

Parasites as biological tags for stock discrimination of the Brazilian flathead *Percophis brasiliensis* in the south-west Atlantic

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Three stocks of the Brazilian flathead *Percophis brasiliensis* were identified on the coast of Argentina and Uruguay using parasites as biological tags. A total of 177 fish were examined and 23 parasite species were found. Fish were caught in four zones: north of the Argentine–Uruguayan Common Fishing Zone (34°30′–36°30′ S; 53°30′–56°00′ W), south of the Argentine–Uruguayan Common Fishing Zone (38°08′ S 57°32′ W), El Rincón zone (39–41° S; 60–62° W) and San Matías Gulf (41°40′–42°10′ S; 63°50′–65°00′ W). Discriminant analyses allowed the identification of three discrete stocks in the four zones (86.44% of classified samples were correctly identified), with *P. brasiliensis* from both north and south of the Argentine–Uruguayan Common Fishing Zone clumping together, as a single stock. Some species were important in discriminating among groups, *Anisakis simplex* was related to southern areas, while *Grillotia* sp., *Corynosoma australe* and *Hysterothylacium* sp. were important in determining the position of fish from the Argentine–Uruguayan Common Fishing Zone. These results were corroborated by comparing parasite prevalence and abundance among zones. The main differences were observed in those comparisons involving fish from the San Matías Gulf. Fish from the Argentine–Uruguayan Common Fishing Zone were characterized by higher infections of *Grillotia* sp., *C. australe*, *Corynosoma cetaceum* and *Hysterothylacium* sp., while the samples from El Rincón and San Matías Gulf showed higher infections of *A. simplex*. Samples from San Matías Gulf were characterized by lower levels of parasitism for all other species. Differences in environmental factors and their influence on the distribution of zooplankton and other hosts in the food web may be differentially shaping the parasite community structure in each zone, resulting in identifiable stocks of the *P. brasiliensis*. The present study confirmed the existence of regional biological tags that delineated fish assemblages.

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INTRODUCTION

The Brazilian flathead *Percophis brasiliensis* Quoy & Gaimard, 1894 (Perciformes) is a coastal fish with a geographical distribution restricted to South American Atlantic waters, from Rio de Janeiro, Brazil (23° S), to north of

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Santa Cruz Province in Argentina (47° S). It is a demersal species, inhabiting sandy bottoms where it feeds mainly on demersal fishes (Cousseau & Perrotta, 2004; Froese & Pauly, 2007).

Percophis brasiliensis is commercially exploited within a multispecific fishery that includes other species of such as striped weakfish *Cynoscion guatucupa* (Cuvier), white croaker *Micropogonias furnieri* (Desmarest) and Patagonian smoothhound *Mustelus schmitti* Springer. Despite differences in their population dynamics, all are exploited as a single resource. Furthermore, since 1997, the capture of these species has increased progressively (Carozza *et al.*, 2004). For this reason, it is critical that stock delineation for each of these species is identified to allow a sustainable management of the coastal fishery in Argentina.

This is especially true for *P. brasiliensis*, one of the less-studied species of exploited fish, on which there is no information about stock composition. At present, only age and growth (Perrotta & Fernández-Giménez, 1996) and reproductive biology (Militelli & Macchi, 2001*a, b*) have been addressed. Some parasites have been reported from *P. brasiliensis*: *Trifur tortuosus* (Copepoda), *Cardicola ambrosioi* (Digenea) and *Moravecia argentinensis* (Nematoda) in Argentinean waters (Rohde *et al.*, 1995; Braicovich *et al.*, 2006, 2007), and *Nybelinia* sp., *Grillotia* sp. (Cestoda) and *Anisakis* sp., *Contracaecum* sp., *Hysterothylacium* sp., *Raphidascaris* sp. and *Terranova* sp. (Nematoda) from Brazilian fish (Luque & Poulin, 2004).

Parasites have been used widely as biological tags to provide information on movements and population structure of their fish hosts (Lester, 1990; Williams *et al.*, 1992; MacKenzie & Abaunza, 1998). The abundance and geographical distributions of parasites depend on the abundance and geographical distributions of all host species involved in their life cycles and on the existence of suitable environmental conditions for their transmission (MacKenzie, 1987).

Six studies have been carried out using biological tags in the south-west Atlantic Ocean, for hake *Merluccius hubbsi* Marini and *Merluccius australis* (Hutton, 1872), chub mackerel *Scomber japonicus* Houttuyn, Argentine anchovy *Engraulis anchoita* Hubbs & Marini, *C. guatucupa* and Patagonian blenny *Eleginops maclovinus* Cuvier (MacKenzie & Longshaw, 1995; Cremonte & Sardella, 1997; Timi, 2003; Sardella & Timi, 2004; Timi *et al.*, 2005; Brickle & MacKenzie, 2007).

A common feature of these previous studies is that most hosts share a group of biological tags comprising species with extremely low specificity, such as *Anisakis simplex*, *Corynosoma australe* and *Grillotia* sp. (Timi, 2007), that display similar latitudinal patterns. Timi (2007) predicted that this group of species could be sufficient for discriminating populations of other fishes. Consequently, in a given area, both fish populations, and fish assemblages might be identified according to the occurrence of this group of parasites, characteristic of the region, making them suitable as regional biological tags.

The aim of this study was three-fold: (1) to identify the parasite fauna of *P. brasiliensis* in Argentine and Uruguayan seas, (2) to identify different stocks of the *P. brasiliensis* in this zone, using parasites as biological tags and (3) to test the hypothesis that there is a regional set of biological tags.

MATERIALS AND METHODS

A total of 177 specimens of *P. brasiliensis*, caught between 12 October 2005 and 8 March 2006, were examined for parasites. To minimize the influence of size on the parasite burden, only fish of comparable total length (L_T) were included in the analysis. Fish were caught in four zones: north of the Argentine–Uruguayan Common Fishing Zone (34°30′–36°30′ S; 53°30′–56°00′ W; $n = 35$, NCF), south of the Argentine–Uruguayan Common Fishing Zone, near Mar del Plata city (38°08′ S 57°32′ W; $n = 59$, SCF), El Rincón zone (39–41° S; 60–62° W; $n = 51$, ER) and San Matías Gulf (41°40′–42°10′ S; 63°50′–65°00′ W; $n = 32$, SMG) (Fig. 1). Parasites were recovered from the gills, body cavity and viscera (stomach, intestine, liver, gonads, heart and mesenteries).

Following Bush *et al.* (1997), prevalence and mean abundance were calculated for each parasite species in each area. For those species with prevalence >10%, in at least one of the zones (component species; Bush *et al.*, 1990), χ^2 analyses and *a posteriori* multiple comparisons for proportions were used to test for significant differences in prevalence between zones (Zar, 1999). Kruskal–Wallis and *a posteriori* Dunn's test for unequal samples were used to analyse the effects of locality on abundance of each

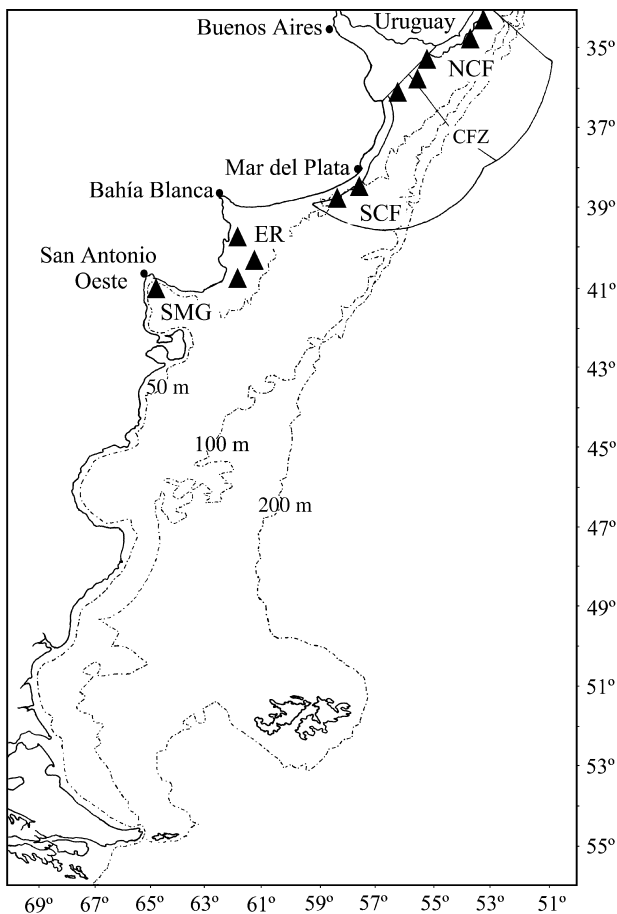


FIG. 1. Map of the south-west Atlantic Ocean showing sampling localities. NCF, Northern Common Fishing Zone; SCF, Southern Common Fishing Zone; ER, El Rincón zone; SMG, San Matías Gulf; CFZ, Argentine–Uruguayan Common Fishing Zone.

parasite species. A measurement of similarity, Jaccard qualitative index, was calculated among infracommunities within and between zones (Magurran, 1988). A discriminant analysis, based on Mahalanobis distances, was used to reveal differences between zones and to identify which parasite species were responsible for these differences. Analyses were computed on square root-transformed data and performed using the Brodgar 1.8 package (Brodgar, 2000).

RESULTS

Mean host L_T from the NCF (493.7 ± 67.2 mm), SCF (522.2 ± 36.7 mm), ER (500.2 ± 36.5 mm) and SMG (529.1 ± 67.2 mm) did not differ significantly among zones ($H_3 = 11.01$, $P > 0.05$).

Analyses of stomach contents showed that *P. brasiliensis* feeds mainly on fishes, molluscs and crustaceans. In NCF, SCF and ER, the main prey were fishes, representing 73.3, 88.9 and 81.8%, respectively, of total items observed. In NCF and SCF, *E. anchoita* and rough scad *Trachurus lathami* Nichols, were found in similar proportions, while in ER, *E. anchoita* was more prevalent. In SMG, the principal items were crustaceans (52.2%), while fishes represented only 39.1% of the diet.

The 100% of the examined *P. brasiliensis* were parasitized by at least one of the 23 species of parasites listed in Table I. A total of 117 361 parasites were found in the total sample. In all zones, *Grillotia* sp. was the dominant species, dominating 100% of infracommunities in both NCF and SCF zones, and reaching values of 96.0 and 78.1% in ER and SMG, respectively.

No differences were observed for either prevalence or mean abundance of *Lecithochirium microstomum* among areas (Tables II and III); conversely, prevalence and abundance of both *Callitetrarhynchus gracilis* and *Terranova* sp. were significantly variable among zones, but despite this, *a posteriori* testing failed to find which zone was responsible for such differences. For the rest of the species, comparisons of prevalence between areas (Table II) showed that a small number of differences occurred between NCF and SCF, only *Scolex polymorphus* and Gnathiidea gen. sp., differing with higher prevalence in SCF for both species. This zone also showed a higher prevalence than ER for *S. polymorphus* and *Hysterothylacium* sp. but lower prevalence for *A. simplex*. A higher number of differences were observed for comparisons involving SMG. In this zone, prevalence was lower for all species, except for *A. simplex* and *Contracaecum* sp. when compared with NCF.

Regarding the comparisons of abundance (Table III), *C. gracilis*, *Contracaecum* sp., *Terranova* sp. and gnathiid pranziae, the species with the lowest burdens in most localities showed overall significant differences, but *a posteriori* tests failed to detect the sources of such variations. For the remaining species, abundances were more homogeneous across samples than those of prevalence, with a lower number of differing pairs of zones. Nevertheless, when differences were observed, the results were the same as those for prevalence. Again, a small number of differences (only for *S. polymorphus*), occurred between NCF and SCF and the opposite situation, were observed for comparisons involving SMG.

Jaccard similarity index within zones showed that NCF was the most homogeneous group (Fig. 2), whereas the lowest similarity was observed among fish from SMG. Analyses between zones showed that the highest similarity values

TABLE I. Taxonomic composition, microhabitat, prevalence and mean abundance of parasites of *Percophis brasiliensis* in four zones of the Argentine and Uruguayan Seas

	Site	NCF		SCF		ER		SMG	
		P	MA ± s.d.	P	MA ± s.d.	P	MA ± s.d.	P	MA ± s.d.
<i>Prosohrynchus</i> sp. (DI)	GI	5.7	0.1 ± 0.2	5.1	0.1 ± 0.3	3.9	0.04 ± 0.20	0.0	0.0
<i>Cardicola ambrosioi</i> (DI)	BV	0.0	0.0	3.4	0.1 ± 0.4	0.0	0.0	0.0	0.0
<i>Derogenes varicus</i> (DI)	ST	0.0	0.0	0.0	0.0	0.0	0.0	6.2	0.1 ± 0.4
<i>Ectenurus</i> sp. (DI)	ST	0.0	0.0	5.1	0.1 ± 0.4	0.0	0.0	0.0	0.0
<i>Lectiochirium microstomum</i> (DI)*	ST	0.0	1.1 ± 2.5	22.03	1.1 ± 2.8	9.8	0.2 ± 1.1	6.2	0.2 ± 0.7
<i>Lectiochirium</i> sp. (DI)	ST	0.0	0.0	0.0	0.0	0.0	0.0	6.2	0.1 ± 0.2
<i>Scolex polymorphus</i> , plerocercoid (CE)*	IN	51.4	12.3 ± 20.3	88.1	90.8 ± 103.5	51	31.3 ± 59.7	65.6	27.7 ± 36.8
<i>Grillotia</i> sp., plerocercoid (CE)	ME	100.0	638.5 ± 635.1	100.0	568.0 ± 358.9	100.0	364.5 ± 222.3	100.0	142.3 ± 191.1
<i>Callitetrarhynchus gracilis</i> (CE)*	ME	5.7	0.1 ± 0.2	23.7	0.3 ± 0.5	9.8	0.1 ± 0.4	3.1	0.0 ± 0.2
<i>Nybelinia</i> sp. (CE)*	ME	31.4	0.6 ± 1.1	35.6	0.6 ± 1.0	39.2	3.5 ± 16.9	6.2	0.1 ± 0.2
<i>Pseudophyllidea</i> plerocercoid (CE)	ME	2.8	0.0 ± 0.2	1.7	0.0 ± 0.1	9.8	0.1 ± 0.3	0.0	0.0
<i>Anisakis simplex</i> (NE)*	ME	11.4	0.2 ± 0.6	33.9	0.6 ± 1.2	98.0	16.5 ± 13.3	53.1	8.7 ± 26.2
<i>Contracaecum</i> sp. (NE)*	ME	0.0	0.0	1.7	0.0 ± 0.3	5.9	0.3 ± 1.5	15.6	0.2 ± 0.4
<i>Hysterothylacium</i> sp. (NE)*	ME	94.3	126.3 ± 179.9	100	65.6 ± 92.6	70.6	2.7 ± 4.3	9.4	0.2 ± 0.5
<i>Hysterothylacium aduncum</i> (NE)	ST; IN	0.0	0.0	1.7	0.2 ± 1.3	13.7	1 ± 5.1	0.0	0.0
<i>Terranova</i> sp. (NE)*	ME	0.0	0.0	1.7	0.1 ± 0.5	11.8	0.2 ± 0.6	0.0	0.0
<i>Moravectia argentinensis</i> (NE)*	BV	17.1	0.2 ± 0.5	42.4	0.7 ± 1.1	45.1	0.7 ± 1.0	6.2	0.1 ± 0.2
<i>Ascarophis marina</i> (NE)	ST	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.03 ± 0.2
<i>Corynosoma australe</i> (AO)*	ME	100.0	95.8 ± 121.2	100.0	92.4 ± 78.3	96.1	24.5 ± 29.1	75.0	5.5 ± 10.2
<i>Corynosoma cetaceum</i> (AC)*	ME	60.0	5.9 ± 28.2	62.7	1.9 ± 2.6	56.9	3.9 ± 8.9	25	1.9 ± 6.4
<i>Gnathidea</i> gen. sp. (IS)*	GI	0.0	0.0	22.0	0.4 ± 1.1	9.8	0.2 ± 0.5	0.0	0.0
<i>Trifur tortuosus</i> (CO)	GI	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0 ± 0.2
Hirudinean	GI	0.0	0.0	0.0	0.0	1.9	0.0 ± 0.1	0.0	0.0

DI, Digenea; CE, Cestoda; NE, Nematoda; AC, Acanthocephala; CO, Copepoda; IS, Isopoda; GI, gills; IN, intestine; ME, mesenteries; ST, stomach; BV, blood vessels. MA, mean abundance. P, prevalence; NCF, Northern Common Fishing Zone; SCF, Southern Common Fishing Zone; ER, El Rincón; SMG, San Matías Gulf.

*Component species.

TABLE II. Comparisons of prevalence of component parasite species of *Percophis brasiliensis* among four zones of the Argentine and Uruguayan Seas (see Table I)

Species	χ^2	P	NCF-SCF	NCF-ER	NCF-SMG	SCF-ER	SCF-SMG	ER-SMG
<i>L. microstomum</i>	5.88	NS						
<i>S. polymorphus</i>	21.35	<0.01	NCF < SCF	NS	NS	SCF > ER	NS	NS
<i>C. gracilis</i>	11.24	<0.01	NS	NS	NS	NS	SCF > SMG	NS
<i>Nybelinia</i> sp.	11.44	<0.01	NS	NS	NCF > SMG	NS	SCF > SMG	ER > SMG
<i>A. simplex</i>	74.07	<0.01	NS	NCF < ER	NCF < SMG	SCF < ER	NS	ER > SMG
<i>Contracaecum</i> sp.	10.71	<0.01	NS	NS	NCF < SMG	NS	NS	NS
<i>Hysterothylacium</i> sp.	98.01	<0.01	NS	NCF > ER	NCF > SMG	SCF > ER	SCF > SMG	ER > SMG
<i>Terranova</i> sp.	11.74	<0.01	NS	NS	NS	NS	NS	NS
<i>M. argentinensis</i>	20.35	<0.01	NS	NCF < ER	NS	NS	SCF > SMG	ER > SMG
<i>C. australe</i>	28.39	<0.01	NS	NS	NCF > SMG	NS	SCF > SMG	ER > SMG
<i>C. cetaceum</i>	13.29	<0.01	NS	NS	NCF > SMG	NS	SCF > SMG	ER > SMG
Gnathiidae gen. sp.	16.68	<0.01	NCF < SCF	NS	NS	NS	SCF > SMG	NS

NS, not significant ($P > 0.05$).

TABLE III. Comparisons of abundance of component parasite species of *Percophis brasiliensis* among four zones of the Argentine and Uruguayan Seas (see Table I)

Abundance									
Species	H	P	NCF-SCF	NCF-ER	NCF-SMG	SCF-ER	SCF-SMG	ER-SMG	
<i>L. microstomum</i>	6-49	NS	—	—	—	—	—	—	—
<i>S. polymorphus</i>	34-14	<0-01	NCF < SCF	NS	NS	SCF > ER	SCF > SMG	NS	NS
<i>C. gracilis</i>	11-23	0-011	NS	NS	NS	NS	NS	NS	NS
<i>Nybelinia</i> sp.	11-79	<0-01	NS	NS	NS	NS	SCF > SMG	NS	NS
<i>A. simplex</i>	108-44	<0-01	NS	NCF < ER	NCF < SMG	SCF < ER	NS	ER > SMG	NS
<i>Contracaecum</i> sp.	10-27	0-016	NS	NS	NS	NS	NS	NS	NS
<i>Hysterothylacium</i> sp.	124-20	<0-01	NS	NCF > ER	NCF > SMG	SCF > ER	SCF > SMG	NS	NS
<i>Terranova</i> sp.	11-52	<0-01	NS	NS	NS	NS	NS	NS	NS
<i>M. argentinensis</i>	21-02	<0-01	NS	NS	NS	NS	SCF > SMG	NS	NS
<i>C. australe</i>	78-47	<0-01	NS	NCF > ER	NCF > SMG	SCF > ER	SCF > SMG	ER > SMG	NS
<i>C. cetaceum</i>	10-71	0-013	NS	NS	NS	NS	SCF > SMG	ER > SMG	NS
Gnathiidae gen. sp.	10-60	<0-01	NS	NS	NS	NS	NS	NS	NS

NS, not significant ($P > 0.05$).

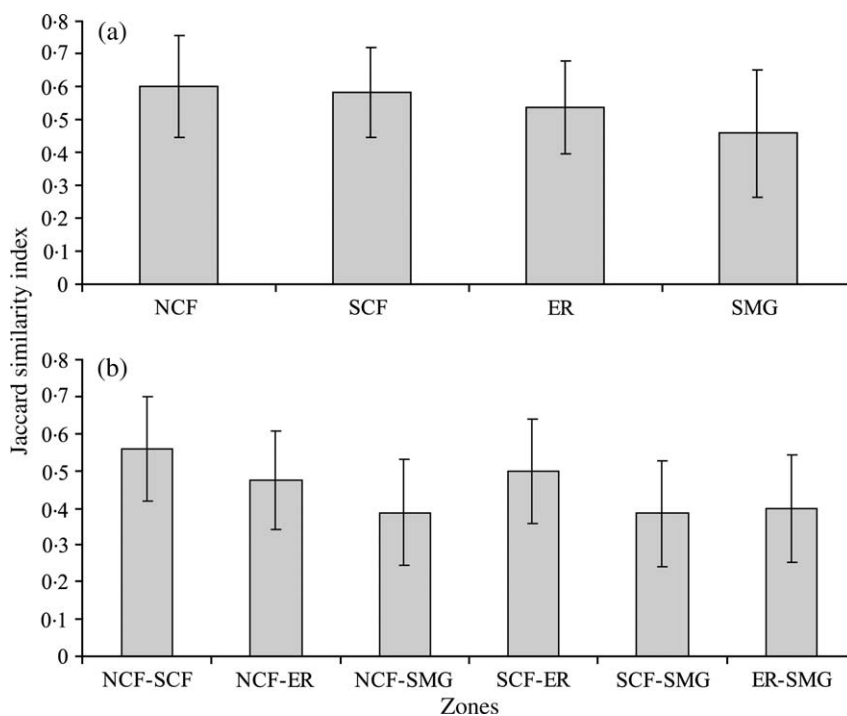


FIG. 2. Jaccard similarity indices (mean \pm S.D.) parasite infracommunities of *Percophis brasiliensis* in four zones of the Argentine Sea: (a) qualitative similarity within zones and (b) qualitative similarity between zones. NCF, Northern Common Fishing Zone; SCF, Southern Common Fishing Zone; ER, El Rincón zone; SMG, San Matías Gulf.

occurred among infracommunities from the Argentine–Uruguayan Common Fishing Zone, which were lower than those within both NCF and SCF. Conversely, the lowest values were those for comparisons involving samples from SMG.

The first two discriminant functions explained 84.8% of the variance, contributing to 65.7% (eigenvalue = 2.435) and 19.11% (eigenvalue = 0.708), respectively. A significant overall group effect was observed (Wilks' $\lambda = 0.109$, $F_{69,452}$, $P < 0.01$).

The scores of individual fish showed a clear discrimination between three groups, one including fish from both northern samples (NCF and SCF), which clumped together, and the other two represented by *P. brasiliensis* from ER and SMG, this pattern was readily observed by representing the group means (Fig. 3). Dimensionality tests for group separation showed that the zones were significantly separated in both dimensions (χ^2_{21} , $P = 0.001$). Each host was classified correctly to the three zones with an accuracy of 86.44% (Table IV), while the percentage of correctly classified samples relative to chance was 13.56%.

The importance of each parasite species with respect to discrimination between groups (Fig. 4), evaluated as canonical correlations between discriminant functions and species scores as variables, showed that *A. simplex*, the most important species in determining the position of samples, was related to fish

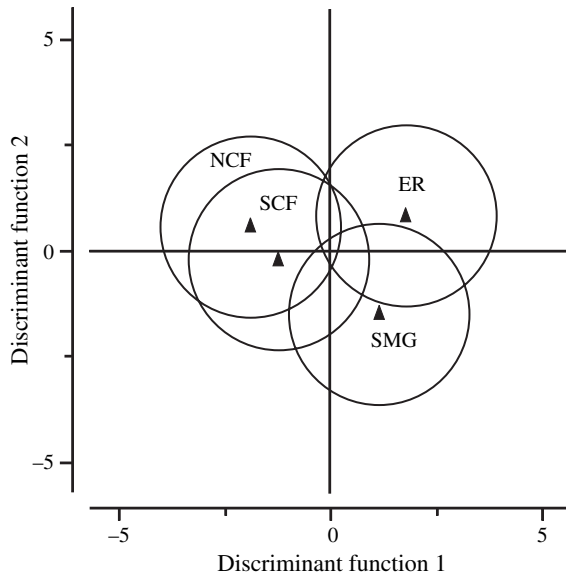


FIG. 3. Sample scores of the first two discriminant functions for specimens of *Percophis brasiliensis* in four zones of the Argentine Sea. ▲, group means; ○, around ▲ are the 90% tolerance regions (e.g. 90% of the observations in a group are expected to lie in this region). NCF, Northern Common Fishing Zone; SCF, Southern Common Fishing Zone; ER, El Rincón zone; SMG, San Matías Gulf.

from ER, whereas *S. polymorphus* behaved in an opposite way. On the other hand, *Hysterothylacium* sp., *Grillotia* sp. and *C. australe* were related to fish from northern areas. *Moravecchia argentinensis* and *Nybelinia* sp. were indicators of samples from both northern areas and ER and inversely correlated to *P. brasiliensis* from SMG, for which the indicators were *Derogenes varicus* and *Lecithocladium* sp. These four species, however, were mainly responsible for the minor discrimination in the y-direction. The remaining species, whose removal resulted in a decrease <2% of the total sum of Mahalanobis distances, were excluded from the figure.

A second discriminant analysis considering both northern samples (NCF and SCF) as a single group (CF) showed that the first two discriminant variables explained 100% of the variance, contributing 77.17% (eigenvalue = 2.339)

TABLE IV. Discriminant analysis classification showing the numbers and percentages of *Percophis brasiliensis* classified in rows correspond to group memberships (see Table I)

	NCF	SCF	ER	SMG	%*
NCF	30	4	0	1	85.71
SCF	8	50	0	1	84.75
ER	0	0	45	6	88.24
SMG	0	0	4	28	87.50

*Percentage of correctly classified fish per zone.

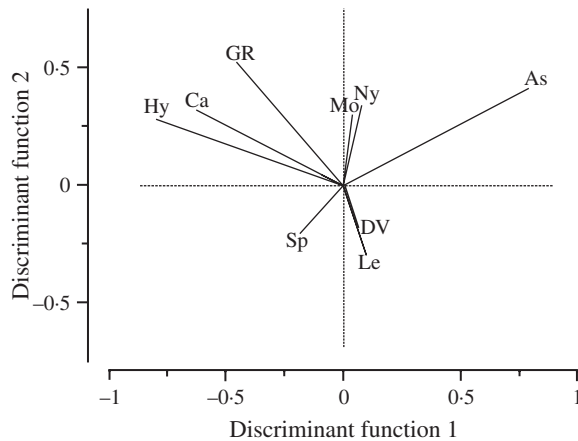


FIG. 4. Canonical correlations between the first two discriminant functions and the parasites of *Percophis brasiliensis* selected as biological tags. As, *Anisakis simplex*; Ca, *Corynosoma australe*; Dv, *Derogenes varicus*; Gr, *Grillotia* sp.; Hy, *Hysterothylacium* sp.; Le, *Lecithocladium* sp.; Mo, *Moravecchia argentinensis*; Ny, *Nybelinia* sp.; Sp, *Scolex polymorphus*.

and 22.83% (eigenvalue = 0.692), respectively. A higher significance for an overall group effect was observed in this analysis (Wilks' $\lambda = 0.177$, $F_{46,304}$, $P < 0.001$). Also a higher number of correctly classified hosts was obtained (93.22%), with an improvement of correctly classified fish corresponding to NCF and with no changes in the other two zones (Table V).

DISCUSSION

The present study increases the knowledge of the parasite fauna of *P. brasiliensis* in the Argentine and Uruguayan Seas. With the exception of *T. tortuosus*, Gnathiidea gen. sp., *C. ambrosioi* and *M. argentinensis*, the remaining species are new host records for this zone. Excluding *Nybelinia* sp., *Grillotia* sp., *Anisakis* sp., *Contracaecum* sp., *Hysterothylacium* sp., *Terranova* sp., reported previously for *P. brasiliensis* from Rio de Janeiro, Brazil, by Luque & Poulin (2004), the remaining species are recorded for the first time in this host species.

Because the samples were collected over a relatively short period (warm season), it is assumed that seasonal variations did not influence parasite burdens.

TABLE V. Discriminant analysis classification showing the numbers and percentages of *Percophis brasiliensis* classified in rows correspond to group memberships (see Table I)

	NCF	ER	SMG	%*
NCF	92	0	2	97.87
ER	0	45	6	88.24
SMG	0	4	28	87.50

*Percentage of correctly classified fish per zone.

On the other hand, the homogeneity in host age or size across zones ensured that these variables had no effects on the results of comparisons among areas.

The structure of the food web has been hypothesized to have some effect on transmission rates of some parasite species (Marcogliese, 2002). Therefore, host feeding habits can influence the number of parasite species exploiting a host species (Luque *et al.*, 2004); furthermore, beyond the specific habits of fish species, differential availability of prey species can account for the heterogeneity in parasite burdens observed among geographical zones. Indeed, the highest number of differences in both prevalence and abundance were observed in those comparisons including SMG where carcinophagous habits were notably higher than for northern regions. Among the latter areas, ichthyophagy was the dominant habit and parasite burdens showed higher similarity.

The characteristics of local ecosystems and their trophic webs can determine not only the richness but also the abundance of larval helminths in fishes (Luque & Poulin, 2004). For example, *E. anchoita*, one of the main prey items of *P. brasiliensis* in all three northern areas studied, showed higher levels of parasitism by *A. simplex* in ER than in either NCF or SCF (Timi, 2003), a situation that mirrored the observed distribution of *A. simplex* in *P. brasiliensis*.

At parasite population level, the observed significant differences for parasite indices among zones, mainly for prevalence, demonstrated the utility of parasites as biological tags in discriminating stocks of *P. brasiliensis*. Most of species showing differences among zones were larvae, transmitted through trophic interactions and, with the exception of *S. polymorphus*, all were in the body cavity. These can therefore persist in the host for a long time and, in general, corresponded with those groups suitable as biological tags for other fishes (MacKenzie & Abaunza, 1998), including those studied in South American Atlantic waters (Timi, 2007).

Similarity values among infracommunities within NCF and SCF were similar to those of comparisons between these areas, indicating the integrity of the stock inhabiting this zone. On the other hand, comparisons of samples from ER with those from both northern zones, despite showing some degree of similarity, displayed enough differences to be considered as a discrete stock unit. In fact, studies based on growth variables have suggested that flatheads from ER belong to a stock independent from fish inhabiting the Argentine–Uruguayan Common Fishing Zone (Perrotta & Fernández-Giménez, 1996). Finally, fish from SMG were members of a third stock unit, clearly different from northern fish. This stock was also the most heterogeneous in terms of parasite assemblage structure, showing the lowest within-group similarity values, even lower than those values observed between both northern zones and ER.

Results of discriminant analysis showed further evidence of the existence of three independent stocks of *P. brasiliensis*. Both north zones (NCF and SCF) were separated as one group, characterized for high levels of parasitism by *Hysterothylacium* sp., *Grillotia* sp. and *C. australe*. These species have been identified as suitable markers for other host species in this region (Sardella & Timi, 2004, Timi *et al.*, 2005). The integrity of the stock from the Argentinean–Uruguayan Common Fishing Zone was especially evident after pooling fish from both NCF and SCF. Both *M. argentinensis* and *Nybelinia* sp. were related to fish from all three northern regions, probably as a consequence of the

proximity of these areas. The principal biological tag for samples from ER was *A. simplex*, a species typically associated with southern (colder) waters (Timi, 2003; Sardella & Timi, 2004). *Scolex polymorphus* has been defined as a species complex (Chambers *et al.*, 2000), which can have different geographic distributions and, therefore, cannot be used as a reliable biological tag.

The composition and distribution of marine communities are governed by the dynamics of oceanographic conditions on a regional scale. Marine parasites are not an exception and thus their abundance and distribution patterns are determined mainly by temperature and salinity profiles (Esch & Fernández, 1993) through the influence of physical conditions on both, on food webs and the availability of infective stages for trophically transmitted parasites (Kimpel & Rükert, 2005). Indeed, each one of the three stocks identified in the present study inhabits one area with differential oceanographic and biological characteristics.

The Argentine–Uruguayan Common Fishing Zone is greatly influenced by both the Brazil current (tropical warm and saline waters) and the discharge of the Río de la Plata (Martos, 1989; Bakun & Parrish, 1991; Guerrero & Piola, 1997), especially during spring and summer when their influence reaches the coasts of Mar del Plata (Guerrero *et al.*, 1997). Some enclosed and semi-enclosed areas have been identified in other regions of the Argentinean shelf, such as San Matías Gulf and the semi-protected coastal areas of ER, which can generate their own oceanographic features. These locally modified waters create frontal zones with important biological properties (Acha *et al.*, 2004). They provide reproductive grounds and zones of concentration for juveniles of several coastal species by promoting retention of larvae, especially during the warm season. (Guerrero & Piola, 1997; Piola & Rivas, 1997; Carozza *et al.*, 2004). In fact, two marine fronts are present in the study area, one associated with the Río de la Plata Estuary (in the NCF) and other in the El Rincón Estuary (Acha *et al.*, 2004). The processes associated with the formation of these fronts also influence the distribution of mesozooplankton on coastal waters, which by displaying a differential composition between the northern region and ER, have been classified as different faunistic areas (Marrari *et al.*, 2004).

In contrast, SMG is an isolated coastal basin, which has oceanographic conditions differing markedly from those on the continental shelf. In spring, the gulf presents two zones with markedly different water masses, one in the north-east is characterized by high temperature and salinity and the other, in the south and south-east, has a lower temperature and salinity (Carreto *et al.*, 1974; Gagliardini & Rivas, 2004). Furthermore, geomorphology of the gulf mouth restricts the interchange of water with open sea (Piola & Rivas, 1997).

Some ichthyological studies carried out in this region support the belief that oceanographic conditions are important in determining the stock composition of fish species. In fact, differences in otolith microchemistry between samples of *C. guatucupa* and *M. furnieri* suggest the existence of different stocks inhabiting ER and the northern region of the Argentine Sea (Río de la Plata Estuary) (Volpedo & Fernández Cirelli, 2006). Furthermore, the physical characteristics of SMG are thought to be responsible for larval retention and therefore of stock discreteness for *M. hubbsi* and *M. australis*, inhabiting the gulf (Di Giacomo *et al.*, 1993).

Evidence from parasitological analyses clearly showed that three stocks of *P. brasiliensis* can be identified in the four areas. *Percophis brasiliensis* from SMG clearly belong to a discrete stock. Despite showing a higher level of similarity, *P. brasiliensis* from the Argentine–Uruguayan Common Fishing Zone and ER can be assigned to other two independent stocks.

Stock assessment is the first step in the development of a sustainable fisheries policy, and this is the first evidence of the presence of several populations of *P. brasiliensis* in the South Atlantic, supporting suggestions of Perrotta & Fernández-Giménez (1996). Other stock assessment techniques are still needed in order to confirm the present findings (Begg & Waldman, 1999), but it is clear that *P. brasiliensis* requires assessment for its integrated management in the coastal fishery of Argentina.

The present results agree with previous studies on parasites as biological tags for fish stock discrimination which have been a successful tool for all populations of marine fishes to which they were applied (Timi, 2007). In fact, parasites of both *M. hubbsi* and the Brazilian sandperch *Pinguipes brasiliensis* Cuvier allowed the identification of discrete stocks of these species in SMG (Sardella & Timi, 2004; Timi *et al.*, 2008), whereas *E. anchoita* and *C. striatus* caught in NCF and SCF displayed similar parasite assemblages in both zones to be considered as a single units of stock (Timi, 2003; Timi *et al.*, 2005). Furthermore, all these fish species share a set of species, identified as suitable tags, and closely associated with specific zones; for example, *C. australe* was an indicator of waters of the Argentine–Uruguayan Common Fishing Zone also for *E. anchoita*, *M. hubbsi*, *C. guatucupa* and *P. brasiliensis*. The same situation has been observed for *Grillotia* sp., although it was absent in *E. anchoita* samples. On the other hand, *A. simplex* and *Contracecum* sp. were characteristic of samples of *M. hubbsi* and *E. anchoita* from Patagonian waters, including *M. hubbsi* and *M. australis* from SMG. Therefore, the hypothesis for the existence of regional biological tags, applicable not only to fish species but also to fish assemblages was confirmed.

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