MOLLUSCAN BIO-INDICATORS OF THE TIDAL SHELL CREEK, FLORIDA

FINAL REPORT

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"Shell Creek/Lower Peace River Estuary Mollusk and Macroinvertebrate Survey"

Task 1

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MOLLUSCAN BIO-INDICATORS OF THE TIDAL SHELL CREEK, FLORIDA.

INTRODUCTION

The objectives of the mollusk project are to:

- Describe the present distribution of major macro-mollusk species and communities in the lower, tidal reach of Shell Creek, a tributary of the Peace River,
- Identify taxa of potential importance to the ecological structure and functioning of the tidal Creek
- Compare and contrast mollusk data collected by similar methods from other tidal rivers of southwest Florida.

Mollusks are a dominant element of estuarine and tidal river ecosystems. Their number, diversity, dispersion, and condition have been studied for decades, forming a large and robust body of information on the adaptations of numerous taxa to the physical and chemical conditions unique to estuaries. Numerous studies have demonstrated that spatial and temporal trends in mollusk attributes vary in consistent form with variations of river flow, current speed, salinity, dissolved oxygen, and foodstuffs such as particulate organic carbon, phytoplankton, macrophytes, and prey.

In recent years, a variety of studies have been published which indicate the extent to which molluscan attributes can be related specifically to independent variables of interest in the present study-- freshwater inflow, salinity, and dissolved oxygen. Depending on the estuary, faunal groups, attributes, and collateral factors such as depth, sediment type, or tide range, relationships have been defined which satisfy criteria for statistical significance (Mote Marine Laboratory 2001; 2003).

SHELL CREEK AND WATERSHED

The Charlotte Harbor National Estuary Program's 1999 "*Synthesis of Existing Information*" provides data on Shell Creek's watershed attributes as follow. The watershed of Shell Creek encompasses 366 square miles, with most (83%) of its area in a single soil type having low to moderate grain size and runoff potential. In 1990, 72% of the basin was agricultural. By 2010, agricultural uses are expected to increase to 88%. Mean annual precipitation ranges from 40 to 70 inches, with most falling from June to September, inclusive. Total annual flow ranges from 2000 to 7000 cubic feet per second (cfs). In an average year flows increase steadily from a low in May to a peak (ca. 700 cfs) in September, although flows to tide are sometimes prevented by an instream barrier created for Punta Gorda's water supply, presently a diversion of 4.2 million gallons per day (mgd). The Hendrickson Dam at RK 10.0, just upstream of Myrtle Slough's confluence with Shell Creek, divides the Creek into tidal and non-tidal reaches. Conductivity is higher downstream of the dam (to 15 mmho) than upstream of it (typically < 1 mmho). Average nutrient concentrations are comparable though tidal nutrients are more variable. Mean and extreme chlorophyll concentrations are higher in the tidal reach than in the non-tidal reach. Over time, there have been significant declining trends in ortho-phosphate above and below the dam, and in total phosphorus below the dam. No other significant trends are known. The majority of total nitrogen, phosphorus, and suspended solid loads to the creek are caused by agriculture, although there are 4 domestic and 6 industrial discharges permitted by the State of Florida.

The tidal reach of Shell Creek runs west ten kilometers to the Peace River. For two kilometers below the dam there are twin channels and Myrtle Slough enters the southern channel. From RK 8 to 6 there is basically one channel, though during high stage or high tide, water follows a minor distributary hard on the northern shore. At RK 5 there are four channels of unequal width and depth; these merge into two channels at RK 3, below which Shell Creek widens and enters the Peace River at two junctures. Channels upstream of RK 7 are narrow and deep, in places to 7 m. Downstream of RK 3 the channels are wide and shallow, with much bottom at intertidal elevation. Throughout the Creek, intertidal environment is dominated by grassy marshes (predominantly *Juncus roemerianus* with increasing amounts of brackish and tidal-fresh species closer to the dam) fringed by mangroves and leather ferns. In the 3 km closest to the Peace River, unvegetated shoals and point bars are common, extensive, and bare at chart datum.

METHODS

Mollusk populations and communities do not respond instantaneously to conditions of river flow, salinity, or other physicochemical variables. Spatial patterns in mollusk distribution develop as a result of differential reproductive periods, larval development rates, recruitment variables, life history characteristics, and mortality patterns and rates. As a result, a spatial pattern observed at a given time is the result of antecedent conditions, generally on the order of weeks to months.

One set of samples was collected during the last week of April, 2004. Flows at USGS 02298202 "Shell Creek Near Punta Gorda FL" were below long-term average flows during the week of sampling, but had been higher earlier in May. Antecedent conditions were very wet with 14 of 19 prior months having larger discharges than median daily stream flow based on 32 years of record.

A river kilometer system developed for the District's minimum flow studies was adapted for Shell Creek (**Figure 1**). Samples were collected at half-kilometer intervals from the confluence of Shell Creek with the Peace River, to the spillway at Punta Gorda's reservoir. Owing to the sinuous nature of the stream, no sample was taken at RK 5.5. For safety reasons, no sample was taken immediately below the spillway. Data are provided for all stations in **Appendix Table 1.**

Transects normal to the creek's center-line and intersecting it at half-kilometer intervals were reconnoitered to decide the distribution of sampling effort across each transect. Because the primary objective of the study was to identify down-river patterns in species dispersion, samples were collected across each transect at representative sites, and data were pooled for the entire transect.

In single-channel reaches of the river, subtidal samples were collected close by opposite banks and at evenly spaced intervals across the channel. In reaches with islands and multiple channels, subtidal effort was distributed so as to sample in each channel or basin.

Collection of intertidal samples was biased by two criteria. First, accreting banks were preferred over eroding ones, meaning in practice that the insides of bends were preferred over outsides, and that samples were collected more from point-bars, mangrove islands, and shoals than from steeply inclined banks. Second, a preference was used for the bank judged to be least altered by human activity. Sea walls and filled areas were avoided where possible.

Subtidal samples (< MLW) were collected by a petite ponar grab rather than pipe cores because larger bivalve such as *Rangia* were often missed or lost by the cores. Ponar grabs offered a larger sampling surface area (0.0232 square meters) than pipe cores (0.00456 square meters). A sample was comprised of two ponar grabs (surface area = 0.0464 square meters) at a given location. Five such subtidal samples were taken along each half-kilometer transect, giving a per-transect sampling surface area of 0.2320 square meters. Contents of each sample were concentrated over a 3.0 millimeter sieve, processed in the field (light samples), or bagged and returned to the Laboratory (heavy samples).

Intertidal samples (> MLW) were usually collected by spade although ponar grabs were sometimes used during high tides. Intertidal effort was the same as subtidal effort except that hand collections of particular species were sometimes added to intertidal samples so as to record the presence of rare or cryptic species. The gastropods *Neritina* and *Littorina*, for example, often were found in low numbers, near the tops of black needlerush shoots. Oysters and mussels likewise grow cryptically behind mangrove roots or within crevices of fallen wood.

Specimens were sorted as live or dead and identified in the field or Laboratory. For each species in each sample, median size was determined by arranging specimens from smallest to largest and measuring the median specimen to the nearest millimeter. Gastropods were measured from the apex to opposite end; bivalves were measured from front end to hind end. For data analysis, a mean value of median sizes was computed for each species. Condition was scored for each whole live animal or single dead valve as percent covered by mechanical erosion, shell dissolution, or other loss or damage.

RESULTS

A total of 19 sites were visited. Contamination was rare except for the introduced and naturalized bivalve *Corbicula*. Only a few fossil shells were found at sites near steep and recently filled riverbanks and these were not counted.

SPECIES RICHNESS

Eleven taxa were encountered and all were identified to species (**Table 1**). Four species constituted 99% of specimen counts, with the remaining species present only in low numbers or as one individual.

SPECIES ACCOUNTS

Accounts are given below of the numerically dominant species and some of interest. Data are provided for all species in **Appendix Table 2.** Accounts emphasize down-river presence and absence in terms of live and dead specimens found both intertidally and subtidally, but other information is summarized on mean sizes, evidence of recruitment, and condition (as weathering indices). As used here, mean size represents the arithmetic average of a set of median sizes measured for each species. Accounts are listed in descending order of the species= numerical abundance. Scales used to graph density and size data vary between species.

Table 1. Summary list of Shell Creek mollusk species collected on 0.5 km transects.

Species	Cumulative Percent
Polymesoda caroliniana	55.8
Rangia cuneata	86.4
Tagelus plebeius	97.0
Corbicula fluminea	98.2
Neritina usnea	99.1
Ischadium recurvum	99.5
Littorina (Littoraria) irrorata	99.6
Crassostrea virginica	99.7
Geukensia demissa granossissima	99.8
Mulinia lateralis	99.9
Mytilopsis leucophaeata	100.0

N = 11 taxa

POLYMESODA CAROLINIANA

The marsh clam *Polymesoda* belongs to the same bivalve family as *Corbicula*, but differs from it by being larger, more intertidal, and a native species. *Polymesoda* was the most abundant species of mollusk in Shell Creek (**Figure 2**) and was often more abundant subtidally than intertidally, owing to the recent settlement and maturation of a new cohort. In subtidal areas the cohort was 15-20 mm in size. Intertidally it was conspicuous along margins of intertidal wetlands, especially brackish marshes. *Polymesoda* occurred throughout Shell Creek but not continuously so. It occurred in very high abundance at some transects and in general was more dense close to the Peace River. Conversely, *Polymesoda* size increased with distance away from the Peace River, and the largest *Polymesoda* shells were dead ones upstream of RK 8.0.

RANGIA CUNEATA

Rangia cuneata is a large, robust bivalve common in tidal rivers and backwater bays with regular inputs of fresh water. In coastal areas with larger tidal range it tends to be regarded as primarily a subtidal species, especially in comparison to the marsh clam *Polymesoda caroliniana*, but in the tidal

Peace River it is also common intertidally. Like *Polymesoda*, *Rangia* is a characteristic member of the Peace River's transitional fauna. Although not as abundant as *Polymesoda*, *Rangia* was present at more transects in Shell Creek than any other species, including *Polymesoda*. In a majority of cases both live and dead *Rangia* occurred together. It tended to be more abundant in the 4-6 RK subtidal, and more abundant in the 6-9 RK intertidal. Like *Polymesoda*, *Rangia* sizes increased with distance from the Peace River (**Figure 3**).

TAGELUS PLEBEIUS

Tagelus, a member of the family of short razor clams, was common and often abundant throughout the tidal reach of Shell Creek. It was found alive and dead in subtidal areas between RK 0.0 - 3.0 but the intertidal upstream limit of the species was extended as far as RK 4.0 (live) to RK 6.5 (dead). *Tagelus* density decreased with river kilometer (**Figure 4**), meaning that it was most abundant close to the Creek's confluence with the Peace River. Downstream material was slightly larger than upstream material. This species has particular habitat requirements and its dispersion may be highly gregarious or clumped (Holland and Dean, 1977). *Tagelus* is a fragile species and even live material can be weathered substantially.

CORBICULA FLUMINEA

Corbicula fluminea is an introduced, naturalized freshwater bivalve with a tolerance for low salinities. *Corbicula* was the only non-native species of mollusk collected in Shell Creek, and was never abundant. *Corbicula* was more abundant subtidally than intertidally and in both strata was limited to the upper (RK> 5.0) portion of Shell Creek (**Figure 5**). Live *Corbicula* were found only at RK 7.0 and 7.5. Judging from the scarcity and condition of relict shells, *Corbicula* has not been a problem species in Shell Creek's tidal reach.

INTERTIDAL GASTROPODS

Neritina usnea is a shallow-water gastropod with intertidal to supratidal affinities, and is often found grazing on benthic algae mats, submerged aquatic vegetation, and emergent marsh species such as black needlerush, *Juncus roemerianus*. The species is nearly ubiquitous in the tidal reach of Shell Creek, at least as live material, but was nowhere abundant (**Figure 6**). Resident observers report that the nerite was extremely common prior to the last drought, but has been scarce since then. Live nerites were seen only at RK 0.0 and 6.5, and were larger at the downstream site.

Littorina irrorata is the marsh periwinkle found on mangroves and emergent marshes near or above the water line. It occurred only once in Shell Creek, at RK 3.5, where it was found alive (**Figure 7**). In the Peace River, the ranges of *Littorina* and *Neritina* do not overlap, and *Littorina* occurs downstream of *Neritina*. In Shell Creek, *Littorina* occurred only once, in the middle of *Neritina's* range.

COMMUNITY PATTERN

The tidal mollusk community of Shell Creek, sampled as it was in this study, can be studied as a whole for patterns in number and kind as functions of strata and river position. **Figure 7** depicts patterns of live and dead species' overlap as functions of river kilometer. The upper panel depicts species sorted in an upstream direction; the lower panel, in downstream direction. Absence of data at RK 5.5 is an artifact of graphing. Two species, *Polymesoda* and *Rangia*, were present as live and dead material at almost every transect, and *Tagelus* was present as live or dead material at every station below RK 5.0. In an upstream sort, few new species are added with distance. In the downstream sort, species are added rapidly at first and then steadily to the creek mouth. Half of the species were patchily represented, and some were present as live-only or dead-only material.

On the basis of **Figure 7** it may be said that the tidal reach of Shell Creek is characterized by a molluscan community dominated by *Polymesoda* and secondarily by *Rangia*, with a strong representation by *Tagelus* in the Creek's lower half. The fact that *Neritina* is the predominant intertidal and supratidal gastropod, and that *Littorina* is rare, adds to the evidence that Shell Creek's fauna is definitely oligohaline and tidally-freshwater in nature.

Figures 8 and 9 depict species richness as number of taxa in relation to river kilometer. Dead taxa occur throughout the study area, but live taxa show a strong gradient from highest (5 taxa) at RK 0.0 to the absence of live taxa at RK 9.0. The same depression in species richness near the dam is evident for intertidal and subtidal sets of taxa (**Figure 9**); otherwise no trends are evident. In terms of species richness, the tidal reach may be considered to be organized into two sub-reaches divided by RK 4.5 to 5.0 (**Figures 10 and 11**). Above that divide the fauna is depauperate and strictly oligohaline; below the divide a few estuarine taxa are added to the fauna.

Densities of live and dead shells are substantial, especially in the downstream half of the study area. Dead material outnumbers live material in most transects and there is a slight tendency for shell densities to increase with distance downstream of the dam (**Figures 12 and 13**). Very high densities, primarily of *Polymesoda*, were encountered in shallow subtidal water at RK 2.0. *Polymesoda* and especially *Tagelus* were extremely abundant on intertidal shoals at RK 2.0, both as live and dead specimens. Similar densities of live clams have only been seen for *Corbicula* in the Peace River below Horse Creek.

Shell Creek data from 2004 were compared to the corresponding reach of the Peace River, specifically the 10.0 RK of the River upstream of the mouth of Shell Creek (**Figures 14-17**). Peace River data were collected in 1999, a serious limitation to the comparison, but in general the comparison reveals that the core fauna of both waterways were similar in terms of dominant species, species richness, and densities. The 1999 river fauna contained more species, principally among live samples, than the creek, and the relative importance of subtidal versus intertidal strata were the same for both streams. However, Shell Creek's density of live material was greater than that of the Peace.

DISCUSSION

Species-overlap curves allow two questions to be answered. First, how should the river fauna be sampled in order to maximize the probability of accurately defining a species' range? Second, how does the living component of a species lay relative to its "footprint" of dead remains accumulated over the period of years to decades?

In the first case, it is evident in all diagrams that the live-only fraction or single-stratum fraction does not represent all of a species' spatial domain. No species occurred continuously throughout its range along the creek, as living material, although *Polymesoda* came close. Some species had nearly-continuously distributions, notably *Tagelus* in the lower creek, but most species contained gaps when surveyed at half-kilometer intervals. Given the relatively intense effort made to sample the creek, such gaps could be interpreted as the result of natural variation in habitat variability and recruitment success. To the extent a gap represented a result of consequence to the interpretation of data, the gap could be assessed more thoroughly by means of a follow-up visit. No follow-up visits were made to verify gaps in this study.

The second question regards the spatial relationship of a species' living members to its dead ones.

Two species were only found as dead material (**Table 2**). Three species have coincident material and 4 (*Tagelus, Polymesoda, Ischadium, and Tagelus*) had live ranges that were shifted downriver relative to dead material, or were out-of-range relative to dead material. Whether these species' live ranges had shifted during or as a result of the 2003 El Niño floods cannot be discerned from the data.

Table 2. Relation of live to dead shell distribution patterns in Shell Creek.

Relative to dead shells, live animals are	Species
Not found	*Crassostrea, Geukensia*
In the same range	*Mulinia, Rangia, Corbicula*
Toward downriver end	*Tagelus, Polymesoda*
Out-of-range, downriver	*Ischadium, Neritina*

Oysters and Mussels

Although two species forming the largest biocoenosces in rivers tributary to Charlotte Harbor are the intertidal mussel *Geukensia demissa*, and the eastern oyster, *Crassostrea americana*, which occur between high subtidal to mid-intertidal elevations, these species are rare in Shell Creek.

Ischadium is probably more common and abundant than revealed by the survey, owing to the large area of marsh islands with interior elevations suitable for their growth. On balance, oysters are not a dominant feature of the study area and tend to grow in small numbers on aerial roots of mangroves neat the Peace River. Evidently, Shell Creek was named because of the large number of *Polymesoda* and *Rangia* that live there.

The presence of 11 macro-mollusk species in the tidal Shell Creek, as collected by half-kilometer sampling effort, compares in a unique way to the list of mollusks collected by the benthic infaunal community analysis (**Table 3**).

Table 3. Comparison of Mollusk Species Richness by River and Gear.

Effort	Species Number		
	Alafia	Peace	Shell
Mollusk Survey	20	34	11
Invertebrate Survey	45	55	4

Seven more species were obtained in the mollusk survey, owing in part to effort made to sample intertidal and supratidal habitats. On balance, Hydrobiidae collected by the infaunal effort were not represented at all in the mollusk collection. Their presence in the infaunal collection most likely represents the use of a smaller sieve (0.5 mm). One possible reason for relatively low mollusk species richness in the infaunal community was that the infauna was sampled in May 2003 when antecedent river flows had been much larger than for April 2004.

Mollusk species richness was lower than that observed in the tidal Peace River, where similar gear and effort were made as part of the hydrobiological monitoring program (Mote Marine Laboratory, 2001). The mollusk survey collected 70% more species in the Peace than in the Alafia, whereas the infaunal program collected 33% more species. Compared to mollusk diversity of the Peace River, the mollusk diversity of the Alafia was impaired. On balance, the reduced species richness of Shell Creek is sensible given its geographic setting as a tributary to the Peace.

SYNTHESIS AND CONCLUSIONS

Objectives of the mollusk survey are evaluated below:

1. Describe the present distribution of major macro-mollusk species and communities in the tidal reach of Shell Creek.

Eleven macro-mollusk species inhabited the tidal reach of Shell Creek in April 2004. There were more species near the mouth of the creek than near the dam, especially among live material. Species richness and densities were depressed immediately below the dam. Intertidal and subtidal fauna were similar with respect to species numbers, densities, and ratios of live to dead specimens. The 2004 molluscan fauna was essentially an oligohaline to tidal-freshwater community. Relative to dead shells, most live material was in range or shifted down-river, most likely as a consequence of high stream-flows for more than a year, previous.

2. Identify taxa of potential importance to the ecological structure and functioning of the tidal Creek.

The numerically dominant species, *Polymesoda caroliniana*, *Rangia cuneata*, and *Tagelus plebeius* comprised 97.0% of the catch. *Polymesoda* was interesting because it is commonly found in the high intertidal zone within marshes, as it was in Shell Creek, but it was highly abundant as multiple cohorts in the low intertidal and was also abundant as juveniles in the subtidal zones of the creek. *Rangia* was the largest species overall, and its dead material, with *Polymesoda's*, comprised the great majority of dead-shell material on the surface in within the sediments of the creek. *Tagelus*, though thin-shelled, was very abundant in shallow shoals near the creek's mouth. The species is highly valued prey for benthic decapod crustaceans, elasmobranches, and teleosts, but in April there were few signs that predators had moved into the *Tagelus* beds. In addition to the three dominant species, two intertidal gastropods, *Neritina usnea* and *Littorina (Littoraria) irrorata*, are common on mangroves and marshes fringing the creek. These species are important intertidal consumers, and prey for varied predators, but probably were under-sampled by the present effort. Oysters and mussels are present in the creek in low numbers and in 2004 probably were not important in regulating the structure or functioning of the creek; they could easily become more abundant and important with a chronic change in the creek's physico-chemical nature.

3. Compare and contrast mollusk data collected by similar methods from other tidal rivers of southwest Florida.

Mollusk data collected by the rapid survey methods employed here tend to under-estimate species richness and faunal densities because our large sieve passes more material than the fine sieve used for infaunal surveys. For example, 20 and 34 species were collected by rapid survey in the Alafia and Peace rivers, respectively, whereas infaunal methods collected 45 species in the Alafia and 55 species in the Peace. The 11 species collected by rapid survey in Shell Creek is lower than caught in the Alafia or Peace, but Shell Creek is a tributary and its fauna was found to be highly similar with respect to richness, and density, to an analogous reach of the nearby tidal Peace River. One unexpected outcome was that the mollusk survey in April 2004 would collect nearly three times as many species as the infaunal survey made in May 2003. This outcome is attributed to the large stream flows that had occurred prior to the 2003 infaunal sampling effort.

In conclusion, the macro-molluscan fauna of the tidal Shell Creek is abundant, indicative of oligohaline to tidal-freshwater conditions, and as diverse as the analogous reach of a nearby, healthy stream. The exotic and invasive bivalve, *Corbicula fluminea*, is present in Shell Creek but in low numbers; there is no evidence that is has been or presently is a problem species in the tidal study area. Anecdotal evidence suggests that high stream flows caused a sharp decline in the abundance of one intertidal gastropod after 2003, but there is no evidence from the present study to test that idea.

ACKNOWLEDGMENTS

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LIST OF FIGURES

1. The tidal Shell Creek. River kilometer (RK) 0.0 is at the creek's confluence with the Peace River. The Punta Gorda dam is at RK 10. The RK system was developed by SWFWMD and modified for mollusk transects as shown. No RK 5.5 transect was established or sampled.

2. Density, size, and weather index values for live and dead collections of *Polymesoda caroliniana* as a function of distance from the Peace River, in intertidal and subtidal strata.

3. Density, size, and weather index values for live and dead collections of *Rangia cuneata* as a function of distance from the Peace River, in intertidal and subtidal strata.

4. Density, size, and weather index values for live and dead collections of *Tagelus plebeius* as a function of distance from the Peace River, in intertidal and subtidal strata.

5. Density, size, and weather index values for live and dead collections of *Corbicula fluminea* as a function of distance from the Peace River, in intertidal and subtidal strata.

6. Density, size, and weather index values for live and dead collections of *Neritina usnea* as a function of distance from the Peace River, in intertidal and subtidal strata.

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11. Mollusk species-accumulation curves for intertidal and subtidal collections progressing upstream (upper) and downstream (lower).

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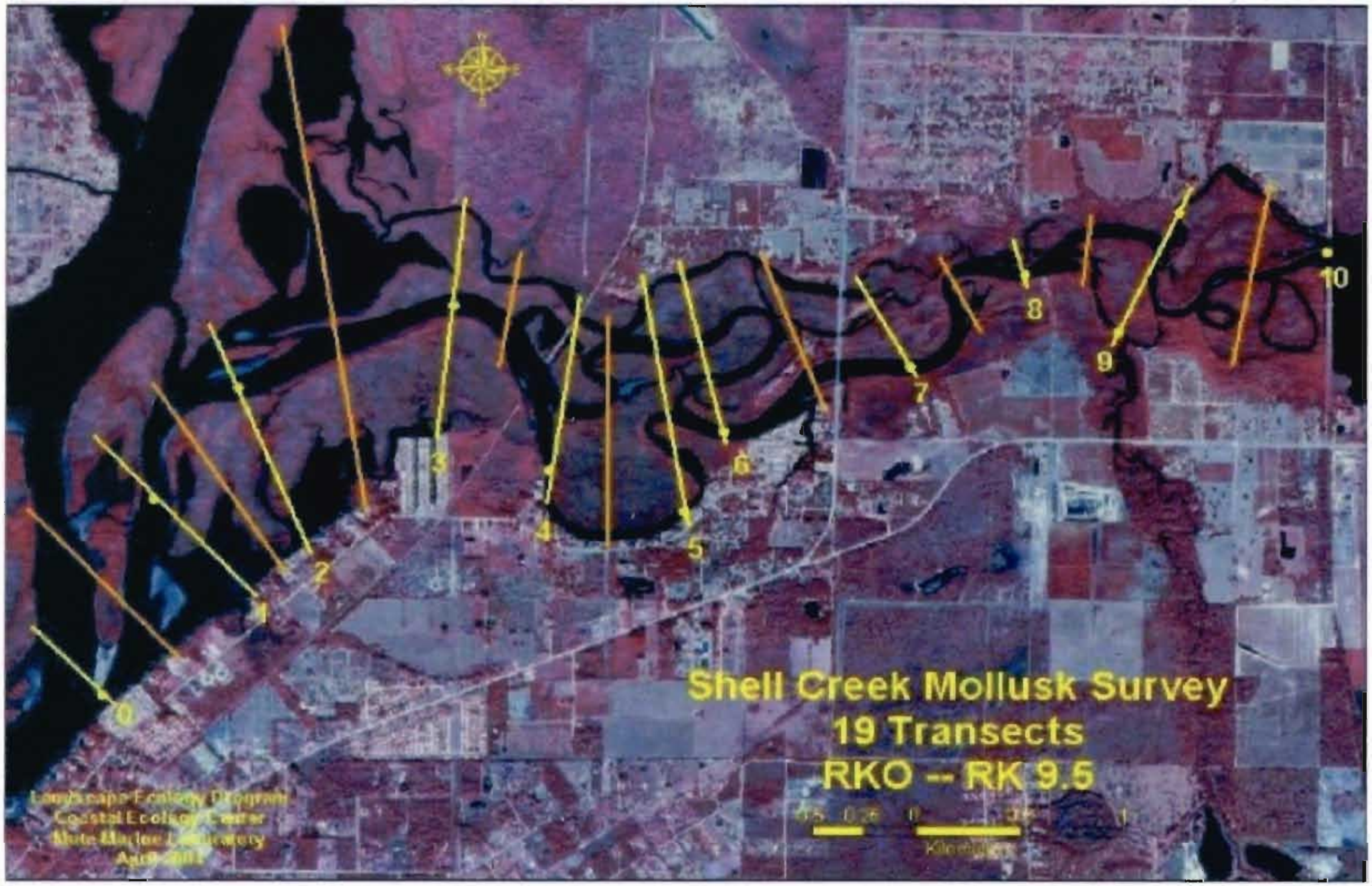
13. Faunal densities for intertidal and subtidal mollusk collections relative to river kilometer.

14. Comparison of Shell Creek (2004) and its analogous reach of Peace River (1999) in terms of number of live and dead taxa.

15. Comparison of Shell Creek (2004) and its analogous reach of Peace River (1999) in terms of number of intertidal and subtidal taxa.

16. Comparison of Shell Creek (2004) and its analogous reach of Peace River (1999) in terms of number of live and dead faunal densities.

17. Comparison of Shell Creek (2004) and its analogous reach of Peace River (1999) in terms of number of intertidal and subtidal faunal densities.



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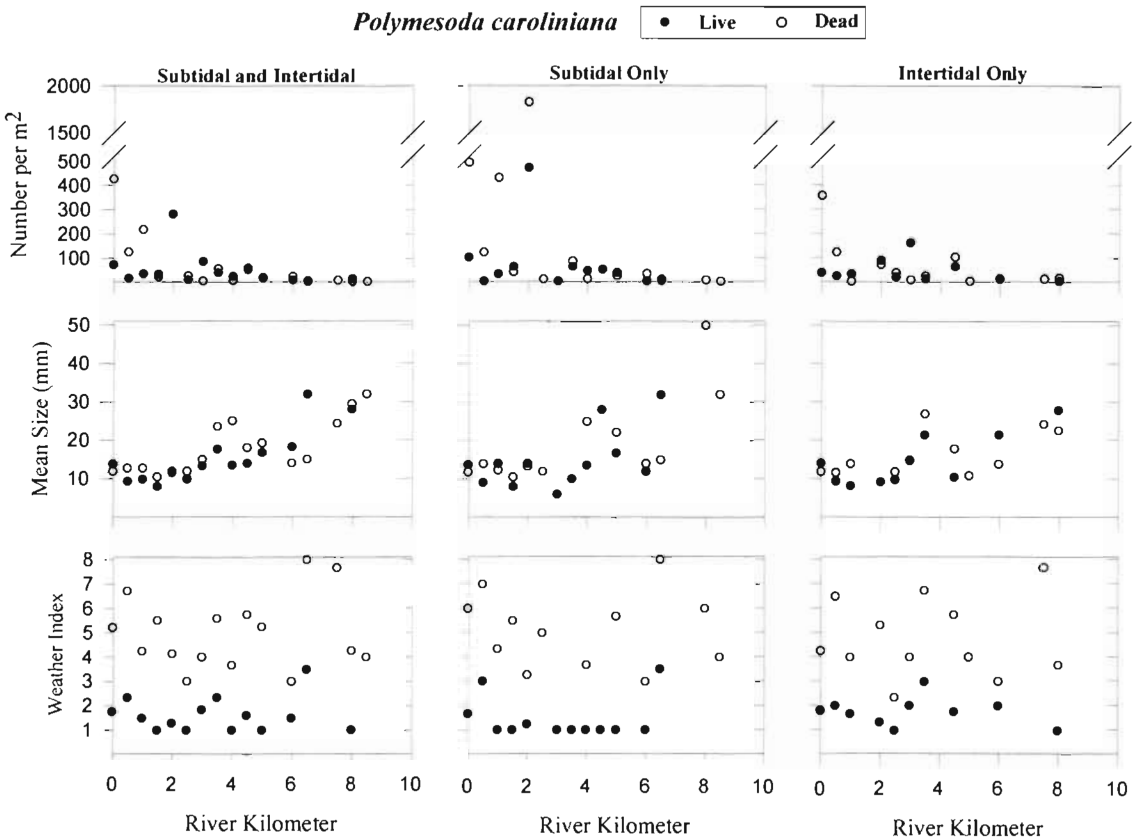

Figure 2. Density, size, and weather index values for live and dead collections of *Polymesoda caroliniana* as a function of distance from the Peace River, in intertidal and subtidal strata.

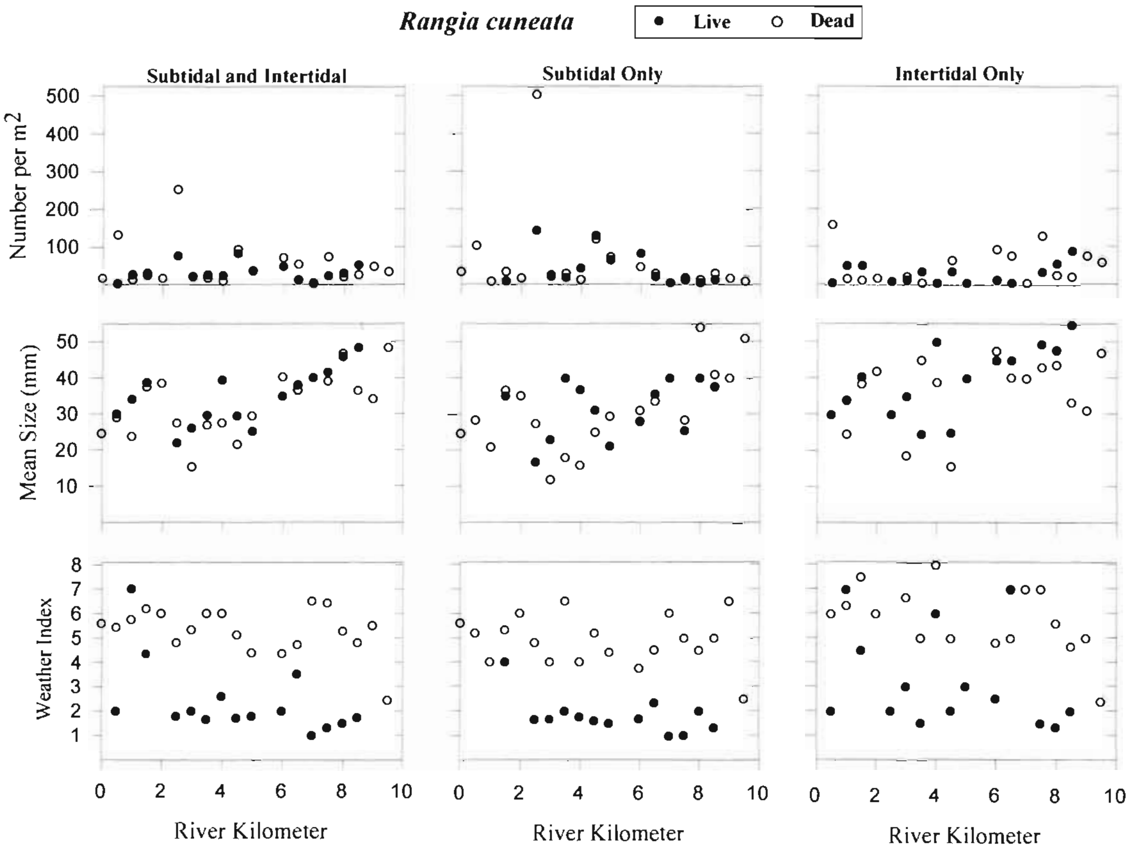

Figure 3. Density, size, and weather index values for live and dead collections of *Rangia cuneata* as a function of distance from the Peace River, in intertidal and subtidal strata.

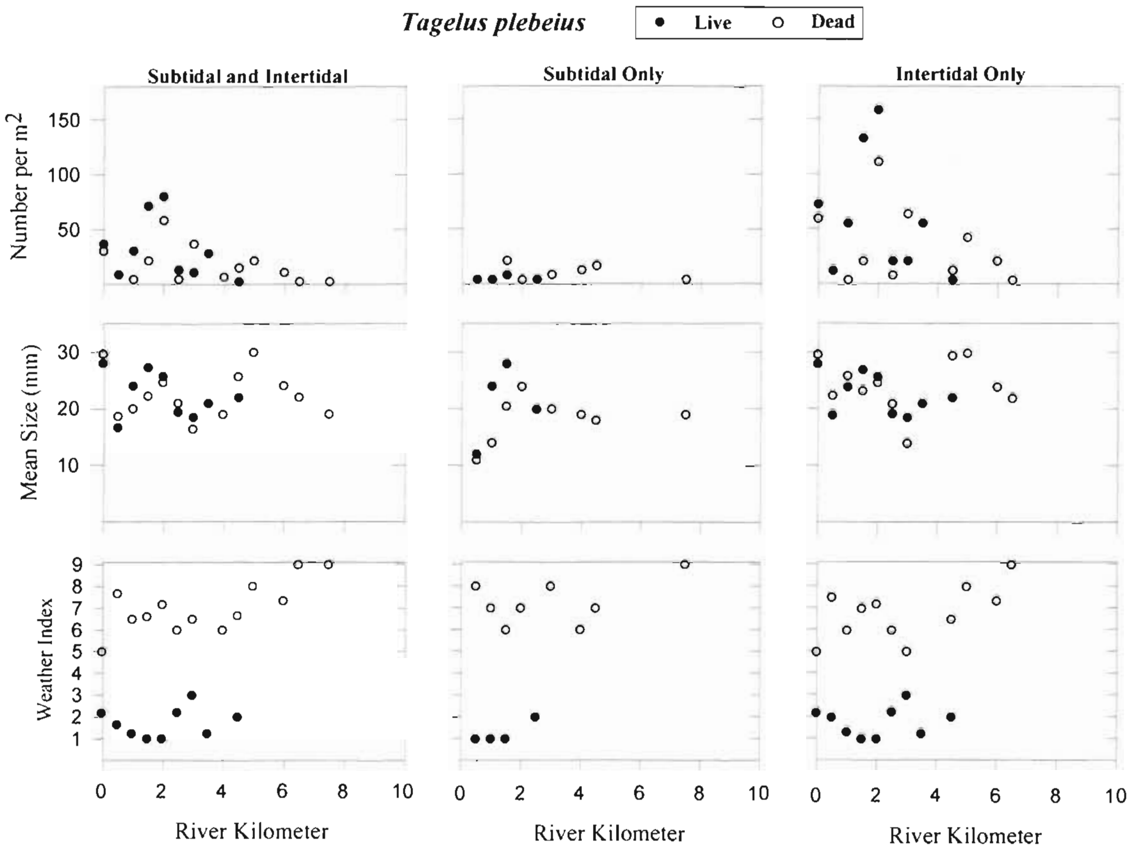

Figure 4. Density, size, and weather index values for live and dead collections of *Tagelus plebeius* as a function of distance from the Peace River, in intertidal and subtidal strata.

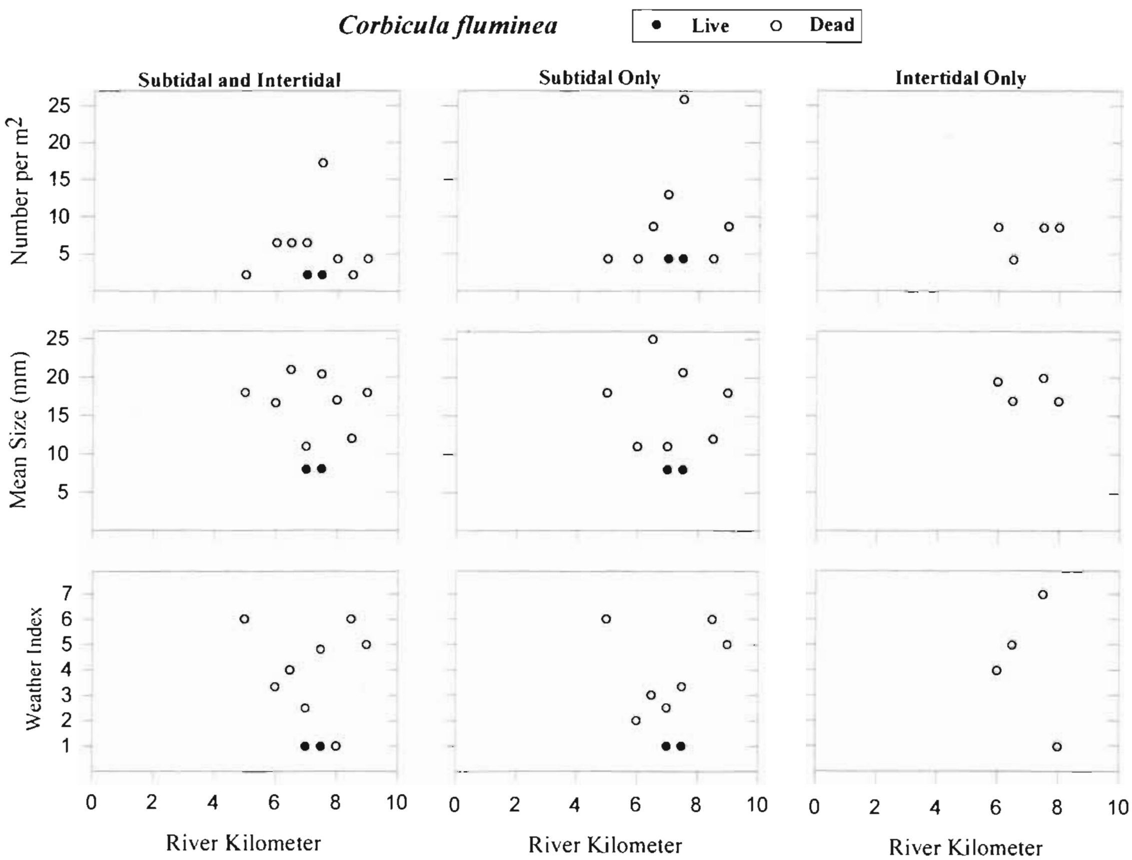

Figure 5. Density, size, and weather index values for live and dead collections of *Corbicula fluminea* as a function of distance from the Peace River, in intertidal and subtidal strata.

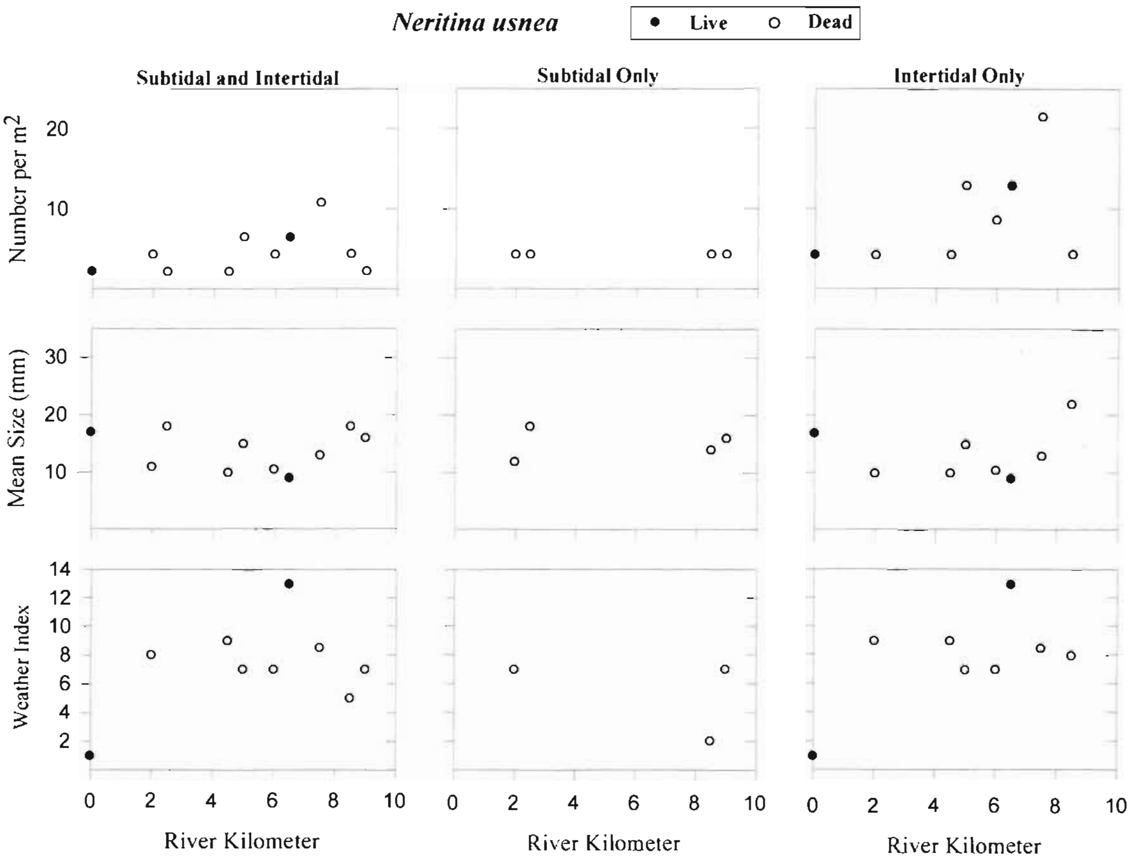

Figure 6. Density, size, and weather index values for live and dead collections of *Neritina usnea* as a function of distance from the Peace River, in intertidal and subtidal strata.

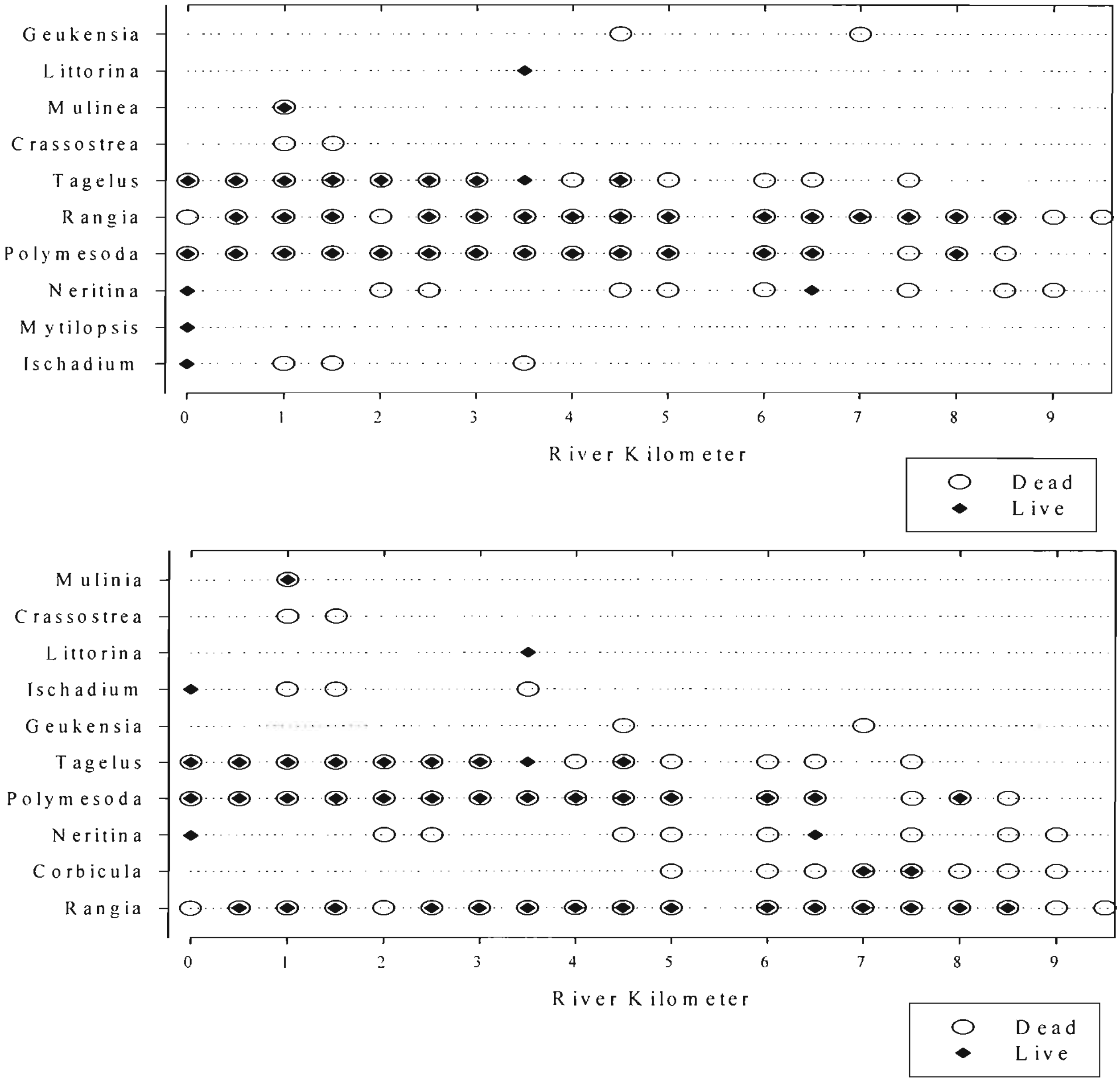

Figure 7. Dispersion of individual mollusk species in Shell Creek, sorted by first occurrence moving upstream (upper panel) and by first occurrence moving downstream (lower panel).

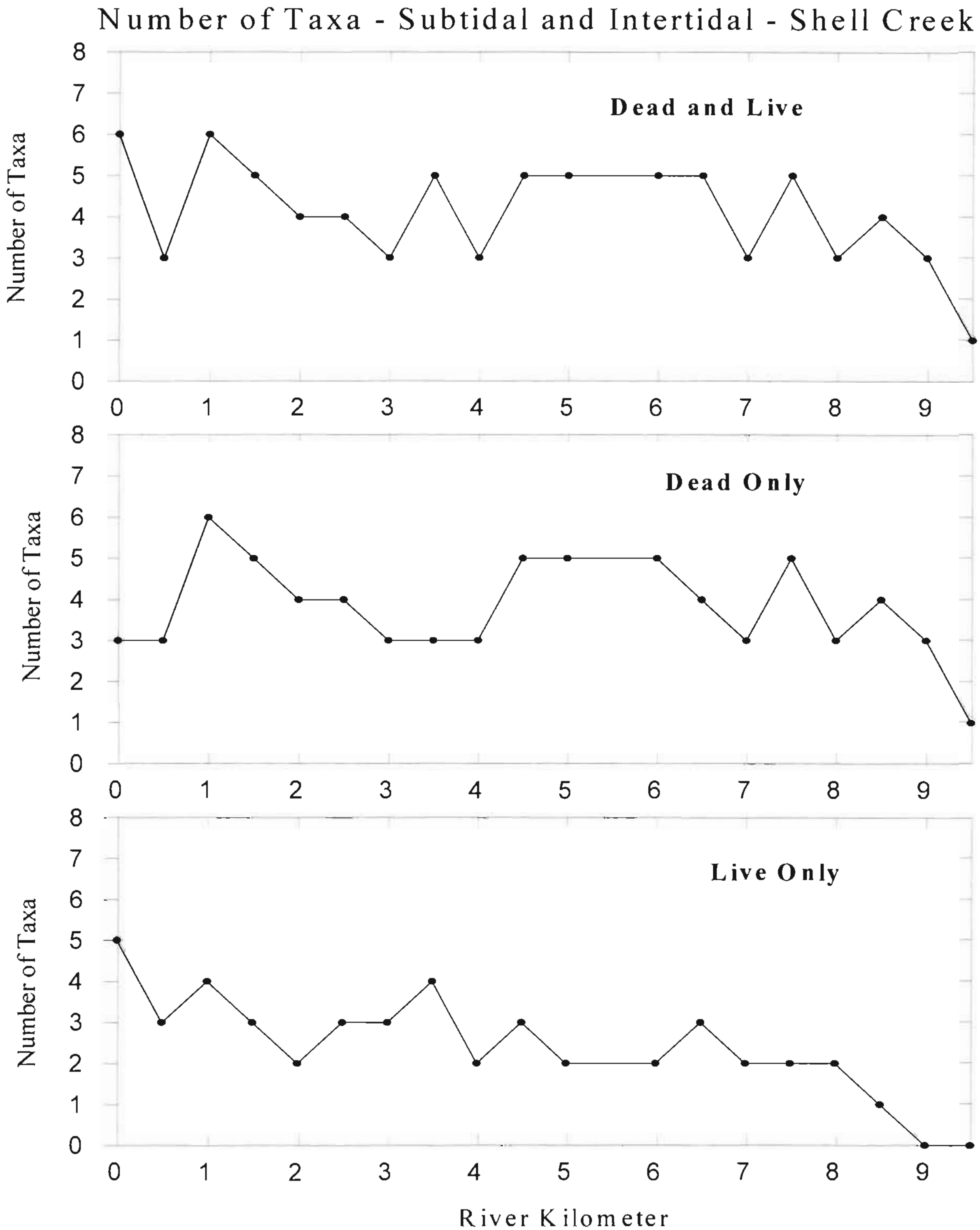

Figure 8. Species richness for live and dead mollusk collections relative to river kilometer.

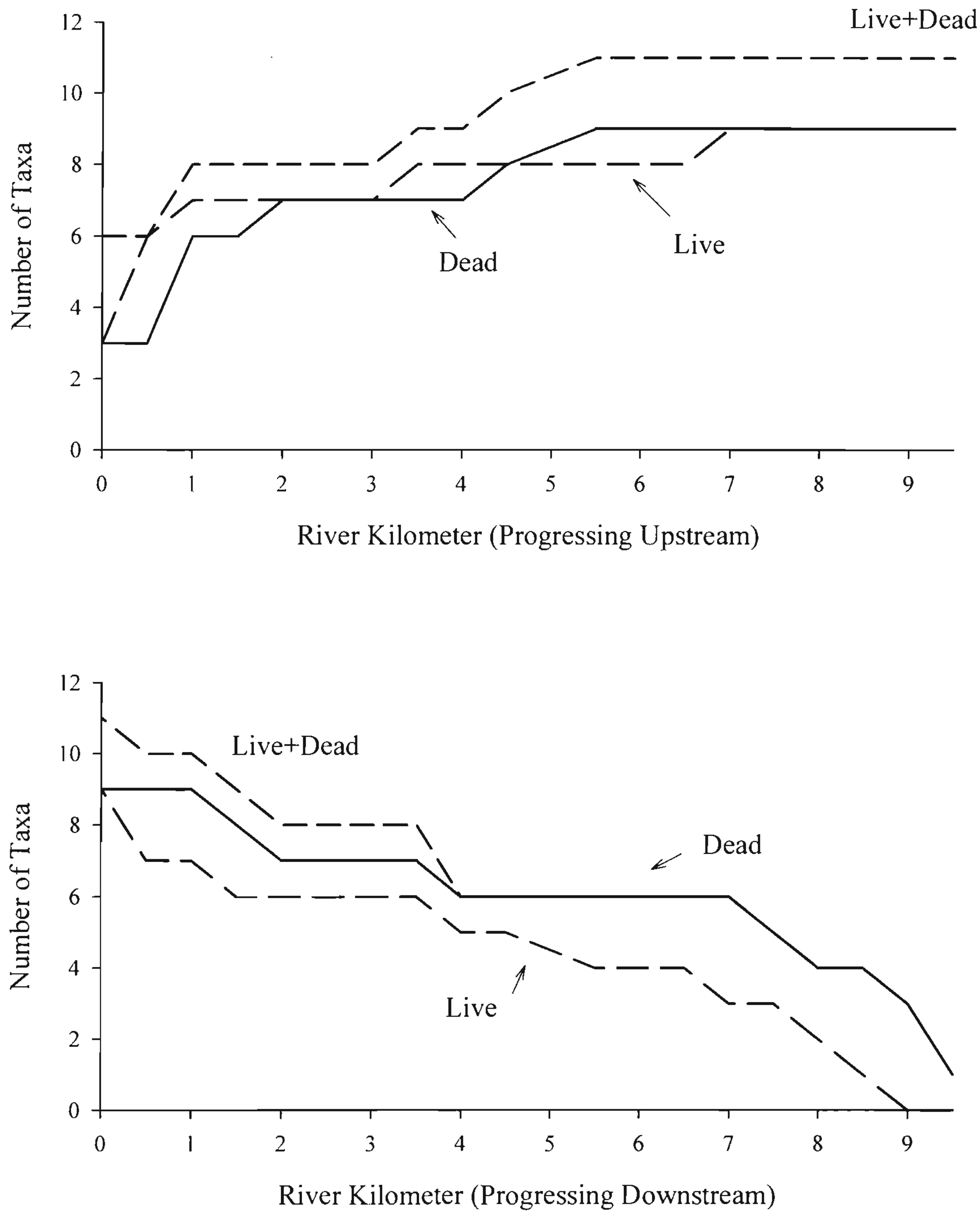

Figure 9. Mollusk species-accumulation curves for live and dead collections progressing upstream (upper) and downstream (lower).

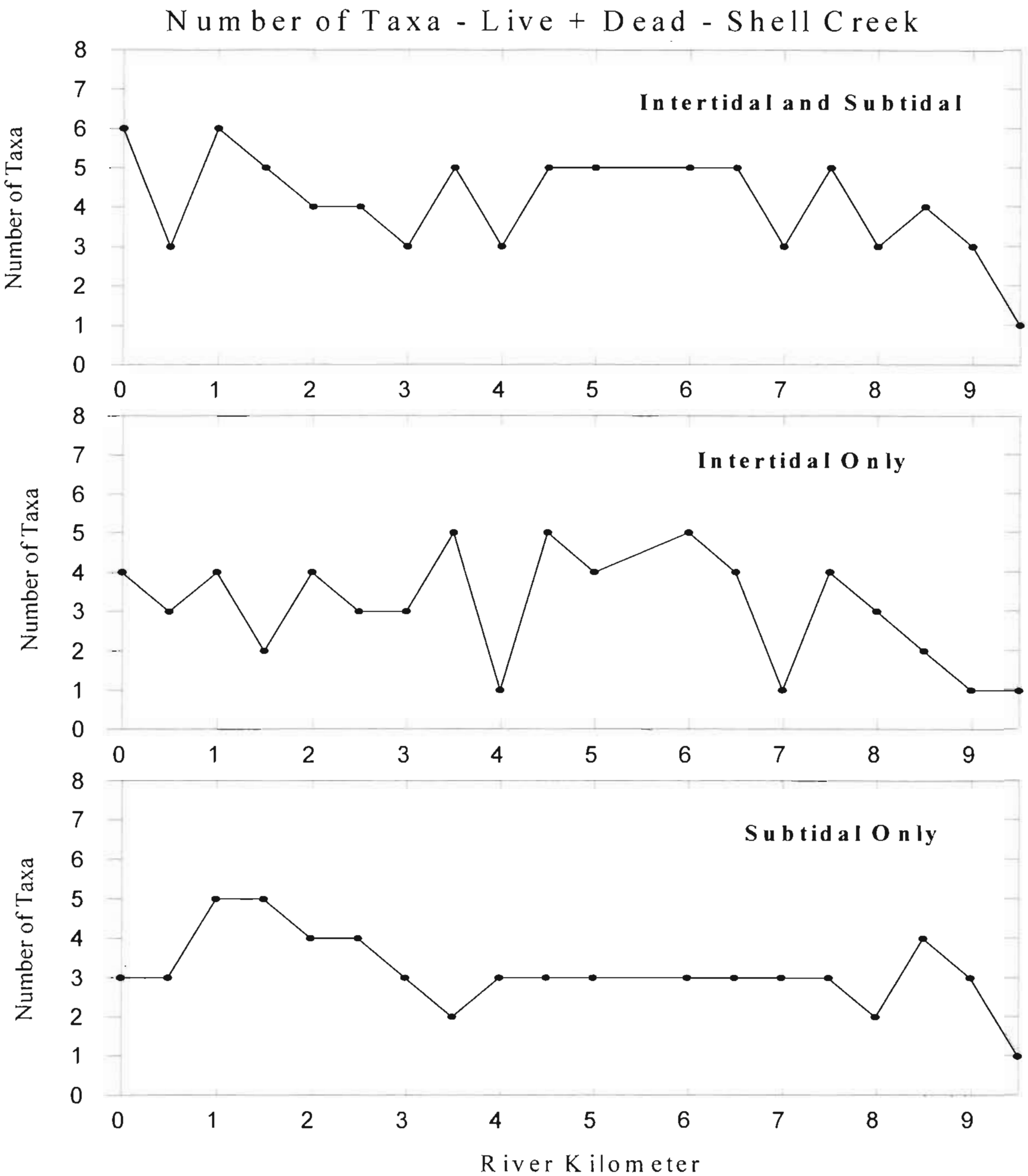

Figure 10. Species richness for intertidal and subtidal mollusk collections relative to river kilometer.

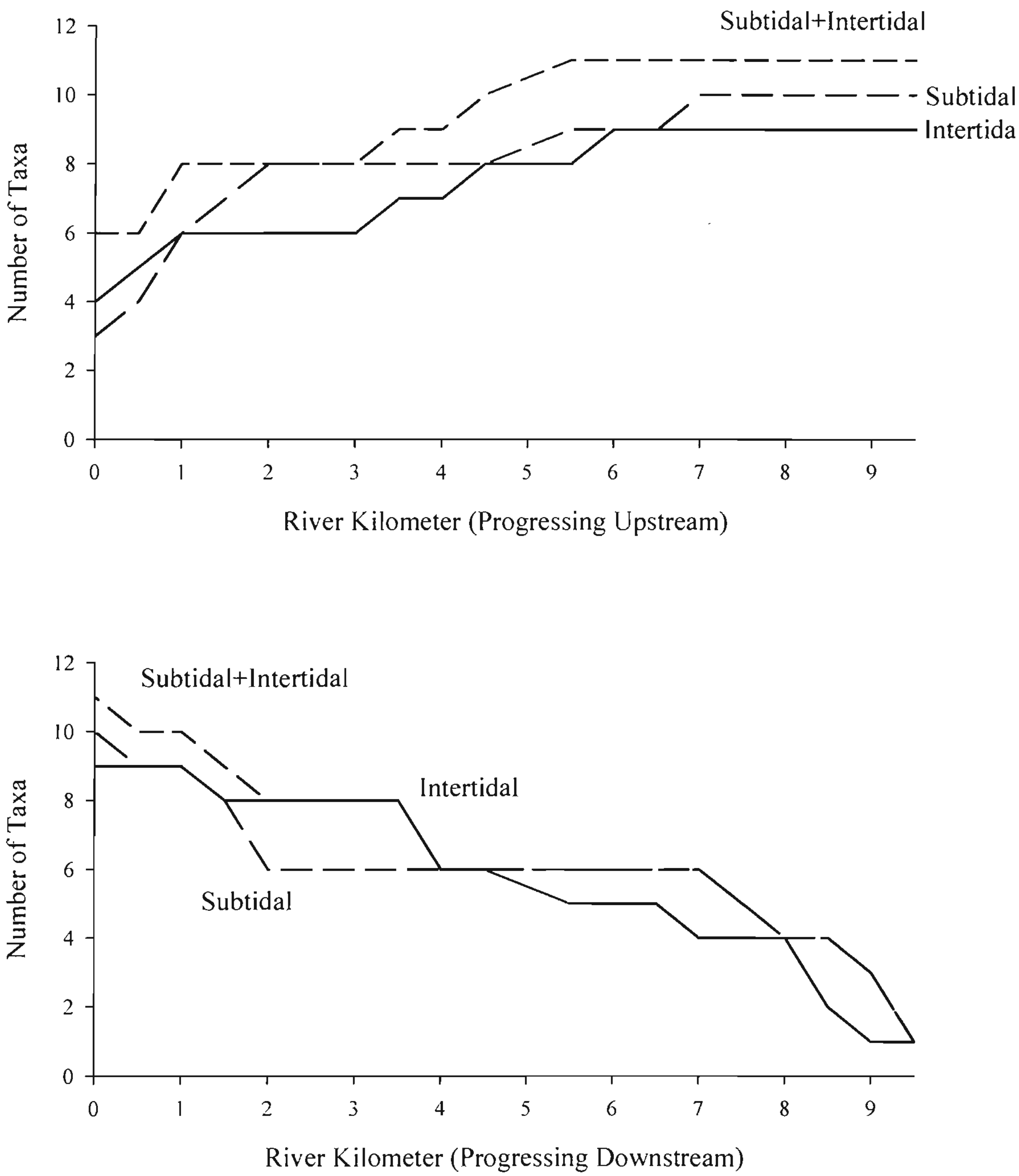

Figure 11. Mollusk species-accumulation curves for intertidal and subtidal collections progressing upstream (upper) and downstream (lower).

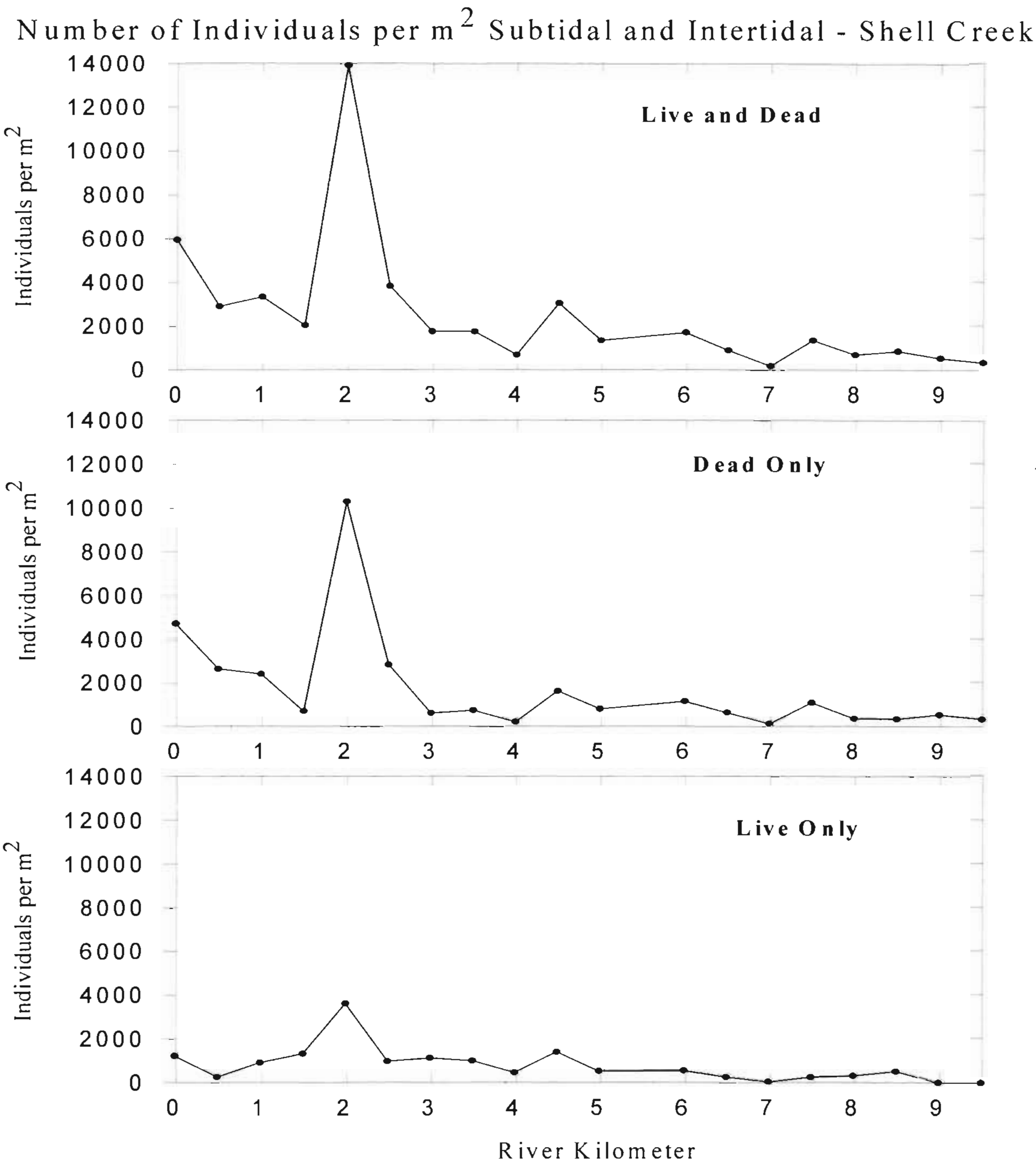

Figure 12. Faunal densities for live and dead mollusk collections relative to river kilometer.

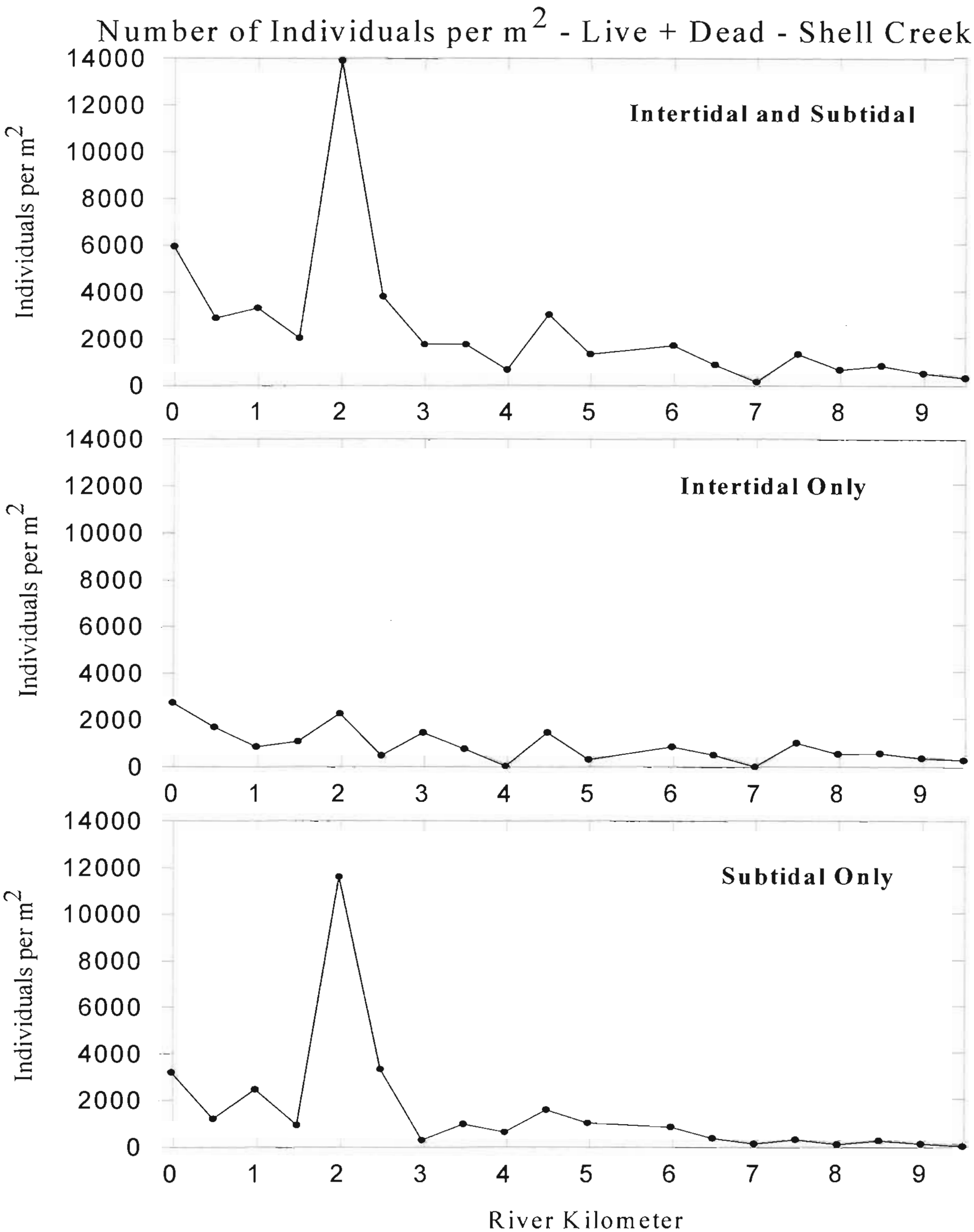

Figure 13. Faunal densities for intertidal and subtidal mollusk collections relative to river kilometer.

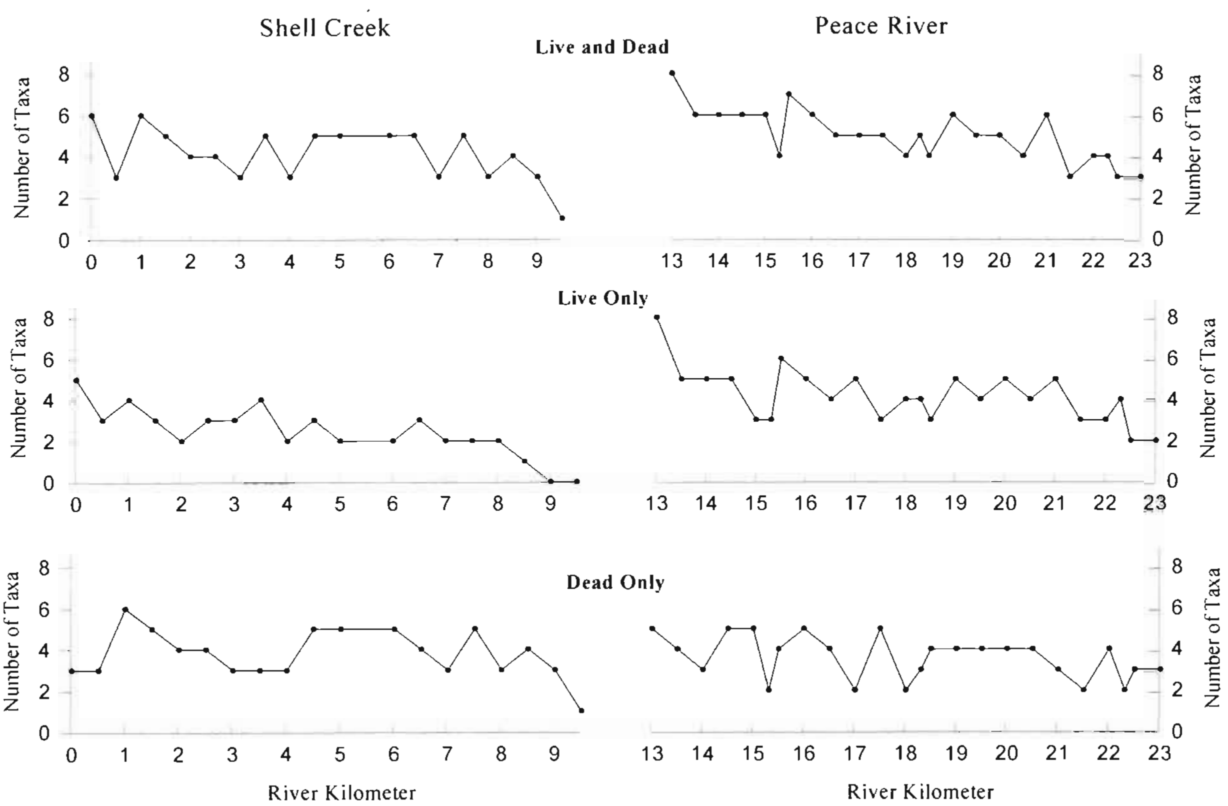

Figure 14. Comparison of Shell Creek (2004) and its analogous reach of Peace River (1999) in terms of number of live and dead taxa.

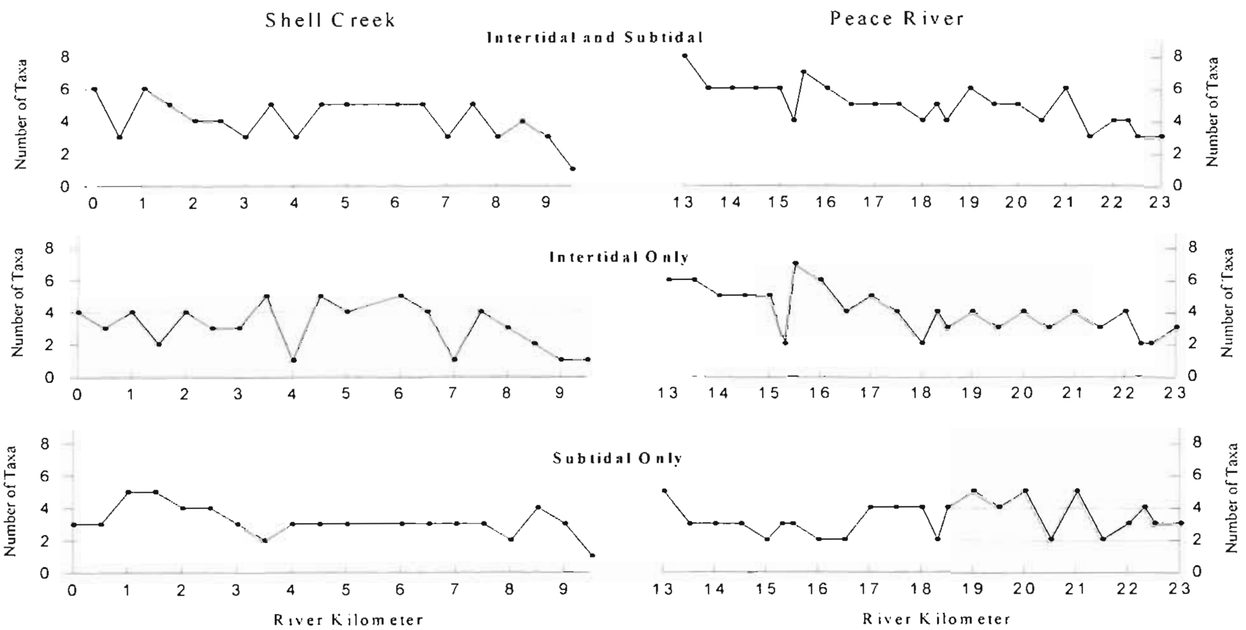

Figure 15. Comparison of Shell Creek (2004) and its analogous reach of Peace River (1999) in terms of number of intertidal and subtidal taxa.

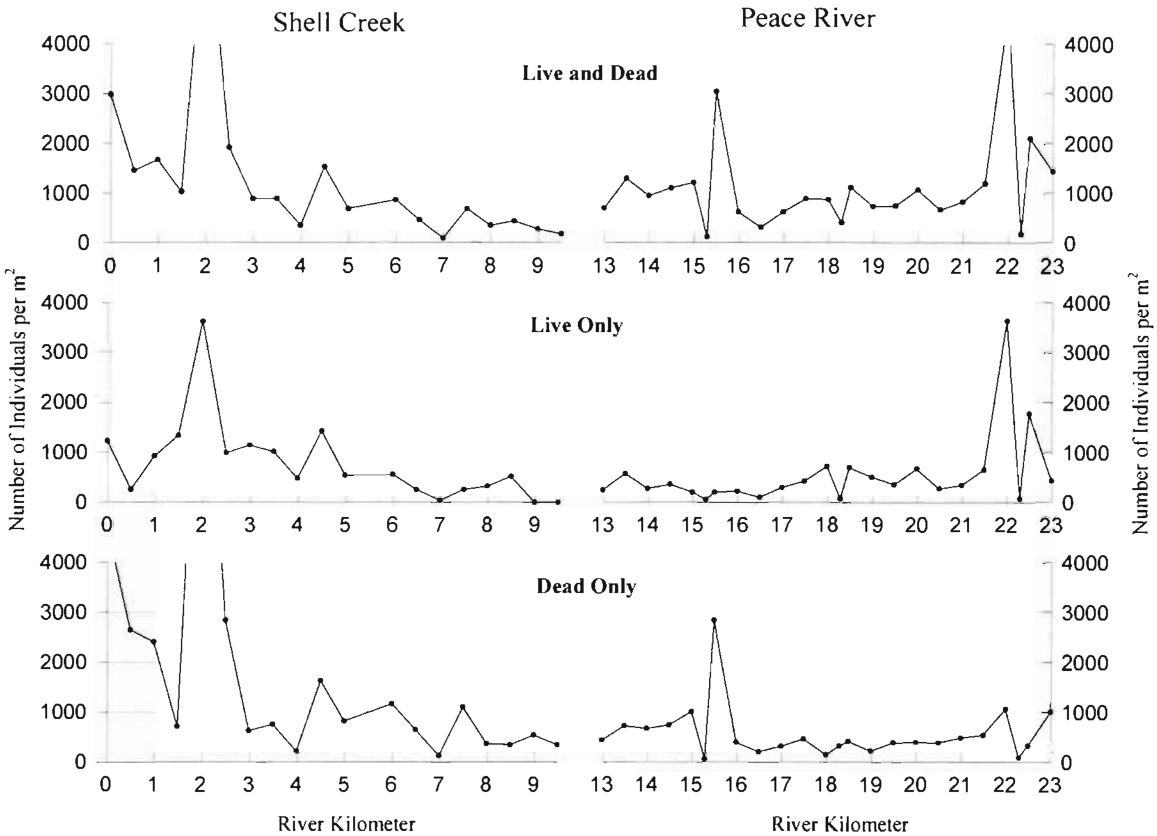

Figure 16. Comparison of Shell Creek (2004) and its analogous reach of Peace River (1999) in terms of number of live and dead faunal densities.

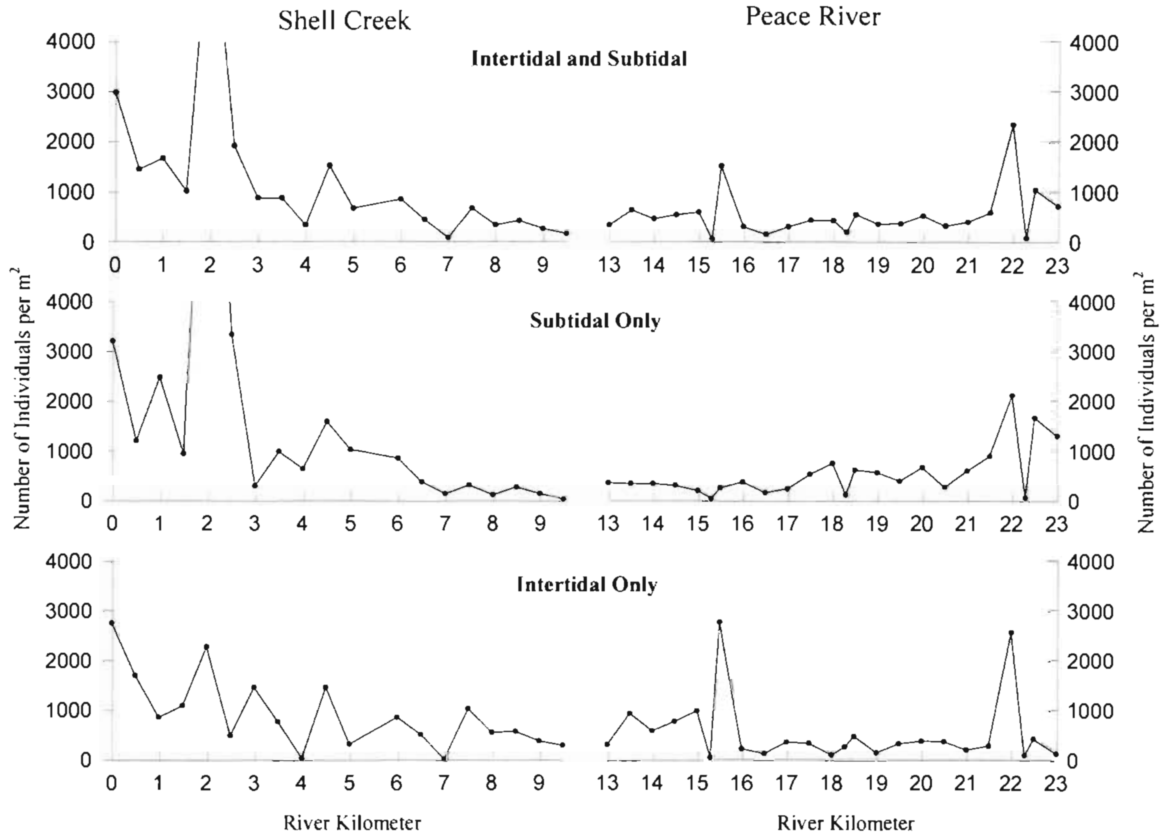

Figure 17. Comparison of Shell Creek (2004) and its analogous reach of Peace River (1999) in terms of number of intertidal and subtidal faunal densities.

DATA APPENDIX 1
Shell Creek Mollusk Survey: Station Data

River Kilometer	Date	Subtidal Time	Subtidal Latitude, 26.x	Subtidal Longitude, 82.x	Subtidal Depth, m	Intertidal Time	Intertidal Latitude, 26.x	Intertidal Longitude, 82.x	Intertidal Depth, m
0	4/28/04	1019	96745	99595	0.58	956	96574	99424	0.3
0.5	4/28/04	1045	97127	93689	1.46	1034	97138	99586	0.06
1	4/28/04	1255	97258	99245	1.55	1234	97209	99143	0.33
1.5	4/28/04	1333	97671	99246	3.1	1316	97629	99145	0.67
2	4/28/04	1202	97156	98508	1.13	1354	97885	98923	0.21
2.5	4/28/04	1512	98024	98981	1.34	1140	97438	98203	0.15
3	4/28/04	1547	98228	97774	1.62	1530	98914	97838	0.3
3.5	4/27/04	1439	98163	97566	2.74	1425	98116	97610	0.9
4	4/27/04	1518	97742	97359	1.58	1513	97767	97312	0.9
4.5	4/27/04	1255	98037	97063	3.02	1252	98073	97068	0.48
5	4/27/04	1232	98026	96859	2.1	1213	98076	96839	0.9
6	4/27/04	1107	97678	96493	0.7	1140	98061	96668	0.76
6.5	4/27/04	1004	98419	96323	1.62	1019	98148	96215	0.33
7	4/26/04	1439	97936	95540	1.1	*0946	98351	95815	0.71
7.5	4/26/04	1337	98271	95406	4.14	1355	98247	95320	0.79
8	4/26/04	1252	98374	95091	4.57	1259	98426	95136	0.27
8.5	4/26/04	1205	98566	94840	3.11	1234	98492	94853	0.37
9	4/26/04	1109	98115	94559	2.38	1116	98253	94383	0.24
9.5	4/26/04	1022	98666	93847	1.68	1037	98553	93667	0.58

Notes

*4/27/04
Ruppia at 7.0 Intertidal

DATA APPENDIX 2
Shell Creek Mollusk Survey: Species Accounts

Species	Sample	Live No.	Live mm	Live Cond	Dead No.	Dead mm	Dead Cond
Rangia	9.5s2				1	50	1
	9.5s3				1	52	4
	9.5i1				5	11	4
	9.5i2				3	50	2
	9.5i3				2	50	1
	9.5i4				2	75	3
	9.5i5				2	50	2
	9s1				1	50	5
	9s5				3	30	8
	9i1				1	12	6
	9i2				1	19	6
	9i3				1	50	4
	9i5				15	44	4
	8.5s1	1	45	2			
	8.5s3	1	18	1	3	50	2
	8.5s4	1	50	1	4	32	8
	8.5i1	3	60	3	1	21	3
	8.5i2	5	48	2			
	8.5i3	7	60	2	3	41	4
	8.5i4	5	50	2			
	8.5i5	1	56	1	1	38	7
	8s4				1	60	3
	8s5	1	40	2	2	48	6
	8i1	7	46	2	2	32	6
	8i2	4	46	1	1	40	4
	8i3	2	51	1	1	54	6
	8i4				1	38	4
	8i5				1	55	8
	7.5s3				1	35	4
	7.5s4	2	40	1	3	22	6
	7.5s5	1	11	1			
	7.5i1	1	41	2	10	48	6
	7.5i2	1	58	1	4	42	9
	7.5i3				7	18	6
	7.5i4	4	45	2	5	62	7
	7.5i5	2	54	1	4	46	7

Species	Sample	Live No.	Live mm	Live Cond	Dead No.	Dead mm	Dead Cond
	7s3	1	40	1	1	40	6
	7i5				1	40	7
	6.5s2	1	40	3	2	60	9
	6.5s3	3	35	1	1	18	2
	6.5s4				2	25	4
	6.5s5	1	32	3	2	31	3
	6.5i3				5	38	3
	6.5i4	1	45	7	12	43	5
	6.5i5				1	40	7
	6s2	1	39	3	1	38	4
	6s3				1	28	4
	6s4	12	39	1	4	23	4
	6s5	6	6	1	5	35	3
	6i1				7	50	3
	6i2				3	45	4
	6i3	1	45	3	8	53	4
	6i4	2	45	2	1	45	7
	6i5				3	45	6
	5s1	9	9	1	9	22	3
	5s2	4	10	1	3	28	3
	5s3	1	31	2	1	37	5
	5s4				1	34	6
	5s5	1	35	2	3	26	5
	5i5	1	40	3			
	4.5s1	14	28	1	7	21	6
	4.5s2	4	26	2	7	26	7
	4.5s3	6	38	3	10	24	5
	4.5s4	5	33	1	3	36	5
	4.5s5	1	30	1	1	18	3
	4.5i2	3	14	2	6	7	6
	4.5i3	5	36	2	8	20	6
	4.5i5				1	20	3
	4s2	4	31	2			
	4s3	3	31	1			
	4s4	1	40	2	3	16	4
	4s5	2	45	2			
	4i4				1	39	8
	4i5	1	50	6			
	3.5s1				1	20	8

Species	Sample	Live No.	Live mm	Live Cond	Dead No.	Dead mm	Dead Cond
	3.5s2	4	40	2	6	16	5
	3.5i3	7	15	1			
	3.5i5	1	34	2	1	45	5
	3s1	4	9	1	1	14	5
	3s2	1	30	2	1	6	2
	3s4	1	30	2			
	3s5				3	16	5
	3i2				1	20	9
	3i3				1	13	6
	3i4	3	35	3	3	23	5
	2.5s1	6	26	2	4	31	5
	2.5s2				9	42	3
	2.5s4	25	14	2	75	18	7
	2.5s5	2	10	1	25	11	3
	2.5s3				4	35	6
	2.5i1	1	40	3			
	2.5i4	1	20	1			
	2s1				4	35	6
	2i4				4	42	6
	1.5s1				6	38	6
	1.5s3				1	30	6
	1.5s4	2	35	4	1	42	4
	1.5i2				2	55	8
	1.5i4	8	28	1	1	22	7
	1.5i5	4	53	8			
	1s4				2	21	4
	1i1				1	33	8
	1i2				2	12	6
	1i4				1	29	5
	1i5	12	34	7			
	0.5s1				6	26	5
	0.5s2				2	29	5
	0.5s3				11	27	5
	0.5s4				2	30	4
	0.5s5				3	30	7
	0.5i1	1	30	2			
	0.5i2				23	32	6
	0.5i3				14	28	6
	0s1				4	25	6

Species	Sample	Live No.	Live mm	Live Cond	Dead No.	Dead mm	Dead Cond
	0s2				1	21	6
	0s3				1	26	4
	0s4				1	28	6
	0s5				1	23	6
Polymesoda	8.5s3				1	32	4
	8s4				2	50	6
	8i3	1	28	1	1	18	4
	8i4				2	30	5
	8i5				1	20	2
	7.5i1				1	23	8
	7.5i3				1	14	8
	7.5i4				1	36	7
	6.5s4	1	28	4	1	15	8
	6.5s5	2	36	3			
	6s3	1	12	1	8	14	3
	6i1				2	13	3
	6i3	2	24		1	15	
	6i4	1	19	2			
	5s1				1	20	8
	5s3	3	28	1	4	16	5
	5s4	4	12	1			
	5s5	2	10	1	1	30	4
	5i5				1	11	4
	4.5s5	12	28	1			
	4.5i2	3	14	3	6	16	6
	4.5i3	4	6	1	11	31	6
	4.5i4	7	11	1	2	11	6
	4.5i5	1	11	2	5	14	5
	4s1	3	11	1			
	4s2	2	12	1			
	4s3	1	15	1	1	21	4
	4s4				1	26	3
	4s5	5	16	1	1	28	4
	3.5s4	15	10	1	20	10	1
	3.5i2	2	32	4	2	25	6
	3.5i3				1	35	8
	3.5i4				2	30	7
	3.5i5	1	11	2	1	18	6
	3s4	1	6	1			

Species	Sample	Live No.	Live mm	Live Cond	Dead No.	Dead mm	Dead Cond
	3i1	17	12	2			
	3i2	7	10	2	1	18	3
	3i3	4	11	2			
	3i4	6	12	2	1	12	5
	3i5	4	29	2			
	2.5s3				3	12	5
	2.5i2	2	10	1	4	12	3
	2.5i3	3	10	1	1	12	3
	2.5i5				4	12	1
	2s2	20	18	2	64	18	4
	2s3	32	10	1	130	11	3
	2s4	28	14	1	110	12	3
	2s5	30	14	1	120	12	3
	2i1				8	10	6
	2i2				7	12	8
	2i3	2	6	1	2	6	2
	2i4	14	10	2			
	2i5	5	12	1			
	1.5s2	4	6	1	3	9	6
	1.5s5	11	10	1	7	12	5
	1s2	8	14	1			
	1s3				48	11	5
	1s4				28	8	5
	1s5				24	18	3
	1i1	3	12	2			
	1i2	4	6	1			
	1i4				1	14	4
	1i5	1	7	2			
	0.5s1				4	12	7
	0.5s2	1	9	3	14	10	7
	0.5s4				11	20	7
	0.5i1	1	9	1	2	9	8
	0.5i2	5	10	3	3	14	6
	0.5i3				16	12	5
	0.5i4				8	12	7
	0.0s1	17	11	1	2	8	5
	0.0s2				13	13	6
	0.0s3	3	18	2	16	16	5
	0.0s4	4	12	2	10	12	7

Species	Sample	Live No.	Live mm	Live Cond	Dead No.	Dead mm	Dead Cond
	0.0s5				74	10	7
	0.0i1	1	18	2	3	14	3
	0.0i2	1	14	2	8	11	
	0.0i3	4	9	1	22	11	3
	0.0i4	1	12	1	17	12	5
	0.0i5	2	18	3	33	12	6
Tagelus	7.5s4				1	19	9
	6.5i5				1	22	9
	6i2				1	21	7
	6i3				1	17	8
	6i5				3	34	7
	5i1				10	30	8
	4.5s2				4	18	7
	4.5i3				2	25	8
	4.5i4				1	34	5
	4.5i5	1	22	2			
	4s4				1	22	6
	4s5				2	16	6
	3.5i2	2	18	1			
	3.5i3	1	25	2			
	3.5i4	5	20	1			
	3.5i5	5	21	1			
	3s4				1	20	8
	3s5				1	20	8
	3i1	1	15	3			
	3i2				1	20	6
	3i4	4	22	3	13	4	
	3i5				1	18	4
	2.5s1	1	20	2			
	2.5i1	2	24	2			
	2.5i2	1	21	4	1	22	3
	2.5i3	1	20	2			
	2.5i4	1	12	1	1	20	9
	2s1				1	24	7
	2i1	17	28	1	9	28	9
	2i2	3	24	1	3	32	6
	2i3				2	15	9
	2i4	11	26	1	6	29	5
	2i5	6	25	1	6	20	7

Species	Sample	Live No.	Live mm	Live Cond	Dead No.	Dead mm	Dead Cond
	1.5s4				1	15	6
	1.5i1	12	25	1	1	28	7
	1.5i2	12	28	1	3	28	6
	1.5i3	7	28	1	1	14	8
	1.5s5	2	28	1	4	26	6
	1s1	1	24	1			
	1s3				1	14	7
	1i1	2	25	2			
	1i4	1	20	1			
	1i5	10	27	1	1	26	6
	0.5s2	1	12	1			
	0.5s5				1	11	8
	0.5i1	1	20	3	2	24	6
	0.5i2	2	18	1	1	21	9
	0i1	6	24	3			
	0i2	3	29	1	9	29	3
	0i3	4	28	2	1	32	7
	0i4	2	29	2			
	0i5	2	30	3	4	28	
Corbicula	9s5				2	18	5
	8.5s4				1	12	6
	8i4				2	17	1
	7.5s1	1	8	1	4	20	5
	7.5s3				1	35	4
	7.5s4				1	7	1
	7.5i3				1	22	6
	7.5i5				1	18	8
	7s2				1	6	1
	7s3	1	8	1	2	16	4
	6.5s5				2	25	3
	6.5i4				1	17	5
	6s3				1	11	2
	6i3				1	19	3
	6i5				1	20	5
	5s5				1	18	6
Neritina	9s5				1	16	7
	8.5s3				1	14	2
	8.5i1				1	22	8
	7.5i4				1	11	9

Species	Sample	Live No.	Live mm	Live Cond	Dead No.	Dead mm	Dead Cond
	7.5i5				4	15	8
	6.5i4	3	9	13			
	6i4				1	14	6
	6i5				1	7	8
	5i2				3	15	7
	4.5i3				1	10	9
	2.5s1				1	18	
	2s1				1	12	7
	2i2				1	10	9
	0i5	1	17	1			
Ischadium	3.5i4				1	30	8
	1.5s4				1	10	8
	1s1				1	13	1
	0i5	4	7	1			
Mulinia	1s1	1	11	1	1	11	1
Crassostrea	1.5s3				1	37	8
	1i1				1	19	8
Mytilopsis	0s2	2	13	1			
Littorina	3.5i5	4	20	2			
Geukensia	7s3				1	26	7
	4.5i3				1	17	3