



BURROW STRUCTURES AND ECO-ETHOLOGY OF BURROWING FAUNA IN THE ADRIATIC SEA

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RIASSUNTO

Strutture di tana ed eco-etologia di organismi scavatori in Adriatico.

Le moderne tecniche di ricognizione subacquea (immersione con autorespiratore e telecamere subacquee) hanno evidenziato nei fondali marini la presenza di numerose tane di organismi appartenenti a diversi phyla. Sui fondali raggiungibili in immersione dai ricercatori subacquei, è stato possibile eseguire calchi in resina di queste tane. Ciò ha consentito di definire la struttura delle tane e di identificarne le specie occupanti, alcune delle quali, come i Callianassidi, escono dalle tane solo eccezionalmente. Altre specie della megafauna che vivono in gallerie scavate nel sedimento, ne fuoriescono periodicamente ed allora possono essere catturate dagli attrezzi da pesca. Tra queste specie si annoverano i crostacei *Nephrops norvegicus* e *Squilla mantis* ed il pesce *Cepola rubescens*. Sulla base dei risultati delle ricerche condotte nell'Adriatico centrale e settentrionale e nelle acque della Gran Bretagna si illustrano le attuali conoscenze sulla struttura delle tane e sull'etologia conseguente alle particolari condizioni di vita delle specie presenti sui fondali sedimentari dell'Adriatico centrale.

ABSTRACT

Direct observation techniques (SCUBA, underwater TV) have revealed that the sea bed contains numerous conspicuous burrows. Resin casts provide detailed information on burrow structure and aid identification of the occupants, some of which never emerge from their burrows under normal circumstances, e.g. callianassid shrimps. Other burrow-dwelling megafauna emerge periodically and may be captured in fishing gear. Such species include the crustaceans *Nephrops norvegicus* and *Squilla mantis*, and the fish *Cepola rubescens*. The paper reviews the burrow-dwelling species that occur on various grounds in the Central Adriatic, refers in less detail to similar information from the Northern Adriatic, gives summary information on burrow structure and notes some aspects of the behaviour of the burrow occupants.



INTRODUCTION

Direct observation techniques such as underwater television (UWTV) and SCUBA diving have revealed that the sea bed is often penetrated by numerous large burrows. These burrows are rarely revealed by ship-borne remote samplers (e.g. grabs and corers) that were historically the only source of information on animal-sediment relationships in the field. Such gear revealed the burrowing habits of many macrofaunal species such as polychaetes and bivalves, but the size of the samplers was usually inappropriate for collecting the deep-burrowing megafauna. Therefore, some inhabitants of large burrows were rarely collected - not because they were scarce, but because they lived below the depth of penetration of most samplers and emerged rarely or not at all (e.g. thalassinidean mud shrimps).

Other megafaunal burrowers emerge periodically, such as the commercially important Norway lobster (*Nephrops norvegicus*) and the mantis shrimp (*Squilla mantis*). They are then available to fishing gear. For such species, periodic availability to gear suggested a fossorial lifestyle, but only relatively recently have the burrowdwelling habits of such species been observed directly and studied. The ecological importance of burrowing species, for example in sediment and solute flux, is addressed by many authors, including Bromley (1996) and Zeibis *et al.* (1996).

Reviews of megafaunal burrow structure include those of Atkinson and Taylor (1988, 1991), Nickell *et al.* (1995) and Bromley (1996). Studies of burrow-dwelling species in Adriatic waters include those of Dworschak and co-workers, mainly on thalassinidean Crustacea, but also including work on stomatopods and bivalves (Dworschak, 1983, 1987a,b, 1992; Pervesler and Dworschak, 1985); work on gobies (Ghirardelli, 1981); and our work on species occurring on *Nephrops* and *Squilla* grounds (Atkinson *et al.*, 1997, 1998; Froglià *et al.*, 1996, 1997; Froglià and Atkinson, 1998). Our work has been in the Central Adriatic: other work has mainly been in the northern Adriatic. In this account we present mainly our own observations conducted during ongoing collaborative investigations commenced in 1990, but also refer in less detail to the work of others. Our account is a selective summary: it does not deal with all megafaunal burrowers in the region and draws on information on burrow structure obtained in both Adriatic and UK waters.

METHODS

Underwater television (UWTV)

Our method is to use an underwater TV camera and lights mounted on a sledge (Shand and Priestley, 1999) towed astern of a research vessel (RV *Salvatore Lo Bianco* in the Adriatic). In Scotland, the method is used for abundance estimation of *Nephrops* as part of the stock assessment process (Tuck *et al.* 1997) and we have applied a similar methodology in the Adriatic (Froglià *et al.*, 1997). This fishery-independent assessment technique involves counting *Nephrops* burrows within a defined field of view as the camera is towed across the sea bed. For the method to be effective, it is essential to be



able to differentiate *Nephrops* burrows from those of other species. This has been the subject of extensive research (see Marrs *et al.*, 1996, 1998). The same methodology may also be applicable to *Squilla mantis* (see Atkinson *et al.*, 1997). The method has also been used to categorise areas of sea bed in terms of their burrowing assemblages (Hughes and Atkinson, 1997). The authors have also used frame-mounted UWTV for single point deployments in Adriatic waters, including filming in infra-red to minimise disturbance to species under observation. This has provided information on the scavenging behaviour of *Nephrops* and other species.

SCUBA diving

This is limited to shallow water, but has proved invaluable for observation of the burrows and burrowing behaviour of some species (see Results and Discussion). The use of polyester (or epoxy) resin to take casts of burrows *in situ* has made it possible to study burrow structure in detail. Methodological details are given by Atkinson and Chapman (1984): the technique is a development of that introduced by Shinn (1968). Resin is mixed with catalyst in the dive tender and then taken to the sea bed in plastic buckets or watering cans to be poured into burrows. During preparatory dives, these have been identified with numbered tags and are reached by following prepared swim lines. After setting of the resin, the resultant burrow casts are dug from the sea bed and brought to the surface. We have used polyester resins: Dworschak and co-workers have employed epoxy resins in a similar manner. In the laboratory, casts are measured, weighed (so that volume can be computed), photographed, and the details of any entrapped animals are recorded.

Observations in laboratory aquaria

Laboratory aquaria containing natural substrata and provided with circulating sea water have proved to be very useful when describing and photographing burrowing behaviour. Information on burrow structure can also be gained in this way and burrow casts can be taken as above.

RESULTS AND DISCUSSION

For the purposes of this account, we divide the Central Adriatic sedimentary environments, partly following Brambati *et al.* (1988), into shallow-water lagoonal or near beach grounds (< 12m depth) with sandy and muddy sand substrata, inshore sandy muds (*ca* 12- *ca* 20m depth), inshore muds (*ca* 20-50m) grading into deeper water muds (>50m, centred on 70m), these in turn grading through a belt of offshore sandy muds (*ca* 70-80m) into a plateau of offshore relict sands, and muddy sands with a low organic content (*ca* 70-80m), and, finally, in depressions such as the Pomo pit (>200m depth), the sediment consists of clay-dominated muds. The depth divisions are approximate: in the Central Adriatic the sediment type depth divisions vary geographically such that a given sediment type tends to extend into deeper water towards the south. The best *Nephrops* grounds consist of soft silt/clay muds. *Squilla*



grounds are centred on the muddy sands that occur further inshore. We have no information on the burrowing megafauna of the offshore sands, but discuss the burrowing species that are characteristic of the other grounds. We refer to published information on burrowing species in the North Adriatic, but have no information for the South Adriatic.

Intertidal and adjacent shallow-water grounds

Lagoonal, intertidal or near-beach sediments often contain the burrows of the callianassid shrimp *Callianassa tyrrhena* whose burrows, bioturbatory significance, and feeding behaviour have been described by Ott *et al.* (1976) and Dworschak (1987a). Ott *et al.* (1976) indicated that *C. tyrrhena* (as *C. stebbingi*), in an aquarium, initially excavated a superficial U-shaped burrow and then extended the burrow downwards before establishing a further opening and abandoning one of the two primary openings. The burrow was dynamic: old openings were abandoned and new ones established, such that 3-4 openings were functional at any given time. Dworschak (1987a) illustrated a resin cast of a *C. tyrrhena* burrow taken in the field. Only one opening is apparent (Fig. 1c) and therefore the cast may be incomplete. According to Dworschak (1987a) the burrows descend in a loose spiral (see Fig. 1c) to depths in excess of 60cm and may occur at high density. More information on the burrows and burrowing behaviour of this species would be useful. The species is a deposit feeder (Dworschak, 1997a). Several other callianassid species are reported from Northern Adriatic grounds. For example, *C. truncata* from 3-8m depth (Abed-Navandi and Dworschak, 1997) *C. candida* from the intertidal and shallow subtidal (Dworschak, 1992, 1998) and *C. acanthura* from 3-6 m depth, this species being considered rare (Abed-Navandi and Dworschak, 1998).

The burrow structure of one of these callianassids is known in some detail. Zeibis *et al.*, (1996) have studied the burrows and geochemical effects of *Callianassa truncata* in shallow water in the Tyrrhenian Sea. Each burrow characteristically has two inhalant shafts with funnel-shaped openings and one exhalant one, its opening being at the apex of a mound of expelled sediment. These branch from a horizon at about 10cm below the sediment surface, but the burrow continues downwards via a series of nodular chambers to 60-80cm depth. The burrows occurred at high density at depths of 2-15m, giving a dramatic mound and funnel topography to the sea bed.

The upogebiid shrimp *Upogebia pusilla* may occur in similar localities, extending from the eulittoral to depths of around 6m (Dworschak, 1992). *U. tipica*, another species occurring in shallow water, never enters the lagoons and usually is found in depths in excess of 10 m (pers. obs., see also Dworschak, 1992). *U. mediterranea*, a species that has been confused with *U. deltaura* has been reported from the Northern Adriatic (3 m depth) by Abed-Navandi and Dworschak (1998). Udekem d'Acoz (1997) considered *U. mediterranea* to be a subspecies of *U. nitida*, a view that is contentious.

Dworschak (1983) provided a detailed description of the burrows of *U. pusilla*, extending that of Ott *et al.* (1976). The burrow is basically Y-shaped (Fig. b). There are nodular galleries at the base of the upper section and along the descending lower

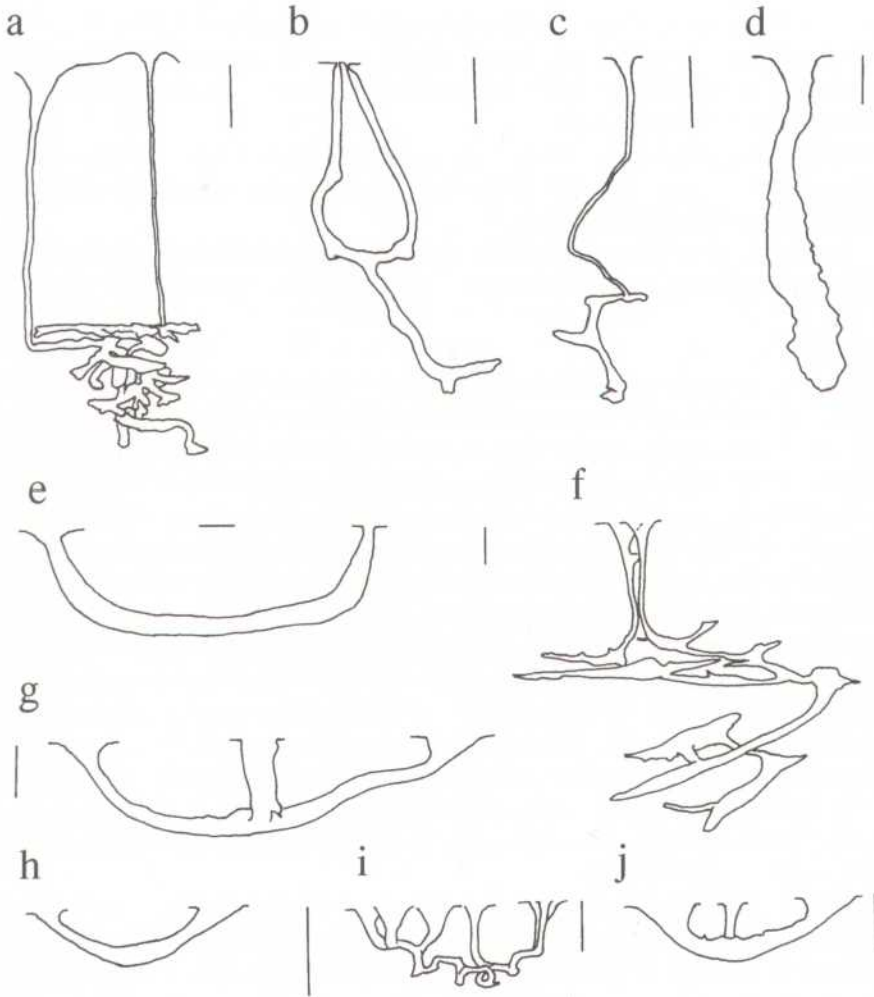


Fig. 1: Burrow structure (drawn from photographs of resin casts of burrows). a) *Callianassa subterranea* (derived from Nickell and Atkinson, 1995); b) *Upogebia pusilla* (derived from Dworschak, 1987a); c) *Callianassa tyrrhena* (derived from Dworschak, 1987a); d) *Cepola rubescens* (derived from Atkinson and Pullin 1996); e) *Squilla mantis* (derived from Atkinson et al., 1997); f) *Jaxea nocturna* (derived from Pervesler and Dworschak 1985); g) *Nephrops norvegicus* (derived from Marrs et al., 1996); h) *Lesueurigobius friesii* (derived from Rice and Johnstone, 1972); i) *Calocaris macandreae* (derived from Nash et al., 1984); and j) *Goneplax rhomboides* (derived from Atkinson, 1974). Scale bars are 10cm

Fig. 1: Struttura di tane (tratte da fotografie di stampi di resina di tane).



section. Like other upogebids, it is predominantly a suspension feeder (Dworschak, 1987a). It is often found at high density (Ott *et al.* 1976; Dworschak, 1983, 1987a). Information on the burrows of *U. mediterranea* is scarce (see Dworschak, 1983; AbedNavandi and Dworschak, 1998).

The seabed contains numerous small, apparently vertical burrows that cannot be assigned with confidence from UWTV data. It is likely that many of these belong to callianassid and upogebiid shrimps.

Lagoonal sediments in the northern Adriatic contain the burrows of several goby species, including the large *Zosterisessor ophiocephalus* (see Ghirardelli, 1981).

Inshore sandy muds

These near-shore grounds, that extend from ca 12-20 m depth, consist of a mixture of shelly sand and mud; the fraction with a particle diameter of <50µm comprises ca 70-95% by weight according to Brambati *et al.* (1988). At 13m and 15m depth off Ancona, Atkinson *et al.* (1997) found the surface sediment to contain 45% silt + clay by weight at the shallower site, and 66% silt + clay at the deeper site where the underlying sediment exceeded 80% silt + clay. These grounds are characterised by the large, two-opening burrows of *S. mantis* (Fig. 1 e). Their burrow openings are usually level with the plane of the sediment surface and one opening is larger than the other. Burrows openings may be over a metre apart. The burrow is a laterally extended U-shape with a central constriction. Details are found in Atkinson *et al.*, (1997) and some field observations are reported by Pervesler and Dworschak (1985). Animals emerge mostly at night, or after heavy storms (perhaps because of reduced light or burrow damage) which is when they are most vulnerable to capture by fishing gear (Manfrin and Piccinetti, 1970; Froglija and Giannini, 1989). Interestingly, a small shrimp *Athanas amazone*, previously known from only a few specimens, was found within *Squilla* burrows (Froglija and Atkinson, 1998).

A number of other burrowing species are present on these grounds, including the upogebiid shrimp *Upogebia tipica*, details of whose U-shaped burrows are reported by Dworschak (1987b, 1992) and Atkinson *et al.* (1998). Also present is the crab *Goneplax rhomboides* (see Atkinson *et al.* 1998) whose burrows have been described from studies in UK waters by Rice and Chapman (1971) and Atkinson (1974). The basic burrow is a shallow U-shape, but may be elaborated with one or more side tunnels (Fig. 1j). Another conspicuous burrow feature consists of large mounds surrounding an apical opening. By analogy with Scottish studies of a related species (Hughes *et al.*, 1996) these are the exhalant openings of the burrow of the echiuran worm *Maxmuelleria gigas*. The inhalant opening is flush with the sediment surface with radiating, spokelike feeding traces. During nocturnal observations, the green proboscis of the worm was sometimes seen extending from this opening (Atkinson *et al.*, 1998). The burrow has not been cast, but by analogy with its close relative *M. lankesteri*, will be a laterally extended U-shape, penetrating deeply into the sediment (possibly to 1 m) and with the openings that may be over a metre apart. The species appears to extend from inshore muddy sands to offshore mud.



At depths of less than *ca* 20m, the small grapsid crab *Brachynotus gemmellari* has been found to occupy simple, shallow burrows with one or two openings (Atkinson *et al.*, 1988). On inshore grounds, black gobies (*Gobius niger*) are frequently observed beside burrows or entering them when disturbed by divers or the UWTV camera sledge. Male and female fish are often seen together. The species will certainly occupy the vacated burrows of other species such as *Squilla mantis* (see Atkinson *et al.* 1988); on shallow-water Scottish grounds it may take over vacated *Nephraps* burrows and it is capable of modifying these (Atkinson and Taylor, 1991; Marrs *et al.*, 1996). There is evidence that the species may be capable of independent burrow construction (Marrs *et al.*, 1996).

Distinctive paired holes are common on these inshore grounds and sight of the siphons of bivalves in some of these reveals the occupants. Resin casts have shown that the large tellinacean bivalves *Solecurtus strigilatus* and *S. multistriatus* form distinctive L-shaped burrows (Dworschak 1987b, Atkinson *et al.* 1998). The species responsible for some burrows cannot yet be assigned. For example, two closely-spaced rings of holes, each surrounding a small mound with an apical opening (Tuck and Atkinson, 1996). In the Adriatic this feature has been seen on both *Squilla* and *Nephraps* grounds and it also occurs on Scottish *Nephraps* grounds. Additionally, numerous small, apparently vertical burrows cannot be assigned with confidence. As for near-shore and lagoonal sediments described above, it is likely that many are those of callianassid shrimps.

Shallow-water muddy grounds (ca 20-50m)

Beyond a depth of *ca* 20m the sandy mud *Squilla* grounds grade into a soft, silt and clay-dominated muds. Brambati *et al.* (1988) characterise these sediments as having over 95% by weight of particles with a diameter <50 μ m and comprising, on average, twice as much clay as silt by weight. The burrows of several species are apparent on these grounds. These include those of Fries' goby, *Lesueurigobius friesii*. The burrows of this species have been described by Rice and Johnstone (1972) and the diel behaviour of the fish by Nash (1982), in Scottish studies. The burrows commonly consist of shallow (to *ca* 10 cm depth) linear burrows with two openings (Fig. 1 h) or T-shaped burrows with three openings. Tunnels are usually less than 30cm in length. The species is often seen on the mud surface, beside a burrow opening. Emergence is mainly by day. The species extends from *ca* 30-250m depth, but is commonest at around 50m.

Distinctive burrow features seen on this ground are the openings of the burrows of the laomediid thalassinidean *Jaxea nocturna*. These are surrounded by a crenulated mound of sediment, the crenulations reflecting the cheliped scrapes of the burrow occupant. The burrow consists of deep shafts with a loose spiral configuration and lateral galleries (Fig. 1 f). There may be numerous openings, most of which are blocked from below by the occupant, leaving two or three functional openings (Peresler and Dworschak, 1985; Nickell and Atkinson, 1995; Marrs *et al.*, 1996). The species may emerge in the vicinity of its burrow opening, possibly to drag organic material into its burrow. It feeds by resuspending sediment deposited within its burrow (Nickell and



Atkinson, 1995). The species occurs throughout a range of depths in suitable muddy sediment. Off Ancona, it appears to be most abundant at between 30-50m depth, is still apparent at 70m, but appears to be scarce in the deep water of the Pomo pit. The burrows described by Pervesler and Dworschak (1985) were from a population at 1217m in the Gulf of Trieste.

The burrows of *Squilla mantis* decrease in number with increasing depth and those of *Nephrops norvegicus* increase in number, but are still relatively scarce at depths of 50m: they do not become common until a depth of around 70m (see below). It is likely that the species is excluded from shallower water by high summer bottom temperatures and excessive light levels. As the sediment becomes muddier, the calocaridid thalassinidean *Calocaris macandreae* begins to occur. Its distinctive burrows are described below.



Fig. 2: *Squilla mantis* on sparsely-burrowed, shallow-water (17m) muddy ground. One of the openings to its burrow is visible at bottom right. The small burrow openings (centre) may include those of *Upogebia tipica*. Image taken from videotape, field width at mid point ca 80cm

Fig. 2: *Squilla mantis* su un fondale fangoso, a bassa profondità (17m), con presenza di tane distribuite su tutta la superficie. Una delle aperture della sua tana è visibile in basso a destra. Le piccole aperture della tana (al centro) possono includere quelle dell'*Upogebia tipica*. Immagine tratta da un videotape, ampiezza di campo al punto medio ca. 80 cm



Deeper-water muddy grounds: muds (ca 50-70m) and sandy muds (ca 70-80m)

These sediments contain a high density of the burrows of *Calocaris macandreae* and a range of sizes of *Nephtys* burrows including large ones, reflecting the catch composition in this area (Froglia *et al.*, 1997). This is the main *Nephtys* ground exploited by the commercial fleet. The sediment on the 70m *Nephtys* mud was found to comprise over 95% silt + clay; that of the adjacent sandy muds varied from 70-90% silt + clay (IMBC, UMBSM and IRPEM 1984).

The *Nephtys* burrows are distinctive and are most easily recognised by their crescentic openings, often with signs of recent excavation and ambulatory tracks radiating from the openings. Peak emergence as reflected in catches is around dawn and dusk (Froglia, 1972; Froglia and Gramitto, 1986). At these times and at night, animals are often seen within their burrow openings or on the mud surface when using UWTV. The fishery exploits this emergence behaviour. By analogy with studies in shallow Scottish waters (Chapman and Rice, 1971; Rice and Chapman, 1971; Tuck *et al.*, 1994; Marrs *et al.*, 1996), *Nephtys* burrows usually have three openings (Fig. 1 g), reflecting a T-shaped branching pattern, but may be complex with numerous branches and openings, particularly when the tunnels of adults and juveniles interconnect.

The burrows of *C. macandreae* are revealed by distinctive clusters of openings, often occurring in groups of three, reflecting the tripartite branching structure of the burrow (Fig. 1i) (Nash *et al.*, 1984). Several such clusters may occur within a given burrow, but closure or collapse of openings may mask the branching pattern. The burrow penetrates to a depth of around 20cm and at this horizon complex circular galleries may be formed. The species is principally a deposit feeder. It rarely leaves its burrow under normal circumstances, but animals may be displaced from the relatively superficial burrows (probably those near burrow openings) by fishing gear, so, unusually for a thalassinidean, the species occurs in trawl catches.

Peres and Picard (1964) considered *C. macandreae* to be characteristic of bathyal depths in the Mediterranean. However, the species is abundant in the relatively shallow waters of the Adriatic, where suitable muddy substrata combine with an appropriate (cool) temperature regime.

The red band-fish, *Cepola rubescens*, occurs on these grounds and the adjacent sandy muds. Its large, deep burrows are distinctive (Atkinson *et al.*, 1977; Atkinson and Pullin, 1996). The burrow principally consists of a vertical shaft that may penetrate the sea bed to a depth of 1 m (Fig. 1 d). An oblique side tunnel is present in some cases. The burrow aperture is elliptical in cross section and there is a mound of mouth excavated sediment beside it. The fish occur in aggregations, giving a highly bioturbated appearance to the sea bed. The fish are planktivorous and emerge to swim and feed in the vicinity of their burrows during the day.

Another burrowing species common trawled on these muds and the adjacent sandy muds is the alpheid shrimp *Alpheus glaber*. Laboratory studies have established the burrowing behaviour of this animal and burrows consistent with laboratory observations have been seen using UWTV (Froglia *et al.*, 1997). More information is required on



this species in order to confirm field identification of its burrows and establish the full range of burrow structure.

The thalassinidean mud shrimp, *Callianassa subterranea* is characteristic of offshore muds and sandy muds in the Central Adriatic. Here, characteristic burrows are observed using UWTV and animals are occasionally taken in grab samples.

Burrows of similar morphology have also been observed less commonly on muddy sands (<50m) in our observations. There have been a number of studies of the burrows and burrowing behaviour of this species, including those of Nickel and Atkinson (1995). The burrow of *C. subterranea* has one or more inhalant openings and usually one distinctive exhalant aperture that is associated with a small mound of grey (reduced) expelled sediment (Fig. 1 a). The opening is often blocked with pelletized sediment, but water can percolate through it.



Fig.3: Heavily-burrowed muddy ground at 70m depth. Clusters of small burrows are those of *Calocaris macandreae* and the larger, often crescentic openings indicate the burrow of *Nephrops norvegicus* (foreground). Image taken from videotape, field width at mid point ca 80cm-

Fig. 3: Fondale fangoso alla profondità di 70m, dove sono presenti parecchie tracce di tane. I gruppi di piccole tane appartengono a Calocaris macandreae e i gruppi di tane più grosse, spesso con apertura a falce di luna, indicano quella del Nephrops norvegicus (primo piano). Immagine tratta da un videotape, ampiezza di campo al punto medio ca. 80 cm



Burrows in sandy sediments usually have several inhalant apertures: those in muddy sediments usually have a single inhalant aperture. The burrow may extend to around a metre in depth and the deep part of the burrow consists of a complex lattice of nodular galleries. The species is primarily a deposit feeder, but shows some plasticity in feeding mode (Nickel and Atkinson, 1995). The burrows of this species have been recognised on both inshore and offshore Central Adriatic grounds and in the Pomo pit.

Offshore deep-water Nephrops grounds

The Pomo pit is characterised by clay-dominated muddy sediments (IMBC, UMBSM and IRPEM, 1994). A high density of small *Nephrops is* present on this ground. Peak catches are crepuscular and the lowest catches are at night, this reflecting emergence behaviour (Froglia, 1972; Froglia and Gramitto, 1986).

The thalassinideans *Calocaris macandreae* and *Callinassa subterranea* are also very common. The red band fish, *Cepola rubescens*, is rarely encountered, but Fries' goby, *Lesueurigobius friesii* is frequently caught and has been seen using UWTV.

The caridean *Alpheus glaber* also occurs on this ground. Its distribution seems related more to the presence of suitable muddy substrata than to depth. There are a number of fish and Crustacea in this area that are almost certainly burrow-dwellers but whose burrows and burrowing behaviour await description (see Marrs *et al.*, 1996).

CONCLUSIONS

Many conspicuous burrows in Adriatic waters can now be confidently assigned to the species responsible for these structures. Species-specific burrow architecture is revealed from resin casts of burrows but, in the absence of this, surface features such as the size, number, orientation and shape of burrow openings are often sufficient to facilitate burrow identification from UWTV or SCUBA observations.

There is sufficient information to undertake stock assessments of the commercially important crustaceans *Nephrops norvegicus* and *Squilla mantis* based on burrow counts using UWTV. Further information on burrow occupancy will refine the accuracy of the method. Information on burrow structure is by no means complete: several species that are known to burrow have still to be associated with their burrows in the field and, conversely, some burrow structures have been observed for which the occupants are presently unknown. The thalassinidean decapods (mud-shrimps) are an ecologically important group of burrow-dwelling crustaceans that are well represented in Adriatic waters, but for which much information is still unknown.

Recent work has extended the list of thalassinidean species present in the Adriatic (Dworschak, 1992, 1998; Aded-Navandi and Dworschak, 1997, 1998), but distribution information for many of them is very incomplete. The extensive areas of offshore sand in the Adriatic have not been investigated in relation to burrow-dwelling fauna and there is also a paucity of information from grounds in the Southern Adriatic.

New areas of research include the effects of trawl gear on grounds containing burrow-dwelling species, but it is premature to report the results of this work at this stage.



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