only bycatch taken on board was sampled. The sets when bycatch was not taken onboard but discarded alive (usually with negligible target species catch) were not analyzed in this study. Large species, sharks and billfishes generally, were weighed and counted. The weights of specimens heavier than 200 kg (*i.e.* Mobulidae) were estimated. When the bycatch was more than 200-300 kg, its species composition and weight was estimated using representative samples.

Sometimes the observer recorded the bycatch in numbers. In these rare cases, the total weights of the fishes were estimated from the average weights of these species in previous catches.

The observers had free access to every fish in the catch. Nevertheless, some observers had difficulties identifying some billfishes, sharks, and Mobulidae species. Therefore, I pooled the records with doubtful species identification in those three groups for my analysis. These are marked by "?" in the tables.

Some observers did not record the type of floating objects that were set on. So the sets on natural floating objects (50 to 90% of the log sets sampled) and on fish aggregation devices (FADs) (10-50%) were grouped.

The spatial and temporal distribution of catch and effort for the Soviet tuna purse-seine fishery in the Indian Ocean are from the YugNIRO database (DB) based on daily radio reports

for 1985-1994 from vessels fishing in the area from 1983 until now[10]. The catches reported by the author's estimates vary by 96-99% during 1985-1991, decreasing to 71% in 1992. This paper does not take into account reflagging of some Soviet (from 1992 – Russian) vessels to Liberian flag and the vessels' nationality is defined here by the location of their shipowners.

Some of the bycatch was retained on board the fishing vessels. Non-utilized bycatch was discarded in the ocean. The observers usually did not record the levels of discards, and it is not possible to assess quantitatively the discards of tuna and associated species.

Average values are presented as arithmetic means, plus or minus 95% confidence intervals of predicted values.

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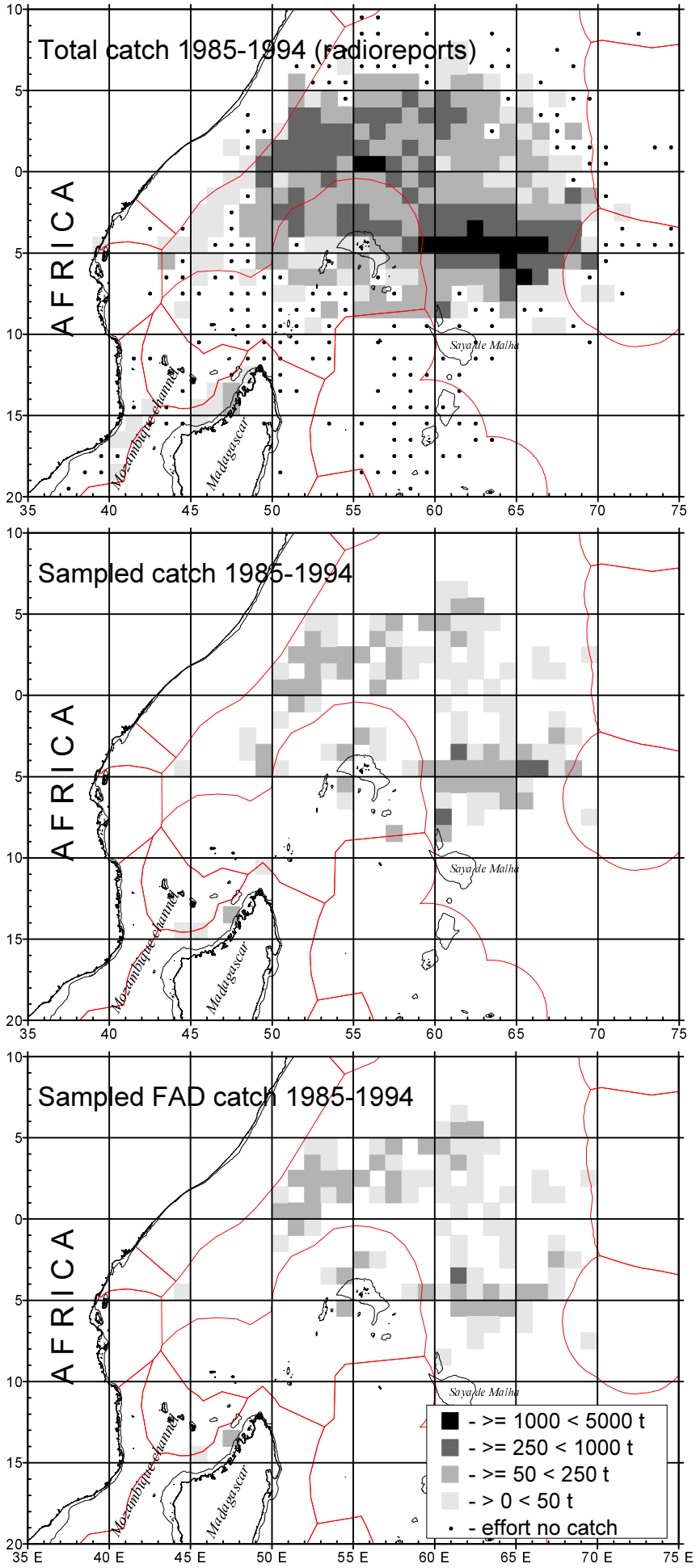

Fig. 1. Total catch, sampled catch and sampled FAD catch by one-degree strata

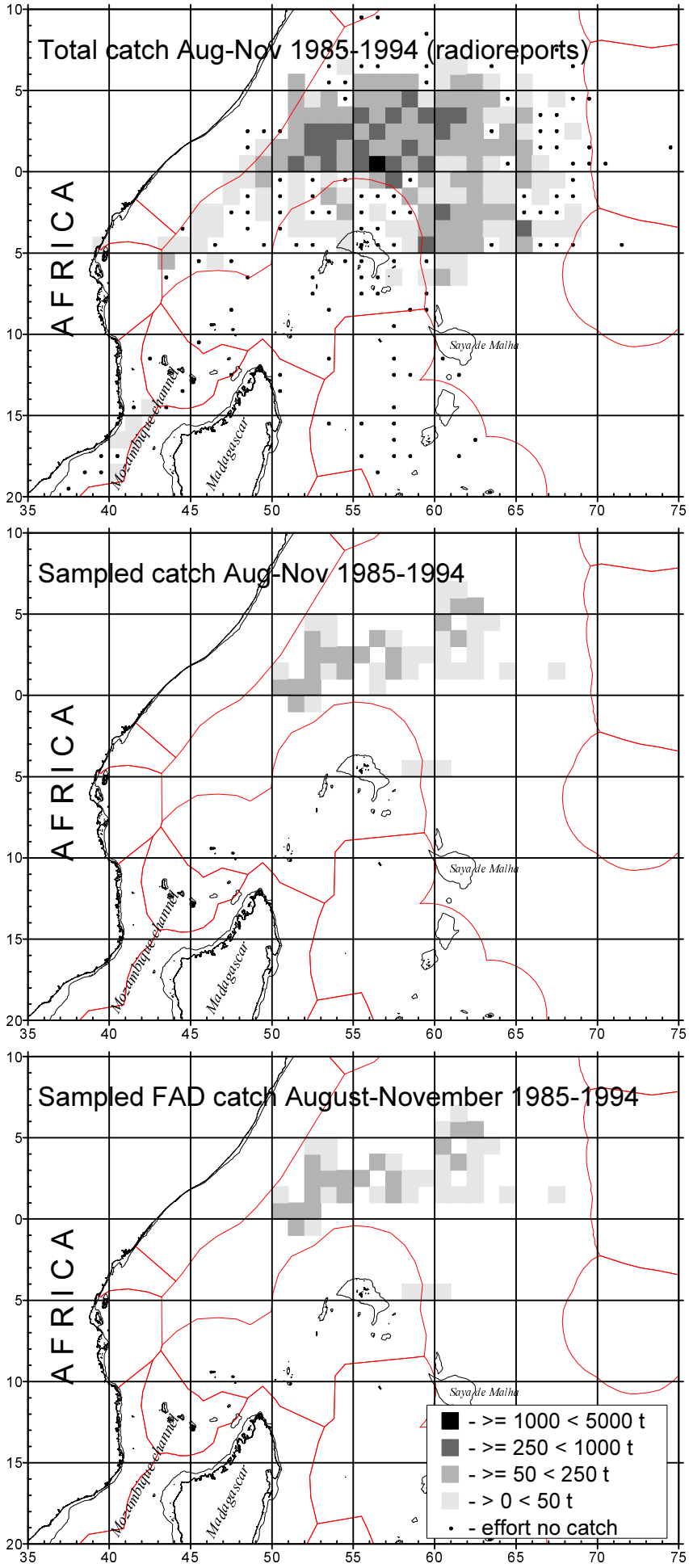

Fig 2. Total catch, sampled catch and sampled FAD catch by one-degree strata in August-November.

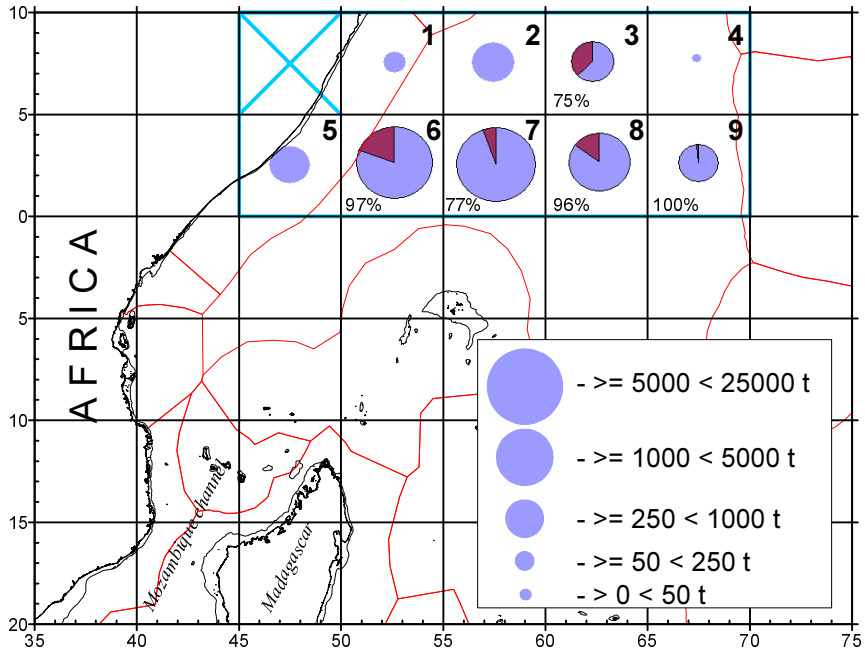

Fig. 3. Purse seine cumulative catch (in August-November 1985-1994) in North Equatorial area by 5-degree squares; pie diagram is share of sampled catch (in August-November 1986-1992) to cumulative catch, numbers in upper right corners in number of 5-degree strata, and numbers in lower left corner is percentage of FAD sets within sampled sets.

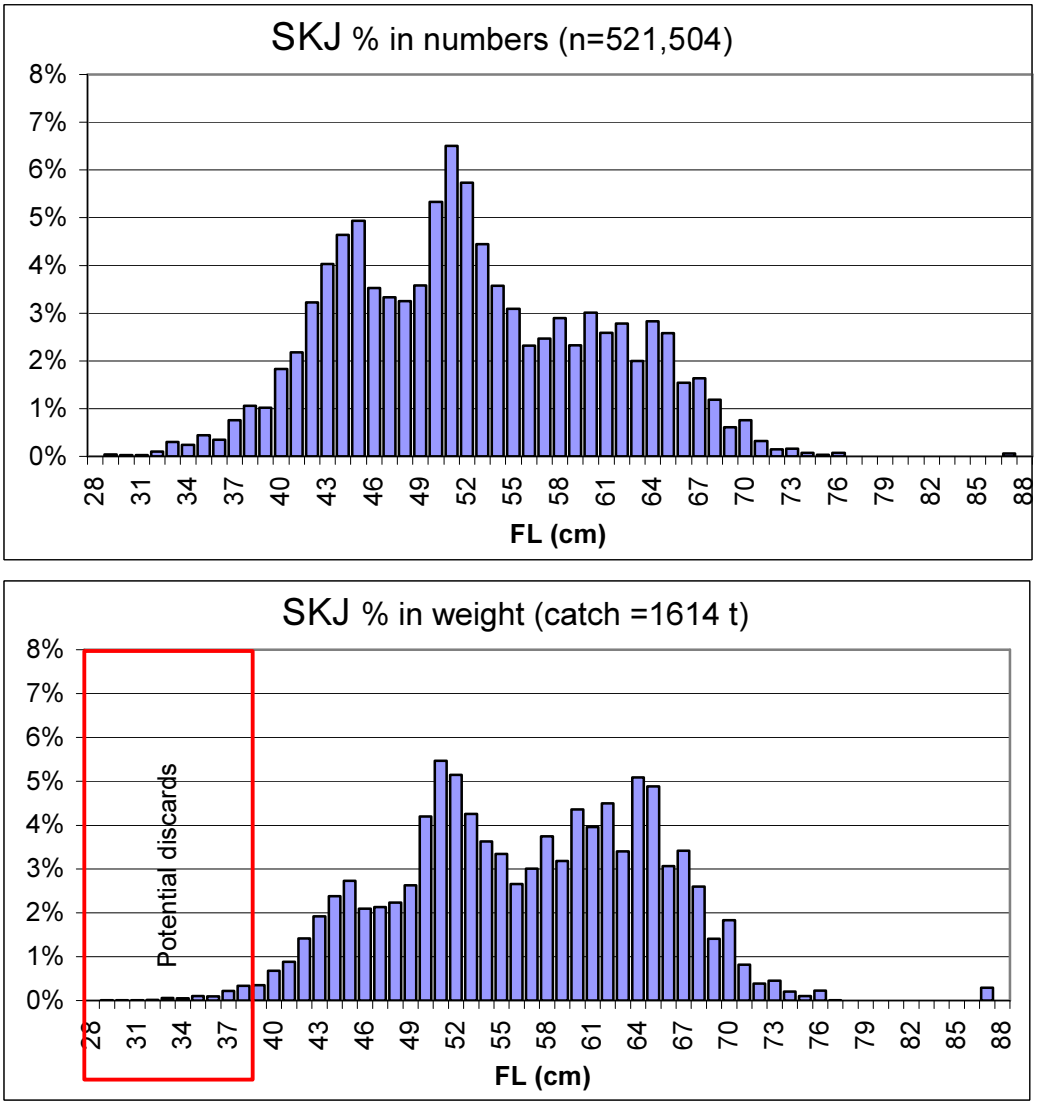

Fig. 4. Length frequencies of skipjack from the Soviet purse seine catches in North Equatorial area.

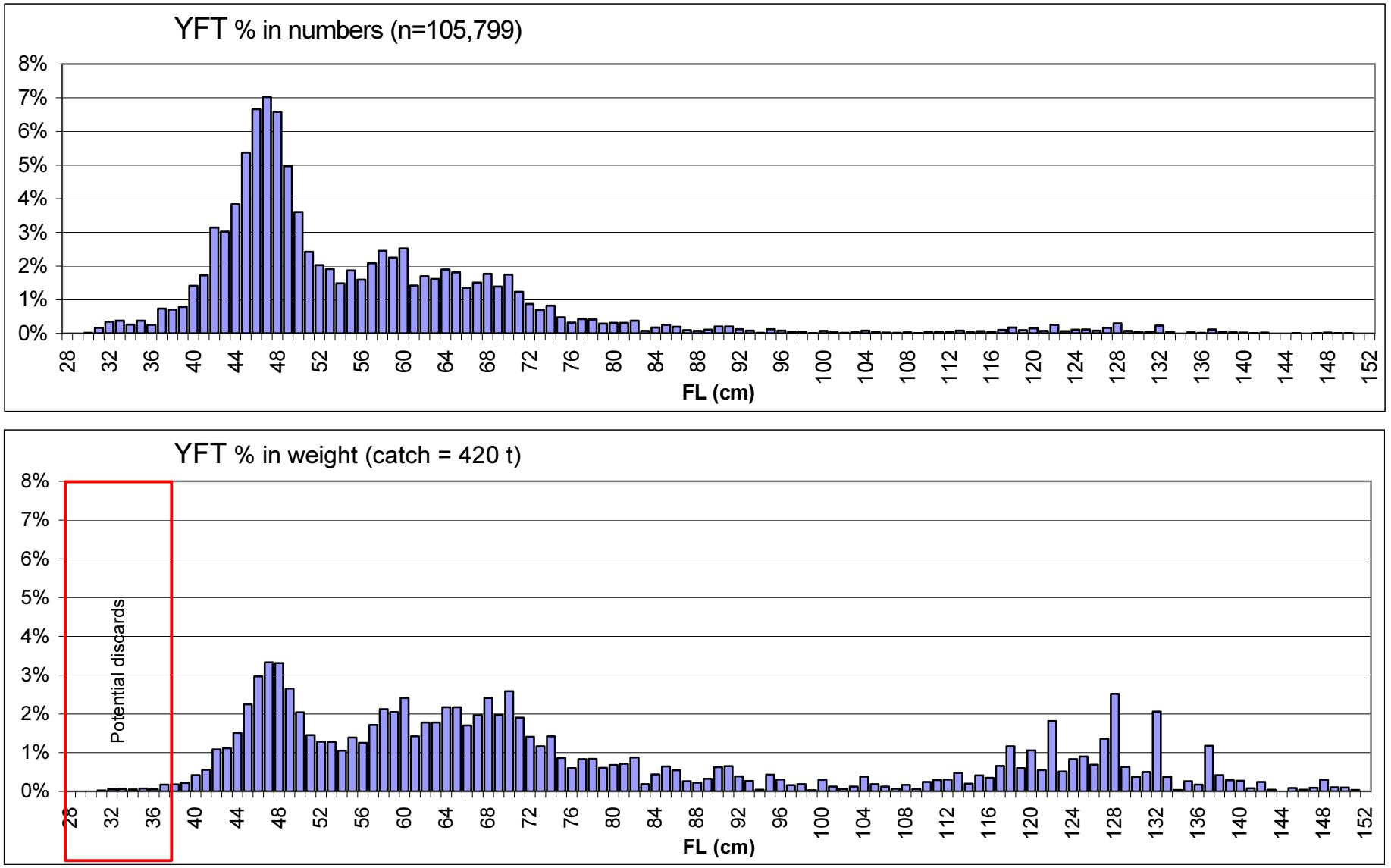

Fig. 5. Length frequencies of yellowfin from the Soviet purse seine catches in North Equatorial area

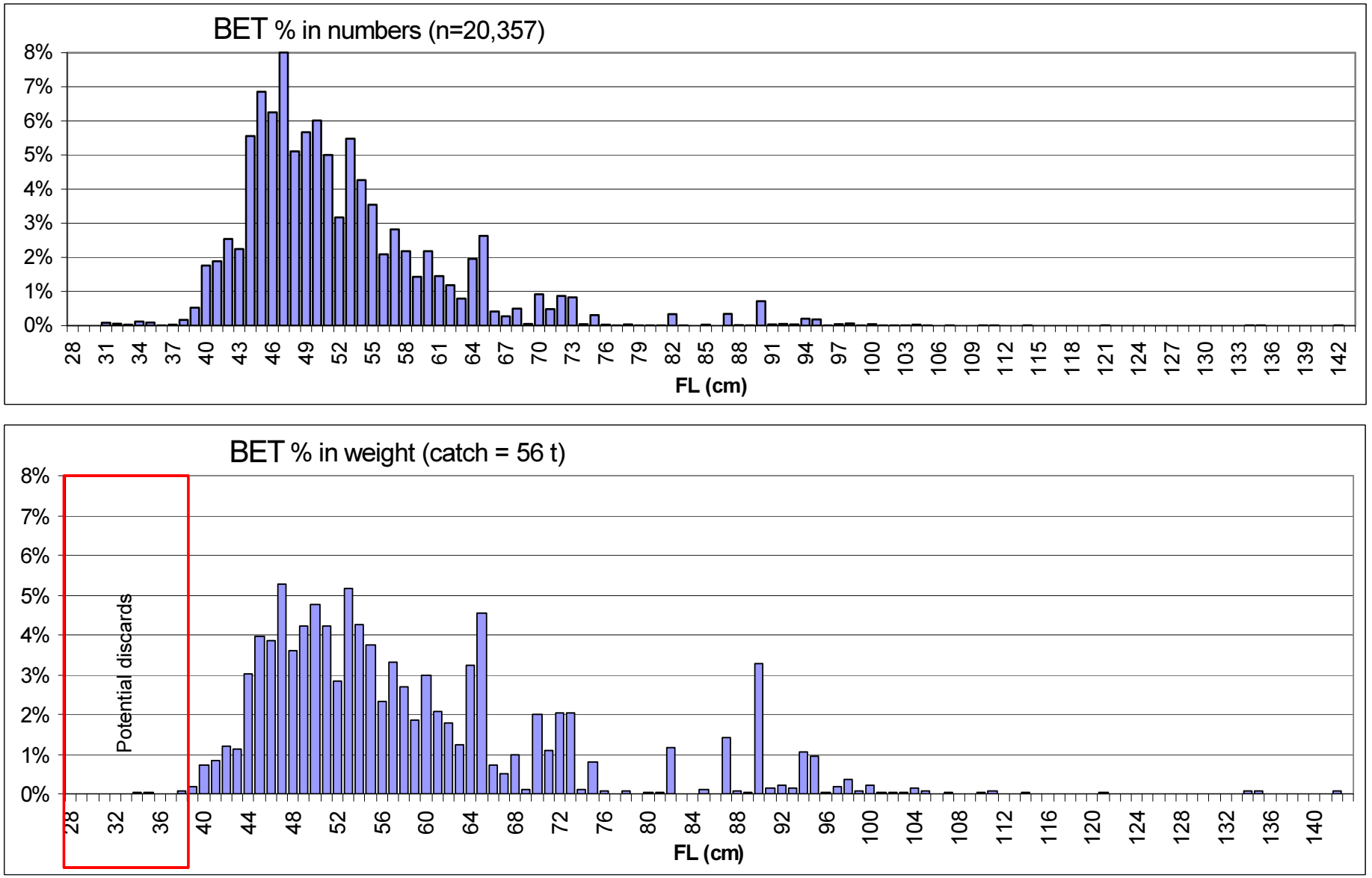

Fig. 6. Length frequencies of bigeye from the Soviet purse seine catches in North Equatorial area