# Characterizing Trichoptera trophic structure in rivers under contrasting land use in Patagonia, Argentina

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## Abstract

Trichoptera is a widely distributed and diversified group in Andean Patagonia (Subandean Patagonic Province). This group exhibits a wide array of functional adaptations to exploit the available food resources. It is well known that changes in the relative abundance of functional-feeding groups (FFG) occur when the distribution of energetic resources (organic matter) is altered. In order to determine the functional structure variation among rivers subjected to different land uses, we selected 3 disturbance types (exotic plantation, pasture and logging) and native forest as reference. Three sites were assessed for each land use type (*n*=12) seasonally (every 3 months) and 6 samples with a Surber net (0.09 m$^{-2}$ and 250 pore size) were taken. Larvae obtained were identified to the lowest possible taxonomic level, counted and assigned to a FFG using available references, knowledge of feeding modes and analysis of gut contents. A total of 32 taxa were identified belonging to 11 families. Mean annual densities of Trichoptera varied between 131 and 4231 ind.m$^{-2}$. Pasture sites showed significantly higher density than pine and native forest sites. Overall Trichoptera FFG species composition was: shredder (10), predator (9), scraper (6), collector-filterer (5), algal-piercer (1), and collector-gatherer (1). The scraper *Mastigoptila* sp. was abundant in native forest rivers. Predators presented high density in logged forest sites. Shredders (53–98%) dominated rivers having dense forest cover; *Parasericostoma ovale* (Schmid) and *Myotrichia murina* Schmid (Sericostomatidae) being the most abundant species. Collector-filterers, mostly *Smicridea annulicornis* (Blanchard) and *S. frequens* (Navás) (Hydropsychidae), were the dominant group in pastures (42-96%), probably due to an increase of transported seston. According to these results, Trichoptera communities can be used as an early warning tool to assess changes in disturbed headwater systems in Patagonia.

**Key words:** Pastures, exotic forest, logging activities, functional-feeding group

## Introduction

According to Ward (1989) there are multiple interactions between a stream and its adjacent landscape.  One of the key elements in river function is the link between the lateral and vertical dimensions represented by the multiple pathways through the channel and the riparian corridor (Vannote *et al*. 1980, Munné *et al*. 2003). The presence of riparian vegetation stabilizes banks, moderates water temperature, filters nutrients and sediments and influences the availability of light and inputs of particulate organic matter (Gregory *et al*. 1991). It also provides protection against seasonal flooding and buffers large discharge events (Whiting & Pomeranets 1997).

Land use change results in profound modifications of running waters in mountain streams of temperate areas. These modifications vary depending on the landscape setting, and the type and

intensity of the impact (Allan & Castillo 2007). The loss of riparian vegetation is one of the most obvious consequences of land use practices. It is typically accompanied by bank erosion, silt deposition and changes in thermal regime (Lowrance *et al.* 1997, Hickey & Doran 2004). Moreover, by reducing the amounts of allochtonous leaf material entering the river, food webs can be modified (Abelho & Graça 1998, Miserendino 2005).

Frequently forest harvesting practices alter riparian corridors. This supplies large amounts of organic matter to the streambed, providing food resource for shredders, either directly or via incorporation into fungal and bacterial biomass (Richardson & Thompson 2009). Moreover, by opening the canopy above streams, the light intensity increases, leading to periphyton augmentation, which in turn might favor herbivorous species (Quinn *et al.* 1997, Rutherford *et al.* 1997).

Pastoral development frequently implies the removal of large areas of forest including riparian vegetation. This procedure is often followed by livestock inclusion, which increases land degradation (erosion, soil compaction). Conversion of native forest to pastures augments fine-sediment loads due to catchment and streambank erosion (Quinn *et al.* 1998). Fine sediments have a strong abrasive effect (scouring) on the epilithon and invertebrates, affecting both habitat and food quality (Davies-Colley *et al.* 1992, Quinn 2000).

Quinn (2000) argued that smaller headwater streams are expected to be more responsive to changes in stream shade, sedimentation and nutrient inputs associated with pastoral development and riparian harvesting than larger rivers, due to their greater degree of shading by forest, shallower depths and lower flows (Davies-Colley & Quinn 1998).

Studies conducted in streams draining exotic forested areas indicate few changes in the functional structure of the benthic community (Harding *et al.* 2000). Nevertheless, recent works in Patagonia highlight significant differences on functional attributes of macroinvertebrate communities in streams draining pine plantations from those in native *Nothofagus* forest (Miserendino & Masi 2009).

The effects of land use in Patagonia such as conversion of native forest to pasture, wood collection activities, and substitution of native forest for pine plantation have been the focus of scientific investigation. Recent surveys have assessed water quality and macroinvertebrate response to impairment (Miserendino & Pizzolón 2003, Miserendino *et al.* 2008) and land use effects in different sets of lotic environment in this area (Miserendino & Pizzolón 2004, Miserendino & Brand 2007). Many of these studies used successfully macroinvertebrate trophic guilds to evaluate the ecological integrity in rivers.

Trichoptera constitute one of the most important and diversified groups in rivers in the cordillera (Angrisano & Sganga 2009) and their species exhibit a variety of feeding strategies. Therefore, we conducted this study in order to assess the impacts of different land use practices (native forest, exotic plantation, pasture, and logging) on Trichoptera functional structure in mountain streams of northwest Patagonia (Argentina).

## Methods

### Study area and site selection

The study area is located in Northwest Chubut Province (Fig. 1) in the ecotone between the Subantarctic forest and the Patagonian steppe. Native forest vegetation is composed of deciduous *Nothofagus* species, and the perennial *Maytenus boaria* Mol. and *Austrocedrus chilensis* (D. Don) Pic. Serm. & M.P. Bizzarri. Valleys and lower areas are dominated by shrub-like steppe vegetation (Tell *et al.* 1997). In exotic plantations the dominant tree species are *Pseudotsuga menziesii* (Mirbel)

Franco, *Pinus ponderosa* Laws., *P. radiata* D. Don and *P. lambertiana* Douglas, in many cases these species have replaced the native vegetation in the riparian corridor.
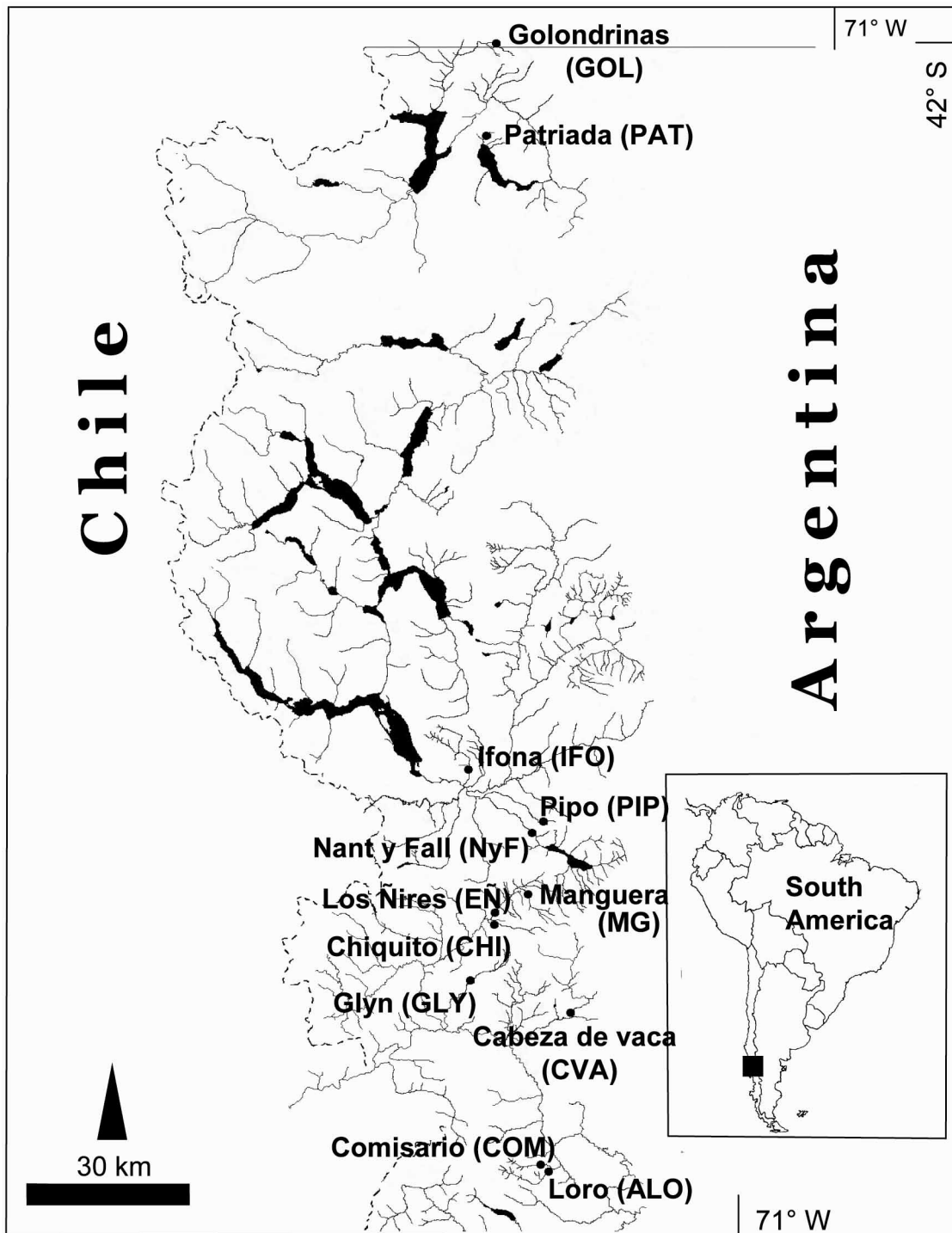


**FIGURE 1.** Study area map, showing location of sampling sites in Northwest Chubut Province, Patagonia, Argentina.

For this study we selected sites under different land uses, exotic tree plantation, harvested forest and pasture. The pine plantations sites corresponded to streams running (950 to 1200 m) through mature exotic forest (Patriada, Ifona, Golondrinas: hereafter PAT, IFO, GOLO, respectively).

Three sites were selected in forest subjected to wood extraction practices (Pipo, Glyn, Cabeza de Vaca: PIP, GLY, CVA, respectively). Logging activities includes the selective extraction of specimens which should not affect more than 50% of the parcel. Pastures sites (Los Ñires, Manguera, Nant y Fall: EÑ, MG, NYF, respectively) were located where the original *Nothofagus* forest was logged and reduced to patches disconnected from the river corridor. These cleared areas are dominated by exotic herbaceous species and subjected to intense cattle grazing. Large areas of the stream presented evidence of bank erosion due to the presence of livestock.

In order to compare these sites with the natural condition, 3 undisturbed streams were selected as reference (Comisario, Loro, Chiquito: COM, ALO, CHI, respectively). The forest structure of these sites remains intact, and the riparian condition was regarded as optimum.

**Environmental characterization and macroinvertebrate analysis**

Sampling sites (n=12) were visited every 3 months from May 2005 to March 2006. At each site, current speed (m.s$^{-1}$) was measured in mid-channel on 3 occasions by timing a float (average of 3 trials) as it moved over a distance of 10 m (Gordon *et al*. 1994). Average depth was estimated from 5 measurements along 1 transversal profile across the channel with a calibrated stick. Wet and dry widths (cm) of the channel were also determined. Discharge (m$^3$s$^{-1}$) was obtained by combining depth, wet width and current velocity as described by Gordon *et al*. (1994). Substratum composition at each sampling reach was estimated visually using a 1 m$^2$ grid and dominant fractions consigned.

On each sampling date, water temperature, pH, specific conductance ($\mu$S.cm$^{-1}$), dissolved oxygen (mg O$_2$ l$^{-1}$) and saturation percentage were measured with a Horiba U2-probe. For nutrient analyses, water samples were collected below the water surface and kept refrigerated during transport to laboratory. Total suspended solids (TSS), soluble reactive phosphate (SRP), nitrate plus nitrite nitrogen (NO$_3$+NO$_2$) and ammonia (NH$_4$) were analyzed following standard methods (APHA 1999). Benthic samples were collected from pools and riffles (n=6) with a Surber net (0.09 m$^2$; 250 $\mu$ mesh size) at each visit (n=4). Samples were fixed in the field in formaldehyde solution (4%).

Larvae of Trichoptera species were sorted manually under 5X magnification, counted and preserved in 70% alcohol. Specimens were identified using available keys (Angrisano 1998, 2001; Angrisano & Korob 2001; Sganga & Fontanarrosa 2006; Angrisano & Sganga 2009). Total taxa richness, mean annual density, and percentage of functional-feeding groups (FFG) were determined.

To determine the significance of differences of environmental features among land uses, non parametric ANOVA tests (Kruskal-Wallis) were performed. Differences on FFG attributes per land use were assessed using Mann Whitney test (MW) (pair site comparison) (Sokal & Rohlf 1995).

**Results**

**Environmental characterization**

Wet width (range 1.2-25 m), depth (range 5.2−41.3) and discharge (range 0.01−8) varied between sites (Table 1). Pasture sites showed significantly higher wet width than the other uses ($p<0.01$). Current velocity varied between 0.1 and 1.66 m.sec$^{-1}$ but did not vary in a systematic manner among land uses ($p=0.19$). At most sites the substrate particle size was mainly boulder, cobble and pebble. However, a higher proportion of sand was observed in some sites (LÑ, PAT, PIP) having sedimentation symptoms.

As expected, native forest sites showed lower water temperature than the other sites. There were also differences in physico-chemistry, with conductivity values lower ($p<0.02$) at native forest sites

than at the others. Turbidity mean values showed higher values at exotic forest sites (33.7 NTU) followed by native forest sites (30.5 NTU), these values being 3 times higher than in pasture and harvested forest sites. Total suspended solids readings were twice those at pasture sites than at those obtained in native and exotic forest sites. Nutrient values (SRP, $NO_3$ and $NH_4$) showed little variation among sites.

**TABLE 1.** Mean annual values and ranges of environmental variables in the study streams (n=12) (Patagonia, Argentina) during the one-year study period (May 2005-March 2006).

| | Pine | | Pasture | | Harvested forest | | Native forest | |
|---|---|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| Water temp. (ºC) | 8.1 | 7.1-11.5 | 8.2 | 3.4-13.6 | 7.1 | 4-10.6 | 4.5 | 1.7-7.4 |
| Wet Width (m) | 4.1 | 1.1-9.2 | 11.3 | 5-25 | 4.3 | 1.3-11 | 4.7 | 1.5-8.9 |
| Depth (cm) | 22 | 7.8-41.3 | 30 | 13.5-33.7 | 18 | 5.2-28 | 25 | 10.4-34.3 |
| W. velocity (m.s$^{-1}$) | 0.59 | 0.20-1.07 | 0.94 | 0.66-1.11 | 0.81 | 0.10-1.66 | 0.92 | 0.10-1.66 |
| Discharge (m$^3$.s$^{-1}$) | 1.09 | 0.02-3.8 | 3.60 | 0.45-8 | 1.03 | 0.01-3.08 | 1.36 | 0.02-4.7 |
| pH | 7.16 | 6.8-7.5 | 7.38 | 6.6-7.9 | 7.28 | 7-7.6 | 7.28 | 7-7.6 |
| Conductivity (µS. cm-$^1$) | 79.8 | 29-137 | 87.3 | 61-118 | 61.3 | 38-97 | 35 | 9-92 |
| Dis. Oxygen (mg.l$^1$) | 11.6 | 8.6-15.7 | 11.1 | 7.7-14.9 | 12.7 | 8.9-18.8 | 14.1 | 11-20 |
| Turbidity (NTU) | 33.7 | 0-240 | 9.7 | 2-32 | 7.6 | 0-37 | 30.5 | 0-192 |
| TSS (mg.l$^1$) | 2.15 | 0.27-5.59 | 5.29 | 1.08-16.1 | 4.24 | 0.67-33.9 | 1.97 | 0.1-6.1 |
| SRP (ug.l$^1$) | 0.50 | 0.19-1.24 | 0.72 | 0.32-1.79 | 0.72 | 0.21-2.65 | 0.56 | 0.16-1.88 |
| $NO_3$+$NO_2$ (ug.l$^1$) | 0.42 | 0-1.61 | 0.16 | 0-0.60 | 0.22 | 0.07-0.62 | 0.20 | 0-1.55 |
| $NH_4$ (ug.l$^1$) | 0.96 | 0.08-1.58 | 1.15 | 0.38-2.49 | 1.28 | 0.14-4 | 1.20 | 0.17-3.89 |

## Macroinvertebrate analysis

Trichoptera density ranged between 131 and 4200 ind.m$^{-2}$ at IFO (exotic forest sites) and NYF (pasture site), respectively. Density in pasture sites was 3 to 4 times higher than in the sites associated with other uses; however, differences were statistically significant between pasture sites and pine and native forest sites (T-test$_{(df=22)}$ $p<0.02$, $p<0.04$, respectively). Maximum taxa richness (21 taxa) was recorded at CHI (native forest) whereas the lowest values (8 taxa) corresponded to IFO (exotic forest) and MG (pasture) (Fig. 2).

Of the total 32 taxa collected in the entire study (Table 2), 10 are shredders, 9 predators, 6 scrapers, 5 collector-filterers, 1 algal-piercer and 1 collector-gatherer.
At exotic forest sites, shredders contributed 40 to 95% of the relative proportion of FFG. Pasture sites were dominated by collector-filterers (73 and 96%), except at NYF where the dominant group was shredders (82%) (Fig. 3).

At harvested forests, shredders dominated (PIP) or co-dominated with collector-filterers (GLY and CVA). At native forest sites, scrapers were the dominant group at COM whereas shredders were at ALO and CHI. However, scrapers still contributed, with 13 and 32% of the relative abundance at CHI and ALO, respectively (Fig. 3).
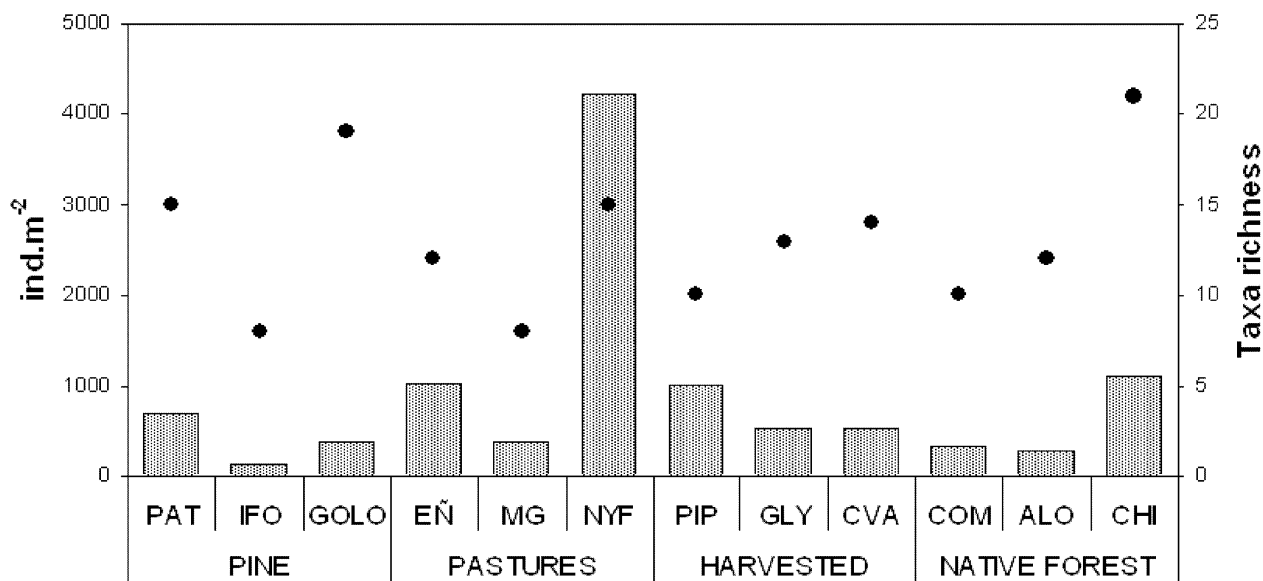
**FIGURE 2.** Mean annual density (bars) and taxa richness (dots) at 12 low-order streams (Patagonia, Argentina), during the study period (May 2005-March 2006).
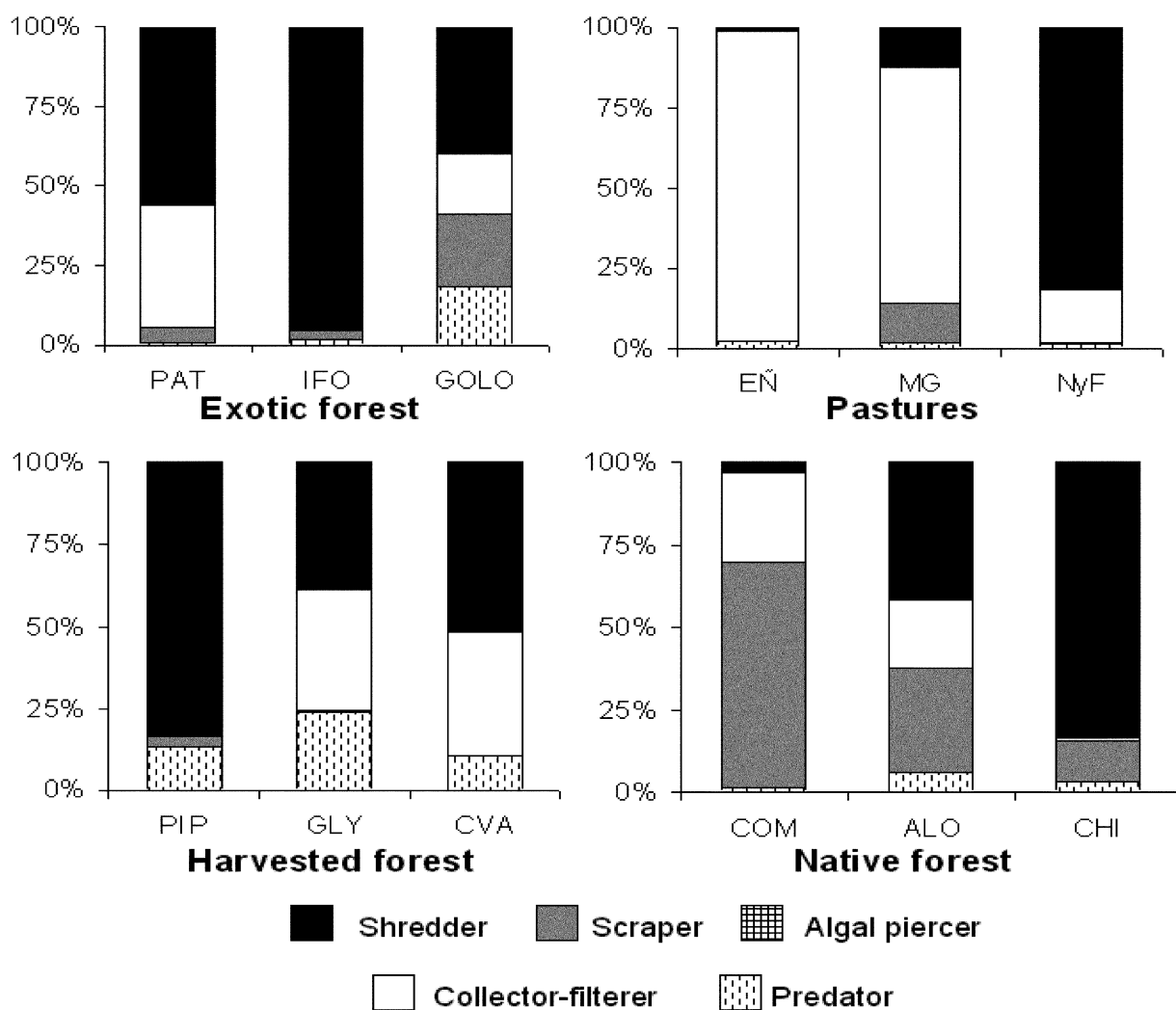


**FIGURE 3.** Relative abundance of functional-feeding groups per land use in 12 low-order streams (Patagonia, Argentina).

**TABLE 2.** Species of Trichoptera collected at 12 low-order streams (Patagonia, Argentina), functional-feeding group (FFG) and land-use type. Shredder (Sh), scraper (Scr), predator (Pr), collector-filterer (C-f), algal-piercer (A-p) and collector-gatherer (C-g). Land use codes: PAS: pastures; EXOT: Pine plantation; HF: harvested native forest; NF: native forest.

| Family | Species | FFG | Land use |
|---|---|---|---|
| **Hydrobiosidae** | *Atopsyche* sp. | Pr | HF, NF |
| | *Neoatopsyche brevispina* Schmid | Pr | EXO, PAS, HF, NF |
| | *Neoatopsyche unispina* Flint | Pr | EXO, PAS, HF |
| | *Cailloma* sp. | Pr | PAS, HF, NF |
| | *Neopsilochorema tricarinatum* Schmid | Pr | EXO, PAS, HF, NF |
| | *Reochorema* sp. | Pr | EXO, PAS, HF, NF |
| | *Metachorema griseum* Schmid | Pr | PAS |
| **Polycentropodidae** | *Policentropus* sp. | Pr | EXO, HF, NF |
| **Glossosomatidae** | *Mastigoptila* sp. | Scr | EXO, PAS, NF |
| | *Mastigoptila longicornuta* (Schmid) | Scr | PAS, HF |
| **Hydroptilidae** | *Oxyethira bidentata* Mosely | A-p | PAS, HF |
| | *Metrichia patagonica* (Flint) | Scr | EXO, NF |
| | *Metrichia neotropicalis* Schmid | Scr | EXO, HF, NF |
| **Hydropsychidae** | *Smicridea annulicornis* (Blanchard) | C-f | EXO, PAS, HF, NF |
| | *Smicridea frequens* (Navás) | C-f | EXO, PAS, HF, NF |
| | *Smicridea dithyra* Flint | C-f | EXO, NF |
| | *Smicridea* sp. A | C-f | EXO, PAS, NF |
| **Philorheithridae** | *Psilopsyche molinai* Navás | Pr | EXO, PAS, HF, NF |
| **Limnephilidae** | *Austrocosmoecus hirsutus* Schmid | Sh | NF |
| | *Verger* sp. A | Sh | EXO, PAS, HF, NF |
| | *Verger* sp. B | Sh | PAS, NF |
| **Leptoceridae** | *Hudsonema flaminii* (Navás) | Sh | EXO, PAS, HF, NF |
| | Leptoceridae sp. A | Sh | PAS, NF |
| | *Brachysetodes* sp. | Sh | EXO, PAS, HF, NF |
| | *Triplectides* sp. | Sh | EXO, HF |
| | *Nectopsyche* sp. | C-g, Sh | PAS |
| **Helicophidae** | *Austrocentrus valgiformis* Flint | Scr | EXO, NF |
| | *Eosericostoma* sp. | Scr | EXO, NF |
| **Sericostomatidae** | *Parasericostoma ovale* (Schmid) | Sh | EXO, PAS, HF |
| | *Parasericostoma cristatum* Flint | Sh | NF |
| | *Myotrichia murina* Schmid | Sh | EXO, PAS, HF, NF |
| **Philopotamidae** | *Sortosa* sp. | C-f | EXO, NF |

Shredder density did not vary in a consistent manner among land uses (Fig. 4a, Kruskal-Wallis $p=0.26$). Mean scraper density was significantly higher in native forest than in the rest ($p<0.05$ Mann Whitney U-test) (Fig. 4b), whereas collector filterer density was significantly higher at pasture sites

than at the others (MW U-test, $p<0.05$, Fig. 4c). Significant differences in predator density was observed among land uses with more predators found in harvested forest sites than in exotic and native forest sites (MW U-test, $p<0.05$) (Fig. 4d).
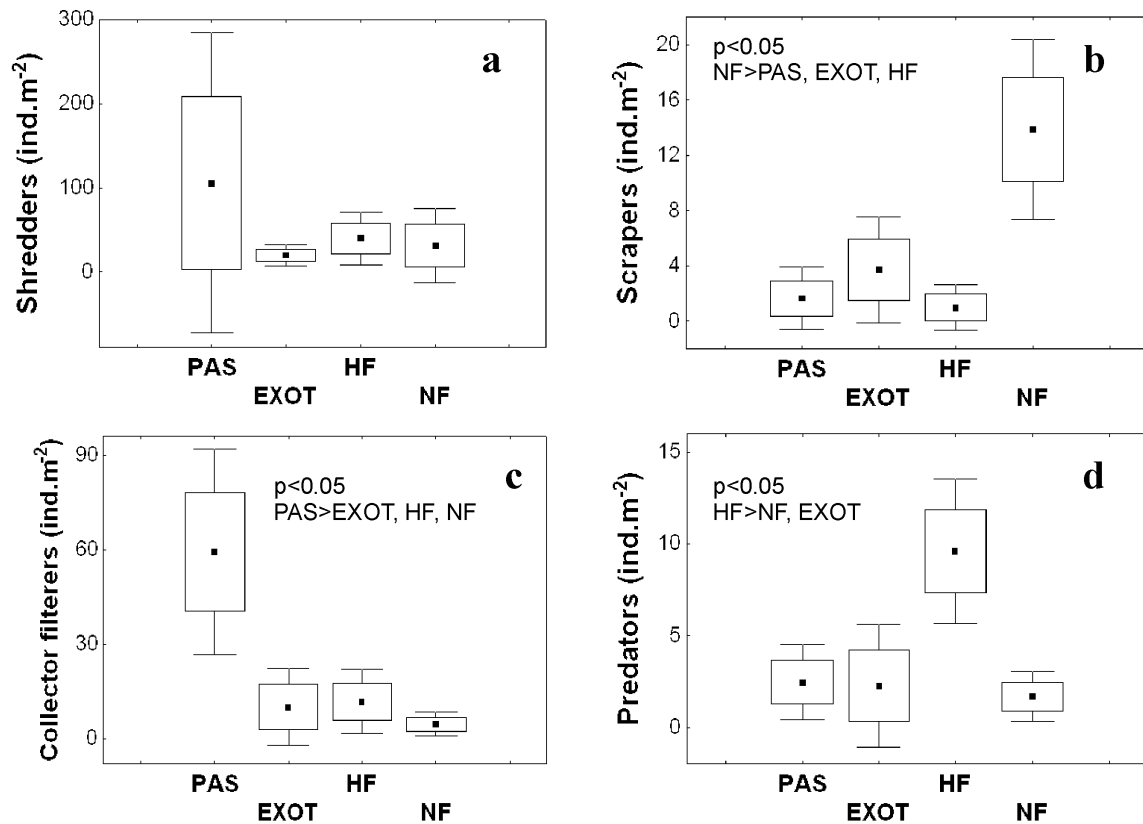


**FIGURE 4.** Density (ind.m$^{-2}$) of the main functional-feeding groups at Patagonian streams during the study period (May 2005-March 2006). Land use codes in Table 2. Range bars show maxima and minima, boxes are interquartile ranges (25-75%), small squares are medians.

## Discussion

Our results suggest that Trichoptera functional structure differed among land uses, which is consistent with those reported for other regions. Dohet (2002) stated that Trichoptera provide a wide spectrum of responses to environmental stresses, which make them useful to assess disturbances in European rivers. Chakona *et al.* (2009) found that Trichoptera communities were good indicators of degradation in river systems affected by agricultural practices in Zimbabwe (Africa). Similarly, Blinn and Ruiter (2006) documented significant changes in composition and abundance of Trichoptera species in rivers draining forests, grasslands, deserts and urban areas in Colorado (USA).

Shredders were well represented at all our forested sites (native forest, harvested forest and exotic forest). This is a common feature of low-order streams where interaction between riparian and in-stream habitats is very strong due to the constant supply of organic debris (Richardson & Danehy 2007). Shredder relative abundance at exotic forest sites did not differ significantly from that at native forest sites. Sericostomatidae, mostly represented by *Myotrichia murina* Schmid and *Parasericostoma ovale* (Schmid), where the most common shredders at both exotic and native forest. Experimental studies carried out in similar Patagonian streams outlined a preference of the sericostomatid *P. cristatum* Flint for native leaf litter (Albariño & Balseiro 2002). According to our

results *M. murina* and *P. ovale* might not be affected by the nature of leaf litter. They were very abundant in streams with pine needles as unique leaf material, which suggest some trophic plasticity. However, this should be confirmed in future experimental trials.

The caddisfly community found at harvested sites exhibited co-dominance of shredders and collector-filterers, except at site PIP, where shredders were dominant. At this site, a large amount of organic debris covered the streambed since muchwoody material was deposited in the stream. Predator abundance was significantly higher at harvested forest sites than at pasture and native forest sites. Significant augmentation of macroinvertebrate density (mostly chironomids and molluscs) has been reported after tree harvest (Baillie *et al.* 2005, Miserendino & Masi 2009). Probably the higher proportion of predators in this study could be related with an increase of the prey numbers.

Contrary to our expectation, scrapers were not dominant at our pasture sites. It is known that a combination of sunlight and nutrients can enhance periphyton communities at open-canopied sites, which in turn favors scraping herbivory (Quinn *et al.* 1997, Rutherford *et al.* 1997). However, pastoral development also usually accelerates stream bank erosion, siltation and scouring, processes that have a negative impact on scraper density (Harding *et al.* 2000, Quinn 2000). The highest scraper density was found at native forest sites where bryophytes had a significant coverage (15−35%) of the streambed, this constitutes an optimum substratum for grazing (Stream Bryophyte Group 1999, Riley *et al.* 2003).

The dominance of collector-filterers at our pasture sites may reflect an increase in seston transport in the water column, which is consistent with results reported in other studies in the Andean cordillera (Miserendino & Pizzolón 2004, Miserendino & Masi 2009) and worldwide (Allan *et al.* 1997, Sieh *et al.* 2003, Utz *et al.* 2009). We observed dominance of the net spinners *Smicridea annulicornis* (Blanchard) and *S. frequens* (Navás) (Hydropsychidae) at our most degraded pasture sites (LÑ and MG), and this coincides with the results of Blinn and Ruiter (2006), who found North American *Smicridea* species tolerating more than 50% of substrate embeddedness.

The NYF site showed marked differences in functional structure, with a clear dominance of shredders with respect to the other pastures sites. The presence of remnant patches of native forest upstream of this site may explain the significant contribution of this functional group here. Recent works suggest that upstream riparian forest may have an ameliorative effect on macroinvertebrate assemblages and can be critical to the distribution of many taxa in catchments subjected to mixed land use (Sweeney 1993, Storey & Cowley 1997, Sponseller *et al.* 2001).

According to our results the caddisfly community at exotic forest sites was not significantly different from that at reference sites, suggesting that the presence of riparian vegetation is vital in maintaining the requirements for most species (e.g., thermal regime, input of leaf litter, and habitat for adults) (Richardson 2004). However, Thompon & Towsend (2004) warned that debris material proceeding from exotic pine plantations can be sub-utilized by microorganisms, having consequences on higher trophic levels. Studies carried out in Patagonia found that macroinvertebrate shredder richness was significantly lower at pine plantation sites than at native forest sites (Miserendino & Masi 2009). This indicates that management of exotic forest requires a holistic approach to evaluate all possible interactions.

Several studies noted the importance of a riparian buffer reserve in land use practices because they maintain some of the function of streamside forests in providing shade, organic matter input and bank stability (Harding *et al.* 1998, Sponseller *et al.* 2001, Richardson & Danehy 2007, Richardson 2008). In Patagonian rivers, Trichoptera functional structure seems to be responsive to land use change. As found by other authors in different regions of the world (Dohet 2002, Blinn & Ruiter 2006, Chakona *et al.* 2009), we agree that this community is suitable to assess different impacts associated with land use activities.

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