19

^{18}O Analysis of *Littorina littorea* Shells from Ferriter's Cove, Dingle Peninsula: preliminary results and interpretations

Michael J. Kimball, William Showers, Sinéad McCartan and Bernard J. Genna

Seasonality studies can facilitate identification of variability in the purposes for which Mesolithic sites were occupied and relations among forager mobility, economy, and society. Analyses of fish remains at the site of Ferriter's Cove have produced evidence for occupation during the summer half of the year. Our study – an oxygen isotope analysis of seven Littorina littorea *(periwinkle) shells from a pit feature (F488;* c. *5200–5350 BP) at Ferriter's Cove – complicates this pattern by introducing preliminary evidence for occupation during the winter half of the year as well. These results, when corroborated by further research, will inform the development of explanatory models for Later Mesolithic settlement and mobility and, because of F488's late date, those for social change during the last quarter of the Later Mesolithic and the transition to Ireland's Neolithic.*

Introduction

In keeping with the current trend to revisit generalisations about the Mesolithic and, indeed, the definition of 'Mesolithic' itself (eg, Larsson *et al.* 2003; Lovis *et al.* 2006; Milner & Woodman 2005), evidence and perspectives are emerging that call into question normative approaches to explaining Ireland's Later Mesolithic (Woodman & McCarthy 2003; Woodman 2005; Kimball 2000a; 2006).

One set of methods that can contribute to this process is seasonality studies, which permit site functionality to be linked with season of use. From these linkages, it is possible to recognise duration and timing of occupation, which then permit the role of the site in settlement patterns to be hypothesised. However, as Milner (2005, 59) points out in her consideration of the long history of debate over Star Carr and her study of oyster consumption at the site of Norsminde, 'the ways in which we study seasonality tend to ignore variability and social reasons for food consumption.'. Thus, it is important to recognise the complexity inherent in subsistence evidence and explore its diverse causes and effects.

Ireland's later Mesolithic

By all appearances, Ireland's Later Mesolithic

– a period spanning approximately 2000 years, from *c.* 7500 to 5500 BP – consists of small groups of highly mobile foragers whose lifeways focused on aquatic and marine resources. All excavated Later Mesolithic sites suggest a settlement pattern characterised by short-term food and raw material procurement and processing camps oriented towards coasts, estuaries, rivers, and lakes. No inland, terrestrially-focused sites have yet been identified. Woodman's (1978) seminal study of Mesolithic assemblages from the northeast drew attention to this pattern almost thirty years ago. More recent regional surveys from the southeast (Green & Zvelebil 1990), east (Zvelebil *et al.* 1996), and northwest (Kimball 2000b) have lent further support.

Excavations at the floodplain site of Newferry in County Antrim (Woodman 1977), the coastal, industrial site of Bay Farm, also in County Antrim (Woodman & Johnson 1996), and the coastal site of Ferriter's Cove in County Kerry (Woodman *et al.* 1999) highlight the small-scale, short-term nature of occupations. Subsistence activities at these and other sites cover a wide spectrum of food resources including plant resources (eg, hazelnuts), marine mammals, salmonids, eels, ocean fish species, shellfish, and wild pig (Brinkhuizan 1977; McCarthy 1999; Woodman 1986; 1990). The absence of red deer from the diet is notable and likely due to a Neolithic period arrival of *Cervus elaphus* to Ireland (Woodman *et al.* 1997; Woodman & McCarthy 2003).

For the most part, the settlement and subsistence evidence encourages a broad-brush approach to explaining the Later Mesolithic settlement pattern: small groups of highly mobile foragers moved from place to place, taking advantage of Ireland's peculiar array of food and raw material resources. The evidence for lithic technology during this period makes over-generalisation even more tempting: stone artifact types and the technology used to make them are remarkably similar across the island, regardless of variation in physical geography. There is neither stylistic nor regional variation in the broad blades and flakes that, to-date, characterise Later Mesolithic technology; likewise, only hard-hammer percussion was used to produce them (Woodman 1978; Woodman & Anderson 1990).

Seasonality studies for Ireland's later Mesolithic

In Ireland, a recent example of the application of seasonality studies to the Later Mesolithic comes from analyses of faunal specimens from Ferriter's Cove on the western edge of the Dingle Peninsula in County Kerry (Woodman *et al.* 1999). In one such study, McCarthy (1999, 89) infers season of occupation based on species and size of fish recovered from the excavation:

> 'From the available evidence it can be inferred that fishing took place during the summer and autumn, and all of the fishes could easily have been captured in the immediate vicinity of the site. The size of most of the species caught (eg, small whiting, cod and saithe) indicates summer catches when they frequent coastal waters. Spawning of whiting takes place at the beginning of spring and the size of the fishes indicates that they were in their first year when netted. Herring make seasonal movements inshore and today they are caught in summer and early autumn. Tope make seasonal migrations with summertime warming of the sea, which brings it into northern European inshore waters. The other marine species in the sizes concerned will also have been most easily caught within the summer half of the year when they live near the coast. The salmon and eel bones represent summer and autumn catches respectively, but the samples involved for these migratory species are too small to reliably interpret seasonal patterns.'

In another study, Irving (1999) analyses the growth patterns of three ballan wrasse (*Labrus bergylta*) scale fragments recovered from a dump of burned stones, bones, and shell from the central area of the site. She argues that these fish died during mid-late summer. McCarthy and Irving's findings lead Woodman *et al.* (1999, 137) to conclude that the 'evidence of the fish bones and scales thus suggests that the site was most likely used in the summer and perhaps into the autumn – a possibility confirmed by the concentrations of burnt hazelnut shells present at the site.' The authors discuss a conjectural model of summer and autumn seasons spent at Ferriter's Cove, followed by eastward movements to winter campsites on the northern shore of the Dingle Peninsula (Woodman *et al.* 1999).

These results suggest the time of year during which foragers used the Ferriter's Cove area for fishing activities. Further research needs to be conducted into seasonality indicators from other fauna before a firm foundation is laid upon which to build a more complete understanding of when and for what purposes the site was occupied. From there it will be possible to construct models that recognise and account for variation in landscape and resource use by foragers.

Seasonality and periwinkles

It is in this spirit that we conceived and conducted the seasonality study reported in this paper. In the following paragraphs, we present preliminary results and interpretations stemming from our oxygen stable isotope analysis of seven *Littorina littorea* (periwinkle) shells from Ferriter's Cove. First, we briefly explain the significance of oxygen isotopes for seasonality studies. Second, we describe the context and quality of the sample of shells used for the study and methods we used for sampling and analysing them. We then present the results of our analysis and discuss some preliminary interpretations that call for more research – especially stable isotope investigations – into the use history of Ferriter's Cove and other Later Mesolithic sites. Based on this call, we conclude with a consideration of our findings in light of recent research.

Methods

Oxygen stable isotopes and seasonality

Stable isotope compositions vary with the geographic origin and environmental context of the material being analysed (Criss 1999). For this reason, stable isotopes of oxygen have been used as proxy data in a variety of archaeological applications, including seasonality studies (eg, Andrus & Crowe 2000; Kennett & Voorhies 1996; Bailey *et al.* 1983; Killingley 1981; Mannino *et al.* 2003; Shackleton 1973). The ratios of stable oxygen isotopes in shell carbonates can document changes in the temperature of a mollusc's seawater environment, which, in turn, reflect seasonal temperature variation. The edge of a shell marks the most recent deposition of carbonate for the organism; thus, the oxygen isotope signature (δ^{18}O) for a sample taken from the edge of the shell documents the temperature of the ocean – and season of the year – when the mollusc was harvested.

Context of the* L. littorea *sample

For this study we selected a small sample of shells and employed a sampling strategy that, as Mannino *et al.* (2003, 668) put it, 'seeks to optimise seasonal discrimination while keeping the number of samples to an economic level.' In the end, our method yielded results that were informative for the generation of provisional inferences about season of harvest for the shells associated with a shallow pit feature (F488; Fig. 19.1), and, thus, the human group that created that feature. F488 is described in Woodman *et al.* (1999, 12) as follows:

> 'The second area (of two activity areas identified for the Northern Area of the site) was much more extensive, but most of the activity appeared to centre on the large pit F488, 90 cm across and 20 cm deep. It was a shallow, sloping-sided, dished pit containing a burnt basal layer and a lens of unburnt shell, charcoal, and burnt soil. Samples from the pit were submitted to the Radiocarbon Unit, Cambridge. These were dated by Switzur as part of a programme in which marine shell ^{14}C dates were compared to dates obtained from

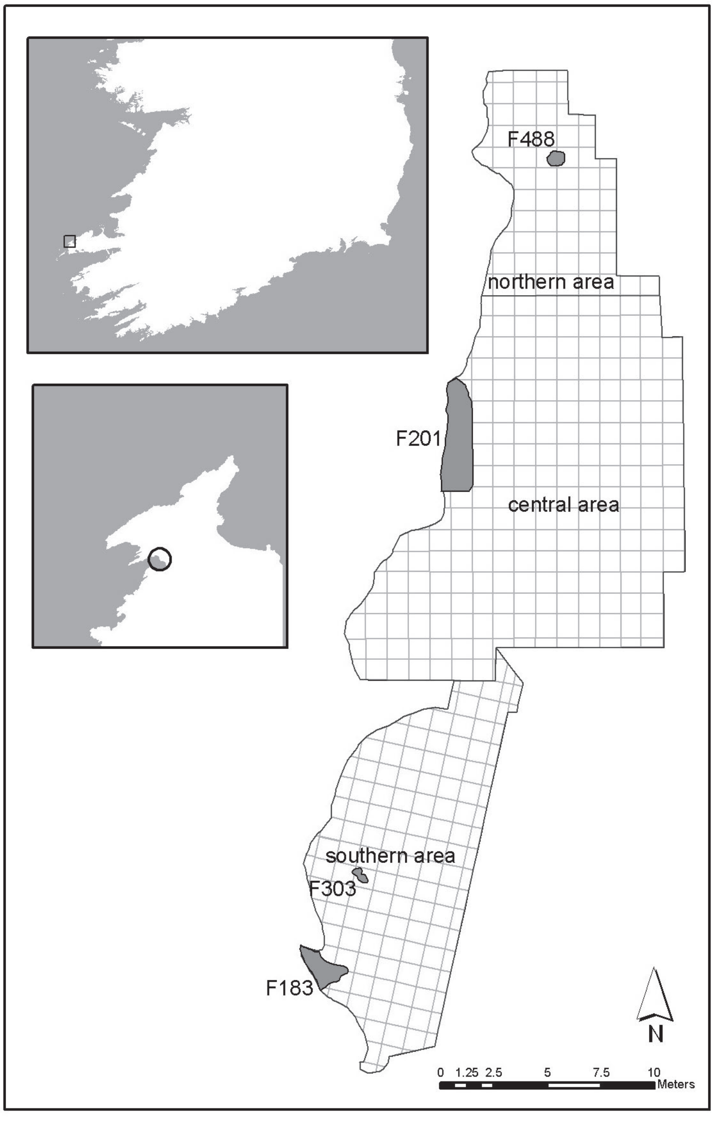

Figure 19.1. Ferriter's Cove site with F488 indicated. The site's location on the Dingle Peninsula is shown on the inset map of Ireland. The site of Ferriter's Cove is circled on the inset map of western Dingle Peninsula

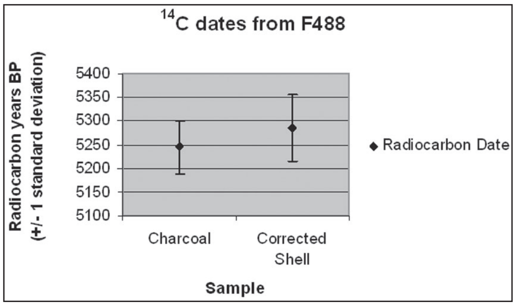

Figure 19.2. One standard deviation overlap of F488 charcoal (Q-2641) and corrected shell (Q-2634) radiocarbon dates. Correction of the shell date (-395 years) is based on advice in Switzur & Mellars 1987 (cited in Woodman et al. 1999:12)

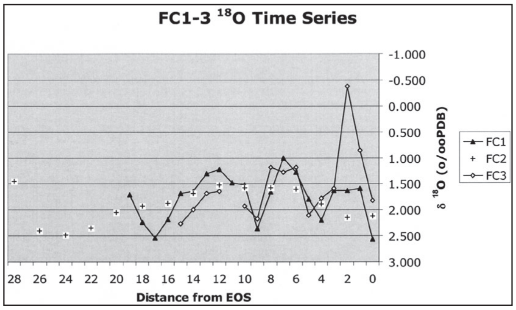

Figure 19.3. δ18O results for FC1–3 charted as time series. The Y axis has been inverted on this chart to show a more intuitive representation of sea water temperature trends (low δ18O values indicate warmer sea water temperatures). The X axis runs from the right side of the chart (EOS) to the left and represents distance in mm from the edge (aperture) of the shell

> charcoal derived from the same context: 5245±55 BP (Q-2641, charcoal) and 5680±70 BP (Q-2634, shell). Work by Switzur and Mellars (1987) suggests that there is a tendency for ^{14}C dates based on sea shells taken from the Atlantic coast to be approximately 395 years too old.'

Later in their monograph (p.126), the authors suggest that although 'there is little convincing evidence for roasting pits, it is possible that F488, which was dug early in the excavations, might have served this function.' Thus, the sample of seven shells we acquired from F488 might have been part of a roasted shellfish meal or meals. Indeed, the overlapping dates of the charcoal and corrected shell samples (Fig. 19.2), combined with the dimensions of the feature and its possible function, allow for the possibility that F488 was created during one or perhaps only a few visits to Ferriter's Cove.

For our study, we selected shells whose structural integrity suggested minimal impact from taphonomic processes such as those discussed by Claassen (1995, 55–66), namely encrustation, perforation/fragmentation, abrasion, acid dissolution, and heating. The specific microenvironment from which they were harvested is unknown. Different microenvironments, such as a location near the outflow of a stream vs. one distant from freshwater, can result in different isotopic signatures across a sample of shells (Bailey *et al.* 1983; Deith 1986; Mannino *et al.* 2003). There is a small stream within walking distance from the site and it is possible that some periwinkles derived from microenvironments associated with such a stream. Analysis of a larger sample of *L. littorea* and a comparison with modern controls is necessary before reaching definitive conclusions. However, our results clearly show variations that are consistent with seasonal fluctuations in temperature. Furthermore, reference ranges, which we report in the results section below, overlap for three shells from which samples were taken for time-series baselines.

Shell preparation and sampling

The seven shells selected for sampling were iteratively washed in a weak hydrochloric acid solution and then sonicated in distilled water to remove impurities on their surfaces at the University of Maine Stable Isotope Lab. We selected three shells (FC1–3) for extensive sampling to identify reference ranges for seasonal variation over more than one year. The remaining four shells (FC4–7) were reserved for edge sampling only.

Each shell was sampled using a hand-held RotoMatic™ rotary tool with a diamond dental bur (FG 801/009M, Henry Schein, Inc.). Sampling began at the aperture of the shell (hereafter referred to as the EOS or 'end of shell'). Rather than spot sampling along the surface of the shell, each locus was sampled along a line *c.* 5 mm long, running approximately parallel to the shell's observable growth lines. Twenty samples were taken from shell FC1 at *c.* 1 mm increments; 15 were taken from FC3 at the same incremental distance. To gain a longer time sequence, FC2 was sampled 15 times at *c.* 2 mm intervals. Samples were stored in labeled gelatin capsules (0.30 ml 'Lock Ring' capsule, Torpac Inc.) and shipped en masse to the North Carolina State University Stable Isotope Laboratory.

The carbonate powder from each sample was then vacuum-roasted for one hour at 220 °C to remove organic contaminants. The samples were then reacted with 100% orthophosphoric acid in a Kiel Autocarbonate device (Thermoquest Finnigan MAT, Bremen, Germany) and the resultant CO_2 analysed for both $\delta^{13}C$ and $\delta^{18}O$ in a MAT 251 Isotope Ratio Mass Spectrometer (Thermoquest Finnigan MAT, Bremen, Germany). Samples were calibrated against an internal lab standard

(CM-5), as well as external NIST carbonate standards (NBS-18, 19, & 20).

Results

Table 19.1 shows δ^{18}O results by shell (FC1–3) for each sampling locus. Table 19.2 shows δ^{18}O EOS results for shells FC1–7. Table 19.3 shows descriptive statistics for FC1–3, including medians and quartiles (Q1 & Q3). Fig. 19.3 charts δ^{18}O results for FC1–3 as time-series for each shell. To facilitate the interpretation of EOS values from shells FC4–7 (see Discussion), reference ranges were calculated for shells FC1–3 based on their respective interquartile ranges (the distance between their 75th and 25th percentiles, or Q3–Q1). Seasons of capture for FC1–7 were inferred by considering the relations between each shell's EOS value and the FC1–3 reference ranges. Fig. 19.4 shows EOS values for all seven shells plotted against the reference ranges.

Discussion

To interpret δ^{18}O results in Fig. 19.3, one must read from the right side of the chart (EOS values) to the left (earlier depositions of carbonate). Peaks and troughs in the trend lines represent warmest and coolest seawater temperatures, respectively. Thus, for shells FC1 and FC3, it is possible to observe similar trends wherein EOS values suggest a relatively cold season in which the periwinkles were harvested.

One of the values for FC3 – the data point corresponding to the sample taken at *c.* 2 mm from the EOS (Table 19.1; Fig. 19.3) – is anomalously low at -0.378. This value is not consistent with the minima for the rest of its series. Furthermore, without it, the curve for FC3 would have roughly the same amplitude as FC1 and FC2. Thus, it is likely to be an erroneous value, but retaining it does not change the overall pattern exhibited by the three shells.

The curve for FC2 is significantly less informative than those for FC1 and FC3, probably because the shell was sampled at 2 mm intervals, resulting in a smoothed distribution that is missing many maxima and minima. From this result, we must conclude that periwinkle shells should be sampled at ≤ 1 mm intervals to achieve a satisfactory level of resolution. In this case, it is helpful to turn to the method recommended by Mannino *et al.* (2003, 674–675) in which edge series are established by sampling shells three times, 'one at the edge…and two others immediately behind the edge.' This procedure yields a sequence that permits one to identify the position of the edge

Distance from EOS (mm)	***FC1***	***FC2***	***FC3***
0	2.563	2.123	1.816
1	1.596		0.853
2	1.635	2.139	-0.378
3	1.635		1.593
4	2.198	1.895	1.774
5	1.795		2.106
6	1.278	1.602	1.189
7	1.013		1.282
8	1.652	1.577	1.188
9	2.363		2.171
10	1.523	1.574	1.936
11	1.480		(not sampled)
12	1.219	1.516	1.648
13	1.301		1.684
14	1.645	1.682	1.998
15	1.679		2.270
16	2.183	1.878	
17	2.541		
18	2.234	1.923	
19	1.712		
20		2.051	
21			
22		2.345	
23			
24		2.479	
25			
26		2.404	
27			
28		1.456	

Table 19.1. (right) δ18O results by shell (FC1–3) for each sampling locus. Shells FC1 and FC3 were sampled at c. 1 mm intervals starting from the aperture (end of shell, or EOS) and moving back. Shell FC2 was sampled at c. 2 mm intervals

FC	***$\delta^{18}O$***
1.01	2.563
2.01	2.123
3.01	1.816
4.01	1.756
5.01	1.629
6.01	2.147
7.01	1.979

Table 19.2. (above) δ18O EOS results by shell (FC1–7)

Variable	***N***	***Mean***	***Median***	***StDev***	***SE Mean***
FC1	20	1.7623	1.6485	0.4434	0.0991
FC2	15	1.9096	1.895	0.3389	0.0875
FC3	15	1.542	1.684	0.668	0.172

Variable	***Minimum***	***Maximum***	***Q1***	***Q3***
FC1	1.013	2.563	1.4908	2.1942
FC2	1.456	2.479	1.577	2.139
FC3	-0.378	2.27	1.189	1.998

Table 19.3. (above) Descriptive statistics for FC1–3, including medians and quartiles (Q1 & Q3)

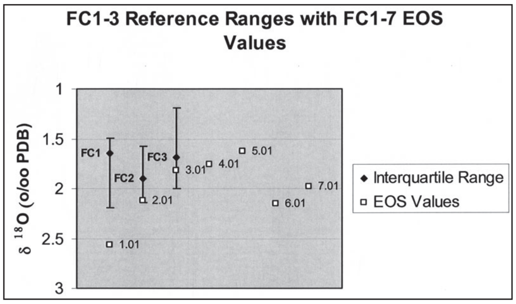

Figure 19.4. EOS values for FC1–7 graphed with interquartile reference ranges for FC1–3 based on descriptive statistics in Table 19.3. Note that all EOS values but one (FC5.01) fall below at least two median values, suggesting that most of the shells were likely harvested during the cold half of the year

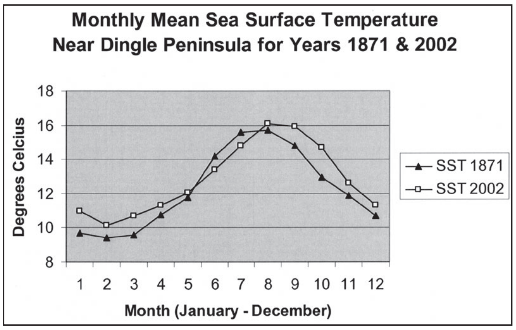

Figure 19.5. Monthly mean sea surface temperatures for years 1871 and 2002 (data source: BADC 2006)

value in the series, ie, whether it is part of a downward or upward trend or marks a shift in direction. Based on this approach – but relying on two samples instead of three – the EOS value for FC2 might mark an upward shift, which would suggest this periwinkle was harvested as sea water temperatures were entering a warming trend.

What months of the year are represented by the EOS values for FC1–3? To estimate season-of-harvest, we used the Global Ice Coverage and Sea Surface Temperature (GISST) database of the Meteorological Office (BADC 2006) to chart monthly mean sea surface temperatures for a GISST sampling locus nearest the Dingle Peninsula. Fig. 19.5 shows the monthly mean sea surface temperature for the years 1871 and 2002. This chart shows that January, February, and March are the coldest months of the year in terms of sea water temperature, with February representing the minimum monthly mean sea surface temperature. Returning to Fig. 19.3, it is possible to conclude – with an assumption that sea surface temperature trends would have been similar *c.* 5200 BP – that the EOS value for FC1 indicates this periwinkle was harvested during the cold months, possibly February as the δ^{18}O value is the highest (and therefore indicative of the coldest water) for the entire series. The EOS value for FC3 forms part of a downward trend approaching the δ^{18}O maxima for the series. This supports an estimate of a harvest time during the late autumn/early winter, perhaps between November and January. As discussed above, the EOS value for FC2 is more problematic. However, with all necessary caveats, it would not be unreasonable to posit for FC2 a late cold season of harvest such as March or April.

In summary, a conservative estimate of harvest times for shells FC1–3 would be during the cold half of the year, ie, between November and April. Do EOS values from shells FC4–7 support this pattern? This is a difficult question to answer because these shells were not sampled in a manner that permits the identification of edge series. However, Fig. 19.4 permits a preliminary consideration of all EOS values with respect to the interquartile (or reference) ranges of FC1–3. Values that fall above or below the reference ranges are more likely to represent seasons of harvest that correspond to the maxima and minima (coldest and warmest months, respectively) of their δ^{18}O time series. Those that fall within the reference ranges are less informative because, without the directionality that an edge series offers, it is impossible to differentiate spring and autumn signatures. For example, the EOS value for FC1 falls well below the interquartile range for its time series as well as those for FC2 and FC3. Based on the GISST data, this is consistent with a February harvest time. However, the EOS value for FC3 falls inside all three reference ranges. Its lower position in two of the three ranges favors a colder season estimate, but only through a comparison with other values in the FC3 time series (Fig. 19.3) is it possible to infer a November–January season of harvest due to its position in a downward temperature trend.

Based on the approach described above, the δ^{18}O results for FC4–7 can be provisionally evaluated. The EOS values for FC4 and FC5 could represent autumn or spring signatures. FC5 is the only EOS value that supersedes the median value for all three reference ranges. Perhaps it is a bad value due to taphonomic factors or, alternatively, represents a deposition event for F488 in mid spring or autumn. Without an edge series, little more can be said about this shell. The EOS value for FC6 resides at the low end of one reference range (FC1) and below the ranges for the other two (FC2 and FC3). FC7 is at the low end of all three reference ranges. Thus we hypothesise that FC6 and FC7 were harvested during the cold months of the year.

It is important to reiterate the preliminary nature of this dataset and the interpretations we offer to explain it. With the exception of FC5, a glance at the array of data points in Fig. 19.4 reveals that all EOS values fall within or below the low end of two or three interquartile ranges. Thus, we infer that most of the shells in our sample were harvested during the cold half of the year (November through April). Two of the shells (FC1 and FC6) could have been harvested within a narrower timeframe, perhaps sometime between January and March.

Conclusion

It is useful to return to the results of seasonal analyses of fish remains reported in Woodman *et al.* (1999). To summarise, fish size estimates suggest a summer harvest; fish spawning behavior (whiting) suggests early spring; fish migration patterns (eg, herring, tope, salmon, and eel) suggest summer and early autumn; and fish scale growth patterns lend support to summer/autumn fishing. In other words, fishing activities appear to have taken place 'within the summer half of the year' (McCarthy 1999, 89). In contrast, our oxygen isotope study of a small sample of periwinkle shells from F488 suggests that these animals were harvested during the winter half of the year (November–April). Interestingly, there is a possible point of overlap between the $\delta^{18}O$ results for the problematic shell FC2 and McCarthy's whiting.

Based on our results, we propose that the Ferriter's Cove site includes evidence for both cold and warm season occupations. Should our proposition hold up under the light of further scrutiny and the weight of larger samples, two avenues of inquiry emerge. First, we must revisit speculations on how Ferriter's Cove fit into the Later Mesolithic settlement system. All evidence seems to point to short-term occupations, but the site might have been used differently throughout the year. For example, in the summer and autumn, people could have stopped by primarily for the fishing. During the cold months, Ferriter's Cove might have served as a pit stop for raw material procurement supplemented by shellfish meals.

To explore this avenue more thoroughly, more shells must be analysed from F488. Furthermore, there are three other dated contexts containing shell (*Littorina littorea*, *Nucella lapillus*, *Patella vulgata*, *Mytilis edulis*, and *Cerastoderma edule*) (Woodman *et al.* 1999; Fig. 19.6): F201, a large shell dump in the site's central area with two charcoal-based 14C dates, 5750±140 BP (BM-2228R) and 5850±140 BP (BM-2228AR); F183, a shell midden deposit in the southern area with a charcoal-based date of 6300±140 BP (GrN-18772); and F303, a spread of burnt and unburnt shells also in the southern area with a charcoal-based date of 5479±56 BP (UB-3597). Oxygen isotope analyses of shell carbonate from these features would represent the seasonality of shellfish harvesting across a broad span of the site's occupation history.

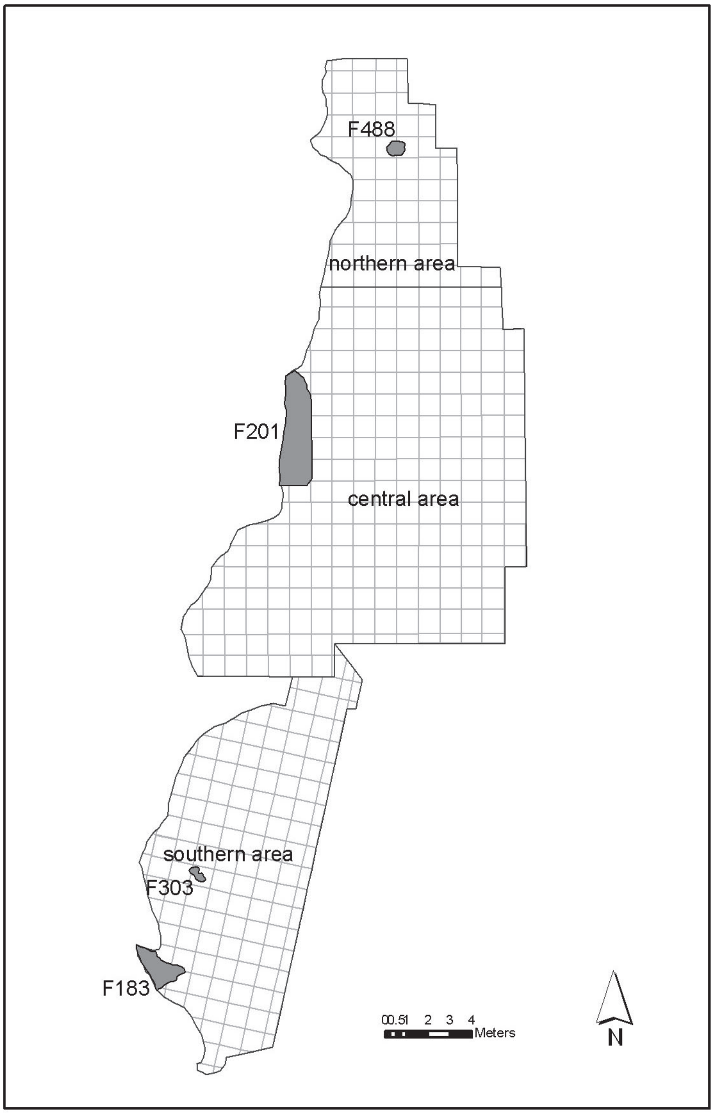

Figure 19.6. Ferriter's Cove site plan showing Features 488, 201, 183, and 303

A second avenue of inquiry lies in a consideration of our results with particular regard to F488's 14C dates. With radiocarbon dates in the region of 5350–5200 BP (Fig. 19.2), this feature is associated with the tail end of a period of social change proposed for the last quarter of the Later Mesolithic (Kimball 2006; Woodman & McCarthy 2003). In short, F488 was in use during a time when foraging groups had quite likely gained access to domesticated cattle as cuts of meat or, possibly, quasi-pastoralist components of their subsistence system. The political and economic ramifications of this development are just beginning to be explored. Further research into the function and seasonality of contemporary archaeological features such as F488 will inform efforts to understand the impact of this new lifeway on Later Mesolithic society and its relation to the advent of Ireland's Neolithic.

Acknowledgements

Kimball wishes to express his gratitude to Peter Woodman for offering him an entrée into Irish Later Mesolithic research; Karl Kreutz and Doug Introne, UMaine Climate Change Institute, for their generosity in providing advice on and support with shell preparation and sampling; Mike Matis, University of Maine Machias, for his valuable assistance with GISST data processing; Lori Gustafson for statistical advice and editorial assistance; and Kathleen Ahearn, Liz Sullivan, and Tora Johnson for development of the GIS database that made Figs 19.1 and 19.3 possible. The authors are grateful to the British Atmospheric Data Centre, which provided access to UK Meteorological Office Global Ice Coverage and Sea Surface Temperature (GISST) data.

Bibliography

Andrus, C.F.T. & Crowe D.E. 2000. Geochemical analysis of *Crassotrea virginica* as a method to determine season of capture. *Journal of Archaeological Science* 27, 33–42

Bailey, G., Deith, M. & Shackleton, N. 1983. Oxygen isotope analysis and seasonality determinations: Limits and potential of a new technique. *American Antiquity* 48 (2), 390–398

British Atmospheric Data Centre (BADC), 2006. UK Meteorological Office Global Sea Ice Coverage and Sea Surface Temperature Data (1856–present). http://www.badc.rl.ac.uk/data/gisst/

Brinkhuizan, D. 1977. Appendix I: The fish remains. In P.C. Woodman, Recent excavations at Newferry, Co. Antrim, *Proceedings of the Prehistoric Society* 43, 197

Claassen, C. 1995. *Shells*. Cambridge: Cambridge University Press

Criss, R.E. 1999. *Principles of Stable Isotope Distribution*. Oxford: Oxford University Press

Dieth, M.R. 1986. Subsistence strategies at a Mesolithic camp site: Evidence from stable isotope analyses of shells. *Journal of Archaeological Science* 13, 61–78

Green, S. & Zvelebil M. 1990. The Mesolithic colonization and agricultural transition of south-east Ireland. *Proceedings of the Prehistoric Society* 56, 57–88

Irving, B. 1999. Fish scales. In P.C. Woodman, E. Anderson & N. Finlay (eds), *Excavations at Ferriter's Cove, 1983–95: Last Foragers, First Farmers in the Dingle Peninsula*, 92–93. Bray: Wordwell Ltd.

Kennett, D.J. & Voorhies B. 1996. Oxygen isotopic analysis of archaeological shells to detect seasonal use of Wetlands on the Southern Pacific Coast of Mexico. *Journal of Archaeological Science* 23 (5), 698–704

Killingley, J.S. 1981. Seasonality of mollusk collecting determined from O–18 profiles of midden shells. *American Antiquity* 46, 152–158

Kimball, M. 2000a. Variation and context: ecology and social evolution in Ireland's Later Mesolithic. In A. Desmond, G. Johnson, M. McCarthy, J. Sheehan, & E.S. Twohig (eds), *New Agendas in Irish Prehistory: papers in commemoration of Liz Anderson*, 31–43. Bray: Wordwell Ltd.

Kimball, M. 2000b. *Human Ecology and Neolithic Transition in Eastern County Donegal, Ireland: The Lough Swilly Archaeological Survey*. Oxford: Archaeopress, British Archaeological Reports, British Series 300

Kimball, M. 2006. Common pools and private tools? Mobility and economy during Ireland's Later Mesolithic. *Journal of Anthropological Archaeology* 5 (2), 239–247

Larsson, L., Kindgren H., Knutsson K., Leoffler D. & Åkerlund A. 2003. *Mesolithic on the Move: Papers Presented at the Sixth International Conference on the Mesolithic in Europe, Stockholm 2000*. Oxford: Oxbow Books

Lovis, W.A., Whallon R. & Donahue R.E. 2006. Introduction to Mesolithic mobility, exchange, and interaction: A special issue of the Journal of Anthropological Archaeology. *Journal of Anthropological Archaeology* 5 (2), 175–177

Mannino, M.A., Spiro B.F. & Thomas K.D. 2003. Sampling shells for seasonality: Oxygen isotope analysis on shell carbonates of the inter-tidal gastropod *Monodonta lineata* (da Costa) from populations across its modern range and from a Mesolithic site in southern Britain. *Journal of Archaeological Science* 30, 667–679

McCarthy, M. 1999. Faunal remains. In P.C. Woodman, E. Anderson & N. Finlay (eds), *Excavations at Ferriter's Cove, 1983–95: Last Foragers, First Farmers in the Dingle Peninsula*, 85–92. Bray: Wordwell Ltd.

Milner, N. 2005. Seasonal consumption practices in the Mesolithic: Economic, environmental, social or ritual?. In N. Milner & P. Woodman (eds), *Mesolithic Studies at the Beginning of the 21st Century*, 56–68. Oxford: Oxbow Books

Milner, N. & Woodman P. 2005. *Mesolithic Studies at the Beginning of the 21st Century*. Oxford: Oxbow Books

Shackleton, N.J. 1973. Oxygen isotope analysis as a means of determining season of occupation of prehistoric midden sites. *Archaeometry* 15, 133–141

Switzur, V.R. & Mellars P.A. 1987. Radiocarbon dating of the shell-midden sites. In P.A. Mellars (ed.), *Excavations at Oronsay*, 139–152. Edinburgh: Edinburgh University Press

Woodman, P.C. 1977. Recent excavations at Newferry, Co. Antrim. *Proceedings of the Prehistoric Society* 43, 155–199

Woodman, P.C. 1978. *The Mesolithic in Ireland: Hunter-Gatherers in an Insular Environment*. Oxford: Archaeopress, British Archaeological Reports, British Series 58

Woodman, P.C. 1986. Problems in the colonization of Ireland. *Ulster Journal of Archaeology* 49, 7–17

Woodman, P.C. 1990. The Mesolithic of Munster: A preliminary assessment. In C. Bonsall (ed.), *The Mesolithic in Europe: Proceedings of the Third International Symposium, Edinburgh*, 116–132. Edinburgh: University of Edinburgh Press

Woodman, P.C. 2005. It's too light to be right. In N. Milner & P. Woodman (eds), *Mesolithic Studies at the Beginning of the 21st Century*, 126–143. Oxford: Oxbow Books

Woodman, P.C. & Anderson E. 1990. The Irish Later Mesolithic: A partial picture. In P.M. Vermeersch & P. Van Peer (eds), *Contributions to the Mesolithic of Europe*, 377–387. Leuven: Leuven University Press

Woodman, P.C. & Johnson G. 1996. Excavations at Bay Farm 1, Carnlough, Co. Antrim, and the study of the 'Larnian' technology. *Proceedings of the Royal Irish Academy* 96C, 137–235

Woodman, P.C. & McCarthy M. 2003. Contemplating some awful(ly interesting) vistas. In I. Armit, E. Murphy, E. Nelis & D. Simpson (eds), *Neolithic Settlement in Ireland and Western Britain*, 31–39. Oxford: Oxbow Books

Woodman, P.C., McCarthy M. & Monaghan N. 1997. The Irish Quaternary Faunas Project. *Quaternary Science Reviews* 16, 129–159

Woodman, P.C., Anderson E. & Finlay N. 1999. *Excavations at Ferriter's Cove, 1983–95: Last Foragers, First Farmers in the Dingle Peninsula*. Bray: Wordwell Ltd.

Zvelebil, M., Macklin M.G., Passmore D.G. & Ramsden P. 1996. Alluvial Archaeology in the Barrow Valley, Southeast Ireland: The 'Riverford Culture' re-visited. *The Journal of Irish Archaeology* 7, 13–40