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# SOUTHAMPTON WATER AND THE SOLENT : BIOLOGICAL EFFECTS OF THE MULTI-USE OF AN ESTUARINE SYSTEM.

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ABSTRACT. An outline is provided of (1) some factors which have influenced the clam and oyster populations of the area (2) the effect of nutrient load on phytoplankton production (3) the correlation beween *Mesodinium* blooms and the summer oxygen levels in the stratified part of the estuary and (4) a description of the fauna and flora in regions adjacent to some industrial inputs.

Southampton Water and the Solent, with their associated river inputs, form a complex waterway interesting scientifically both in its own right and from what may be learnt of the effects of human influence. In both respects the area parallels the baie de Seine. The region contains a number of locations which have been designated sites of special scientific interest (SSSIs) because of the presence of rare species or of uncommon communities or threatened habitats (fig. 1). It is also subject to intense human activity of a variety of kinds.

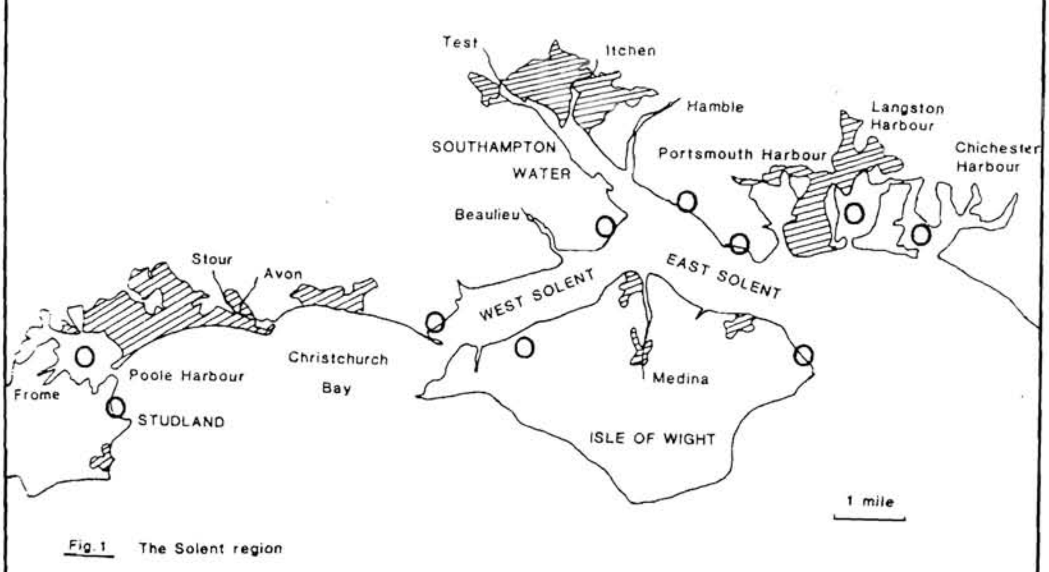


Fig. 1 The Solent region

Sites of Special Scientific Interest O

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Principal amongst these are :
1) civic and domestic inputs via a number of sewage outlets,
2) industrial effluents, particularly along the western shore of Southampton Water,
3) river inputs with their associated nutrient load from agricultural land, trout farm etc...,
4) dredging for gravel and the maintenance of shipping lanes,
5) sport sailing, and
6) commercial fishing for Oysters (*Ostrea edulis*), American Clam (*Mercenaria mercenaria*) and Bass (*Dicentrachus labrax*) together with semi-commercial

or sport fishing for Cod *(Gadus morhua)*, Mackerel (*Scomber scomber*) Plaice (*Pleuronectes platessa*) and other species. In addition the Test is an important salmon river.
The recent issue of licences for oil exploration in Christchurch Bay, Poole Bay and Solent seems likely to add another dimension to the anthropogenic effects. Many of these factors impinge in one way or another on the fauna and flora of the region, but before discussing their effects, it is perhaps appropriate to outline briefly the history and physical features of the region.

Originally the Solent was a river system draining the output of the Stour, Avon and Frome rivers to the west, the Test, Itchen, Beaulieu, Hamble and Medina centrally and Portsmouth, Langstone and Chichester Harbours to the east. However, some 5000 years ago, during the Flanderian Transgression, the sea broke through the ridge joining the region south of Poole Harbour to the Isle of Wight and the rapid erosion of the tertiary rocks in the vicinity resulted in the formation of Christchurch Bay and the westerly opening of the Solent. (See West, 1980 for a detailed geological history of the area). The advent of this westerly opening, taken together with the hydrodynamics of the Channel, has resulted in a complex current regime a feature of which is that slack water does not coincide with high water and low water. Interaction between the geographical features and the constraints imposed on the natural period of oscillation in Channel waters by the constriction of the Channel width by the protrusion of the Cherbourg Peninsular and Isle of Wight are thought to be responsible for the unusual tidal regime in Southampton Water. (Webber 1973, 1980). This is characterised by a slow rising phase, usually with a "stand" at mid-tide, a double high water with a short and minor fall in tide height between the peaks and finally a rapid ebb. The long rise and stand, amounting to some nine hours out of the 12hr 25 minute cycle, has contributed to the role of Southampton as a major port.
Important in terms of disposal of introduced nutrients and other potentially polluting substances is the rapid flushing of the Solent relative to the volume of inputs. The net change in tidal volume for the Solent, is estimated to be 540 x $10^6 m^3$ on a typical spring tide and 270 x $10^6 m^3$ on neaps (Blain, 1979). In each case the change in the volume of Southampton Water is about one fifth of the total. More important, from the point of view of flushing, is the net change in the water throughput. The flow entering and leaving the Solent at Hurst Castle on a spring tide is estimated at some 900 x $10^6 m^3$ and on neaps 550 x $10^6 m^3$. (Blain, 1979).
The catchment area for the rivers draining into the present Solent system is relatively small (3000 $km^2$) and the two main rivers, the Test and Itchen, between them have a flow of some 23 cumecs in winter and 13.5 cumecs in summer (Collins, 1978). Together this amounts to less than 2% of the Neap tidal prism and hence Southampton Water is very much a marine dominated system with salinities in excess of 30‰ extending, at least in the sub-surface waters, up to and beyond the confluence of the estuaries of the Test and Itchen (Dyer, 1973). Typically the water column is well mixed below this juncture except under exceptional conditions such as the melting snow run off during January/February 1985 when some stratification was observed in both temperature and salinity as far south as Calshot (Boxall, S. person. comm.) (fig. 2). Stra-

tification does occur in the Test estuary and, at least during the summer months may involve temperature, salinity, oxygen and nutrient load (Rees & Williams, 1982; Crawford, 1985 person. comm.).
Traditionnaly the Solent and Southampton Water have been the site of substantial fisheries for the European Oyster and in the early part of the last century there were significant beds underlying the present site of the Eastern Docks and near Netley Hospital.

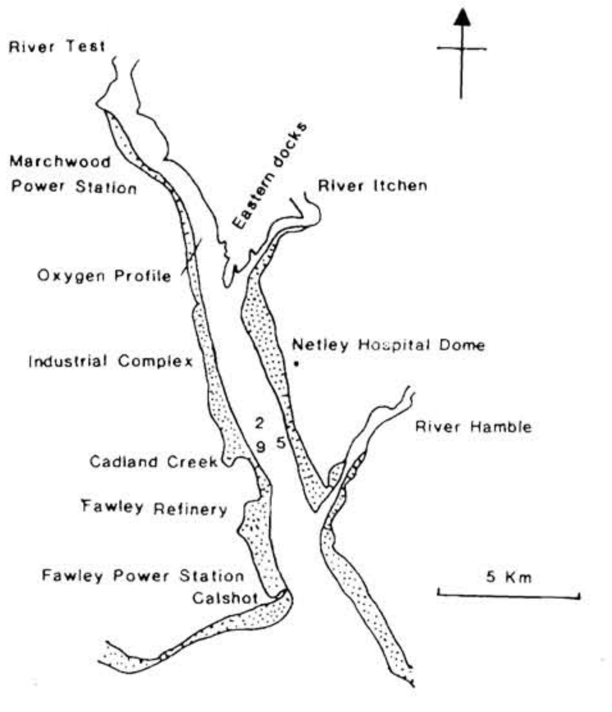


Fig.2 Southampton Water locations of the sites mentioned in the text

Commercial fishing for *Ostrea* is however now restricted to the Solent. This fishery was severely curtailed following the 1962/63 winter which eliminated much of the stock. Recovery was initiated by a major spatfall in Stanswood Bay in 1969, perhaps from larvae originating in the Beaulieu River. Extension of the stock to include the Lepe Middle Ground (Central Solent) and Newtown Bank (West Solent)occurred in 1971 followed by still more successful spawning a few years later which recruited to the 35 mm size range in 1976. Minor recruitment has occurred in subsequent years but as a result of lack of major year class successes since the 1976 recruitment, continued fishing has resulted in a decline in stock and in some areas the stock index is lower than it was in 1973/74. The severity of the 1962/63 winter also had the effects of diminishing the numbers of the Neogastropod, *Ocenebra* (the Oyster Tingle) which *inter alia* drills *Ostrea*. Stocks of this animal have also recovered so that in the early 1980's it was estimated that some 60% of the oysters were being drilled. Previously this gastropod had been thought to have direct development like *Urosalpinx* (Carriker, 1957) a feature which places restrictions on the speed of recolonization after loss from an area. Recently however it has been reported (Hawkins, 1985) that the local stock of *Ocenebra* can hatch as veliger larvae both in the field and in the laboratory. It also appears that local *Ocenebra* are attracted preferentially to oysters showing high metabolic activity rather than individuals in poor conditions (Hamphrey, 1955, Person. Comm.).

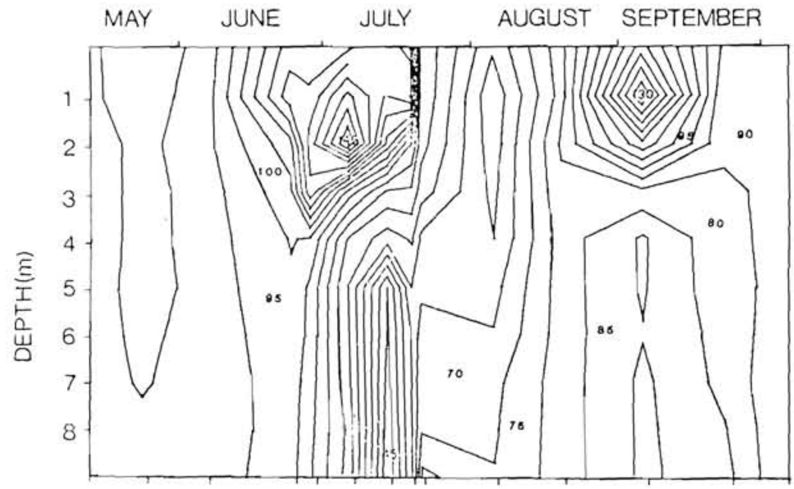


FIG 3 Oxygen contours at Cracknore (T3). Contour lines at 5% saturation intervals. Marks on bottom axis indicate sampling times

From Rees and Williams (1982)

The complexity of problems involved in estuarine management is rather neatly exemplified by conditions in the Test estuary during the summer. As mentioned earlier, the Test is a river of major importance from the point of salmon angling and there is a substantial run of fish through the estuary in the summer months (Soulsby *et al.*, 1985). It is important therefore that the quality of the water remains high. Observations indicate however that oxygen can become substantially depleted in the sub-surface waters during July and August. Values as low as 30% saturation have been observed at depths greater than 5m during July even though the surface waters at this time may be more than 95% saturated and occasionally reach supersaturation levels of 130% (Rees & Williams, 1982). (fig. 3) The period of the major oxygen sag in the deeper water is correlated with the bloom of the holotrich ciliate *Mesodinium rubrum*, an organism which can reach densities in excess of 5000 cells $ml^{-1}$ at 1 metre in the region near the docks (Crawford, D. 1985 person. comm.). *Mesodinium* contains a symbiotic photosynthetic cryptomonad. The ciliate is a rapid swimmer and is observed to concentrate at about two metres depth at around noon but to disperse through the water column at night (Soulsby *et al.*, 1985).
Significantly when a model predicting $O_2$ levels in terms of input values for biological activity is run, the observed and predicted values only approximate to one another when this downward dispersion of *Mesodinium* is taken into account (Soulsby *et al.*, 1985).
Typically the *Mesodinium* bloom peaks in mid July and generally the population has crashed by mid-August. As might be anticipated from the cell density, rather high chlorophyll levels may be observed during the bloom, a value of 240 $\mu gl^{-1}$ chlorophyll $\underline{a}$ having been noted in July 1979 (Soulsby *et al.*, 1985). These values compare with annual maxima usually in the range 10-20 $\mu gl^{-1}$ at N.W. Netley ( a kilometre to the south of the conjuncture of the Test and Itchen) though with peaks exceeding 40 $\mu gl^{-1}$ during blooms (Williams, 1980). Typically there is a decrease in chlorophyll $\underline{a}$ levels from mid-estuary seawards.

Associated with the high chlorophyll levels, carbon fixation is substantial and Bryan (1979) estimates the annual phytoplankton productivity at some 150 g C $m^{-2}$ $y^{-1}$ in the uppper part of the estuary, declining to somewhat less than 100g C $m^{-2}$ $y^{-1}$ at the lower end of Southampton Water. The average productivity is circa 120g C $m^{-2}$ $y^{-1}$, a value not untypical of temperate estuaries (Williams, 1979).

Much of the photosynthesis in the region is attributable to the microplankton. Savage (1967) noted that over an 18 month period the percentage of the total chlorophyll a associated with algae retained by a 60 µm mesh net averaged only 7% and that in the period February to June some 73% of carbon fixation was due to cells passing through a 20 µm mesh.

Comparaison of gross oxygen production by photosynthesis and plankton respiration for the estuary over a two year period suggests that there is a net excess production of $O_2$ in the water column during July, August and September but that there is typically a small deficit at other times (Williams, 1980). It seems likely that the deficit during the winter months is too large to be attributable solely to the endogenous element in the estuary and that anthropogenic discharges contribute significantly to the B.O.D. load (de Souza Lima & Williams, 1978). Values given by Collins (1978) for B.O.D. inputs from the Test and Itchen, sewage and industrial sources in 1974/75 suggest that the last was then the largest of the contributing sources to non-endogenous B.O.D. though additional input from local salt marshes also contributes to the total. The annual B.O.D. inputs (tonnes $O_2$ demand) quoted by Collins are respectively, Rivers (Test & Itchen) 1537, Sewage 341, Industrial 13 461.

In the seventies industry also contributed significantly to nutrient inputs sustaining the phytoplankton, particularly in respect of ammonia. Ammonia input via the rivers and sewage insputs was relatively small at 3.0 and 515 tonnes N per annum. Estimated industrial input (1974/5 values) was howaver a little over 2700 tonnes N. as $NH_4$ and a further 420 tonnes N as nitrate. Nitrate at this time from sewage was 118 tonnes N and via the rivers 2360 tonnes (Collins, 1978). All told, on the basis of these figures, industry was contributing significantly to the total nitrogen input in 1974/75.

Other industrial inputs considered to influence the fauna and flora include hydrocarbons and heavy metal ions and there is speculation about the possible effects of dredging for clams, tributyl tin release from antifouling paints and thermal inputs.

The Fawley refinery, situated on the Western Shore of Southampton Water, is one of the larger refineries in Europe with a (1981) capacity of just under 20 million tonnes per year. It was designed as a once through system with water extracted from the estuary being used in cooling and processing prior to discharge across a salt marsh.

Effluent hydrocarbon levels in the mid-sixties were some 40-50 mg $l^{-1}$ and at times earlier may have been higher (Dicks, 1981). A ten year programme to reduce the oil output in the effluent water cut the concentration from circa 31 ppm (1963-70) to 10 ppm by 1980 whilst over the same period the water flow was reduced from 28000 $m^3 h^{-1}$ to 21000 $m^3 h^{-1}$ (Lemlin, in Dicks, 1980).

By 1970 an area of marsh about 1000 m x 600 m in the region of Cadland Creek close to the outfalls had been devegetated (Dicks and Hartley, 1982). However, since 1970 the reduction in oil effluent has been associated with a significant regrowth of both *Spartina anglica* and *Salicornia spp.* into the damaged area. Natural seeding of *Spartina* in 1977 and successfull "takes" of transplanted *Spartina* in some areas has also contributed to the process (Dicks, 1981). Recovery of the flora seems to have been correlated with reduction in the formation of surface oil films (Dicks & Hartley, 1982). Dicks (1981) suggests that the effect of aliphatics on the fauna of the marsh is greater than that on the flora, and this conclusion is reflected in the fact that in the sublittoral region off the industrialised coast-line the fauna also differs significantly from that in other parts of Southampton Water. In part this is due to the finer nature of the sediments on the western side of Southampton Water but it is probable that the presence of hydrocarbons and heavy metals is also of importance. Dicks designates sediments containing < 1000 ppm hydrocarbon as highly polluted. A number of the offshore stations established by Oyenekan (1981) fall into this category including four out of the five stations on the western side of the shipping channel. Sediments on the eastern side of Southampton Water generally have a lower hydrocarbon burden (Oyenekan, 1981). The highest level of hydrocarbon (mainly aliphatics) was adjacent to Cadland Creek. In this region too the level of copper in the sediment was also high (c. 400 ppm) declining to less than 50 ppm on the eastern shore and southern end of the region away from the industrial discharges (fig. 4). Consideration of the species diversity and secondary production of the macrobenthos in stations in zones adjacent to sources of effluent input and on the eastern side of the estuary suggests that the fauna is influenced by the anthropogenic inputs. The point is exemplified by three selected stations :

Station 2 (600 m north east of Cadland Creek). Characterised by a high silt clay fraction (90% silt clay) & moderately rich benthic macro fauna (23 species). The number of species decreased throughout the 20 month study period

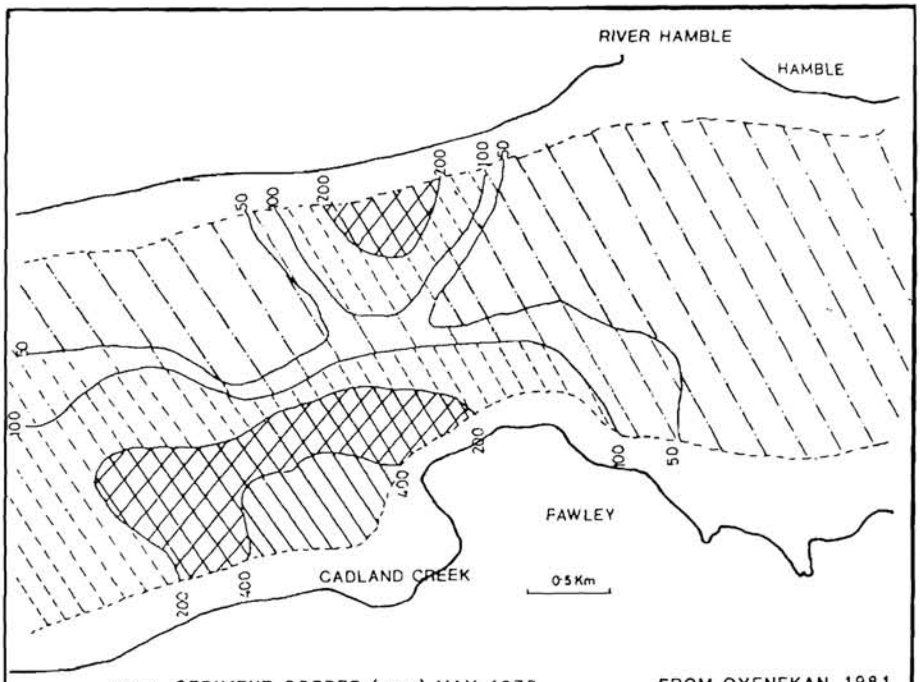


FIG.4 SEDIMENT COPPER (ppm) MAY 1978 FROM OYENEKAN 1981

declining from 17 $m^{-2}$ in sept. 1978 to 3 $m^{-2}$ in November 1979. The number of individuals also declined markedly in the same period. The polychaete *Caulleriella caputesocis* was initially dominant but declined and virtually disappeared during 1978 and early 1979, being replaced initially by *Sabella pavonina* and subsequently by the adventitious forms *Nereis diversicolor* and *Capitella* *capitata*. *Eteone longa* was generally also well represented. Molluscs and crustacea were only rarely found between July 1978 and the end of the survey in 1979.

Station 5 (600 m south west of Netley Dome) lies on the eastern side of Southampton Water. The substratum is sandy mud with gravel and coarse sand. The macro-benthos was the most varied of the four stations (59 species) and though, polychaetes were still the major group (42.4% of species), crustaceans 38.9% and molluscs 13.6% were well represented. In terms of biomass the molluscs dominated through the presence of the American Clam *Mercenaria mercenaria*. Polychaetes dominated in numbers of individuals (94% of total abundance). Throughout the period *Caulleriella caputesocis* was by far the most abundant species present.

Station 9 (400 m east of Cadland Creek) has a silty sediment but contains the lowest species diversity of the stations examined (21 species) and the maximum number of species at any one time was 14. Except during March 1980, when *Nereis diversicolor* marginally surpassed it in numbers, *Capitella capitata* dominated suggesting that this environment is limited in its capability to support forms other than those which are essentially opportunistic.

The generally low condition of Station 9 as a biological environment is also indicated by the mean annual secondary production of the main species of the macrobenthos. For the period July 1978 to March 1980 the mean annual production (mg ash free dry weight, $m^{-2}y^{-1}$) was,Station 2 : 4930; Station 5 : 99310; Station 9 : 2780; Station 20 : 6230. The station closest to the industrial outfalls at Cadland Creek thus showed the lowest secondary production as well as the lowest species diversity (Oyenekan, 1981).

The large production at Station 5 is due essentially to the presence of the American Clam *Mercenaria mercenaria*. This animal is widespread through Southampton Water and has formed the basis of a significant clam fishery since the early 1960's and particularly over the last 10 years.

The origins of this animal are uncertain, its presence in Southampton Water being variously attributed to seeding by fisherman in the 1930's and disposal overboard from vessesls in the docks. Individuals have been caught in the region which were spat in the early 1940s but it seems that there was no significant breeding of the stock until the mid-1950s more or less co-incident with the opening of the power station at Marchwood. This power-station is now closed and spat-fall for the last few years, apart from that in the warm summer of 1984, has been limited. Atribution is uncertain but it would appear that the power station may have contributed to the reproductive success of the clam. Other non-endemic species forming substantial components in the fauna include : the copepods *Acartia tonsa* and *A. grani*, the isopods *Limnoria tripunctata* and *L. quadripunctata*, the barnacle *Elminius modestus*, the molluscs *Crepidula fornicata* and *Petricola pholadiformis* and the tunicate *Styela clava*. The macro alga *Sargassum muticum*, though not invasive in the Solent,has colonised regions on the Isle of Wight. Because of the relatively large size and success of some of the organisms it has been suggested that more than half the benthic biomass in Southampton Water may be accounted for by non-endemic forms (Sheader, M. unpub.).

Smart (1972) reported that some 15200 yachts were using the Solent and that additional moorings for a further nine thousand were projected. The potential for damage to the fauna from antifouling paint has therefore been raised, particularly since attention has been drawn to the possible effects of tri-butyl tin on molluscs.

One of the features attributed to the effect of tri-butyl tin is the inducing of the development of a non-functional penis in female *Ocenebra erinacea* (Feral and Le Gall,1982). Working with Solent and Torquay animals (Hawkins, 1985) has confirmed that low concentrations of tin (0.25 mg $l^{-1}$ phenyl tin trichloride (which is believed to speciate like tri-butyl tin))cause both disruption of hydromineral balance and penile morphogenesis. However, he believes that the development of penes in females is a natural event but exacerbated by tin since the occurrence of penile vestiges was reported in drills (Griffiths & Castagena, 1962) before the development of tri-butyl tin paints. Inadequate data is yet available for the Solent to indicate whether the releases from antifouling painL are at levels which may influence the fauna though this subject is likely to receive further attention.

SUMMARY

An outline is provided of some of the major factors affecting the biological populations in Southampton Water and the Solent. Emphasis is placed (1) on the influence of nutrient load on phytoplankton production and the effects of *Mesodinium* blooms on the oxygen levels in the stratified part of the estuary (2) on floral and faunal systems in the region adjacent to industrial inputs.

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