Some observations on the Mesolithic crustacean assemblage from Ulva Cave, Inner Hebrides, Scotland.

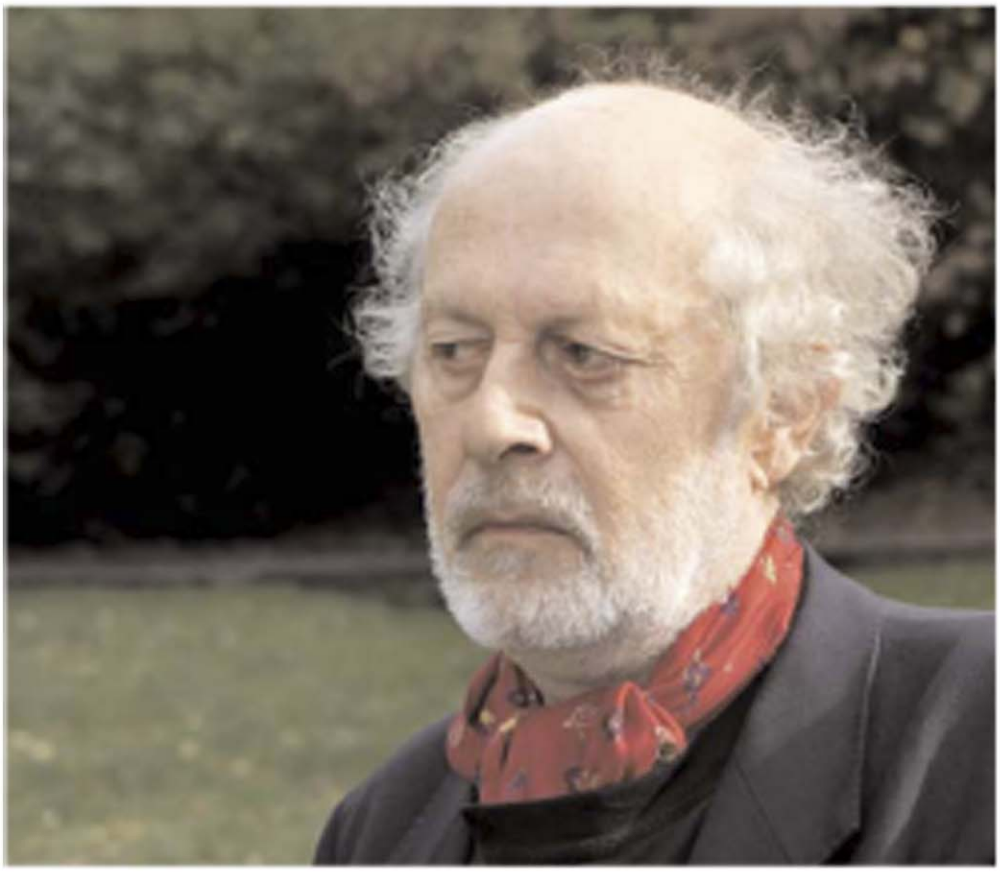
Citation for published version:
Pickard, C & Bonsall, C 2009, 'Some observations on the Mesolithic crustacean assemblage from Ulva Cave, Inner Hebrides, Scotland.'. in JM Burdukiewicz, K Cyrek, P Dyczek & K Szymczak (eds), Understanding the Past: Papers Offered to Stefan K. Kozowski. University of Warsaw Center for Research on the Antiquity of Southeastern Europe, Warsaw, pp. 305-313.

Published In:
Understanding the Past

Understanding the Past

Papers offered to Stefan K. Kozłowski

UNIVERSITAS VARSOVIENSIS



Stefan Karol Kozłowski
Professor at the University of Warsaw,
Professor at the Cardinal Stefan Wyszyński University in Warsaw,
Member of PAU (Polish Academy of Arts and Sciences),
Researcher of European Mesolithic and Middle East Neolithic,
Inventor and long-standing President of Mesolithic Commission of UISPP
(International Union for Prehistoric and Protohistoric Sciences),
Lecturer of Collège de France (Paris)
and Maison de l'Orient et de la Méditerranée (Lyon, France)

Under stand ing the Past

Papers offered to Stefan K. Kozłowski

edited by
Jan Michał Burdukiewicz,
Krzysztof Cyrek,
Piotr Dyczek
and Karol Szymczak

Center for Research on the Antiquity of Southeastern Europe
University of Warsaw
Warsaw 2009

Contents

Afterwords

Some Observations on the Mesolithic Crustacean Assemblage from Ulva Cave, Inner Hebrides, Scotland

CATRIONA PICKARD and CLIVE BONSALL

Introduction

The existence of Mesolithic shell middens along the west coast of Scotland has been known since the nineteenth century, yet the first systematic investigations of these sites took place only in the 1970s with Paul Mellars' work on the island of Oronsay (Mellars, 1987). With its emphasis on chronometric dating and the recovery of detailed information on economy, environment and seasonality of site use, the Oronsay Project set new standards for shell midden research in the region.

The west coast middens are generally small and associated with rocky shorelines, yet they often contain a surprisingly wide variety of food and other remains. Much has been written about the molluscan, fish, and mammalian components of the middens. Although the presence of crustacean remains has frequently been reported (e.g., Mellars, 1978; Connock et al., 1993), hitherto there has been no detailed published account for any site[1] – yet, potentially, crustaceans are an important source of palaeoeconomic and palaeoenvironmental data.

This paper provides an account of the crustacean assemblage from the Mesolithic shell midden in Ulva Cave, a large sea-cut cave on the south side of a small island that lies off the west coast of the much larger island of Mull in the Inner Hebrides – about 50 km straight line distance to the north of the island of Oronsay (Figure 1).

[1] Since this paper was written (April 2008) a study of the crab remains from a Mesolithic shell midden at Sand, on the west coast of Scotland, has been published (Milner, 2009).

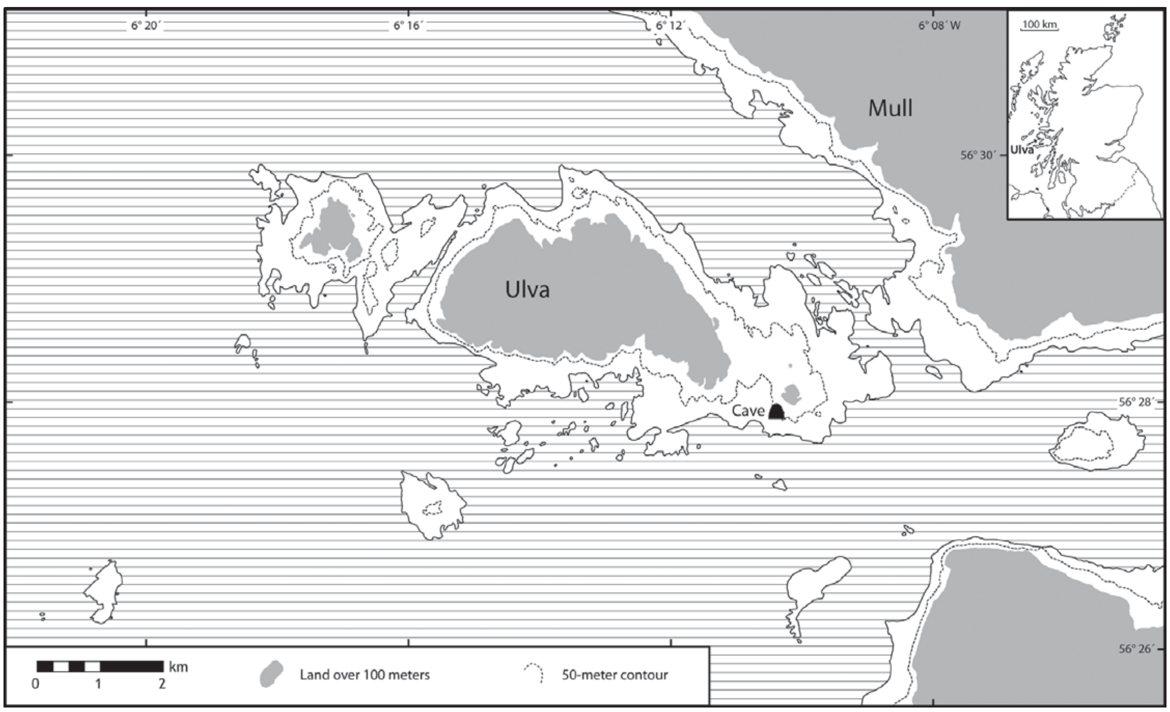


Figure 1. Location of Ulva Cave.

The crustacean assemblage: sampling and analysis

The Ulva Cave excavation began in 1987 and, to date, five field seasons have been completed (Bonsall et al., 1991, 1992, 1994; Russell et al., 1995). The shell midden in the entrance area of the cave was investigated in 1989–1991 and 1999. Lacking clear stratification, the midden was excavated according to a 50 cm grid in horizontal unit-levels ("spits") of ca. 5 cm thickness – except for an initial sondage, which was dug on a one-meter grid, in 10 cm spits (Figure 2). All excavated material from the 1999 field season and control samples from five grid squares dug in 1989–1991 (see Russell et al., 1995: figure 4) were processed under laboratory conditions to maximize the recovery of palaeoenvironmental and economic indicators. Faunal remains recovered from these samples include fish, shellfish, land and sea mammals, crustaceans, echinoderms and cnidarians. The last two groups were sparsely represented, but crustaceans were common and consisted exclusively of remains of brachyuran crabs. The following discussion is based on a study of 1373 individual elements from crabs, which were recovered from midden samples excavated in 1989 and 1999 (the crab remains from samples collected in 1990 and 1991 have yet to be analyzed). Species identification was facilitated by reference collections held at the University of Edinburgh and the Royal Museum of Scotland, and the assemblage was quantified by counts of the number of identifiable specimens (NISP) and minimum number of individuals (MNI).

The *Brachyura* (true crabs) are a morphologically diverse group (Hughes and Seed, 1995). Species-specific characteristics such as coloring or the distinctive shape, size or surface texture of the exoskeleton may facilitate identification. Attribution of archaeological specimens to species is possible if diagnostic elements, such as chelipeds (claws) or surface pigmentation, are preserved. Preservation in the Brachyura assemblage from Ulva Cave was highly variable. Carapace elements were extremely fragmented, which generally precluded identification beyond the infraorder level. In contrast, cheliped elements were well preserved, often bearing traces of surface coloration — a reflection of the robust nature of the highly mineralized claw compared to other elements of the crab exoskeleton (cf. Boßelmann et al., 2007). Of the 1373 fragments identified from Ulva Cave, 396 retained diagnostic features sufficient for attribution to family or species level.

A maximum of eight species are represented in the Ulva assemblage (Figure 3, Table 1). Species-diagnostic elements were found to be predominantly dactyl and propodus remains; cheliped dactyl tips were preferentially used to establish MNI. Closely-related species of crabs are often only distinguishable by pigmentation. Sandy swimming crab (*Liocarinus depurator*) and velvet swimming crab (*Necora puber*) largely differ only in the coloration of cheliped tips. Species-level identification was possible only where surface pigmentation was preserved. Specimens with abraded surfaces, particularly common in the lower part of the midden, were identified to family level. Both species of swimming crab were considered as a single category for the purpose of quantification. Certain minor species (e.g., scorpion spider crab [*Inachus dorsettensis*] and the European spider crab [*Maja squinado*]) were represented by antero-lateral teeth and tubercles of the carapace, reflecting perhaps the more fragile nature of the chelipeds of spider crabs. Such elements are not absolutely diagnostic, and so attribution to species is tentative.

NISP and MNI counts indicate that the main species targeted by Mesolithic foragers at Ulva Cave were edible crab (*Cancer pagurus*), green shore crab (*Carcinus maenas*), sandy swimming crab (*Liocarcinus depurator*) and/or velvet swimming crab (*Necora puber*) (Table 1). However the two quantification methods produce rather different impressions of the economic importance of the four species (Figure 4). In particular, the relative abundance of swimming crabs is significantly greater in the NISP counts. Swimming crabs have distinctive surface tubercles on carapace, chelipeds and pereopeds. Consequently, identification of very small fragments to species level is straightforward and would be expected to result in over-representation in NISP counts. Swimming crabs comprise 41.7% of the Ulva Cave Brachyura assemblage by NISP, but only 28.6% by MNI — the latter is generally considered more representative of the relative species abundance in fragmented assemblages (Marshall and Pilgram, 1993). Therefore, all further discussion of the relative abundance of the species identified at Ulva Cave will be based on MNI, even though the highly variable size range of fragmentary and complete claw dactyls suggests that MNI will underestimate the absolute abundance of Brachyura at Ulva Cave (the size difference between left and right chelipeds [cf. Vermeij, 1977] presents a problem for MNI calculations).

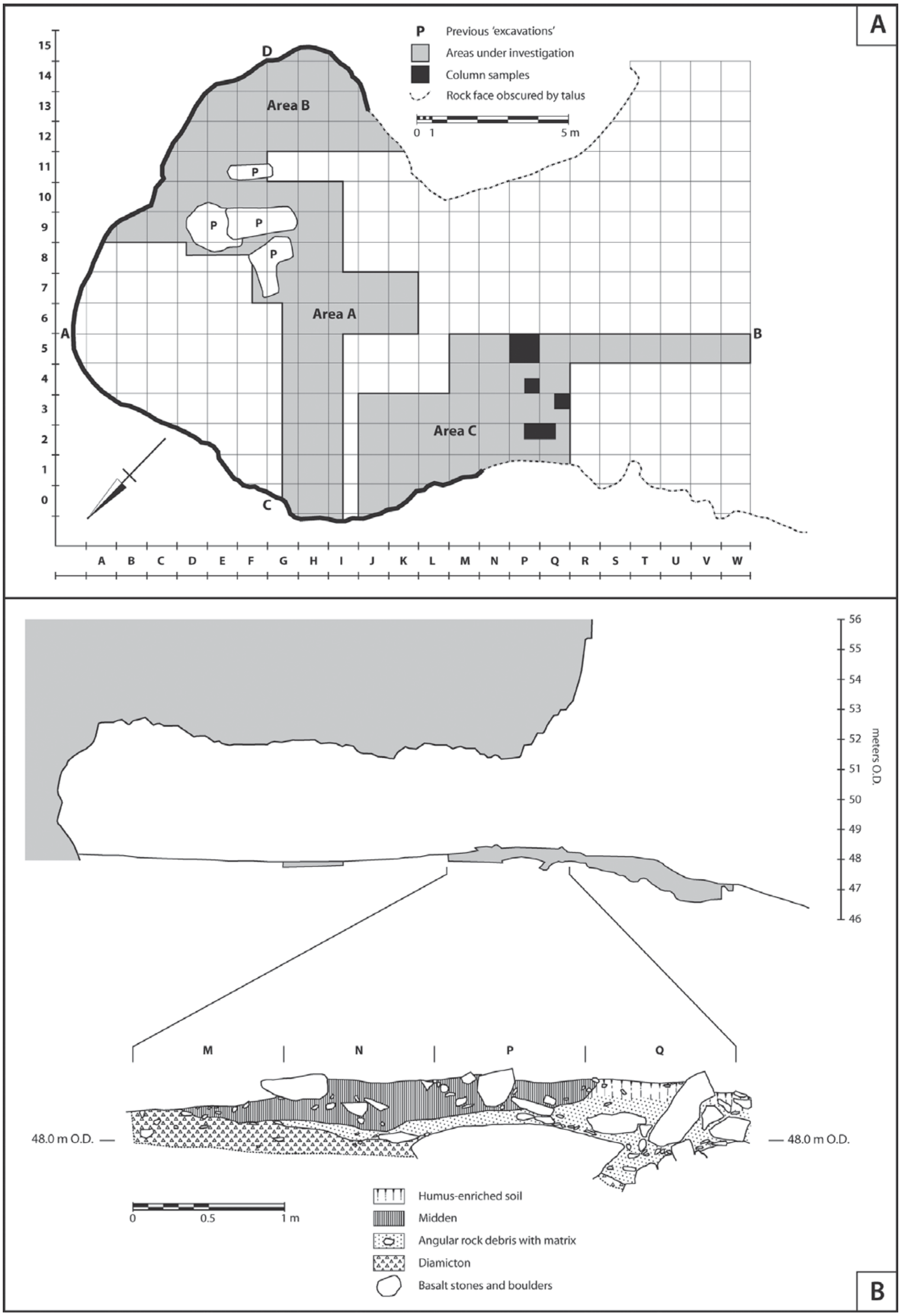


Figure 2. Ulva Cave. A – areas investigated between 1987 and 1999; B – cross-section of the cave and stratigraphic profile of the midden. After (Russell et al., 1995: figures 4 and 5).

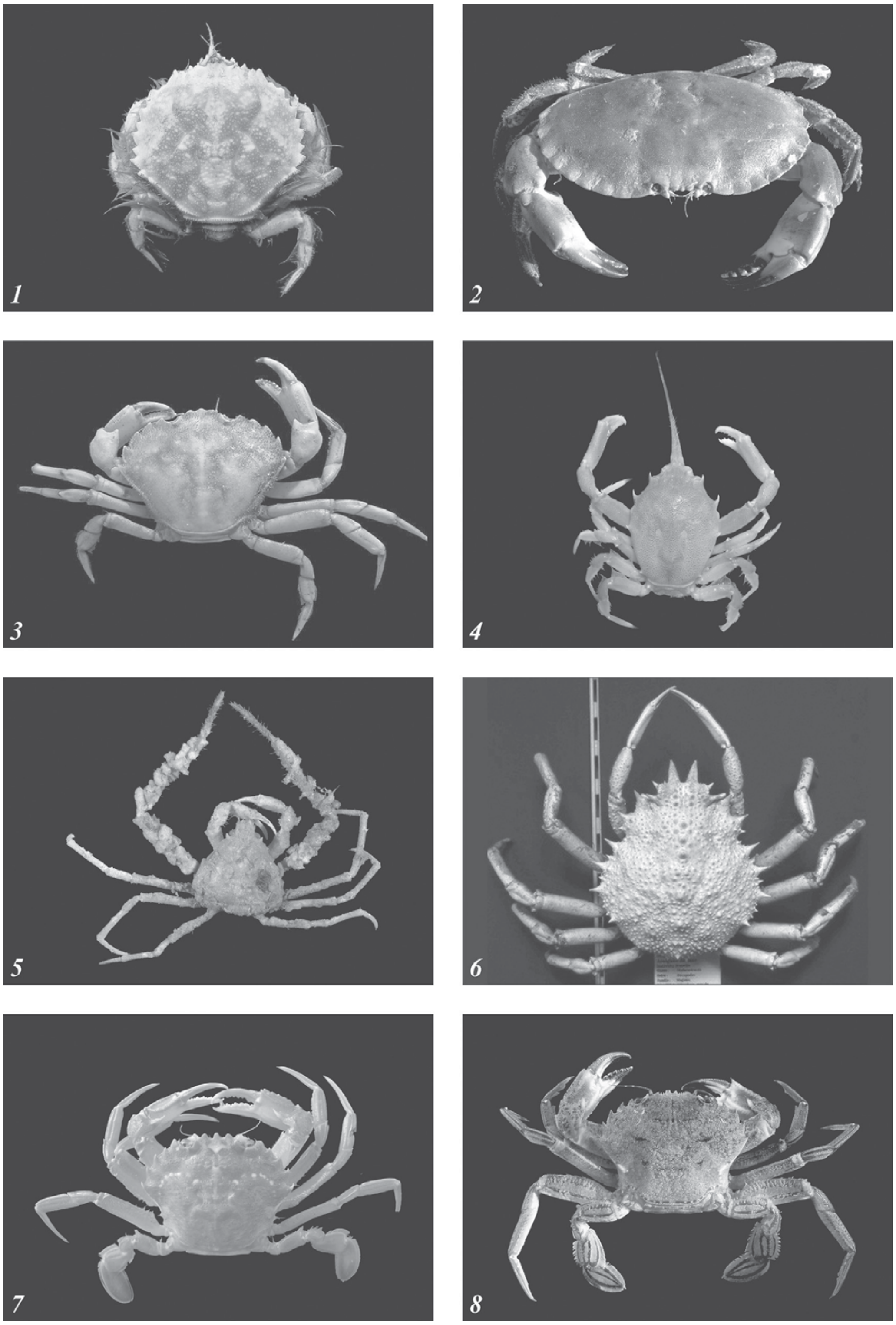


FIGURE 3. Photographs of the crab species represented in the Ulva Cave midden. 1 – Circular crab (*Atelecyclus rotundatus*); 2 – Edible crab (*Cancer pagurus*); 3 – Green shore crab (*Carcinus maenas*); 4 – Masked crab (*Corystes cassivelaunus*); 5 – Scorpion spider crab (*Inachus dorsettensis*); 6 – Spider crab (*Maja squinado*); 7 – Sandy swimming crab (*Liocarcinus depurator*); 8 – Velvet swimming crab (*Necora puber*). Photographs, no. 1–5, 7, 8 – H. Hillewaert (reproduced under the Creative Commons Copyright License); no. 6 – S. Miquel.

Table 1. Brachyuran crab species identified at Ulva Cave.

Latin name	Common name	MNI	%	NISP	%
Atelecyclus rotundatus (Olivi, 1782)	Circular crab	1	2.38	1	0.25
Cancer pagurus (Linnaeus, 1758)	Edible crab	17	40.48	165	41.67
Carcinus maenas (Linnaeus, 1758)	Green shore crab	9	21.43	59	14.90
Corystes cassivelaunus (Pennant, 1777)	Masked crab	1	2.38	2	0.51
Inachus dorsettensis (Pennant, 1777)	Scorpion spider crab	1	2.38	1	0.25
Maja squinado (Herbst, 1788)	Spider crab	1	2.38	3	0.76
Liocarcinus depurator (Leach, 1814)	Sandy swimming crab	12	28.57	165	41.67
Necora puber (Linnaeus, 1767)	Velvet swimming crab				
	Totals	42	100.00	396	100.00

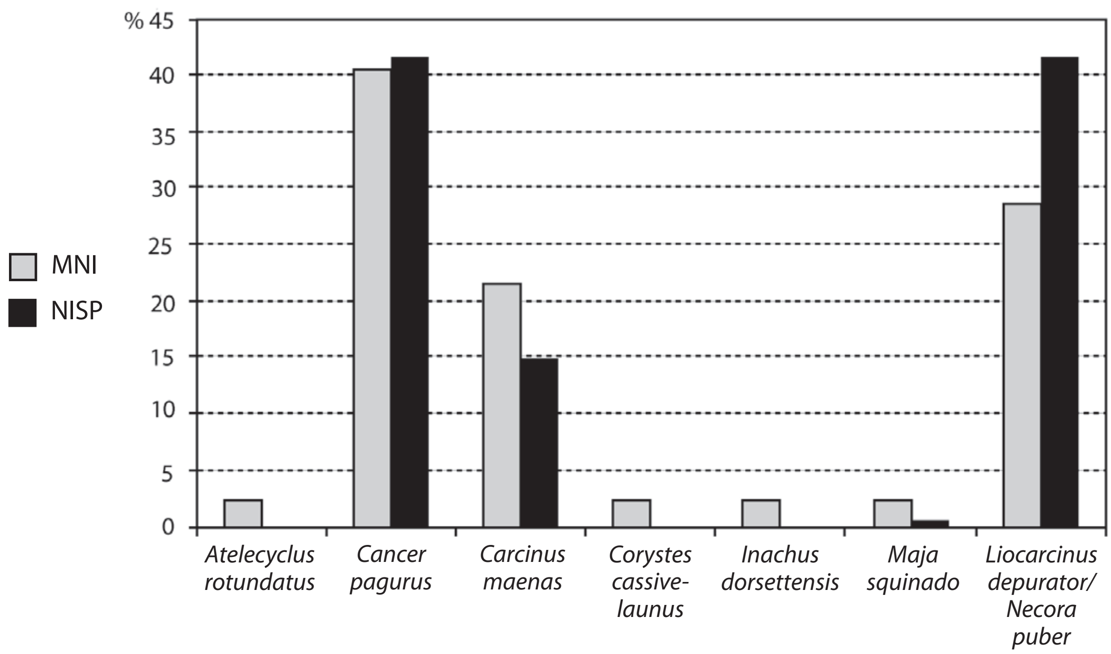


Figure 4. Ulva Cave: Brachyuran crab species representation by NISP and MNI.

Discussion

Brachyura remains were recovered from all grid squares and vertical units sampled, which implies consistent exploitation of crabs throughout the period of midden accumulation (ca. 8460–6480 cal B.C.) at Ulva Cave.

Crab Biology and Behaviour, and Human Harvesting Strategies

Over 50 native species of Brachyura inhabit British coastal waters today. The restricted species diversity of the assemblage from Ulva Cave suggests selective harvesting by Mesolithic foragers. The four main species represented – edible crab (*Cancer pagurus*), green shore crab (*Carcinus maenas*), sandy swimming crab (*Liocarcinus depurator*), and velvet swimming crab (*Necora puber*) together comprise over 84% of the assemblage. These are also the main target species of lucrative commercial pot fisheries along the Atlantic seaboard of Europe today. The species structure of the Ulva assemblage is therefore suggestive of Mesolithic prey selection for palatable, high food value species. The distinctive biology and behaviour of the four main species of crabs permits some observations on procurement strategies and techniques, and seasonality of crabbing activities at Ulva Cave.

The timing of traditional crab fisheries and the techniques employed are species specific, reflecting

Table 2. Seasonal availability and preferred habitat of crab species represented at Ulva Cave.

Species	Shoreline availability	Preferred habitat
Atelecyclus rotundatus	Year round – lower shore	Soft substrates
Cancer pagurus juvenile	Year round – lower shore or sublittoral	Rocky shores under stones and seaweed – tolerates a range of substrates
Cancer pagurus adult female	May–August – lower shore or sublittoral	Rocky shores under stones and seaweed – tolerates a range of substrates
Cancer pagurus adult male	April–November – lower shore or sublittoral	Rocky shores under stones and seaweed – tolerates a range of substrates
Carcinus maenas	Year round – middle and lower shore	Tolerates a range of substrates
Corystes cassivelaunus	Year round – lower shore	Burrows in sandy substrates
Inachus dorsettensis	Year round – lower shore	Among seaweed on rocky shores
Liocarcinus depurator	Year round – lower shore	Soft substrates
Maja squinado juvenile	Year round – lower shore	Among seaweed on rocky shores
Maja squinado adult	Warmer months – lower shore	Among seaweed on rocky shores
Necora puber	Year round – lower shore	Rocky shores under stones and seaweed – larger specimens offshore to depths of 80 m

the food preferences, habitat, activity patterns, and aggression of the prey (Skajaa et al., 1998). Scheduling of crabbing activities and harvesting methods may further vary according to age-dependent characteristics of species behaviour, i.e., the seasonal availability of juveniles and adults of the same species may be significantly different and they may be suited to capture by different methods (Howard, 1982; Hines et al., 1995). Accurate reconstruction of specimen size (and therefore age) of the Ulva Cave Brachyura was hampered by the fragmentary nature of carapace remains. However, an approximate indication of specimen size can be established from metrical traits of crab claws (Vermeij, 1977). Reconstruction of specimen size determined from complete dactyls at Ulva Cave indicated that both juveniles and adults of the four principal species were collected. The remains of all other species identified were too fragmentary to permit size estimation.

Several of the species identified at Ulva Cave permanently occupy onshore or intertidal habitats; velvet and sandy swimming crabs, circular crab, scorpion spider crab, masked crab, juvenile edible crab, and European spider crab can all be gathered throughout the year (Table 2; Regnault, 1994; Hines et al., 1995). By contrast the harvesting of mature specimens of some economically important species *from the shore* is seasonally restricted. Mature female edible crabs are seldom taken in commercial or traditional crab fisheries. After mating in shallow waters in late summer the ovigerous female migrates to deeper water for a period of 6–9 months, from November to August. During this period the female crab takes shelter in crevices or buries into soft substrate and does not feed or respond to bait and is unlikely to be harvested (Howard, 1982). Adult males also migrate to sublittoral waters in winter (Brown and Bennett, 1980). Similar winter migrations to deeper water are undertaken by adult European spider crab and green shore crab in northern Britain (Crothers, 1968; Latrouite and Le Foll, 1989; Dittman and Villbrandt, 1999; Gonzalez-Gurriaran et al., 2002). Juvenile edible crab and European spider crab are available in intertidal waters throughout the year (Table 2). It is likely that crabs were collected during shellfishing or general beachcombing expeditions. Limpet morphology (*Patella vulgata*) at Ulva Cave is consistent with the collection of this species from the lower to middle shore zone (Russell et al., 1995), which is also the preferred habitat of the Brachyura identified in the midden samples. Scorpion spider crab is a small species (maximum carapace width of 30 mm) and is of little economic value (Table 3). It may have been taken to the cave inadvertently attached to the seaweeds in which it resides. Seaweed collection for food or fuel has been inferred from the frequent presence in the Ulva midden of small shellfish that inhabit *Laminaria*, such as the blue-rayed limpet (*Helcion pellucidum*) (Russell et al., 1995).

HARVESTING GEAR AND BAIT

Modern commercial fisheries along British coasts harvest crabs from deep offshore waters using crab-

TABLE 3. Adult size range of crab species represented in Ulva Cave.

Species	Size
Atelecyclus rotundatus	Up to 40 mm across
Cancer pagurus	> 200 mm across, up to 4 kg in weight
Carcinus maenas	< 80 mm in length, up to 80 mm across
Corystes cassivelaunus	Up to 40 mm in length, 25 mm across
Inachus dorsettensis	Up to 30 mm across
Liocarcinus depurator	< 40 mm in length, up to 40 mm across
Maja squinado	Up to 150 mm across
Necora puber	< 90 mm in length, up to 90 mm across

pots or creels. Wilson envisaged a similar fishery in Mesolithic Scotland, suggesting that crabs were taken "from the deep waters off Oronsay and Oban by means of plaited baskets" (Wilson, 1991: 17). However, as noted above, all the Brachyuran species represented at Ulva Cave could have been taken onshore or in shallow waters at certain times of the year. Comparison with traditional practices suggests that crab-fishing expeditions into deep waters are unlikely to have been undertaken in the Mesolithic (Pickard and Bonsall, 2004). Moreover, traditional methods of fishing predatory crabs involve a wide range of techniques including hand capture and the use of simple gear (e.g., Van Stone, 1962; Nelson, 1969; Lee et al., 2004; Paolisso, 2007). The specific method employed is dependent on species behaviour. For example, hand collection of aggressive predatory crabs or species with pronounced spines or antero-lateral teeth can result in painful injuries. Such species are best captured remotely using nets, pots or lines. Tangle nets are commonly used to harvest species with carapace spines and pronounced antero-lateral teeth (Gonzalez-Gurriaran et al., 2002). Swimming crabs (*Liocarcinus depurator* and *Necora puber*), which are renowned for their ferocity (Huntingford et al., 1995), are often taken in dip nets. More passive species such as the green shore crab and even the edible crab can be taken by hand and are widely reported to have been captured by children at play (Gregor, 1891).

For the capture of predatory species baited gear is most efficient. However, during ecdysis ("molting") most species of crab do not feed and will not respond to baited gear (Freire, 1996). Any type of carrion, with the exception of the flesh of conspecifics, will act as effective crab bait (Hancock, 1974).

Nocturnal feeding behaviour makes the edible crab, swimming crabs, and the green shore crab more vulnerable to capture at night (Ropes, 1968; Skajaa et al., 1998). Crab pots are therefore most effectively set overnight. Torches were used in traditional fisheries as lures attracting surface swimming crabs, which were lifted in dip nets. However, all of the species identified at Ulva Cave could have been collected at low tide, from under stones, seaweed, in crevices and shallow burrows with minimal equipment, especially in the warmer months of the year.

PROCESSING

Unlike most other seafoods crabs can live for several days after capture, that is, they do not need to be immediately dispatched for consumption. Although crab may be eaten raw, the meat is much more easily removed from the shell after cooking. Moreover, the meat is more palatable if the crab has been killed immediately prior to cooking. There is little evidence for the cooking methods used in the Mesolithic at Ulva Cave. Common practice today is to boil or steam the crab, although baking can be employed. Baking may have been more common in the Mesolithic, although charred crustacean remains, which would attest to this method of processing, were rare in the Ulva Cave midden.

PALAEOENVIRONMENTAL SIGNIFICANCE

The preferred habitats of the crab species represented at Ulva Cave are varied. Green shore crab, for example, favors sheltered rocky shores with algae for camouflage (Crothers, 1968), edible crab and velvet swimming crab prefer moderately exposed shores (Edwards, 1979; Lee et al., 2006), whereas sandy swimming crab and masked crab dominate Brachyuran populations on very exposed shores (Crothers, 1968). However these species tolerate a wide range of conditions and the overall species structure of the assemblage is suggestive of collection from a moderately exposed, predominantly rocky shoreline, perhaps somewhat less exposed than present shore conditions below the cave. This is consistent with dog-whelk elongation data, which point to the existence of a sheltered marine inlet below the cave at the time of midden formation, related to a higher relative sea level (Russell et al., 1995).

European spider crab was identified from the presence of characteristic antero-lateral teeth and tubercles. Today, this species reaches its northernmost distribution in southern Britain. Its presence in the Ulva midden contributes to the growing body of data from the site that point to warmer sea temperatures, by at least 1–2 °C, at the time of midden deposition. The presence of green ormer (*Haliotis tuberculata*) and thick topshell (*Monodonta lineata*) in the middle and lower midden deposits are also suggestive of warmer sea temperatures; both species have more southerly distributions in the British Isles today.

Conclusions

Crustacean remains (especially crabs) are common in Mesolithic shell middens along the coast of western Scotland, but they have received little attention in the archaeological literature. This paper has outlined the results of a preliminary study of the crustacean assemblage from Ulva Cave in the Inner Hebrides. Eight species of crabs were identified in the midden at Ulva Cave, although three or four species dominate the assemblage and appear to have been deliberately targeted for food; these are edible crab, green shore crab, sandy swimming crab and/or velvet swimming crab. All the species identified could have been collected from the intertidal zone more or less throughout the year, although adult specimens of edible crab and spider crab would have been more readily available in the warmer months (April to November). Some species (e.g., green shore crab) are easily collected by hand; others, such as aggressive predatory crabs (e.g., velvet swimming crab and sandy swimming crab) or those with carapace spines and pronounced antero-lateral teeth (e.g., Europe spider crab) may have been captured using nets, traps or baited lines. The presence of European spider crab at Ulva Cave suggests that average annual sea temperatures around Ulva at the time of midden formation were somewhat higher than at the present day.

References

Bonsall, C., Sutherland, D.G., and Lawson, T.J., 1991, Excavations in Ulva Cave, Western Scotland 1987: A Preliminary Report. *Mesolithic Miscellany* 12: 18–23.

Bonsall, C., Sutherland, D.G., Russell, N.J., Coles, G., Paul, C., Huntley, J., and Lawson, T.J., 1994, Excavations in Ulva Cave, Western Scotland 1990–91: A Preliminary Report. *Mesolithic Miscellany* 15: 8–21.

Bonsall, C., Sutherland, D.G., Russell, N.J., and Lawson, T.J., 1992, Excavations in Ulva Cave, Western Scotland 1989: A Preliminary Report. *Mesolithic Miscellany* 13: 7–13.

Boßelmann, F., Romano, P., Fabritius, H., Raabe, D., and Epple, M., 2007, The Composition of the Exoskeleton of Two Crustacea: The American Lobster *Homarus americanus* and the Edible Crab *Cancer pagurus*. *Thermochimica Acta* 463: 65–68.

Brown, C.G., and Bennett, D.B., 1980, Population and Catch Structure of the Edible Crab (*Cancer pagurus*) in the English Channel. *Journal du Conseil* 39: 88–100.

Connock, K.D., Finlayson, B., and Mills, C.M., 1993, Excavation of a Shell Midden Site at Carding Mill Bay, near Oban, Scotland. *Glasgow Archaeological Journal* 17: 25–38.

Crothers, J.M., 1968, The Biology of the Shore Crab, *Carcinus maenas* (L.) 2: The Life of the Adult Crab. *Field Studies* 2: 579–614.

Dittmann, S., and Villbrandt, M., 1999, Size Frequency, Distribution and Colour Variation of *Carcinus maenas* in the Spiekeroog Backbarrier System. In *The Wadden Sea Ecosystem: Stability Properties and Mechanisms*, edited by S. Dittmann, Springer Verlag, Berlin: 163–173.

Edwards, E., 1979, *The Edible Crab and Its Fishery in British Waters*. Farnham: Fishing News Books.

Freire, J., 1996, Feeding Ecology of *Liocarcinus depurator* (Decapoda: Portunidae) in the Ria de Arousa (Galicia, North-West Spain): Effects of Habitat, Season and Life History. *Marine Biology* 126: 297–311.

Gonzalez-Gurriaran, E., Freire, J., and Bernardez, C., 2002, Migratory Patterns of Female Spider Crabs *Maja squinado* Detected Using Electronic Tags and Telemetry. *Journal of Crustacean Biology* 22: 91–97.

Gregor, W., 1891, The Scotch Fisher Child. *Folklore* 2: 73–86.

Hancock, D.A., 1974, Attraction and Avoidance in Marine Invertebrates — Their Possible Role in Developing an Artificial Bait. *Journal du Conseil* 35: 328–331.

Hines, A.H., Wolcott, T.G., Gonzalez-Gurriaran, E., Gonzalez-Escalante, J.L., and Friere, J., 1995, Movement Patterns and Migrations in Crabs: Telemetry Studies of Juvenile and Adult Behaviour in *Callinectes sapidus* and *Maja squinado*. *Journal of the Marine Biological Association of the UK* 75: 27–42.

Howard, A.E., 1982, The Distribution and Behaviour of Ovigerous Edible Crabs (*Cancer pagurus*), and Consequent Sampling Bias. *Journal du Conseil* 40: 259–261.

Hughes, R.N., and Seed, R., 1995, Behavioural Ecology of Brachyura Crustaceans: An Experimental Approach. *Journal of Experimental Marine Biology and Ecology* 193: v.

Huntingford, F.A., Taylor, A.C., Smith, I.P., and Thorpe, K.E., 1995, Behavioural and Physiological Studies of Aggression in Swimming Crabs. *Journal of Experimental Marine Biology and Ecology* 193: 21–39.

Latrouite, D., and Le Foll, D., 1989, Données sur les Migrations des Crabes Tourteau *Cancer pagurus* et Araignées de Mer *Maja squinado*. *Océanis* 15: 133–142.

Lee, C.-G., Huettel, M., Hong, J.-S., and Reise, K., 2004, Carrion-feeding on the Sediment Surface at Nocturnal Low Tides by the Polychaete *Phyllodoce mucosa. Marine Biology* 145: 575–583.

Lee, J.T., Coleman, R.A., and Jones, M.B., 2006, Population Dynamics and Growth of Juveniles of the Velvet Swimming Crab *Necora puber* (Decapoda: Portunidae). *Marine Biology* 148: 609–619.

Marshall, F., and Pilgrim, T., 1993, NISP vs MNI in Quantification of Body-part Representation. *American Antiquity* 58: 261–269.

Mellars, P.A., 1978, Excavation and Economic Analysis of Mesolithic Shell Middens on the Island of Oronsay (Inner Hebrides). In *The Early Postglacial Settlement of Northern Europe*, edited by P.A. Mellars, Duckworth, London: 371–396.

Mellars, P.A., 1987, *Excavations on Oronsay: Prehistoric Human Ecology on a Small Island*. Edinburgh University Press, Edinburgh.

Milner, N., 2009, Consumption of Crabs in the Mesolithic, Side Stepping the Evidence? In *Mesolithic and Later Sites around the Inner Sound, Scotland: The Work of the Scotland's First Settlers Project 1998–2004*, edited by K. Hardy and C. Wickham-Jones, Scottish Archaeological Internet Reports 31 (online), http://www.sair.org.uk/sair31/section3-13.html.

Nelson, R.K., 1969, *Hunters of the Northern Ice*. University of Chicago Press, London.

Paolisso, M., 2007, Cultural Models and Cultural Consensus of Chesapeake Bay Blue Crab and Oyster Fisheries. *National Association for the Practice of Anthropology Bulletin* 28: 123–135.

Pickard, C., and Bonsall, C., 2004, Deep-sea Fishing in the European Mesolithic: Fact or Fantasy? *European Journal of Archaeology* 7: 273–290.

Regnault, M., 1994, Effect of Air Exposure on Ammonia Excretion and Ammonia Content of Branchial Water of the Crab *Cancer pagurus*. *Journal of Experimental Zoology* 268: 208–217.

Ropes, J.W., 1968, The Feeding Habits of the Green Crab, *Carcinus maenas* (L.). *Fishery Bulletin of the US Fish and Wildlife Service* 67: 183–203.

Russell, N.J., Bonsall, C., and Sutherland, D.G., 1995, The Exploitation of Marine Molluscs in the Mesolithic of Western Scotland: Evidence from Ulva Cave, Inner Hebrides. In *Man and Sea in the Mesolithic*, edited by A. Fischer, Oxbow Books, Oxford: 273–288.

Skajaa, K., Ferno, A., Lokkeborg, S., and Haugland, E.K., 1998, Basic Movement Pattern and Chemo-oriented Search Towards Baited Pots in Edible Crab (*Cancer pagurus* L.). *Hydrobiologia* 372: 143–153.

Van Stone, J.W., 1962, *Point Hope – An Eskimo Village in Transition*. University of Washington Press, Seattle.

Vermeij, G.J., 1977, Patterns in Crab Claw Size: The Geography of Crushing. *Systematic Zoology* 26: 138–151.

Wilson, C.A., 1991, *Food and Drink in Britain: From the Stone Age to the 19th Century*. Chicago.

Authors' addresses

Catriona Pickard
School of History, Classics, and Archaeology
University of Edinburgh
Old High School, Infirmary Street
Edinburgh EH1 1LT, UK
catriona.pickard@ed.ac.uk

Clive Bonsall
School of History, Classics, and Archaeology
University of Edinburgh
Old High School, Infirmary Street
Edinburgh EH1 1LT, UK
clive.bonsall@ed.ac.uk