

## Stocks and seasonal migrations of the flounder *Xystreureys rasile* as indicated by its parasites

A. J. ALARCOS\* AND J. T. TIMI

*Laboratorio de Parasitología, Instituto de Investigaciones Marinas y Costeras (IIMyC), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET)-Facultad de Ciencias Exactas y Naturales, Universidad Nacional de Mar del Plata, Funes 3350, (7600) Mar del Plata, Buenos Aires, Argentina*

(Received 19 December 2012, Accepted 30 May 2013)

The aims of this study were (1) to compare the structure and composition of parasite assemblages of the flounder *Xystreureys rasile* in two regions of the Argentine Sea in order to evaluate the hypothesis for the existence of different stocks, and (2) to test the hypothesis for *X. rasile* migration from the Argentine–Uruguayan Common Fishing Zone (AUCFZ) towards more southern waters during spring. Parasitological evidence shows that at least two stocks of *X. rasile* inhabit the coastal and shelf waters of the northern Argentine Sea, one in El Rincón and the other in the AUCFZ. These stocks should be considered as discrete entities in management plans to ensure a sustainable use of these resources. The results also confirm the existence of migratory patterns in the northern stock.

© 2013 The Fisheries Society of the British Isles

Key words: parasite assemblages; south-western Atlantic; stock dynamics.

### INTRODUCTION

Paralichthyid flounders, mostly *Paralichthys patagonicus* Jordan 1889, *Paralichthys orbignyanus* (Valenciennes 1839), *Paralichthys isosceles* Jordan 1891 and *Xystreureys rasile* (Jordan 1891), are intensely exploited in the south-western Atlantic Ocean, especially on northern coasts of the Argentine Sea (Díaz de Astarloa, 2002). Despite flatfishes being mainly taken as a by-catch in the demersal trawl fisheries and representing only a small fraction of *c.* 7% of the total landings in the region (Rico, 2010), they are considered as fine fishing owing to their value as a food fish, attaining a high price in the market (Fabrè & Díaz de Astarloa, 2001; Díaz de Astarloa, 2002).

At present no specific assessment methods or fishery management plans are established in Argentina for paralichthyid resources (Díaz de Astarloa, 2002; Rico, 2010). Although they are included in the management of a multispecies fishery named ‘variado costero’, with maximum catches under government regulation (Rico, 2010), all paralichthyid species are considered together for management purposes and discriminated only by size (Fabrè & Díaz de Astarloa, 1996).

\*Author to whom correspondence should be addressed. Tel.: +54 223 4752426; email: jalarcos@mdp.edu.ar

It has been proposed that in the continental shelf waters *P. patagonicus*, *P. isosceles* and *X. rasile* co-occur in two main groups, a northern group between 34° and 38° S, in the zone known as the Argentine–Uruguayan Common Fishing Zone (AUCFZ), and a southern group between 38° and 41° S, a zone known as El Rincón (Díaz de Astarloa, 2002).

In the Argentine Sea, paralicthyid species differ in their latitudinal and bathymetric distributions in relation to environmental factors as well as in their reproductive periods (Perier & Di Giacomo, 2002; Díaz de Astarloa & Fabré, 2003). For this reason, and to ensure a sustainable management of these resources, the stock composition of each species should be assessed individually. Notwithstanding, little effort has been made on this, except for *P. patagonicus*, whose spawning areas were recently studied in the north Argentine Sea (34°–42° S) (Militelli, 2011), and *X. rasile*, whose population dynamics were evaluated in the central and northern areas of the same region (34°–40° S) (Fabré *et al.*, 2001). These authors compared the abundance and size structure of catches, sex ratios, gonad maturity and condition factors between samples caught at different latitudes and depths, in a seasonal sampling programme. On the basis of these analyses, Fabré *et al.* (2001) concluded that mature fishes from the northern region of the study area may migrate to shallow waters at 38° S and southwards, where the spawning area could be localized. The sampling region encompassed by this study was the AUCFZ, with no samples from El Rincón being included.

Parasites have been used previously as tools for discriminating fish stocks between these two regions (Timi, 2007), as well as to trace migrations of silversides *Odontesthes smitti* (Lahille 1929) along Argentine coasts (Carballo *et al.*, 2012). The parasite communities of *X. rasile* have been studied in coastal waters off Necochea (Szidat, 1961; Alarcos & Timi, 2012), the northern limit of El Rincón, where some systematic studies have also been carried out on parasitic copepods and cestodes (Menoret & Ivanov, 2009; Alarcos & Timi, 2011), but there is no information on parasites of this species in northern regions, apart from a recent taxonomic study on trypanorhynch cestodes in paralicthyids from Rio de Janeiro, Brazil (Gonçalves da Fonseca *et al.*, 2012).

The structure and composition of parasite assemblages in a sample from Necochea, caught during autumn (Alarcos & Timi, 2012), were compared with those of other two samples, one from the same season but from the AUCFZ and the other from the same region (Necochea) but caught during spring. The aims were to evaluate the hypothesis that different stocks exist in both regions and to test the hypothesis that *X. rasile* migrate from AUCFZ towards more southern waters during spring.

## MATERIALS AND METHODS

Fish samples were taken from catches made by trawlers of the coastal fleets operating at the ports of Mar del Plata and Necochea (Argentina). These vessels, known as coastal ice chilled vessels, perform fishing trips for periods of 3–4 days covering distances <200 km from the port, during which several trawls are carried out. This means that samples may come from different localities in a wide area. Fishes are landed classified by species, except for paralicthyids which are classified by size so it is not possible to know the exact location where each fish was caught.

One hundred and thirty-three specimens of *X. rasile* were collected in three samples from two different localities in the north Argentine Sea (Table I). Data from autumn samples from

TABLE I. Sample details for *Xytreurys rasile* from two regions of the Argentine Sea

Region	Locality	Sample code	Latitude and longitude	<i>n</i>	Date (season)	Mean $L_T$ (range) (cm)
Northern	Villa Gesell	VGA	36° 44' S; 55° 44' W	55	March 2011 (autumn)	32.1 (27.5–35.5)
Southern	Necochea	NEA	38° 36' S; 58° 42' W	48	May 2009 (autumn)	29.2 (25–39)
Southern	Necochea	NES	38° 52' S; 58° 10' W	30	October 2009 (spring)	30.3 (25–37)

*n*, sample size;  $L_T$ , total length.

Necochea were taken from a previous study by Alarcos & Timi (2012). Fish examination and parasitological analyses were carried out as described by Alarcos & Timi (2012).

Samples from commercial catches do not allow programming sampling designs, so replicate samples in each area are desirable to avoid pseudoreplication problems (Millar & Anderson, 2004), because fishes were caught by trawls with different (unknown) positions in each area, however, it is expected that they will incorporate some of the true structure of randomness present in fish communities in each zone, diminishing the possibilities of inflating type I errors.

Total lengths ( $L_T$ ) were compared between samples by means of a one-way ANOVA (Zar, 1999). Prevalence and mean abundance were calculated for each parasite species in each sample following Bush *et al.* (1997).

Differences in community structure among samples were tested by means of a one-way permutational multivariate analysis of the variance (PERMANOVA; Anderson *et al.*, 2008) on parasite abundances. The structures of parasite infracommunities between samples (1 × 3 factorial design, 'samples' as fixed factors) were compared, testing for main effects after 9999 permutations. According to the information available on the possible migratory patterns of *X. rasile* in the study region, the sample caught in Necochea during spring could belong to either of the northern or southern areas. Therefore, it would have been logical to treat the factor 'sample' as random and nested in 'area' (NES + VGA nested in 'northern region' in the first case, or NES + NEA nested in 'southern region' in the second). In the present design, with only two samples from the same area, inferences concerning inter-seasonal variation in general could not be considered as precise. Thus, 'sample' was treated as a fixed factor, which focused the analyses on results obtained for the available samples only.

Following Anderson *et al.* (2008) a permutation of residuals under a reduced model was used as the method of permutation. A sequential sum of squares (type I SS) was applied because host size was introduced as a covariable (ANCOVA model) and because samples were unbalanced (different numbers of fish examined by sample).  $L_T$  was included as a covariable because of the known effect of size and age on fish parasite burdens. Where differences were detected by PERMANOVA, pair-wise comparisons were used to determine which samples differed. The Bray–Curtis index was used as similarity measure, because the Bray–Curtis coefficient is undefined when two samples contain no individuals (*e.g.* uninfected fish) (Clarke *et al.*, 2006); only fish harbouring at least one parasite species were included in the analyses. These procedures were repeated by applying the Jaccard index as a similarity measurement. This index uses binary presence or absence data (Magurran, 1988) to compare species composition between samples.

As PERMANOVA is sensitive to differences in multivariate dispersion between groups (*sensu* homogeneity of variances, which can inflate type I error even when centroids have identical locations), the same models were tested for differences in dispersion using the routine PERMDISP (Anderson *et al.*, 2008). Dispersions were measured as distances to the centroids and each term in the analysis was tested using 9999 permutations.

Multivariate PERMANOVA analyses were applied to untransformed data for long-lived larval parasites because this group of parasites is recommended for studies on fish stock discrimination (Lester & MacKenzie, 2009). These analyses were repeated on short-lived

parasites to reveal possible differences due to seasonality in their abundance, because samples were caught in autumn and spring.

Differences between infracommunities among samples from autumn were examined in more detail using canonical analysis of principal coordinates (CAP) (Anderson & Willis, 2003; Anderson *et al.*, 2008). Potential overparameterization was prevented by choosing the number of principal coordinates axes ( $m$ ) that maximized a leave-one-out allocation success to groups (Anderson & Robinson, 2003). CAP analyses were based on abundance data using Bray–Curtis dissimilarity coefficient and repeated on qualitative composition of samples using Jaccard coefficients. To test for significant differences between infracommunities among the samples, a permutation trace test (sum of squared canonical eigenvalues) was applied, the  $P$  being obtained after 9999 permutations. In order to estimate if fish from northern and southern zones mix during spring–summer south of 38°, *X. rasile* from NES were included in the adding new samples subroutine of the CAP analyses, and the new samples were placed onto the canonical axes of the obtained CAP model, which classified each of them into one of the existing groups. CAP analyses were carried out including all parasites, because both short- and long-lived species displayed the same results in previous comparisons.

Multivariate analyses on parasite infracommunity data were implemented in PERMANOVA+ for PRIMER package (Anderson *et al.*, 2008).

## RESULTS

Mean host  $L_T$  were significantly different between samples ( $F_{2,130} = 16.84$ ;  $P < 0.01$ ), with samples from VGA being significantly longer than those from NEA ( $P < 0.01$ ) and NES ( $0.01 < P < 0.05$ ). The two samples from Necochea showed no significant difference in  $L_T$  ( $P > 0.05$ ).

Eight individuals of *X. rasile* were uninfected, six in the sample from NES and two in VGA, the rest being infected by at least one of 18 parasite species (Table II), 16 of which were harboured by fish from NEA, five of them being found exclusively in this sample, including *Derogenes varicus* and *Anonchocephalus argentinensis* with prevalence  $>10\%$ . Samples from NES and VGA had poorer communities, with 12 and 13 parasite species, respectively, most of them shared except for *Hysterothylacium aduncum*, which was found only in VGA at very low prevalence.

After selecting hosts with one or more long-lived parasite species, 21 fish from VGA, 17 from NES and seven from NEA were excluded from analyses. Results of PERMANOVA analyses on abundance data (Table III) showed a strong effect of host size on the response variables, and therefore on the parasite community structure. The interaction of host  $L_T$  with samples showed that the nature of the relationship between the covariate and the multivariate response differs within different levels of the factor. Furthermore, taking into account the variations among samples due to host size, significant variability was detected among the parasite assemblages. Pair-wise tests between host samples showed that there were significant differences for those comparisons involving fish from NEA, but not between VGA and NES (Table IV).

After selecting hosts with one or more short-lived parasite species, 26 fish from VGA, 12 from NES and four from NEA were excluded from analyses. Results of PERMANOVA analyses on abundance data (Table V) showed a strong effect of host size on the response variables, although in this case no interaction was observed between host  $L_T$  and samples. After taking into account the variations among samples due to host  $L_T$ , significant variability was detected among the parasite assemblages.

TABLE II. Prevalence (P) and mean  $\pm$  S.D. abundance (A) of metazoan parasites in three samples of *Xystreurus rasile* from the northern Argentine Sea, south-western Atlantic Ocean

Parasite species	Stage Site		Necochea autumn		Necochea spring		Villa Gesell	
			P	A	P	A	P	A
Digenea								
<i>Derogenes varicus</i>	Ad	St	37	1.29 $\pm$ 2.29	0	0	0	0
<i>Lecithochirium microstomum</i>	Ad	St	10	0.17 $\pm$ 0.56	0	0	0	0
Cestoda								
<i>Scolex polymorphus</i>	Pl	St-In	46	4.42 $\pm$ 9.39	3	0.23 $\pm$ 1.28	2	0.02 $\pm$ 0.13
Tentaculariidae gen. sp.*	Pc	Me-In	50	1.60 $\pm$ 2.18	63	3.80 $\pm$ 6.07	62	3.05 $\pm$ 3.73
<i>Grillotia carvajalregorum</i> *	Pc	Me	56	5.04 $\pm$ 9.75	10	2.93 $\pm$ 11.66	9	0.29 $\pm$ 1.40
Unidentified larva*	Pl	Me	2	0.02 $\pm$ 0.14	0	0	0	–
<i>Anonchocephalus argentinensis</i>	Ad	In	15	0.23 $\pm$ 0.79	0	0	0	–
Nematoda								
<i>Contraecum</i> sp.*	LIII	Me	13	0.21 $\pm$ 0.62	3	0.03 $\pm$ 0.18	9	0.11 $\pm$ 0.37
<i>Pseudoterranova</i> sp.*	LIII	Me	2	0.06 $\pm$ 0.43	0	0	0	0
<i>Hysterothylacium deardorffoversreeterum</i> *	LIII	Me	31	0.65 $\pm$ 1.34	7	0.13 $\pm$ 0.57	18	0.20 $\pm$ 0.45
<i>Hysterothylacium aduncum</i> *	LIII	Me	2	0.02 $\pm$ 0.14	0	0	2	0.02 $\pm$ 0.13
<i>Ascarophis marina</i>	Ad	In	2	0.02 $\pm$ 0.14	7	0.40 $\pm$ 2.01	18	0.47 $\pm$ 1.50
<i>Dichelye</i> sp.	Ad	In	0	0	13	0.40 $\pm$ 1.30	7	0.09 $\pm$ 0.35
<i>Cucullanus bonaerensis</i>	Ad	In	60	1.19 $\pm$ 1.33	17	0.30 $\pm$ 0.67	7	0.09 $\pm$ 0.35
Acanthocephala								
<i>Corynosoma australe</i> *	Ju	Me	90	9.23 $\pm$ 9.38	53	1.67 $\pm$ 3.12	71	3.20 $\pm$ 7.39
<i>Corynosoma cetaceum</i> *	Ju	Me	2	0.04 $\pm$ 0.29	7	0.37 $\pm$ 1.83	15	0.22 $\pm$ 0.66
Copepoda								
<i>Acanthochondria sagitta</i>	Ad	Gi	2	0.06 $\pm$ 0.43	10	0.10 $\pm$ 0.30	24	0.27 $\pm$ 0.52
Isopoda								
Gnathiidae gen. sp.	Pr	Gi	0	0	3	0.03 $\pm$ 0.18	7	0.20 $\pm$ 0.87

Ad, adult; Ju, juvenile; LIII, third-stage larva; Pc, plerocercus; Pl, plerocercoid; Pr, pranzia; Gi, gills; In, intestine; Me, mesenteries; St, stomach.

\*Long-lived larval parasites.

Pair-wise tests between host samples showed the same results as those comparisons of long-lived parasites (Table IV).

None of these differences can be attributed to differences in multivariate dispersions of parasite infracommunities in terms of their deviations from centroids, because PERMDISP results were not significant when only long-lived parasites were included in the analyses ( $F_{2,116} = 0.25$ ,  $P$  (perm)  $> 0.05$ ), as well as for those analyses restricted to short-lived parasites ( $F_{2,80} = 3.09$ ,  $P$  (perm)  $> 0.05$ ).

Similar results were obtained when analyses were applied to composition of infracommunities (presence-absence data) (Tables III and IV), but in this case no effect of host  $L_T$  was observed for assemblages composed of long-lived parasites and no interactions were observed between  $L_T$  and samples. PERMDISP results were also similar for all long-lived parasites ( $F_{2,116} = 0.76$ ,  $P$  (perm)  $> 0.05$ ). Nevertheless, differences in multivariate dispersions could be affecting the results of comparisons

TABLE III. One-factor PERMANOVA results of infracommunity data of parasites of *Xystreurus rasile* in three samples based on Jaccard dissimilarity measures with host total length ( $L_T$ ) as covariable.  $P$ -values obtained after 9999 permutations

Infracommunity	Source	d.f.	SS	MS	Pseudo $F$	$P$ (perm)
Long-lived larval parasites	Host $L_T$	1	3376.9	3376.9	1.8489	>0.05
	Host sample	2	22 132	11 066	6.0586	<0.0001
	Host $L_T \times$ sample	2	4696.6	2348.3	1.2857	>0.05
	Residual	113	2.0639 e <sup>5</sup>	1826.5		
	Total	118	2.3659 e <sup>5</sup>			
Short-lived parasites	Host $L_T$	1	25 706	25 706	8.47	<0.0001
	Host sample	2	39 709	19 855	6.54	<0.0001
	Host $L_T \times$ sample	2	7990.2	3995.1	1.32	>0.05
	Residual	77	2.3369 e <sup>5</sup>	3035		
	Total	82	3.071 e <sup>5</sup>			

$L_T$ , total length.

for short-lived species, as they were significantly different ( $F_{2,80} = 5.29$ ,  $0.01 < P$  (perm)  $< 0.05$ ), although these differences were observed for comparisons between NEA and NES ( $0.01 < P$  (perm)  $< 0.05$  in both cases), but not for the pair NES–VGA ( $P$  (perm)  $> 0.05$ ).

The CAP analysis based on parasite abundance showed significant differences between samples ( $tr = 0.75$ ;  $P < 0.001$ ). The selected orthonormal PCO axes ( $m = 12$ ) described 96.5% of the variation in the data cloud, with a high percentage of correct allocations (91.09%). Cross-validation results showed that 94.3% of fish from VGA and 87.5% from NEA were correctly allocated to their own sample. Fish from NES were mainly allocated to the sample from VGA (79.2% of them), with only 20.8% of fish associated with NEA.

Similar results were obtained for the CAP analysis based on parasite composition, which showed significant differences between samples ( $tr = 0.71$ ;  $P < 0.001$ ). The

TABLE IV. One-factor PERMANOVA results of pair-wise comparisons between samples of *Xystreurus rasile* based on abundance (Bray–Curtis dissimilarity) and presence–absence (Jaccard dissimilarity) measures with host total length ( $L_T$ ) as covariable.  $P$ -values obtained after 9999 permutations

Comparison	Bray–Curtis dissimilarity				Jaccard dissimilarity			
	Long-lived parasites		Short-lived parasites		Long-lived parasites		Short-lived parasites	
	$t$	$P$ (perm)	$t$	$P$ (perm)	$t$	$P$ (perm)	$t$	$P$ (perm)
VGA–NEA	2.76	<0.0001	3.28	<0.0001	2.49	<0.0001	3.46	<0.0001
VGA–NES	0.93	>0.05	1.19	>0.05	1.07	>0.05	1.25	>0.05
NEA–NES	3.24	<0.0001	2.11	<0.001	3.03	<0.0001	2.23	<0.001



TABLE V. One-factor PERMANOVA results of infracommunity data of parasites of *XySTreurys rasile* in three samples based on Bray–Curtis dissimilarity measures with host total length ( $L_T$ ) as covariable.  $P$ -values obtained after 9999 permutations

Infracommunity	Source	d.f.	SS	MS	Pseudo $F$	$P$ (perm)
Long-lived larval parasites	Host $L_T$	1	8797.7	8797.7	3.8434	<0.001
	Host sample	2	33 472	16 736	7.3113	<0.0001
	Host $L_T \times$ sample	2	12 123	6061.3	2.648	<0.01
	Residual	113	2.5866 e <sup>5</sup>	2289		
	Total	118	3.1305 e <sup>5</sup>			
Short-lived parasites	Host $L_T$	1	21 953	21 953	6.63	<0.0001
	Host sample	2	39 036	19 518	5.89	<0.0001
	Host $L_T \times$ sample	2	9469.1	4734.6	1.43	>0.05
	Residual	77	2.5513 e <sup>5</sup>	3313.4		
	Total	82	3.2559 e <sup>5</sup>			

$L_T$ , total length.

selected orthonormal PCO axes ( $m = 6$ ) described 76% of the variation in the data cloud, with a high percentage of correct allocations (93.07%). Cross-validation results showed that 96.3% of fish from VGA and 89.6% from NEA were correctly allocated to their own sample. Fish from NES were mainly allocated to the sample from VGA (83.3% of them), with only 16.7% of fishes correctly associated with NEA.

## DISCUSSION

*XySTreurys rasile* has a wide distribution in the south-eastern Atlantic Ocean, inhabiting waters at a depth range between 71 and 100 m, from Cabo Frio, State of Rio de Janeiro, Brazil to the latitude of 47° S in Patagonia, Argentina (Figueiredo & Menezes, 2000; Díaz de Astarloa & Fabr , 2003). In the northern Argentine Sea, the water mass between these depths is known as continental shelf waters, which extends into the northern continental shelf from the south-west and occupies the central portion of the shelf. It is separated from coastal waters by the 50 m isobath, with the exception of the coast between 38° 30' and 37° 30' S (between Necochea and Mar del Plata), where it reaches the coast (Guerrero & Piola, 1997). The penetration of shelf waters into the coastal region around 38° S is due to the closeness of the 50 m isobath to the coast, which generates a marked bathymetric gradient (Lucas *et al.*, 2005). Two of the samples (NEA and NES) were caught in this region.

Both coastal zones, separated by continental shelf waters, represent different basins with contrasting oceanographic and biological characteristics. The AUCFZ is greatly influenced by the Brazilian current (tropical saline and warm waters), as well as by the discharge of the R o de la Plata (Bakun & Parrish, 1991; Guerrero *et al.*, 1997). El Rinc n is a semi-enclosed area that generates its own oceanographic features. In both zones, locally modified waters create frontal zones with important biological properties (Acha *et al.*, 2004), providing breeding grounds and zones of concentration for juveniles of several fish species by promoting retention of larvae (Piola & Rivas, 1997). These zones, with different oceanographic characteristics, harbour distinct fish populations, mainly of resident species (Jauregu zar *et al.*, 2006), as

has been demonstrated in some ichthyological studies (Díaz de Astarloa & Bolasina, 1992; Perrotta & Fernández-Giménez, 1996; Militelli & Macchi, 2006; Volpedo & Fernández Cirelli, 2006; Sabadin *et al.*, 2010). These include *P. patagonicus*, for which it has recently been shown that discrete populations inhabit these regions, one in the AUCFZ (34°–38° S) and the other in El Rincón (38°–42° S), based on the identification of spawning areas and reproductive biology (Militelli, 2011).

Parasites have been used to identify stocks of several fish species in these zones, including the anchovy *Engraulis anchoita* Hubbs & Marini 1935 (Timi, 2003), two species of sandperch, *Pseudoperca semifasciata* (Cuvier 1829) and *Pinguipes brasiliensis* Cuvier 1829 (Timi & Lanfranchi, 2009; Timi *et al.*, 2009, 2010), the flathead *Percophis brasiliensis* Quoy & Gaimard 1824 (Braicovich & Timi, 2008, 2010) and the rough scad *Trachurus lathami* Nichols 1920 (Braicovich *et al.*, 2012). As in these previous studies, the significant differences observed between parasite assemblages of *X. rasile* from both zones, but caught during the same season, support the hypothesis that two stocks of *X. rasile* inhabit these regions. These differences indicate that in each zone fish are exposed to qualitatively different assemblages of infective stages of parasites. Indeed, the marine fronts formed in both coastal basins influence the distribution of mesozooplankton, leading to their classification as different faunistic areas (Marrari *et al.*, 2004). These fronts can also act as barriers for parasite dispersal, leading to significant differences in composition of their assemblages.

The differences recorded between the two samples from Necochea, especially for long-lived parasites (*e.g.* those parasites not expected to be influenced by seasonal oscillations), indicate that there is no temporal component in such variations. On the other hand, the similarity between fish caught during spring and samples from the AUCFZ, especially when short-lived parasites were considered (*e.g.* those prone to undergo seasonal variations included), supports the hypothesis that spring migrations of the northern stock towards shallow waters at 38° S and southwards (Fabrè *et al.*, 2001) occur.

Despite the transient nature of short-lived species, the lack of seasonality in abundance and composition of their assemblages could be explained by the fact that spring samples were caught at the beginning of the warm season, and some inertia in community composition could be expected, as time elapsed in southern waters could be not long enough for losing seasonal parasites or acquiring parasites in the new region. Furthermore, the dynamics of the oceanographic regimes in the northern Argentine continental shelf maintain the stability of environmental conditions, and therefore of parasite assemblages. Waters across this region undergo a seasonal oscillation in distribution and extension that implies a spring–summer reversal of the characteristic shelf-wide north-northeast direction of flow within the coastal zone (Jaureguizar *et al.*, 2006). This warmer period is characterized by Río de la Plata waters flowing to the south and east, and an invasion of continental shelf waters into the coastal areas (Lucas *et al.*, 2005), meaning that northern flatfishes are to a certain degree accompanied by their winter habitat during their spring migration. This synchrony of geographic displacements between flatfishes and habitat could explain the maintenance of parasite infracommunity structure and composition during migrations.

Stock discrimination can be complicated by the occurrence of migratory cycles that include regions inhabited by other stocks. Therefore, consideration of stock structure should incorporate the effects of migration behaviour in population dynamics (Secor, 1999). This is the case with *X. rasile*, for which the migratory patterns of the northern



stock proposed by Fabr e *et al.* (2001) are in agreement with the present results. Management plans for this species, when applied, should consider that in the region of Necochea, two stocks are being exploited in different seasons.

The spawning area of the southern stock is still unknown, as the work by Fabr e *et al.* (2001) did not cover this region. Further studies should incorporate samples from southern areas of El Rinc n to assess whether movements towards these latitudes occur in the southern stock during the warm season. The spawning area for this stock could be located at San Mat as Gulf, a north Patagonian gulf located in the southern limit of El Rinc n. This hypothesis is based on the increase in relative abundance and the maximum reproductive activity of *X. rasile* observed in this gulf during the warm season (Perier & Di Gi como, 2002).

A more extensive sampling programme, in both time and space, is desirable to accurately assess the stock composition and migratory routes of *X. rasile* in this region, as well as their temporal persistence in geographical locations and the possible mixture of stocks during migrations. The results validate the utility of parasites as biological markers in the region, confirming their value as ancillary tools to be combined with other methodologies of stock identification. They constitute a step forward towards understanding the stock dynamics of *X. rasile* in the northern Argentine Sea.

The authors thank K. MacKenzie for his valuable suggestions on the manuscript. Financial support was provided by grants from CONICET (PIP 112-200801-00024) and Universidad Nacional de Mar del Plata (EXA 621/12).

## References

- Acha, E. M., Mianz n, H. W., Guerrero, R. A., Favero, M. & Bava, J. (2004). Marine fronts at the continental shelves of austral South America physical and ecological process. *Journal of Marine Systems* **44**, 83–105.
- Alarcos, A. J. & Timi, J. T. (2011). A new species of *Acanthochondria* (Copepoda: Chondranchthidae) parasitizing the flounder *Xystreureys rasile* (Pleuronectiformes: Paralichthyidae) from Argentina. *Folia Parasitologica* **58**, 164–168.
- Alarcos, A. J. & Timi, J. T. (2012). Parasite communities in three sympatric flounder species (Pleuronectiformes: Paralichthyidae): similar ecological filters driving toward repeatable assemblages. *Parasitology Research* **110**, 2155–2166. doi: 10.1007/s00436-011-2741-5
- Anderson, M. J. & Robinson, J. (2003). Generalized discriminant analysis based on distances. *Australian and New Zealand Journal of Statistics* **45**, 301–318. doi: 10.1111/1467-842X.00285
- Anderson, M. J. & Willis, T. J. (2003). Canonical analysis of principal coordinates: a useful method of constrained ordination for ecology. *Ecology* **84**, 511–525.
- Anderson, M. J., Gorley, R. N. & Clarke, K. R. (2008). *PERMANOVA+ for PRIMER: Guide to Software and Statistical Methods*. Plymouth: PRIMER-E.
- Bakun, A. & Parrish, R. H. (1991). Comparative studies of coastal pelagic fish reproductive habitats: the anchovy (*Engraulis anchoita*) of the southwestern Atlantic. *Journal of Marine Science* **48**, 343–361.
- Braicovich, P. E. & Timi, J. T. (2008). Parasites as biological tags for stock discrimination of the Brazilian flathead, *Percophis brasiliensis* Quoy & Gaimard, 1824, in the South West Atlantic. *Journal of Fish Biology* **73**, 557–571. doi: 10.1111/j.1095-8649.2008.01948.x
- Braicovich, P. E. & Timi, J. T. (2010). Seasonal stability in parasite assemblages of the Brazilian flathead, *Percophis brasiliensis* (Perciformes: Percophidae): predictable tools for stock identification. *Folia Parasitologica* **57**, 206–212.

- Braicovich, P. E., Luque, J. L. & Timi, J. T. (2012). Geographical patterns of parasite infra-communities in the rough scad, *Trachurus lathami* Nichols off southwestern Atlantic Ocean. *Journal of Parasitology* **98**, 768–777. doi: 10.1645/GE-2950.1
- Bush, A. O., Lafferty, K. D., Lotz, J. M. & Shostak, A. W. (1997). Parasitology meets ecology on its own terms: Margolis *et al.* revisited. *Journal of Parasitology* **83**, 575–583.
- Carballo, M. C., Cremonte, F., Navone, G. T. & Timi, J. T. (2012). Similarity in parasite community structure to trace latitudinal migrations of *Odontesthes smitti* (Pisces: Atherinopsidae) in Argentinean coasts. *Journal of Fish Biology* **80**, 15–28. doi: 10.1111/j.1095-8649.2011.03125.x
- Clarke, K. R., Somerfield, P. J. & Chapman, M. G. (2006). On resemblance measures for ecological studies, including taxonomic dissimilarities and a zero-adjusted Bray–Curtis coefficient for denuded assemblages. *Journal of Experimental Marine Biology and Ecology* **330**, 55–80. doi: 10.1016/j.jembe.2005.12.017
- Díaz de Astarloa, J. M. (2002). A review of the flatfish fisheries of the south Atlantic Ocean. *Revista de Biología Marina y Oceanografía* **37**, 113–125. doi: 10.4067/S0718-19572002000200001
- Díaz de Astarloa, J. M. & Bolasina, S. N. (1992). Análisis estadístico de los caracteres morfométricos y merísticos de la pescadilla de red (*Cynoscion striatus*) en el área comprendida entre 34° y 39° S. *Frente Marítimo* **11**, 57–62.
- Díaz de Astarloa, J. M. & Fabrè, N. N. (2003). Abundance of three flatfishes (Pleuronectiformes: Paralichthyidae) off northern Argentina and Uruguay in relation to environmental factors. *Archive of Fishery and Marine Research* **50**, 123–140.
- Fabrè, N. N. & Díaz de Astarloa, J. M. (1996). Pleuronectiformes de importancia comercial del Atlántico Sudoccidental, entre los 34° 30' y 55° S. Distribución y consideraciones sobre su pesca. *Revista de Investigación y Desarrollo Pesquero* **10**, 45–55.
- Fabrè, N. N. & Díaz de Astarloa, J. M. (2001). Distributional patterns and abundance of paralichthyid flounders in the south-west Atlantic (Pleuronectiformes: Paralichthyidae). *Thalassas* **17**, 45–55.
- Fabrè, N. N., Cousseau, M. B. & Denegri, M. A. (2001). Aspectos de la dinámica poblacional del lenguado *Xystreurus rasile* (Jordan, 1890) en el sector del Atlántico Sudoccidental comprendido entre 34° y 40° S. *Investigaciones Marinas* **29**, 83–105.
- Figueiredo, J. L. & Menezes, N. A. (2000). *Manual de peixes marinhos do Sudeste do Brasil*, Vol. VI (5 Teleostei). São Paulo: Universidade de São Paulo, Museu de Zoologia.
- Gonçalves da Fonseca, M. C., de São Clemente, S. C., Felizardo, N. N., Gomes, D. C. & Knoff, M. (2012). Trypanorhyncha cestodes of hygienic-sanitary importance infecting flounders *Paralichthys patagonicus* Jordan, 1889 and *Xystreurus rasile* (Jordan, 1891) of the Neotropical region, Brazil. *Parasitology Research* **111**, 865–874. doi: 10.1007/s00436-012-2912-z
- Guerrero, R. A. & Piola, A. R. (1997). Masas de agua en la plataforma continental. In *El Mar Argentino y sus Recursos Pesquero, Tomo I: Antecedentes históricos de las exploraciones en el mar y las características ambientales* (Boschi, E., ed), pp. 107–119. Mar del Plata: Instituto Nacional de Investigación y Desarrollo Pesquero.
- Guerrero, R. A., Acha, E. M., Framinan, M. B. & Lasta, C. A. (1997). Physical oceanography of the Río de la Plata Estuary, Argentina. *Continental Shelf Research* **17**, 727–742.
- Jaureguizar, A. J., Menni, R., Lasta, C. & Guerrero, R. (2006). Fish assemblages of the northern Argentine coastal system: spatial patterns and their temporal variations. *Fisheries Oceanography* **15**, 326–344. doi: 10.1111/j.1365-2419.2006.00405.x
- Lester, R. J. G. & MacKenzie, K. (2009). The use and abuse of parasites as stock markers for fish. *Fisheries Research* **97**, 1–2. doi: 10.1016/j.fishres.2008.12.016
- Lucas, A. J., Guerrero, R. A., Mianzán, H. W., Acha, E. M. & Lasta, C. A. (2005). Coastal oceanographic regimes of the Northern Argentine Continental Shelf (34–43°S). *Estuarine, Coastal and Shelf Science* **65**, 405–420. doi: 10.1016/j.ecss.2005.06.015
- Magurran, A. E. (1988). *Ecological Diversity and Its Measurement*. Princeton, NJ: Princeton University Press.
- Marrari, M., Viñas, M. D., Martos, P. & Hernández, D. (2004). Spatial patterns of mesozooplankton distribution in the Southwestern Atlantic Ocean (34°–41° S) during austral spring: relationship with the hydrographic conditions. *Journal of Marine Science* **61**, 667–679. doi: 10.1016/j.icesjms.2004.03.025

- Menoret, A. & Ivanov, A. V. (2009). New name for *Progrillotia dollfusi* Carvajal et Rego, 1983 (Cestoda: Trypanorhyncha): description of adults from *Squatina guggenheim* (Chondrichthyes: Squatiniformes) off the coast of Argentina. *Folia Parasitologica* **56**, 284–294.
- Militelli, M. I. (2011). *Paralichthys patagonicus* spawning areas and reproductive potential in the Bonaerense Coastal Zone, Argentina (34°–42°S). *Latin American Journal of Aquatic Research* **39**, 131–137. doi: 10.3856/vol39-issue1-fulltext-12
- Militelli, M. I. & Macchi, G. J. (2006). Spawning and fecundity of striped weakfish, *Cynoscion guatucupa*, in the Río de la Plata estuary and adjacent marine waters, Argentina–Uruguay. *Fisheries Research* **77**, 110–114. doi: 10.1016/j.fishres.2005.08.004
- Millar, R. B. & Anderson, M. J. (2004). Remedies for pseudoreplication. *Fisheries Research* **70**, 397–407. doi: 10.1016/j.fishres.2004.08.016
- Perier, M. R. & Di Giacomo, E. (2002). Distribución, abundancia y reproducción de *Paralichthys isosceles*, *P. patagonicus* y *Xistreuris rasile* (Pleuronectiformes: Bothidae) en aguas patagónicas, Argentina. *IBMP Serie Publicaciones* **1**, 32–39.
- Perrotta, R. G. & Fernández-Giménez, A. F. (1996). Estudio preliminar sobre la edad y el crecimiento del pez palo (*Percophis brasiliensis* Quoy et Gaimard 1824). *INIDEP Informe Técnico* **10**, 25–36.
- Piola, A. R. & Rivas, A. L. (1997). Masas de agua en la plataforma continental. In *El Mar Argentino y sus Recursos Pesqueros. Antecedentes históricos de las exploraciones en el mar y las características ambientales* (Boschi, E. E., ed), pp. 119–132. Mar del Plata: INIDEP.
- Rico, M. R. (2010). Pesquería de lenguados en el ecosistema costero bonaerense al norte de 39° S. *Frente Marítimo* **21**, 129–135.
- Sabadin, D. E., González-Castro, M., Iudica, C., Díaz de Astarloa, J. M. & Fernández-Iriarte, P. J. (2010). Morphometric and genetic assessment of the *Cynoscion guatucupa* population structure from Buenos Aires coast, Argentine Sea. *Revista de Biología Marina y Oceanografía* **45**, 513–517.
- Secor, D. H. (1999). Specifying divergent migrations in the concept of stock: the contingent hypothesis. *Fisheries Research* **43**, 13–34.
- Szidat, L. (1961). Versuch einer Zoogeographie des Süd-Atlantik mit Hilfe von Leitparasiten der Meeresfische. *Parasitologische Schriftenreihe* **13**, 1–98.
- Timi, J. T. (2003). Parasites of Argentine anchovy in the Southwest Atlantic: latitudinal patterns and their use for discrimination of host populations. *Journal of Fish Biology* **63**, 90–107. doi: 10.1046/j.1095-8649.2003.00131.x
- Timi, J. T. (2007). Parasites as biological tags for stock discrimination in marine fish from South American Atlantic waters. *Journal of Helminthology* **81**, 107–111. doi: 10.1017/S0022149X07726561
- Timi, J. T. & Lanfranchi, A. L. (2009). The metazoan parasite communities of the Argentinean sandperch *Pseudoperca semifasciata* (Pisces: Perciformes) and their use to elucidate the stock structure of the host. *Parasitology* **136**, 1209–1219. doi: 10.1017/S0031182009990503
- Timi, J. T., Lanfranchi, A. L. & Etchegoin, J. A. (2009). Seasonal stability and spatial variability of parasites in Brazilian sandperch from the northern Argentine sea: evidence for stock discrimination. *Journal of Fish Biology* **74**, 1206–1225. doi: 10.1111/j.1095-8649.2009.02190.x
- Timi, J. T., Lanfranchi, A. L. & Luque, J. L. (2010). Similarity in parasite communities of the teleost fish *Pinguipes brasilianus* in the southwestern Atlantic: infracommunities as a tool to detect geographical patterns. *International Journal for Parasitology* **40**, 243–254. doi: 10.1016/j.ijpara.2009.07.006
- Volpedo, A. V. & Fernández Cirelli, A. (2006). Otolith chemical composition as a useful tool for sceaenid stock discrimination in the south-western Atlantic. *Scientia Marina* **70**, 325–334.
- Zar, J. H. (1999). *Biostatistical Analysis*, 4th edn. Upper Saddle River, NJ: Prentice Hall.