Burgess, E.; Dimech, M.; Caruana, C.; Darmanin, M.; Raine, H. & Schembri, P.J. (2010) Non-target by-catch in the Maltese bluefin tuna (*Thunnus thynnus*) longline fishery (Central Mediterranean). [ICCAT SCRS/2009/059] *ICCAT Collective Volume of Scientific Papers* 65(6): 2262-2269.

SCRS/2009/059

NON-TARGET BY-CATCH IN THE MALTESE BLUEFIN TUNA (*THUNNUS THYNNUS*) LONGLINE FISHERY (CENTRAL MEDITERRANEAN).

Emma Burgess[1] Mark Dimech[2*], Raymond Caruana[2], Michael Darmanin[2], Helen Raine[3], Patrick J. Schembri[4]

1. Centre for Wildlife Assessment & Conservation (CWAC), University of Reading, U.K, email: jigglypuff89@hotmail.com
2. Malta Centre for Fisheries Sciences (MCFS), Fort San Lucjan, Marsaxlokk BBG 1283, Malta, email: mark.dimech@gov.mt, Michael-j.darmanin@gov.mt, raymond.caruana@gov.mt
3. Birdlife Malta, 57/28, Marina Court, Abate Rigord Street, Ta' Xbiex MSD 2080 Malta, email: helen.raine@birdlifemalta.org
4. Department of Biology University of Malta, Msida MSD2080, Malta, email: patrick.j.schembri@um.edu.mt

*corresponding author: mark.dimech@gov.mt

SUMMARY

The Bluefin Tuna longline fishery is one of the most important pelagic fisheries in the Mediterranean but recently there has been increasing concern about the catches of non-target species. This study presents an assessment of the non-target by-catch from the Maltese Bluefin Tuna longline fleet and examines the effect of various environmental and spatiotemporal factors on non-target species catch rates. Field observations were made during 85 fishing days. In terms of number, Bluefin Tuna comprised a relatively small portion of the total catch while the Loggerhead Turtle (Caretta caretta) was the predominant by-catch species. Catch Per Unit Effort (CPUE) was calculated in terms of weight (kg/1000hooks/hr) and number (no/1000hooks/hr) for all the species caught. General Linear Mixed Models (GLMMs) were applied to examine the effect of environmental and spatiotemporal variables on non-target by-catch CPUE. The model for CPUE (number) was not found to be significant. Date, lunar cycle, species and longitude were found to be significantly correlated with CPUE (weight). The results of this study suggests the need for the continual implementation of mitigation measures to minimise the impacts of fishing activities on threatened non-target species in the Mediterranean.

KEYWORDS

Long lining, tuna fisheries, by-catch, CPUE, environmental factors

Introduction

In recent years there has been a global expansion of fishing activity without much regard for sustainable management resulting in more than two-thirds of global fisheries being categorized as fully exploited, overexploited or depleted (Botsford *et al*. 1997). Another concern arising from this is by-catch, which refers to non-target organisms that become hooked or entangled in the fishing gear (Soykan *et al*., 2008). Alverson *et al*. (1994) estimated mean global by-catch at between 17.9 - 39.5 million metric tonnes annually, or 31% of total marine fisheries catch at that time. This makes by-catch a major management and conservation issue, especially with the incomplete data associated with fisheries worldwide. Data on by-catch are even more limited as this information cannot rely solely on reported landings but requires on-board observers or the keeping of logbooks, which is expensive (Lewison *et al*, 2004).

Pelagic longlines are one of the main methods of catching fish worldwide, targeting mainly tuna, swordfish and billfish. Erzini *et al*. (1996) investigated species and size selectivity of longlines using different hook sizes and found that all hook sizes caught a wide variety of size classes of non-target species. Apart from poor selectivity and widespread use, pelagic longlines cover large spatial areas since a single longline can be many kilometres in length. Therefore, the incidental mortality of elasmobranches, sea birds and turtles on these longline hooks requires immediate attention (Brothers *et al*. 1999).

The Mediterranean Sea contains important biological diversity, with many species at risk of extinction, but is characterised by high fishing intensity; it is estimated that 2.3 million pelagic longline hooks are set each year, with large pelagic species contributing ca 4% of the reported landings (Ancha, 2008). Here we present a preliminary assessment of non-target by-catch resulting from the Maltese pelagic longline fleet operating in the central Mediterranean. The influence of various environmental and spatiotemporal factors was also examined to determine their effect on catch rates.

Methodology

Field observations were made on board six different longline vessels in the period 30 April to 30 June 2008 during 85 fishing days, with a total fishing effort of 109,155 hooks and an average 1, 284 hooks/ day. Fishing activity was concentrated in the Central Mediterranean, between N34’47.167, E012’19.850 and N36’50.200, E015’13.853 (Figure 1).

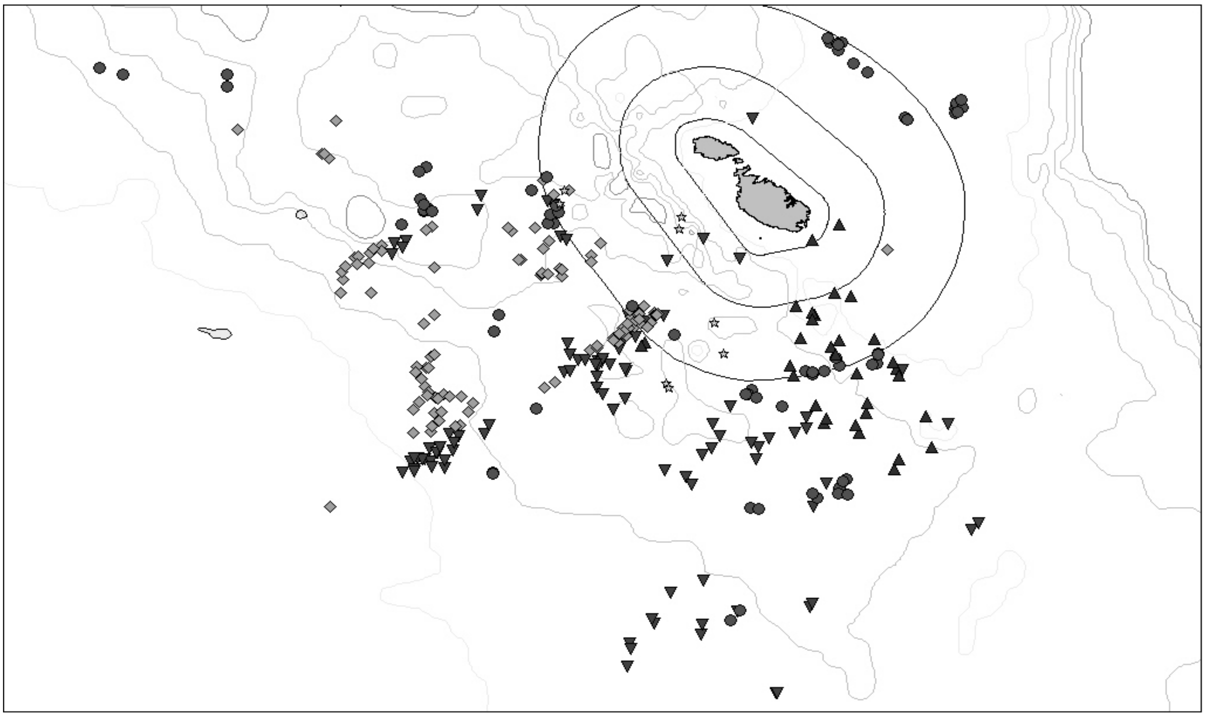

Figure 1 Map showing fishing stations for each vessel during the study period. Each symbol corresponds to a different fishing vessel. The 25 Nautical Mile isobar (the outermost one) indicates the boundary of the Malta Fisheries Management Zone.

The target species was Bluefin Tuna (*Thunnus thynnus*) and depending on the size of the vessel, between 500 and 1800 hooks were set on each line. The most common bait used was mackerel (*Scomber* spp.) and Japanese Squid (*Illex coindetti*). For each fishing operation, data on location, number of hooks deployed, and mean soaking time was recorded together with detailed data on the individuals caught including length (cm) and estimated weight (kg).

The mean soak time was defined as the difference between the mean setting time and mean hauling time. Catch-Per-Unit-Effort (CPUE) was expressed in number of individuals caught/1000 hooks/ hour (N) and calculated for individual species on each fishing day using the following equation:

$$N = ((n/x)*1000)/t$$

Were $\boldsymbol{n}$ = *total number captured*; $\boldsymbol{x}$ = *total number of hooks deployed* and $\boldsymbol{t}$ = *average soak time*.

CPUE was also expressed as weight (kg/1000 hooks/hour) (W) and calculated for individual species on each fishing trip using the following equation:

$$W = ((w/x)*1000)/t$$

Were w = *total weight/kg* of each species captured.

Hence two measures of CPUE were used for the analysis CPUE (wt) and CPUE (no).

Two separate analyses were made to investigate what factors influence CPUE (wt) and CPUE (no). Species, wind speed, wind direction, temperature, lunar phase, date, latitude and longitude were set as independent variables in a Generalized Linear Mixed Model (GLMM), using a Poisson distribution, a log transformation and CPUE (wt) and CPUE (no) as the response variables. The Poisson distribution and log transformation of CPUE were chosen on account that the data was over-dispersed (Elston *et al*. 2001) while GLMMs were selected to allow fixed and random factors to be added; vessel and observer were included as random factors to account for variation resulting from these variables. All analyses were conducted in GenStat 6^{th} edition (VSNi, 2008). MapInfo Professional, version 8.5 was utilized to plot the location of the vessel on each fishing day.

Results

The observers recorded 94 individual Bluefin tuna (*Thunnus thynnus*) totalling 9,767.1 kg caught on the tuna longline, during this study. This represented only 11.8% of the total catch in number but 65.7% of the total catch in weight. The remainder of the catch consisted of 13 other marine species, of which three species dominated in terms of number: Loggerhead Turtle (*Caretta caretta*), Broadbill Swordfish (*Xiphius gladius*), and Violet Stingray (*Pteroplatytrygon violacea*) (Table 1). When measured as a percentage of total catch in weight, the majority of the non-target by-catch was comprised of two species: 21.1% Broadbill Swordfish (*Xiphius gladius),* and 7.3% Loggerhead turtle (*Caretta caretta*) (Table 1).

Table 1. Species captured during the sampling period by Maltese tuna longliners fishing in the central Mediterranean expressed as a % of the total catch recorded in number and as a % of the total catch in weight. * refers to missing data.

Species		**Total Catch in no. (%)**	**Total catch in wt. (%)**
Loggerhead turtle	*Caretta caretta*	40.3	7.3
Broadbill swordfish	*Xiphius gladius*	31	21.1
Bluefin tuna	*Thunnus thynnus*	11.8	65.7
Violet or Pelagic stingray	*Pteroplatytrygon violacea*	9.8	0.7
Dolphin fish	*Coryphaena hippurus*	2.5	1.3
Oilfish	*Ruvettus pretiosus*	1.6	0.1
Longfin tunny	*Thunnus alalonga*	1	0.2
Mediterranean spearfish	*Tetrapterus belone*	0.8	0.6
Blue shark	*Prionace glauca*	0.4	0.3
Ocean sunfish	*Mola mola*	0.3	0.5
Devil fish	*Mobula mobular*	0.3	1
Porbeagle shark	*Lamna nasus*	0.3	1.2
Silver scabbardfish	*Lepidopus caudatus*	0.1	*
Great White Shark	*Carcharodon carcharias*	0.1	*
TOTAL		100 (796 individuals)	100 (14, 871.5 kg)

Date, moon phase, longitude and species all had a highly significant effect on the log-transformed CPUE (wt) (Table 2) for all non-target by-catch species listed in Table 1. Wind speed (-0.06±0.04) and latitude (-0.79±0.25) had a negative effect on CPUE (wt) (figure 2). Date (0.018±0.01) and longitude (0.03±0.32) had a positive effect on CPUE (wt), while wind direction (0.0004±0.0005) and temperature (-0.007±0.07) had no effect.

Relative to phase 1 (new moon), the 5th lunar phase (full moon) had the highest positive effect on CPUE (wt) for all non-target by-catch species (Figure 3).

Blue shark (*P. glauca*) had the largest estimated positive effect on CPUE (wt) relative to Loggerhead turtle (*C. caretta*) i.e. total catch biomass of non-target species was higher when this species was captured (Table 3). Long-fin Tunny (*T. albacore*) had the largest estimated negative effect on CPUE (wt) relative to *C. caretta* i.e. total catch biomass of non-target species was lower if this species was captured (Table 3). Great White Shark and Silver Scabbardfish were not included in the model as data on their CPUE (wt) was missing.

The same model with the same variables was applied using the log-transformed CPUE (no) as the response variable; no factor resulted significant (Table 3).

Table 2 The fitted terms from the GLMM with CPUE (wt) and CPUE (no) as the response variable, their corresponding degrees of freedom (d.f.) and p-values. NS= not significant.

Fixed terms	**d.f.**	**Chi-Square probability (χ^2)**	
		CPUE (wt)	CPUE (no)
Date	1	<0.001	NS
Latitude	1	NS	NS
Longitude	1	<0.01	NS
Moon phase	7	<0.001	NS
Species	10	<0.001	NS
Temperature	1	NS	NS
Wind direction	1	NS	NS
Wind speed	1	NS	NS

Table 3 The estimated effect ± standard error of each non-target species on CPUE.

SPECIES	EFFECT	
	CPUE (wt)	CPUE (no)
M.mola	-0.21 (±0.61)	-2.54 (±0.45)
C.caretta	0 (±0.61)	-1.5 (±0.08)
C.hippurus	0.1 (±0.61)	-1.96 (±0.28)
L.nasus	0.69 (±0.61)	-3.12 (±0.43)
M.mobular	-0.21 (±0.61)	-1.91 (±0.51)
P.glauca	1 (±0.61)	-2.67 (±0.44)
P.violacea	-1.97 (±0.61)	-1.58 (±0.19)
R.pretiosus	-2.54 (±0.61)	-1.90 (±0.24)
T.belone	-0.66 (±0.61)	-2.19 (±0.29)
T.alalonga	-1.44 (±0.61)	-1.72 (±0.35)
X.gladius	0.09 (±0.61)	-1.49 (±0.07)

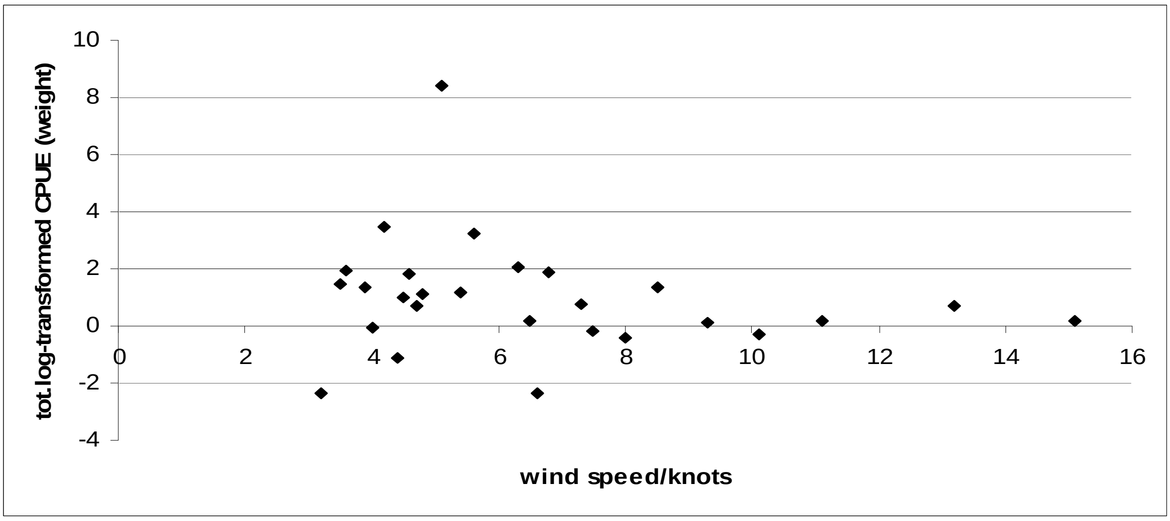

Figure 2 Scattergraph showing the effect of wind speed/knots on the total log-transformed CPUE (wt) of non-target by-catch species during the present study.

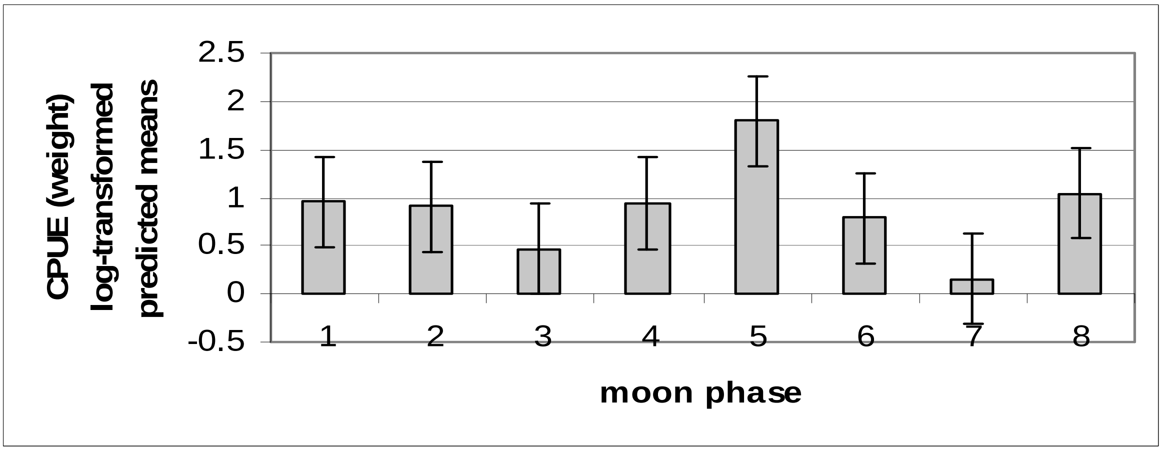

Figure 3 The predicted mean log-transformed CPUE (weight) of non-target by-catch species in the present study for different lunar cycles. The error bars represent the standard error.

Discussion

When measured as numbers of individuals captured, non-target species far outnumbered the target species (Bluefin Tuna). Loggerhead turtles (*Caretta caretta*) were the most abundant non-target by-catch species.

High catch rates of Broadbill Swordfish were also recorded. In summer this species migrates towards temperate and cold waters from the warmer waters it resides in over autumn and winter (Damalas *et al.* 2005). This coincides with the migration of Bluefin Tuna into the Mediterranean Sea. Carey & Robinson (1981) reported that Swordfish preferred to stay at a depth of ca 90m during the day and move up to the surface at night, while Holts *et al.* (1994) found that these fish spent about 75% of their time at depths between 10-50m or just below the upper mixed layer, therefore bringing them into contact with the pelagic tuna longlines. This agrees with a study carried out in the Pacific that found swordfish catch to primarily result from by-catch in longline fisheries targeting Bigeye (*Thunnus obesus*) and Southern Bluefin tuna (*Thunnus maccoyii*) (New Zealand Fish. Serv. 2006).

In terms of weight of individuals captured, the target species accounted for the majority of the total catch, compared to the non-target by-catch. Two factors contributed to this: (a) weight of by-catch species was underestimated as not all observers provided weight data on these, and (b) the sheer weight of Bluefin Tuna compared to any of the other species captured. The average weight of an individual Bluefin tuna captured by the vessels under investigation was 105.3kg, compared with an average weight of 13.3kg for loggerhead turtles captured.

The model analysing CPUE (no) was not explained by any of the eight environmental or spatio-temporal factors used. This could be due to the large variation in numbers of small species captured compared to large species.

For the model analysing CPUE (wt), date were found to be having a positive effect with an increasing trend from May through to June. As an explanatory variable this incorporates environmental factors such as temperature, as well as biological factors such as migration of certain species through the central Mediterranean. During the summer months, loggerhead turtles move into shallower waters to breed on beaches in the area i.e. Sicily, Lampedusa, Tunisia, Libya, Cyprus, Greece and Turkey. Baez *et al*. (2006) found the capture of sea turtles and swordfish hard to avoid when targeting Bluefin Tuna off southern Spain as these species have a similar distribution at this time of year.

The Mediterranean is also an important breeding area for the Broadbill Swordfish which moves into shallower waters in late spring through summer to spawn.

The results suggest that the highest rate of by-catch CPUE (wt) occurs during the full moon period. The behaviour of many animals is known to be attuned to the phases of the moon. Di Natale & Mangeno (1995) reported a significant relationship between phases of the moon and CPUE of swordfish in the Italian driftnet fishery, as well as for the total catch. Two possible reasons suggested were: (a) behaviour is affected by the different ambient light produced at night by the moon, and (b) a change in distribution of prey species. This is consistent with a study carried out by Santos & Garcia (2005), who investigated the effect of moon phase on CPUE of swordfish in the Portuguese fishery. These authors found that the full moon plays an important role in horizontal and vertical movements associated with prey location in swordfish.

Gandini & Frere (2006) found by-catch in the Argentinean longline fishery to be significantly affected by moon phase, with 65% of the seabird by-catch occurring 5 days before and 5 days after the full moon, which concurs with the hypothesis that seabird by-catch is reduced by darkness.

The present study demonstrated a spatial effect in that fishing further north decreased CPUE (wt) of non-target by-catch. Maltese fishers believe that bigger catches are obtained closer to Libya (south of Malta) as this area has not experienced the intense fishing effort found elsewhere in the Sicilian Channel.

An increase in CPUE (wt) was noted towards the east of the study area. Megalofonou *et al.* (2005) also found area to be a significant factor affecting the incidental capture of sharks by the tuna and swordfish longline fisheries in the Mediterranean. Location embraces information on habitat and bathymetry for example, which are important factors associated with the presence or absence of particular species. However, it should be noted that fishing activity tends to be concentrated in certain areas, leading to a masking of the actual situation i.e. fishers do not spread their activity evenly over space and time. This is a continual problem associated with most fisheries studies.

As the wind speed increased CPUE (wt) decreased. When wind speed reached >7 knots, CPUE (wt) decreased significantly. One reason for this could be that very little fishing activity occurred when wind was greater than force 4 or 5, therefore producing a malapportioned effort.

Highest total CPUE (wt) was obtained when wind speed reached 4-5 knots. Maltese fishers felt this was because the bait moved more, therefore giving the impression it was alive and so helping to attract predators.

The main aim of this study was to present a preliminary assessment of non-target by-catch resulting from the Maltese tuna pelagic longline fleet operating in the central Mediterranean. Data on by-catch species in the Mediterranean is seriously lacking. In a review Cooper *et al.* (2003) reported that quantitative data on seabird by-catch was only available for Spain. The present results indicate that the Maltese pelagic longline fleet is not exempt from the global problem of non-target by-catch, however the threatened (IUCN) Loggerhead turtle (*Caretta caretta*) and the Pelagic Stingray (*Pteroplatytrygon violacea*) by-catch are the greatest concern as opposed to seabird by-catch, which resulted to be negligible.

Acknowledgements

We would like to express our thanks to all the Maltese fishers who allowed us to join them on their trips. Our appreciation also goes out to Carlos Barahona from the Statistics Advisory Centre at Reading University and Alan Harrison from the Statistics Advisory Centre at Queen's University.

References

Alverson, D.L.; Freeberg M.H.; Pope J.G. and Murawski S.A. 1994. A global assessment of fisheries bycatch and discards. FAO Fisheries Technical Paper 339.

Ancha, L. 2008. Regional by-catch of long-lived species (sea birds, marine mammals and sea turtles) in the Mediterranean and Black Seas. http://hdl.handle.net/10161/478

Báez, J.C., Camiñas, J.A. & Rueda, L. 2006. Incidental Capture of Marine Turtles in Marine Fisheries of Southern Spain. Marine Turtle Newsletter 111:11-12.

Botsford, L.W., Castilla, J.C., Peterson, C.H. 1997. The Management of Fisheries and Marine Ecosystems. Science 277:509 - 515

Brothers, N.P; Cooper, J. and Lokkeborg, S. 1999. The incidental catch of seabirds by long line fisheries: worldwide review and technical guidelines for mitigation. FAO Fisheries Circular No.937.

Carey, F.G. and Robinson, B.H. 1981. Daily patterns in the activities of swordfish, *Xiphius gladius,* observed by acoustic telemetry. U.S. Nat. Mar. Fish. Serv. Fish. Bull., 79(2): 277- 292.

Cooper, J.; Baccetti, N., Belda, E.J.; Borg, J.J.; Oro, D.; Papconstantinou, C. and Sanchez, A. 2003. Sea bird mortality from long line fishing in the Mediterranean Sea and Macaronesian waters: a review and a way forward. Scientia Marina 67 (suppl.2): 57-64.

Damalas, D., Apostolopoulou, M. and Megalofonou, P. 2005. Environmental, spatio-temperal and operational effects on long-line swordfish catch rates in the Eastern Mediterranean Sea. ICES CM 2005/0:33.

Di Natale, A. & A. Mangano. 1995. Moon phase influence on CPUE: a first analysis of swordfish driftnet catch data from the Italian fleet between 1990 and 1991. Collect. Vol. Sci. Pap. ICCAT. 44: 264-267.

Elston, D.A., Boulinier, T., Arrowsmith, C. and Lambin, X. 2001. Analysis of aggregation, a worked example: numbers of ticks on red grouse chicks. Parasitology 122: 563-569.

Erzini, K.; Gonçalves, J.M.S; Bentes, L.; Lino, P.G. and Cruz, J. 1996. Species and size selectivity in a Portuguese multispecies artisanal long-line fishery. ICES Journal of Marine Science 53(5): 811-819.

Gandini, P. and Frere, E. 2006. Spatial and temporal patterns in the bycatch of seabirds in the Argentinian longline fishery. Fish. Bull. 102: 482-485.

Holts, D.B., Bartoo, N.W. and Bedford, D.W. 1994. Swordfish tracking in the Southern California Bight. U.S. Nat. Mar. Fish. Serv. Southwest Fish. Sci. Center, Admin. Rep., LJ 94-15: 9p.

Megalofonou, P.; Yannopoulos, C.; Damalas, D.; De Mitrio, G.; Deflorio M; de la Serna, J.M. and Macias D. 2005. Incidental catch and estimated discards of pelagic sharks from the swordfish and tuna fisheries in the Mediterranean Sea. Fish. Bull., 103:620-634.

New Zealand Fisheries Services 2006. Swordfish (*Xiphius gladius*),.http://services.fish.govt.nz/fishresourcespublic/Plenary2006/SWO_06.pdf

Lewison, R.L., Crowder, L.B., Read, A.J. and Freeman, S.A. 2004. Understanding impacts of fisheries by-catch on marine megafauna. Trends in Ecology and Evolution 19(11): 598-604.

Santos M.N.D. and Garcia A. 2005. The influence of the moon phase on the CPUEs for the Portuguese Swordfish (*Xiphius gladius* L., 1758) Fishery. Col. Vol. Sci. Pap. ICCAT 58(4): 1466-1469.

Soykan CU., Moore JE., Zydelis R., Crowder LB., Safina C., Lewison RL. 2008. Why study by-catch? An introduction to the theme Section on Fisheries By-catch. Endangered Species Research, 5: 91-102

VSN International, Software for bioscience, 2008. http://www.vsni.co.uk/resources/training/genstat-resources/