

Methods collecting Axiidea and Gebiidea (Decapoda): a review

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Abstract

Axiidea and Gebiidae (formerly treated together as Thalassinidea) have a cryptic lifestyle. Collecting these shrimp therefore requires special field methods. The present paper reviews these methods according to habitats and provides recommendations as well as data on their efficiency. In addition, information on the preservation of these animals is presented.

Key words: Thalassinidea, Axiidea, Gebiidea, method, collecting, preservation

Zusammenfassung

Maulwurfskrebse aus den zwei Unterordnungen der zehnfüßigen Krebes Axiidea und Gebiidea (früher zusammengefaßt als Thalassinidea) kommen in temperaten, subtropischen und tropischen Meeren vor und zeichnen sich durch ein Leben im Verborgenen aus. Viele Arten legen tiefe und ausgedehnte Bauten an. Diese Lebensweise erfordert eigene Methoden, um die Krebse zu fangen. Die verschiedenen Fangmethoden werden hier vorgestellt und Angaben zur Effizienz gemacht. Zusätzlich werden Angaben zur Fixierung und Konservierung der Krebse präsentiert.

Introduction

Formerly treated together as the thalassinideans, the infraorders Gebiidea DE SAINT LAURENT, 1979 and Axiidea DE SAINT LAURENT, 1979 represent two distinctly separate groups of decapods (ROBLES et al. 2009; BRACKEN et al. 2009; DWORSCHAK et al. 2012, POORE et al., 2014). They are commonly called mud shrimp or ghost shrimp, although they are only distantly related to true (dendrobranchiate or caridean) shrimp. The Axiidea contains 9 families with 423 species distributed among 83 genera and the Gebiidae contain 4 families with 192 species in 20 genera (DE GRAVE et al. 2009). By April 2014, these numbers had increased to about 465 and 209 species, 128 and 20 genera and 14 and 4 families, respectively. The habitus of thalassinideans ranges from lobster-like with a well calcified exoskeleton (Thalassinidae, Axiidae) to weakly calcified elongated forms (Callianassidae) that show strong adaptations to a burrowing lifestyle (Fig. 1). The size of adult shrimp ranges from about 1.5 cm (Thomassiniidae, many Callianassidae) to over 35 cm (Thalassinidae).

Thalassinideans have a cryptic lifestyle. Most species burrow in various types of sediments, from coarse coral rubble to sand and mud, and even in firmer ground. Probable understudied habitats of thalassinideans include coral reefs, where many axiid shrimp live in cryptic environments. A few species of Upogebiidae and members of the family Eiconaxiidae are sponge commensals, whereas members of the upogebiid genus *Pomatogebia* bore in corals.

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All species of Thalassinidea live in marine habitats or in seawater-influenced habitats, such as reduced salinity estuaries (e.g. many Upogebiidae and Callianassidae). Members of the genus *Lepidophthalmus* are especially dominant in low-salinity habitats (MANNING & FELDER 1991), and mass migrations into rivers have been reported in Cameroon for *L. turnerana* (WHITE, 1861)(see VANHÖFFEN 1911).

Thalassinidea occur from the intertidal to water depths of more than 2000 m, but most species (95%) live in shallow water, less than 200 m deep. They occur worldwide between 71°N and 55°S and have not been found in polar regions. Their distribution shows a clear latitudinal gradient with low species numbers in high latitudes and high species numbers in low latitudes. Highest species numbers (36.5%) occur in the Indo-West Pacific followed by the Southwest Atlantic (21.6%), with two-thirds of those occurring in the Caribbean and the Gulf of Mexico (DWORSCHAK 2000, 2005).

Collecting

Intertidal

In temperate, intertidal regions, thalassinideans often occur in high population densities and are used as fishing bait or even for human consumption. Therefore, recreational as well as commercial fishermen have developed different collecting methods. This may be as simple as digging the animals up by hand [*Thalassina anomala* (HERBST, 1804) in mangrove mud, see PILLAI 1985]. Some species, such as *Nihonotrypaea petalura* (STIMPSON, 1860), *Neotrypaea biffari* (HOLTHUIS, 1991) and *Pestarella whitei* (SAKAI, 1999), occur on boulder beaches. Here, the shrimp have to be dug up from the sand between the boulders by hand. TAMAKI et al. (1999) reported a catch per unit effort (CPUE) between 1 specimen in 150 min and 50 specimens in 90 min for such shores.

Digging may be facilitated by using a garden fork or spade. In firm sediment, a spade is pushed into the sediment near the water's edge and rocked back and forth. This creates an alternating water flow with the animals swept out of their burrows and collected by hand or with a small net (as in the burrows of *Upogebia pusilla*; see DWORSCHAK, 1988).

In soft sediment, simply wading through the mud can bring animals to the surface. Wading and trampling is also used with the Kiwi method, which involves jumping on the mud until it liquefies, causing animals to float to the surface where they can be picked up by hand (TORRES et al. 1977). This method has also been described as the *Callianassa* Stomp by GARCIA et al. (2003). It consists of 8-10 researchers marching in a 5 m diameter circle on a section of mud flat. As the mud liquefies, the circle is closed, and mud shrimp can be collected by hand when they swim to the surface. This method has been compared with coring in collecting *Neotrypaea uncinata* (A. MILNE-EDWARDS, 1870) and was found to be less effective.

Liquefying the sediment is also the underlying principle of a method described as puddling by LEFLEUR (1940) for collecting *Callichirus major* (SAY, 1818). Instead of digging beyond the tide wash as in the other method, an area is selected, well marked by holes, approximately three inches below the surface of the water. Once a spadeful of sand is taken out, it is then a simple matter of stirring the sand in the hole by a vigorous digging motion. This movement loosens the sand until it is of the consistency

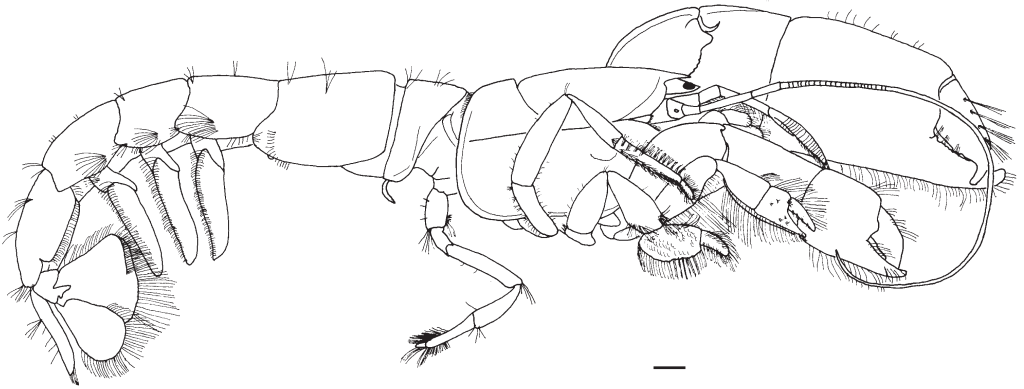
of quicksand to a depth of almost four feet. Any specimens disturbed, either by the great amount of sand stirred up or by the destruction of its burrow, swim to the surface where they can be easily captured.

A more efficient method is liquefaction of the deeper sediment layers with the aid of a hydraulic pump or water jet (Fig. 4). This device consists of a gasoline-powered water pump on a float. Water is sucked up at the intake and then forced through a fire hose connected to a long (up-to-3 m) nozzle that is inserted deep into the sediment (HAILSTONE 1962, BYBEE 1969). Shrimp are washed to the surface and can be picked up by hand or with a net. This method is especially suitable when specimens are needed for physiological experiments as it is considered very productive and least injurious to animals (FELDER 1978). It has also been used in some studies of deep burrowing thalassinidean species (FELDER & LOVETT 1989, FELDER & GRIFFIS 1994, KINOSHITA et al. 2003).

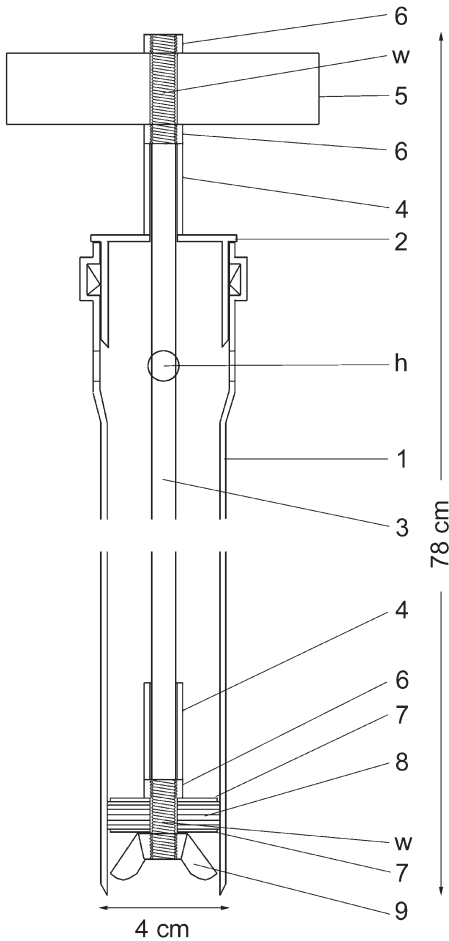
In South Africa, *Upogebia africana* (ORTMANN, 1894) is commonly collected with a tin can (75 mm diameter) or a prawn pusher (150–200 mm diameter) (HODGSON et al. 2001). Similarly, *U. pusilla* in France is collected locally with a casserole (CHAUD 1984). These devices consist of an open cylinder whose bottom usually is attached to the lower end of a spade handle. The open end is placed over the burrow openings of the mud shrimp and pushed downwards; compressed air is thus forced into the burrows, pushing the animals out of corresponding burrow openings. HODGSON et al. (2001) reported that such devices are more efficient (prawn pusher: CPUE 0.1 to 1; tin can: CPUE 0.1 to 0.3) than a yabby pump (below) (CPUE 0.08 to 0.12) when collecting *U. africana*.

The most universal tool for collecting thalassinideans is the yabby pump. This device was introduced by bait collectors and mentioned for the first time in a scientific paper by HAILSTONE (1962). HAILSTONE & STEPHENSON (1966) described two models, the first of which is actually a modified coring device. The second, now the most commonly used model, consists of a tube (3–5 cm diameter, 50–100 cm long), a plunger with a handle on the upper end, and a washer that can be adjusted with a thumb screw on the lower end (Figs 2, 3). Several commercial models made of stainless steel are available in hardware or angler shops locally in Australia, USA, UK, and South Africa or can be purchased online. Early self-made pump models of the same design constructed from brass using leather as washers were described by DEVINE (1963) and RODRIGUES (1966). In Brazil, yabby pumps made of household PVC tubing are sold in angler shops (S. Rodrigues. pers. comm. 1987). Self-designed pumps made of 4–5 cm diameter PVC sewage tubes are frequently used. MANNING (1975) described a very simple improvised model consisting of an acrylic coring tube and a cork (or better rubber) stopper attached to a broomstick. This simple model, modified with an aluminum rod and a handle, has been used successfully to collect *Pestarella tyrrhena* (PETAGNA, 1792) and *P. candida* (OLIVI, 1792) (see DWORSCHAK 1998). Efficiency was high, but its operation in only one direction (pull) with the need of frontloading for the next pull made collecting cumbersome.

For collecting small species and/or those occurring in high densities, one pull usually yields one or more shrimp. For large-sized and deep-burrowing forms, several subsequent pulls are necessary. The tube is re-inserted into the hole created by the first attempt, the plunger is pulled out vigorously, the contents are discarded, and the process is repeated, with the yabby pump pushed deeper into the sediment with each pull (Fig. 5).



1



2

- 1, PVC tube with 4 \varnothing 10 mm holes (h)
- 2, PVC cap with central \varnothing 8.5 mm hole
- 3, brass rod \varnothing 8 mm with M8 windings (w) at both ends
- 4, plastic tubes as distance holders
- 5, PVC handle \varnothing 18 mm
- 6, M8 brass nuts
- 7, 1 mm thick brass disks
- 8, rubber foam washer disks
- 9, brass thumb nut

Figs 1–2: 1, *Callianassa aqabaensis* DWORSCHAK, 2003, habitus lateral view (from DWORSCHAK 2003); scale bar is 1 mm; 2, self-designed yabby pump, sectional view.

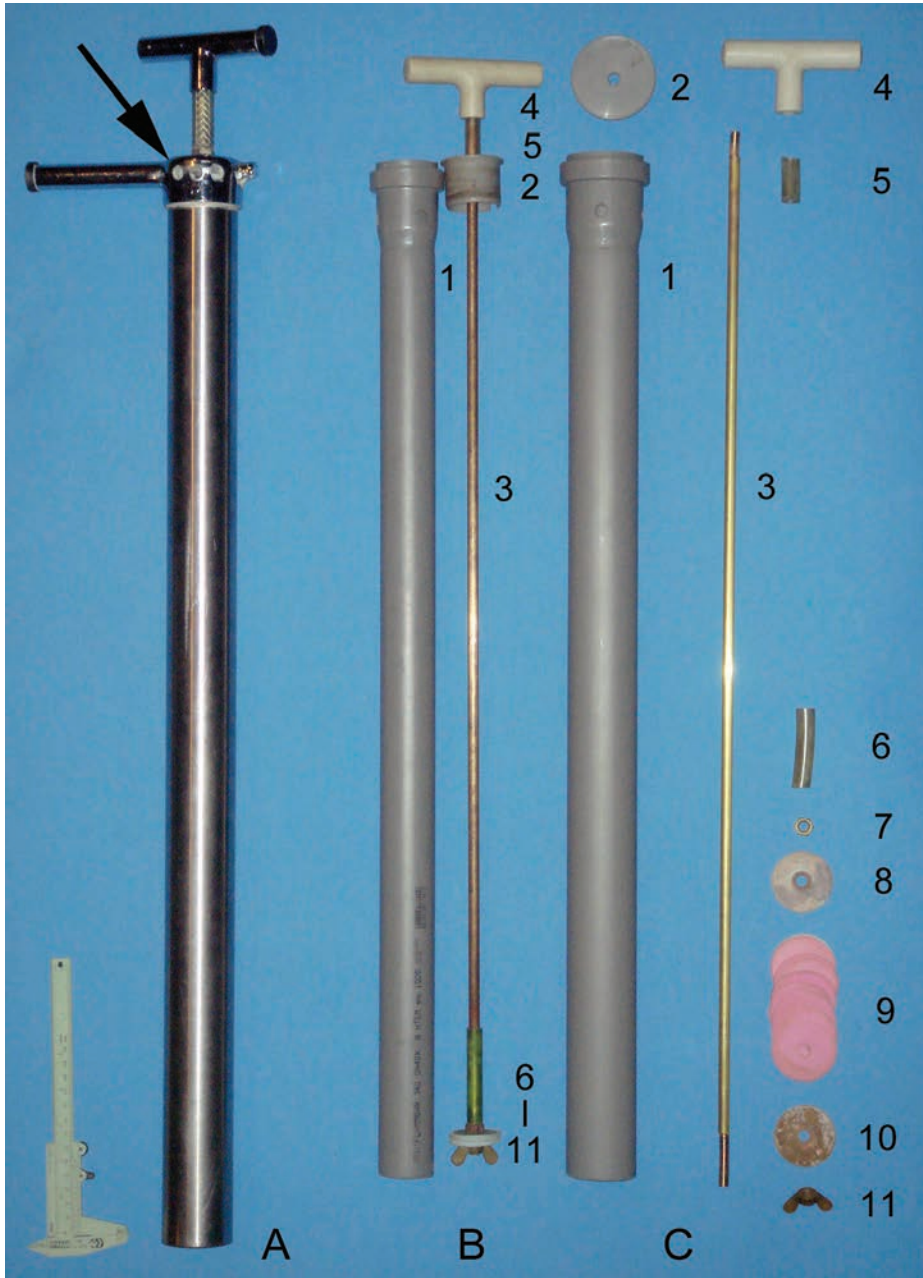


Fig. 3: Yabby pumps. A, commercial stainless steel model (Emro) with additional holes drilled for underwater use (arrow); B, self-designed pump Ø 4 cm with plunger removed; C, self-designed pump Ø 5 cm disassembled. 1, PVC sewage tube with 4 Ø 10 mm holes drilled in the upper section; 2, PVC cap with central Ø 8.5 mm hole; 3, Ø 8 mm brass rod with M8 windings at both ends; 4, handle made of polypropylene; 5, 6, plastic tubes as distance holders; 7, M8 brass nut; 8, 10, 1 mm brass disks Ø 32 mm with central holes; 9, rubber foam disks Ø 35 mm with central holes; 11, M8 brass thumb nut.

The efficiency of yabby pumping in the intertidal is highest at incoming tide (pers. obs.). DEVINE (1966) reported a 70–80% efficiency under optimal conditions for *Biffarius filholi* (MILNE-EDWARDS, 1878); SOUZA et al. (1998) reported almost 100% efficiency when collecting *Callichirus major*.

Yabby pumps have also been used to obtain quantitative samples (12 pumps in a 0.1 m² quadrat) in some studies on populations of *Trypaea australiensis* (ROTHERHAM & WEST 2003, 2007). These authors found the method more effective than coring alone.

Yabby pumps are most efficient in sandy sediments. They do not perform well if too much coarse material, i.e. coral rubble, is present, and they are not very efficient in sticky mangrove type mud. Another disadvantage of the yabby pump is that the specimens are often damaged; chelipeds or other legs can become detached or the body ruptured open, especially in species with long, soft abdominal somites 1 and 2, as in the genus *Callichirus*.

After use, the yabby pump should be disassembled, cleaned and rinsed with freshwater, especially after use under water (below). An application of oil or silicone spray avoids corrosion of the plunger and nuts. After some time, the rubber washer has to be replaced as it gets worn off or becomes brittle from repeatedly drying out. The PVC pump needs a replacement of the whole tube eventually, as the tube gets rough inside from the grinding sand, which in turn abrades the washers.

Some species, especially of the callianassid genus *Glypturus*, construct large burrows (up to 2 m deep and with a horizontal extension exceeding 1.5 m) in sediments where application of the yabby pump is not effective. DE VAUGELAS (1985) developed a weighted line trap for these large-sized shrimp (up to 16 cm total length). This consists of a freely moving reel on a stick to which a thin braided fishing line of 4 m length is attached at one end (Fig. 6). On the free end of the line are several lead weights (ca 0.5 g each). The method takes advantage of the feeding behavior of the shrimp: material that is too large to be immediately ingested is sorted by the shrimp and stored in blind tunnels. The weights are lowered into the burrow. When the shrimp handles the weights attached to the line, it becomes completely entangled in the line (Fig. 7). The traps have to be checked daily over several days. Promising traps can be recognized by the line having moved deeper down the burrow. If a shrimp is entangled, it has to be dug out carefully by hand or with the help of an airlift sampler in subtidal sediments. This method is rather time consuming, with a variable efficiency. DE VAUGELAS (1985) reported that 10 traps over 2–3 days yielded 1–2 shrimp sublittorally, in the intertidal the success rate was 50%. Experimenting with this method caught 7 specimens with 14 traps over 17 days in Belize (ABED-NAVANDI & DWORSCHAK 2005) and 1–2 specimens using 8 to 10 traps over 10 days in Aqaba (unpublished observations). The low success rate is often the result of the presence of more inactive than active funnels in the burrows of *Glypturus* species. Another drawback is that the locations of the traps must be marked by buoys in order to find them again.

The mud-lobster *Thalassina* which is used as a food source locally is caught with several types of traps. PILLAI (1985) mentioned a bamboo bow and arrow device from the Philippines and figured a traditional snare trap used in Fiji. MOH et al. (2014) describe another trap for the mud-lobster consisting of a stiff steel wire of 50 cm length, with a tied piece of fish gill net on one end, and a T-handle on the other. The net end is pushed

into the burrow with the T-handle resting across the opening of the mound, and the traps were left overnight. The authors reported that only 30% of the traps yielded a specimen because their burrows have several openings.

Some species [*Axiopsis serratifrons* (A. MILNE-EDWARDS, 1873), *Neaxius acanthus* (A. MILNE-EDWARDS, 1878), *Corallianassa longiventris* (A. MILNE-EDWARDS, 1870)] appear at their burrow opening in order to catch floating seagrass, which is then pulled into the burrow. These shrimp can be lured with seagrass or any other bait, and the retreat into the burrow can be cut off with a machete, metal spike or long screwdriver (ABED-NAVANDI & DWORSCHAK 2005). This method works best in clean sands. In sediments with numerous pieces of coral rubble, it is difficult to ram the cut-off tool of choice into the sediment. The following modifications have proven useful. Selected burrow openings are prepared by removing large pieces of rubble around them. The animals are allowed to recover for about half an hour from this disturbance, after which time a lure (seagrass) is positioned near the opening within reach of the shrimp and fixed with a lead weight. When the shrimp emerges from its burrow and hangs on to the lure, any retreat into the burrow is quickly cut off by ramming the tool into the sediment at an angle of about 60°. This method requires some experience as the shrimp retreat quickly when disturbed and often are cut in half when the collector is not fast enough. The bulk of sediment, now containing the shrimp, is moved by hand into a mesh bag or sieved. Careful handling is required to prevent the animals from autotomizing their chelipeds.

Other methods take advantage of the shrimp's behavior to defend its territory –the burrow– against all intruders. A brush or feather is used in traditional fishing methods for *Upogebia major* (DE HAAN, 1841) in the Ariake Sea, western Kyushu, Japan. SATO et al. (2001) described this method as follows: In ebb tides, they insert a writing brush into the burrow opening of the shrimp, and after a while, pull slowly the writing brush up near to an opening of the burrow. Then, a shrimp which comes up to push out the writing brush is caught by hand with a small spatula. By this method, many intact shrimp can be caught with the least disturbance to their habitat. Essentially, the shrimp get stuck with their chelipeds between the brush and the burrow wall, as the burrow narrows near the opening. Often, the shrimp can be pulled out with the brush (TAMAKI et al. 2008).

Other objects, usually a piece of shell or plug of sand, introduced into the burrow of *Callichirus major* have been used by LUNZ (1937) and POHL (1946), using a shovel to cut of any backwards retreat. WASS (1955) reported that this method did not work with *Callichirus islagrande* (SCHMITT, 1935) nor *Lepidophthalmus louisianensis* (SCHMITT, 1935).

Quantitative samples of thalassinideans for population studies often have been collected with frames or corers, pushed to various sediment depths according to animal density, size of the species and burrowing depth. KEVREKIDES et al. (1997) used a metal frame of 1 m² area, 40 cm high, pushed into the sediment; its contents to a depth of 30 cm were then removed and sieved for collecting *Upogebia pusilla*. HANEKOM & ERASMUS (1989), when collecting *Upogebia africana*, used a 50 x 50 cm frame to 30 cm depth; BERKENBUSCH & ROWDEN (1998) used a 0.25 m² area frame to 50 cm depth for *Biffarius filholi*; whilst DUMBAULD et al. (1996) used a 40 cm diameter stainless steel core to a depth of 60 cm for *U. pugettensis* (DANA, 1852) and a depth of 90 cm for *Neotrypaea californiensis* (DANA, 1854). For population studies on *Nihonotrypaea japonica* (ORTMANN, 1891) and

N. harmandi (BOUVIER, 1891), TAMAKI et al. (1997) used a 25 x 25 cm frame 12 cm deep, and 100 cm² cores 35 to 50 cm deep. Similarly, TAMAKI et al. (1999) used 100 cm² cores 100 cm long to a depth of 70–80 cm, whilst Garcia et al. (2003) used a 10 cm diameter, 90 cm long PVC pipe for *Neotrypaea uncinata*. With frames and larger corers the sediment up to the desired depth can be removed with a small shovel or with the aid of a yabby pump. Smaller cores have to be excavated as a whole. In finer sediments, closing off the top with a lid enables the retrieval of the core with the entire sediment column intact.

For collecting the deep burrowing shrimp *Upogebia major*, KINOSHITA et al. (2003: fig. 2) constructed a core sampler consisting of a 150 cm long, 10 cm diameter plastic pipe fitted at the top with a rubber spigot. First, the plastic tube was pushed down fully into the sediment. Next, a steel pipe with a wire inside was passed through a hole in the center of the spigot, and this was pushed down through the center of the plastic pipe. Finally, the wire was removed, and the core sampler was pulled up. The wire and steel pipe assemblage allowed air to enter the hole as the sampler was pulled up, making the task of retrieving the core sample far easier.

Regardless of quadrat or core size, and depth of coring, removed sediment is sieved on location using various mesh sizes ranging from 0.5 to 3 mm, depending on sediment type, size of the targeted species, and specific study aims.

Sublittoral (accessible with snorkel or SCUBA)

Some methods used in the intertidal also can be used under water, such as the weighted line method, coring, cutting off the retreat of animals, and the yabby pump (Fig. 8).

To use a yabby pump underwater, additional holes have to be drilled in the upper part of a commercial yabby pump, which allows the escape of water above the plunger when it is pulled up (Fig. 3, arrow). When snorkeling, one dives down, sucks up sediment around a hole, closes the lower end with one hand and returns to the surface where the content of the pump is emptied into a mesh bag that retains the animals and lets the sediment through. This is then repeated on the next dive. When using SCUBA, the content of the yabby pump is best emptied into a sieve at the bottom; the animals can then be picked up and put into containers individually.

Species that appear near the burrow opening may also be captured by using a small harpoon, as reported by LEJJA-TRISTAN (1994) for *Neaxius vivesi* (BOUVIER, 1895) and ABED-NAVANDI & DWORSCHAK (2005) for *Axiopsis serratifrons*. The method is not very effective and can result in heavily damaged specimens.

A very useful method for collecting burrowing organisms from soft bottoms within SCUBA diving range is an airlift suction sampler (Fig. 9). A full description of these devices is found in BARNETT & HARDY (1967), KEEGAN & KÖNNECKER (1967), THOMASSIN (1978), and TUNBERG (1983). Briefly, compressed air is pumped into a pipe, expanding as it ascends up the pipe (which is usually between 4–10 cm in diameter and from 1–6 m long), drawing the sediment up through the pipe and sieving it through a mesh collection bag. Usually, compressed air from diving bottles (scuba tanks) is connected via a pressure resistant hose to an injector tube that has a valve for regulating air flow. This injector tube with valve is located a few cm above the lower pipe opening. These suction



Figs 4–8: 4, hydraulic jet, Bay Saint Louis, MS (i, water intake; p, water pump; n, nozzle); 5, author collecting with yabby pump, Nabq, Egypt (photo: Michael Stachowitsch); 6, weighted line trap, Aqaba, Jordan (m, mound; f, funnel; s, spool with line)(photo: Alexander Stargardt); 7, shrimp entangled in weighted line, Motupore Island, Papua New Guinea (photo: Tom Suchanek); 8, author collecting with yabby pump sublittorally, Aqaba, Jordan (photo: Karl Svardal).

samplers can be operated at full pressure (> 200 bar) or after reduction to about 50 bar or less using the first stage of a scuba regulator as a reduction valve. For quantitative samples, the airlift sampler can be combined with a sample cylinder digging into the substrate by the same suction, which is emptied after removal of the lid connecting the cylinder to the pipe (BARNETT & HARDY, 1967: fig. 2). Minimum operational depths of airlift suction samplers are given as 6 m (KEEGAN & KÖNNECKER, 1973), 3–4 m (Barnett

& Hardy, 1967), and 3 m (Tunberg 1983). However, they have been successfully used in water as shallow as 1 m (THOMASSIN 1978, S. De Grave pers. comm.). Quantitative samples of *Upogebia deltaura* have been taken in this manner by TUNBERG (1986). Recently, airlift sampling complemented by brushing (see below) has proved to be very successful during marine biodiversity surveys (BOUCHET et al. 2002) and yielded many thalassinidean species during the Panglao 2004 Marine Biodiversity Project (pers. obs.)

Another useful method for collecting cryptic fauna from coral reef habitats is brushing. Coral rubble taken from the bottom is held over a basket lined with a fine screen and gently brushed with a soft brush, so that animals fall/swim off the rubble into the basket (Fig. 10). After brushing, the rubble is replaced on the bottom in the same position that it was found.

MANNING (1960) described the application of a rotenone-based poison for the collection of crustaceans from cryptic habitats. These poisons, however, work only with species living in crevices. Pouring or injecting irritating substances (formaldehyde, bleach) or poisons (rotenone, quinaldine) into burrows does not force the shrimp out, but rather kills them in their burrows (SAMUELSEN 1974; pers. obs.). In addition, application of such substances for use in marine research has been increasingly restricted or prohibited (ROBERTSON & SMITH-VANIZ 2008).

Collecting thalassinideans living in sponges is best done by cutting open the host sponges and inspecting them for commensals. For obtaining specimens boring in corals, putative bore holes need to be identified and the substrate broken open.

Occasionally, thalassinideans and other burrowing organisms, which have left their burrows due to anoxic events, may be picked up from the sediment surface (STACHOWITSCH 1983, RABALAIS et al. 2001). Anoxia can also be induced by covering the sediment with large (5 x 6 m) plastic sheets for one day or up to one week (SUCHANEK & COLIN 1986, KNEER et al. 2013) which yields large specimens usually not collected with the yabby pump (DWORSCHAK 2011). In most cases, however, such specimens are already in an advanced stage of decay.

Deeper sediment bottoms

Although new cutting-edge trimix gas and rebreather technology has allowed divers access to depths of 120–140 m (PYLE 1999, 2000), this technology is not yet widely used by the research community. Consequently, collecting thalassinideans beyond the reach of standard SCUBA is still done mostly by means of remote, ship-based techniques. Interestingly, about 20% of all thalassinidean species have been collected only by trawls and dredges. Usually, no specific method is mentioned in the literature, nor do detailed studies exist on the efficiency of trawls and dredges in collecting these burrowing shrimp. Most trawls and dredges scrape only the upper layers of the sediment and therefore retrieve only shallow burrowing forms, which are much too often damaged and represented by only a few specimens. Even the Deep Digging Dredge (Triple-D), specifically constructed for sampling infaunal, low abundance species, digs down to a sediment depth of only about 10 cm (BERGMAN & VANSANTBRINK 1994). GUSTAFSON (1934) reported that anchor dredges are not very effective on sand and mud bottoms, as they do not dig deep enough; he therefore used a Ring-dredge for collecting thalassinideans from sedimentary bottoms along the Swedish west coast. This



Figs 9–12: 9, airlift sampler, Panglao, Philippines (photo: Panglao 2004 Marine Biodiversity Project); 10, brushing, Panglao, Philippines (photo: Panglao 2004 Marine Biodiversity Project); 11, Van Veen grab, Rovinj; 12, Reineck box sampler on R/V Senckenberg.

Ring-dredge has an opening diameter of 90 cm and is operated with two different mesh bags (10–12 and 20 mm).

Several types of grabs (Day, Smith-McIntyre, Petersen, Van Veen) (Fig. 11) are commonly used for obtaining quantitative samples in benthic surveys (see ELEFThERIOU & HOLME, 1984). These grabs usually penetrate deeper into the sediment (15–25 cm) than do most dredges and may collect small sized thalassinideans. Their sample size, however, is rather small, and their CPUE is low. In addition, their penetration depth remains inadequate for deep burrowing species.

Box-corers (see ELEFThERIOU & HOLME, 1984) have a much deeper penetration depth, especially in finer sediment. ROWDEN & JONES (1994) used an unspecified 0.25 m² box-corer, achieving penetration depths of 30–40 cm in 47 m water depth in a population study of *Callianassa subterranea* (MONTAGU, 1808). Deep penetration depths (up to 50–60 cm) are achieved by the Reineck box corer (REINECK 1963) (Fig. 12). Although this piece of equipment retrieves undisturbed sediment cores with its infauna and their traces, because of its weight (1 ton) it can be used only on larger research vessels. Recently, grabs and cores have been TV-guided, which enables to a certain extent taking the sample from promising locations, e.g. from areas with burrow openings (DWORSCHAK & CUNHA, 2007).

A detailed discussion of the efficiency of remote sampling devices is found in ELEFThERIOU & HOLME (1984) and BLOMQVIST (1991).

Preservation

When collecting thalassinideans it is best to keep the specimens individually separated. One reason for this is that most species are aggressive and will fight when placed together, potentially resulting in the loss of legs or other bodily damage. Another reason is that, even after fixation, legs may fall off during handling and transport, and the researcher might end up with many bodies and legs but few (or no) entire and complete specimens. Before fixation, the shrimp should be cooled in a refrigerator to minimize autotomy. The most commonly used fixatives are buffered 4% seawater-formaldehyde solution or 75% ethanol (which is not a true fixative). Formalin-fixed material should be transferred to 75% ethanol after some weeks. For molecular studies a subsample (a leg or abdominal muscle tissue) can be removed from larger specimens, or the entire shrimp can be placed in 96% ethanol. High concentrations of ethanol are not favorable for morphological investigations as the specimens become stiff and brittle, leading to damaged appendages when handled. Recently, several workers have started using propylene-glycol as a field preservative because it is a non-toxic, non-flammable substance. In propylene-glycol, the specimens stay soft and flexible, and their tissue becomes slightly cleared. After returning to the laboratory, the specimens must be transferred into standard long-term preservatives, commonly ethanol. A comparative study of preservatives by VINK et al. (2005) has shown that propylene-glycol storage is suitable for molecular studies, and this is currently being studied for decapods. For histological and TEM studies, fixation with Bouin's liquid and glutaraldehyde solution, respectively, are good choices.

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