WATERSHED CONSERVATION AND AQUATIC BENTHIC MACROINVERTEBRATE DIVERSITY IN THE ALBERTO D'AGOSTINI NATIONAL PARK, TIERRA DEL FUEGO, CHILE

ESTADO DE CONSERVACIÓN DE LAS CUENCAS HIDROGRÁFICAS Y DIVERSIDAD DE LOS MACROINVERTEBRADOS BENTÓNICOS DULCEACUÍCOLAS DEL PARQUE NACIONAL ALBERTO D'AGOSTINI, TIERRA DEL FUEGO, CHILE

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ABSTRACT

Southern South America is known globally for its remote and rugged landscapes, which include one of Chile's largest national park: Alberto De Agostini. The singular nature of this area, however, is also found in is flora and fauna. The recent designation of Magellanic Sub-Antarctic Forests as one of the world's last wilderness areas propelled us to question whether there was detailed evidence for this classification in the Tierra del Fuego portion of the De Agostini Park. Therefore, in January 2004 and 2005 boat-based expeditions were carried out around the south-west portion of Tierra del Fuego Island, as well as adjacent islands south of the Beagle Channel. Their purpose was to evaluate the current state of the park's natural resources and to create a baseline of physical, chemical, biological and ecological information that can be used in the administration, conservation and future research of this area. We utilized a watershed analysis approach, examining vegetation cover, habitat type and disturbance. Along the major watercourse of each basin, we quantified the presence of exotic species, water quality and the aquatic macroinvertebrate assemblage.

We found that habitats types were highly diverse with mixed and deciduous forests dominating the eastern portion of the study area and Magellanic evergreen forests and tundra in the west. On average, approximately 50% of the watersheds' areas were covered by forests with exposed rock and tundra occupying 28% and 17%, respectively. Glaciers and herbaceous habitats only made up 3% of study sites. Disturbances from human impacts and introduced species were rare and focused mainly outside the national park and in the eastern portion of the Brecknock peninsula, but significant localized exceptions occurred even in isolated fjords and where fishing and tourism activities were being carried out.

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Finally, one quality of the archipelago that had not previously been well evaluated was its freshwater ecosystems and biota. Our water quality analysis showed that these streams were highly pristine and contained a diverse and largely endemic aquatic macroinvertebrate fauna (*e.g.* Trichoptera *Monocosmoecus hyadesi* and *Rheochorema magellanicum* and the Plecoptera *Notoperla fuegiana*). Furthermore, many of these taxa provide ideal taxonomic, evolutionary and biogeographic study subjects, given their isolated and ancient lineages, as well as the fact that several orders and families reach their global southern distribution limit in the Fuegian Archipelago (*e.g.* Ephemeroptera, Trichoptera, Plecoptera and Diptera Simuliidae and Coleoptera Dytiscidae). We expect these data to further a greater appreciation and understanding of the pristine areas of Tierra del Fuego and that it will help to establish ecological monitoring criteria for Alberto De Agostini National Park, which is also part of the new Cape Horn Biosphere Reserve, and mitigate impacts of development on an area that is currently still in a largely natural state.

Key words: Biosphere Reserve, Cape Horn, Tierra del Fuego, macroinvertebrates, sub-Antarctic, disturbance, wilderness area.

RESUMEN

El extremo austral de Sudamérica es conocido por sus paisajes remotos y escabrosos, incluyendo los de uno de los parques nacionales más grandes de Chile: Alberto De Agostini. El carácter singular de esta área, no obstante, se encuentra también en su flora y fauna. La reciente designación de los Bosques Subantárticos Magallánicos como uno de los lugares más prístinos en el mundo nos impulsó a preguntar si existe evidencia empírica que sustente esta clasificación. Durante enero de 2004 y 2005 fueron llevadas a cabo navegaciones por el sector sur-oeste de la Tierra del Fuego y sus islas aledañas al sur del canal Beagle con fin de evaluar el estado actual de los recursos naturales del parque, y crear una línea base de información física, química, biológica y ecológica para mejorar la administración, conservación e investigación futura en el área de estudio. Para ello se examinó la cobertura de la vegetación, tipo de hábitat y grado de perturbación de las cuencas hidrográficas. En cada cuenca se cuantificó la presencia de especies introducidas, calidad de agua y la comunidad de macroinvertebrados acuáticos.

Se encontró una gran diversidad de tipos de hábitat: bosques mixtos y deciduos predominan en la porción oriental del área de estudio, mientras que bosques siempreverdes magallánicos y tundras en la parte occidental. Un promedio de aproximadamente 50% de las cuencas tenía cobertura de bosque. Roca desnuda y tundra ocuparon 28% y 17%, respectivamente. Glaciares y hábitats de plantas herbáceas sólo constituyeron el 3% de la superficie. Perturbaciones debidas al impacto humano y la introducción de especies exóticas fueron localizadas principalmente fuera del parque nacional y en la parte este de la península Brecknock, pero aún existían excepciones notables en varios fiordos aislados y donde se está practicando la pesca y el turismo.

El análisis de calidad de agua demuestra que estos arroyos son muy limpios y albergan una fauna invertebrada diversa y en gran parte endémica (*e.g.* Trichoptera *Monocosmoecus hyadesi* y *Rheochorema magellanicum* y Plecoptera *Notoperla fuegiana*). Muchos de estos taxa proveen sujetos ideales para estudios taxonómicos, filogenéticos y biogeográficos, dado sus antiguos y aislados linajes, y el hecho que estos ejemplares del archipiélago fueguino constituyen el límite austral para varios órdenes y familias (*e.g.* Ephemeroptera, Trichoptera, Plecoptera y Diptera Simuliidae y Coleoptera Dytiscidae). Esperamos que estos datos contribuyan a apreciar y conocer estas áreas prístinas de Tierra del Fuego y al establecimiento de criterios ecológicos para el monitoreo en el Parque Nacional Alberto De Agostini, lo que a su vez es parte de la Reserva de Biosfera Cabo de Hornos, y así mitigar impactos de desarrollo en un área que todavía se conserva en un estado natural.

Palabras clave: Reserva de la Biosfera, cabo de Hornos, Tierra del Fuego, macroinvertebrados, subantártico, perturbación, áreas prístinas.

INTRODUCTION

The extreme austral tip of South America is home to the world's southernmost forests. These ecosystems share a circum-Antarctic taxonomic affinity with those of New Zealand, South Africa and Australia, given that they all once constituted the Gondwana continent. Consequently, the extreme southern tip of Chile also can be thought of as a refuge for ancient evolutionary lineages. Furthermore, at the landscape level, the Magellanic Sub-Antarctic Archipelago has remarkably diverse habitat types, including: 1) broad-leafed evergreen forests, dominated by *Nothofagus betuloides* and *Drimys winteri*; 2) deciduous forests dominated by *Nothofagus pumilio* and (or) *N. antarctica*; 3) high Andean habitats dominated by cushion floras and prairies of lichens; 4) complex and diverse tundra formations; 5) formations of glaciers; 6) a series of freshwater ecosystems (Pisano 1977). The southwestern peninsula of Tierra del Fuego Island, containing a vast area of the Alberto De Agostini National Park, includes mainly evergreen forests and bogs (*sensu* Gajardo 1994). This habitat combination is characteristic of the Magellanic Sub-Antarctic Evergreen Rainforest ecoregion (Rozzi *et al.* 2004).

This ecoregion has been identified recently as one of the thirty-seven most pristine wilderness areas remaining on the planet (Mittermeier *et al.* 2001). Such recognition emphasizes both biogeographic importance and relevance for conservation at regional, national, and international levels. The area is known as a global conservation priority; however, the remote and extensive Alberto De Agostini National Park has had limited oversight and administrative support. The park's area covers approximately 1,460,000 hectares, which is 16.4% of state protected land in Chile, but the park's isolation and vastness are also the reasons that it is largely unstudied, even though it is under increasing pressure from tourism and development (Jax & Rozzi 2004). In this context, the watersheds in this area are extremely valuable study units from scientific and economic perspectives (Rozzi *et al.* 2004).

The terrestrial ecosystems of the D'Agostini National Park are insular, embedded in an intricate system of fiords, channels, estuaries, and bays (Fig. 1). Using an ecosystem perspective we characterized the ecology of twenty-one watersheds to integrate abiotic, biotic, and landscape variables. We quantified landcover and predominant vegetation habitat

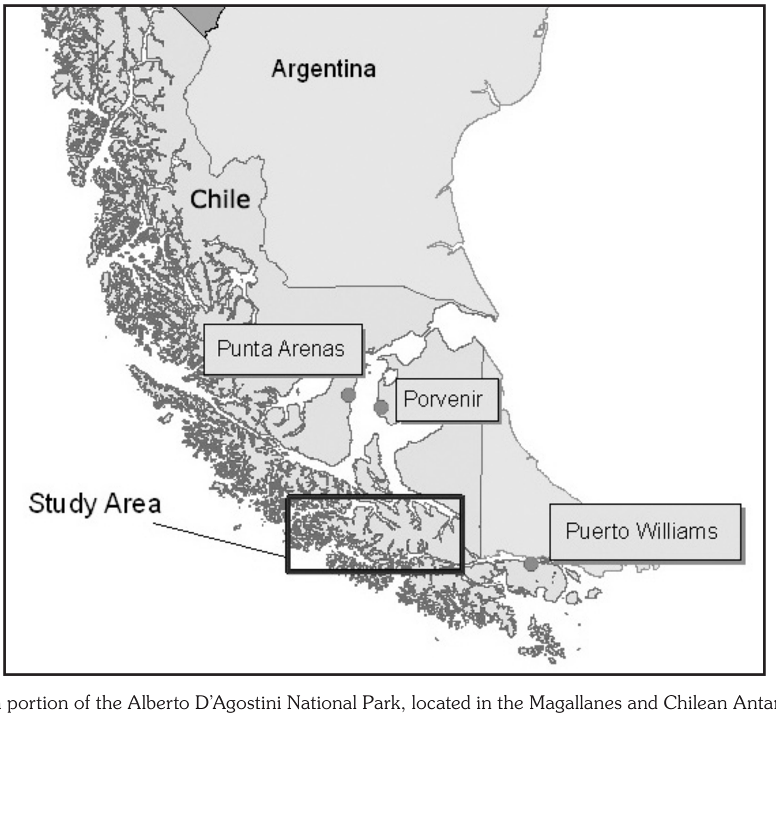

Fig. 1. The study area is a portion of the Alberto D'Agostini National Park, located in the Magallanes and Chilean Antarctic Region.

type, disturbance from humans and the introduced North American beaver (*Castor canadensis* Kuhl), the presence of introduced plant species, water quality and stream macroinvertebrate communities during two expeditions around the southwestern peninsula of the Alberto D'Agostini National Park on Tierra del Fuego Island. Our goal was to measure these variables to better describe the ecosystems, serving both as baseline data for management and monitoring, as well as to expand our knowledge about this remote area of the sub-Antarctic forest biome.

TABLE 1. List of each site surveyed during the expedition, indicating its number, name, latitude-longitude and the type of sampling conducted.

#	Site	Latitud (°S)	Longitude (°W)	Sample
1	Isla Tres Mojotes	54.43837	69.07625	Landcover and disturbance
2	Caleta María	54.48225	68.99098	Landcover, disturbance and aquatic invertebrates
3	Bahía Blanca	54.55075	69.13969	Landcover and disturbance
4	Parry	54.62674	69.32671	Landcover, disturbance, water quality and aquatic invertebrates
5	Ainsworth	54.40904	69.62829	Landcover, disturbance, water quality and aquatic invertebrates
6	Gallegos W	54.47931	69.87324	Landcover, disturbance, water quality and aquatic invertebrates
7	Gallegos E	54.49965	69.84719	Landcover, disturbance, water quality and aquatic invertebrates
8	Seno Serrano W	54.54993	70.30931	Landcover, disturbance, water quality and aquatic invertebrates
9	Seno Serrano E	54.52151	70.30314	Landcover and disturbance
10	Agostini Sur	54.49896	70.37415	Landcover and disturbance
11	Torres De Agostini	54.46194	70.36231	Flora and macroinvertebrate transects
12	Bahía Keta	54.34589	70.73285	Landcover and disturbance
13	Brecknock	54.66451	71.55681	Landcover and disturbance
14	Ventisquero	54.7292	70.284	Landcover and disturbance
15	Ventisquero Ribera W	54.73744	70.28488	Landcover, disturbance, water quality and aquatic invertebrates
16	Ventisquero Ribera E	54.82303	70.31788	Landcover, disturbance, water quality and aquatic invertebrates
17	Pomar – O'Brien	54.84511	70.46323	Landcover, disturbance, water quality and aquatic invertebrates
18	Pía I	54.79631	69.60713	Landcover, disturbance, water quality and aquatic invertebrates
19	Pía II	54.77334	69.59232	Landcover and disturbance
20	Pía III	54.76127	69.60305	Landcover, disturbance, water quality and aquatic invertebrates
21	Caleta Olla	54.94321	69.12648	Landcover and disturbance

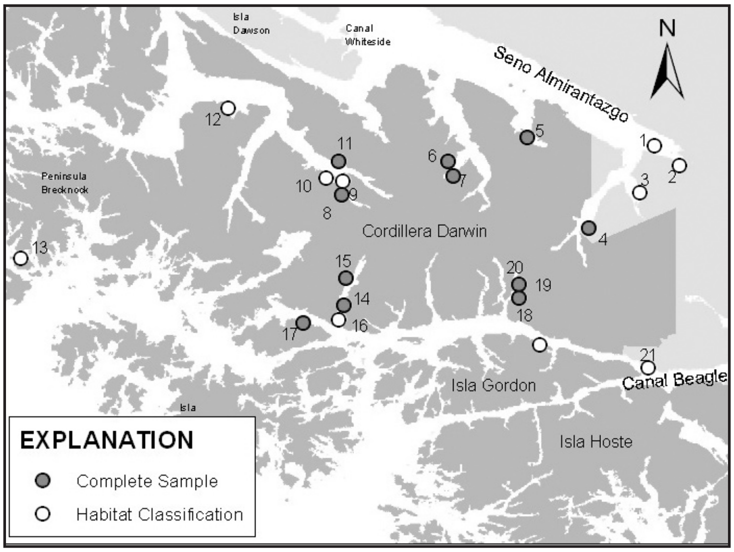

Fig. 2. Sample sites were distributed throughout the Tierra del Fuego portion of D'Agostini National Park. The map indicates sampling sites, as well as whether a complete survey was done or only habitat-vegetation classification.

MATERIALS AND METHODS

Study Area

During January 2004 and 2005 boat-based expeditions were made to the southwestern peninsula of Tierra del Fuego Island's Alberto De Agostini National Park. The study area was bounded by Argentina on the east, Contraalmirante Martínez Sound on the west, the Beagle Channel on the south and the Almirantazgo Sound on the north (Fig. 1). During the expedition, a total of twenty-one sites were surveyed (Table 1 and Fig. 2).

The criteria for selecting the sampling sites were to identify and differentiate the principal ecosystems of Alberto De Agostini National Park and provide insight into the relationship between aquatic macroinvertebrates communities, water quality, landcover, and disturbance information. The selection and classification of the sites were made using maps of Chilean Forest Inventory (CONAF-CONAMA-BIRF, 1999), aerial photographs, the phytosociological classification of Pisano (1977) and biome definitions of Rozzi *et al.* (2004). Sites were selected in the field according to the following criteria: 1) presence of a permanent river, 2) representation of the diversity of vegetation types, 3) presence/absence of exotic species/disturbance, and 4) accessibility in terms of navigation facilities, slope, and land features.

Watershed Characterization

The methodology used to characterize the biota for this project was designed by the authors and based on standardized sampling techniques used by the United States Geological Survey (Cuffney *et al.* 1993). A watershed approach was employed as a way to integrate the study of abiotic and biotic variables. A reach 200 meters in length and beginning 50 meters above the high tide mark was sampled for each watershed. Watersheds, defined by a river basin and delineated by the topography of the land surface, are a central function of ecosystem classification and monitoring. For this reason, it was decided to use watersheds and their principal rivers as the basis for describing the area's ecology.

A general habitat classification of each watershed was noted from the boat by approximating the percentage of landcover for each of the following habitat classes: littoral rock or sand, herbaceous vegetation, tundra/heath lands, forest, exposed rock and glacier/ice. These are general habitat classifications previously determined using Moore (1983) and Pisano (1977). Field notes, water quality measurements, and the location of the mouth of each river using a Geographic Positioning System (GPS) were recorded.

TABLE 2. Major habitat types per sample site. Classification is based on criteria of Pisano (1977), Moore (1983) and Rozzi *et al.* (2004).

#	Site	Habitat type	Description
1	Isla Tres Mojotes	Coastal grasses	
		Mixed Magellanic evergreen forest (Pisano 1977) with presence of *Nothofagus antarctica*	Association of *Nothofagus betuloides - Drimys winteri*
2	Caleta María	Coastal grasses	
		Mixed Magellanic evergreen forest (Pisano 1977)	Association of *Nothofagus betuloides - Drimys winteri*
3	Bahía Blanca	Coastal	River outlet – beach with cobble and cobble (10-15 cm) and gravel (1 cm)
		Mixed Magellanic forest (Pisano 1977)	Association of *Nothofagus betuloides - N. pumilio*
4	Parry	Coastline	River outlet – beaver with sand + mussel mantle – and cobble (5-10 cm)
		Mixed Magellanic forest (Pisano 1977)	Association of *Nothofagus betuloides - N. pumilio*
		Mixed Magellanic forest (Pisano 1977)	Association of *N. betuloides - N. antarctica*
		Rush wetlands (Rozzi *et al.* 2004)	*Marsipospermum* with *N. antarctica*
5	Ainsworth	Coastline	River outlet with rapids and bog / coast with small island and with cobble and boulders (10-15 cm) (20-25 cm) + gravel and consolidated mud
		Mixed Magellanic forest (Pisano 1977)	Association of *N. betuloides - N. antarctica - Empetrum rubrum*
		Littoral wetland	Association of *Aster vahlii - Armeria maritima*
6	Gallegos W	Coastline	River outlet and beach with cobble (10-15 cm) + gravel (1 cm) + fine particles
		Wetland – riparian bog	Association of *Aster vahlii - Poaceas - Sphagnum*
		Mixed Magellanic evergreen forest (Pisano 1977)	Association of *Nothofagus betuloides - Drimys winteri*
		Magellanic tundra complex: tundra of cushion plant formation (Rozzi *et al.* 2004)	Predominant of *Astelia,* with *Sphagnum*
7	Gallegos E	Coastline	River outlet and beach with gravel (0.5-1 cm) (2-5 cm) and cobble and boulders (10-20 cm) (30-50 cm) + dead tree trunks
		Mixed Magellanic forest (Pisano 1977)	Association of *N. betuloides - N. antarctica*
		Magellanic tundra complex: tundra of *Sphagnum* (Rozzi *et al.* 2004) edge with riparian forest	Association of *N. betuloides - N. antarctica* --- Predominance of *Sphagnum* with presence of *Astelia*
8	Seno Serrano W	Coastline	River outlet with cobble (10-15 cm) over fine sediments and bedrock outcrops
		Bush/heath formation dominated by *Chiliothrichium diffusum*	Association of *Chiliothrichium - Marsipospermum*
		Wetlands and hydrophytic grasslands (Pisano 1977)	Association of *Iocenes – Anthoxanthum redolens*
9	Seno Serrano E	Coastline	River outlet and beach with course sand, fine gravel and some fine sediments with rocky outcrops in areas
		Magellanic deciduous forest: *N. antarctica* (Pisano 1977)	Association of *Nothofagetum antarcticae*: *N. antarctica – Chiliothrichium*
		Edge of *Pernettya mucronata*	
		Graminea tundra: cypress tundra (Pisano 1977)	Association of *Schoenetum antarcticis: Schoenus, Carpha, Marsipospermum* with presence of *Iocenes, N. antarctica*

TABLE 2 (continued). Major habitat types per sample site. Classification is based on criteria of Pisano (1977), Moore (1983) and Rozzi *et al.* (2004).

10	De Agostini Sur	Pure Magellanic evergreen forest	Forest dominated by *N. betuloides*
11	Torres De Agostini	Coastline	River outlet and intertidal flats with gravel over sand and edge of cobble (10-15 cm)
		Magellanic deciduous forests: Forest of *N. antarctica* (Pisano 1977)	Association of *Nothofagetum antarcticae*: *N. antarctica - Chiliothrichium*
		Rush wetlands (Rozzi *et al.* 2004)	Association of *Marsipospermum - Berberis ilicifolia - Chiliothrichium*
12	Bahía Keta	Pure Magellanic evergreen forest	Sub-association of *Nothofagus betuloides - Philesia magellanica*
13	Brecknock	Mixed Magellanic evergreen forest (Pisano 1977)	Sub-association of *Nothofagus betuloides - Blechnum magellanica*
14	Ventisquero	Magellanic deciduous forests: Forest of *N. antarctica* (Pisano 1977)	
15	Ventisquero Ribera W	Coastline	River outlet and beach with sand and gravel, small cobbles (15-20 cm) and some rock outcrops
		Magellanic deciduous forests: Forest of *N. antarctica* (Pisano 1977)	Coastal association of *N. antarctica - N. betuloides - P. mucronata*
		Mixed Magellanic forest	Association of *N. betuloides - N. antarctica*
16	Ventisquero Ribera E	Coastline	River outlet – beach with pebbles over sand + mussel mantle + rock outcrops
		Rush wetlands (Rozzi *et al.* 2004)	Association of *Marsipospermum - Chiliotrichium - Pernettya*
		Mixed Magellanic evergreen forests (Pisano 1977)	Association of *N. betuloides - D. winteri*, with presence of *N. antarctica* and *Lebethanthus*
		Magellanic tundra complex: tundra of cushion plants (Rozzi *et al.* 2004)	Predominance of *Astelia*
17	Pomar –O'Brien	Tundra with *Pilgerodendron uviferum* (Pisano 1977)	
18	Pía I	Mixed Magellanic forest	Association of *N. betuloides - N. antarctica*
19	Pía II	Mixed Magellanic forest	Association of *N. betuloides - N. antarctica*
20	Pía III	Coastline	River outlet adjacent to glacier – Flat intertidal sand and sediment beach with icebergs. Moraine with boulders and cobble
		Mixed Magellanic forest	Dominance of *N. betuloides* – with presence of *N. antarctica - P. mucronata*
		Magellanic deciduous forest: *N. antarctica* (Pisano 1977)	Association of *Nothofagetum antarctica*: *N. antarctica - Marsipospermum* with presence of *N. betuloides*
21	Caleta Olla	Coastline	River outlet and sand with fine gravel and mussel mantle + intertidal edge with cobble and rock outcrops
		Graminea bog: Tundra with cypress (Pisano 1977)	
		Forest of *Drimys winteri*	
		Mixed Magellanic evergreen forest (Pisano 1977)	Association of *N. betuloides - D. winteri*
		Magellanic tundra complex: *Sphagnum* tundra (Rozzi *et al.* 2004)	Predominance of *Sphagnum*
		Magellanic tundra complex: Cushion plant tundra (Rozzi *et al.* 2004)	Predominance of *Astelia*

Human Impact and Introduced Species

After disembarking, each site was examined for introduced flora. For each species detected, a sample was collected and preserved using a botanical press. Each species was identified in the field and verified later according to Moore (1983). The flora herbarium was mounted and stored at the University of Magallanes' Puerto Williams Field Station. In addition, the area was surveyed for direct human disturbance and the presence or impact of the rapidly expanding introduced mammal species *Castor canadensis*, the North American beaver. At each study site evidence (tracks and scat) of introduced American mink (*Mustela vison* Schreber) and Patagonian grey fox (*Pseudalopex griseus* Gray) were searched for along river banks.

Stream Water Quality Measurements

At each river where the transect data for flora and macroinvertebrates were collected, water quality data (pH, specific conductance, temperature, and dissolved oxygen concentration) were collected with hand-held water quality meters. We used an YSI 85D meter to measure dissolved oxygen and specific conductance, and a Beckman 250 probe was used to collect the pH and temperature data. At each sampling location, a general description of the river habitat and substrate was noted. Photographs were taken at the mouth of each river and upstream and downstream at each transect.

Sampling of Freshwater Macroinvertebrates

The aquatic macroinvertebrates were sampled at each site by using a kicknet with a dolphin catcher to collect debris. The net was placed in the flow of the river, and the substrate upstream from the kicknet was disturbed to release aquatic macroinvertebrates. Five rocks also were chosen from the upstream substrate and washed with a brush into the net. When no riffles were present in the river for sampling, the net was swept through submerged macrophytes. The contents then were emptied into a tray, and the aquatic invertebrates were separated from the sediment and debris. The specimens were placed in vials with 70% alcohol for preservation and further examination and classification in the laboratory. Samples were shipped to the Institute of Ecology at the University of Georgia (USA) for examination and classification in accordance with Merritt & Cummins (1996), Fernández & Domínguez (2001) and Mercado & Elliott (2004). In addition, world experts on particular taxa were consulted (see Acknowledgments). The reference collection is maintained by the Omora Ethnobotanical Park – UMAG and specimens have also been deposited in the collection of *Laboratorio Benthos*, Valdivia, Chile (www.benthos.cl). Southern distributions for invertebrates to compare with these species' range descriptions were obtained from Biota Australis Terrestris (Ashworth *et al.* 2000), an online database of Antarctic and Sub-Antarctic species.

RESULTS

Habitat Diversity and Landcover

The study area was characterized by a mosaic of evergreen Magellanic forests dominated by *Nothofagus betuloides*, Magellanic tundra, exposed rock and glaciers. In addition, the area's coastal ecosystems had formations of scrub/heath or strips of herbaceous plants. Table 2 synthesizes the diversity of habitats encountered at the study sites, including both the prevalent habitat type in the watershed and the habitat along the coastal edge.

Most of the river basins sampled in the study area had a high percentage of forest cover (Table 3). In seven of the eleven watersheds studied forests were the predominant (64%) vegetation cover. The average of all watersheds was slightly less (50%). The second most common type of land cover was exposed rock, which was present in ten of the eleven sites (91%) and constituted an average of 28% on average of the surface area at these sites. At sites such as Torres D'Agostini and Seno Pía II, exposed rock was 50% or more of the land cover.

The tundra/heath matrix was present in only six of the eleven river basins (55% of the sites). The tundra-dominated sites were hills and areas of depressed relief. On average, tundra covered 17% of the watersheds, but was the dominant cover in Pomar Channel (60%) and Ventisquero II Sound. These sites were especially fragile, considering their intolerance to foot traffic and human activity in general due to their frail soils. Three watersheds (27%)

had coastal-edge habitats with grasses, and glaciers were part of only two (18%) of the sampled river basins. These two landcovers (grasses and glaciers) made up an average of 3% of the land cover in the sampled watersheds (Table 3).

Human Impacts and Introduced Species

In the Alberto De Agostini National Park, disturbances included fires, the cutting of forests, the creation of trails for hiking, and the presence of introduced flora and fauna (Table 4). Many watersheds in this area were essentially pristine, where infrastructure and development have not yet transformed the landscape. The cutting of trees was localized and rare except in the María Cove watershed, located outside the national park, where cutting was more extensive because of the presence of a ranch. María Cove and Tres Mojotes Island were the only two watersheds in which there was evidence of previous burns. The major disturbance within the park boundaries was from tourism, which was most evident in Olla Cove and Ainsworth Bay, where we found trash, cutting, and soil compaction from unplanned trails.

Twelve of the twenty-one study sites (57%) did not display any signs of direct human disturbance and seven of these sites (33%) showed only slight signs of human disturbance, such as the presence of one or two introduced species of plants or the removal of a few trees (Table 4). In general, human disturbance was associated with the areas bordering the park where cattle ranching had occurred in the past (in the sector of Almirantazgo Sound), and the sporadic presence of fishermen and unregulated tourism in the archipelago.

Introduced American mink (*Mustela vison*) and the gray fox (*Pseudalopex griseus*) were not observed, detected or trapped during the study, but have been documented previously for other parts of Tierra del Fuego Island (Lizarralde & Escobar 2000). One must consider, when interpreting these data, the brief time (approximately four hours) spent surveying for feces and tracks at each study site during this expedition, and trapping was only done over night. As a result, the absence of detection does not necessarily imply the absence of the species in the area. A greater sampling effort in search of these species is necessary.

TABLE 3. Percentage of landcover types in each of the watersheds sampled. General habitat cover types were classified as forest, tundra-heathland, exposed rock, herbaceous-grasses and glacier-ice cap.

Site Name (#)	Forest (%)	Tundra - Heathland (%)	Exposed Rock (%)	Herbaceous – Grasses (%)	Glacier – Ice cap (%)
Parry (4)	35	35	30	0	0
Ainsworth (5)	75	0	15	10	0
Gallegos W (6)	60	10	30	0	0
Gallegos E (7)	60	25	5	0	10
Serrano (8)	30	0	40	10	20
Torres De Agostini (11)	40	0	60	0	0
Seno Ventisquero (14)	90	10	0	0	0
Ventisquero Ribera W (15)	30	50	20	0	0
Pomar / O'Brien (17)	25	60	15	0	0
Pía I (18)	50	0	40	10	0
Pía II (19)	50	0	50	0	0
Number of Sites	**11**	**6**	**10**	**3**	**2**
Percentage of Sites with Habitat Type	**100**	**55**	**91**	**27**	**18**
Mean Percent Coverage per Watershed	**50**	**17**	**28**	**3**	**3**

TABLE 4. Evidence of different types of disturbance impacts was minimal within the Agostini National Park. Most impacts were located in the eastern portion of the peninsula. Disturbance in the study area included human effects of cutting, burning, trash, construction and soil compaction, as well as exotic species presence from beavers and introduced flora.

#	Site	Evidence of Human and Introduced Species Disturbance
1	Isla Tres Mojotes	Burns, cutting, old fisherman camp, beaver and exotic flora
2	Caleta María	Burns, cutting, beaver and exotic flora
3	Bahía Blanca	Cutting, beaver and exotic flora
4	Parry	Cutting, beaver and exotic flora
5	Ainsworth	Tourism (soil compaction, cutting) and beaver and exotic flora
6	Gallegos W	No evidence
7	Gallegos E	Exotic flora
8	Seno Serrano W	Exotic flora
9	Seno Serrano E	No evidence
10	De Agostini Sur	Cutting
11	Torres D'Agostini	No evidence
12	Bahía Keta	No evidence
13	Brecknock	No evidence
14	Ventisquero	No evidence
15	Ventisquero W	No evidence
16	Ventisquero E	No evidence
17	Pomar – O'Brien	No evidence
18	Pía I	No evidence
19	Pía II	No evidence
20	Pía III	No evidence
21	Caleta Olla	Tourism (trash, soil compaction, cutting) and beaver and exotic flora

Other than humans, the species with the greatest level of ecosystem disturbance was the beaver (*Castor canadensis*). Beaver ponds and dams were found only in the eastern part of study area (Sites 1-7 and 21; Table 4). This distribution, which excludes the western part of the archipelago, was previously noted by Anderson *et al.* (in press)[1]. An important consideration in the future management of the park would be control of beaver populations and its perturbations in ecosystems, especially in protecting the western sector from invasion.

The presence of introduced plants was low, as well, except in the eastern edge of the park (Fig. 3). Nine of the twenty-one watersheds (43%) contained some evidence of introduced flora (Table 5). María Cove, just outside of the park, harbored nine identified introduced plant species. Like human and beaver impacts, introduced plants were concentrated in the east, but exceptions include sites at Ainsworth, Gallegos E, Serrano E, Ventisquero W and Olla Cove, where introduced plants were also found (Fig. 3).

[1] Anderson, C.B., R. Rozzi, J.C. Torres-Mura, S.M. McGehee, M.F. Sherriffs, E. Schuettler & A.D. Rosemond in press. The exotic vertebrate fauna of the Cape Horn Archipelago. *Biodiversity and Conservation.*

Instream Habitat and Water Quality

All sampled rivers were high gradient with a heterogeneous substrate of bedrock, boulders, cobble, gravel, sand and silt (Table 6). Heavy siltation was encountered in one study site, Serrano Sound, and a substrate composed primarily of sand was dominant in four of eleven streams sampled. However, coarser substrates, such as gravel and cobble, are present in almost all streams (82%). Gravel and/or cobble were encountered in all the watersheds sampled (Table 6).

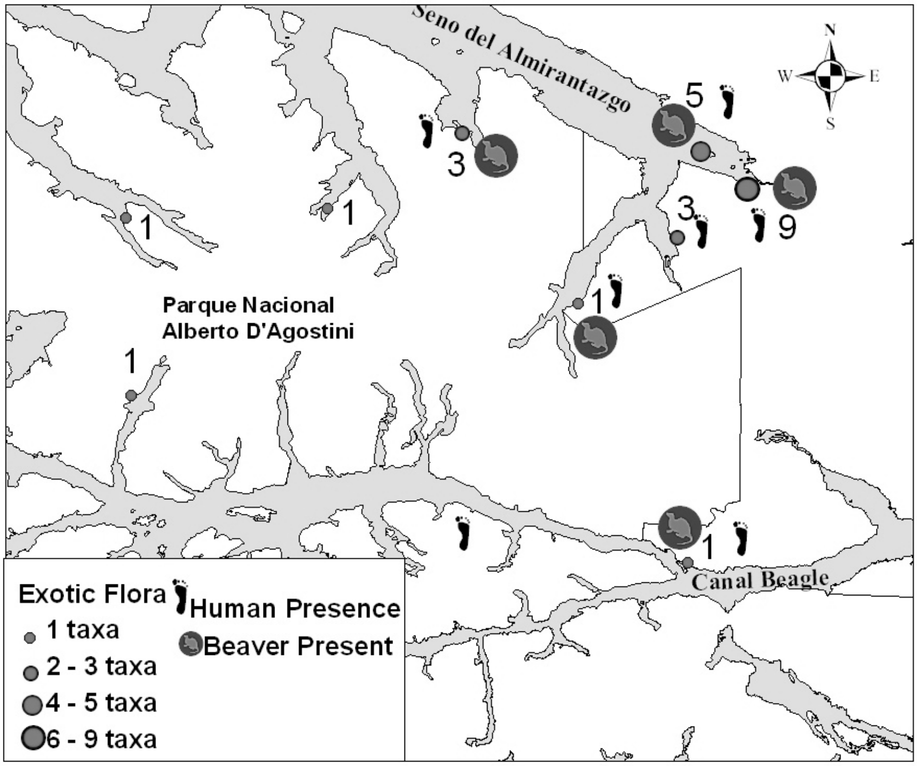

Fig. 3. Distribution of disturbance impacts found in the D'Agostini National Park. Human perturbation, introduced beavers (*Castor canadensis*) and exotic flora were concentrated in the eastern portion of the peninsula, but some localized exceptions were evident.

Water temperatures ranged between 5.7°C (Ventisquero I Sound) and 12.5°C (Ainsworth). The median summer temperature was 8.4°C (Table 6). With the exception of the intertidal stream sampled at Ainsworth Bay and Ventisquero W, the streams were all well oxygenated, being at or near levels of saturation for their given temperatures (Allan 1995) (Table 5). This high oxygen content is due to the many rapids and waterfalls that oxygenate the stream.

TABLE 5. Nine study sites had introduced plants. The total species richness of introduced plant species found is presented for each site, and sites in the eastern portion of the study area are most heavily impacted.

#	Site	Introduced Plant Species Richness
1	Isla Tres Mojotes	5
2	Caleta María	9
3	Bahía Blanca	3
4	Parry	1
5	Ainsworth	3
7	Gallegos E	1
9	Serrano E	1
15	Ventisquero W	1
21	Caleta Olla	1

TABLE 6. The water quality of streams was characterized in each watershed where macroinvertebrates were collected. Temperature (°C), pH, specific conductance (µS/cm), dissolved oxygen (mg0_2/L), habitat type and substrate were quantified for each stream and indicated highly pristine waters. The presence or absence of beaver in each watershed is also indicated.

Site	Temp ºC	pH	Conductivity (µS/cm)	D.O. (mg0_2/L)	Habitat	Substrate	Beaver
Parry (4)	9	7.2	24.3	11.4	Riffles	Cobble, gravel and sand	Yes
Ainsworth (5)	12.5	6.9	158	9.9	Intertidal pools	Gravel and sand	Yes
Gallegos W (6)	10.4	6.8	23.3	10.3	Riffle	Cobble and rock	No
Gallegos E (7)	8.5	6.5	25.5	11.7	Riffle	Cobble, gravel and sand	No
Serrano (8)	6.2	6.3	16.3	12.4	Riffle	Rock, cobble, gravel, sand and silt	No
Torres De Agostini (11)	6.7	7.3	71.2	12.4	Riffle and open channel	Rock, cobble, gravel and sand	No
Ventisquero Ribera W (15)	5.7	6.4	20.4	6.41	Riffle	Bedrock, rock, cobble and gravel	No
Ventisquero Ribera E (16)	7.1	6.5	34.3	12.6	Riffles	Cobble, gravel and rock	No
Pomar-O'Brien (17)	10.1	7.0	22.9	10.9	Riffles	Bedrock, rock, cobble and gravel	No
Pía I (18)	8.0	5.4	19.4	12.1	Riffles	Bedrock, rock and cobble	No
Pía II (19)	8.3	6.9	11.4	11.8	Riffles	Bedrock, rock and cobble	No
Median	**8.4**	**6.8**	**23.3**	**11.7**	The most common stream habitat type was fast moving riffles	Rock, cobble and gravel were predominant substrate types	Beaver were restricted to eastern part of study area
Maximum	**12.5**	**7.3**	**158**	**12.4**			
Minimum	**5.7**	**5.4**	**11.4**	**6.41**			

All the streams sampled have a circum-neutral pH (Table 6). The specific conductance measured ranged from 9.9 microsiemens per centimeter (µS/cm) to 71.2 µS/cm with a median value of 23 µS/cm (Table 6), excluding the data from Ainsworth (158 µS/cm), where the higher specific conductance value could be the result of salt water mixing with freshwater in the intertidal pools. All of these values fall in the very low range of conductance and indicate that few ions are suspended in the water column. The low specific conductance values and high dissolved oxygen levels support the assertion that these waters lack organic or chemical contamination (Likens 1991).

Freshwater Invertebrate Fauna

Ten orders of aquatic macroinvertebrates and twenty-eight species or morpho-species were found in this section of the D'Agostini National Park (Table 7). All pertained to two phyla: Annelida and Arthropoda. Sixteen taxa were identified to the genus/species level.

We found Annelida at eight of the sample sites, including leeches (Hirudinae) and worms (Oligochaeta). The majority of specimens (twenty-five of twenty-eight morpho-species) were Arthropoda. More specifically 79% of the aquatic invertebrates were insects (class Insecta). The most speciose

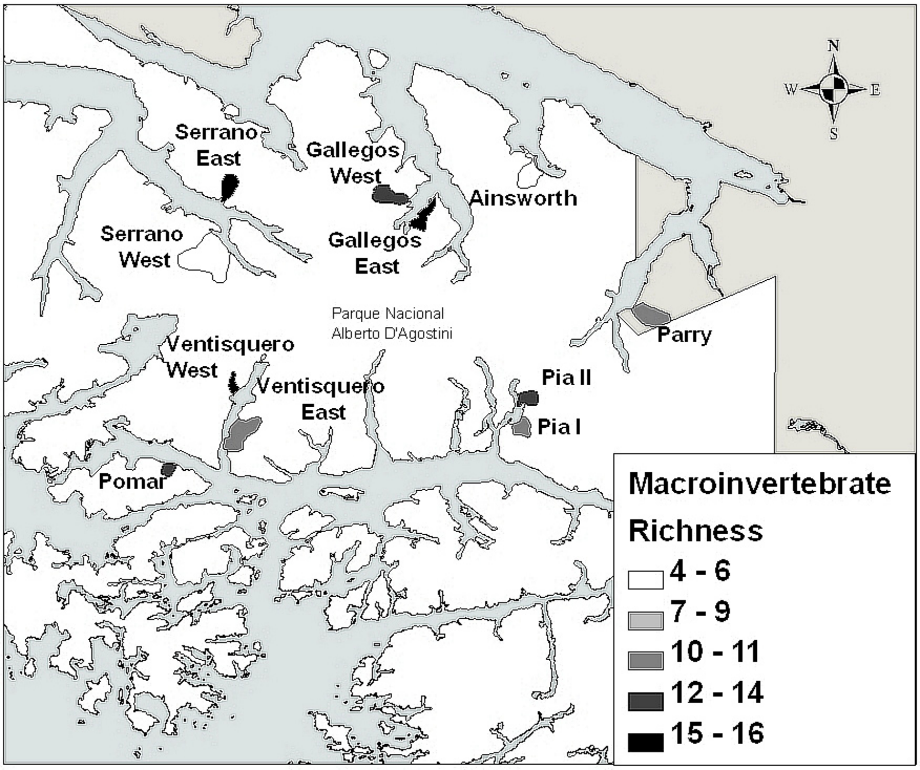

Fig. 4. Aquatic macroinvertebrate taxa richness in the surveyed watersheds totaled at least twenty-nine morpho-species. The greatest number of taxa found in one stream was sixteen.

order was Diptera (flies) with seven families and at least eight species. Plus, it is very likely that these specimens pertain to many more species, given that several diverse families, such as Chironomiadae and Tipulidae, were not identified in this study to a lower classification. The order Plecoptera was the second most diverse with a richness of six taxa from three families. All other orders had from two to four taxa and as many as three families. The remaining specimens were crustaceans [*Hyalella simplex* and a wood louse (Isopoda)]; springtails (Collembola) and mayflies, caddisflies and beetles (Insecta: Ephemeroptera, Trichoptera, and Coleoptera).

Figure 4 shows the distribution of taxa richness within the study site. Richness per catchment ranged from three to sixteen species with seven of the ten sites having between ten and fourteen species. The evolutionary lineage of the community found in the study area showed a combination of Gondwanic and Nearctic affinities. For example, the Plecoptera families Gripopterygidae and Austroperlidae are of southern origin (Antarctoperlaria), while the family Notonemouridae is northern (Arctoperlaria) (Zwick 2000). Furthermore, several taxa were found that were endemic to the Magallanes and Tierra del Fuego areas, including the two Trichoptera *Rheochorema magellanicum* and *Monocosmoecus hyadesi* (Flint 1974) and the Plecoptera *Notoperla fuegiana* (Illies 1963). A number of others are endemic to the temperate forests of southern South America, such as *Antarctoperla michaelseni* and *Rhithroperla rossi* (Plecoptera), *Meridialaris chiloeensis, Metamonius anceps* and *Andesiops torrens* (Ephemeroptera) and *Gigantodax* bryophii complex (Diptera).

The division of trophic roles within the food web was relatively uniform. Only two sampled taxa were parasites and filterers: Hirudinae (leeches) and *Gigantodax* spp. (blackflies), respectively. Shredders constituted only four species, while scraper and predator functional feeding groups made up seven and four taxa, respectively. The largest group was generalist collector-gatherers of fine particulate organic matter (FPOM) with thirteen taxa. The high number of taxa that combined several feeding modes

TABLE 7. At least twenty eight freshwater invertebrate taxa found in the study area. FFG refers to "functional feeding group" and indicates the trophic role of the organism. *indicates endemic to the Magallanes and Tierra del Fuego areas.

CLASS/ORDER	FAMILY	SUB-FAMILY	*GENUS*	*SPECIES*	FFG	SITE #
ANNELID						
Hirudinae (Leech)					*Parasite or predator*	7, 11, 15, 17
Oligochaeta	(Aquatic worm)				*Collector/gatherer*	6, 7, 8, 15, 17, 19
	(Semi-aquatic earthworm)				*Collector/gatherer*	7, 15, 17, 18, 19
ARTHROPODS						
Collembola						
Entomobryomorpha					*Collector/gatherer and predator*	5, 7, 11, 15, 19
Crustaceans						
Amphipoda (Scud)	Hyalellidae		*Hyalella*	*simplex* Shoemaker	*Collector/gatherer and shredder*	11, 15, 17, 19
Isopoda (Wood louse)					*Collector/gatherer and shredder*	7, 11, 15, 16
Insects						
Coleoptera (Beetle)	Elmidae		*Luchoelmis*	sp.	*Scraper*	16, 17
	Dytiscidae		*Lancetes*	sp.	*Predator*	5
	Scirtidae				*Predator*	11, 16, 17
Diptera (Fly)	Blephariceridae		*Edwardsina*	sp.	*Scraper*	4
	Ceratopogonidae				*Collector/gatherer and predator*	11
	Chironomidae	Orthocladiinae	*multiple genera*	*multiple species*	*Collector/gatherer*	4, 5, 6, 7, 8, 11, 15, 17, 18, 19*
		Tanypodinae			*Predator*	5, 15, 18
	Empididae		*Hemerodromia*	sp.	*Collector/gatherer and predator*	4, 11, 15
	Simuliidae		*Gigantodax*	Bryophii complex (*rufescens* Edwards & *antarcticus* Bigot)	*Filterer*	4, 6, 7, 11, 15, 16, 17, 18, 19
	Thaumaleidae				*Scraper*	20
	Tipulidae				*Collector/gatherer, shredder and predator*	4, 6, 7, 15, 17, 18
Ephemeroptera (Mayfly)	Nesameletidae		*Metamonius*	*anceps* Eaton	*Scraper*	4, 6, 19
	Baetidae		*Andesiops*	*torrens* Lugo-Ortiz & McCafferty	*Scraper*	4, 6, 7, 11, 16, 17, 18
	Leptophlebiidae		*Meridialaris*	*chiloeensis* Demoulin	*Scraper*	4, 6, 7, 11, 15, 16, 17, 18, 19

TABLE 7. (continued).

ORDER	FAMILY	SUB-FAMILY	GENUS	*SPECIES*	FFG	SITE #
Plecoptera (Stonefly)	Austroperlidae		*Klapopteryx*	sp.	*Shredder*	8, 17
	Gripopterygidae		*Antarctoperla*	*michaelseni* Klapálek**	*Collector/gatherer and shredder*	6, 7, 11, 16
			Limnoperla	*jaffueli* Navás	*Shredder*	7
			Notoperla	*fuegiana* Illies*	*Scraper*	19
			Rhithroperla	*rossi* Froehlich	*Collector/gatherer and shredder*	6, 15, 18
	Notonemouridae		*Udamocercia*	sp.	*Collector/gatherer and shredder*	6, 7, 15, 16, 17, 19
Trichoptera (Caddisfly)	Hydrobiosidae		*Rheochorema*	*magellanicum* Flint*	*Predator*	4, 6, 11, 15, 16, 18, 19
	Limnephilidae		*Monocosmoecus*	*hyadesi* Mabille*	*Shredder*	5, 7, 11, 15, 16, 18
Total Orders = 10				**Total Taxa = at least 29**		

(collector-gatherer, shredder and predator) indicated that omnivory was very common. Also the high number of shredders and collector-gatherers that fed on course particulate organic matter (CPOM) and FPOM, respectively, showed a dependence on allochthonous inputs from riparian vegetation in the form of leaves and other organic matter.

DISCUSSION

Natural disturbances are an important part of the succession and function of ecosystems in general (Pickett & White 1985) and of forest ecosystems dominated by *Nothofagus* species in particular (Veblen *et al.* 1996). However, the current scale of human-caused habitat fragmentation and the invasion of introduced species constitute two of the main causes of current global ecological change (Vitousek *et al.* 1996). Here, we found evidence to support the assertion that southern Chile's Magellanic Sub-Antarctic Archipelago constitutes a very pristine temperate forest ecosystem, which has also been put forward as one of the world's last wilderness areas, due to its intact native vegetation cover, extensive size and low human population density (Mittermeier *et al.* 2001).

The terrestrial and freshwater ecosystems of Alberto De Agostini National Park still retained watersheds that were unimpacted by human or exotic species disturbances. Water quality measures further demonstrated that biological and chemical contamination has not affected any part of the area. In addition, the natural vegetation coverage within the park was almost 100% intact. Therefore, we can say that indeed De Agostini National Park does represent a rare ecological (and potentially economic) resource that should be protected.

Such protection, however, requires monitoring and planning based on scientific information to manage and sustainably use the landscape. Our findings highlighted that where activities, such as fishing and tourism did exist, they have been carried out in an uncontrolled, unplanned and unregulated way within the park, which has caused negative impacts on several localized areas. For example, fishermen have cut and burn small areas of coastal habitat. Plus, yacht-based tourism is impacting Olla Cove and cruise ship passengers disembarking at several ecologically sensitive areas are compacting soil. Linked to these direct human impacts was the discovery that introduced plants and animals existed throughout the park. The most highly impacted areas were located along the eastern border and outside of the park (*e.g.* María Cove). However, we also found introduced plants even in remote fjords, such as Ventisquero Sound, indicating these organisms' potential to colonize even isolated areas and demonstrating the need to implement a management plan that includes exotic species in the park.

We make special reference here to the freshwater invertebrates, due to a general lack of their consideration in previous works in the region. It is significant to note that we could not identify all taxa to species level due to the fact that there are a lack of systematic keys and reference collections for aquatic invertebrate fauna. It is important to point out, therefore, that some of the taxa in the Fuegian Archipelago are yet to be described by science and probably constitute an even greater diversity and endemism rate than we report here. Nonetheless, it is a conservative estimate to state that at least three aquatic invertebrate species we found in the Alberto De Agostini National Park are endemic to the Magallanes-Tierra del Fuego area, and four are unique to southern South America.

Furthermore, several of these species are the most austral examples of their family and even order in the whole world. These southern range limits constituted the furthest south record for the families Scirtidae, Elmidae and Dytiscidae (Coleoptera); and Blephariceridae, Ceratopogonidae, Empididae, Simuliidae, Thaumaleidae and Tipulidae (Diptera) and the orders of Ephemeroptera, Plecoptera and Trichoptera (Ashworth *et al.* 2000). On average, most watersheds contained ten to sixteen macroinvertebrate taxa per catchment, which is similar to the average number of taxa (seven to twelve) reported for the temperate deciduous forests of the same latitude (55-56°) in Alaska (Hernández *et al.* 2005).

Finally, these aquatic insects, which represent one of the most primitive groups of arthropods, provide us ancient and isolated lineages directly linked to Gondwana and which retain circum-Antarctic affinities with New Zealand, Australian and South African taxa (Illies 1968). As such, the study of these species in southern Chile can be important to the disciplines of evolution, biogeography, taxonomy and ecology. These taxa serve to re-enforce the singular nature of this remote area and demonstrate that the majority of biodiversity is found in the little known "micro" world of small organisms.

For Alberto De Agostini National Park to continue to serve as a natural laboratory for global studies and monitoring, scientific information must be integrated into the planning and implementation of the park. The effort for the real protection of the Alberto De Agostini National Park, while at the same time utilizing the resources in a sustainable manner, is already underway via an inter-institutional public-private initiative to declare the entire archipelago the Cape Horn Biosphere Reserve (Rozzi *et al.* 2004). This proposal would permit a coordinated administration between the different governmental and private actors in the area of the natural resources and facilitate an equitable distribution of benefits to the human population. Alberto De Agostini National Park is included as a core area of the new reserve, and our results serve to highlight and emphasize its importance and singularity and hopefully will also help to facilitate its protection and wise use.

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