Effect of Target Strength equation selection on PELGAS anchovy and sardine biomass estimates

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Introduction

Knowledge of the acoustic response of single fish (or Target Strength: TS) is of prime importance for acoustic target classification (Barange, 1994; Doray *et al.*, 2006), and abundance estimation (Rose, 1992; Jech and Horne, 2001). TS is hence the scaling factor used to convert acoustic density (NASC) into fish density. TS is classically expressed in dB as a function of total fish length Lcm in cm as:

TS = 20log10(Lcm) – b20 Eq. 1

where b20 is a species specific parameter.

Ifremer uses b20 = 71.2 (taken from the work of (Edwards *et al.*, 1984) on 7-27 cm herrings), and IEO, AZTI, IPMA use b20 = 72.6 (taken from the work of Degnbol et al. (1985) on 19-26 cm herrings&sprats to assess anchovy biomass, . Another classical b20 value was provided by (Foote, 1987 for physostoms: 71.9.

Fish density is classically expressed in fish per square nautical mile as a function of fish TS as:

Fish density = NASC / (10^(TS/10)) Eq. 2

Fish swimbladder produces at least 90% of swimbladdered fish (Foote, 1980). The swimbladder compresses with pressure at depth, which induces a decrease of the fish TS with increasing depth.

The effect of pressure on swimbladder volume and fish TS has been namely investigated by:

i) (Ona, 2003), who proposed an expanded target-strength relationship for herring. (IJMS, 60: 493–499), based on an extensive set of TS measurements on 32 cm Herring, conducted in situ from 40 to 470 m and ex situ from 0 to 100m deph:

TS = 20log10(Lcm) – 65.4 – 2.3log10(1+depth/10) Eq. 3

Ona’s work suggest that the swimbladder compression with depth could be less than what would be predicted by Boyle’s law for a free balloon model.

ii) (Zhao *et al.*, 2008) measured in situ TS of 6-15cm japanese anchovy in situ, during 1night, between 10 and 45m depth and derived another equation, which is in line with Boyle’s law:

TS = 20log10(Lcm) – 67.6 – (23/3)log10(1+depth/10) Eq. 4

The figure 1 presents these TS(Lcm) relationships at different depths.

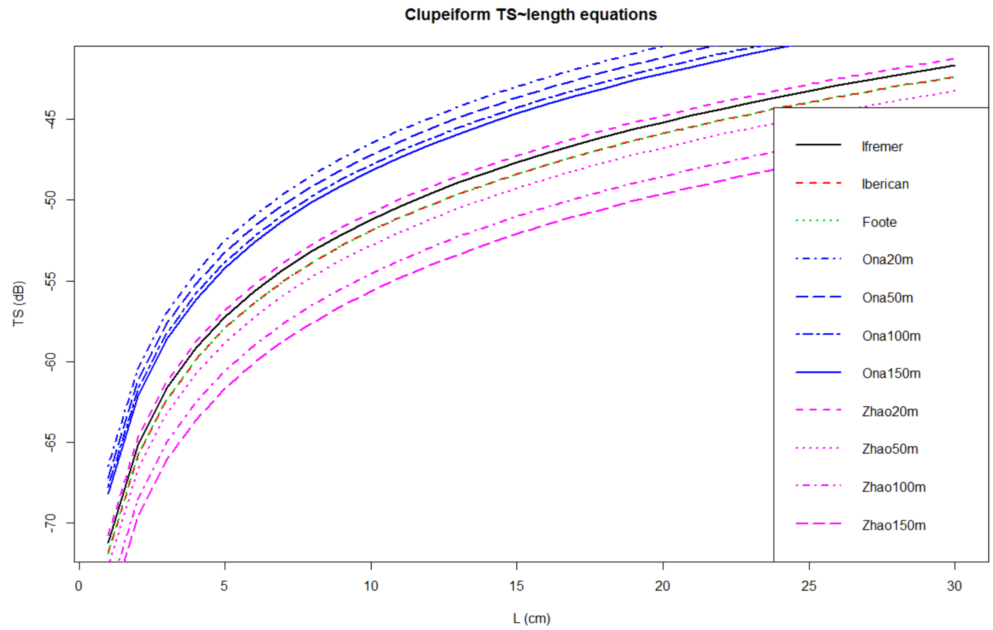

Figure 1. TS~length equations predictions

Ifremer, Iberican and Foote (1987)'s TS(Lcm) equations predictions are close. Within the depth range sampled by the PELGAS survey (20-150 m), Ona (2003)'s equation predicts higher TS values than Ifremer, Iberican and Foote (1987)'s equations, whereas Zhao(2008) 's equation predicts lower values. The differences between TS predictions mainly stem from differences in the b20 constant, which is inversely proportional to TS. The depth correction term yields lower magnitude TS differences, the TS decreasing with depth.

Acoustic biomass estimates of small pelagic fish provided by WGACEGG are proxies of the real fish biomass, whose inter-annual variations must be considered in relative terms. Changing the b20 term in the TS equation used to derive such biomass estimates has hence no effect on the biomass trends provided to the stock assessment groups for a given species. It has however been postulated that inter-annual changes in the depth distribution of Bay of Biscay anchovy might have a significant and non linear effect on the acoustic biomass estimates, if a depth correction term was included in the TS equation (ICES, 2016).

In this paper, we aim at assessing the respective effects of b20 and depth correction terms on anchovy biomass acoustic estimates derived from the PELGAS survey, in order to evaluate the magnitude of a potential non linear effect of fish depth on acoustic biomass estimates. The survey data are re-analysed using several TS equations with different b20 values and/or depth correction terms to assess the respective effects of each single term on PELGAS anchovy and sardine biomass estimates.

Material and methods

To investigate the respective effects of depth and b20 on anchovy and sardine Target Strength and biomass estimates, total biomass estimates and proportions at-age were re-computed for PELGAS 2012, 2014, 2015 and 2016 surveys, using either the Ona (2003)'s equation b20 (65.4 dB) without depth correction term, or the full Ona (2003)'s equation. The new sardine and biomass estimates were compared to the results obtained with Ifremer b20s, in order to assess the respective effects of b20 and depth correction terms on the essential population parameters provided to the WGHANSA assessment group (total biomass and age structure).

The surveys that were included in the re-analysis were selected to cover contrasted anchovy spring depth distributions. The anchovy depth distributions were assessed based on: i) the seabed depth at positive anchovy trawl haul locations, ii) the seabed depth at acoustic Elementary Sampling Distance Units (ESDU) locations, weighted by the anchovy acoustic biomass per ESDU, adjusted to take into account the typical anchovy school position in the water column. Anchovy mean depths per survey obtained with the 2 methods were compared.

The mean depth assigned to fish in the surface layer (ie. in surface hauls and echotypes) was 10 m. The actual depth of clupeiforms closer to the bottom was estimated as the seabed depth minus 20 m, based on the typical altitude of clupeiforms schools in the Bay of Biscay (Villalobos, 2008).

We applied the biomass assessment method per post-stratification region routinely used during the PELGAS surveys, described in details in (Doray *et al.*, 2010).

Results

The depth distributions of anchovy during all PELGAS surveys estimated based on trawl hauls data are presented in Figure 2. Summary statistics are presented in Table 1.

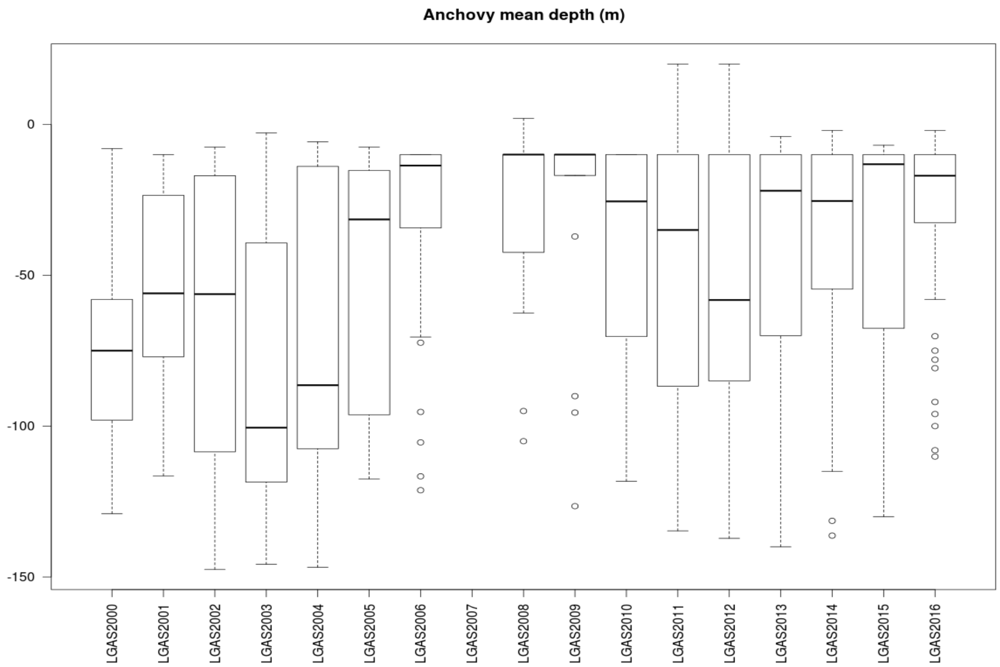

Figure 2: Anchovy depth distribution estimated based on seabed depth at anchovy positive hauls.

Survey	**Mean depth (m)**	**Median depth (m)**	**SD depth (m)**
PELGAS2000	70	75	34
PELGAS2001	53	56	31
PELGAS2002	65	56	47
PELGAS2003	81	101	46
PELGAS2004	73	86	48
PELGAS2005	54	32	41
PELGAS2006	33	14	35
PELGAS2008	25	10	28
PELGAS2009	28	10	36
PELGAS2010	41	26	38
PELGAS2011	50	35	43
PELGAS2012	55	58	43
PELGAS2013	42	22	41
PELGAS2014	40	25	35
PELGAS2015	39	13	40
PELGAS2016	28	17	27
Average	*49*	*40*	*38*
SD	*17*	*29*	*6*

Table 1: Anchovy depth mean, median and SD (m), based on seabed depth at positive haul locations.

The mean anchovy depths obtained based on seabed depths at the trawl haul and ESDU locations are presented in Figure 3.

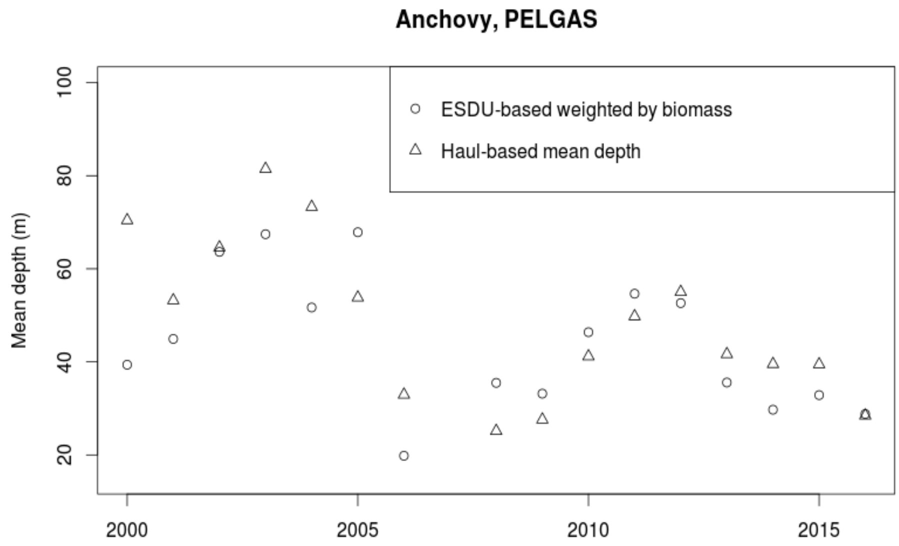

Figure 3: Mean anchovy depths estimated based on seabed depth at positive hauls locations (triangle) and ESDUs, weighted by anchovy biomass (circle).

The mean anchovy depths estimated with both methods are close, especially after 2007, thanks to the additional trawl hauls performed by commercial fishermen since 2007 (Figure 3). The seabed depth at the hauls locations appear to be a good proxy for estimating the anchovy depth.

The anchovy mean depth variations were moderate over the series, ranging from 25m (2008) to 81m (2003), around an average value of 49m (SD=38m).

The surveys included in the data re-analysis comprised a year characterised by a relatively deep anchovy distribution (2012, mean depth = 55m), contrasting with year with below average depth distributions (2014, 2015, 2016).

The anchovy and sardine biomass estimates obtained with the different TS equations are presented in Table 2. Biomass estimates obtained for all species are presented in Annex 1.

Species	**Cruise**	**Biomass (t) b20=71.2**	**Biomass (t) b20=65.4**	**Biomass (t) OnaTSzCor**	**Ifremer/OnaTSzCor biomass difference**	**Biomass difference induced by b20**	**Depth correction effect on biomass**
ENGR-ENC	*mean*	*28 186*	*33 483*	*33 483*	*-61%*	*-74%*	*13%*
ENGR-ENC	PELGAS2012	187 848	49 460	74 870	-60%	-74%	14%
ENGR-ENC	PELGAS2014	125 427	32 993	46 119	-63%	-74%	10%
ENGR-ENC	PELGAS2015	372 916	98 142	144 144	-61%	-74%	12%
ENGR-ENC	PELGAS2016	89 727	23 602	37 809	-58%	-74%	16%
SARD-PIL	*mean*	*29 636*	*28 857*	*28 941*	*-62%*	*-74%*	*12%*
SARD-PIL	PELGAS2012	206 510	54 387	82 004	-60%	-74%	13%
SARD-PIL	PELGAS2014	339 607	89 418	122 588	-64%	-74%	10%
SARD-PIL	PELGAS2015	416 524	110 073	179 123	-57%	-74%	17%
SARD-PIL	PELGAS2016	229 742	60 638	80 206	-65%	-74%	9%

Table 2. Anchovy and sardine biomass estimates obtained with different TS equations.

Using Ona (2003)'s equation leads to a mean decrease of 61% and 62% of the anchovy and sardine and biomass estimates, respectively. Using a 65.4 b20 parameter instead of 71.2 induces a reduction of biomass of 74%.

Using Ona (2003)'s depth correction induces an increase of 13% (anchovy) and 12% (sardine) biomass on average. The magnitude of the depth correction term effect does not seem to be related to the anchovy depth distribution, as estimated infra (Figure 4).

Figure 4: Depth correction effect on anchovy biomass as a function of anchovy mean depth derived from trawl haul data

No significant difference in the age structures (Figure 4) or CVs (Annex 1) estimates was found when comparing the results obtained with the different TS equations.

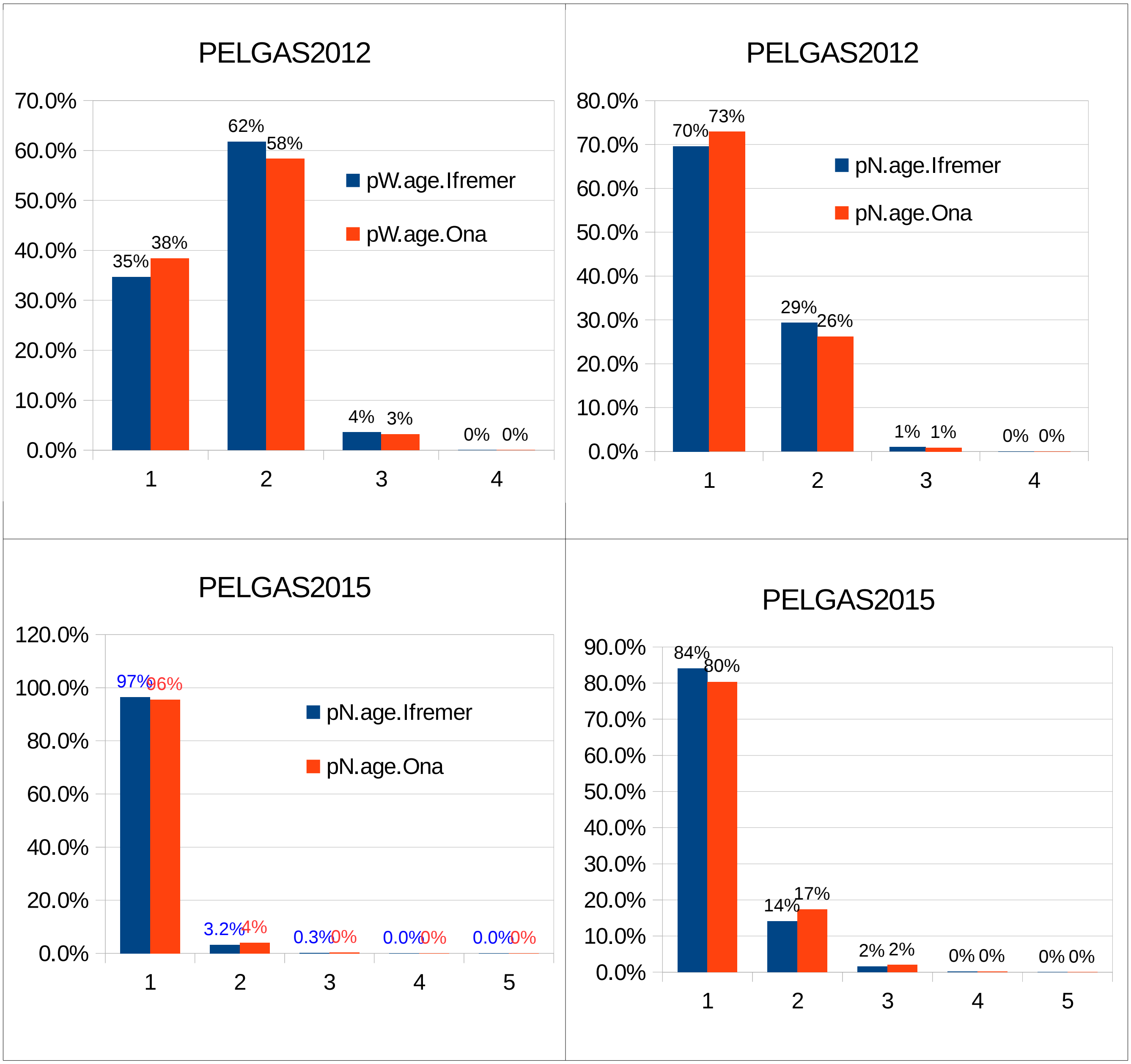

Figure 4. Anchovy age structure estimation in numbers (left panels) and weights (right panels) obtained with the Ifremer (blue) and Ona TS equations with PELGAS2012 (upper pannels) and PELGAS2015 (lower pannels) data.

Discussion and conclusions

No relationship was found between the anchovy TS depth correction effect and their mean depth estimated based on trawl haul data. This is certainly due to the fact that all trawl hauls do not have the same weight or influence in the biomass asssesement procedure: i) trawl data are weighted by the fish NASC in the vicinity of the haul, ii) as biomass are estimated within post-stratification regions, trawl hauls in regions with high mean NASC have more influence. The small difference between mean depths estimated based on haul data and on ESDU data, weighted by anchovy biomass, suggest that the segregation of trawl hauls per post stratification regions effect has probably more influence.

These results confirm that the main TS equation parameter influencing the spring Biscay anchovy and sardine biomass estimations is the b20. In comparison, the Ona (2003)'s depth correction term yields marginal and more or less constant changes in the biomass estimates. The hypothesis of a strong and non linear effect of a depth-correction term in the TS equation used to derive acoustic biomass estimates of anchovy or sardine in the Bay of Biscay is invalidated by these results.

The annual depth distributions of anchovies, as estimated based on PELGAS catch and ESDU data, show moderate variability, which does not seem to be related to biomass fluctuations.

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Annex

Species	Cruise	Biomass (t) b20=71.2	Biomass (t) b20=65.4	Biomass (t) OnaTSzCor	Ifremer/OnaTSzCor biomass difference	Biomass difference induced by b20	Depth correction effect on biomass	CV b20=71.2	CV b20=65.4	CV OnaTSzCor
CAPR-APE	PELGAS2014	17 593			-100%	-100%	0%	5%		
CAPR-APE	PELGAS2015	62 491	62 491	62 491	0%	0%	0%			
CAPR-APE	PELGAS2016	4 475	4 475	4 475	0%	0%	0%			
ENGR-ENC	*mean*	*28 186*	*33 483*	*33 483*	*-61%*	*-74%*	*13%*			
ENGR-ENC	PELGAS2012	187 848	49 460	74 870	-60%	-74%	14%			
ENGR-ENC	PELGAS2014	125 427	32 993	46 119	-63%	-74%	10%	9%	9%	10%
ENGR-ENC	PELGAS2015	372 916	98 142	144 144	-61%	-74%	12%			
ENGR-ENC	PELGAS2016	89 727	23 602	37 809	-58%	-74%	16%			
MERL-MCC	PELGAS2015	8 006	8 006	8 006	0%	0%	0%			
MERL-MCC	PELGAS2016	16 780	16 780	16 780	0%	0%	0%			
MERL-MNG	PELGAS2015	1 676	1 676	1 676	0%	0%	0%			
MICR-POU	PELGAS2012	73 390	72 876	73 125	0%	-1%	0%			
MICR-POU	PELGAS2014	28 704	26 236	26 236	-9%	-9%	0%	28%	28%	28%
MICR-POU	PELGAS2015	4 600	4 580	4 585	0%	0%	0%			
MICR-POU	PELGAS2016	11 852	11 735	11 820	0%	-1%	1%			
SARD-PIL	*mean*	*29 636*	*28 857*	*28 941*	*-62%*	*-74%*	*12%*			
SARD-PIL	PELGAS2012	206 510	54 387	82 004	-60%	-74%	13%			
SARD-PIL	PELGAS2014	339 607	89 418	122 588	-64%	-74%	10%	7%	7%	8%
SARD-PIL	PELGAS2015	416 524	110 073	179 123	-57%	-74%	17%			
SARD-PIL	PELGAS2016	229 742	60 638	80 206	-65%	-74%	9%			
SCOM-JAP	PELGAS2012	18 098	15 881	16 479	-9%	-12%	3%			
SCOM-JAP	PELGAS2014	14 793	14 025	14 034	-5%	-5%	0%	49%	50%	50%
SCOM-JAP	PELGAS2015	21 963	19 042	19 983	-9%	-13%	4%			
SCOM-JAP	PELGAS2016	111 206	111 199	111 204	0%	0%	0%			
SCOM-SCO	PELGAS2012	2 003 998	2 002 697	2 003 272	0%	0%	0%			
SCOM-SCO	PELGAS2014	841 360	1 251 347	1 251 975	49%	49%	0%	55%	37%	37%
SCOM-SCO	PELGAS2015	242 935	118 772	166 546	-31%	-51%	20%			
SCOM-SCO	PELGAS2016	3 339 690	3 297 308	3 335 193	0%	-1%	1%			
SPRA-SPR	mean	#REF !	#REF !	#REF !	-55%	#REF !	#REF !			
SPRA-SPR	PELGAS2012	6 580	1 731	2 101	-68%	-74%	6%			
SPRA-SPR	PELGAS2014	33 894	8 915	11 679	-66%	-74%	8%	28%	28%	28%
SPRA-SPR	PELGAS2015	91 248	24 001	30 224	-67%	-74%	7%			
SPRA-SPR	PELGAS2016	36 593	9 625	12 810	-65%	-74%	9%			
TRAC-MED	PELGAS2014	51 382			-100%	-86%	-14%	3%		
TRAC-MED	PELGAS2015	8 583	7 159	7 891	-8%	-17%	9%			
TRAC-MED	PELGAS2016	10 317	10 317	10 317	0%	0%	0%			
TRAC-TRU	PELGAS2012	11 852	11 814	11 826	0%	0%	0%			
TRAC-TRU	PELGAS2014	69 894	59 674	59 817	-14%	-15%	0%	23%	26%	26%
TRAC-TRU	PELGAS2015	77 142	76 653	76 797	0%	-1%	0%			
TRAC-TRU	PELGAS2016	119 230	119 227	119 228	0%	0%	0%			