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Artisanal Shark Fishery at Tres Marias and Isabel Islands, Nayarit, Mexico
(Elasmobranch Fisheries – Poster)

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Abstract

Biological and fishery information was obtained of sharks caught south of Tres Marias Islands during the fishing season of 1995-96, and around Isabel Island (east of Tres Marias Islands) during the fishing season 2000-2001. South of Tres Marias Islands 2 004 organisms were observed and caught by drift gill nets. It was possible to observe a change in the specific composition due to the oceanographics conditions, with a first period in November with a great abundance of subadult and adult silky sharks *Carcharhinus falciformis* (27%), and the second period from January to March composed by subadult of smooth hammerheads *Sphyrna zygaena* (35%) and subadult and adult blue sharks *Prionace glauca* (25%). Around Isabel Island 7 464 organisms were observed and the principal fishing gear used was bottom longline. Most important species were juvenile scalloped hammerheads *Sphyrna lewini* (49%) and subadult and adult sharpnose sharks *Rhizoprionodon longurio* (45%). In this zone it was possible to observe a periodicity of fifteen days in the fishing effort and in the captures of the sharpnose shark *R. longurio*, which suggests a relation with the lunar cycle. A list of all species of sharks caught, the abundance of the principal species through the fishing season, their size distribution, sex ratio and mature organisms percentage will be described for both fishing areas.

Keywords: shark fishery, “Tres Marias” Islands, Isabel Island, México.

Introduction

Mexican shark fisheries are very heterogeneous. The type of vessels and gears used vary regionally, as well as the seasonality of harvest and degree of utilization of the different species (Bonfil, 1994). Because of its larger coastal extension, the Pacific coast contributes 65% of total shark catches in Mexico while the remaining 35% comes from the Gulf of México and Caribbean (Anuario Estadístico de Pesca, 1999).

Subsistence shark fisheries along the Pacific coast of Mexico have always been an important resource to rural communities. This fishery became an important multi-species and multi-gear fishery with important social an economic value throughout the Gulf of California and the west coast of Baja California (Holts *et al*., 1998).

The size of the artisanal fleet operating along the Mexican Pacific coast is unknown but probably exceeds 2,000 small boats (“pangas”). This fleet is very mobile, the small boats are easily trailered from one area to another to take advantage of favorable fishing conditions and/or market prices (Holts *et al*., 1998).

In some regions of the Gulf of California the shark fishery arose in the early-1940s when the prices for shark liver oil increased. During these boom years, a number of fishermen with small boats became specialists in shark fishing, acquiring its basic skills, technology and capital. The activity diminished after the Second World War, but later there was a recovery based upon the marketing of diverse products: shark’s fins, hides, meat, liver oil, and fhismeal (McGoodwin, 1976).

During several decades in the Central Mexican Pacific shark fishing activities normally have been carried out around Isabel Island, a small island 20 miles off the mainland coast. Occasionally the fishing activities are carried out in the vicinity of "Tres Marias" Islands, particularly southward of Maria Cleofas Island (McGoodwin, 1976).

However, in spite of being an important region for sharks fishing only the study of Kato and Hernandez-Carvallo (1967) had contributed with some information about sharks that inhabit near the "Tres Marias" and Isabel Islands.

In this study we describe the abundance throughout the fishing season, size distribution, mature organisms percentage, sex ratios, as well as a list of all shark species caught to the south of "Tres Marias" Islands by the artisanal fleet that lands at La Cruz de Huanacaxtle, Nayarit, México and those caught around Isabel Island by the artisanal fleet located in this island.

Material and Methods

The "Tres Marias" Islands are located at 60 km to the Isabel Island that is located at 21°52' N and 105°54' W in the Central Mexican Pacific (Fig. 1). The area is considered to be a transitional zone between the tropical and temperate zones with a very complicated and dynamic oceanographic structure (Roden and Groves, 1959; Wyrtki, 1965, Stevenson, 1970; Badan, 1997). At the surface three water masses can be detected: 1) the cold and low salinity water of the California Current, 2) the warm and intermediate salinity water of the Tropical Oriental Pacific, and 3) the warm and highly saline water of the Gulf of California (Roden and Groves, 1959).

In La Cruz de Huanacaxtle place in that land the artisanal fleet (composed by 21 small boats) that catches sharks south of "Tres Marias" Islands we obtained the biological and fishery data on daily bases from October 26 of 1995 to March 10 of 1996. At Isabel Island there is a temporary fishing camp in where lands an artisanal fleet (composed by 40 small boats average) that catches sharks around this island, even though a small percentage makes it in the east of "Maria Magdalena" Island. At that Island we obtained the biological and fishery data on daily bases from November 15 of 2000 to February 28 of 2001.

Sexual maturity for males was determined according to the development of the claspers and for females according to the development of the shell gland, ovaries and uterus.

The catch per unit effort was estimated south of "Tres Marias" Islands as the number of sharks per set carried out with two drift gill-nets 200 meters in length each one, that were used for each small boat ("panga"), and around Isabel Island as the number of sharks per set carried out with a bottom longline (with a Norwegian hook No. 5) with 400 hooks. Each small boat used one, two and sometimes three longlines, each one with an average of 400 hooks.

We obtained temperature data from the home page of the National Oceanographic and Atmospheric Administration (NOAA), from a point in the sea (21°35'N y 105°30') very close to the Isabel Island, with the purpose of checking if the best captures around this Island were related with the cold months. Unfortunately, temperature data for the years 1995 and 1996 were not available so we could not check the possible relationship between the captures south of "Tres Marias" Islands with that parameter.

To check if the sets and sharks per set around Isabel Island had periodicity we realized an spectral analysis. After we found a periodicity of fourteen days for the sets and sharks per set and with the purpose of checking if they had relationship with the lunar cycle, we realized a cross correlation analysis using the tide amplitude as indicator of the lunar cycle. Both analysis were made in the software "Statistica".

Results

South "Tres Marias" Islands

We recorded 2 004 sharks belonging to 10 species (Table 1) caught by 605 sets carried out using drift gill-nets with a mesh size of 12 inches. The most of the organisms of smooth hammerhead *S. zygaena*, silky shark *C. falciformis* and blue shark *P. glauca* had lengths ranging from 160-210 cm. The biggest organisms were of thresher shark *A. pelagicus* and those of scalloped hammerhead *S. lewini* were the smallest (Fig. 2).

Most of the organisms were sexually mature, except those of the hammerhead species which were mainly juveniles (Table 2). The smooth hammerhead *S. zygaena* was the only species that showed segregation by size, since in most of the sets were caught subadults organisms of both sexes having similar sizes.

Relative abundance of the main species throughout the fishing season

Throughout the fishing season two periods were observed: the first one in November, with great abundance of silky shark *C. falciformis*. The second period includes the months from January to March and was multispecific, with a great abundance of smooth hammerhead *S. zygaena* and blue shark *P. glauca*, including in small numbers the scalloped hammerhead *S. lewini* and the blacktip shark *C. limbatus*. The abundance of the pelagic thresher shark *A. pelagicus* was constant through the months, except for October where it was more abundant (Fig. 3). However the catch per unit effort estimated for October was biased since only four sets were registered.

Around Isabel Island

We registered 7 464 organisms of sixteen shark species, even though only 4,765 were biologically analyzed. The scalloped hammerhead *Sphyrna lewini* and the sharpnose shark *Rhizoprionodon longurio* accounted for 95% of all of the sharks caught (Table 3). Most of the organisms had length less than 1.50 meters (Fig. 4).

The sharks caught by 572 sets with bottom longline (Norwegian hook No. 5) accounted for 95% of all shark landed. The rest were caught with other gear such as: bottom-fixed and drift gill-nets, bottom longline (Norwegian hook No. 000) and harpoon. The organisms bigger than 1.80 meters were caught with thirteen sets carried out using bottom longline (each set with 60 hooks No. 000) to the east of “Maria Magdalena” Island, and the two whitetip reef sharks Triaenodon obesus were caught in the same fishing area with harpoon.

Of 4 765 biologically analyzed sharks, only 438 were sexually mature. The sharpnose shark *R. longurio* accounted for 86% of all those mature organisms (Table 4). All of the organisms of scalloped hammerhead *S. lewini*, smooth hammerhead *S. zygaena*, silky shark *C. falciformis* and tiger shark *G. cuvieri* were immatures.

Relative abundance of the main species throughout the fishing season

The catch of the seven main species increased starting from January, except in the silky shark *C. falciformis* which was very rare in February (Fig. 5). Starting from middle of January it was observed a decrease in the average temperature that caused an increase in the captures of scalloped hammerhead *S. lewini* and mainly in the sharpnose shark *R. longurio* (Fig. 6). Using temperature as independent variable we obtained significant linear regressions for sharks per set ($n = 20$; $F = 23.85$, $df = 18$, $p < 0.001$) and sharpnose shark *R. longurio* per set ($n = 20$; $F = 16.74$, $df = 18$, $p < 0.001$), and not significant linear regressions for scalloped hammerhead *S. lewini* per set ($n = 20$; $F = 2.66$, $df = 18$, $p = 0.120$) (Fig. 7).

Fleet dynamic, catch per unit effort and lunar cycle

In general three factors determined that during some days the fishermen did not carry out fishing effort to catch sharks: holy days as the new year (all the fisherman returned to their towns), the bad weather during some moon quarters and the great abundance of some teleost species of the genera *Lutjanus*, which are the target species for the most of the fishermen.

We observed that the most of the fishing days were mainly during the full and new moon periods, except during the crescent quarter of early December (Fig. 8A). Thus, the sharks per set had the same trend that sets, except during the crescent quarter of early December where in spite of there were many sets there were not many sharks per set (Fig. 8B). The sharpnose shark *R. longurio* was more abundant during the full and new moon periods starting from January (Fig. 9B), whereas smooth hammerhead *S. lewini* was more abundant towards the moon quarter periods (Fig. 9A).

The sharpnose shark *R. longurio* is the most valuable shark species for the fishermen, because this species appear at the fishing area in “corridas” (word used for the fishermen to refer days of great abundance of some shark species), allowing them to obtain until 500 kg per fishing trip. During the present study we registered three ‘corridas” of this species starting from January (Fig. 9B). However, the fishermen mentioned that not every year there is great abundance of this species, since in some years they did not find any “corrida” around Isabel Island.

In the spectral analysis the sharks per set and the sharpnose shark *R. longurio* per set had significant values for the fourteen days period (Table 5). The significant values for sets were fifty-two and fifteen days periods (Fig. 10).

In the cross correlation analysis using tide amplitude as first variable it was observed that the significant correlation values for number of sets were obtained with thirteen to fourteen delays, for sharks per set with cero, one and fourteen delays (Fig. 11), for the scalloped hammerhead *S. lewini* with two and twelve delays and for the sharpnose shark *R. longurio* with cero, one, fourteen and fifteen delays (Fig. 12). Thus we observed that number of sets, sharks per set and sharpnose shark *R. longurio* per set had correlation with the tide amplitude and therefore with the lunar cycle.

Discussion

The discrepancy in specific composition between the places was due mainly to the different fishing gear used by the fishermen, and throughout the fishing season in both places was related to the change of surface water masses pattern which causes a marked division starting from January due to the presence of the California Current that carries subartic water to these regions (Wyrtki, 1965; Stevenson, 1970; Badan, 1997).

South "Tres Marias" Islands

The three main species caught in this region showed clearly the marked division caused by the water masses pattern. Thus the most caught species before January was the silky shark *C. falciformis* which inhabits tropical waters (Castro, 1996) and starting from January were the smooth hammerhead *S. zygaena* and the blue shark *P. glauca* which inhabits warm-temperate waters (Castro 1996). The blue shark *P. glauca* may arrives there because it carries out its migration coming from the north following the California Current. The migratory pattern of two another shark species are unknown.

The great number of mature organisms in the landings, except for hammerheads sharks, was due that the fleet carries out a semioceanic fishing. In spite of smooth hammerhead *S. zygaena* had a similar size structure that the silky shark *C. falciformis* and blue shark *P. glauca*, this hammerhead shark reach its sexual maturity at a bigger size (Compagno 1984).

Around Isabel Island

The sharpnose shark *R. longurio* opposite to stated by Compagno (1984) and Castro (1996) was mainly caught during the cold months, and apparently it carries out north to south migrations in the Gulf of California being this region the southern portion of their distribution. This small species did not show segregation by size or sexes, since in most of the sets starting from January were caught juveniles, subadults and adults of both sexes.

Because this is a heavily exploited species we suggest that is very important to carry out a demographic analysis to know if its populations parameters (fecundity, reproductive cycle, age and growth) allow it to support the exploitation rates. The Atlantic sharpnose shark *Rhizoprionodon terranovae*, a similar small shark species of the same genera that inhabits in the Gulf of Mexico, has a fast growing and early sexual maturity allowing it to have a good intrinsic rebound potential (Smith et al. 1998). The same can be happening in the Pacific sharpnose shark *R. longurio*, since it has at less thirty years supporting high exploitation rates. Hernández-Carvallo (1971) point out that this shark species is the most abundant in the coast of the Sinaloa State (north of Isabel Island) to late-1960s.

The scalloped hammerhead *S. lewini* is a warm-water species (Castro, 1996), and is abundant in some regions of the Gulf of California during throughout the year (Galván-Magaña *et al*., 1989, Castillo-*Géniz et al*., 2000). We registered only juvenile organisms of this hammerhead shark because along the east coast of the Gulf of California there are great number of coastal lagoons that are used for this species as nursery areas. This may be true for most of the shark species that inhabits this region in which we registered mainly juvenile organisms.

In the coast of the Sinaloa State (north of Isabel Island), same as around Isabel Island a great number of juveniles of scallop hammerhead *S. lewini* are caught during the autumn and winter months, and some fishermen communicate us that during the spring and summer months they caught some mature organisms. However, considering that starting from August until December fishermen target shrimp species (because they have the highest commercial value), the shark fishing periods are only from five to six months throughout the year (personal observations).

Therefore in this hammerhead shark the exploitation of the immature and mature stock are not constant through the year, and in spite of having a late sexual maturity of 15 years (Branstetter, 1987), its fecundity is relatively high with 15 to 31 embryos by litter (Compagno, 1984) and has an annual reproductive cycle (Castro, 2000). These life history parameters have played an important role along exploitation history on this shark species, which is considered as important in the shark captures since the 1960s (Hernandez-Carvallo, 1967).

On the other hand, the relationship that we found between the fishing effort and the sharks per set with the lunar cycle is uncommon. With this phenomenon there are mainly two factors associated: the tides that generate tidal currents and the light intensity. The tidal currents are used by the fish during their migrations and some fish species tend to aggregate at current boundaries because there are food supplies (Laevastu, 1993). The light intensity changes the diurnal behaviour in some fish species and caused that they did not be available for the fishing gear (Hela and Laevastu, 1970).

In our present study we were not able to determine what caused such aggregations of sharpnose shark *R. longurio* during the full and new moon. Although, Blaylock (1988) found that the cownose rays *Rhinoptera bonasus* carry out their movements according to the tidal cycle, and Wetherbee *et al.* (2000) obtained the same result in juveniles of lemon shark *Negaprion brevirostris*, we can not tell that the same occurs with the sharpnose shark *R. longurio*, because it could be due that fishermen carried out most of their sets during the full and new moon periods. However, there are two arguments that reject this hypothesis: 1) when the fishermen carried out a lot of sets during the moon quarter (early December) they did not catch many sharks, and 2) the coupling with the lunar cycle was only for the captures of sharpnose *shark R. longurio*, and not for the hammerhead shark *S. lewini*.

Whatever the reasons for this coupling between the captures of this small shark species with the lunar cycle, is important to know this periodicity to optimize future researches and because it contributes to achieve a better understanding of the migratory behaviour of this species.

Management and conservation

The past July was approved the Mexican Official Norm (NOM-029-PESC-2000) that regulates the commercial exploitation of sharks and rays in the Mexican waters. This is a great step to achieve a necessary management and conservation plan in the following years.

At the Gulf of California has been registered forty five shark species (Galvan-Magaña *et al*., 1989), but through the years this number has shown a decrease. In spite of we registered eighteen species in both places, the most important were only smooth hammerhead *S. zygaena*, silky shark *C. falciformis* and blue shark *P. glauca* to the south of “Tres Marias” Islands and scalloped hammerhead *S. lewini* and sharpnose shark *R. longurio* around Isabel Island.

The eighteen species are a small number if we consider that Kato (1965) in only one day registered nineteen species in 1964 at “Playa Sur”, a fishing camp located in Mazatlan, Sinaloa, north of Isabel Island.

In recent years, in the artisanal elasmobranch fishery in the Gulf of California it has been observed that the captures are composed mainly of small shark species and rays species, to difference of the beginning of the fishery with a predominance of bigger shark species that obviously due theirs life histories did not support the exploitation rates. Currently the artisanal fishery for big sharks is very rare in the Gulf of California, and the fleet that come from Chiapas and operates south of “Tres Marias” Islands was one of the last that carry out this type of fishery.

We did not obtain fishery information from spring and summer months because the fishing season to the south of “Tres Marias” and around Isabel Islands is just during the autumn and winter months. From the middle of March until October the fleet that began its activity in 1994 and operated to the south of “Tres Marias” islands (we know that currently it did not fishing any more at this fishery area) it moved toward the fishing camps located in the central region of the Gulf of California, in the Peninsula side (San Francisquito, Baja California Sur) or in the Continent side (Yavaros, Sonora), since fishermen indicated that sharks moved to that region during this period.

The fleet that operates around Isabel Island since 1940s presently targets mainly on teleost species (genera *Lutjanus*), directing their fishing effort on small sharks only when those important species are not very abundant. However, at the beginning of the fishery the fleet caught only big sharks around Isabel and “Maria Cleofas” Islands (McGoodwin, 1976), but through the years these species showed a decrease and twenty years ago the fishermen could only catch them around “Tres Marias” Islands.

This way, currently most of the fishermen target some teleost species because these have a higher commercial value and are closer to the Isabel Island, and only a small group follows catching sharks around “Tres Marias” Islands. Besides during the shrimp season most of the fishermen remain in their coastal towns. Thus an adequate management plan for the most valuables species (shrimp and teleost), will allow to reduce even more the fishing mortalities of the shark species.

In Mexico we lack of statistics of catch and effort for shark species that prevents to evaluate fluctuations through the years, even to determine at date if there is decrease in captures of the main species or if they have maintained a constant catch per unit effort. The improvement of the statistics in the Mexican shark fishery is a good objective that the Official Norm NOM-029-PESC-2000 seeks to achieve during the next years.

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Table 1. Sharks species caught south of “Tres Marias” Islands from October 26 of 1995 to March 10 of 1996.

Species	Number of organisms
Sphyrna zygaena	700
Carcharhinus falciformis	551
Prionace glauca	503
Alopias pelagicus	97
Sphyrna lewini	88
Carcharhinus limbatus	44
Isurus oxyrinchus	17
Nasolamia velox	2
Isurus oxyrinchus	1
Negaprion brevirostris	1
Total	2004

Table 2. Percentage of mature organisms of the main species caught south of “Tres Marias” Islands.

Species	% sexually mature	
	Females	Males
S. zygaena	23	1
C. falciformis	70	55
P. glauca	86	95
A. pelagicus	61	74
S. lewini	18	23
C. limbatus	100	100

Table 3. Sharks species caught around Isabel Island from November 15 of 2000 to February 28 of 2001.

Species	Number of organisms
Sphyrna lewini	3,699
Rhizoprionodon longurio	3,375
Sphyrna zygaena	183
Carcharhinus falciformis	61
Carcharhinus limbatus	59
Nasolamia velox	27
Galeocerdo cuvieri	23
Carcharhinus obscurus	9
Mustelus lunulatus	8
Carcharhinus altimus	6
Ginglymostoma cirratum	5
Carcharhinus porosus	3
Prionace glauca	2
Triaenodon obesus	2
Carcharhinus leucas	1
Negaprion brevirostris	1
Total	7464

Table 4. Percentage of mature organisms of the main species caught around Isabel Island.

Species	% sexually mature	
	Females	Males
R. longurio	22	16
C. limbatus	8	11
N. velox	0	14

Table 5. Periodogram values obtained by means of the spectral analysis (***** no significant).

Variable	Period	Cosine coefficient	Sine coefficient
R. longurio/set	17	3.94	-0.016 *
R. longurio/set	14.57	2.19	-2.90
Sets	14.85	-1.44	-1.66
Sets	52	-2.67	2.14
Sharks/set	17	4.47	-1.67
Sharks/set	14.57	1.57	-4.63
S. lewini/set	25.50	-1.54	-2.51

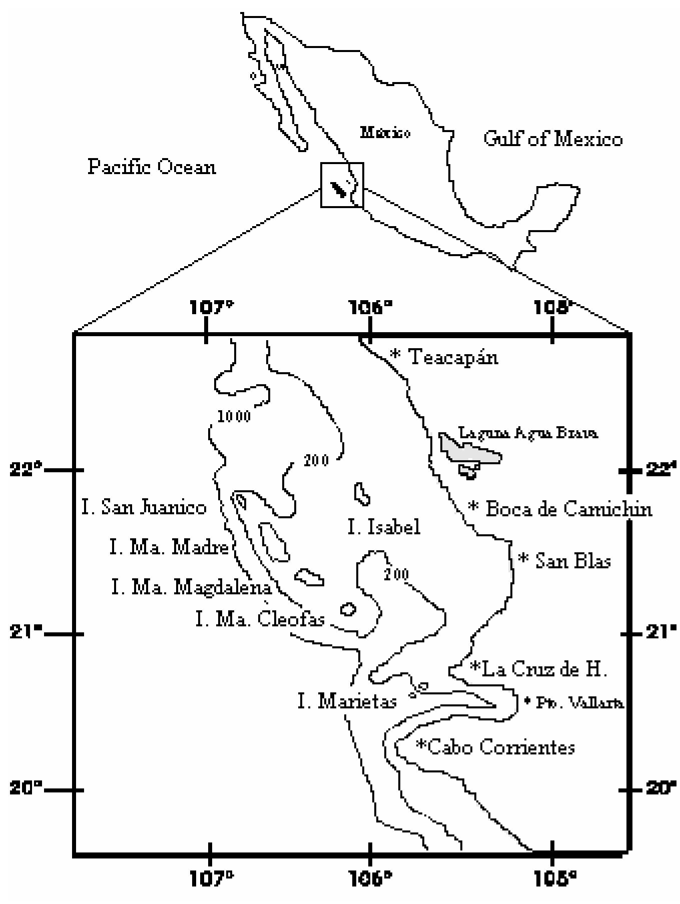


Fig. 1. Geographical localization of “Tres Marias” and Isabel Island in the Central Mexican Pacific.

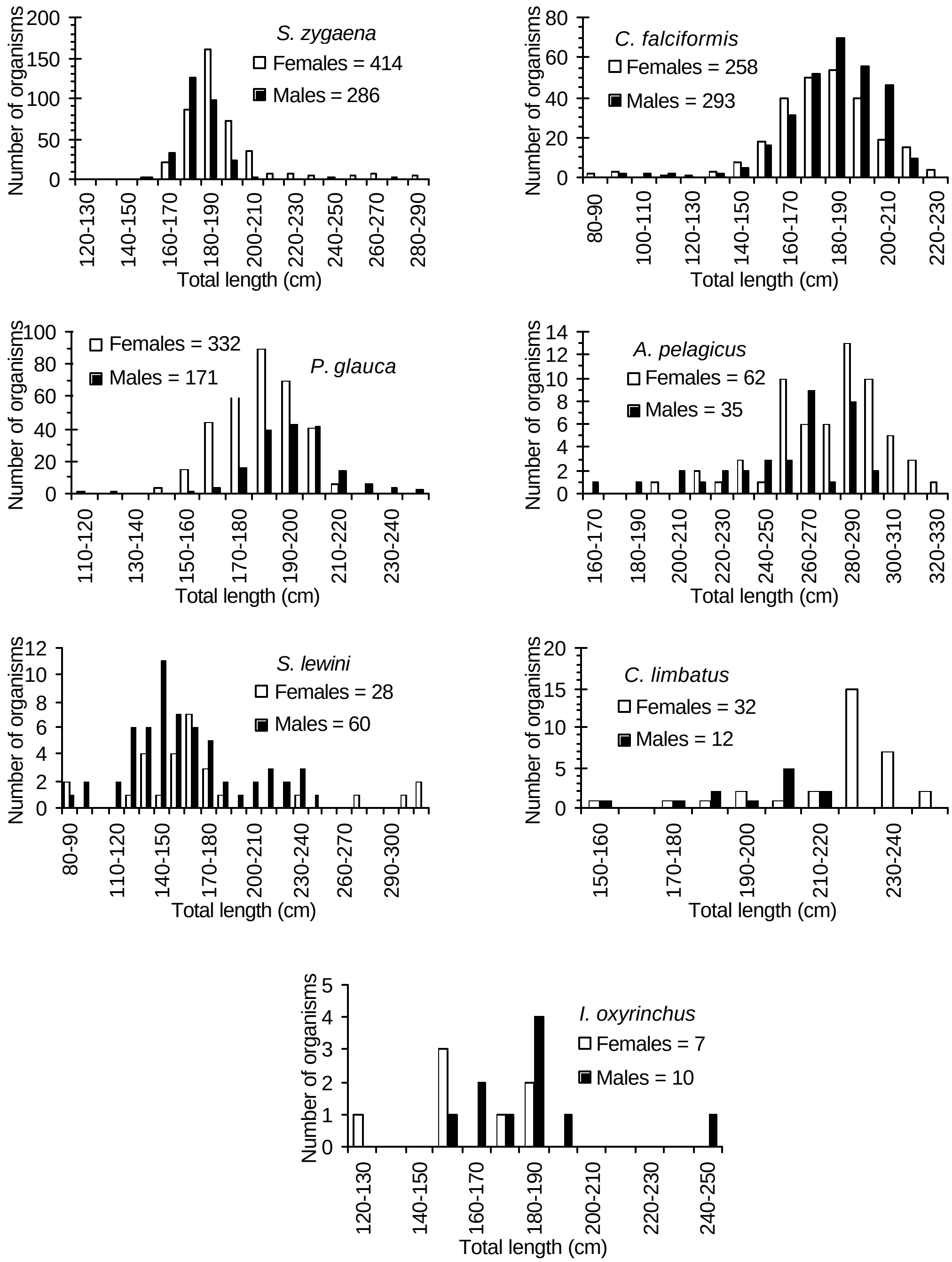


Fig. 2. Length-frequency distributions for the main species caught south “Tres Marias” Islands.

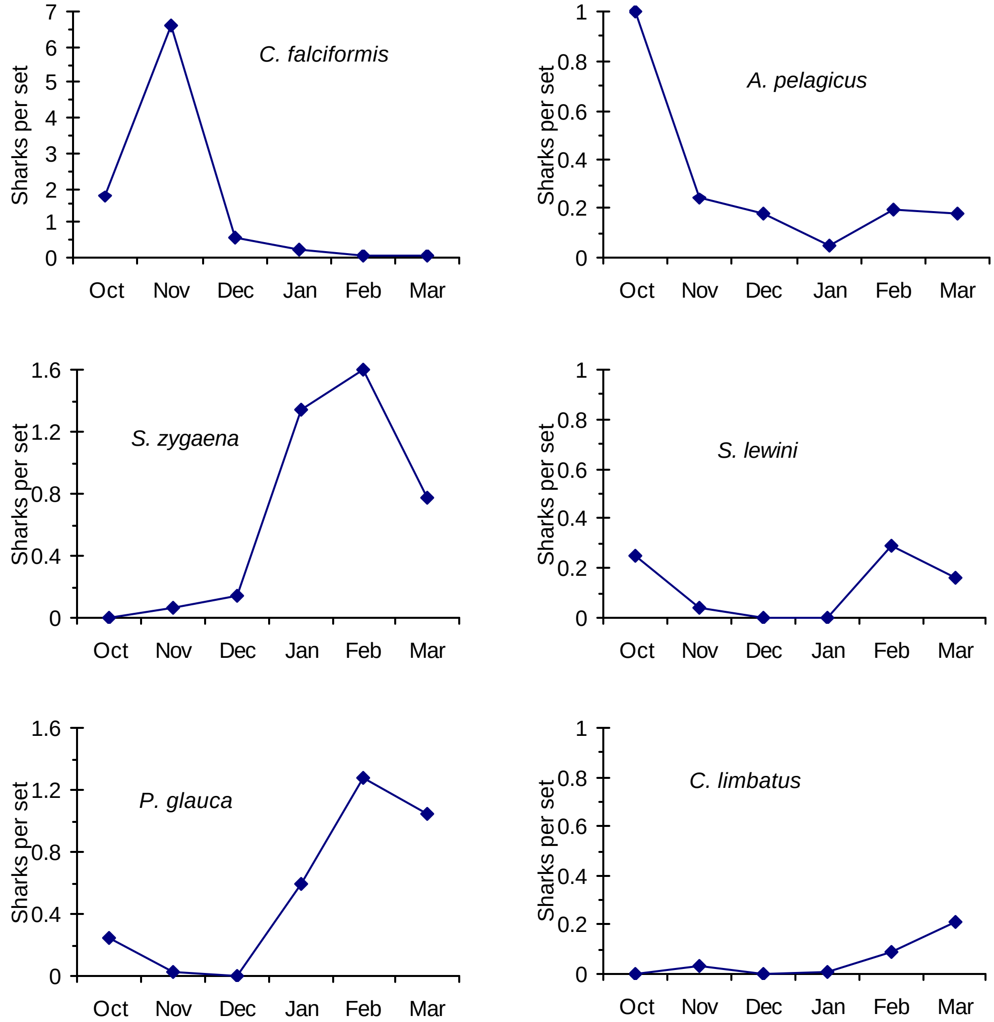


Fig. 3. Catch per unit effort (number of sharks per set) of the main species caught south of "Tres Marias" Islands throughout the fishing season.

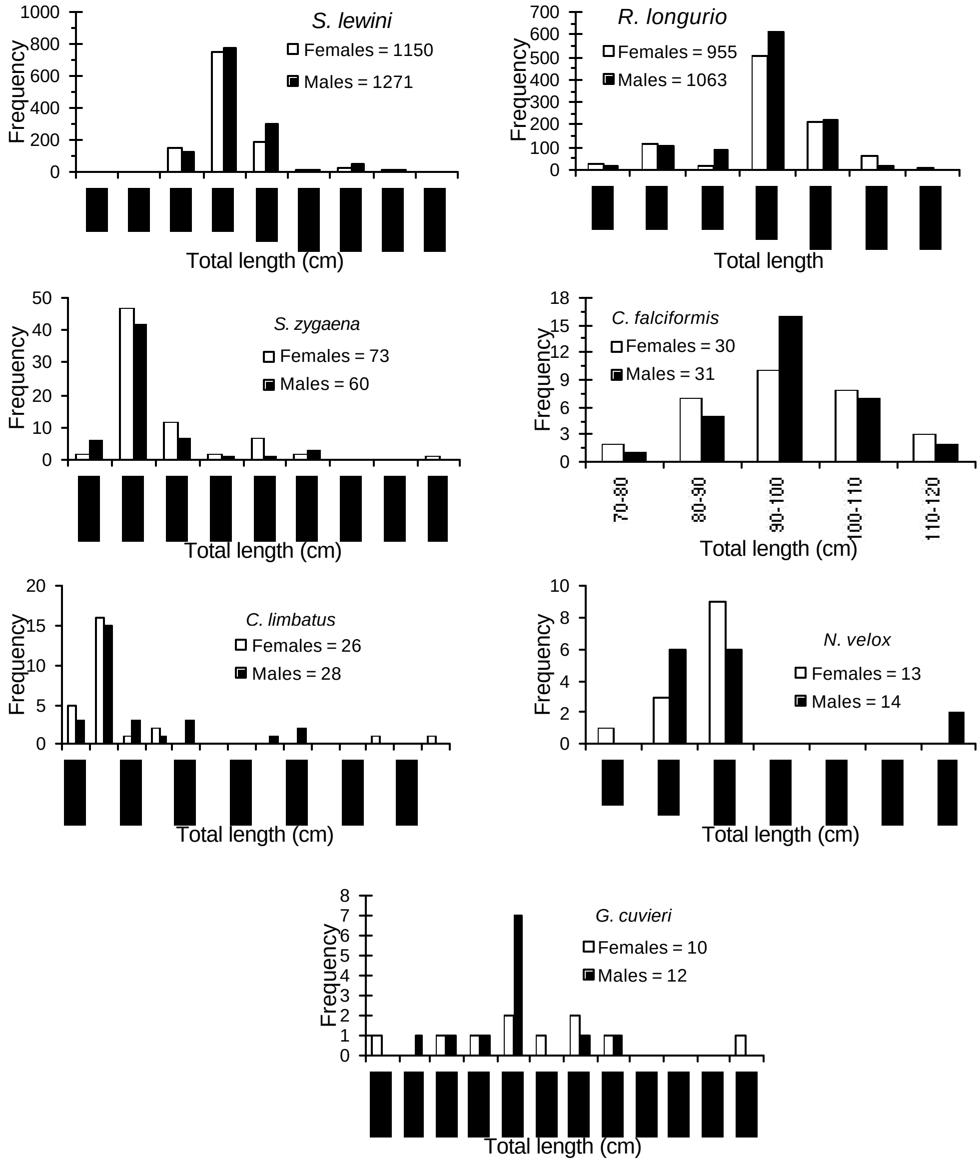


Fig. 4. Length-frequency distributions for the main species caught around Isabel Island.

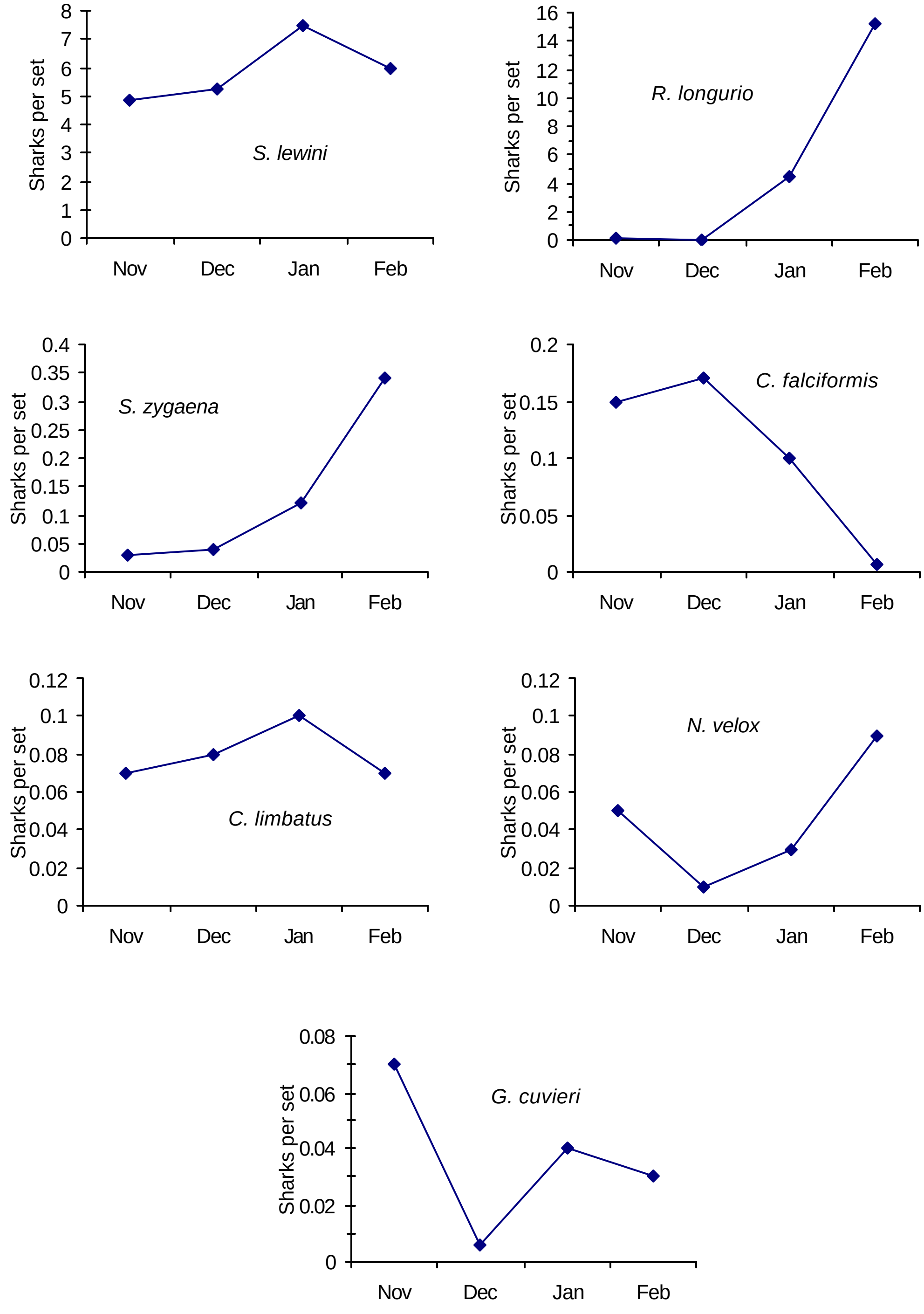


Fig. 5. Catch per unit effort (number of sharks per set) using bottom longline (hook No. 5) of the main species caught around Isabel Islands throughout the fishing season.

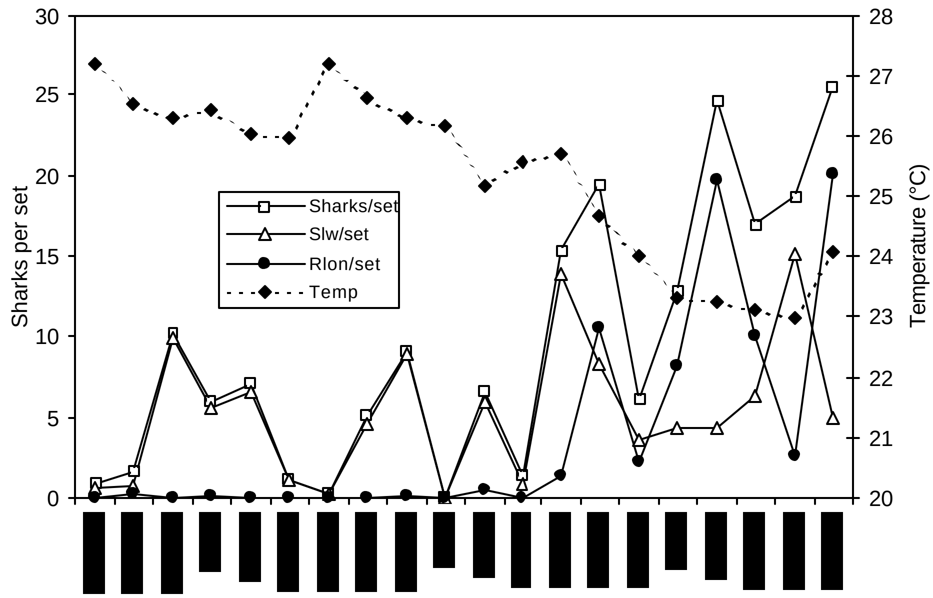


Fig. 6. Sharks per set, scalloped hammerhead *S. lewini* per set and sharpnose shark *R. longurio* per set with relation to the temperature. Time series every five days.

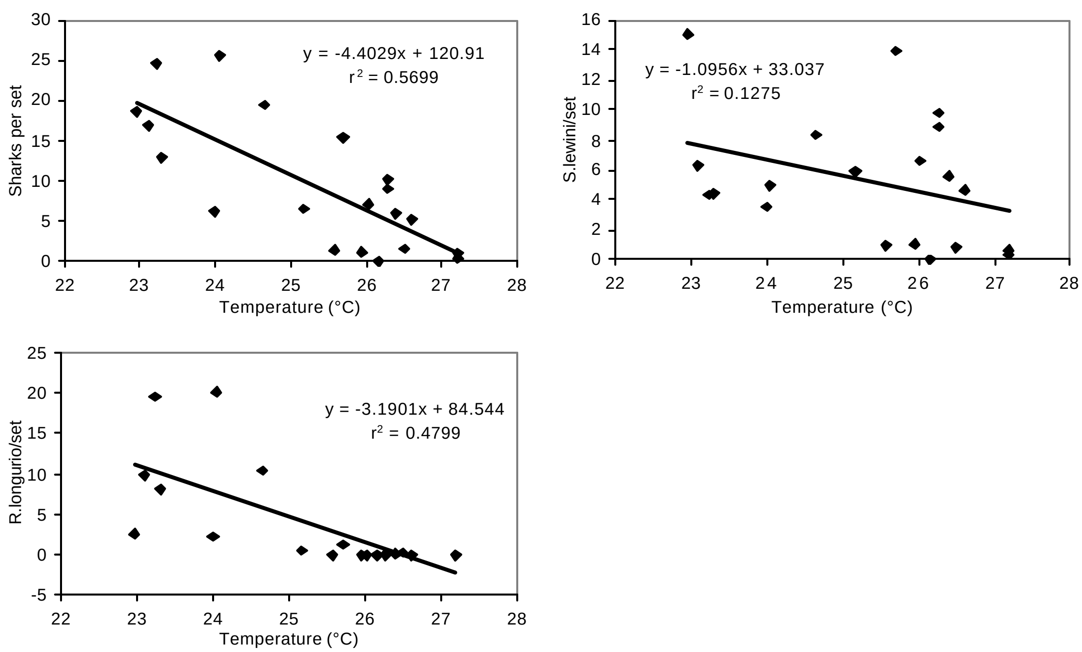


Fig. 7. Linear regressions between sharks per set, scalloped hammerhead *S. lewini* per set and sharpnose *shark R. longurio* with temperature.

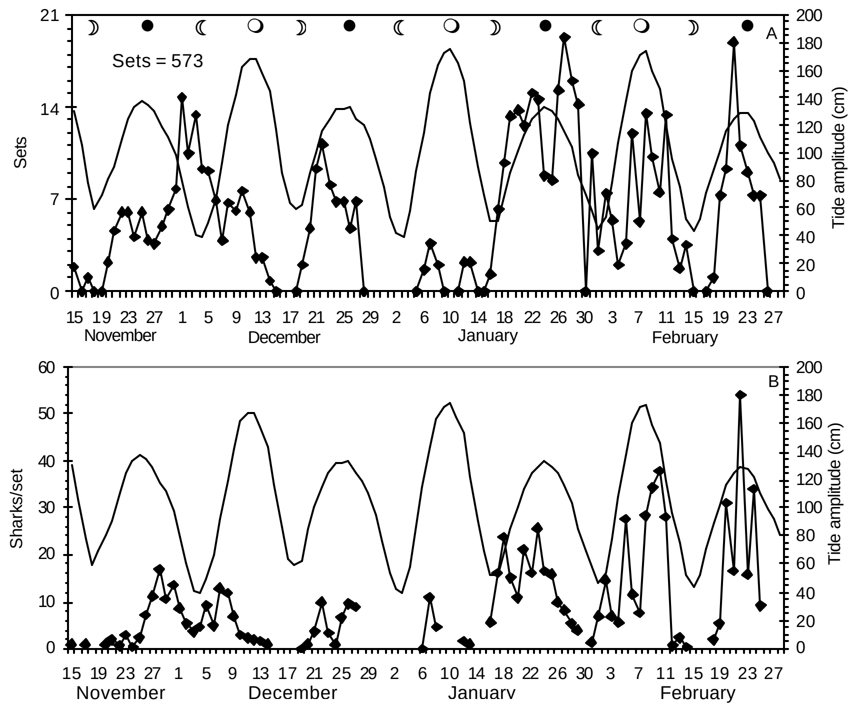


Fig. 8. Number of sets using bottom longline (hook No. 5) and sharks per set with relation to the tide amplitude throughout the fishing months. Tide amplitude as indicator of lunar cycle.

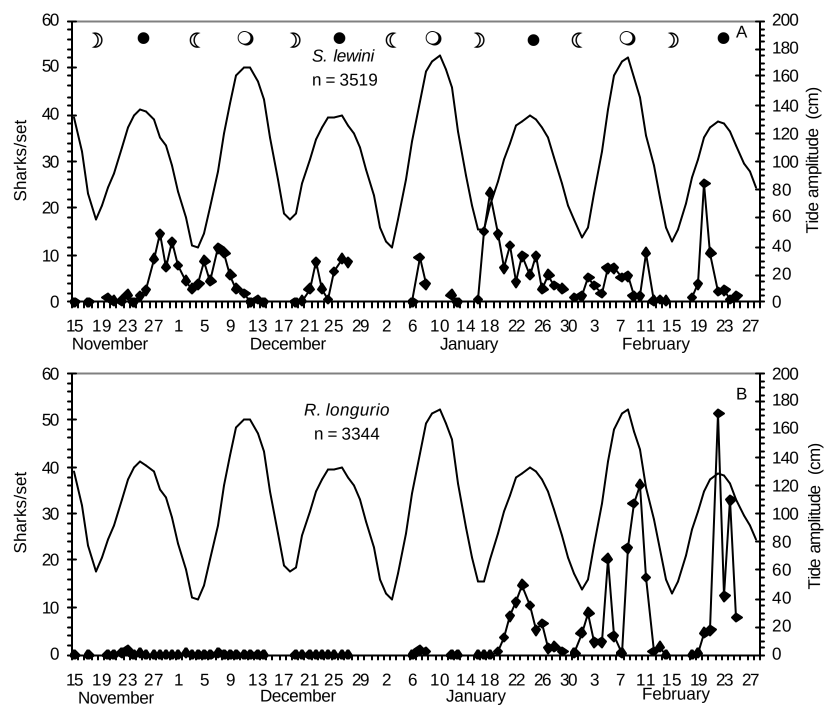


Fig. 9. Scalloped hammerhead *S. lewini* per set (A) and sharpnose shark *R. longurio* per set (B) using bottom longline (hook No. 5), with relation to the tide amplitude throughout the fishing months. Tide amplitude as indicator of lunar cycle.

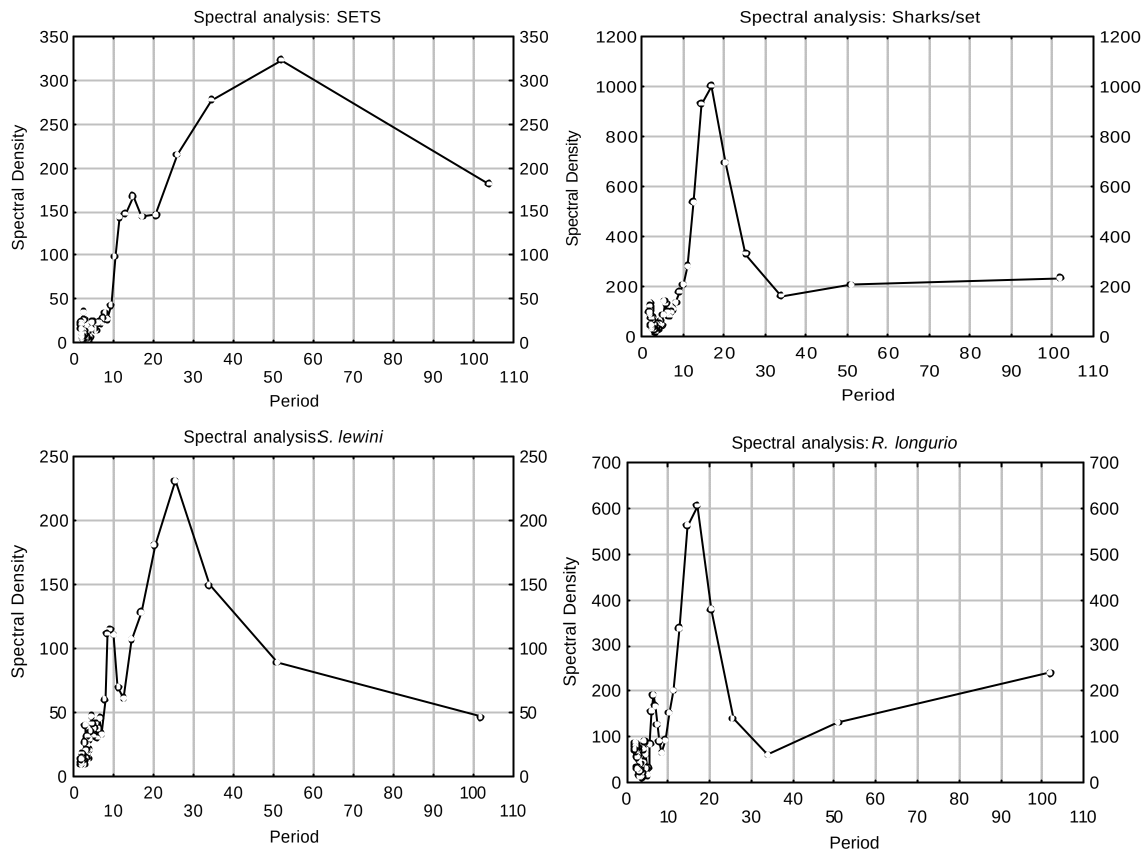
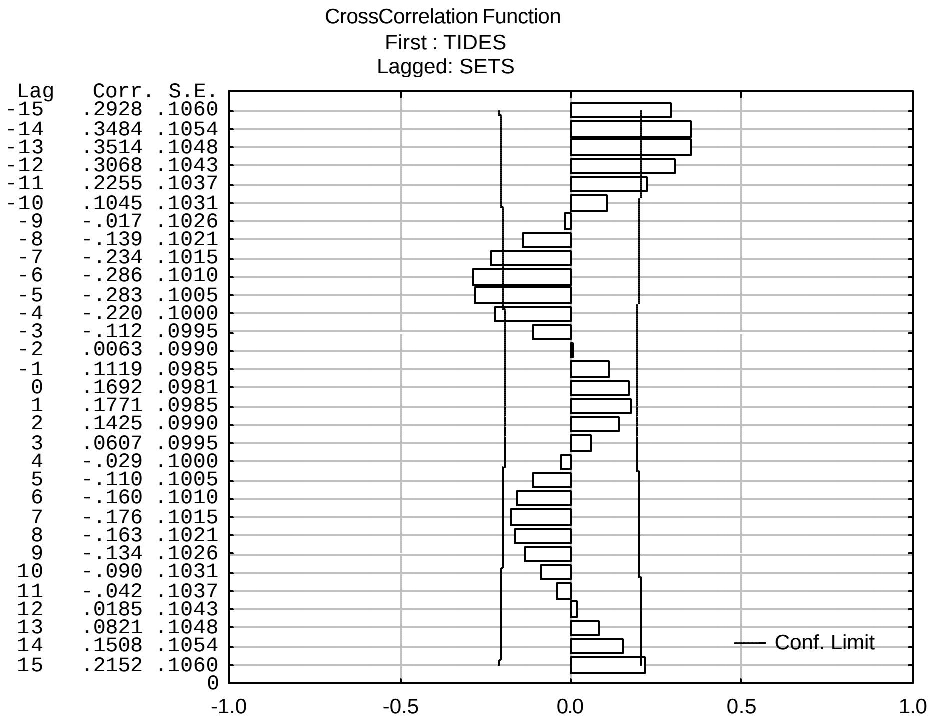


Fig. 10. Periodogram values by period obtained by means of the spectral analysis.



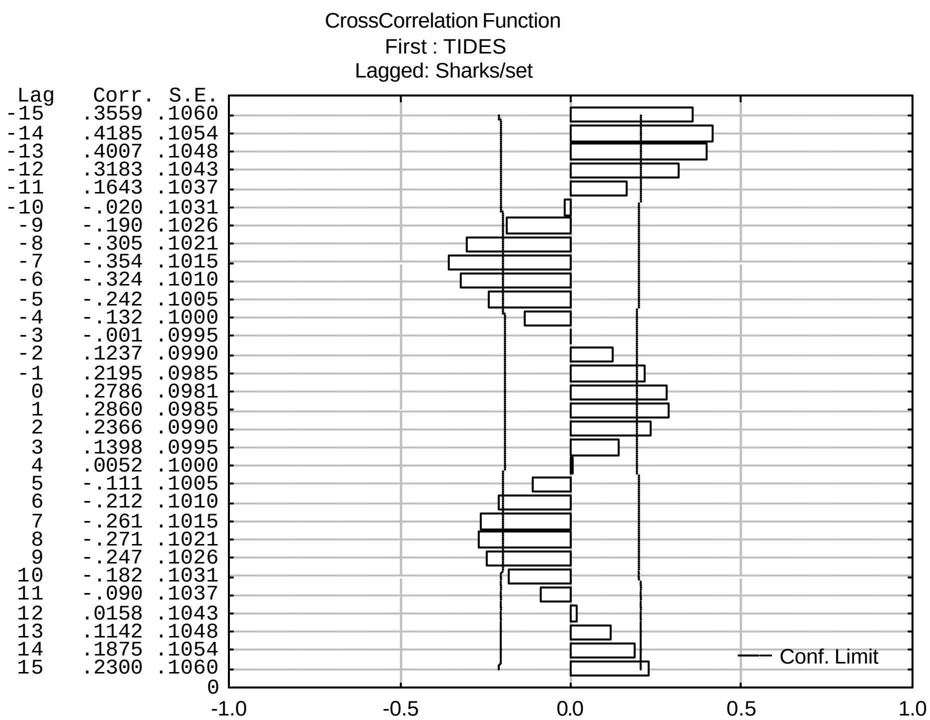


Fig. 11. Number of sets and sharks per set with relation to the tide amplitude (as indicator of the lunar cycle) in a cross correlation analysis.

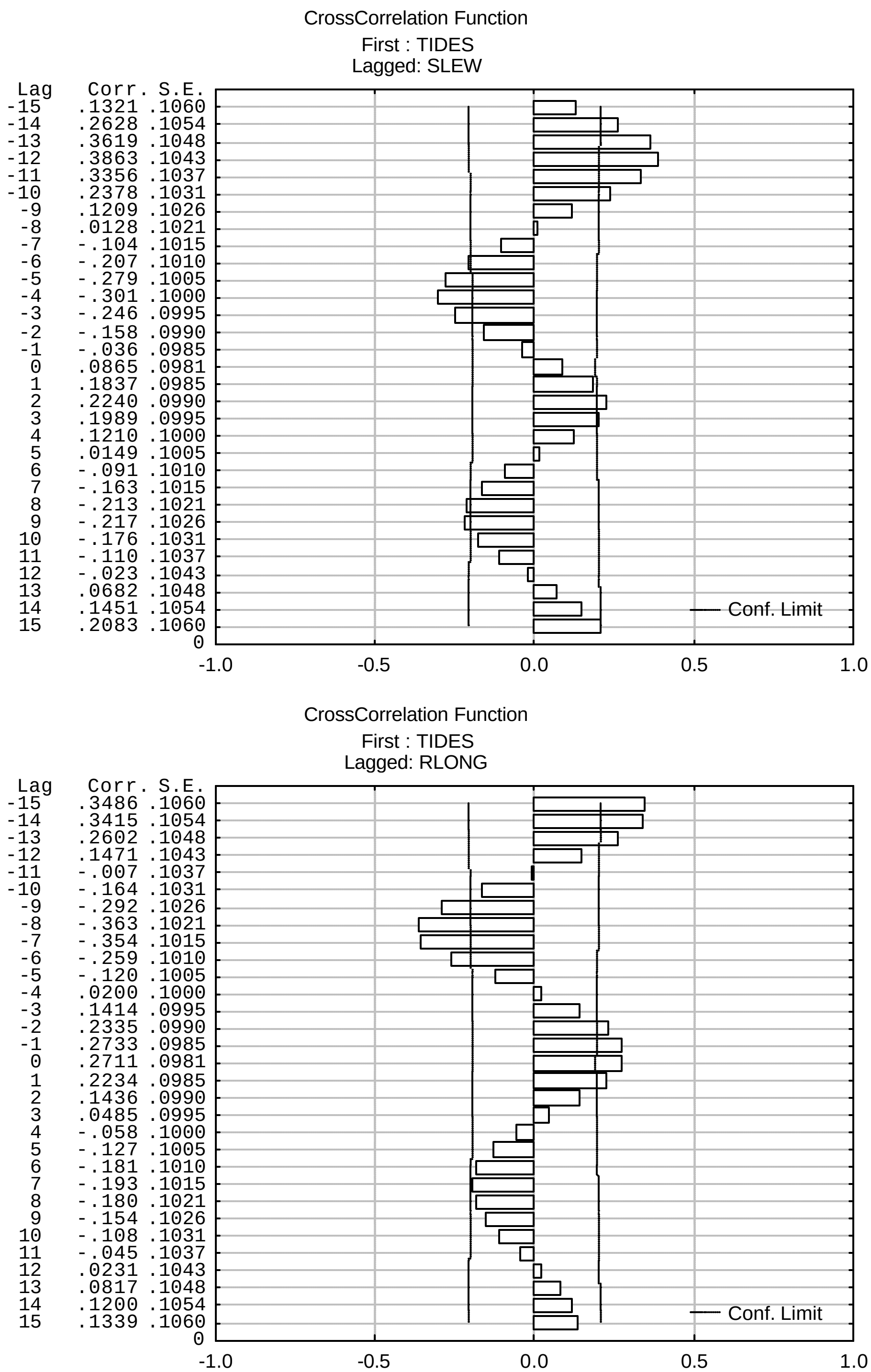


Fig. 12. Scalloped hammerhead *S. lewini* per set and sharpnose shark *R. longurio* per set with relation to the tide amplitude (as indicator of the lunar cycle) in a cross correlation analysis.