# Pilot study assessing the impacts of recreation on invertebrates that inhabit in the Tofino Mudflats WMA

## Submitted to the Clayoquot Biosphere Trust

February 25, 2008

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## ABSTRACT

The west coast of Vancouver Island has been gaining popularity with people from all around the world who come to enjoy the natural wild beauty of the area. The mudflats on the east side of the Esowista Peninsula and on the southwest coast of Meares Island have been gaining popularity with locals and visitors alike. There is concern that increased activities on the mudflats may have detrimental effects on the habitat and the organisms that live there. During the spring and summer of 2007, we conducted a study to assess the impacts of recreation between disturbed and undisturbed sites in the Tofino mudflats. Counterintuitively, we found a greater abundance of the four target organisms in the disturbed site. There were more burrowing organisms in the heavily trampled area and more mobile polychaetes in the less trampled area of the disturbed site. We recommend further investigation of additional parameters in order to determine whether this trend occurs in other areas of the mudflats and during other times of the year. We found greater biodiversity in the undisturbed area and suggest continued monitoring of the mudflats as part of the development of sustainable recreational activities for the Tofino mudflats.

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## 1.0 INTRODUCTION

Over the years the west coast of Vancouver Island has been gaining popularity with people from all around the world. The Pacific Rim area is renowned for vast expanses of pristine beaches and natural wild beauty which includes the Tofino Mudflats on the east side of the Esowista Peninsula and on the southwest coast of Meares Island. As the local population and tourism continue to grow there has been concern about habitat degradation and potential negative interactions between humans and wildlife in natural areas (Beasley, 2007). In 1997 the Tofino Mudflats Wildlife Management Area (WMA) was established to protect the natural resources of the mudflats area and include 1770 hectares of tidal flats and 338 hectares of terrestrial forest (Beasley, 2007).

The Tofino Mudflats Wildlife Management Area (WMA) provides important year round habitat for numerous fish as well as marine and terrestrial species of invertebrates, local and migratory birds, and both large and small mammals (Butler *et al.*, 1992; Dunham and Duffus, 2001; Beasley, 2007). The region holds the only mudflats on the west coast of Vancouver Island known to support significant populations of shorebirds and, combined with the populations of water birds, the area exceeds the criteria for international significance under the Convention on Wetlands of Importance, especially as waterfowl habitat (Butler *et al.*, 1992). This critically important habitat lies within the territory of the Tla-o-qui-aht First Nations and is bordered by private, municipal, commercial and national park properties (Beasley, 2007). A management plan for the Tofino Mudflats WMA was prepared in November 2002 (Eggen *et al.*, 2002) and calls for stewardship and educational programs that will increase awareness in order to prevent activities that negatively affect the WMA.

The response by local naturalist and environmental organizations has been positive. In 2004 the Raincoast Education Society began regular educational activities to create enthusiasm for conserving the ecological integrity of the Tofino Mudflats Wildlife Management Area (Beasley, 2007). And, over the past few years, the Clayoquot Field Station at the Tofino Botanical Gardens has conducted eco-tours in which visitors explore a small portion of mudflats with the goal of making people conscious of the natural significance of the area.

These activities bring more people and more activities out into specific regions of the Tofino mudflats. Previous studies have shown recreational use and associated trampling in mudflats can have a wide range of effects from enhancing densities of herbivorous mollusks (Keough and Quinn, 1998) to decreasing and nearly eliminating numerous other invertebrate species populations from trampled areas (Wynberg and Branch, 1997; Keough and Quinn, 1998; Lindegarth and Hoskins, 2001). The current study was performed to assess the potential impacts of recreation on invertebrates that inhabit the mudflats. We are interested to see if there are suitable, readily and easily identifiable target invertebrate taxa to uncover relatively simple methods to monitor these few target species of invertebrates and to assess potential differences in biodiversity between a pristine area of the mudflat (with limited human activity) compared with a potentially impacted site (with elevated levels of human activity). We make some recommendations with regards to sustainable activities within the Tofino Mudflats WMA.

## 2.0 METHODS

### 2.1 Study area and sampling design

The study took place on a portion of the Tofino Mudflats Wildlife Management Area (WMA) located near Tofino on western Vancouver Island (49° 08'N, 125° 52'W). Specifically, our study was conducted in front of the "Evian" (a salmon troller exhibit) at the Tofino Botanical Gardens (disturbed site; 49° 08'N, 125° 53'W) and on the mudflats north of Jensens Bay (undisturbed site; 49° 07'N, 125° 52'W; see Figure 1). Our disturbed site has periodic trampling from naturalist tours conducted out of the Tofino Botanical Gardens and the Clayoquot Field Station. This periodic trampling is often done in a relatively small area, so we divided the disturbed area into more heavily trampled (0-40m) and less trampled (50-100m) as the frequency of disturbances is much higher in the heavily trampled area of the disturbed site that is accessed directly in front of the Evian. Invertebrate sampling took place in May, July and August 2007 at the disturbed site and in July and August 2007 at the pristine site. At each locality there were three, 100m transects, (spaced 10m apart) starting approximately 15m off of the high tide mark and ran parallel to shore. At the disturbed site these transects were laid out on a 120º vector from north, while at the undisturbed site transects were laid out approximately 180º from north. These sites were chosen because they appeared to encompass characteristics of a disturbed and undisturbed locality. Before each sampling effort two of the three transects at each locality were randomly chosen.

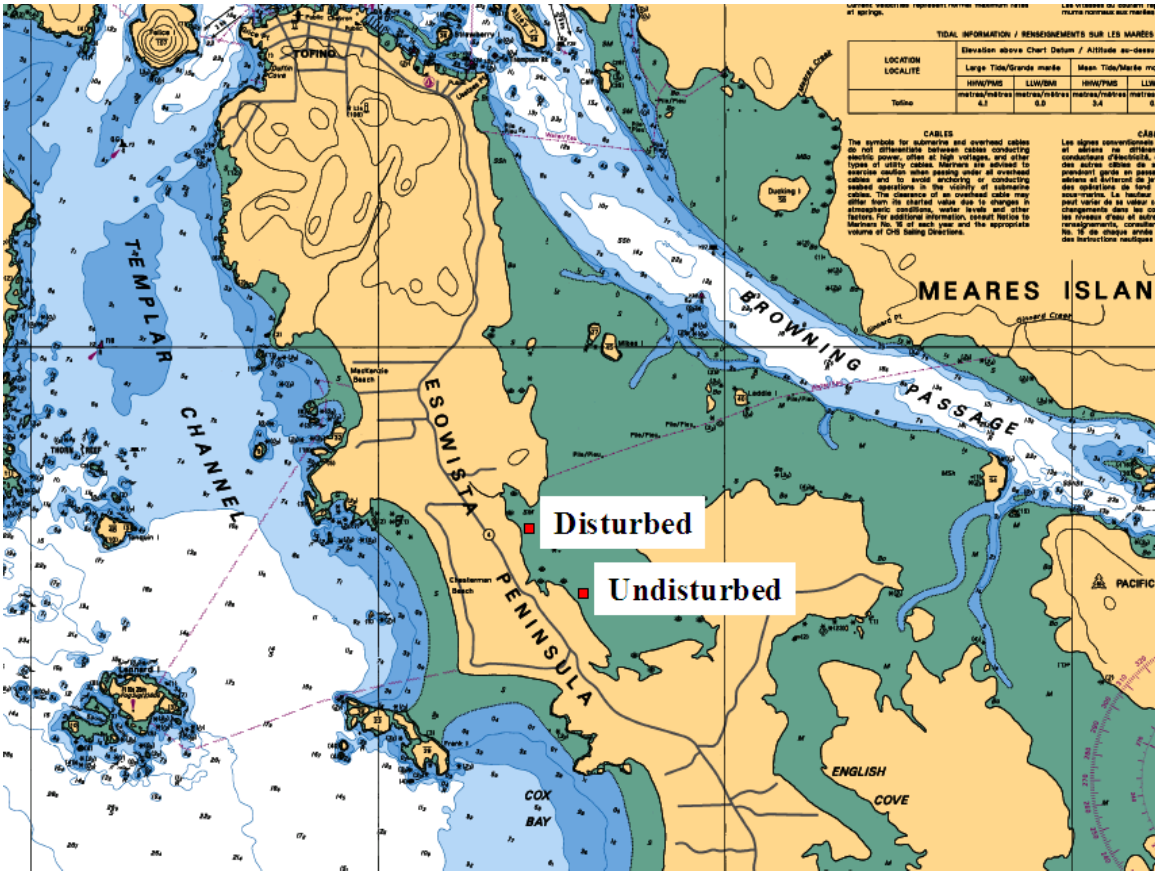


**Figure 1.** Map of the Esowista Peninsula showing the location of the two study sites in the Tofino Mudflats Wildlife Management Area.

Each transect was divided into 10 meter sections (0-9, 10-19, 20-29…90-99m) and five of the 11 sections along each transect were randomly selected and sampled.

### 2.2 Lugworm sampling

To obtain the abundance of lugworms at our two study locations we visually surveyed for the lugworm's tell-tale "castings" around their burrows. At each of the five randomly selected areas on two of the three randomly chosen transects at each locality, a 300cm$^2$ section of each 10m section (i.e., 10- 13m or 30-33m) was visually scrutinized for evidence of lugworms. A coin was flipped to determine which side of the transect sampling was to be conducted. Upon discovery, lugworms were retrieved (if possible) and identified to species. After identification each individual was released. There was usually one opportunity to dig out a specimen (area refills with water and mud after removal of shovel scoop). Therefore if the casting was present but we could not find the specimen it was enumerated as "unknown". We found evidence of a total of 49 lugworms combined from each site. Of these 38 were identified as the Neapolitan lugworm (*Abarenicola pacifica*) and 11 were unknown.

### 2.3 Percent cover estimates

We were interested in estimating the relative abundance of macroinvertebrates found inhabiting the mud. Early in the spring (May) there was limited algal (*Chaetomorpha sp*.) cover. However, as the photoperiod and ambient temperatures increased thick "mats" of algae blanketed the study areas. At each of the five randomly selected areas on two of the three randomly chosen transects at each locality (and on the same side of the transect that was chosen by coin flip for lugworm sampling), we randomly placed a $100cm^2$ quadrat on the substrate and estimated the percent algal and eelgrass (*Zostera sp.*) cover within the quadrat. Previous investigation has shown that ghost shrimp (*Neotrypaea californiensis*) are abundant in the TMWMA (Carty, 2001; Dunham and Duffus, 2001). We counted the number of burrows in each of our $100\ cm^2$ quadrats at each locality. Within each of the $100\ cm^2$ quadrats we randomly placed three - $30cm^2$ quadrats and counted the number of ghost shrimp burrows.

**2.4 Macroinvertebrate sampling**

To collect invertebrates we took equal shovel scoops (shovel dimensions: 25.4x 20.3cm) of mud from each of the $30cm^2$ quadrats and measured and recorded the volume of mud in each shovel scoop using a graduated bucket. Each mud sample was placed one at a time in a mesh bag and thoroughly rinsed in marine water. The remaining sample was sifted through a mesh screen (mesh 2.5mm wide) and rinsed with marine water in order to identify and count the number of macroinvertebrates present. All individuals were returned after identification and enumeration.

**2.5 Substrate composition estimates**

The composition of the muddy substrate was roughly estimated. We had four categories of substrate: mud/clay, mud/silt, mud/sand and mud/gravel. Each shovel scoop was categorized after it was poured onto the mesh sifting screen. We could roughly estimate the two main components of the substrate by what remained on the screen before additional rinsing.

## 2.6 Statistical analysis

We compared the abundance of four target organisms between undisturbed and disturbed localities. The data collected in this study were largely non-normal in distribution. However, we ran a parallel analysis throughout the study using both parametric (robust against deviations from normality) and non-parametric statistics (appropriate form non-normal data). Target taxa were chosen for their relative abundance and include lugworms (primarily *Abarenicola pacifica*), ghost shrimp (*Neotrypaea californiensis*), Batic macoma bivalves (*Macoma balthica*) and bloodworm (*Glycera americana*). With the exception of lugworms, we performed all analysis on the "number of individuals per liter of mud" and on strictly the "number of individuals" from each shovel scoop. The counts of lugworms were not transformed because usually a single lugworm was targeted and dug out of the mud. Analysis was done pooled data (May, July and August where noted) and on data partitioned by month. Chi-square tests of independence were used to determine if the abundance of lugworms was dependent on location and independent sample T-tests (parametric) and Mann-Whitney U tests (non-parametric) were used to determine if differences in the mean number of individuals differed between study sites. Pearson correlation was used to test for a relationship between ghost shrimp burrows and numbers of ghost shrimp as well as the number of burrows and percent cover. We used ANOVA (parametric) and Kruskal Wallis Chi-square (non-parametric) to test for a difference in abundance among transects at each locality. Independent sample T-tests and Mann-Whitney U tests were used between less and more heavily trampled areas of the disturbed site. Chi-square tests were used to determine if there was a difference in abundance of species between localities, and if any differences were related to substrate type. Jackknife estimate of species richness ($\hat{S}$= S+(((n-1)/n)*K)), Evenness ($J' = H'/H_{max}$) and the Shannon-Wiener's Index ($H' = -\sum(p_i * \log(p_i))$) were used to estimate species diversity at each locality.

## 3.0 RESULTS

### 3.1 Differences in percent algae and eel grass cover between sites

There was no overall statistical difference between the percent algal (*Chaetomorpha sp.*) cover between sites (disturbed $\mu$=50.2 and undisturbed $\mu$=39.5; independent samples t-test: df=38, t=7.9, p=0.43; Mann-Whitney U test: Z=-0.34, p=0.76). There was a significant difference in the percent cover of eelgrass (*Zostera sp.*) between the two localities (disturbed $\mu$=0.0 and undisturbed $\mu$=17.0; independent samples t-test: df=38, t=-2.35, p<0.03; Mann-Whitney U test: Z=-3.33, p<0.002). The results for both algae and eelgrass cover were the same when the data were partitioned by month.

### 3.2 Differences in the abundance and average numbers of the target taxa

*3.21 Lugworms*

The number lugworms found inhabiting undisturbed and disturbed localities of the Tofino Mudflats Wildlife Management Area WMA) was compared in July and August 2007. When we pooled the data from July and August the number of lugworms was independent of locality ($\chi^2_5$= 4.6, p=0.47). The result was consistent in each month as the number of lugworms was also independent of locality (July: $\chi^2_4$=6.4, p=0.17; August: $\chi^2_4$=6.3, p=0.18). We also compared the average number of lugworms found inhabiting pristine and disturbed localities of the TMWMA. In July there was no difference (independent samples t-test: df=18, t=-0.17, p=0.87; Mann-Whitney U test: Z=-0.33, p=0.75) in the average number of lugworms found between the undisturbed (μ=1.1) and disturbed localities (μ=1.0). Similarly in August, there was no statistical difference (Independent samples t-test: df=18, t=0.93, p=0.37; Mann-Whitney U test: Z=-0.69, p=0.49) in the average number of lugworms found between the undisturbed (μ=0.7) and disturbed localities (μ=2.1).

We compared the number of lugworms found between transects within each site. In the pristine locality all three transects were sampled over July and August and the number of lugworms was independent of the transect that was sampled ($\chi^2_8$=12.0, p=0.15). The results for the undisturbed location were the same when the data was partitioned by month. In the disturbed locality all three transects were sampled were sampled over May, July and August, and the number of lugworms was independent of the transect that was sampled ($\chi^2_8$=5.42, p=0.71). Similarly, when we partitioned the data by month in the disturbed locality the number of lugworms was independent of the transect that was sampled.

We also compared the number of lugworms found between the more heavily trampled area (0-40m) and the less trampled area (50-100m) of the disturbed site. The number of lugworms in the disturbed locality is independent of trampling pressure ($\chi^2_4$=2.21, p=0.7). The results were the same when the data was partitioned by month (May, July and August). Similarly the mean number of lugworms was the same between the more ($\mu$=1.44) and less heavily ($\mu$=0.64) trampled regions of the disturbed locality (independent samples t-test: df=28, t=0.77, p=0.45; Mann-Whitney U test: Z=-0.69, p=0.76). The results were the same when the data was partitioned by month.

*3.22 Ghost shrimp*

We counted the number of ghost shrimp burrows and compared it to the total number of ghost shrimp collected in both July and August. Overall there was a positive correlation between the number of burrows and the number of ghost shrimp (Pearson correlation: n=120, r=0.59, $p<0.001$; Figure 2). When we partitioned the data between localities the positive correlation between the number of burrows and the number of ghost shrimp remained, but the relationship was only statistically significant in the disturbed locality (undisturbed: Pearson correlation: n=60, r=0.2, p=0.12; disturbed: Pearson correlation: n=60, r=0.57, $p<0.001$). When we partitioned each locality by month we did not find any significant correlations in the undisturbed locality, but we could predict the number of ghost shrimp by the number of burrows present in the disturbed locality in both July and August (disturbed July: Pearson correlation: n=30, r=0.5, $p<0.01$; disturbed August: Pearson correlation: n=30, r=0.75, $p<0.001$). The lack of correlation between the number of burrows and the number of Ghost shrimp present in the undisturbed locality may be due to a significant difference in the percent cover of eelgrass (*Zostera sp.*) between the two localities, which made counting burrows difficult.

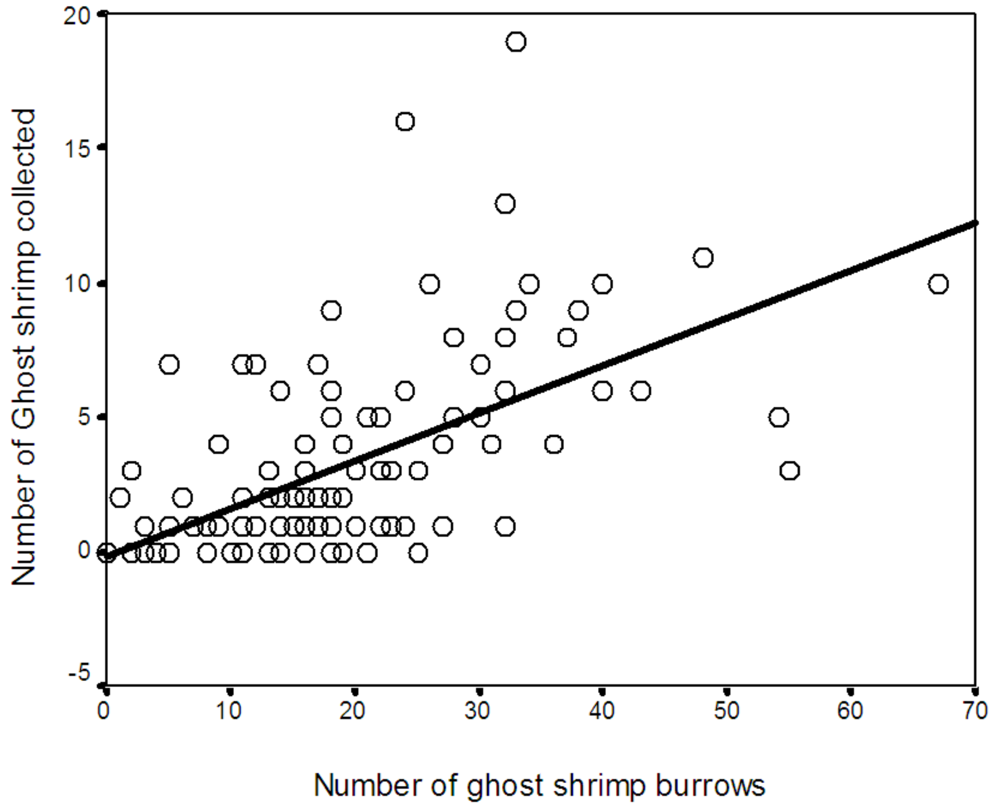


**Figure 2.** Scatter plot showing the overall relationship between the number of ghost shrimp and the number of ghost shrimp burrows.

The number of ghost shrimp collected per liter of mud was compared between the two study areas. In total (July and August) there were more ghost shrimp per liter of mud in the disturbed ($\mu=0.76$) than the undisturbed ($\mu=0.22$) locality (Independent samples t-test: df=118, t=6.2, $p<0.001$; Mann-Whitney U test: Z=-5.17, $p<0.001$; Figure 3). The result was the same when we used the just the number of ghost shrimp collected (disturbed: $\mu=4.8$; undisturbed: $\mu=1.2$; Independent samples t-test: df=118, t=6.03, $p<0.001$; Mann-Whitney U test: Z=-6.59, $p<0.001$). Similarly there were more ghost shrimp per liter of mud in the disturbed locality in both July and August (July disturbed: $\mu=0.99$; July undisturbed: $\mu=0.18$; July independent samples t-test: df=58, t=6.05, $p<0.001$; July Mann-Whitney U test: Z=-4.43, $p<0.001$; August disturbed: $\mu=0.53$; August undisturbed: $\mu=0.25$; August independent samples t-test: df=58, t=2.9, $p<0.01$; August Mann-Whitney U test: Z=-2.66, $p<0.01$). The results were the same when we used just the number of ghost shrimp collected.

We compared the number of ghost shrimp collected per liter of mud between transects at each site. There was a difference among transects in the number of ghost shrimp per liter of mud at the pristine locality (ANOVA: $F_{2,57}=3.9$, $p<0.04$) with the greatest differences occurring between transects 1 and 3 (mean difference=0.19) and transects 1 and 2 (mean difference=0.16). However, the number of ghost shrimp per liter were only normally distributed in transect 2 and when we ran nonparametric statistics there was no difference in the number of ghost shrimp per liter of mud between transects (Kruskal Wallis $\chi^2_2=2.61$, $p=0.27$). The results for both the ANOVA and Kruskal Wallis tests were the same when we used the number of ghost shrimp alone. We did not find a

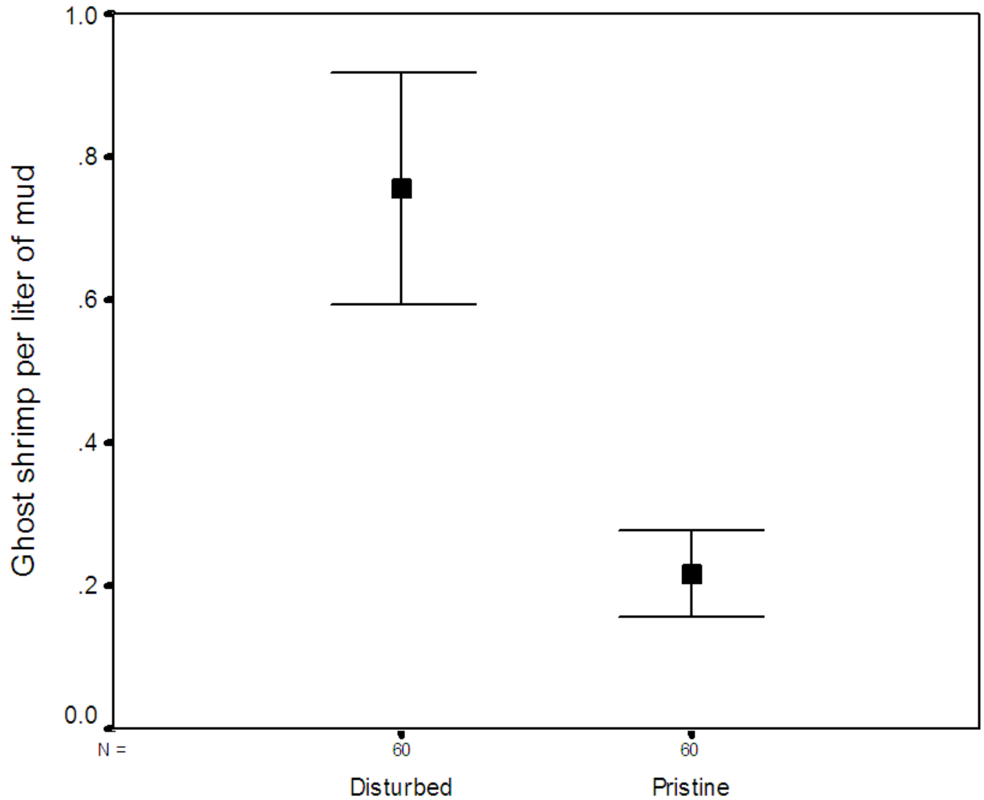


**Figure 3.** Mean and 95% confidence limits of the number of ghost shrimp per liter of mud between the disturbed and undisturbed localities.

difference in the number of ghost shrimp per liter of mud at the disturbed locality (ANOVA: $F_{2,58}$=2.01, p=0.14; Kruskal Wallis $\chi^2_1$=1.98, p=0.16). However, when we examined just the number of ghost shrimp collected in May, July and August there was a significant association (ANOVA: $F_{2,87}$=4.2, p<0.03; Kruskal Wallis $\chi^2_2$= 6.3, p<0.05) with the greatest difference occurring between transects 1 and 2 (mean difference=2.7). In both the undisturbed and disturbed sites there were more Ghost shrimp found close to shore (transect 1).

The number of ghost shrimp per liter and just the number of ghost shrimp between the more heavily trampled area (0-40m) and the less trampled area (50-100m) of the disturbed site were also examined. There were significantly more ghost shrimp per liter of mud in the more heavily trampled area (μ=0.9) than in the less trampled area (μ=0.54) of the disturbed site (independent samples t-test: df=59, t=2.28, p<0.03; Mann-Whitney U test: Z=-3.12, p<003). When the data was partitioned by month the results were consistent (more ghost shrimp per liter of mud in the heavily trampled area) but only reached statistical significance in August (Independent samples t-test: df=28, t=5.63, p<0.001; Mann-Whitney U test: Z=-4.26, p<0.001).

*3.23 Baltic Macoma Clams*

The number of Baltic macoma clams per liter of mud collected in July and August were compared between the undisturbed and disturbed sites. There were more Baltic macoma per liter of mud in the disturbed (μ=5.55) than the undisturbed (μ=1.96) locality (independent samples t-test: df=118, t=7.6, p<0.001; Mann-Whitney U test: Z=-7.76,

$p<0.001$; Figure 4). The result was the same when we used the just the number of Baltic macoma collected (Disturbed: $\mu=32.7$; undisturbed: $\mu=12.4$; independent samples t-test: $df=118$, $t=8.84$, $p<0.001$; Mann-Whitney U test: $Z=-4.54$, $p<0.001$). In both July and August there were more Baltic macoma per liter of mud in the disturbed locality (July disturbed: $\mu=4.3$; July undisturbed: $\mu=1.6$; July independent samples t-test: $df=58$, $t=5.48$, $p<0.001$; July Mann-Whitney U test: $Z=-5.35$, $p<0.001$; August disturbed: $\mu=6.8$; August undisturbed: $\mu=2.3$; August independent samples t-test: $df=58$, $t=5.99$, $p<0.001$; August Mann-Whitney U test: $Z=-6.03$, $p<0.001$). The results were the same when we used just the number of Baltic macoma collected.

We compared the number of Baltic macoma clams per liter of mud between transects at each site. There was a difference among transects in the number of Baltic macoma per liter of mud at the disturbed locality (ANOVA: $F_{1,58}=13.4$, $p<0.002$; Kruskal Wallis $\chi^2_1=10.3$, $p<0.002$). The result was the same using just the number of Baltic macoma collected (ANOVA: $F_{2,87}=12.94$, $p<0.001$; Kruskal Wallis $\chi^2_2=27.4$, $p<0.001$) with the greatest differences occurring between transects 1 and 3 (mean difference=24.3). There was no statistical difference among transects at the undisturbed locality.

The number of Baltic macoma per liter of mud between the more heavily trampled area (0-40m) and the less trampled area (50-100m) of the disturbed site was also examined. Although not statistically significant there were more Baltic macoma per liter of mud in the more heavily trampled area ($\mu=6.25$) than in the less trampled area

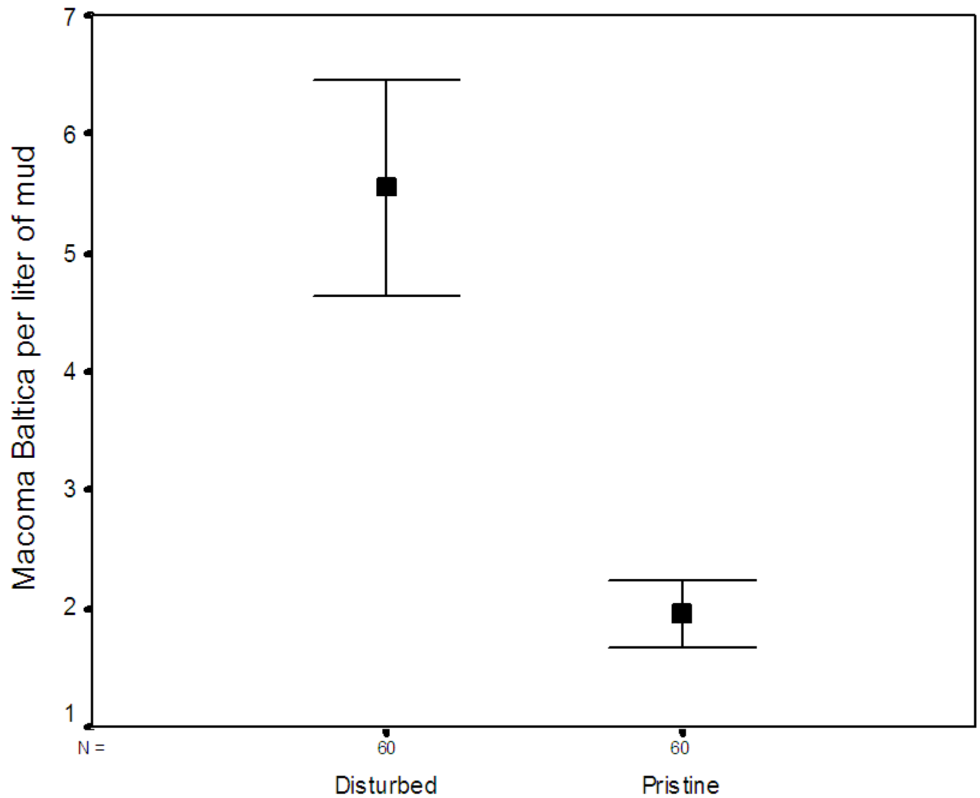


**Figure 4.** Mean and 95% confidence limits of the number of Baltic macoma clams per liter of mud between the disturbed and undisturbed localities.

($\mu$=4.69) of the disturbed site (independent samples t-test: df=58, t=1.74, p=0.09; Mann-Whitney U test: Z=-0.83, p=0.41).

*3.24 Bloodworm*

The number of bloodworms per liter of mud collected in July and August were compared between the undisturbed and disturbed sites. There was no difference in the number of bloodworms per liter of mud between the disturbed ($\mu$=0.27) than the undisturbed ($\mu$=0.22) locality (independent samples t-test: df=118, t=1.24, p=0.22; Mann-Whitney U test: Z=-0.87, p= 0.39). Although not statistically significant, in each month there were slightly more bloodworms per liter of mud in the disturbed compared to the undisturbed site (July disturbed: $\mu$=0.22; July undisturbed: $\mu$=0.16; August disturbed: $\mu$=0.31; August undisturbed: $\mu$=0.27). The results were the same when only the numbers of bloodworms were used in the analysis.

The number of bloodworms per liter of mud was compared between transects at each site. There was a difference among transects in the undisturbed locality (ANOVA: $F_{2,57}$=4.61, p<0.02; Kruskal Wallis $\chi^2_2$=7.96, p<0.02) with the greatest difference occurring between transects 1 and 2 (mean difference=0.18). The results were the same when just the number of bloodworms was used. There was no difference among transects at the disturbed location.

We also compared the number of bloodworms per liter of mud between the more heavily trampled area (0-40m) and the less trampled area (50-100m) of the disturbed site.

There were significantly more bloodworms per liter in the less trampled ($\mu$=0.4) than the heavily trampled section ($\mu$=0.97) of the disturbed site (Independent samples t-test: df=58, t=-4.21, $p<0.001$; Mann-Whitney U test: Z=-3.8, $p<0.001$). The results were consistent when the data was partitioned by month indicating that there were more bloodworms in the less trampled area of the disturbed site (July independent samples t-test: df=28, t=-2.48, $p<0.03$; July Mann-Whitney U test: Z=-2.16, $p<0.04$; August Independent samples t-test: df=28, t=-3.88, $p<0.002$; August Mann-Whitney U test: Z=-3.25, $p<0.002$).

**3.3 Species proportions in relation to locality**

We tested whether species proportions were dependent on locality and whether any differences could be related to substrate type at each locality. Given that the above results were the same when the unadjusted data was used (i.e., data not standardized for the volume of mud) we used the unadjusted data for the analysis. Combining data from both July and August we determined that the proportion of the different species is dependent on location ($\chi^2_{14}$=124.0, $p<0.001$). Similarly, in July and August the proportion of the different species is dependent on location (July: $\chi^2_{12}$=78.1, $p<0.001$; August: $\chi^2_{10}$=64.9, $p<0.001$).

**3.4 Species proportions in relation to substrate type within locality**

There were four rough approximations of substrate type in this study (see methods). Substrate type was independent of locality ($\chi^2_3$=4.54, p=0.21) indicating that both the **undisturbed** and disturbed sites have compositions of mud with similar proportions. However, detailed analysis between the more heavily trampled area (0-40m) and the less trampled area (50-100m) within the disturbed locality indicates that the substrate types were different ($\chi^2_3$=67.9, p<0.001), with the heavily trampled area having mostly mud/gravel and the less trampled area mud/silt. In the **undisturbed** locality the abundance of organisms was independent of substrate ($\chi^2_{30}$=37.1, p=0.17). However in the disturbed locality species proportions were dependent on substrate type ($\chi^2_{33}$=121.5, p<0.001).

### 3.5 Estimates of invertebrate diversity at each locality for July and August 2007

We used three relatively simple methods to obtain an estimate of species diversity within each site. There were a total of sixteen macroinvertebrates and one vertebrate species identified in this study (Table 1). The Jackknife estimate was used to determine if there were differences in invertebrate richness between the localities for each comparative sample. We determined that in July the disturbed locality had a slightly higher estimate of invertebrate richness (July Jackknife estimate: $\hat{S}$=13.9) than the pristine locality (July Jackknife estimate: $\hat{S}$=12.8). However, the disturbed location had a less even distribution of species (July evenness: J′=0.28) compared to the undisturbed area (July evenness: J′=0.35) and therefore slightly lower diversity (July Shannon index disturbed: H′=0.35; July Shannon index undisturbed: H′=0.44). In August both sites had similar species richness (August Jackknife estimate disturbed: $\hat{S}$=9.0; August Jackknife estimate pristine: $\hat{S}$=9.0) but the disturbed site had a less even distribution of species (August evenness: J′=0.21) compared to the undisturbed site (August evenness: J′=0.36),

**Table 1.** Organisms enumerated in the study period. The disturbed locality was sampled in May, July and August 2007 and the pristine site was sampled in July and August 2007. One juvenile fish (bay goby, *Lepidogobius lepidus*) was captured and then promptly and safely released.

| Common name | Genus species | Total disturbed | Total pristine |
|---|---|---|---|
| Neapolitan lugworm | *Abarenicola pacifica* | 23 | 14 |
| Ghost shrimp | *Neotrypaea californiensis* | 516 | 82 |
| Baltic macoma | *Macoma balthica* | 2307 | 745 |
| Bloodworm | *Glycera americana* | 139 | 84 |
| Bent nose macoma | *Macoma nasuta* | 12 | 23 |
| Manila clam | *Venerupis philippinarum* | 7 | 10 |
| Horse clam | *Tresus capax* | 8 | 0 |
| Ribbon worm | *Tubulanus* sp. | 4 | 3 |
| Sea nymph | *Nereis* sp. | 1 | 0 |
| Hairy crab | *Hemigrapsus oregonensis* | 8 | 3 |
| Amphipod | *Traskorchestia sp.* | 12 | 23 |
| Bay goby | *Lepidogobius lepidus* | 0 | 1 |
| Peanut worm | *Phascolosoma sp.* | 1 | 0 |
| Unknown polychaete | n/a | 1 | 0 |
| Unknown flatworm | n/a | 1 | 0 |
| Unknown roundworm1 | n/a | 0 | 1 |
| Unknown roundworm2 | n/a | 0 | 2 |

giving the undisturbed locality moderately higher diversity (August Shannon index disturbed: H′=0.27; August Shannon index pristine: H′=0.46).

**4.0 DISCUSSION**

One of the objectives of this pilot study was to uncover relatively simple methods to monitor a few target species of invertebrates that inhabit the Tofino Mudflats Wildlife Management Area and compare their densities between areas that are trampled by people (“disturbed”) and areas that are not (“undisturbed”). Lugworms (Class Polychaeta) were chosen as possible indicator species because their presence in the mud can affect community structure (Volkenborn and Reise, 2006) and they are easily located by their coiled fecal casting on the mud surface immediately adjacent to the individual’s “J-shaped” burrow (Kozloff, 1993). The bivalve Baltic macoma (*Macoma balthica*) and a polychaete bloodworm (*Glycera americana*) were chosen due to their relative abundance in mud habitats (Kozloff, 1993). Beasley (2007) suggested the crustacean ghost shrimp (*Neotrypaea californiensis*) as a species whose abundance is relatively easy to monitor. Ghost shrimp are prolific in mudflats throughout the Pacific Northwest (Kozloff, 1993) and their abundance can often be determined by counting the number of burrow holes in a given area (Carty, 2001; Dunham and Duffus, 2001).

Overall, we found a significant positive correlation between the number of burrows and the abundance of ghost shrimp. Our result falls within the range reported by Carty (2001) in which ghost shrimp density explained between 32-80% of the variability in the number of burrow holes. However, when we partitioned the data between localities only the correlation in the disturbed site remained significant. We also found significant statistical differences in the abundance of ghost shrimp and Baltic macoma clams between disturbed and undisturbed habitats, with each organism having greater abundance in the disturbed site and higher abundance closer to shore. Although the differences were not statistically significant we did find a slightly higher average number of bloodworms and lugworms in the disturbed locality.

These results can be partially explained by differences in the amount of eelgrass present in each of the two sites. The pristine site had eelgrass (*Zostera sp.*; ~17% cover per 1m quadrat) while the disturbed site did not. Ghost shrimp are often most abundant at lower intertidal levels and exhibit a reduction in density in areas of eelgrass (Swinbanks and Luternauer, 1987), and possibly as a result of the binding effect the eelgrass roots have on the substrate (i.e., it is difficult for the animal to dig a burrow) (Beasley, 2007). It is plausible that this explanation may also account for the greater abundance of the other target organisms in the disturbed site as well. Future detailed habitat mapping and continued invertebrate sampling of the mudflats would help clarify results.

We also found differences in the abundance of the target organisms within the disturbed site. The abundance of ghost shrimp and Baltic macoma clams was significantly greater in the more heavily trampled area of the disturbed site. There were slightly more lugworms in the heavily trampled region as well. Trampling algal mats into the substrate has been shown to increase the densities of herbivorous mollusks (Keough and Quinn, 1998) and it is possible that the increased trampling in the more disturbed area has had a similar effect on organisms in our study by providing more food for secondary consumers and in turn, organisms with a higher trophic status. Alternatively, increased human presence can significantly reduce the amount of time shorebirds and other water fowl spend feeding (Burger, 1981; Yalden and Yalden, 1989; Pfister *et al.*, 1992; Burger, 1994) which could lead to marked population increase in these potential prey items. Conversely, the abundance of bloodworms was significantly greater in the less trampled area of the disturbed site. Ghost shrimp, bivalves and lugworms burrow into the substrate where as bloodworms are active highly mobile predators (Kozloff, 1993). These contrasting results can often be the result of natural biological variation where each patch of sediment supports an assemblage of species that differ in minor and or major respects from other local areas (Dyer *et al.*, 2000). We found a significant difference in substrate type between the less and more heavily trampled areas of our disturbed site where there was a higher proportion of gravel in the more heavily trampled area and a higher proportion of silt in the less trampled area of the disturbed site. It is possible that higher gravel content limits the motility of the soft-bodied bloodworm (Dyer *et al.*, 2000) yet provides substrate stability for the burrowing organisms. It is unknown whether the high gravel content of the mud in the more heavily trampled area is present due to natural geological processes or as a consequence of human activities.

Through the course of the pilot study it became apparent that there could be a few additional parameters that should be collected in the future to assist in the explanation of the distribution of the target organisms. Data for tidal range and the gradient (slope) for each transect at the pristine and disturbed localities would be relatively easy to collect with the appropriate tools. The mean density of the mud and detailed sediment analysis would be a little more challenging to obtain but are essential for disentangling the ecology of the area. It is important to obtain seasonal comparison as a mudflat can have different community structure in summer and winter (Dyer *et al.*, 2000). Gathering knowledge of species emigration or mortality would also be useful. We did not attempt to distinguish or quantify emigration or mortality during the course of our study. It is possible that individuals displaced by our sampling methods may have entered the water column when the tide came up and dispersed out into the experimental area (Brown and Wilson, 1997). As the mudflat is covered with water half of the time, it would be also useful to know the consequences of food resources for fishes and other marine organisms (Brown and Wilson, 1997). We often finished sampling right as the tide came up and could see numerous fishes swimming and foraging with the rising tide.

Our results for the tests of invertebrate diversity were conclusive. We found that the number of different species (species richness) was similar between our two study sites, but the relative proportion of each species were more similar (evenness) in the undisturbed site compared to the disturbed locality. The combination of species richness and evenness indicate that the pristine site has a higher level of diversity than the disturbed locality. We also found that the substrate composition was independent of locality suggesting that the differences in diversity are not a function of habitat differences between our two localities, but rather due to human associated impacts with trampling the mud. It is important to continue studying the consequences of human impacts on all levels of organisms (Drewitt, 2007). The loss of biodiversity is a consequence of degraded or disturbed habitats, which is often a result of expansion of human populations and other human related activities (see Wilson, 1988 for review). This loss of species is happening on a global scale and extrapolation of current trends in the reduction of diversity implies organism loss in the next 100 years comparable to that of a nuclear winter (Ehrlich, 1988). Biodiversity must be treated as a global resource to be indexed, used and preserved (Wilson, 1988). Although our project is comparably small on a global scale, our results reflect the consequences of human population expansion. As Tofino's population continues to grow and expand further into natural critically important areas such as the mudflats (Butler *et al.*, 1992), more research is needed to clearly outline what can be included as sustainable recreational activities for the Tofino Mudflats Wild Life Management Area.

**ACKNOWLEDGEMENTS**

We would like to thank the Clayoquot Biosphere Trust Marine and Aquatic Committee for funding, Tofino Botanical Gardens for sampling equipment, mudflat access, and administration services. M. A. S. would like to thank to Barb Beasley and Josie Osborne for technical assistance, George Patterson for setting the project in motion, and Alana Jung for field assistance.

## REFERENCES


Beasley, B. 2007. Proposal to monitor tourism and recreational use and the power of educational programs to protect wildlife in the Tofino Mudflats Wildlife Management Area.

Brown, B. and Wilson, J., H.W. 1997. The role of commercial digging of mudflats as an agent for change of infaunal intertidal populations. *Journal of Experimental Marine Biology and Ecology* **218**: 49-61.

Burger, J. 1981. The effect of human activity on birds at a coastal bay. *Biological Conservation* **21**(3): 231-241.

Burger, J. 1994. The effects of human disturbance on foraging behaviour and habitat use in Piping Plover (*Charadrius melodus*). *Estuaries* **17**(3): 695-701.

Butler, R. W., Dorst, A. and Hobson, M. A. 1992. Seasonal abundance and biomass of birds in eelgrass habitats in Browning Passage on the west coast of Vancouver Island. Ottawa, Occasional paper. Canadian Wildlife Service.

Carty, S. 2001. *Zostera marina* and *Neotrypaea californiensis* as indicators of ecosystem integrity in Grice Bay, British Columbia. M.Sc. Thesis. University of British Columbia.

Drewitt, A. L. 2007. Birds and recreational disturbance. *Ibis* **149 (Suppl.)**: 1-2.

Dunham, J. S. and Duffus, D. A. 2001. Foraging patterns of gray whales in central Clayoquot Sound, British Columbia, Canada. *Marine Ecology Progress Series* **223**: 299-310.

Dyer, K. R., Christie, M. C. and Wright, E. W. 2000. The classification of intertidal mudflats. *Continental Shelf Research* **20**: 1039-1060.

Eggen, M., Diggon, S. and Mason, A. 2002. Tofino mudflats wildlife management area management plan, Ministry of Water, Land and Air Protection.

Ehrlich, P. R. 1988. The loss of diversity causes and consequences. In: E. O. Wilson. *Biodiversity*. Washington DC: National Academy Press**:** 21-28.

Keough, M. J. and Quinn, G. P. 1998. Effects of periodic disturbances from trampling on rocky intertidal algal beds. *Ecological Applications* **8**(1): 141-161.

Kozloff, E. 1993. Seashore life of the Northern Pacific coast. Seattle.

Lindegarth, M. and Hoskins, M. 2001. Patterns of distribution of macro-fauna in different types of estuarine, soft sediment habitats adjacent to urban and non-urban areas. *Estuarine, Coastal and Shelf Science* **52**: 237-247.

Pfister, C., Harrington, B. A. and Lavine, M. 1992. The impact of disturbance on shorebirds at a migration staging area. *Biological Conservation* **60**(2): 115-126.

Swinbanks, D. D. and Luternauer, J. L. 1987. Burrow distribution of Thalassinidean shrimp on a Fraser delta tidal flat, British Columbia. *Journal of Paleontology* **16**(2): 315-332.

Volkenborn, N. and Reise, K. 2006. Effects of *Arenicola marina* on polychaete functional diversity revealed by large-scale experimental lugworm exclusion. *Journal of Sea Research* **57**(1): 78-88.

Wilson, E. O. 1988. Biodiversity. Washington DC, National Academy Press.

Wynberg, R. P. and Branch, G. M. 1997. Trampling associated with bait-collection for sandprawns *Callianassa kraussi* Stebbing: effect on the biota of an intertidal sandflat. *Environmental Conservation* **24**(2): 139-148.

Yalden, D. W. and Yalden, P. E. 1989. The sensitivity of breeding Golden Plovers *Pluvialis apricaria* to human intruders. *Bird Studies* **36**(1): 49-55.