Field Studies, **8**, (1996) 533–542

LONG-TERM STUDY OF THE NATURAL ENVIRONMENT AT SLAPTON LEY

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ABSTRACT

Long-term study of the natural environment is an important and indispensable task and there has been growing recognition of the worth of such information in recent years. Detailed study of the Slapton Ley Nature Reserve began with the establishment of the Field Studies Council Centre in 1959; since then, the monitoring programme has been sustained and extended, complemented by detailed experiments of a more short-term nature. This brief introduction to a special issue of *Field Studies* considers the general significance of long-term studies of the natural environment, and places the Slapton research programme within this framework. For many reasons, the Slapton Ley National Nature Reserve can now be considered a site of international importance: the opportunity to conduct question-driven science within a context of long-term observation has proved extremely fruitful.

INTRODUCTION

Slapton Ley is a coastal lagoon, 10 km south west of Dartmouth, Devon (UK grid reference SX 825479: Fig. 1). The Ley is part of a wetland, 116 ha in area, which is divided into two basins: the Higher Ley (39 ha) is mainly reed swamp; the Lower Ley (77 ha) is open water, fringed with reed. The Ley, together with the surrounding woodland, ancient cliff-line and shingle ridge is a grade-1 Site of Special Scientific Interest (SSSI) and, in 1993, was designated a National Nature Reserve.

Early studies of the reserve were concerned with the morphology and origins of the lake basin (Mercer, 1966; Morey, 1976), its climate (Ratsey, 1975), its flowering plants (Brookes & Burns, 1969), the phytoplankton community in the lake (Benson-Evans *et al.*, 1967) and the fish (Kennedy, 1975). A number of these descriptions are updated and extended in the papers which follow. Perhaps the most active experimental research to be conducted in the area concerns the hydrology and hydrochemistry of the catchments which drain into Slapton Ley and, in particular, the patterns and processes of nutrient export from land to stream. The latter is significant because, in the 1960s, it became apparent that the Ley was becoming increasingly eutrophic. In order to gauge water, sediment and nutrient inputs to the lake, measurements have been maintained on the main catchments since 1969. Hydrological and water quality records of this length are unique in Britain for small rural basins and have provided an important context for experimental studies of catchment hydrology, palaeo-environmental reconstruction within the lake basin and on adjacent floodplains using sediment cores, and for environmental modelling.

JUSTIFICATION FOR LONG-TERM STUDIES

Monitoring is too often dismissed as low-grade science which can contribute little or nothing to our understanding of how natural systems function or change. And yet the verb *to monitor* can mean 'to remind or give warning' or 'to maintain regular surveillance'. These definitions suggest a deliberate plan of action and imply that long-term monitoring can yield valuable results if the programme of measurements is properly organised. There has been growing recognition of the value of long-term monitoring in recent years: for example, the U.K.'s Environmental Change Network (E.C.N.) was established in 1992. Lawton (1990) suggests three reasons why monitoring is important in environmental science (see also Burt, 1994):

1. Long-term data suggest hypotheses for scientists to explain. Short-term experimentation may be able to test hypotheses, but only after they have been formulated. Long data sets reveal important patterns—the existence of trends, cycles and rare events. Taylor (1989) argues that experimental science is a useful but limited technique in the study of the environment because of the importance of the historical element, or contingency. The legacy of the past may not be all that obvious in a brief study of the present environment. Given the influence of past conditions on the present and future trajectory of a system, the goal of long-term observation is to document important events before they become lost from the record—in other words to prevent the past from becoming obscure and to allow prior influence to be known rather than unknown. Well-designed monitoring programmes provide the best conditions for studying processes whose effects can only be identified gradually. These include slow processes, such as plant succession, which take place over relatively long periods of time (*i.e.* much longer than the normal grant duration or completion time for a research degree), and subtle processes embedded within highly variable systems whose signals are so weak that they cannot be extracted without a long record (*e.g.* long-term changes in beach dimensions). In addition, since by definition rare events occur infrequently, the best chance of observing them is by long-term monitoring. It is often the case that only where long-term records exist can the significance of high magnitude but low frequency events such as storms be evaluated. In the Slapton catchment, for example, it is now acknowledged that storms are responsible for generating the bulk of the nutrient export from the catchment to the drainage network. Without the long-term data to compare storm nutrient loads with annual catchment loads for a variety of water years, such claims would go unsupported. Likens (1989: x) has noted that, because of the complexity of natural systems, it may take longer in ecology (and, presumably, in the environmental sciences generally) than in other disciplines to build up a useful background of information whereby enough insight is gained to develop meaningful hypotheses. Meanwhile, experimentalists must be patient: there are no short cuts or quick fixes (Tilman, 1989; Holdgate, 1991)!
2. Long-term data sets are essential for revealing new questions which could not have been anticipated at the time the monitoring began (*e.g.* evaluation of the causes of fish kills in the Lower Ley—see Kennedy, 1996). Lack of foresight may make long-term study hard to justify, but the important point is that the benefits of long-term study invariably arise, not from the initial questions which prompted the study in the first place, but from discoveries that are made later. The original questions may well be sensible ones, but the new ones which emerge cannot be anticipated. All that

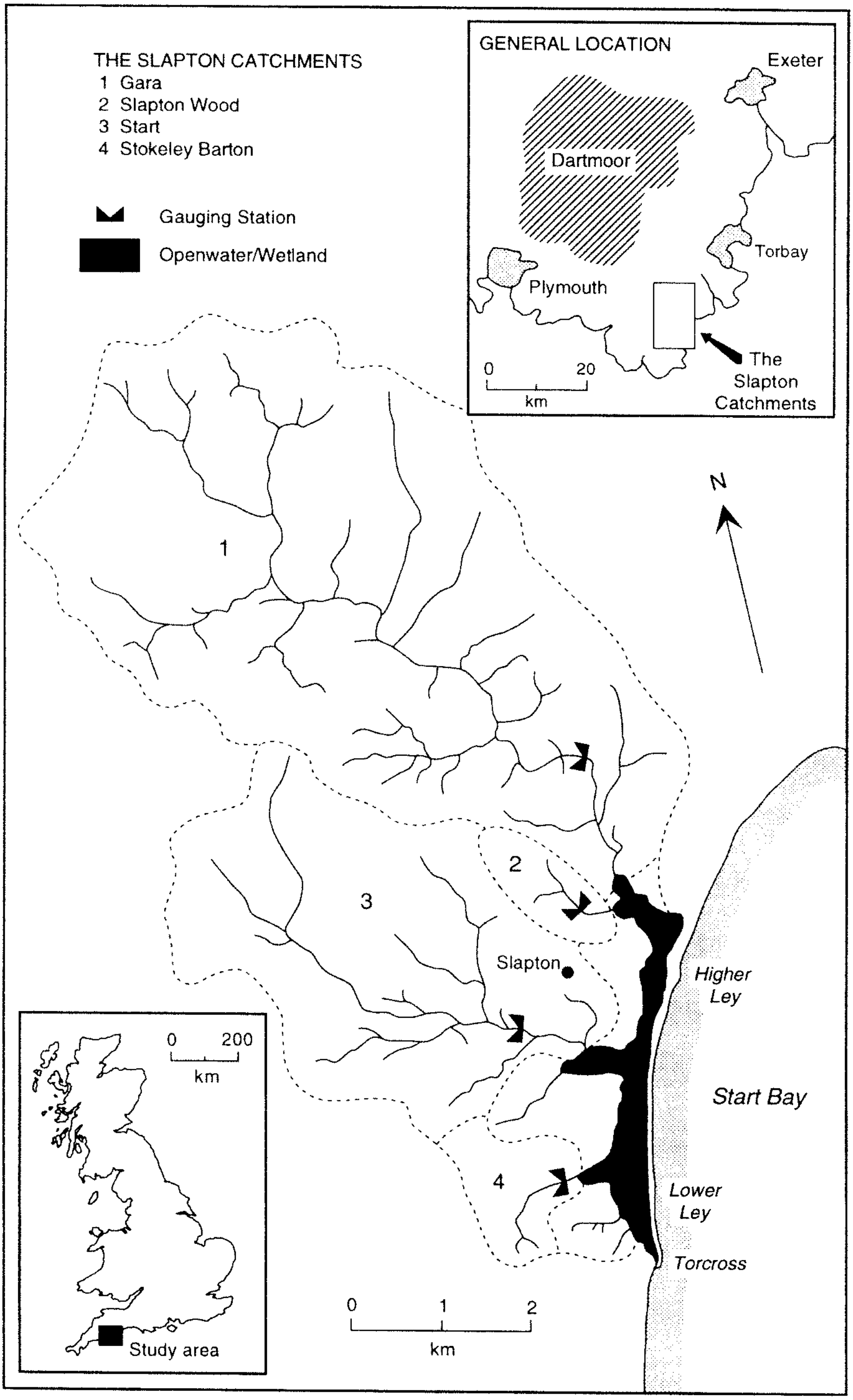

FIG. 1.
Slapton Ley and its catchment.

can be done is to design carefully (and maintain meticulously) a measurement programme which seems most likely now to provide indications of change in the future. Thus, long-term study can be perceptive in the broad sense, but never prescient (Burt, 1994).

3. Monitoring is an essential way of discovering whether there are important detrimental changes taking place in the environment that may ultimately be harmful to ecosystems and to people themselves; this is the very essence of surveillance. If perceptively conceived and rigorously conducted, long-term monitoring will hopefully provide data which reveal changes and which allow new questions to be explored. Moreover, since the notion of surveillance suggests not only close supervision but also appropriate action when required, long-term monitoring may well provide valuable guidance for environmental management.

Despite the essential nature of monitoring, there are nevertheless some limitations. Burt (1994) has suggested four other approaches to studying the natural environment, though none of these appear to provide a complete substitute for long-term study:

1. Short-term experiments. These are vital to an understanding of cause-and-effect relations; monitoring provides the necessary context within which they can be most profitably conducted.
2. Modelling. Since monitoring takes such a long time, the opportunity to forecast changes has strong appeal. However, no model is better than the assumptions and data it relies on. Often, long-term data sets provide both the means of calibrating a model and verifying its performance.
3. Space-time substitution. Under certain conditions, sampling through space can be equivalent to sampling through time. However, given differences in site history, spatial comparison may not be matching like with like so that long-term study provides a useful parallel method.
4. Use of palaeoenvironmental data. Analysis of cores from lakes, peat bogs and floodplains has yielded much useful information about environmental change, though not necessarily in sufficient detail to document changes over small timescales (months to years). Core analysis is perhaps best suited to detailing changes over decades to millennia and for identifying rare events. Again, these techniques appear complementary rather than interchangeable.

RESEARCH AT SLAPTON LEY IN ITS LONG-TERM CONTEXT

In this brief review of long-term monitoring and associated research at Slapton Ley, we make the following assumptions:

1. Long-term study is regarded as a regular and sustained monitoring effort.
2. We prefer the description 'short-term study' to 'short-term experiment' since *sensu stricto* the latter implies research under controlled conditions (Church, 1984). A less strict definition can include research programmes in which a formalised programme of measurements was carried out for a short time, as well as more truly experimental studies.
3. Our classification of reasons why long-term studies are important follows that of Lawton (1990) described above.
4. Where direct use of monitored information has been used to assist management of the Nature Reserve, this is acknowledged.

TABLE 1. *Long-term monitoring and parallel research at Slapton Ley*

Category	LTS	patterns to explain?	new hypothesis?	undesirable trends?	short-term studies	modelling	coring studies	management application
climate	*							
hydrology	*	*	*		*	*		
water quality	*	*	*	*	*	*	*	*
limnology	*				*	*	*	
sediment yields	*				*	*	*	
vegetation	*	*	*	*	*			*
fungi	*							
fish	*	*	*	*	*			
mammals	*			*	*			
birds	*			*				
education	*			*				
coastal landforms	*	*	*	*	*	*	*	*

A summary of research carried out in the Slapton Ley Nature Reserve, together with related research in the immediate locality is provided in Table 1. The following comments may be made:

- *Climate.* Standard meteorological observations have been made at the Field Centre since 1959. A preliminary analysis was conducted by Ratsey (1975) but nothing else has been published. An automatic weather station was operated by the Institute of Hydrology in the Slapton Wood catchment during the early 1990s as part of a NIREX-funded study of catchment hydrology.

- *Hydrology.* Measurement of water, sediment and nutrient inputs to the lake from the four main catchment areas (Stokeley Barton, Start, Slapton Wood and Gara) began in 1969. Continuous monitoring of discharge and a weekly programme of water sampling have been maintained by the Field Centre ever since. Analyses of the early records were provided by Troake & Walling (1973); an up-to-date review is given by Burt & Heathwaite (1996). The long-term monitoring has been supplemented by a number of short-term projects which have sought to identify significant hydrological processes operating within the Slapton catchments. Most such studies have been concerned with the generation of subsurface runoff, examination of the long-term record having suggested the significance of this flow mechanism (Burt & Butcher, 1985). In recent years the increased frequency of overland flow (with associated soil erosion) has caused concern (see below and Heathwaite & Burt, 1992). Chappell & Franks (1996) describe recent investigations of subsurface hydrology, and attempts to model streamflow in the Slapton Wood catchment are described by Fisher & Beven (1996).

- *Water quality.* The nitrate issue has been of particular interest at Slapton following the early study of Troake *et al.* (1976). Though many longer-time series exist for large rivers like the Thames, the long record of nitrate data for the Slapton catchments is unique for small rural basins in the United Kingdom. Burt *et al.* (1988) described the first 15 years of the record; subsequent statistical analysis has shown that the trends

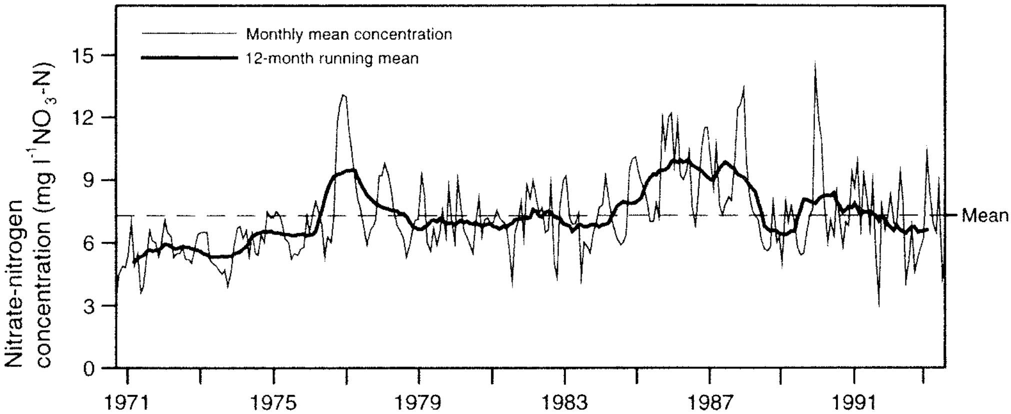

FIG. 2.
The long-term nitrate (NO_3-N) record for the Slapton Wood catchment.

they identified are still continuing (Burt *et al.*, 1996). The long-term nitrate record for the Slapton Wood catchment, shown in Fig. 2, demonstrates all three of Lawton's criteria: interesting patterns to explain (long-term trends, annual regime); new hypothesis to explore (the relative influence of climate and land-use change; antecedent climatic controls on winter leaching); and, a means of confirming the existence of undesirable changes in water quality. A number of short-term experiments have investigated nutrient losses in surface and subsurface runoff (reviewed in Burt *et al.*, 1996), nitrate and phosphorus export has been modelled (Whelan *et al.*, 1995; Johnes & Wilson, 1996; Johnes & Heathwaite, 1996), and complementary analyses of the nutrient content of lake cores have been conducted as a means of extending the historical record (Heathwaite & O'Sullivan, 1991; Heathwaite, 1994). Attention has focused more recently on phosphorus (Burt & Heathwaite, 1993) and, at the time of writing, field studies of sediment delivery (Jenns, in prep.) and potassium (Stott, in prep) are in progress.

- *Limnology.* There have been weekly measurements of chlorophyll *a* (also pH, conductivity and, less regularly, dissolved oxygen—DO) but this record seems never to have been analysed in any detail. Johnes & Wilson (1996) review the limnological studies conducted at Slapton Ley. The flora of the Lower Ley has been surveyed irregularly (Brookes & Burns, 1969; Cole, 1984; Wilson, 1991; Burns, 1996); Cannell (1992) is the only detailed study of vegetation changes in the Higher Ley. There have been few short-term studies of nutrient cycling in the Lower Ley, (*e.g.* Smith, 1988) but modelling studies (Johnes & O'Sullivan, 1989; Johnes & Heathwaite, 1996) and palaeolimnological reconstruction based on sediment chemistry (Heathwaite & O'Sullivan, 1991; Heathwaite, 1994) have filled this gap to some extent. Studies of the phytoplankton community in the Ley have also been irregular (Johnes & Wilson, 1996). It is generally agreed that the lack of detailed study of the impact of nutrient enrichment on the biogeochemistry of the Ley is perhaps the largest gap in the research programme at Slapton. The long-term record has, nevertheless, been important in guiding management of the Ley, notably the decision to install a phosphate stripper on the Slapton village sewage treatment works.

- *Sediment yield.* Park (unpublished) analysed four years of suspended sediment concentration data on the Slapton streams from the late 1970s, but otherwise the long-term stream record has not been analysed in detail. An important factor in this is the difficulty of using weekly sample data to calculate sediment yields; sediment transport is much more episodic than solute transport, being almost entirely confined to periods of storm runoff. There have, however, been a number of studies of short-term sediment dynamics (reviewed in Burt *et al.*, 1996) and several studies of lake and floodplain sedimentation (reviewed in Foster *et al.*, 1996) which have established the long-term pattern of sediment delivery in the Slapton catchments.
- *Vegetation.* Though studies of vegetation on the Reserve have been sporadic (Brookes & Burns, 1969; Burns, 1996), they have nevertheless met all three of Lawton's criteria: changes in vegetation cover to explain (e.g. loss of open shoreline on the Lower Ley), generation of new hypotheses (e.g. floating islands in the Higher Ley), and indication of unwelcome developments (e.g. terrestrialisation of the Higher Ley). The studies have also aided management decisions, for example, grubbing up willow in the Higher Ley, and the strapwort recovery programme on the Lower Ley. Exclosures have been built to enable more detailed studies to be undertaken, for example on the shingle ridge, but to date these have not been surveyed regularly.
- *Mammals and other animals.* These studies have been reviewed by Riley (1996). Monitoring has been irregular but of sufficient detail to guide management (albeit by non-intervention) of the invasive mink.
- *Fungi.* As Dobson & Hawksworth (1996) note, Slapton Ley possesses the richest record in the world, due entirely to the many surveys which have been conducted over the years. Some interpretation of changes has been possible and it is to be hoped that the detailed catalogue will provide the basis for more interpretative studies in the future.
- *Fish.* Kennedy (1996) reviews the 25-year record of roach, rudd, perch and pike numbers in the Ley; the only British lake with a comparable record is Windermere. He stresses the importance of being able to relate changes in the fishery directly and causally to the changes in the catchment area and in the lake itself. The long-term study, punctuated by several periods of more intense investigation, has provided a number of patterns to explain, generated new hypotheses requiring attention, and has uncovered unwelcome changes, notably the fish kill during the winter of 1984–85. Management of the fishery remains non-interventionist, whilst fish records have been instrumental in allowing the Reserve Officer to judge the changing health of the fish stocks in the Ley.
- *Birds.* Elphick (1996) reviews the long-record of bird census and ringing at Slapton Ley. Little detailed analysis of the record has been undertaken to date; even so, major changes in population have been documented and the national and international importance of the Reserve amply demonstrated. There has been no attempt as yet to link the bird population to the changing fish numbers.
- *Education.* Trudgill *et al.* (1996) review education and conservation issues in the Slapton Ley NNR. These are seen as compatible activities by making conservation

part of the educational agenda and by careful zonation of educational activities so that they are compatible with the robustness and value of the site. Whilst much of the long-term research is 'management-relevant', truly 'management-led' research has been on a small scale so far. Some research is in hand to assess the impact of continued teaching at given sites within the reserve. Zonation ensures that both educational experience (both formal and informal) and conservation priorities can be met.

- *Coastal landforms.* Unfortunately this special issue of *Field Studies* does not include a review of research on coastal processes and landforms conducted within Slapton Ley NNR and nearby; readers are referred to Job (1993). The long-term survey of beach morphology in Start Bay, which is regularly added to by sixth-form students, has provided important evidence of changes in beach volume over the past century (There are surveys at Hallsands dating from the early 1900s), has revealed new hypotheses to explain, and has allowed unwelcome developments to be identified, for example, recent erosion just north of the 'monument' which is threatening the main A379 road. There have been important short-term studies (Hails, 1975; Job, 1987) and the survey data continue to guide management decisions for erosion control.

FUTURE PROSPECTS

Increasingly, Slapton Ley provides the focus for short-term research studies. Meanwhile, the long-term monitoring continues with the steady accumulation of information. Clearly, the burden placed on the Field Centre to maintain the monitoring programme to the highest standards is a great one, especially given the inevitable turn-over of Centre staff. All those who conduct short-term research at Slapton owe a huge debt of gratitude to all the Centre staff who have helped collect all this information over the years. It is fortunate that the monitoring programme underpins both the educational purposes of the Centre and the management requirements of the Reserve. Whilst the future of the monitoring seems assured, the efforts required to maintain it should not be forgotten. At the same time, as new staff arrive at the Centre, the need to emphasise the importance and uniqueness of the work is paramount.

Slapton Ley is, of course, a delightful place to conduct research! That many and varied researchers have been drawn to its shores has been indeed propitious. The combination of studies undertaken has proven fortunate, often in unexpected ways (Kennedy, 1996). Since potential links between subject areas cannot always be anticipated, it is to be hoped that this variety of interest will continue, and indeed extend into new areas. As Trudgill *et al.* (1996) comment, gaps in the data sets and lack of simultaneity barely detract from the fact that Slapton's wealth of accumulated data is one to be proud of and one which will continue to be the basis for analysis—and, in some cases, Reserve management—well into the next century.

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