Impact of feral pigs and other predators on macro-invertebrates, D'Urville Island

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Abstract

The effect of feral pigs and weka on the abundance, composition and biomass of above- and below-ground macro-invertebrates was assessed every November over 3 years at two sites where pigs and weka, just pigs, and neither species were excluded on Attempt Hill, D'Urville Island. The large carnivorous snail *Powelliphanta hochstetteri obscura* increased both inside and outside the exclosures, and significantly more so within the'no pigs plus weka' treatment. The main cause of mortality of snails outside the exclosures over the 3 years was predation of adult snails by pigs (73% of 33 shells). Over the same period 34 dead snails were counted on plots inside the exclosures, but the main cause of death (82%) was predation by thrushes (or perhaps hedgehogs) on hatchling and juvenile snails. Counts and biomass estimates of soil macro-invertebrates generally showed significant changes over the 3 years and between sites, but we could detect no effect of excluding pigs or weka. Therefore, although there is clear evidence that pigs and weka eat invertbrates, the temporal and spatial variability in the numbers of invertebrates meant our limited sampling over a short period was incapable of detecting strong treatment effects.

1. Introduction

Landcare Research, Lincoln, reviewed the impacts of feral pigs in New Zealand for the Department of Conservation and the Animal Health Board (Nugent et al. 1996). They concluded, from dietary studies and from anecdotal concerns expressed by Conservancy staff, that feral pigs might be the critical threat to the viability of some invertebrate fauna, particularly giant snails and native earthworms. In 1996, the Department of Conservation commissioned Landcare Research to measure the impacts of feral pigs on the above- and below-ground macro-invertebrate fauna in a forest ecosystem. The study was carried out on D'Urville Island between 1996/97 and 1999/2000.

2. Background

Feral pigs *(Sus scrofa)* were first liberated in New Zealand in the late 18th century, and now their range includes about 35% (93 000 km2) of the country (Fraser et al in press). Pigs are omnivorous but require a protein-rich diet to thrive, particularly in the breeding season, when sows need at least 25% protein in their diet to successfully raise young (Choquenot et al. 1996). Therefore, although they rely chiefly on plant material in New Zealand, animals, in particular earthworms, form a major part of their diet. For example, 26% by dried weight of pig diet on Auckland Island (Chimera et al. 1995) and about

10% by dried weight in the Urewera National Park (Thomson & Challies 1988) were annelids. This suggests that, even at low to moderate densities, pigs may have a significant adverse impact on earthworms. Pigs also prey on the indigenous giant land snails and are listed as potential causes of the decline of these large predatory snails in the Department's threatened species plan (Parrish et al. 1995).

Pigs may affect macro-invertebrate populations in several ways. They may directly affect invertebrate species' viability by eating them, they may affect the invertebrates by destroying their habitat by rooting up the litter and low vegetation or by the ecosystem changes consequent to this, and they may compete with land snails for earthworms as food (heads et al. 1984).

We conducted this study on D'Urville Island because a confounding factor in determining any impacts of feral pigs on invertebrates, giant snails in particular, is that these are also preyed upon by other species. Possums *(Trichosurus vulpecula)* and ship rats *(Rattus rattus)* are absent from the island, although other potential predators (kiore *(Rattus exulans)*, weka *(Gallirallus australis)*, thrushes *(Turdus philomelos)*, hedgehogs *(Erinaceus europaeus)*, and stoats *(Mustela erminea))* are present.

3. Objectives

- To determine the effects of excluding pigs on the abundance, composition and biomass of above- and below-ground macro-invertebrates on D'Urville Island.

- To describe the diet of pigs on D'Urville Island.

4. Methods

In the summer of 1996/97 two study sites were established on D'Urville Island, in areas frequented by pigs, and known to have snails present. The sites were selected in forest habitat where (a) live snails were presumed (by the presence of empty shells) to be present, (b) pig rooting or sign was present, and (c) we could physically construct a fence to exclude pigs.

The northern site was on a broad ridge with flat topography and deep soil, most of which had been rooted over by pigs at some time. The forest is dominated by silver beech *(Nothofagus menziesii)* and kamahi *(Weinmannia racemosa)* with some red beech *(N. fusca)* and matipou *(Myrsine australis)* in the canopy, with a sub-canopy dominated by *Coprosma* species, particularly *C. foetidissima*. The ground vegetation is dominated by crown fern *(Blechnum discolor)*, with lesser amounts of *B. capense, Hymenophyllum* sp., *Microlaena avenacea,* and *Uncinia* sp.

The southern site was located on a steeper and narrower ridge, where boulders and bedrock were at or close to the ground surface. This meant pig rooting was restricted to small areas between the rocky outcrops. The vegetation differed on each side of the ridge. On the western slope the vegetation is similar to that at the northern site, although the canopy is more open, and the creeping *Metrosideros fulgens* is common on the ground. On the western side, mahoe *(Melicytis ramiflorus)*, broadleaf *(Griselinia littoralis)* and pigeonwood *(Hedycarya arborea)* dominates the canopy over a sparse sub-canopy.

At each site, a 50 m x 50 m fence was constructed to exclude pigs. Half of each exclosure was also fenced to exclude weka, giving us three treatments (pigs and weka present, weka but no pigs, and no weka or pigs present). At each site, 20 snail plots were established of 5 m x 5 m; 10 within the pig fence (five in each half), and 10 outside. Each November following establishment of the exclosures, the number of dead and alive *Powelliphanta hochstetteri obscura* were counted on these plots following the methods described by Walker (1997). All empty snail shells found on the plots at the start of the study were removed, and the 'standing crop' density of empty snail shells was estimated from the counts in 1996, plus shells discovered in subsequent years that had obviously been missed in earlier counts (37 of 176 shells). These missed shells included fragments and intact shells that may have rolled on to steeper plots. The shells of dead snails that accumulated on the plots between surveys were measured, the cause of death was noted, and then they were removed. All live snails found were measured and replaced.

Each year four soil samples (25 cm x 25 cm, and 25 cm deep or down to base rock) were taken just outside each snail plot, i.e. 80 each year. These samples were sieved on site and all macro-invertebrates were collected. Subsequently, invertebrates collected from soil samples were sorted, identified and counted. Total biomass for each group of soil invertebrates was also calculated for the plots.

In the laboratory, a total of 31 pig gut samples provided by hunters on the island were analysed (following the methods outlined in Coleman & Parkes (1997)) for the presence of any invertebrate fauna.

Before the data were analysed, the annual counts of snails and soil invertebrates by species/group for each treatment were square-root transformed before analysis, and soil invertebrate biomasses were cube-root transformed to improve the distribution of the model residuals. These transformed counts were then compared by fitting linear mixed-effects models using S-Plus 2000. The plots and the three treatments at each site (pigs plus weka, no pigs plus weka, and no pigs and no weka) were taken as random effects, and the autocorrelation between repeated measures on the same plots was modelled as an autoregressive process of order 1. Wald *F*-tests (which account for auto correlation) were used to test for significant differences.

5. Results

5.1 LAND SNAILS

The mean number of live snails increased both inside and outside the exclosures at both sites over the 4 years (Figure 1). Overall there was a treatment effect with snail numbers increasing more rapidly inside the exclosures ($F_{3,108}$ = 2.74, P = 0.016). However, most of this appears to be due to the increase in snails in the `no pig plus weka' plots, which increased at both sites from 0 to 1.8/plot and 0.8 to 4.6/plot at the north and south site, respectively. There was little change in the half of the plots where both pigs and weka were excluded (Figure 1). The effect of the exclosures appeared to be largely on juvenile recruitment of snails, as adult numbers remained similar inside and outside the fences throughout the study, but there was a marked increase in juvenile snails inside the fences (Figure 2).

The `standing crop' density of empty and preyed-on snail shells averaged 4.4 ± 1.4 per plot, a density of 1760 ± 560 snail shells/ha. Clearly, this density represents many years' accumulation of shells because the average annual recruitment of empty and preyed-on shells (in the plots outside the exclosures) was only 0.55 ± 1.01 per plot, a density of 220 ± 404 snail shells/ha/year.

There was a marked change in the causes of snail mortality during the study. Before the exclosures were erected, 139 empty snail shells were removed from the plots in 1996: 24 from the northern sites and 115 from the southern site. Of these, 61% had been killed by pigs, 21% by weka, 12% were intact but empty, and 6% were so old or fragmentary that we could not determine the cause of death. After the exclosures were erected, these proportions remained similar for the plots outside the fences; of the 33 snails that died over the 3 years, 73% were killed by pigs, 12% by weka, 6 % by thrushes, 6% were intact, and 3% died of unknown causes. However, inside the fences the cause of death of the 34 dead shells found was very different. Over the 3 years, 82% had been killed by thrushes, 3% by weka, and 15% were intact. Thus, although predation by pigs had been eliminated and that by weka reduced, the increase in juvenile snails had allowed the predation by thrushes to become apparent.

Pigs can kill snails of all sizes, although they apparently swallow smaller ones whole, as we found few small shells typically crushed by pigs. Weka take both small and medium-sized snails, leaving shells with a neat hole picked through the central whorl. Thrushes kill only small ones, leaving shatter holes through the outer whorl (Table 1). Note: it is difficult to distinguish between predation by thrushes and hedgehogs, but hedgehogs are not common deep in the forest so we blamed the bird.

There was strong evidence that there were more live snails on plots with the most empty shells present in 1996 ($F_{1,30}$ = 20.4, P<0.001) and this was not dependent on the treatment or site. There was also some evidence that the accumulation of dead snails over 1997 to 1999 was highest in plots with the most dead shells in 1996 ($F_{1,30}$= 4.63, P = 0.040). This suggests that there are no refugia from predation for the snails.

5.2 SOIL INVERTEBRATES

The counts of most classes of soil invertebrates (we compared counts of annelids, mainly *Hoplochaetina durvilleana,* amphipods, chilopods, diplopods) varied significantly over time, but there was no consistent effect of the exclosure treatments or between the two sites (Figure 3).

There was a significant treatment effect over time for annelid biomass ($F_{6,108}$ =2.45, P = 0.029), and for site differences that varied with time ($F_{3,108}$ = 3.50, P = 0.018), although a simple interpretation of the means in Figure 3 is not immediately obvious. The number of diplopods (millipedes) also increased significantly ($F_{3,108}$ = 8.56, P < 0.0001), and there were significantly more at the northern site ($F_{1,2}$= 20.6, P = 0.045), but there was no treatment effect (Figure 3).

5.3 ARE THERE MORE SNAILS WHERE THERE IS MORE SNAIL FOOD?

There is contradictory evidence that the counts of live snails are related to the biomass of worms. At the northern site there were clearly more worms about the plots with most snails (r = 0.58, SE = 0.27), but there was no such relationship at the southern site (r = -0.23, SE = 0.27).

5.4 PIG DIET

Seven of the 31 pig stomach samples sorted contained earthworms, but few other invertebrates were found, and only one pig had eaten *Powelliphanta hochstetteri obscura* (Table 2). Most of the pigs sampled had been shot on grassland and scrub areas, often far from the range of snails. The sampled diet of the D'Urville Island pigs contained far less animal matter than seen in other studies: only 4.2% compared with 28% in the Urewera forests (Thomson & Challies 1988) and 30% on Auckland Island (Chimera et al. 1995).

6. Conclusions

If both pigs and weka affected snail numbers we would have expected no change or a decline outside the exclosures, an increase in the half of the fences excluding both pigs and weka, and perhaps an increase in the half with weka but no pigs, depending on the importance of weka as a predator. A significant proportion of snails outside the exclosures are killed by pigs or weka each year, with a mean annual accumulation of 0.48 dead shells per plot from a mean density of live snails of 0.62 snails/plot. Despite this, we could detect only weak effects of excluding the two predators (pigs and weka) that contributed 82% of the observed predation outside the fences.

There was some evidence that the recruitment of young snails was enhanced by excluding pigs and weka, whether by reducing predation or by reducing the effects of soil disturbance by rooting, but that many of these were then eaten by thrushes. Whether this predation will be reduced as cover from litter and ground vegetation increases after pig exclusion is unclear.

This project was envisaged as a pilot trial to test the methods, and generally, we suspect that our sampling intensity (two sites) was too low to detect significant trends in invertebrates over the short period (3 years) in which the predators were excluded, and the year-to-year variation is obviously very high. Two possibilities exist to overcome this spatial and temporal variability: establish more plots and/or measure them over a longer period. The expense of establishing the exclosures precluded a larger sample size unless the area enclosed was reduced. We did not want to make the exclosures too small because the home range of snails is likely to be about 1000 m2 (K. Walker, unpubl. data), and our fences did not stop snail dispersal.

Temporal changes in invertebrate fauna inside and outside 30 plots that excluded ungulates such as deer and goats, and perhaps pigs, were measured after at least 20 years across a wide range of forest sites by Wardle et al. (2000). They found few consistent trends among the micro-fauna, but showed that nearly all the macro-fauna were adversely affected by the presence of browsing mammals, with reductions in densities of over 70%. They thought the impact was more likely to be due to trampling effects on the litter than to changes in the vegetation, but did not consider predation within their design. We have considered predation but not the trampling effects of ungulates or in fact of people during our surveys. More complex and expensive experimental designs would be needed to distinguish between these effects.

7. Recommendations

- The fences around the two established exclosures should be maintained.
- The snail plots should be measured annually and live snails should be marked to measure survival and dispersal.
- The soil invertebrate plots should be measured every second year.

8. Acknowledgements

We thank Jacqui Whitford, Peter Berben, NigelYoung, Bruce Thomas (Landcare Research) and Pete Brady (DOC) for help with data collection on the island. Thanks to Tony Partridge for constructing the exclosures. We are also deeply indebted to Pip and Jeanette Aplin for maintaining the exclosures for the duration of the study, helping with data collection, and for the use of their vehicle on the island. Andrea Byrom commented on a draft of the report, and Aaron McGlinchy, Wendy Ruscoe, and Ray Webster provided statistical support. We owe special thanks to the D'Urville Island Residents'Association for allowing us the use of the Community Lodge while based on the island, and to Mr P. Ruruku of Ngati Koata for allowing access to their land.

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Table 1. Number and mean shell size of *Powelliphanta hochstetterii obscura* preyed upon by pigs, thrushes, weka, or dead but intact that accumulated on 40 plots, D'Urville Island 1997 to 1999.

Cause of death	Number of shells 1997	Number of shells 1998	Number of shells 1999	Mean diameter ± CL
Pig	2	5	17	55.1 ± 4.0[1]
Thrush (or hedgehog)	2	14	17	18.6 ± 1.7
Weka	3	2	0	36.8 ± 6.8
Intact but empty	2	1	5	29.1 ± 16.8

1 Pigs crunch and flatten the snail shells making it difficult to measure the exact diameter of the shell.

Table 2. Diet of 31 feral pigs shot on D'Urville Island, 1996-1999.

Food items	Mean % dried weight	Frequency
Grasses	21.3	63
Ferns	19.6	
Trifolium repens	18.3	28
Herbs	10.3	59
Microlaena avenacea	2.1	6
Elaeocarpus dentatus fruit	18.2	25
Dysoxylum spectabile fruit	5.8	13
Beilschmiedia tawa fruit	0.1	6
Annelids	3.4	25
Powelliphanta hochstetteri	0.5	3
Other invertebrates	0.4	
Feathers	0.1	6
Total plant leaf	71.6	
Total fruit	24.1	
Total animal	4.2	

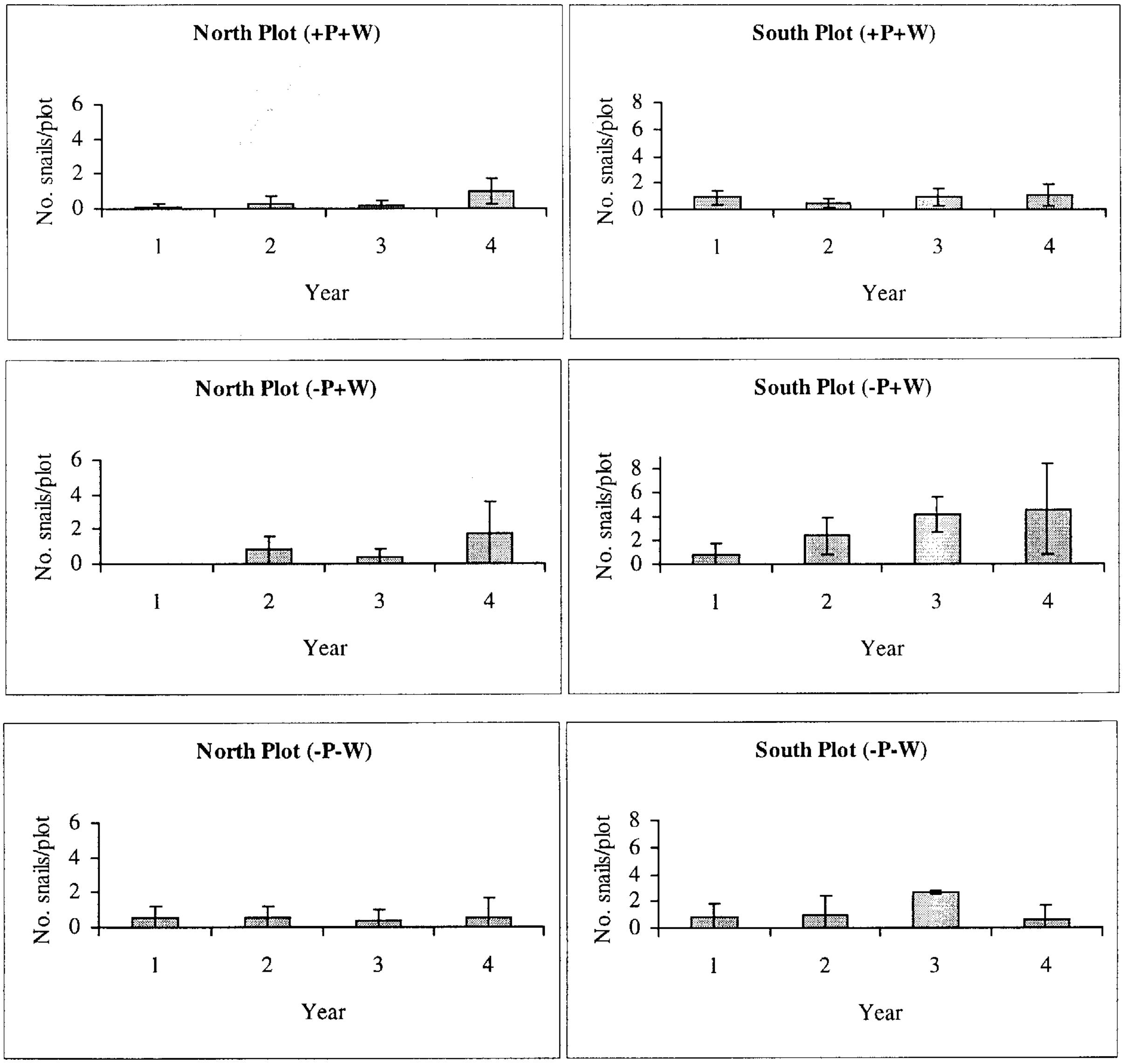


Figure 1. Changes in the mean number (± 95% CI) of live *Powelliphanta hochstetteri obscura* at two sites with pigs and weka present (+P+W) , absent (-P-W), and with weka present but not pigs (-P+W).

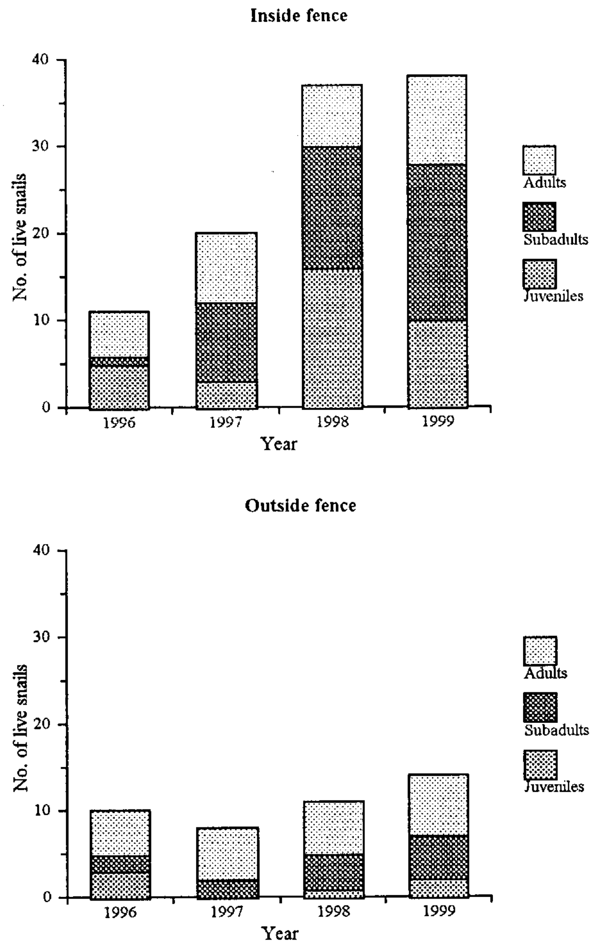


Figure 2. Changes in the numbers of live snails in three size classes (juveniles = > 25 mm; subadults = 25-49 mm; adults = 50+ mm diameter) inside and outside the exclosures between 1996 and 1999.

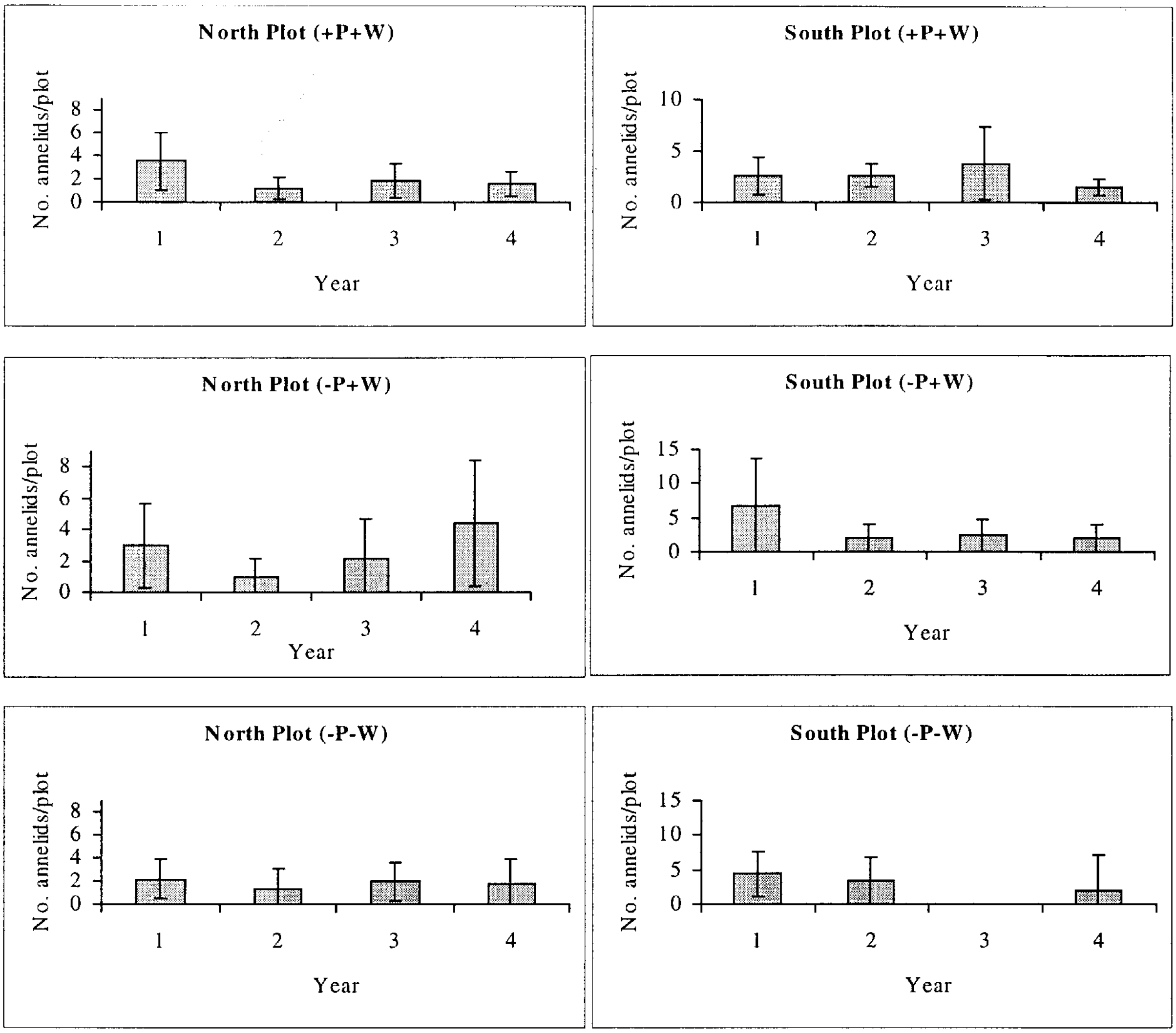
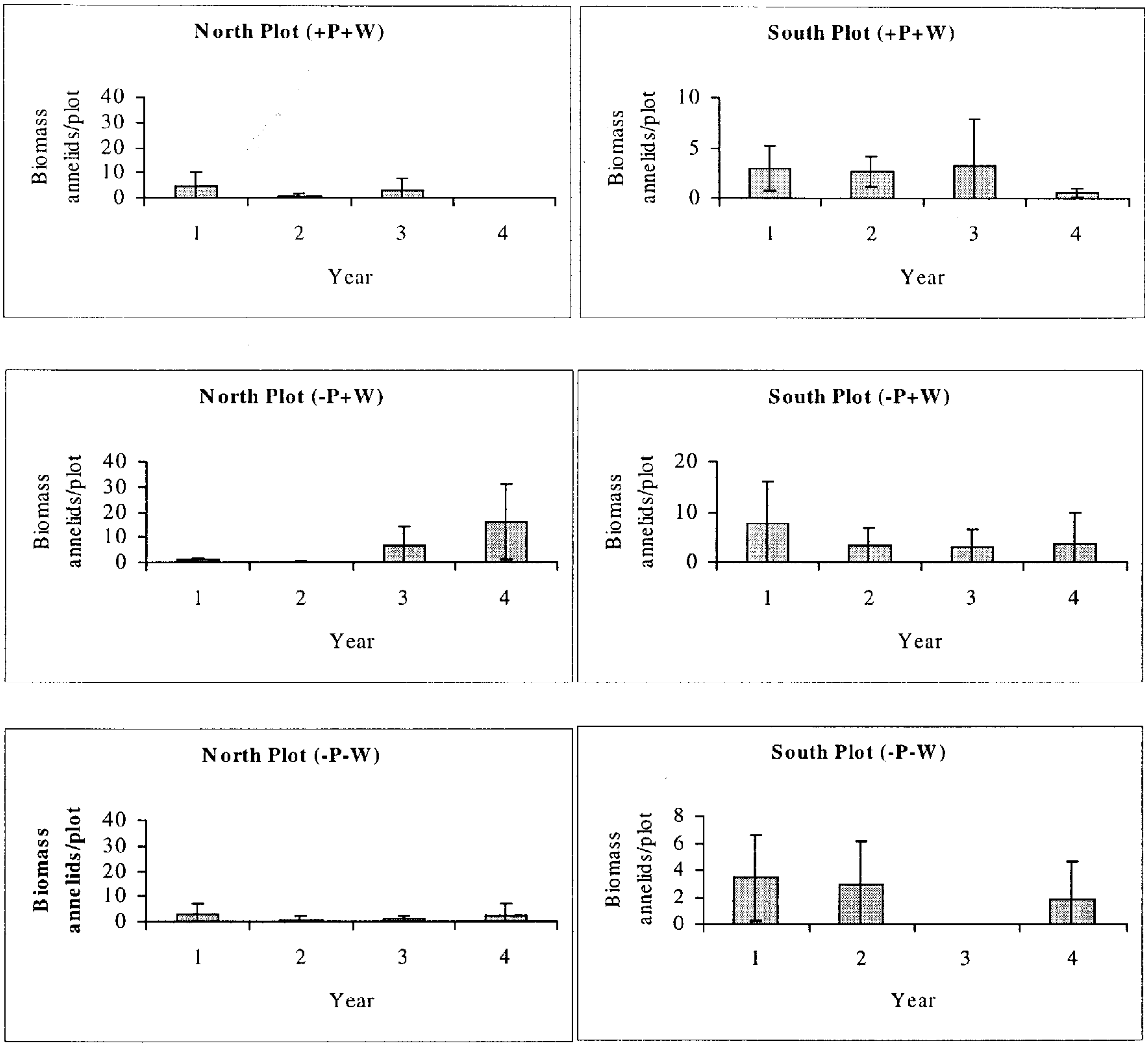


Figure 3. Changes in the mean number (± 95% CI) of classes of soil invertebrates, and biomass of annelids and all other soil invertebrates combined at two sites with pigs and weka present (+P+W) , absent (-P-W), and with weka present but not pigs (-P+W) [*continued over.....*]



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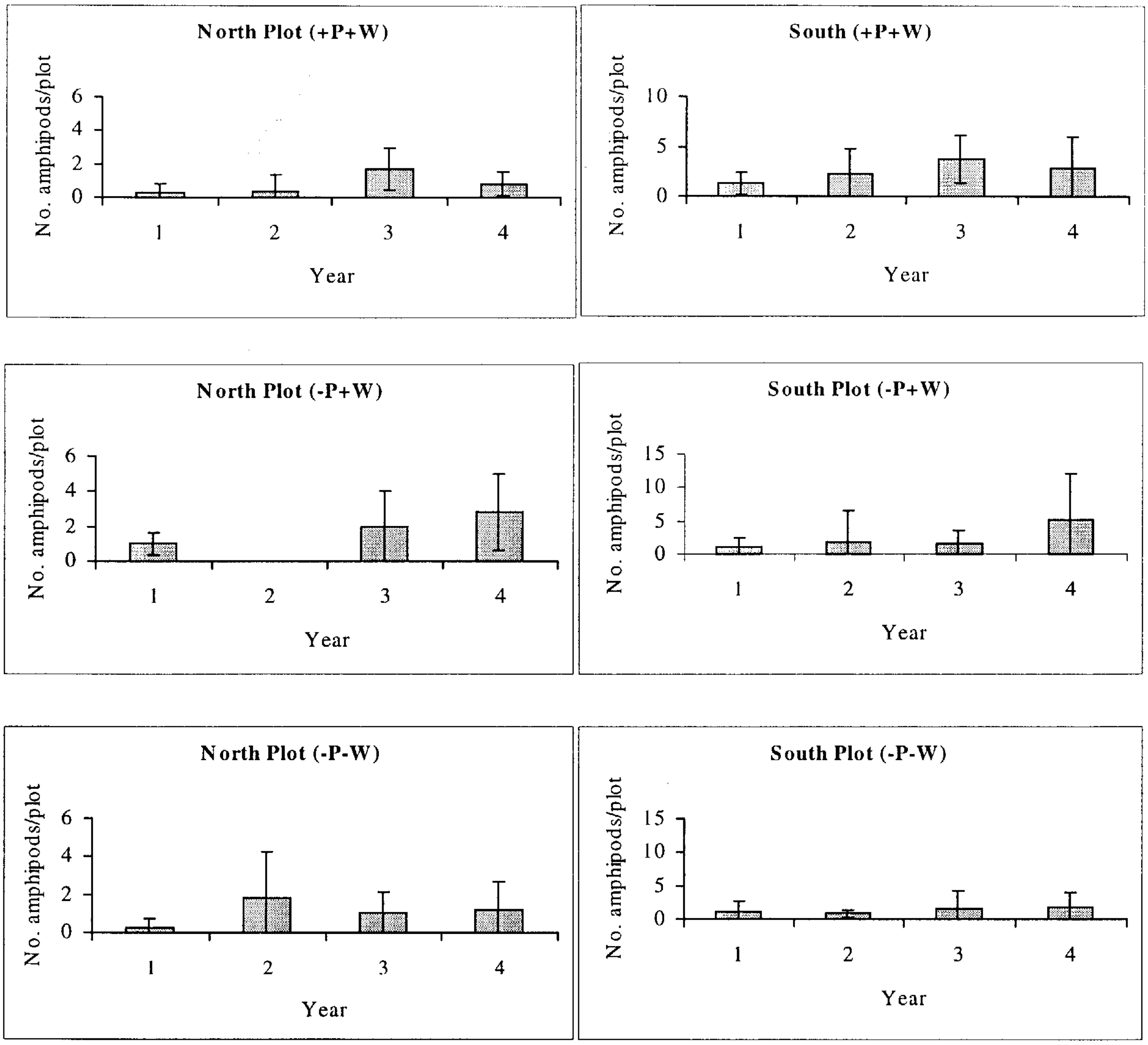

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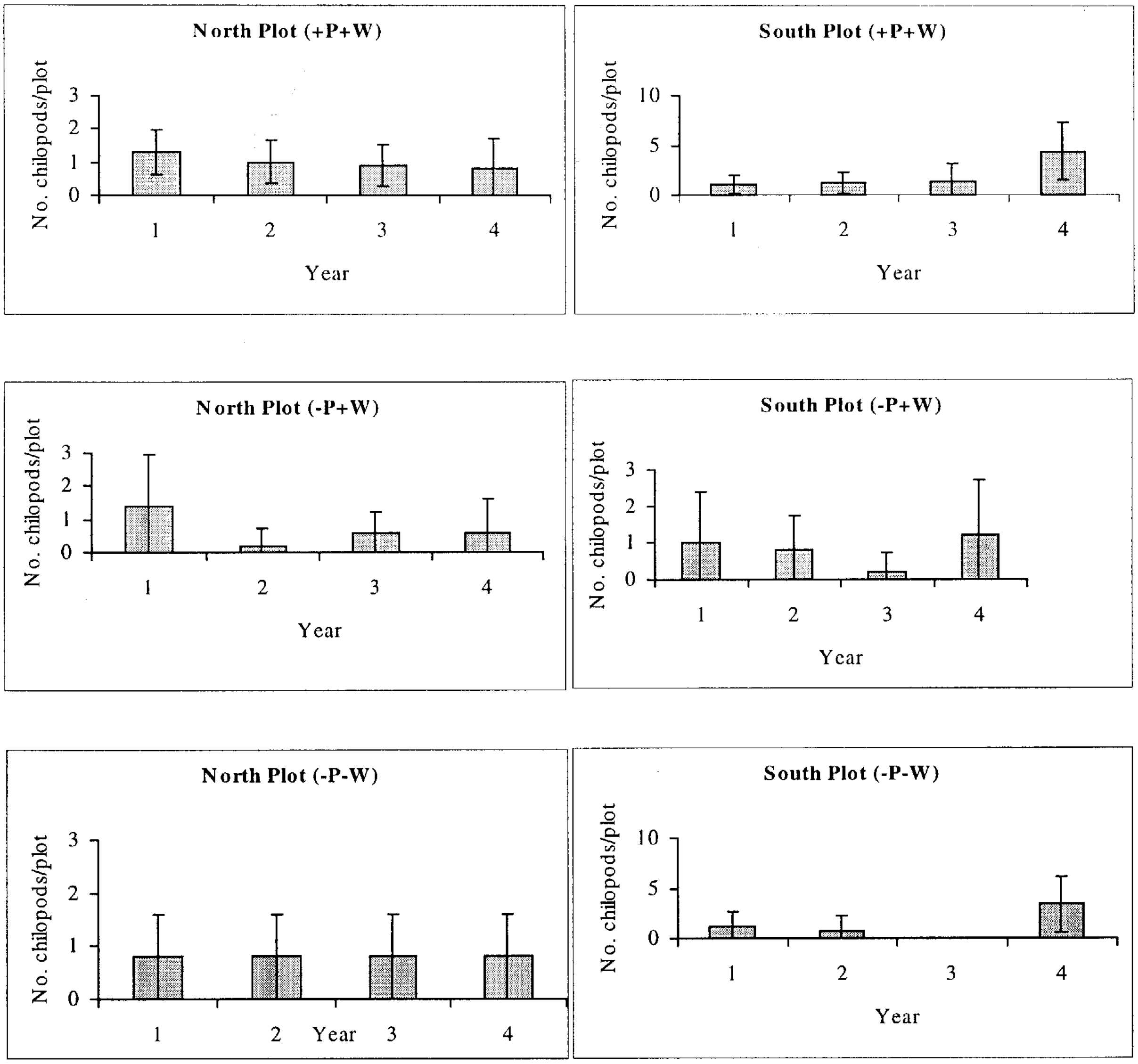

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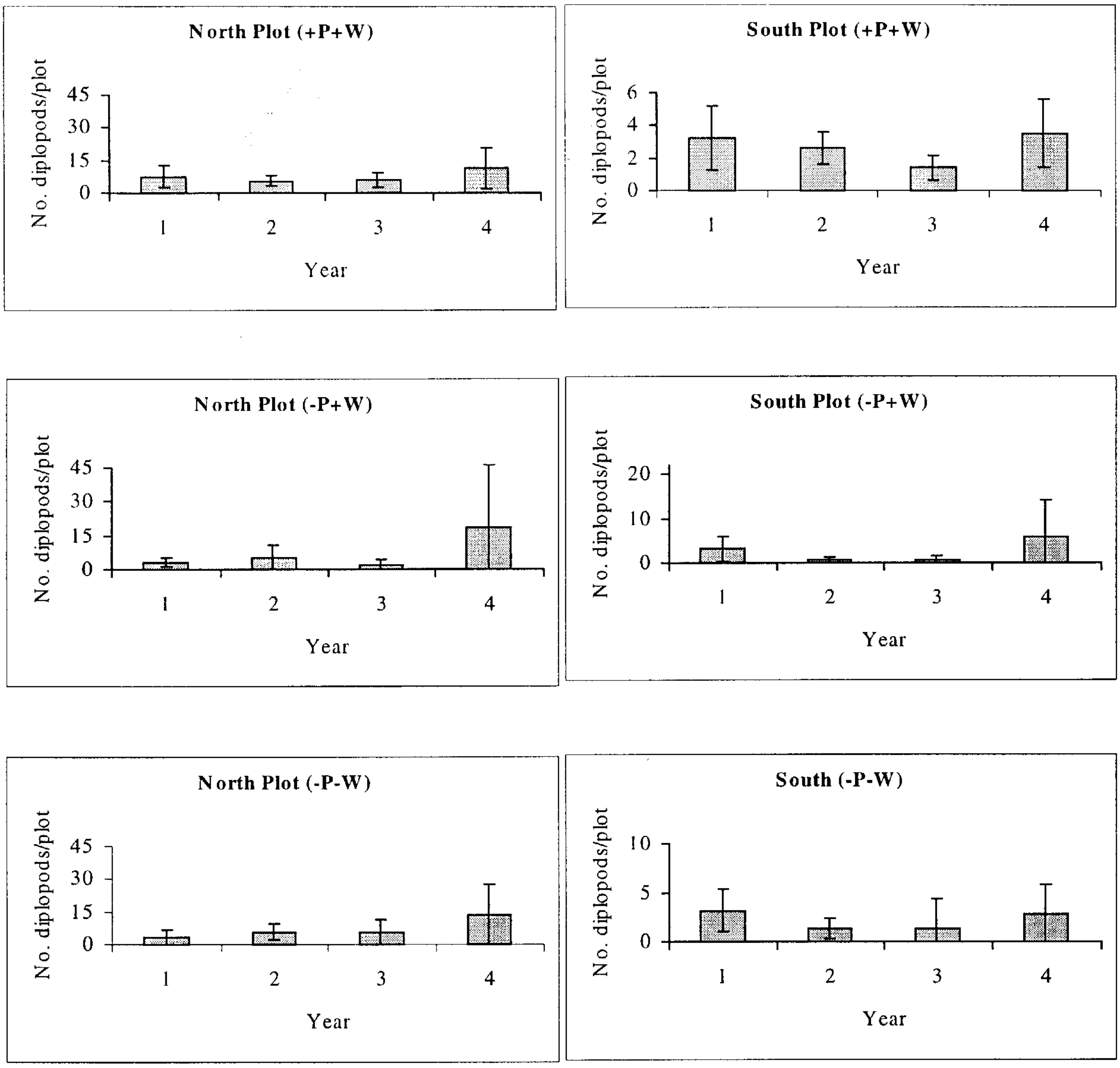

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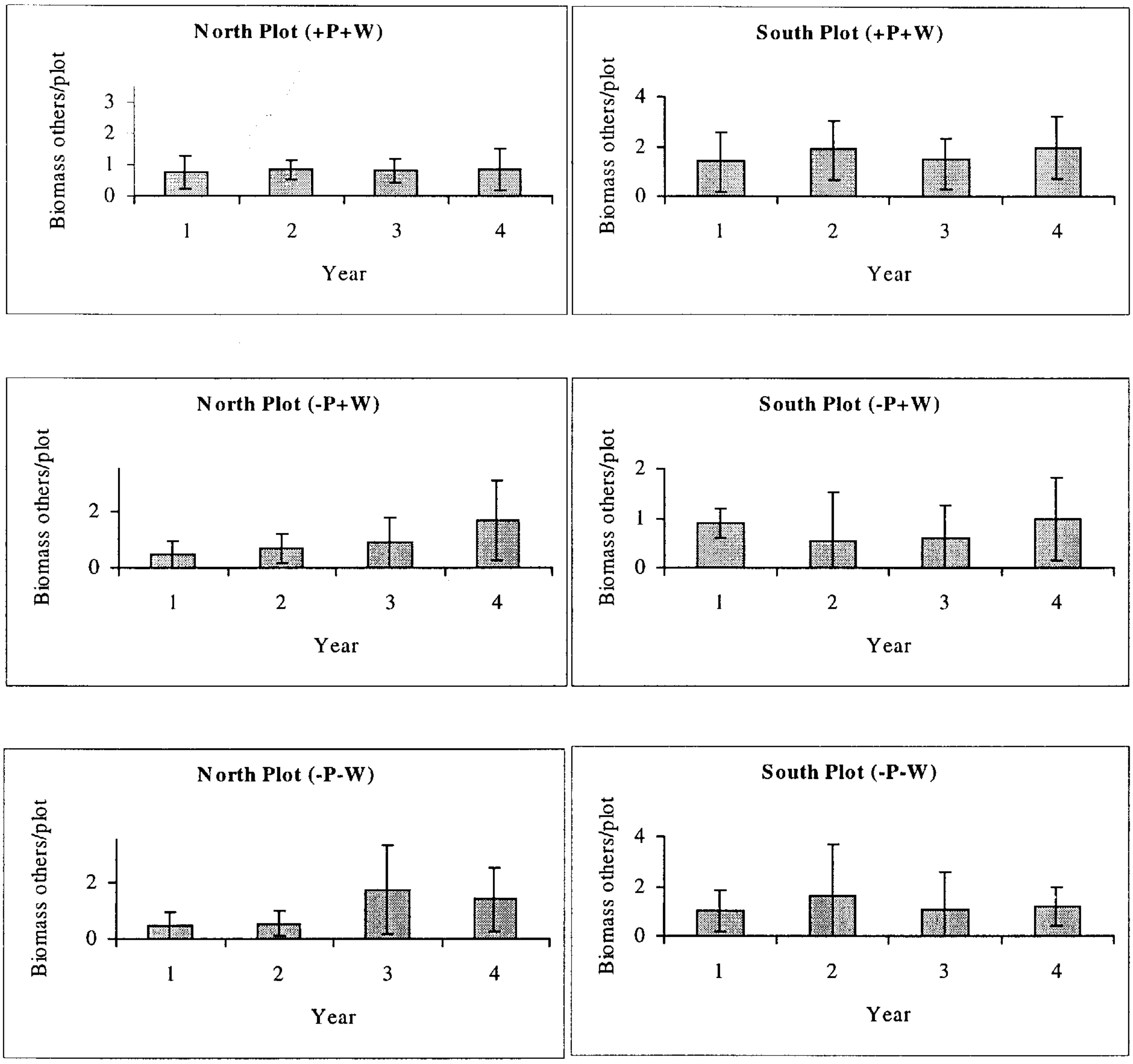

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