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Standardization of the LPUE series of the Northern Spanish coastal bottom otter trawl fleet to tune the assessment of the Iberian megrims stocks

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ABSTRACT

There are two tuning fleets which have been used in the assessment of Iberian stocks of megrim: Northern Spanish coastal bottom otter trawlers landing in A Coruña port ("SP-CORUTR8c") and Avilés port ("SP-AVILESTR"). However, it is known the existence of changes in the fishing strategy of this fleet in recent years, which has diversified into demersal and pelagic fishing activities. As consequence, these tuning fleets show noisy behaviour through the time series, and they are partially used in the assessment of megrims (1990-1999 for "SP-CORUTR8c" tuning fleet in the assessment of four-spot megrim and 1990-2003 for "SP-AVILESTR" in the megrim assessment). In the present work the disaggregation in metiers of the whole time series available (1986-2012) is provided for landings and effort of the Northern Spanish coastal bottom otter trawlers landing in both harbours (A Coruña and Avilés): métier targeting demersal fish (OTB_DEF_>=55_0_0) and métier targeting a mixed of demersal and pelagic fish (OTB_MPD_>=55_0_0). The first metier is considered the most appropriate to assess benthic fish as megrims.

INTRODUCTION

Administrative control is achieved through a common fishing license for the whole Northern Spanish coastal trawl fleet, the size of which has decreased from 279 vessels in the early 1990s (STECF, 1994) to 99 vessels registered in 2012 (64.5% of reduction). During the last two decades, the Northern Spanish coastal trawl fleet has been made up of boats using two main gear types, the bottom otter trawl and the bottom pair trawl. The pair trawlers have been traditionally defined as a highly mono-specific fleet, targeting blue whiting (*Micromesistius poutassou*) and hake (*Merluccius merluccius*) by using a characteristic gear which permits a vertical opening up to 25 m. However, another fishing strategy targeting mackerel (*Scomber scombrus*) has been recently identified (Castro *et al*., 2010).

Regarding bottom otter trawlers, they use different type of trawl gears depending on the target species (Lema *et al*., 2006): traditional trawl gear to catch demersal species ("*baca*") and a Vertical High Opening (VHO) trawl gear ("*jurelera*") directed to pelagic fish. They can be alternatively used during the same trip, complicating the precise separation of both activities. Therefore, it was determined that the more accurate disaggregation protocol is to apply multivariate methodologies to the landing matrix by trip and species in percentage. Punzon *et al.* (2010) found four different fishing strategies by using the multivariate technique CLARA (Kaufman and Rousseeuw, 1990) to a time series of landings by trip (1983-2004): 1) trips with mixed of demersal species as hake, monkfish (*Lophius piscatorius* and *L. budegassa*), and megrim (*Lepidorhombus boscii* and *L. whifiagonis*) (each one around 10% in weight of

landings), 2) trips targeting horse mackerel (*Trachurus trachurus*) (63%) 3) trips targeting mackerel (76%), and 4) trips targeting blue whiting (62%).

This methodology has been routinely applied to the Spanish logbooks since 2009, when the DCF regulation was implemented, in order to split the Northern Spanish coastal bottom otter trawl activity into the following two DCF metiers:

- **OTB_DEF_>=55_0_0**: bottom otter trawl targeting demersal species by using 70 mm mesh size (Spanish regulation: Real Decreto 1441/1999). This metier is developed by around 60 vessels (mainly between 24-40 m of length) operating in the Spanish waters of ICES Divisions VIIIc and IXa (Castro *et al*., 2011). In the Northern Portuguese waters of Division IXa a smaller number of vessels (around 5 vessels) develop a similar fishing strategy (Map 1). Main ports of landings are in Galicia: A Coruña (30% of total ladings), Vigo (18%), Marín (13%) and Burela (11%).
- **OTB_MPD_>=55_0_0**: bottom otter trawl targeting a mixed of pelagic and demersal species by using 55 mm mesh size (Spanish regulation: APA/16/2002). This DCF métier cover the two fishing tactics identified by Punzon *et al*. (2010) targeting horse mackerel and mackerel (accompanied by some demersal species, mainly hake). This metier is developed by a high number of the same vessels developing the previous metier, but exclusively operating in Spanish waters (mainly VIIIc). Main ports of landings are also in Galicia: A Coruña (39%), Burela (23%) and Ribeira (16%). Trips targeting mackerel show a clear seasonality concentrating in February and March.

A decline in the importance of the fourth fishing tactic targeting blue whiting started to be evident from the late 1990s, probably due to competition with pair trawling (Lema *et al*., 2006). Since 2009, when DCF metier disaggregation started to be routinely applied to Spanish logbooks, this fishing tactic never again was detected.

During the last WGHMM, a number of problems were identified in the megrims assessment in order to be analyzed during the WKSOUTH benchmark (ICES, 2013). Regarding commercial data, the "SP-CORUTR8c" tuning fleet (Northern Spanish coastal bottom otter trawlers landing in A Coruña port) was partially used in the assessment of four-spot megrim (only time series 1990-1999) due to the increasing use of the "*jurelera*" trawl gear targeting other species than megrim in the last decade.

Therefore, the metier disaggregation of the SP-CORUTR8c tuning fleet was developed as inter-seasonal work between WGHMM 2013 and WKSOUTH 2014. Moreover, the "SP-AVILESTR" tuning fleet (Northern Spanish coastal bottom otter trawlers landing in Avilés port), used as tuning fleet in the assessment of megrim just to 2003, was also split in DCF metiers and updated (until 2012). To develop both tasks it was necessary to compile and analyze the commercial data of the period 2004-2008, which was missed between the periods available: 1983-2003[1] (Punzon *et al*., 2010) and 2009-2012 (DCF period).

[1] 2004 data from Punzón *et al*. (2010) was based in partial sampling.

MATERIAL AND METHODS

A dataset was compiled from the official logbooks of the Northern Spanish coastal bottom otter trawl fleet for the period 2004–2008, which has been facilitated by the Spanish ministry responsible for fisheries (MAGRAMA: "*Ministerio de Agricultura, Alimentacion y Medio Ambiente*"). This dataset contains information on fishing area, date of landing, landing port, base port, and landed weight of species by trip, fishing day and ICES rectangle. This dataset was used to develop the analytical work which is here shown.

Moreover, the original data from Punzon *et al.* (2010) was also available in order to split landings and effort by fishing tactic and port (A Coruña and Avilés) for the old time series (1983-2003). Landings and effort data by DCF métier was also taken from the IEO data bases for the recent period (2009-2012). Finally, the time series provided to ICES (1983-2012) for the whole Northern Spanish coastal bottom otter trawl fleet was taken for raising (ICES, 2013). This last process was needed due to the low sampling level detected in some years of the old time series (Table 1): years 1999 and 2000 in A Coruña port and years 1994-2003 for Avilés.

To classify trips, a non-hierarchical cluster technique was applied to the landings matrix by trip and species, the same methodology used by Punzón *et al.* (2010) and currently applied by the IEO fishery data programme. Five multivariate analyses were developed, one per year of the time series (2004-2008). The "*Clustering Large Applications*" method (CLARA) is a partitioning clustering method specifically designed for clustering large data sets (Kaufman and Rousseeuw, 1990). Its algorithm works by applying a "*Partitioning Around Medoids*" method (PAM) to data subsets of fixed size, allowing the user to try different levels of sampling. One valuable advantage of CLARA and PAM methods is that they provide a quality index which facilitates a more objective selection of the most appropriate number of clusters. This "*silhouette coefficient*" is calculated for each cluster (*s*) and the whole clustering procedure (ASW: "a*verage silhouette width*"). An interpretation proposed by Kaufman and Rousseeuw (1990) identifies a reasonable structure when ASW is higher than 0.5.

Computations were performed using the R statistical language (R Development Core Team, 2008). Cluster analysis was performed using R package cluster (Maecheler *et al*., 2005).

RESULTS

After testing different number of groups, the highest ASW values were obtained by splitting into 4 groups for years 2004 and 2005, and by splitting into 3 clusters for years 2006-2008 (Table 2). Except for year 2004, all the ASW coefficients obtained are significant (>0.5). Table 3 shows the specific characterization for each cluster, each of them with different catch profile:

- Cluster k1: mixed landings profile where, in addition of blue whiting and horse mackerel, demersal stocks stand by their higher presence compared to the other métiers: anglerfish (12.5%), hake (8.7%), megrim (7%)…
- Cluster k2: the main species by weight is horse mackerel (80.4%).
- Cluster k3: the main species by weight is mackerel (83.1%).
- Cluster k4: the main species by weight is blue whiting (52.3%).

The cluster disaggregation obtained for the period analyzed (2004-2008) was linked to the periods 1983-2003 (Punzon *et al.,* 2010) and 2009-2012 (DCF period): landings (t) and effort (fishing days standardized by power: fd/1000*HP/100). However, due to the low sampling

level in particular years of the old period, the ICES landings and effort time series of the whole Spanish trawl activity was used in order to raise the values (Figures 1 and 2).

Due that cluster 4 has disappeared in this last decade, the first three clusters were re-aggregated into the current DCF metiers: OTB_DEF_>=55_0_0 (cluster k1 targeting demersal fish) and OTB_MPD_>=55_0_0 (integrating clusters k2 and k3 directed to horse mackerel and mackerel, respectively). Finally, as the species of megrims are not properly identified in logbooks (both recorded at genus level), the ratio of species obtained by yearly sampling (IEO data) was applied to split landings by species, four-spot megrim (*L. boscii*) and megrim (*L. whiffiagonis*). Therefore, LPUE are provided by species (four-spot megrim and megrim), DCF metier (OTB_DEF_>=55_0_0 and OTB_MPD_>=55_0_0) and landing port (A Coruña and Avilés) in Tables 4-5 and Figures 3-4.

DISCUSSION

The same methodology has been applied to the three time series available trying to establish a consistent link: 1983-2003 (obtained from Punzón *et al*., 2010), 2004-2008 (period recovered here) and 2009-2012 (DCF period). The results obtained show the evolution of four fishing tactics with different target species: demersal fish, horse mackerel, mackerel and blue whiting. This last fishing tactic shows a decreasing from the late 1990s, probably as a consequence of the increasing of the pair trawl fishing activity, which obtains higher yields per trip (Lema *et al*., 2006). The OTB fishing activity targeting blue whiting completely disappears in the Avilés and A Coruña fleets in 2001 and 2006, respectively.

The fishing tactic targeting horse mackerel seems to be important from the beginning of the series (Figures 1 and 2). However, it keeps being important for the A Coruña fleet while it has been practically disappeared in Avilés from the late 1990s. The other pelagic fishing tactic, the one targeting mackerel, shows lower levels of effort due to its seasonal character, mainly concentrated in February and March. It takes advantage of the spawning migration of mackerel to the north coast of Spain at the beginning of the year (Sola *et al*., 1990), as do other fleets targeting mackerel in the same areas, such as purse seiners (Villamor *et al*., 1997) and hand lines (Punzón and Villamor, 2009). However, an increase, more evident in Avilés, can be observed from 2000, probably in response to improved market conditions for mackerel (Punzón *et al*., 2004). The fishing tactic targeting demersal fish shows a moderate decreasing through the time series, and results the more important fishing tactic in Avilés compared with the remained trawl fishing tactics.

Since 2009, these three fishing tactics are re-aggregated in two DCF metiers following the pan-European "*Data Collection Framework*" for fishery data: OTB_DEF_>=55_0_0 (corresponds to fishing tactic targeting demersal fish) and OTB_MPD_>=55_0_0 (integrates both fishing tactics targeting horse mackerel and mackerel). This procedure was applied backwards to the recovered time series in order to obtain a robust index (LPUE) feasible to be used as tuning fleet. Due to benthic species are target objective of OTB_DEF_>=55_0_0, it is recommended to use the LPUE of this metier as tuning fleet in the assessment of megrims.

LPUE of A Coruña OTB_DEF_>=55_0_0 shows different levels and trends between megrim species, being higher (average of 13.7 and 2.4 t by standardize effort unit for four-spot megrim and megrim, respectively) and with a remarkable increasing trend for four-spot megrim since middle 90's (Figure 3). However, Avilés OTB_DEF_>=55_0_0 gives similar indices (13.7 and 13.8 t by standardize effort unit for four-spot megrim and megrim, respectively), showing a more

balanced abundance of both species in Cantabrian waters than was observed in North-western Iberian waters (Figure 4).

The changes detected in the fishing strategy of a fleet may have led to variations in trends of the tuning indices used in stock assessment which are not related to species abundance. Therefore, LPUE series should be computed by métier in order to provide more homogeneous yielding indices which can improve the knowledge of the stock evolution.

CONCLUSIONS

Eight new LPUE time series can be obtained by DCF metier, landing port and megrim stock. However, the four time series of the metier targeting demersal fish are recommended to be tested in the assessment of megrims:

- LPUE of metier OTB_DEF_>=55_0_0 in A Coruña port for four-spot megrim (LDB).
- LPUE of metier OTB_DEF_>=55_0_0 in A Coruña port for megrim (MEG).
- LPUE of metier OTB_DEF_>=55_0_0 in Avilés port for four-spot megrim (LDB).
- LPUE of metier OTB_DEF_>=55_0_0 in Avilés port for megrim (MEG).

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Table 1. Available data bases of the Northern Spanish coastal bottom otter trawl fleet used in the time series compilation: number of trips by year and port (A Coruña and Avilés). [Numbers between brackets are based in partial samplings; "*na*": not available].

Year	A Coruña		Avilés	
	Punzón *et al* (2010)	LOGBOOKS	Punzón *et al* (2010)	LOGBOOKS
1983	*na*	*na*	2698	*na*
1984	*na*	*na*	2331	*na*
1985	*na*	*na*	2195	*na*
1986	4446	*na*	2390	*na*
1987	4010	*na*	1858	*na*
1988	4873	*na*	2069	*na*
1989	5295	*na*	*na*	*na*
1990	5542	*na*	1992	*na*
1991	5089	*na*	1786	*na*
1992	5055	*na*	1107	*na*
1993	5694	*na*	1070	*na*
1994	5169	*na*	*na*	*na*
1995	5470	*na*	[144]	*na*
1996	4858	*na*	*na*	*na*
1997	4789	*na*	*na*	*na*
1998	3494	*na*	[110]	*na*
1999	[263]	*na*	[427]	*na*
2000	[504]	*na*	[378]	*na*
2001	3532	*na*	[246]	*na*
2002	3211	*na*	[314]	*na*
2003	2690	*na*	[269]	*na*
2004	[489]	3351	[374]	538
2005	*na*	3542	*na*	855
2006	*na*	3326	*na*	881
2007	*na*	3412	*na*	631
2008	*na*	3216	*na*	579
2009	*na*	3161	*na*	666
2010	*na*	3054	*na*	527
2011	*na*	2312	*na*	488
2012	*na*	2366	*na*	680

Table 2. Results of CLARA clustering (*k*: number of clusters; *ASW*: average silhouette width; and *s*: silhouette coefficient by cluster).

Year	*k*	*ASW*	*S*(k1)	*S*(K2)	*S*(K3)	*S*(k4)
2004	4	0.45	0.05	0.68	0.59	0.47
2005	4	0.50	0.22	0.71	0.75	0.36
2006	3	0.56	0.25	0.69	0.77	--
2007	3	0.58	0.36	0.74	0.70	--
2008	3	0.54	0.40	0.70	0.73	--

Table 3. Mean landing profile (%) by cluster (mean of the analyzed period 2004-2008).

SPECIES	AL3	K1	K2	K3	K4
Atherinidae	SIL	0.3	0	0	0
Boops boops	BOG	0.4	0.3	0	0.1
Eledone spp	OCM	4.0	0.2	0.2	0.5
Galeorhinus galeus	GAG	0.4	0	0	0
Galeus melastomus	SHO	0.4	0	0	0
Illex illecebrosus	SQI	2.4	0.1	0	0.9
Lepidorhombus spp	LEZ	**7.0**	1.0	0.2	4.4
Loligo spp	SQC	1.3	0.2	0	1.4
Lophiidae	ANF	**12.5**	1.4	0.4	5.6
Merluccius merluccius	HKE	**8.7**	2.4	0.7	5.2
Micromesistius poutassou	WHB	24.7	1.8	0.7	**52.3**
Mullus spp	MUX	0.6	0	0	0
Nephrops norvegicus	NEP	1.0	0	0	0.5
Octopus vulgaris	OCC	1.8	0.1	0.1	0.4
OTHERS	OTH	8.5	2	4.6	4.3
Pagellus acarne	SBA	0.3	0.1	0	0.2
Phycis blennoides	GFB	0.3	0	0	0
Raja spp	SKA	1.5	0.4	0.1	0.4
Scomber scombrus	MAC	8.0	8.8	**83.1**	5.4
Scyliorhinidae	SYX	0.4	0	0	0
Trachurus spp	JAX	10.8	**80.4**	9.5	17.3
Triglidae	GUX	1.3	0.1	0.1	0.4
Trisopterus luscus	BIB	3.9	0.5	0.2	0.7

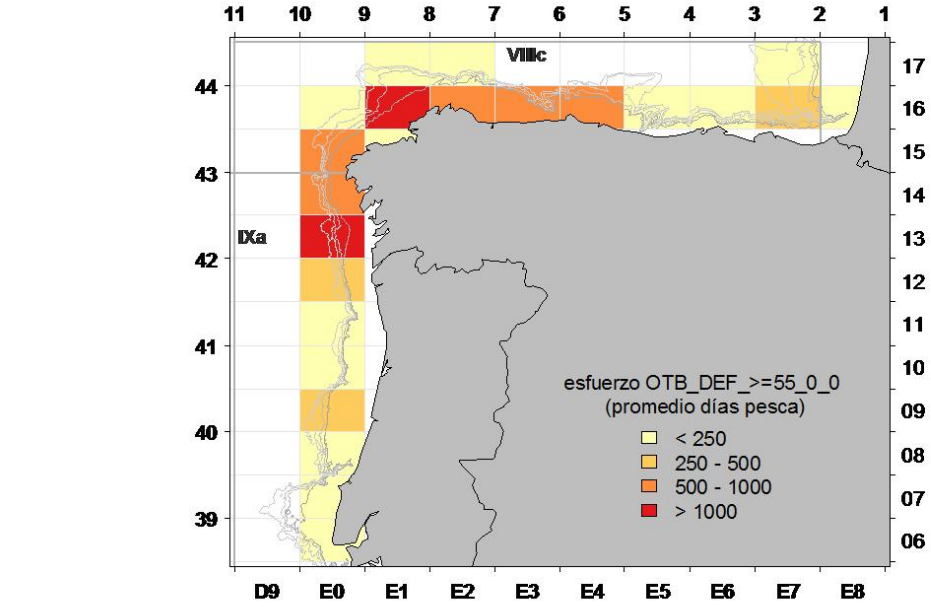
Table 4. LPUE (t/fd/1000*HP/100) of four-spot megrim (*L. boscii*) by DCF metier (OTB_DEF_>=55_0_0 and OTB_MPD_>=55_0_0) and port (A Coruña and Avilés).

Year	A Coruña		Avilés	
	OTB_DEF_>-55_0_0	**OTB_MPD_>-55_0_0**	**OTB_DEF_>-55_0_0**	**OTB_MPD_>-55_0_0**
1986	9.8	8.8	6.8	4.5
1987	14.9	11.7	10.4	8.2
1988	7.0	6.3	14.0	12.5
1989	6.2	4.1	10.9	9.3
1990	7.8	4.2	19.7	17.6
1991	9.8	4.2	12.2	10.1
1992	6.6	3.5	15.5	12.5
1993	7.8	4.2	16.1	13.0
1994	10.6	6.6	14.0	11.0
1995	11.0	7.6	24.7	15.3
1996	7.2	6.2	16.4	12.4
1997	7.9	5.4	18.7	13.9
1998	14.4	11.6	11.0	13.3
1999	11.7	13.2	11.3	9.7
2000	16.4	12.7	13.8	10.1
2001	20.2	9.8	12.5	9.6
2002	13.0	8.0	11.3	4.6
2003	11.6	5.7	5.7	1.9
2004	18.2	8.7	14.8	5.0
2005	13.6	6.0	15.2	1.9
2006	15.9	6.5	11.6	1.5
2007	17.9	7.3	8.9	1.8
2008	22.0	8.1	7.2	0.6
2009	17.3	6.9	18.5	2.2
2010	29.3	13.3	25.4	3.1
2011	24.8	11.9	19.6	4.2
2012	16.7	10.1	4.3	0.8
AVERAGE	**13.7**	**7.9**	**13.7**	**7.8**

Table 5. LPUE (t/fd/1000*HP/100) of megrim (*L. whiffiagonis*) by DCF metier (OTB_DEF_>=55_0_0 and OTB_MPD_>=55_0_0) and port (A Coruña and Avilés).

Year	A Coruña		Avilés	
	OTB_DEF_>-55_0_0	**OTB_MPD_>-55_0_0**	**OTB_DEF_>-55_0_0**	**OTB_MPD_>-55_0_0**
1986	2.2	2.0	21.2	14.2
1987	2.9	2.2	17.6	13.9
1988	2.6	2.3	24.6	22.0
1989	2.0	1.4	19.8	16.9
1990	3.1	1.7	36.9	32.9
1991	3.1	1.3	15.0	12.4
1992	3.1	1.6	15.5	12.5
1993	1.5	0.8	18.5	15.0
1994	3.8	2.3	11.4	8.9
1995	0.9	0.6	9.7	6.0
1996	2.4	2.1	17.1	13.0
1997	2.4	1.6	19.2	14.2
1998	3.6	2.9	12.2	14.7
1999	2.6	3.0	12.7	10.9
2000	3.3	2.6	10.5	7.6
2001	2.3	1.1	11.2	8.5
2002	2.0	1.2	9.1	3.7
2003	1.7	0.8	5.7	1.9
2004	1.7	0.8	14.8	5.0
2005	1.3	0.6	11.1	1.4
2006	1.4	0.6	9.6	1.2
2007	1.8	0.7	4.8	1.0
2008	1.3	0.5	5.3	0.4
2009	1.1	0.4	5.1	0.6
2010	2.0	0.9	11.7	1.4
2011	3.4	1.6	18.7	4.0
2012	5.6	3.5	4.4	0.8
AVERAGE	**2.4**	**1.5**	**13.8**	**9.1**

Map 1. Geographical effort distribution of the two DCF metiers of the Northern Spanish coastal bottom otter trawl fleet: OTB_DEF_>=55_0_0 (bottom otter trawl targeting demersal fish) and OTB_MPD_>=55_0_0 (bottom otter trawl targeting a mixed of pelagic and demersal fish).



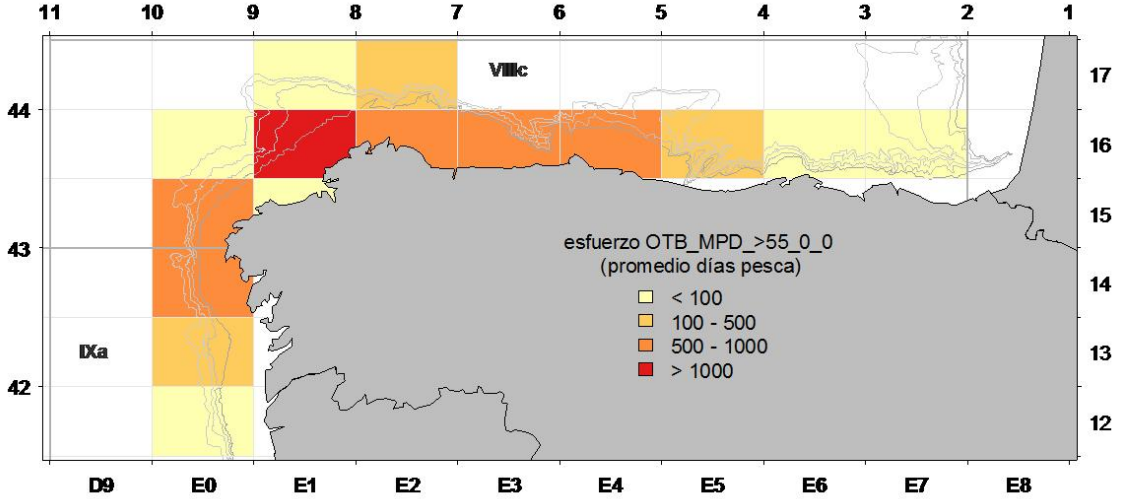


Figure 1. Effort (fd/1000*HP/100) by cluster of the Northern Spanish coastal bottom otter trawl fleet landing in A Coruña port: k1 (fishing tactic exploiting demersal fish), k2 (horse mackerel), k3 (mackerel), and k4 (blue whiting).

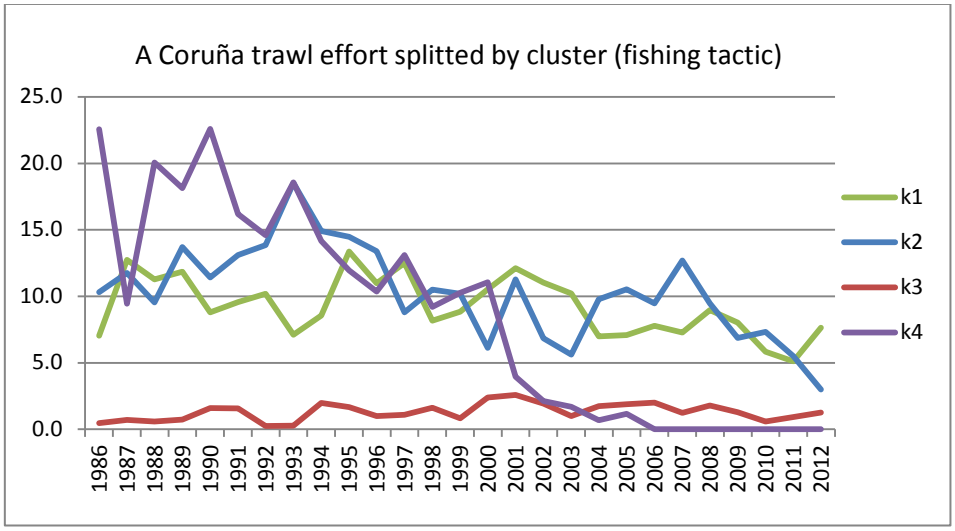


Figure 2. Effort (fd/1000*HP/100) by cluster of the Northern Spanish coastal bottom otter trawl fleet landing in Avilés port: k1 (fishing tactic exploiting demersal fish), k2 (horse mackerel), k3 (mackerel), and k4 (blue whiting).

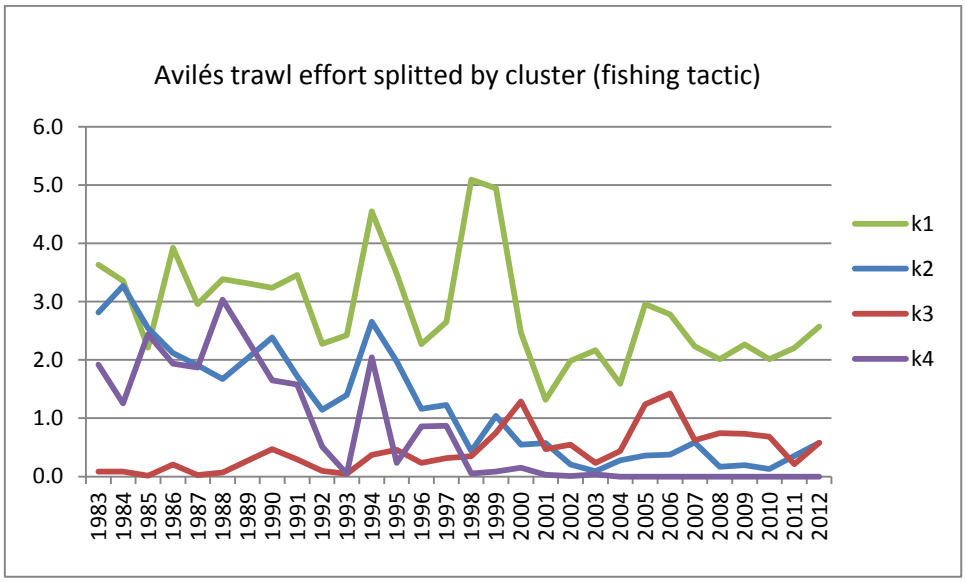


Figure 3. LPUE (t/fd/1000*HP/100) of A Coruña OTB_ DEF_>=55_0_0 metier for four-spot megrim (LDB) and megrim (MEG).

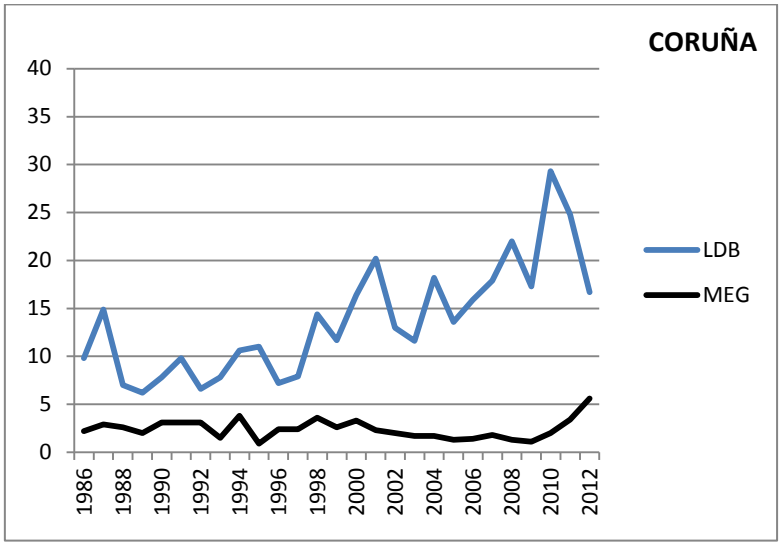


Figure 4. LPUE (t/fd/1000*HP/100) of Avilés OTB_DEF_>=55_0_0 metier for four-spot megrim (LDB) and megrim (MEG).