

Identification and distribution  
of South Africa's  
non-native beachfleas  
(Crustacea: Amphipoda: Talitridae)

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## ABSTRACT

The two introduced beachfleas *Orchestia gammarellus* and *Platorchestia platensis* reported from South Africa have complicated histories, filled with misidentification and inaccurate documentation of distribution records. At the outset of this study, records of *Orchestia gammarellus* were restricted to – Langebaan Lagoon, Knysna and Milnerton Lagoon; while *Platorchestia platensis* had been recorded from Knysna and '34°S/19°E' (Gansbaai area). To verify this information, historical records were re-examined and 16 estuaries and lagoons in the Western Cape and two in the Eastern Cape Province were searched in order to determine the correct historical and current distributions of both species. It was found that historically and still today *O. gammarellus* occurs in Langebaan Lagoon. Its other current known distribution is the Berg River Estuary, Milnerton Lagoon and the Bushman's River; it never occurred in Knysna and records from that site were misidentifications of *P. platensis*. Historic records could only confirm *P. platensis* in Knysna and one other unknown location (specimen apparently mislabelled). Current searches conversely found *P. platensis* to be widespread, its range extending from Langebaan Lagoon to Algoa Bay (regions east of Bushman's River were not searched). Both species were described morphologically in detail taking their growth patterns into account and highlighting their differences, allowing for easier identification.

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*No panegyrist of the Amphipoda has yet been able to evoke anything like popular enthusiasm in their favour. To the generality of observers they are only not repellent because the glance which falls upon them is unarrested, ignores them, is unconscious of their presence. The majority of the species keep themselves effectively concealed from all but pertinacious intruders, beneath stones and weeds and varying depth of water.*

*Of the [family...] to be dealt with in these pages [it is...] the Orchestiidae, or as some might prefer to call it from the genus first described, the Talitridae. This is of all the Amphipoda the family which has made the strongest effort to place itself in evidence and to overcome the disregard of a neglectful world. More than any of the tribe it has invaded the land, so that its representatives may be found, not only in the sand-hills above high water marks, but in gardens, in woods far from the sea, on hills, in craters of extinct volcanoes. It has climbed higher than any of the Crustacea except a few woodlice, some of the fresh water forms having been taken [...] at a height of more than thirteen thousand feet in the Great Andes. Another mark of distinction may be found in the excessive trouble which nature and art have enabled it to give to the systematist. Not only are the descriptions and figures bequeathed to us by eminent naturalists and artists full of puzzles, but the creatures themselves have conspired in various ways to make the path of knowledge thorny and fatiguing.*

*Genera, the species of which have different habits, and which are separated by the unlikeness of the males, are in the females scarcely distinguishable (Talitrus and Orchestia). Genera which have been put apart by a decisive character provokingly join hands just when their separation is most needed. A great increase in the number of known species brings to light the missing links, which as everyone knows, are the curse of classification (Orchestia and Talorchestia). Characters which at one time distinguished large groups, or were valid for the whole family, are gradually nibbled away by exceptions here and exceptions there till all the neatness and completeness of the arrangement they provided are muddled away and spoiled."*

**T.R.R. Stebbing 1898**

## TABLE OF CONTENTS

ABSTRACT .....	2
ACKNOWLEDGEMENT .....	3
TABLE OF CONTENTS .....	5
Chapter 1 –INTRODUCTION AND AIMS .....	6
Chapter 2 – SYSTEMATICS AND ECOLOGY .....	10
Amphipod Anatomy.....	10
Amphipod Systematics .....	11
Beachflea Ecology –based on <i>O. gammarellus</i> and <i>P. platensis</i> .....	15
Habitat and Dispersal.....	16
Chapter 3 – SPECIES CHARACTERISTICS.....	19
Species Descriptions .....	20
<i>Orchestia gammarellus</i> Pallas, 1766.....	20
<i>Platorchestia platensis</i> Krøyer, 1845 .....	24
Species Comparison.....	28
Chapter 4 –SPECIES DISTRIBUTION .....	31
Global Distribution .....	31
South African Distribution - Historical and Current.....	34
<i>Orchestia gammarellus</i> .....	34
<i>Platorchestia platensis</i> .....	35
Chapter 5 – RECOMMENDED FUTURE STUDIES.....	38
REFERENCES .....	39
Appendix A - TABLES.....	45
Appendix B – MAPS .....	47
Search Areas and Sample Collection Sights .....	47
Sample Locations - <i>Orchestia gammarellus</i> .....	48
Sample Locations - <i>Orchestia gammarellus</i> & <i>Platorchestia platensis</i> .....	49
Sample Locations - <i>Platorchestia platensis</i> .....	49
Negative Search Areas for Non-native Beachfleas – Native Samples Recorded .....	52

## Chapter 1 –INTRODUCTION AND AIMS

Our track record in dealing with introduced species has not been on the whole impressive: species have been transported intentionally and accidentally around the globe, thereby establishing themselves outside their historic ranges, since people began navigating the open ocean (Griffiths *et al.* 2009). These introduced species, if highly competitive, often threaten, or displace native species and thereby are able to cause severe environmental damage (Schlaepfer *et al.* 2005) and imbalances in historically established environments. Yet in rare occasions the interaction between two or more species that do not share an evolutionary history could result, by chance, in a positive outcome for the environment, or at least one or more species thereof (Klimaszewski *et al.* 2002). Either way, it is important to monitor these species to enable proper management to ensure a healthy ecosystem and indigenous species preservation. Current literature (Simpson 2011) suggests that at least one of South Africa's non-native beachfleas (*Platorchestia platensis*) has spread along the European coast, outcompeting native species there, thus reducing the amphipod diversity in that ecosystem. This resulted in excess debris along the strandline, as *P. platensis* do not disintegrate wrack as efficiently as some native species, negatively affecting aesthetics and tourism whilst altering the balance of nutrients available for use by other organisms in the intertidal ecosystem (Simpson 2011).

Beachfleas belong to the order Amphipoda. Amphipods are small to medium-sized crustaceans, generally less than 15mm in length, although adult body length can range from less than 1mm (Chapelle & Peck 2004) to a maximum of 340mm measured in a giant species.

Amphipods are found in virtually all permanent waters of the world. Most of them are bottom dwellers, but some are found free swimming in marine, brackish, and freshwater (including ground water) environments (Bousfield & Kabata 1988). They inhabit a wide range of habitats, from the tropics to the Polar Regions, and from tidal zones to the deep ocean bottom and its trenches (Bousfield 1981). Most amphipods are deposit, detritus, or filter feeders and serve as principal secondary producers in aquatic ecosystems (Bousfield 1981). A few, all belonging to the family Talitridae, have adapted to terrestrial or semi-

terrestrial life and are found in moist habitats, mostly along coastlines, but also further inland. Their habitat ranges from sandy beaches, estuaries and mangrove swamps to rain forests at various altitudes (Bousfield 1984), where they feed on wrack (sea weed, sea grasses, kelp or other washed up vegetation) or in the latter case, forest litter. As talitrids depend upon external chloride, almost all of them occur on oceanic islands or continental areas in which the prevailing winds come off the sea, adding an appreciable amount of chlorine ions to the rain (Bousfield 1968).

Worldwide over 9600 species of amphipods have been described (Horton *et al.* 2015), of these over 8300 are marine (WoRMS Editorial Board 2015), at least 1870 species or subspecies are known from fresh or inland waters (Horton *et al.* 2015) and only a very few species are terrestrial. The family Talitridae, which contains all terrestrial and semi-terrestrial species as well as a number of aquatic ones, comprises nearly 300 different species according to Horton *et al.* (2015). Since the recording of the first talitrid around the mid 18<sup>th</sup> century, a steady increase in new species discoveries have been, and are being, made without showing any reduction in pace so far. Hence Bousfield's (1984) prediction that at least a thousand more species of this family are waiting to be found.

South Africa hosts 16 currently described species of the family Talitridae (Milne & Griffiths 2013). Seven of these are fully terrestrial landhoppers of the genera *Talitroides* and *Talitriator*, the latter comprises two introduced species, the distribution of which is very poorly known (Griffiths 1999). Nine further species are semi – terrestrial beachfleas of the genera *Orchestia*, *Platorchestia*, *Floresorchestia* and *Eorchestia* and sandhoppers of the genus *Talorchestia* and *Africorchestia* (Milne & Griffiths 2013). The beachfleas include the introduced species *Orchestia gammarellus* Pallas, 1766 (also known as *O. gammarella*) and *Platorchestia platensis* Krøyer, 1845 (formally known as *Orchestia platensis*) (Griffiths 1975). Eight other fully aquatic marine species, belonging to the genera *Hyale* and *Parhyalella* were historically included in the family Talitridae as listed in Griffiths (1974; 1975; 1976), but now have been moved to the family Hyalidae. A detailed list of the 16 South African species can be found in Appendix A.

South Africa's non native beachfleas *Orchestia gammarellus* and *Platorchestia platensis*, which form the focus of this dissertation, were introduced to the country more than a century ago, most probably through dry ballast of visiting ships (Griffiths *et al.* 2009). Both species are currently wide spread globally, with *P. platensis* being cosmopolitan. Mead *et al.* (2011) suggest that *P. platensis* may be a species complex.

The first published report of the species now recognised as *O. gammarellus* from South Africa was that of Barnard (1951), who described what he believed to be a new, endemic species *Talorchestia inaequalipes* based on specimens collected from Langebaan Lagoon by the UCT Ecological Survey in 1949. Griffiths (1974) also reported *T. inaequalipes* from Knysna (based on specimens collected by B. Rand in 1946 from 'The Point'). Griffiths (1975) later determined that *T. inaequalipes* was in fact synonymous with *O. gammarellus* (meaning that *T. inaequalipes* is no longer a valid species). *O. gammarellus* has subsequently been reported from Milnerton Lagoon in the suburbs of Cape Town by Mead *et al.* (2011). At the outset of this study, records of this species were thus restricted to three sites – Langebaan Lagoon, Knysna and Milnerton Lagoon. The need to re-examine the distribution of this species has been intensified by further recent studies and surveys. Robinson *et al.* (2004) surveyed the West Coast National Park (which incorporates Langebaan Lagoon) for introduced species and did not come across *O. gammarellus*. This opens the question into whether it was missed, or no longer occurs at this site. Similarly Hodgson *et al.* (2014) carried out a details study of drift line amphipods in Knysna Estuary, but failed to record *O. gammarellus*, suggesting again that previous reports were either incorrectly identified, or the species has disappeared from this site.

*Platorchestia platensis* on the other hand was first recorded in South Africa by Griffiths (1975) from two previously misclassified samples collected from the geographic location 34°South, 19°East. Griffiths (1976) gives the location as 'Danger Point', but it is not clear where this information originates from and if it is perhaps an interpretation of the 34°S/19°E coordinates. Mead *et al.* (2011) repeats this location and misquotes the date as 1904. Dense populations of this species have subsequently been discovered and examined in Knysna by Hodgson *et al.* (2014). The questionable historic distribution, as well as the discovery of a

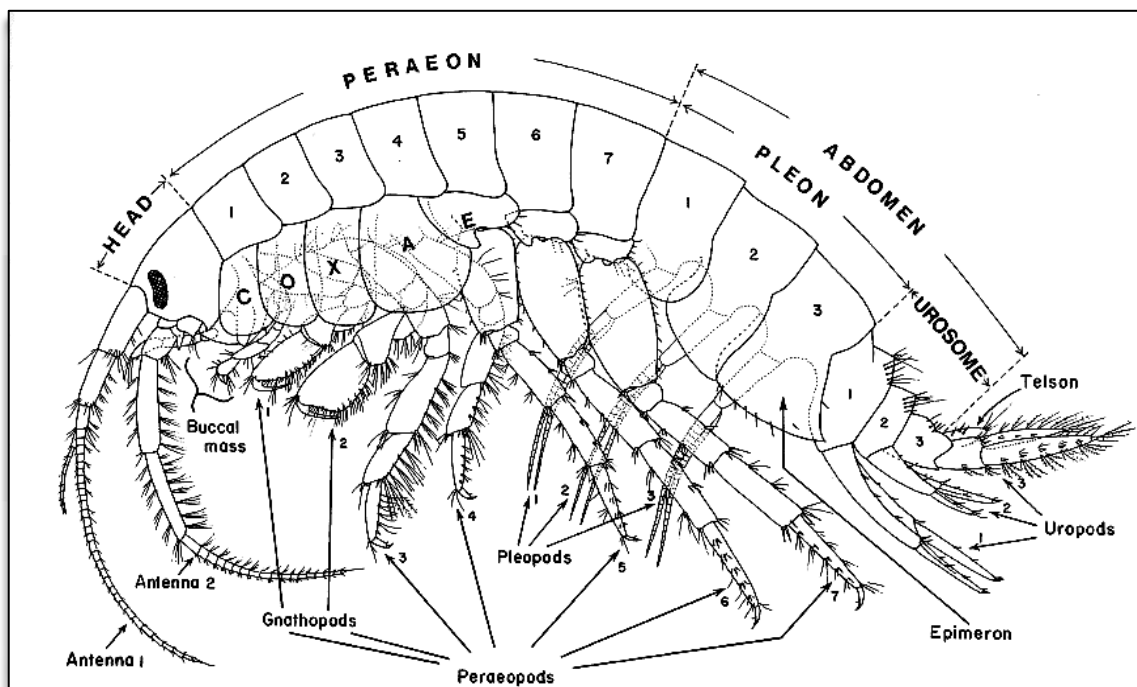
new population in Knysna speaks to the necessity to properly investigate and record the current distribution of this species in South Africa.

The aims of this project are thus to re-examine and check the historical identification of museum specimens of these species and to conduct a new survey to establish their true current distribution patterns in the Western Cape. A further aim is to document additional morphological features that can be used to assist in the accurate future identification of these species. This is complicated by the fact that the existing characters used to differentiate between species in these genera are largely sexually dimorphic and only become clearly evident in large, fully developed adult males. The resultant identification key therefore cannot be applied to juveniles and females (Conlan 1988), which comprise the largest portion of the population, resulting in frequent misidentification.

## Chapter 2 – SYSTEMATICS AND ECOLOGY

### Amphipod Anatomy

The order Amphipoda contains those crustaceans with generally slender and laterally compressed bodies, which lack a carapace, as seen in Figure 2.1. They have distinctly segmented bodies, in which the first thoracic segment is fused to the head in most. The body consists of three tagmata or segments. The head is followed by seven pereaeon segments (somites), the equivalent to the thorax, and is followed by the abdomen, which consisting of two parts, a three segmented pleon (pleosomite) and a three segmented urosome (urosomite). Two pairs of antennae are attached to the head. The antennae are well developed, consisting of a basal peduncle and terminal flagellum segments. The first antennae may have an accessory flagellum and the second may bear sensory organelles (calceoli). Amphipods are characterised by sessile eyes (Reid 1944). They have four mouthparts (mandibles, two pairs of maxillae and a maxilliped) which are all clustered beneath the head and jointly referred to as the buccal mass. Each of the seven somites carries a pair of uniramous, seven-segmented legs (pereaeopods). The first leg segments are



**Figure 2.1.** Illustration of basic Gamaridean and Senticaudatan amphipod (lateral view).  
Source: Bousfield (1973)

modified into the coxae, which are ventro-lateral plates that give a protective cover to the gills and brood sacs. The remaining six segments of the pereopod are the basis, the ischium, the merus, the carpus, the propod and lastly the dactyl in this order. The first two pereopods are generally called gnathopods 1 and 2 and may be subchelate, chelate or simple. The respiratory organs (coxal gills) are thin walled sacs, joined to several but not all coxae. Sternal gills are present in certain groups. Amphipod development is direct; eggs being incubated in a ventral brood-pouch composed of paired, leaf-shaped oostegites attached proximo-medially to the coxae of some, but not all, thoracic legs. The three pleosomites of the abdomen bear lateral epimeral plates as well as three pairs of biramous pleopods (swimming appendages) and the three urosomites have mostly biramous paired uropods, as well as a terminal telson, dorsal to the anus (Friend & Richardson 1986; Stock 1986; Bousfield & Kabata 1988).

### **Amphipod Systematics**

Amphipod classification is based largely on the form of the mouthparts, gnathopods, coxal plates, and details of the urosome (Watling 1993). Historically, there have been four suborders in the Amphipoda. These were Gammaridea Latreille, 1802; Caprellidea Leach 1814; Hyperiidea Milne Edwards, 1830 and Ingolfiellidea Hansen, 1903. The later three have always been recognisable groups defined by one or more apomorphic characters (Novel evolutionary trait that is unique to a particular species and all its descendants). The Gammaridea on the other hand was originally defined on symplesiomorphic (shared ancestral traits), such as a well developed abdomen to distinguish it from the caprellideans and a well developed maxilliped to distinguish it from the hyperiideans. The Gammaridea per se became the repository for any family-level taxon which did not fall into one of the other groups (Lowry & Myers 2013). The beachfleas also fell into this group.

Many attempts have been made to structure the species and groupings (Bousfield 1973, 1977; Barnard & Karaman 1975, 1980) within this suborder, until Myers & Lowry (2003) established the suborder Corophiidea, removing it from the Gammaridea as their first attempt to split this very general suborder. The following attempt to create a testable phylogenetic classification for the Amphipoda by Lowry & Myers (2013) demoted this new

suborder back to the infraorder Corophiida and created yet again a new suborder Senticaudata, which incorporates 95 families formerly in the Gammaridea. This new suborder was accepted and is defined by the presence of robust setae on the apices of uropods 1–2. Lowry & Myers (2013) recognised six infraorders (Carangoliopsida, Talitrida, Hadziida, Corophiida, Bogidiellida and Gammarida) in the Senticaudata and eight parvorders (Carangoliopsidira, Talitridira, Corophiidira, Caprelliidira, Melitidira, Bogidiellidira, Crangonyctidira and Gammaridira).

Talitrida is the infraorder that contains the beachflea. The first modern revision of this group was carried out by Bulycheva (1957). He raised the family Talitridae to superfamily Talitroidea, retaining the family Talitridae within and adding two new families (Hyalidae and Hyaellidae). As this division was not based on morphological characteristics but rather took into consideration ecological aspects of the species, his families were shortly demoted to subfamilies (Talitrinae, Hyalinae and Hyaellinae) under the family Talitridae by Barnard (1972) only to be reinstated again by Bousfield (1978). The Talitridae have a broader ecological range than any other amphipod family (Friend & Richardson 1986), which makes an ecological division very attractive although scientifically not very favourable. Bousfield (1984) divided the family into four morphological-ecological groups. He states that although these groupings have some phyletic basis, they are predominantly informal due to the degree of overlap of characters of some genera (Bousfield 1984; Bousfield 1991). The first of these four morphological-ecological groups consist of the morphological primitive palustral talitrids; these are semi aquatic and rarely terrestrial and are found in estuarine and some freshwater habitats. The second group represents the beachfleas (including *Platorchestia* and *Orchestia*), which are morphologically more advanced and found in semi-terrestrial or terrestrial supralittoral habitats and coastal rainforests. The highly apomorphic semi-terrestrial and supralittoral sandhoppers (including *Talorchestia*) belong to the third group and are found on sand beaches. The last group contains the apomorphic landhoppers, which are fully terrestrial and found in coastal continental and high-island rain forests (Bousfield 1984). Although these groups were not accepted as systematic groupings, the common names were adopted by many but not all. Beachfleas therefore may also be called sand hoppers, beach hoppers or shore hoppers in the literature.

Further attempts were made to treat the systematics and distributional ecology of this family on a more comprehensive and phyletically significant basis (Bousfield & Heard 1986) until Serejo (2004) conducted a cladistic revision of this entire group based on a strict consensus tree, taking into account 34 terminal taxa and 43 morphological characters. Ecological aspects were not considered. The outcome of this study elevated the superfamily Talitroidea to infraorder Talitrida, where it stands today. The superfamily Talitroidea and family Talitridae have been retained. More superfamilies and families have been added.

Lowry & Myers (2013) describe the Infraorder Talitrida Rafinesque, 1815 as follows: "*The taxa in the infraorder Talitrida have an apically setose or asetose basal endite of maxilla 1, no oblique setal row on the basal endite of maxilla 2, loss of (or vestigial) mandibular palp, loss of (or vestigial) maxilla 1 palp, loss of an accessory flagellum, absence of (or vestigial) endopod on uropod 3 (except in Biancolinidae) and presence of curl-tipped setae on the oostegites (except in Caspicolidae)*". The infraorder Talitrida consists of one parvorder Talitrida (same as Infraorder), four superfamilies (including superfamily Talitroidea with 11 families), and 15 families. Lowry & Myers (2013) further describe the Superfamily Talitroidea Rafinesque, 1815 as "*Mandibular palp vestigial or absent. Oostegites with curl-tipped setae. Telson entire or notched.*"

This takes us to the family Talitridae Rafinesque, 1815, which is described as follows by Bousfield (1982a, 1982b), Serejo (2004) and Lowry & Myers (2013): The body is predominantly laterally compressed, smooth and rarely dorsally toothed or carinate. The eyes are lateral, well developed, medium to large and round or ovoid and rarely small or absent. Both antennae are weakly setose and noncalceolate. Antenna 1 is short and rarely longer than the peduncle of antenna 2, which is often sexually dimorphic. The accessory flagellum is absent. The buccal mass is directly beneath the head or slightly prognathous. The mouthparts are modified with an upper lip that is rounded below and a tall lower lip that lacks inner lobes. The mandible has a strong molar and incisor and the palp is absent. The maxilliped plates are well developed and the dactyl of the palp is usually reduced or lacking. In maxilla 1 the inner plate is slender and apically setose. The outer plate has apical spine teeth. In maxilla 2 the plates are distally setose. Coxa 1 is reduced and not posteriorly cusped. Coxae 2-4 are medium to deep and overlapping, occasionally small, each with

posterior marginal cusp which may be small or lacking. The gnathopods are unlike. Gnathopod 1 is simple (lacking palm), subchelate or chelate and similar in males and females. It is smaller or similar in size to gnathopod 2 and has a propodus palm without robust setae along the palmar margin. Gnathopod 2 may be sexually dimorphic and is minutely subchelate, subchelate or chelate and propod mitten-shaped in females, in immature and in many terrestrial males. In semi-terrestrial males it often is powerfully subchelate and of “amplexing” form. The pereopods are slender and spinose. Pereopods 3–4 may or may not be alike and are not sexually dimorphic. Pereopod 4 may have a small postero-ventral lobe. Pereopods 5-7 tend to be dissimilar in form and size. Their coxae are equilobate or with postero-ventral, postero-dorsal or large antero-ventral lobe. Pereopod 5 is usually much shorter than pereopod 6 and 7. The three pleopods are slender and may be modified, reduced or vestigial. The urosome is short with segment 2 and 3 usually telescoping into segment 1. It is without slender or robust dorsal setae. Urosomite 1 and 2 are well developed with moderately long linear rami, which are apically and frequently marginally spinose. Uropod 1 is regularly set on short ‘prepeduncle’. Uropod 3 is small with short outer ramus. The inner ramus is generally lacking. The telson lobes are short and variously fused frequently into a single plate and often separated to the base, with apical and commonly dorsal spines. Coxal gills are short, plate or sac-like, in marine intertidal species or large, pleated, convoluted or lobal in most terrestrial species. Sternal gills are absent. The brood plates are broad and often linear and rarely absent. The oostegites fringing setae are simple or curl-tipped.

Currently there are 63 genera in the family Talitridae. *Orchestia gammarellus* was the first species in this family to be described in 1766 by Pallas. The genus *Orchestia* was described a few decades later by Leach in 1814. As new discoveries were made, the number of species within this genus kept on increasing. Characterisation of genera and species historically were based nearly exclusively on characters of the gnathopods. Only in the last few decades were descriptions sublimated by more reliable and important characteristics of all body regions (Bousfield 1982a). This enabled Bousfield (1982a) to constrict the description of the genus *Orchestia*. In 1982 and 1984 he created 15 new genera from species originally found in the genus *Orchestia*. Among these were *Platorchestia*, *Floresorchestia* and *Eorchestia* which are also found in South Africa.

## **Beachflea Ecology –based on *O. gammarellus* and *P. platensis***

The ecology of both *Orchestia gammarellus* and *Platorchestia platensis* were studied in detail by Dahl (1946) on the Danish and Swedish coast. He observed that the two species were very rarely found together, although they inhabit the same biotopes and regardless that they are not hostile towards each other. His studies found that *P. platensis* are more successful in their habitat except if food is scarce. Simpson (2011) states that *P. platensis* co-existing with *O. gammarellus* were often found out-competing them by enduring lower salinities and up to 30% water loss. Supralittoral habitats are frequently subject to major changes in salinity as a result of inundation by sea water during high tides, or fresh water in the course of land run-off and rainfall, or through evaporation (Merritt & Spicer 1996). Furthermore *P. platensis* are more active jumpers, thereby better evading predation. Talitrids living on land are the only species that are able to leap. They do this by suddenly extending the in-tucked, short posterior end of their body. This leap thus is undirected, with the result that the individual may land almost anywhere. Multiple consecutive leaps ensure a higher probability to reach safety (Reid 1947). Although these talitrids live on land, they do not avoid the water (Dahl 1946). Persson (2001) determined that both species can survive submerged for more than 3 months.

*P. platensis* according to Dahl (1946) also has a greater reproduction power than *O. gammarellus*, due to a longer period of reproduction, faster rates of development and larger brood sizes for females (Simpson 2011). Both species breed seasonally, during the warmer months and have multiple broods. Ingólfsson *et al.* (2007) showed that temperature shapes the breeding period of these beachfleas. This could be due to the fact that low temperatures markedly limit their activity (Pavesi *et al.* 2007). The egg maturation and hatchling brood time of *O. gammarellus* is 13-15 days and that of *P. platensis* is 15 days (Conlan 1991). Mature females can only be fertilised directly after moulting, when the cuticle is flexible enough to permit the release of the eggs through the genital pores into the brood pouches. For fertilisation to be successful the male consequently has between a few hours to a few days (species dependent) between moulting and ovulation to deposit sperm into the brood pouch (Conlan 1991). Different mating behaviours have therefore developed

to ensure reproductive success. Talitrids are mate-guarding carriers. The male grasps the female's dorsum or lateral plates and holds her with his first gnathopod until she eventually moults, using his second gnathopods to fend off other males (Conlan 1991). Morino (1975, 1978, 1981) studied the life history and breeding activity of *P. platensis* in great detail. He further looked at the growth and development of the gnathopods and other dimorphic body parts with detailed drawings. Studies by Dahl (1946), Moore & Francis (1985), Dias & Sprung (2004) and Ingólfsson *et al.* (2007) among others looked at the life history, population dynamic and productivity of *O. gammarellus*.

Whereas no aspects of the biology of *O. gammarellus* has been studied in South Africa so far, a recent study by Hodgson *et al.* (2014) looked into the density, population structure, growth, mortality and aspects of reproduction of *P. platensis* in Knysna Estuary.

## **Habitat and Dispersal**

The intertidal talitrids displays a key role in the functioning of coastal habitats such as sand and salt marshes, estuaries and beaches, mainly due to their role in the decomposition processes of organic matter, algae and other vegetation (Mantzouki *et al.* 2012). As the macro-invertebrate fauna of wrack is often dominated by talitridaen amphipods (Hodgson *et al.* 2014) they can be considered a main contributor in secondary production (Mantzouki *et al.* 2012). In addition, due to its high densities and biomass in some regions they represent the main food resource there for some insects (Pavesi *et al.* 2007), birds and juveniles of several fish species when land is flooded by the tides (Mantzouki *et al.* 2012). *P. platensis*, unlike some other Talitridae, has been observed in a variety of habitats. These include wrack beds, pebbly, rocky and stony shores, sandy shores, estuaries, salt marshes and beneath dead leaves on the upper shore (Pavesi *et al.* 2007; Simpson 2011). *O. gammarellus*, unlike *P. platensis*, is generally absent from sandy shores according to Persson (1999,2001) and prefers wrack beds on harder substrata such as rocks, stones, gravel, and shore meadows (Persson 1999). In South Africa, *O. gammarellus* has been observed on sandy shores though and Dahl (1946) also found little difference in the habitats the two species inhabit.

Many studies have dealt with the theory of supralittoral amphipods dispersal (Henzler & Ingólfsson 2008; Wildish *et al.* 2012; Baldanzi *et al.* 2013; Faninia & Lowry 2014), especially in northern Europe, where *P. platensis* is spreading (Persson 2001; Simpson 2011; Wildish 2012) and invading new coastlines. Both human mediated and natural dispersal has been considered.

Among human mediated dispersal mainly ballast water is being investigated, and it is believed that this might be the most common dispersal method currently (Simpson 2011). Most studies examine dispersal methods, so as to understand how to reduce synanthropic dispersals today. Few studies look into historic distribution methods. Many *P. platensis* and *O. gammarellus* records were established in the first half of the 1900's showing already well established populations, suggesting that the introductions were made over a century ago and earlier at a time where ballast water did not exist. Griffiths *et al.* (2009) therefore suggest that dry ballast was a cause of many introductions around the world from the 15<sup>th</sup> to 19<sup>th</sup> century and that this was the means these two species utilised to arrive on the South African coast.

Natural dispersal considered by scientists is rafting on wrack that was swept away by the sea, log rafting, being carried by sea currents, and clinging to birds and other animals. Although mentioned as a possibility, the latter (clinging to birds and other animals) have not been researched as yet. Talitrids are also not generally species affiliated to log rafting and therefore this method of dispersal is also less likely. According to Simpson (2011) it can be assumed that the most widespread natural methods of dispersal for these species are moving with ocean currents. Rafting on wrack could precede this. For rafting to occur, the re-floating of wrack stranded on a beach or marsh has to take place. This only happens when strong offshore winds coincide with a rising tide at full flood. The wrack raft itself has a relatively short life and usually will break up at sea, with the loss of all passengers, before making another landfall (Wildish 2012). Persson (2001) believes the ability of these animals to be submerged for longer periods of time (more than 3 months) demonstrates that dispersal is, in theory, possible over long distance, not only in ballast water, but also in ocean currents after their raft disintegrates. Both species have been observed on wrack rafts, although *O. gammarellus* only once (Henzler & Ingólfsson 2008). Simpson (2011)

stated that *P. platensis* clings tenaciously to anything floating. This gives this species a stronger dispersal power. *O. gammarellus*, on the other hand, is a poor or unwilling swimmer according to Henzler & Ingólfsson (2008). Rafting therefore is unlikely to be a regular dispersal mechanism in *O. gammarellus*.

### Chapter 3 – SPECIES CHARACTERISTICS

Identification of supralittoral talitrids are generally conducted by examining secondary sexual characters of male specimens, which differ between species. Females of different species, by contrast, are hardly distinguishable. The difficulty of proper identification becomes evident when considering that only approximately 10 percent of the specimens of both non-native species collected for this study showed some or all secondary sexual characteristics, despite the fact that larger individuals were targeted during the collection process.

*Orchestia gammarellus* and *Platorchestia platensis* hatch looking like miniature versions of mature females. Differences to mature females are found only in size and body proportions, number of flagellum articles and lack of visible sexual characteristics. Developing keys for juvenile and female specimens could be possible, but are complicated by the fact that the few observed differences are difficult to specify or quantify unless compared to another species. For example characteristics such as “more spinose” and “shorter segment” or “smaller, less marginally setose” that have been used in describing *Platorchestia* are of little use when observing only specimens of one species. Concrete differences, such as presence or absence of unique characters, are needed for positive identification. For this reason growth and development patterns have most probably also been neglected as aspects for species identification, although they are mostly unique to each species and could assist in species identification. For this reason a study was conducted later in this chapter to record the unique relationship between growth and development of certain body characteristics.

South Africa’s two foreign beachfleas are closely related, indeed until 1982 they were both classified in the same genus, *Orchestia*. However, Bousfield (1982a) created a new genus *Platorchestia* using *P. platensis* as its type species. *Platorchestia* differs from *Orchestia* mainly in the generally more spinose appendages, powerfully incrassate antenna 2 in males, short segment 5 (carpus) of pereopod 4, right-angled and processiferous hind lobe of coxa 6, marginally unarmed or weakly armed outer ramus of uropod 1, more heavily spinose pleopod peduncles, and smaller, less marginally setose brood plates (Bousfield 1982a). The following account provided taxonomic references to each species, describes the key

identification features of each and gives an account of how key taxonomic features change in appearance during growth.

## Species Descriptions

### *Orchestia gammarellus* Pallas, 1766

(Figure 3.1 and 3.2)

<i>Orchestia gammarella</i> ,	Stephensen 1935, pp. 5.
<i>Orchestia gammarellus</i> ,	Reid 1947, pp. 12-13, fig. 5.
<i>Talorchestia inaequalipes</i>	Barnard 1951, pp. 705-706, Fig. 5.
<i>Orchestia gammarella</i> ,	Karaman 1970, pp. 21-27, TAB. VI (Abb. 44-51), TAB. VIII; Griffiths 1975, pp.170; Griffiths 1976, pp.77-80, Fig. 49, 50A, 52G/H.

#### **Material examined:**

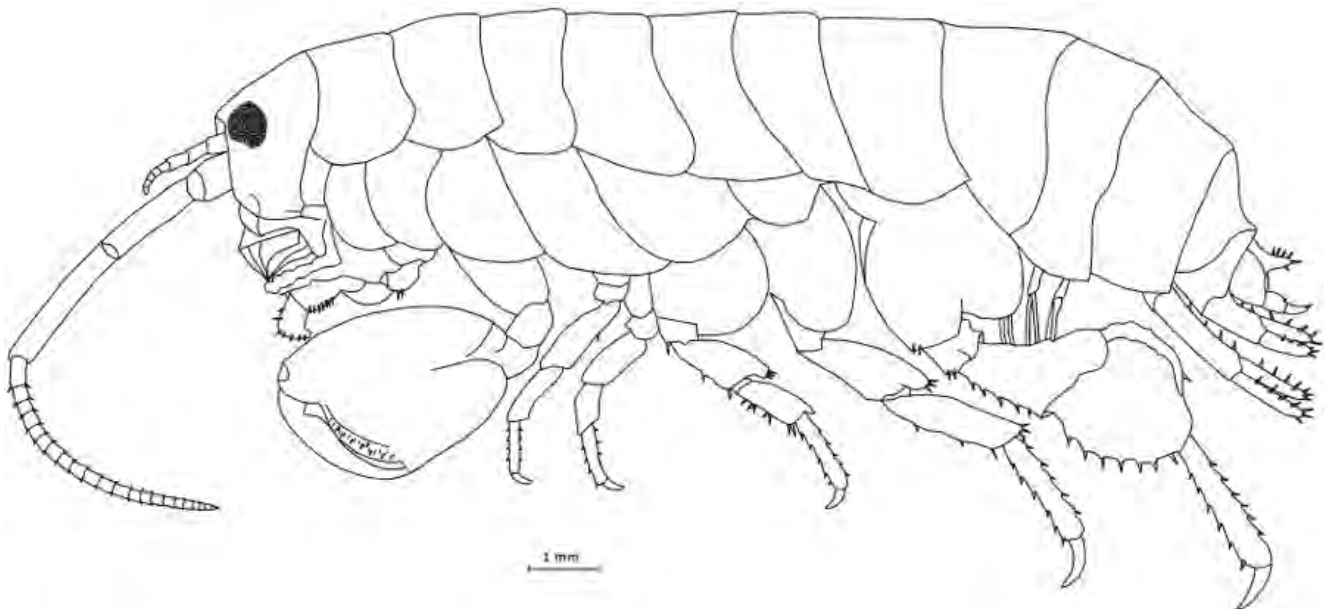
Over 500 specimens from the banks of the Diep and Berg River and Langebaan Lagoon in the Western Cape Province of South Africa.

#### **Description:**

Body robust; largest male 19mm in length; largest female 20mm in length; live specimen body colour greenish-brownish with light underside that turns orange in older specimens. In alcohol preserved specimens partially translucent with a body colour varying from white to light orange. Eyes medium to large, round and black. Preservation alcohol containing this species turns bright orange.

Antenna 1 not quite reaching distal end of second article of antenna 2; peduncle consisting of three articles, first article shorter than article 2 and 3; peduncle similar in length to flagellum; flagellum of 2 - 6 articles. Antenna 2 approximately half of body length; first peduncle article short, second peduncle article roughly 3 times length of first; third peduncle article roughly equal to combine length of article 1 and 2; peduncle similar length as flagellum; flagellum consisting of 5 - 21 articles in juveniles and females and 13 - 21 in adult males.

Coxae overlapping, small and nearly equally sized; coxae rounded with one small posterior tooth each, hidden by overlap. Gnathopod 1, *in males*: weakly subchelate; palm slightly spinose; carpus with a distal-posterior protrusion (hump) with spines. *In females*: gnathopod 1 weakly subchelate with a weak palm; propod and carpus appears ventro-posteriorly hairy with thin spines. Gnathopod 2 basis slightly expanded; *in males*: powerfully subchelate; apical margin of palm with small spines; propod distal end slightly wider than proximal side; propod protrudes slightly distally where it joins with dactyl, thereby causing a gap between dactyl and palm (when closed) on the ventro-anterior side. *In females*: minutely subchelate with palm extending distally to distal end of dactyl; dactyl very small; propod flattened; Peraeopod 3 and 4 almost identical with peraeopod 4 being slightly smaller. Peraeopods 5 to 7 posteriorly directed; basis broadly expanded; merus slightly triangular, posteriorly slightly overhanging carpus; merus overhang has apical spines; peraeopod 5 smallest and peraeopod 7 largest of these three peraeopods. Peraeopod 7 in mature males flattened and expanded (oar-like) and merus strongly triangular through distal-posterior expansion.



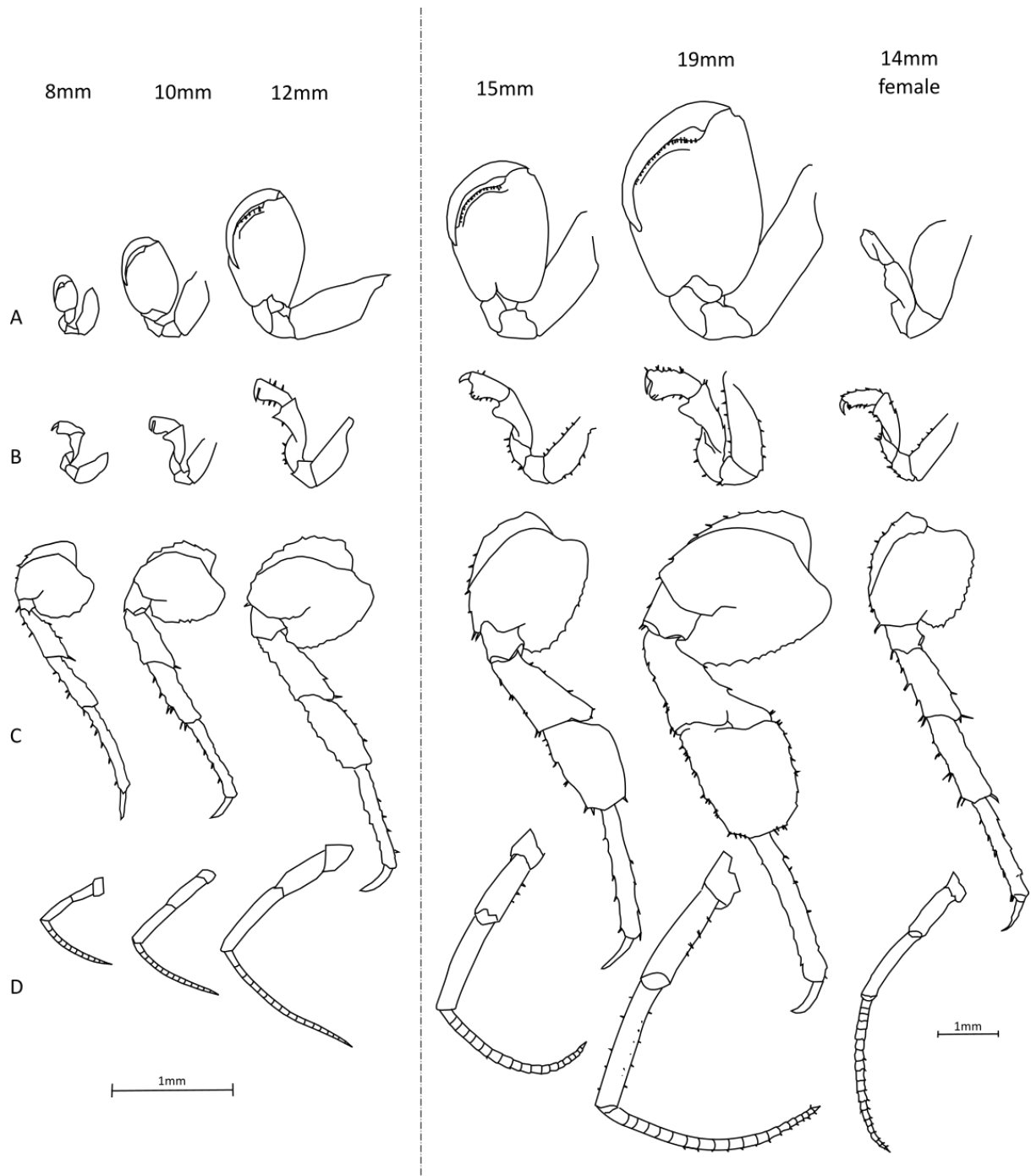
**Figure 3.1.** Lateral view of a 19mm male *Orchestia gammarellus*

Pleopods 1 to 3 slender and biramous; rami approximately the same length as the peduncle. Uropod 1 and 2 biramous with apical and marginal spines on peduncle and rami; uropod 1 peduncle roughly 1.5 times the length of rami; Uropod 2 and 3 peduncle approximately equal to length of rami. Uropod 3 uniramous; peduncle approximately equal to length of ramus; peduncle with distal spines; ramus with small apical spines. Telson with spines on the lateral-apical margin.

***Growth and development:***

Visible primary and secondary sexual characters in *O. gammarellus* are the development of oostegites in females, gnathopod 1 and 2 that develop differently in both sexes and the widening of the carpus and distal end of the merus of peraeopod 7 in males. As described above and depicted in Figure 3.2. To establish the development of these characteristics 213 specimens (148 juveniles and females and 65 adult males) were studied in more detail.

*O. gammarellus* hatch with an approximate body length of 2mm with 2 flagellum articles on antenna 1 and 5 on antenna 2. The females first become ovigerous at a minimum body length of 11mm. At this time they have at least 4 flagellum articles on antenna 1 or 14 on antenna 2. The male gnathopod 2 starts changing at a minimum body length of 8mm, when it has 4 flagellum articles on antenna 1 and 13 on antenna 2. At a body length of 13 - 14mm some males showed a gradual broadening of the carpus on the last peraeopod. At this time they displayed at least 5 segments on antenna 1 or 17 - 19 on antenna 2. All males that exceed these measurements showed dimorphism in peraeopod 7.



**Figure 3.2.** *Orchestia gammarellus*, successive change of secondary sexual characters. Row A: gnathopod 2, row B: gnathopod 1, row C: peraeropod 7, row D: antenna 2 of specimen of the body length (columns): 8mm, 10mm, 12mm, 15mm-and 19mm males and 14mm female. Rows A-C exclude coxae.

## ***Platorchestia platensis* Krøyer, 1845**

(Figure 3.3 and 3.4)

<i>Orchestia platensis</i> ,	Chilton 1921, pp. 538-541, Text-fig. 7; Stephensen 1935, pp. 8; Reid 1947, pp. 14-15, fig. 7; Karaman 1970, pp. 12-17, TAB. III, TAB. IV (Abb.25-31); Morino 1975, pp. 172-175, Text-figs. 1-3; Morino 1981, pp. 3-4, Figs. 2-3; Griffiths 1975, pp. 170-171; Griffiths 1976, pp.79-80, Fig 52B/C.
<i>Platorchestia platensis</i> ,	Stock 1996, pp. 153. Fig 2D.

### ***Material examined:***

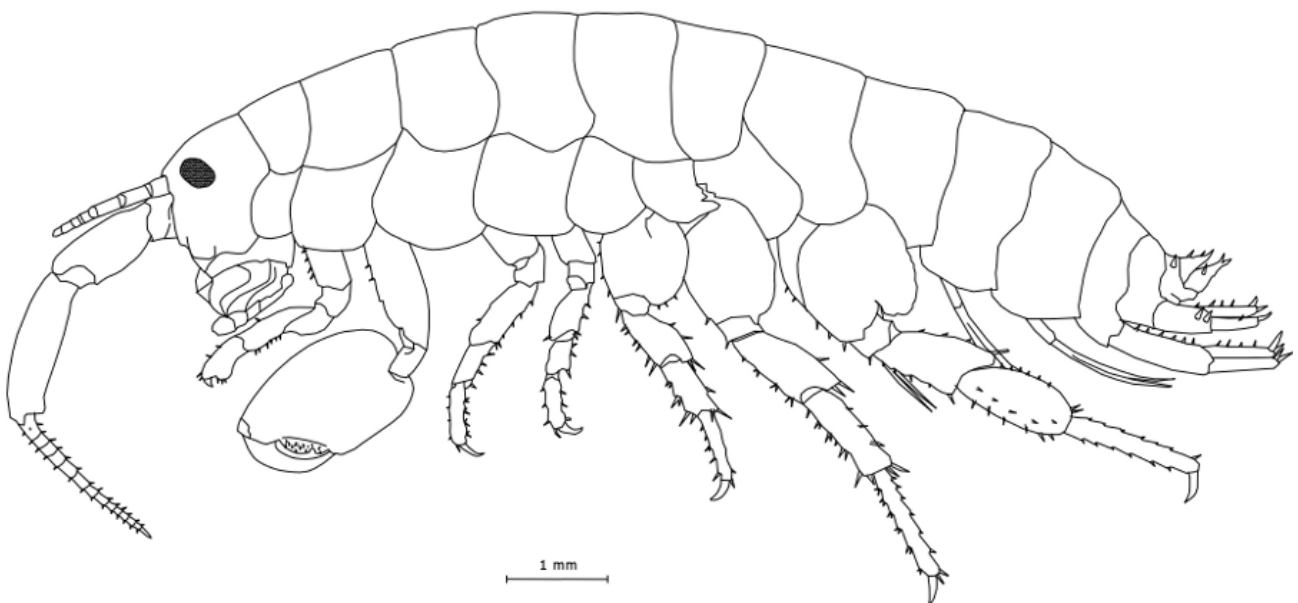
Over 900 specimens from six estuaries between Langebaan Lagoon and Keurbooms River Estuary in the Western Cape Province of South Africa.

### ***Description:***

Body robust with largest specimens reaching a length of 14mm (both male and female); males generally slightly larger than females; live specimen body colour white with grey or dark greyish teal; In alcohol preserved specimen partially translucent, with a body colour varying from white to light orange. Eyes medium sized, oval to round and black. Preservation alcohol turns dirty yellowish.

Antenna 1 reaching distal end of second article of antenna 2; peduncle consisting of three almost equal length articles, first article being slightly shorter than other two; peduncle longer than flagellum; flagellum consisting of 2 - 7 articles. Antenna 2 less than half body length; first peduncle article very short, second peduncle article roughly 3 - 4 times length of first; third peduncle article roughly twice length of second; peduncle longer than flagellum. *In males:* peduncle increasingly swollen with increased maturity; in some, not all specimens, swollen peduncle slightly dorso-ventrally flattened; flagellum consisting of 9 - 17 articles; proximal 2 - 5 flagellum articles may fuse in mature adults. *In females and juveniles:* peduncle slender; flagellum consisting of 3 - 15 articles depending on animal size.

Coxae overlapping, small and nearly equally sized; coxae rounded with one small posterior tooth each, hidden by overlap. Gnathopod 1, *in males*: weakly subchelate; palm spinose; spines on distal margin of propod; carpus with a distal-posterior protrusion (hump). *In females*: gnathopod 1 simple. Gnathopod 2 basis slightly expanded; *in males*: powerfully subchelate; apical margin of palm with small spines; in more mature males notch develops on apical margin (closer to posterior end of this margin); a groove develops where dactyl closes against palm. *In females*: minutely subchelate with palm extending distally beyond dactyl; propod flattened. Peraeopods 3 and 4 almost identical, with peraeopod 4 slightly smaller. Peraeopods 5 to 7 posteriorly directed; basis broadly expanded; merus slightly triangular, posteriorly overhanging carpus; merus overhang with apical spines; peraeopod 5 smallest and peraeopod 7 largest of these three posterior peraeopods. Peraeopod 7 in mature males with swollen, bulbous carpus.



**Figure 3.3.** Lateral view of a 12mm male *Platorchestia platensis*

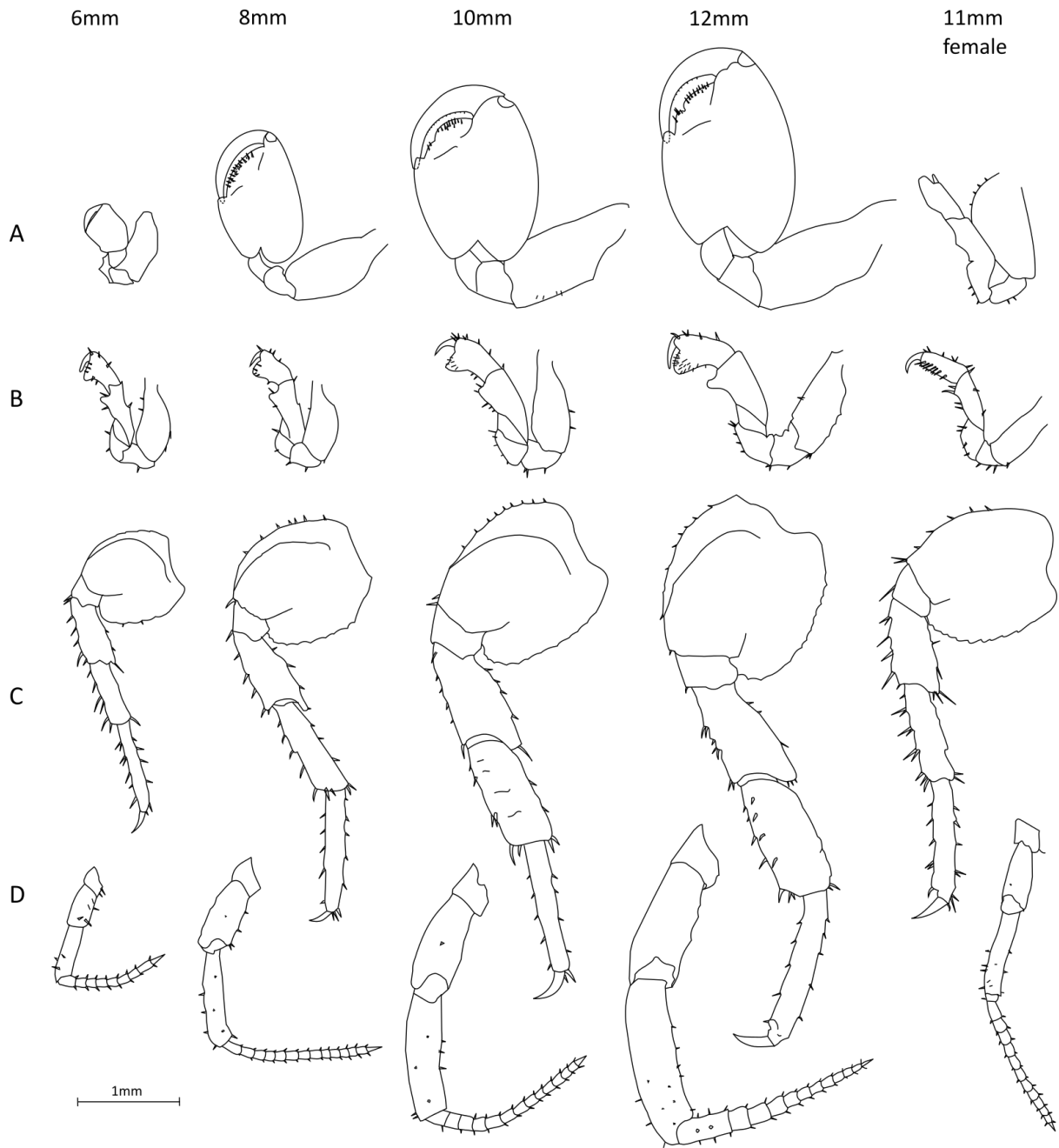
Pleopods 1 - 3 slender and biramous; rami approximately same length as peduncle. Uropod 1 and 2 biramous with apical spines; uropod 1 peduncle roughly 1.5 times the length of rami; spines on medial margin of the peduncle; only inner ramus with marginal spines. Uropod 2 peduncle slightly longer than rami; large dorsally-lateral spine on distal side of

peduncle; inner ramus more spinose than outer ramus. Uropod 3 uniramous; peduncle slightly longer than ramus; peduncle with distal spines; ramus with small apical spines. Telson with spines on lateral-apical margin.

***Growth and development:***

Visible primary and secondary sexual characters in *P. platensis* are the development of oostegites in females, gnathopod 1 and 2 that develop differently in both sexes, the swelling of the carpus of peraeopod 7 and of antenna 2 in adult males. As described above and depicted in Figure 3.4. To establish the development of these characteristics 233 specimens (107 juveniles and females and 126 adult males) were studied in more detail.

*P. platensis* hatch with an approximate body length of 1.5mm with 2 flagellum articles on antenna 1 and 3 on antenna 2. Females first become ovigerous at a minimum body length of 8mm with at least 3 flagellum segments on antenna 1 or 11 on antenna 2. The male gnathopods develop at a body length of 5mm and at least 2 flagellum articles on antenna 1 or 9 on antenna 2. At a body length of 10mm some males show a gradual swelling of the carpus on peraeopod 7 and the development of the notch on gnathopod 2 was first seen at 11mm. At these times they displayed 5 segments on antenna 1 or 13 - 14 on antenna 2. All males that exceeded these measurements showed dimorphism in peraeopod 7 and a notch on gnathopod 2. A further sexual dimorphism for this species is the swelling of antenna 2. This occurs very gradually, making it very difficult to identify when exactly it starts and when it is completed.

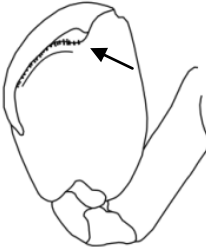
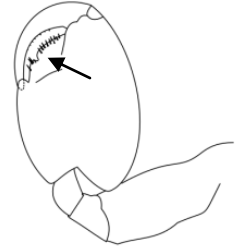
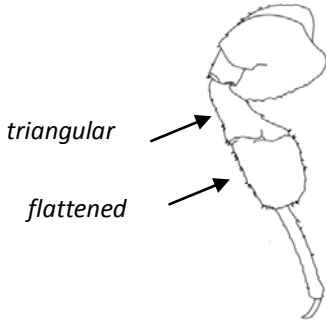
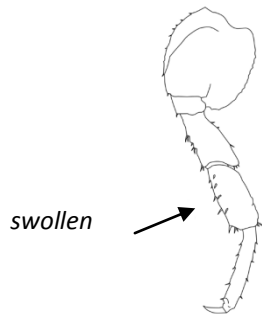


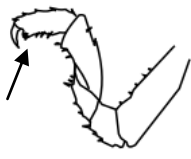
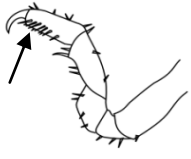
**Figure 3.4.** *Platorchestia platensis*, successive change of secondary sexual characters. Row A: gnathopod 2, row B: gnathopod 1, row C: peraeropod 7, row D: antenna 2 of specimens of the body length (columns) of: 6mm, 8mm, 10mm and 12mm males and 11mm female. Rows A-C exclude coxae.

## Species Comparison

Although closely related the two species *O. gammarellus* and *P. platensis* show a variety of differences. To summarise these are listed and shown in Table 3.1.

**Table 3.1.** Comparison between *O. gammarellus* and *P. platensis*

	<i>O. gammarellus</i>	<i>P. platensis</i>
<b>In all individuals:</b>		
Hatchling size	Approx. 2mm	Approx 1.5mm
Maximum adult size	Approx. 20mm	Approx 15mm
No. of flagellum articles at hatching	5	3
Eyes	Round and larger	Round to oval and smaller
Marginal spines on outer ramus of Uropod 1	Present	Absent
Marginal spines on outer ramus of Uropod 2	Present	Few on distal side only
<b>In adults</b>		
Antenna 2	Peduncle length equals flagellum length	Peduncle longer than flagellum
<b>In adult males:</b>		
Body length when male Gnathopod 2 develops	8mm	5mm
Gnathopod 2	 <p style="text-align: center;"><i>With gap between dactyl and propod</i></p>	 <p style="text-align: center;"><i>With notch on distal margin of propod</i></p>
Antenna 2	slender	swollen
Peraeopod 7	 <p style="text-align: center;"><i>Carpus broadly extended and flattend, merus triangular shaped</i></p>	 <p style="text-align: center;"><i>Carpus swollen and bulbous in shape</i></p>

In females:		
Size when females become ovigerous	11mm	8mm
Gnathopod 1	 <p><i>Weakly subchelate with a weak palm</i></p>	 <p><i>Simple with no palm</i></p>

The Western Cape Province of South Africa also has six native beachfleas and sandhoppers. Two of them, *T. capensis* and *A. quadrispinosa* are more commonly found on less sheltered beaches between washed up kelp. This type of habitat is not inhabited by the other beachfleas and sandhoppers in South Africa. Besides their choice of habitat, these white coloured species differ from *O. gammarellus* and *P. platensis* by having a wider, fatter body.

Of the remaining four native species there are two, *E. rectipalma* and *O. dassenensis*, that have a proportionally longer antenna 1 to the peduncle of antenna 2. The end of antenna 1 reaches the distal part of peduncle article 3 of antenna 2. This makes it very easy to distinguish them from the foreign and other native beachfleas and sandhoppers. *E. rectipalma* is also the smallest of the eight species.

The remaining two native species, *F. ancheidos* and *T. australis*, are more difficult to distinguish from the non-native species especially from *P. platensis*. Here sexually dimorphic characteristics have to be included for a correct identification. *O. gammarellus* is the largest of the eight species and most probably the only one that hatches with 5 flagellum articles on antenna 2. The female is the only one of the four that has a weakly subchelate gnathopod 1; those of *F. ancheidos* and *T. australis* both being simple. Both, *O. gammarellus* and *T. australis* have marginal spines on all their uropods outer rami. In contrast to *F. ancheidos* and *P. platensis* that only have apical and no marginal spines on the outer ramus of the first uropod. Lastly, the easiest way to distinguish *F. ancheidos* from *P. platensis* is through the shape of the male gnathopod 2. It is distally wider and has a noticeable perfect rounded,

concave distal margin on its propod upon which the dactyl closes. A further difference is found only in mature males, where the antenna 2 and the carpus of peraeopod 7 is swollen and square instead of swollen and bulbous/round as in *P. platensis*.

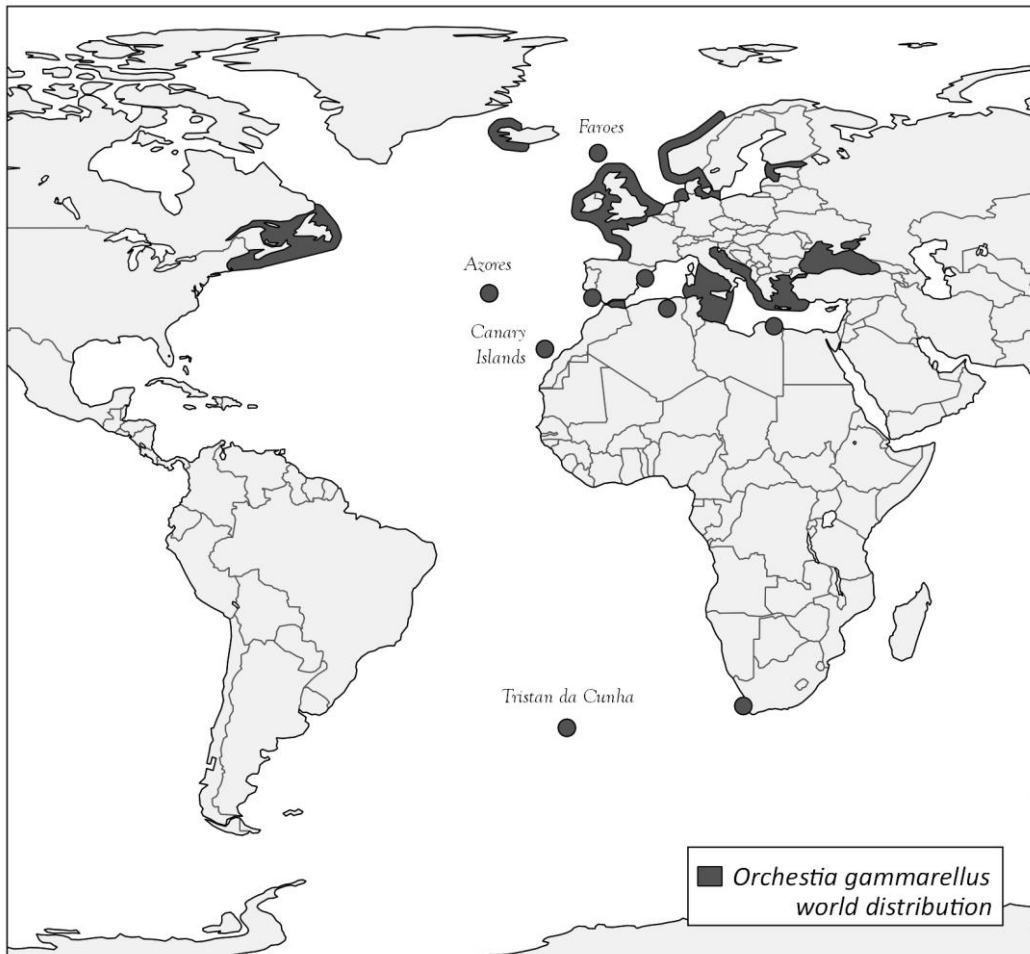
It is clear that the knowledge of all anatomic characteristics, in both sexes and all growth stages, of a species greatly improve the identification success. This can allow for the identification of female or juvenile specimens, besides that of males. Documenting these characteristics therefore is of great importance to enable people to arrive at correct identifications. Knowing this of all species found in a specific region further enhances the identification success as the process of exclusions can be utilised.

## Chapter 4 –SPECIES DISTRIBUTION

### Global Distribution

The native range of *Orchestia gammarellus* covers a wide area of the Mediterranean and North Atlantic (Pavesi *et al.* 2007) as seen in Figure 4.1. It was recorded from the Black Sea and Mediterranean (Stephensen 1949; Henzler & Ingólfsson 2008), specifically the Greek coastline (WoRMS Editorial Board 2015), including Rhodes (Karaman 1970), the Adriatic Sea (Krapp-Schickel 1969), Italy (Pavesi *et al.* 2007) including southern Sardinia and Sicily (Karaman 1970), Malta (Moore & Schembri 1986), Kerkennah Islands (WoRMS Editorial Board 2015) and La Galite Island off Tunis (Karaman 1970), parts of Libya and Algeria (Karaman 1970) and the Mediterranean coast of Morocco (Dias & Sprung 2004) and Margalef in Spain (Karaman 1970). In northern Europe it was found in the Baltic Sea, particularly the Estonian coastline (WoRMS Editorial Board 2015), along the Swedish coast including Gotland (Persson 2001) and along the Danish east coast (Dahl 1946; Moore *et al.* 1991). It was further recorded from the Atlantic along the western Norwegian coast all the way up to Lofoten (Stephensen 1929; Henzler & Ingólfsson 2008), along the German coast (Persson 2001), parts of the Netherlands coast and the French, English and Irish coasts (WoRMS Editorial Board 2015), the Scottish coast (Moore 1986; Moore & Rainbow 1986, 1987; Moore *et al.* 1991) and in southern Portugal (Dias & Sprung 2004). It was observed on some north Atlantic islands; these include the Faroes, Azores and Canaries (Stephensen 1929, 1949) and on the western coast of Iceland (Ingólfsson *et al.* 2007; Henzler & Ingólfsson 2008). In the north-west Atlantic it inhabits areas along the north eastern USA, north of 42N (Watling 1979) and Canada (Persson 2001) from Main to Newfoundland (Henzler & Ingólfsson 2008). In the south Atlantic it was introduced to Tristan da Cunha (Stephensen 1949) and South Africa (Griffiths 1975; personal collections).

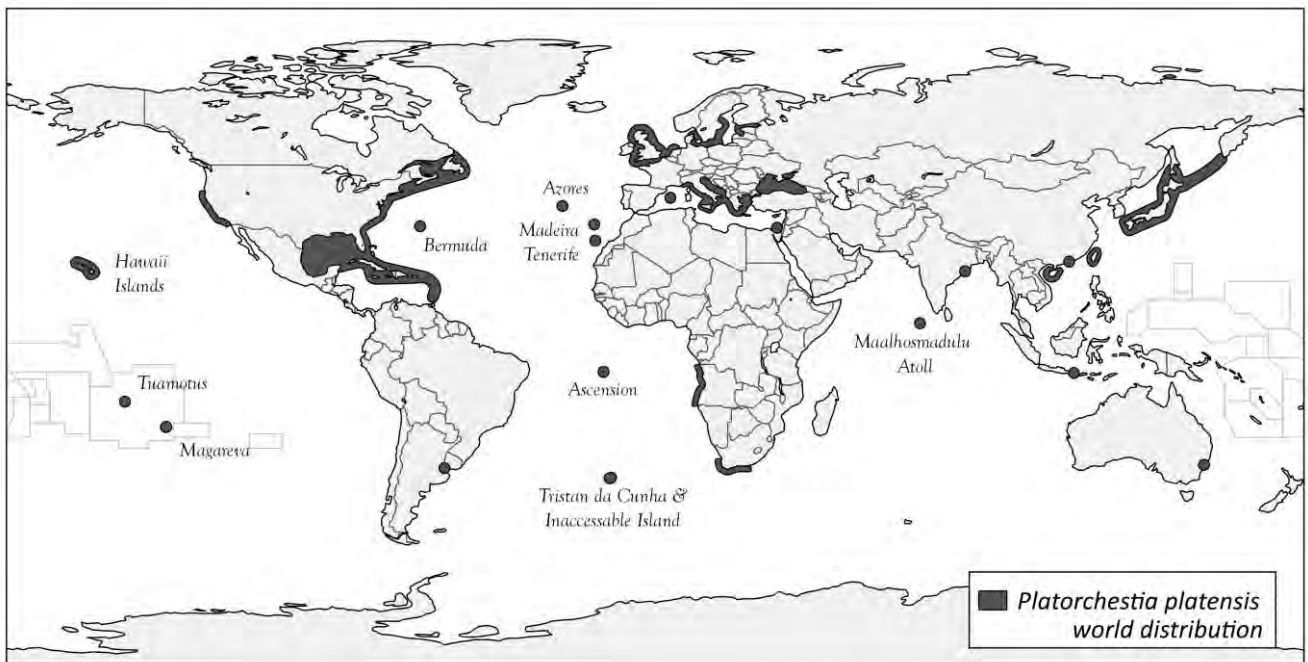
Stephensen (1935) lists and questions its occurrence in Illawara, New South Wales on the east coast of Australia where it was apparently recorded by Stebbing in 1906. This location therefore was excluded from Figure 4.1.



**Figure 4.1.** Known distribution of *Orchestia gammarellus* worldwide.

*Platorchestia platensis* is a cosmopolitan species distributed both in the temperate and tropical region (Persson 2001; Pavesi *et al.* 2007) of all oceans as seen in Figure 4.2. It was first described from Rio de Plata, Uruguay by Krøyer (Chilton 1921). Its native range is not known. This species has been recorded from the North American Atlantic coast from Florida to Newfoundland (Chilton 1921; McDonald 1987; Morino 1978; Watling 1979) in the Gulf of Mexico (Touzet 1979), the West Indies (Morino 1978) and Lesser Antilles (WoRMS Editorial Board 2015). In the Pacific it inhabit the California coast (Chilton 1921) and Hawaiian Islands (Morino 1975, 1978) as well as the Polynesian islands Magareva and Tuamotus (Stephensen 1935). It is found on Bali, Indonesia (Stephensen 1935), in Japan including South Sakhalin, Aniwa Bay and Kuril Islands (Morino 1975,1978), on Hainan Island, Hong Kong (Hou & Li 2003) and Taiwan (Karaman 1970) and in New South Wales, Australia (Stephensen 1935) as well as from India (Chilton 1921) and Mahlosmadulu Atoll in the Maldives. *P. platensis* has been recorded from Africa in South Africa (Hodgson *et al.* 2014), Angola and the Democratic

Republic of Congo (Stephensen 1949). It has been observed on a number of Atlantic islands, these being Tristan da Cunha (Macnae 1953) and Inaccessible island (Barnard 1965), Ascension (Stock & Biernbaum 1994; Stock 1996), Bermuda (Chilton 1921), Canary Islands (Morino 1978), Madeira (Dahl 1950), and the Azores (WoRMS Editorial Board 2015). It inhabits the Black Sea (WoRMS Editorial Board 2015) and Mediterranean waters (Chilton 1921); here it was seen in the Adriatic Sea on the Croatian, Montenegrin and Italian coast (Karaman 1970). It is also found on the west coast of Italy (Diviacco 1982, 1983) from Sicily all the way north along the Gulf of Geneva to Monaco in France (Karaman 1970), on the Mediterranean island of Menorca (Karaman 1970), in Greece (WoRMS Editorial Board 2015), Israel and Sinai (Morino & Ortal 1995). In northern Europe it inhabits the Baltic Sea, where it is found along the Estonian coast (WoRMS Editorial Board 2015) and in the south-west along the Swedish, German and Danish coast (Morino 1975; 1978) and also from Poland (Simpson 2011). Lastly it is known from the Dutch Wadden Sea (Persson 2001), Belgium (WoRMS Editorial Board 2015), the English Channel (Persson 2001) and Great Britain (Wildish & Lincoln 1979). Some publications mention Korea as another country that hosts this species, but according to Jo (1988) these are misclassifications of *Platorchestia crassicornis*.



**Figure 4.2.** Known distribution of *Platorchestia platensis* worldwide.

## South African Distribution - Historical and Current

The two introduced beachfleas reported from South Africa have complicated histories, filled with misidentification and inaccurate documentation of distribution records. In this short chapter historical records are re-examined and corrected where necessary and an attempt is made to establish the true current distribution pattern of each species.

The Western Cape has over 50 estuaries and lagoons, all being potentially suitable to inhabit South Africa's two foreign beachfleas. To establish the true distribution pattern of these species, 17 of these estuaries and lagoons (including one estuary from the Eastern Cape) were searched and 32 samples collected and identified. Four samples contained *O. gammarellus* and 14 *P. platensis*. A detailed list of these estuaries and the species sampled in each can be found in Appendix A2. Appendix B contains all detailed estuary maps showing specific sample locations.

### *Orchestia gammarellus*

The first report of this species from South Africa was of a sample collected on 25 April 1949 from Langebaan Lagoon by the University of Cape Town Ecological Survey. Barnard (1951) identified the specimens of this sample as *Talorchestia inaequalipes*, which he believed to be a new endemic species. The specimens were therefore stored as type species at the South African Museum (reference no. SAM A19004). It has since been discovered by Griffiths (1975) that this species is in fact *Orchestia gammarellus*. The museum catalogue and sample label states its location to be "From rotting weed at drift line at high tide on sandy shore at the foot of Constable Hill". The species is also listed as abundant. There is therefore no doubt that *O. gammarellus* historically occurred in Langebaan Lagoon. Current searches for this species around Langebaan Lagoon found them on the beach, across the lagoon from Constable Hill. The species found around Constable Hill were *P. platensis* and *O. dassenensis*. *P. platensis* is known from Europe to have displaced other talitrids, suggesting that this could be what happened to *O. gammarellus* on the Constable Hill side of the lagoon.

Another location *O. gammarellus* has been historically documented from is Knysna. This is based on the sample KNY113 from the UCT Ecological Survey, collected from 'The Point' on 14 April 1949 and identified by K.H. Barnard as *O. gammarella*. A re-examination of this sample, which contains 19 specimens, shows that they in fact are *Platorchestia platensis*. Recent collections from the same location by Hodgson *et al.* (2014) confirm that *P. platensis* still occurs there. *O. gammarellus* has thus not ever been correctly reported from this area.

*O. gammarellus* was also reported from Milnerton by Mead *et al.* (2011) and additional collections during the course of this study confirm its presence there. During sampling for this study *O. gammarellus* was also discovered on the banks of the Berg River, which is a new locality record at which they were found to be wide-spread and abundant. A sample received from the Eastern Cape, at the very end of this study, suggest that they are also found on the West Bank of the Bushman's River. Unfortunately the sample, although large (more than 60 specimens), did not contain large male. From looking at the body size, antenna growth, gnathopod growth of the three males in the sample and other distinguishing features as well as the coloration of the alcohol they are preserved in, it can safely be said that they in fact are *O. gammarellus*.

To summarise, historically Langebaan Lagoon is the only place *Orchestia gammarellus* was collected from, early reports from Knysna being based on a misidentification. Current collections show its known locations to be Milnerton Lagoon, Langebaan Lagoon and the Berg River Estuary as seen in Figure 4.3. and from the Bushman's River in the Eastern Cape.

### ***Platorchestia platensis***

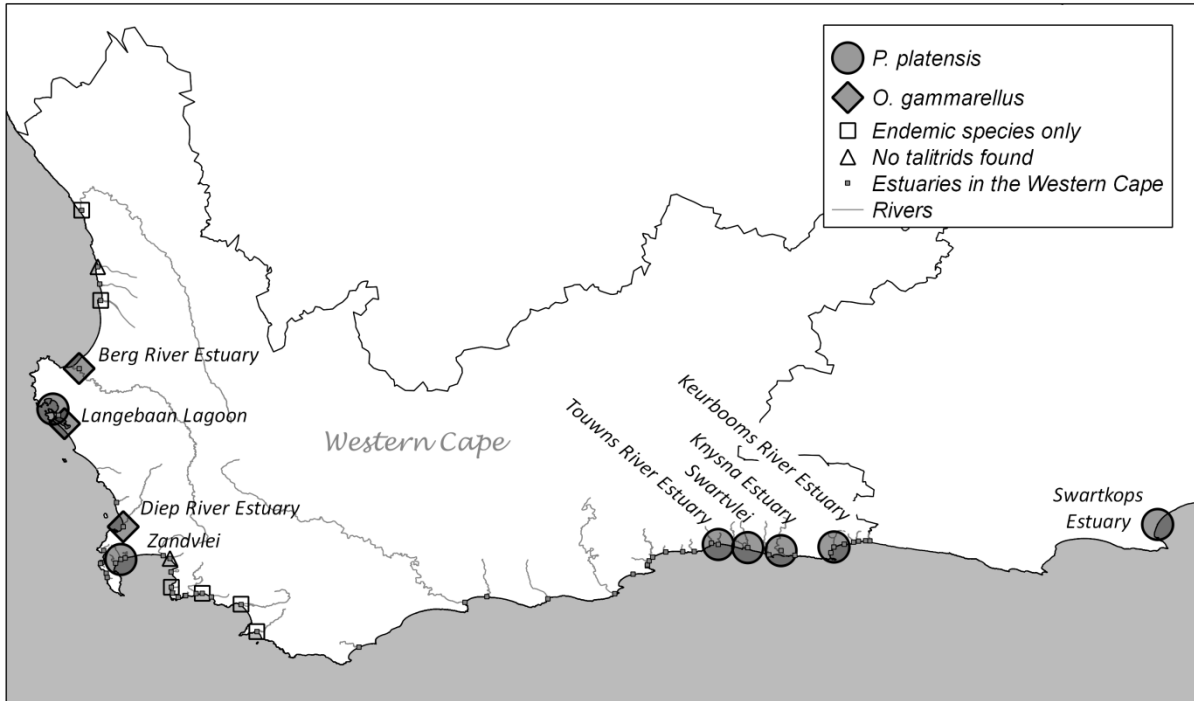
*P. platensis* was first recorded in South Africa by Griffiths (1975) based on two records from the South African Museum collections (SAM A10298 and A10309). The location was stated only as 34°S/19°E in Griffiths (1975), and no further information as to exact location, date, number of specimens etc is given in that paper. These samples were re-examined and found to comprise of 3 and 59 specimens, all collected on 17<sup>th</sup> July 1946 by B. Rand. The specimens were confirmed to be *P. platensis* (although the vials are still incorrectly labelled

*T. australis*). The collection location states Dyer's island (as K.H. Barnard called Dyer Island). Dyer Island is a small island, consisting of mainly rock, off the shore of Danger Point and does not have a suitable environment for *P. platensis* which is normally associated with estuarine conditions. It can thus be presumed that the location was mislabelled. Subsequently Mead *et al.* (2011) report this species as having been recorded from Danger Point in 1904 as per Griffiths (1975), but as stated above Griffiths (1975) in fact gives the location only by grid square and without date. Hence all that can be stated from historical records is that *P. platensis* has been collected from Knysna in 1949 (but originally incorrectly identified (see above)) and three years prior from an undetermined location in South Africa.

More recent studies by Hodgson *et al.* (2014) from 2008 to 2010 also found dense populations (up to 176000m<sup>-2</sup>) of *P. platensis* in Knysna.

Current searches found *P. platensis* to be wide-spread in the study area, where it was collected from seven different estuaries and lagoons. It was found throughout Langebaan Lagoon, in Zandvlei (Muizenberg), in the Touws River Estuary (Wilderness), in Swartvlei (Sedgefield), throughout the Knysna Estuary, in the Keurbooms River Estuary (northeast of Plettenberg Bay) and in the Swartkops Estuary (northeast of Port Elizabeth). The confirmed distribution range is therefore from Langebaan Lagoon on the West coast to Algoa Bay on the South coast. Searches further east from Port Elizabeth could potentially extend their known distribution as no samples were collected from that region.

In summary, Figure 4.3 shows the confirmed locations at which both *P. platensis* and *O. gammarellus* populations are currently known to exist. It must be emphasised that not all potential location within that range were sampled, neither have we sampled further east than Algoa Bay. Late samples received from Bushman's River, not recorded in Figure 4.3, suggest *O. gammarellus* occurs there too.



**Figure 4.3.** Current known locality records for *P. platensis* and *O. gammarellus*. Search areas where only endemic species were found or where no species were found are noted.

## Chapter 5 – RECOMMENDED FUTURE STUDIES

This dissertation is an initial step to accurately document the historic and current distribution of South Africa's foreign beachfleas. A baseline has been set, yet there are many more estuaries, especially along South Africa's South and East Coasts that potentially could host these two species. An extended search might further extend their distribution range.

Hodgson *et al.* (2014) have studied the abundance of *Platorchestia platensis* in Knysna and to date this is the only study documenting population structure of an introduced talitrid amphipod in South Africa. Similar studies could be conducted in the Berg River for *Orchestia gammarellus*, which were found there in great abundance. It would be significant to investigate the effect these two species have, especially were they occur in great numbers, on the native talitrids from the same region as well as on the ecosystem they inhabit. Knowing the location of the native beachfleas will allow for long term monitoring of the endemic fauna and could bring to light any distribution shifts that might be caused by the non-native species.

The supralittoral talitrids are strongly influenced by temperature and humidity. In Europe cold temperature reduce species abundance, whereas in Knysna heat reduced their abundance. It would be interesting to learn what their optimal environmental conditions are, which would also give insight into the effect climate change might have on their future distribution and abundance. In this regard it would be interesting to learn about the dispersal success of these species. Have they spread recently and locally from one historic introduction, or have they spread slowly over many centuries through multiple long distance introductions. Genetic studies could give insight into this.

Although a detailed description of the anatomy of these two talitrids has been documented, it would be beneficial to do the same for South Africa's native species. Although the native species have been described, some descriptions lack detail that could further aid in the identification process of South Africa's talitrid fauna. In contrast to the foreign species, South Africa's natives ones have been poorly studied.

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## Appendix A - TABLES

Appendix A1. Amphipods of the family Talitridae found in South Africa. Source: Griffiths (1976), Griffiths (1999) and Milne & Griffiths (2013).

Species	Synonym	Common Name	Distribution in South Africa
<i>Eorchestia rectipalma</i> (K.H. Barnard, 1940)	<i>Orchestia rectipalma</i> ; <i>Parorchestia rectipalma</i> ; <i>Parorchestia tennis</i>	Beachflea	Namibia to Natal
<i>Floresorchestia ancheidos</i> (K.H. Barnard, 1916)	<i>Talorchestia ancheidos</i> ; <i>Orchestia ancheidos</i>	Beachflea	Lambert's Bay to Mozambique
<i>Orchestia dassenensis</i> (K.H. Barnard, 1916)	<i>Parorchestia dassenensis</i>	Beachflea	Saldanha to Agulhas
* <i>Orchestia gammarellus</i> (Pallas, 1766)	<i>Orchestia gammarella</i> ; <i>Talorchestia inaequalipes</i>	Beachflea	Veldruff (Berg River) and Milnerton
* <i>Platorchestia platensis</i> (Krøyer, 1845)	<i>Orchestia platensis</i>	Beachflea	Langebaan to Algoa Bay (possibly further east)
<i>Africorchestia quadrispinosa</i> (K.H. Barnard, 1916)	<i>Orchestoidea fisherii</i> of Stebb.; <i>Talorchestia quadrispinosa</i>	Sandhopper	Namibia to False Bay
<i>Talorchestia australis</i> (K.H. Barnard, 1916)		Sandhopper	Namibia to Mozambique
<i>Talorchestia capensis</i> (Dana, 1853)		Sandhopper	Namibia to Port St. Johns
<i>Talitriator africana</i> (Bate, 1862)	<i>Talorchestia africana</i> ; <i>Talitriator africanus</i> ; <i>Talitroides eastwoodae</i> forma <i>typica</i>	Landhopper	From Port Elizabeth north and eastwards to KwaZulu-Natal, Swaziland and Mapumalanga
<i>Talitriator calva</i> (Barnard, 1940)	<i>Talitroides eastwoodae</i> forma <i>calva</i> ; <i>Talitriator calva</i>	Landhopper	Cape Town to Grahamstown
<i>Talitriator cylindripes</i> (Barnard, 1940)	<i>Talitroides eastwoodae</i> forma <i>cylindripes</i> ; <i>Talitriator cylindripes</i> ; <i>Talitriator insularis</i>	Landhopper	From Cape Peninsula to Hermanus and Picketberg
<i>Talitriator eastwoodae</i> (Methuen, 1913)	<i>Talitroides eastwoodae</i> forma <i>typica</i>	Landhopper	From Southern KwaZulu-Natal to Limpopo Province.
<i>Talitriator setosa</i> (Barnard, 1940)	<i>Talitroides eastwoodae</i> forma <i>setosa</i> ; <i>Talitroides eastwoodae</i> forma <i>macronyx</i> ; <i>Talitriator setosa</i> ; <i>Talitriator macronyx</i>	Landhopper	Table Mountain to Cederberg and Langeberg Mountains near Heidelberg
* <i>Talitroides alluaudi</i> (Chevreux, 1896)	<i>Talitrus alluaudi</i>	Landhopper	University of Cape Town and Claremont, Cape Town
* <i>Talitroides topitotum</i> (Burt, 1934)	<i>Talitrus topitotum</i> ; <i>Talitrus sylvaticus</i> of Shoemaker 1936	Landhopper	University of Pretoria and Pinelands, Cape Town

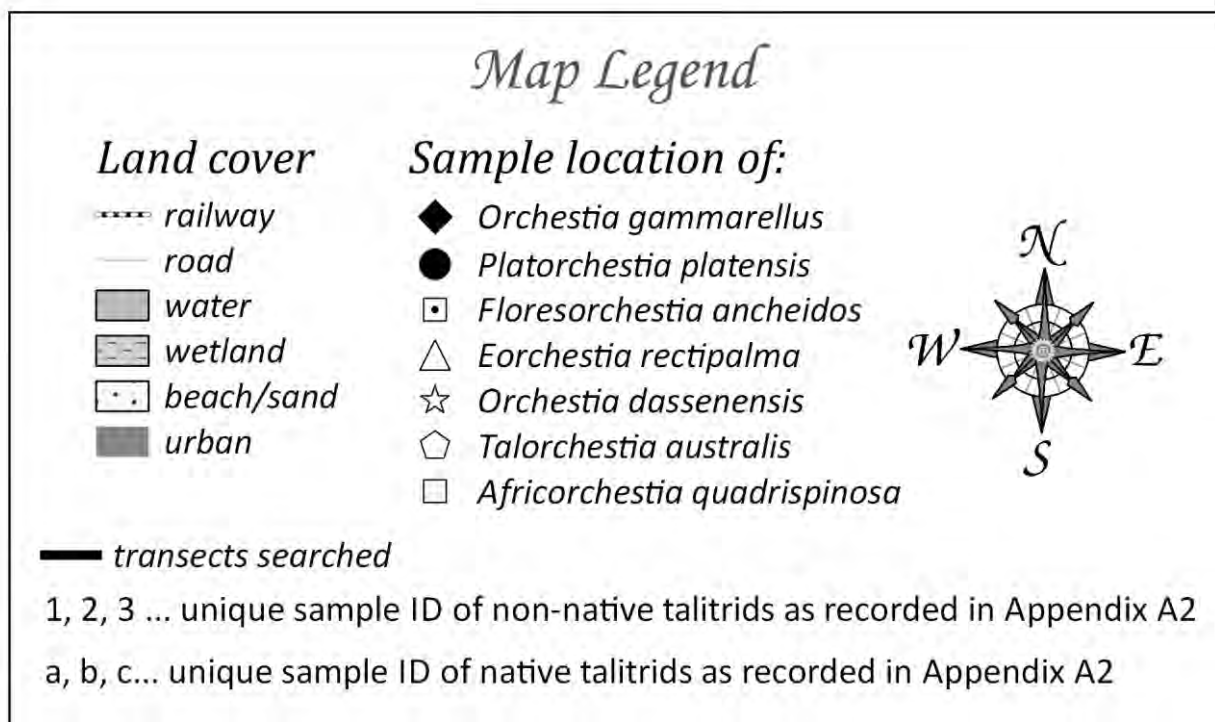
\* = Introduced species

Appendix A2. Species, location, date and collector of samples as well as number of specimens per sample collected.

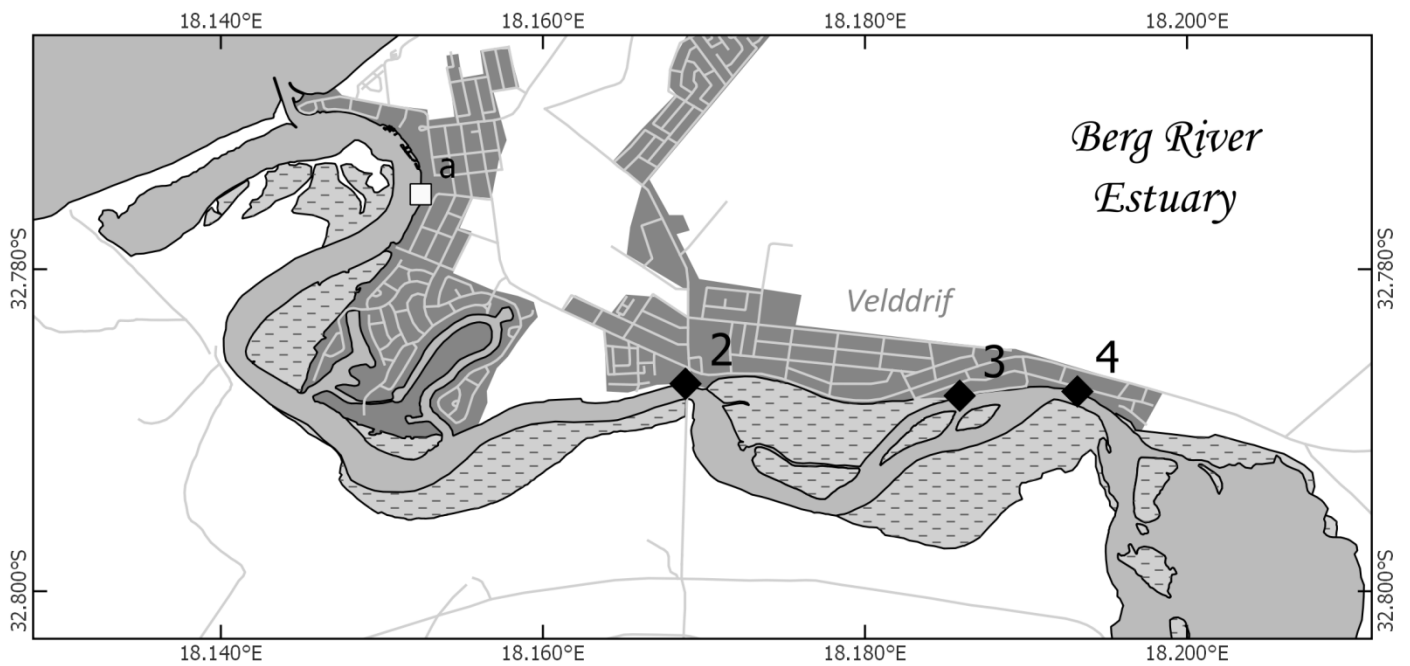
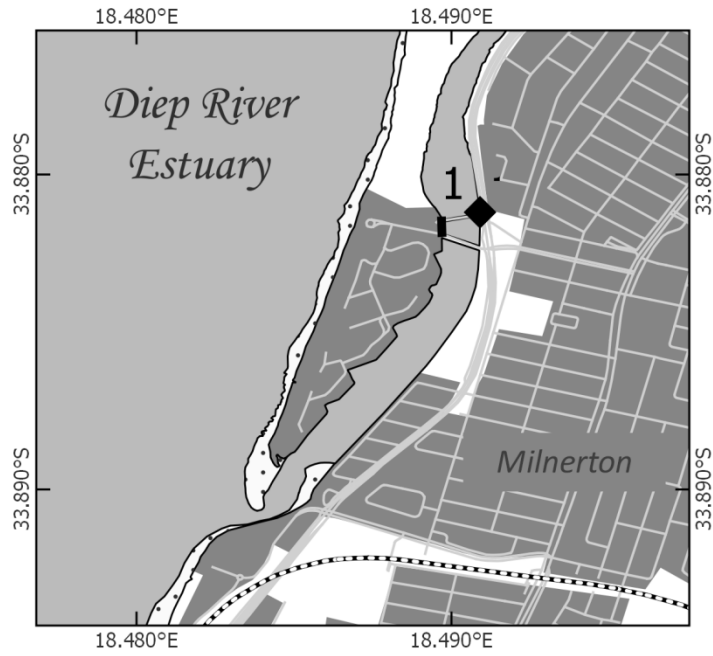
Location	Collector	Date	Sample ID	Non-native Species (incl. no of specimens collected)	Sample ID	Native Species (incl. no of specimens collected)
Diep River Estuary	C. Griffiths/ N. Diemer	30/10/2014	1	110 <i>Orchestia gammarellus</i>		-
Berg River Estuary	C. Griffiths/ N. Diemer	11/11/2014	2	38 <i>Orchestia gammarellus</i>	a	6 <i>Africorchestia quadrispinosa</i>
Langebaan Lagoon	C. Griffiths/ N. Diemer	11/11/2014	3	344 <i>Orchestia gammarellus</i>		-
			4	47 <i>Orchestia gammarellus</i>		
			5	>200 <i>Platorchestia platensis</i>		
			6	>200 <i>Platorchestia platensis</i>		
	N. Diemer	07/12/2014	7	>10 <i>Orchestia gammarellus</i>	b	>30 <i>Talorchestia australis</i>
	N. Diemer	23/12/2014	8	>30 <i>Platorchestia platensis</i>	c	14 <i>Orchestia dassenensis</i>
			9	29 <i>Platorchestia platensis</i>		-
			9	16 <i>Platorchestia platensis</i>		
Zandvlei	C. Griffiths	07/09/2014	10	>100 <i>Platorchestia platensis</i>		-
Touws River Estuary	M. Griffiths	24/08/2014	11	13 <i>Platorchestia platensis</i>		-
Swartvlei	A. Hodgson	02/10/2014	12	>100 <i>Platorchestia platensis</i>		-
			13	18 <i>Platorchestia platensis</i>		
Knysna Estuary	B. Rand	14/04/1949	14	19 <i>Platorchestia platensis</i>		-
	A. Hodgson	16/10/2008	15	13 <i>Platorchestia platensis</i>	d	>100 <i>Eorchestia rectipalma</i>
	A. Hodgson	02/10/2014	16	>10 <i>Platorchestia platensis</i>	e	>10 <i>Talorchestia australis</i>
			17	>100 <i>Platorchestia platensis</i>		
Keurbooms River Estuary	A. Hodgson	03/10/2014	18	>100 <i>Platorchestia platensis</i>	f	>50 <i>Eorchestia rectipalma</i>
			19	34 <i>Platorchestia platensis</i>	g	>50 <i>Floresorchestia ancheidos</i>
Swartkops Estuary	C. Griffiths	19/01/2015	19	34 <i>Platorchestia platensis</i>		-
Dyer's island?	B. Rand	17/07/1946	-	3 <i>Platorchestia platensis</i>		-
				59 <i>Platorchestia platensis</i>		
Olifants River Estuary	N. Diemer	15/01/2015		-	h	>90 <i>Eorchestia rectipalma</i>
Verlorenvlei	N. Diemer	15/01/2015		-	i	>30 <i>Eorchestia rectipalma</i>
Rooi Els Estuary	N. Diemer	10/01/2015		-	j	11 <i>Floresorchestia ancheidos</i>
Kleinmond Estuary	N. Diemer	10/01/2015		-	k	26 <i>Floresorchestia ancheidos</i>
Klein River Estuary	C. Griffiths	31/08/2014		-	l	10 <i>Floresorchestia ancheidos</i>
Uitenkraalsmond Estuary	C. Griffiths	30/08/2014		-	m	21 <i>Floresorchestia ancheidos</i>
Jakkalsvlei	N. Diemer	15/01/2015		-	n	2 <i>Eorchestia rectipalma</i>
Lourens River Estuary	N. Diemer	10/01/2015		-	-	-

## Appendix B – MAPS

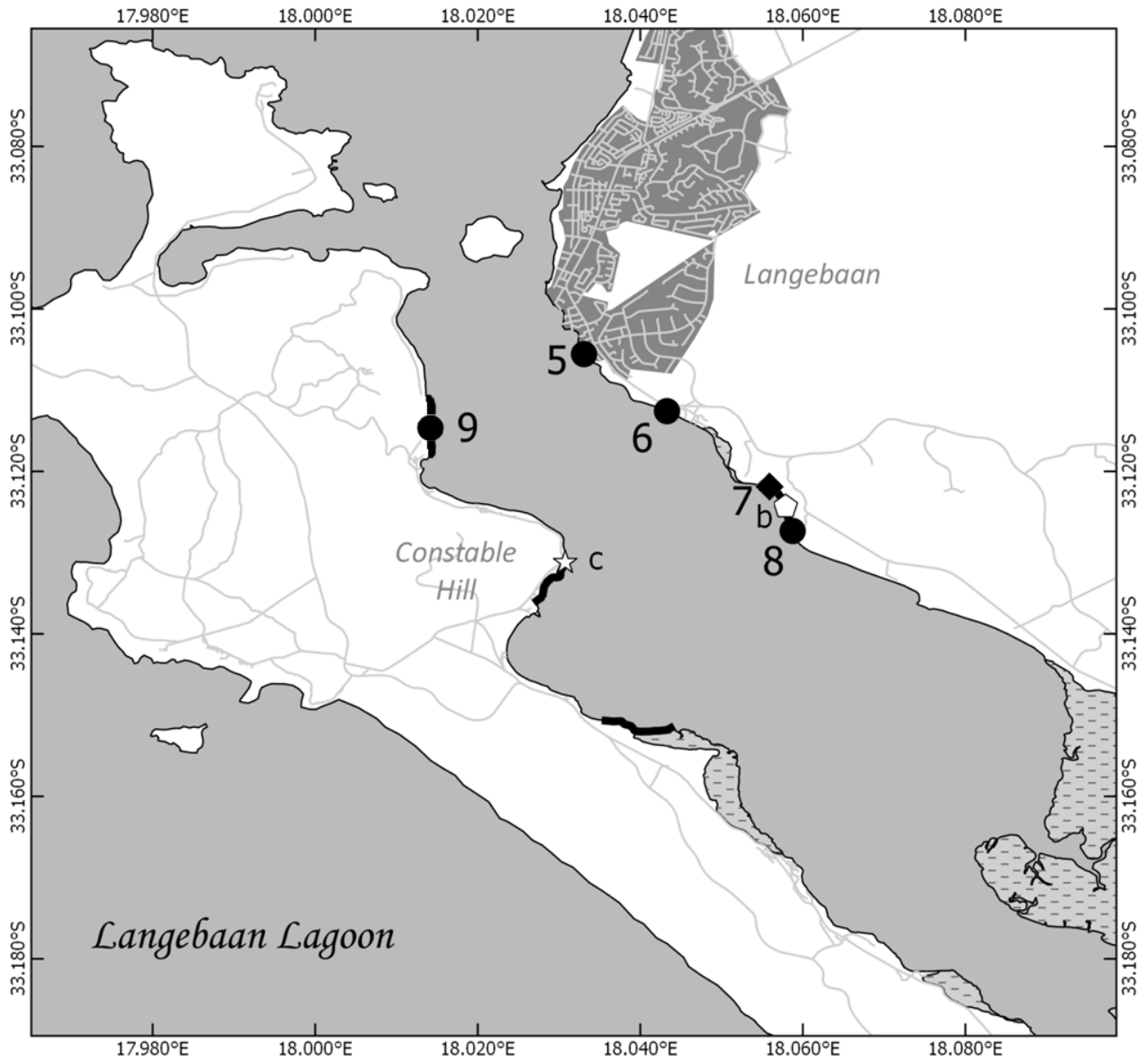
### Search Areas and Sample Collection Sights



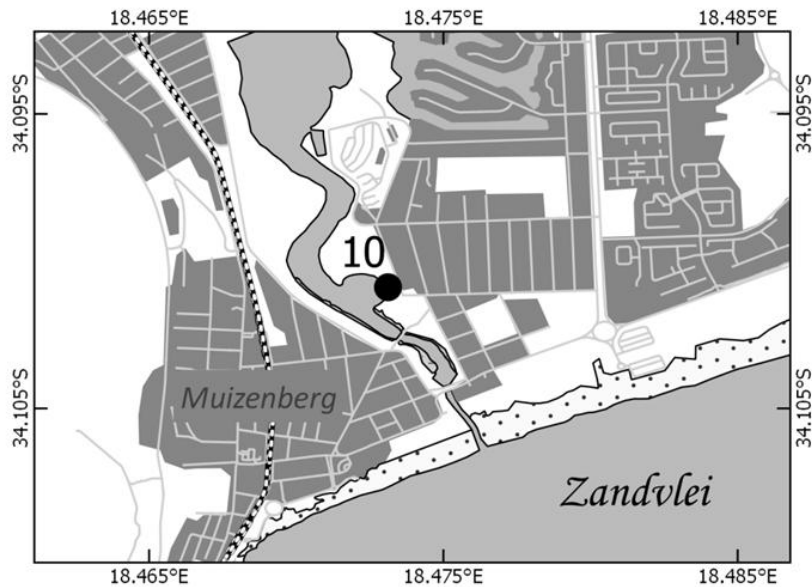
## Sample Locations - *Orchestia gammarellus*

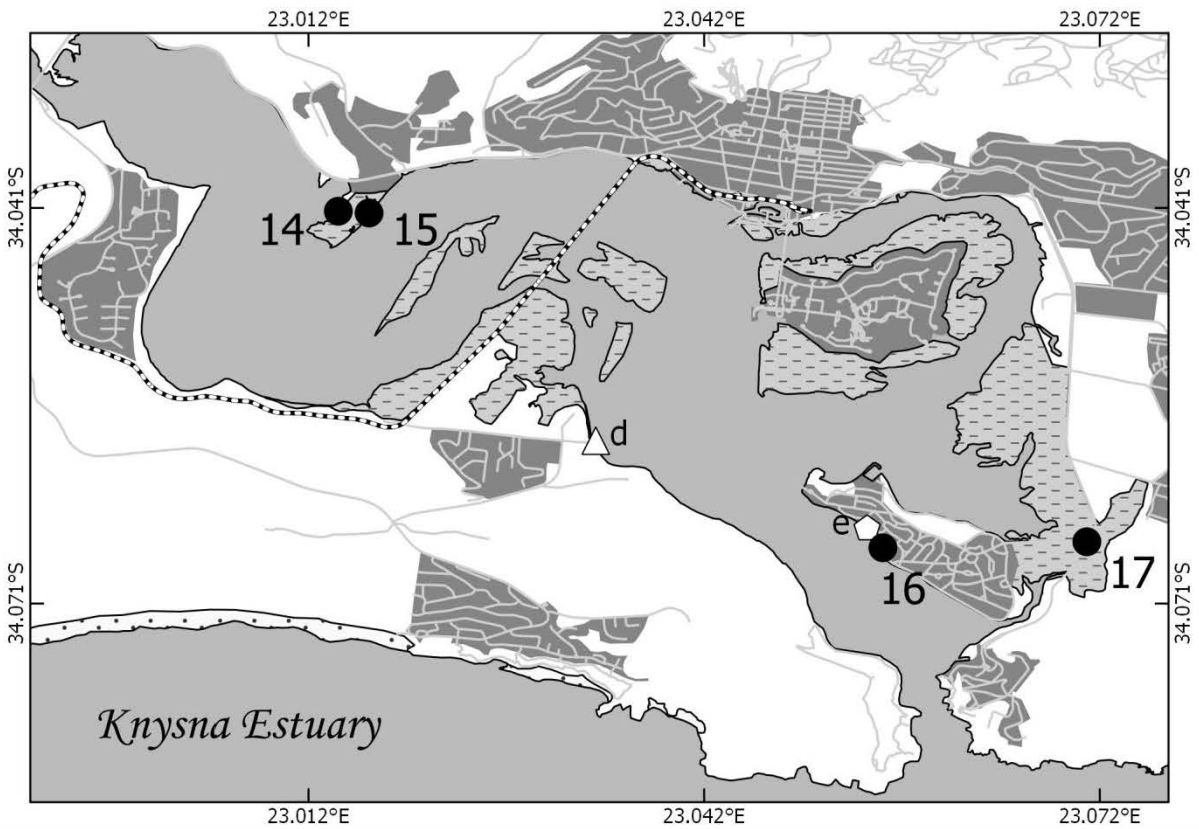
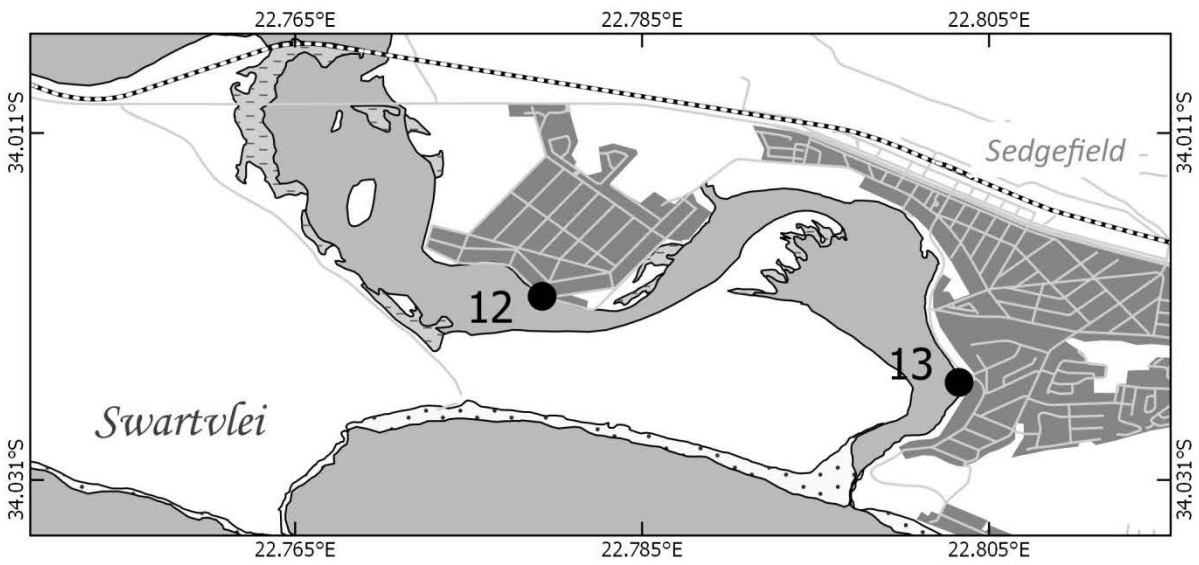
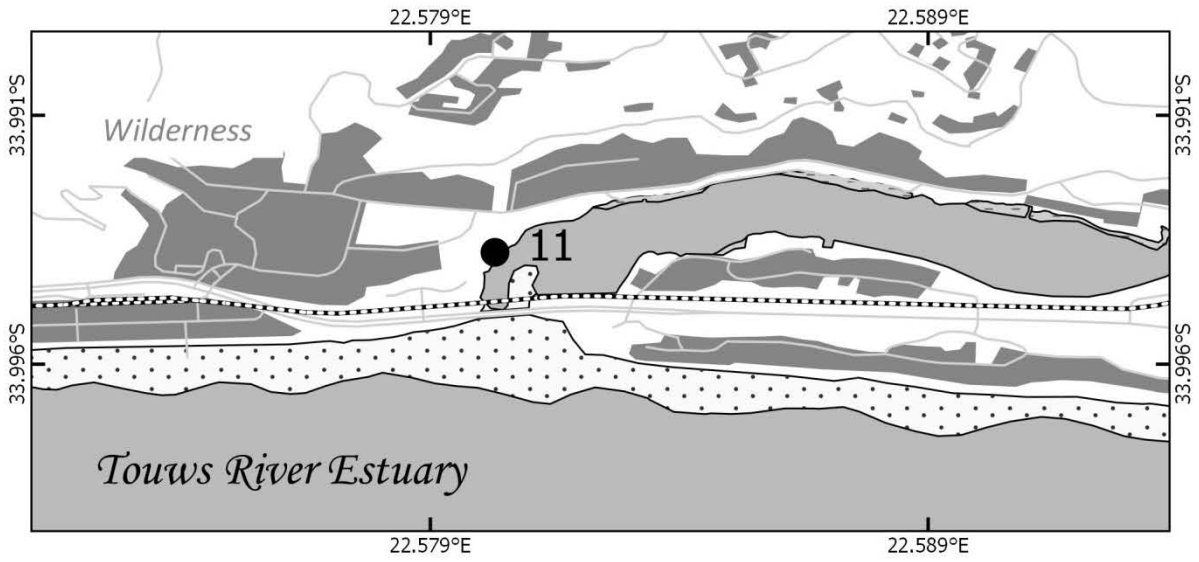


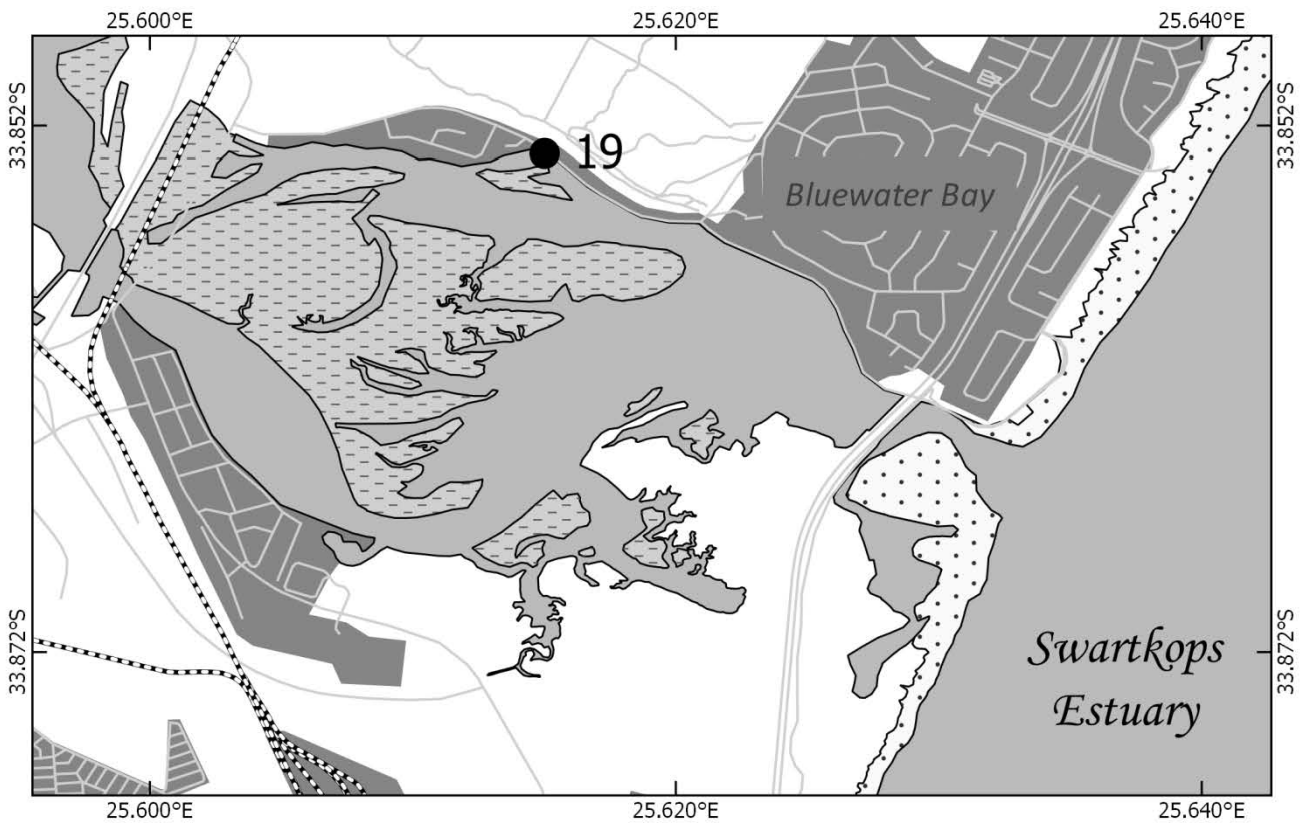
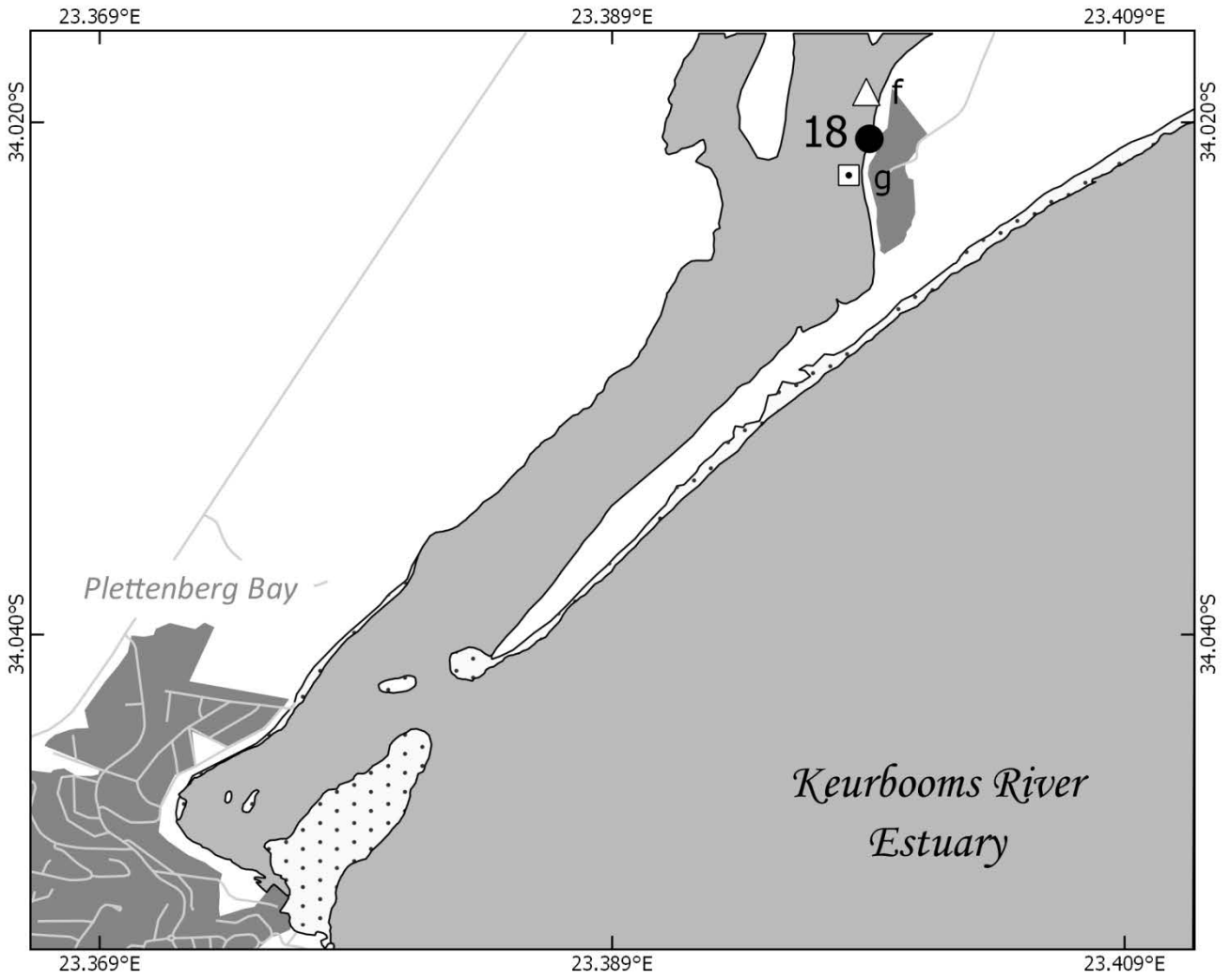
## Sample Locations - *Orchestia gammarellus* & *Platorchestia platensis*



## Sample Locations - *Platorchestia platensis*







# Negative Search Areas for Non-native Beachfleas - Native Samples Recorded

